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Content

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K01

Sensing Global Surface Soil Moisture Using NASA's Soil Moisture Active Passive (SMAP) Mission and its Applications to Terrestrial Water, Energy and Carbon Cycles

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Water stored in the soil column is the primary link mechanism between the terrestrial water, energy and carbon cycles. Without fluctuations in this storage, i.e., soil moisture, the variabilities in the three principal cycles of the Earth system would be decoupled over land regions. In order to properly understand the variabilities in the global and regional water, energy and carbon cycles and in order to reduce the uncertainty of their future projections under changing atmospheric composition and land use, it is necessary to find the relationship between the soil moisture and fluxes at the surface. The relationship can be summarized in the function reducing energy-limited evaporation rate due to soil moisture. This function is the key closure relationship in the terrestrial branch of the water, energy and carbon cycles. Important as this function is, it is virtually unobserved and empirically treated in Earth system models. This key need in Earth system science understanding is one of the major goals and justification for the NASA Soil Moisture Active Passive (SMAP) mission. The mission consists of L-band radiometer and L-band radar systems which share a single 6-m rotating mesh antenna, producing a fixed incidence angle conical scan at 40^0 across a 1000-km swath and a 2-3 day global revisit. By combining data from these two instruments, SMAP will produce an accurate soil moisture product at 9-km resolution across global land surfaces. The SMAP launched is weeks away from the time of this Conference. In this presentation the measurement approach and retrieval algorithms of the SMAP mission will be covered in summary. The relevance of the measurements to the key science question above and to other applications will also be presented.

K02

Scaling carbon dioxide exchange from sites to regions

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Eddy flux towers provide rich information on carbon exchanges, but at a few locations. Thus there are large uncertainties associated with terrestrial carbon flux estimates on regional-global scales. Satellite observations combined with process modelling provide one means of developing regional estimates. A major challenge is to determine whether such upscaling approaches are biased, and their level of uncertainty. In this regard, we implement a Monte Carlo based model-data-fusion approach: we assimilate MODIS LAI, plant-trait data, a tropical biomass map (Saatchi et al.), and the Harmonized World Soil Database (HWSD) into the Data Assimilation Linked Ecosystem Carbon (DALEC) Model, and we implement our approach on an 8-day timestep, 1º resolution, for the period 2001-2010. In addition to observational constraints, we implemented a novel Bayesian parameter inter-dependence network in order to impose ecological and dynamic constraints on DALEC parameter values. Our approach avoids any need for spin-up, assignment of plant functional types, and steady state assumptions. In order to validate our approach, we first implemented our model-data-fusion setup at flux-tower scale, and demonstrated that DALEC NEE fluxes were unbiased against independent in-situ NEE measurements across several biomes and plant-functional types (NEE daily bias = +/- 0.83 gC m^{-2} day^{-1}). Then globally, we determined the spatial and temporal dynamics of major terrestrial C fluxes and model parameter values (global GPP = 123 +/- 8 Pg C yr^{-1}; NEE = -1.8 +/- 2.7 Pg C yr^{-1}), and the spatial variability in key parameters such as C residence time. We anticipate that global model-data-fusion approaches will be an important step towards bridging the gap between globally spanning remotely-sensed biometric data and the full ecosystem C cycle. Particularly, these methods are able to incorporate fire, disturbance and land use/change information from earth observations into C cycle estimates.

K03

Observing and monitoring biodiversity - new horizons and persistent challenges

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Sound and sustainable management of our Earth's natural resources require reliable, comprehensive scientific information, especially on the biosphere. For biodiversity, the inherently large information complexity and the high degree of fragmentation of observation and monitoring programs and data sets remain significant challenges, especially for achieving higher levels of data integration and targeted information delivery. Whereas biodiversity has traditionally been and continues for large parts to be recorded by various on ground ("in situ") approaches and techniques, increasingly high resolution satellite imagery, large scale data sets from meta-genomics, and technological innovations in other sectors put biodiversity information in the realm of "big data" also providing new and important opportunities for analysis and forecasting.

With comprehensive and accurate information about the state of biodiversity and ecosystems increasingly in demand by research, decision makers and other stakeholders, free data access and available as well as interoperability of data sets is still a limiting factor for many on ground monitoring areas, which continue to be dominated by national or local, very often peculiar programs and initiatives. Examples of state of the art biodiversity observation and monitoring efforts are provided from a number of European and local biodiversity information projects and initiatives (e.g., EU BON, LTER, DATA One) aiming to overcome these barriers.

The important role of recently established and newly emerging international information infrastructures (e.g., GBIF, GenBank, GEOSS) towards facilitating free data access and availability and data integration will be highlighted, also in the light of further support and sustainability of these infrastructures for research and broader services to politics and society at large.

To achieve higher levels of integration of biodiversity data, possible measures to be proposed are: 1) Ensuring free access and open data sharing principles at all levels; 2) Wider implementation of international data standards by research funders, donors, and (public) institutions to enable greater interoperability between individual projects and platforms; 3) Enabling national/regional networks of long-term, site-based standardized recording/monitoring activities & programs; 4) Sustaining international/global information infrastructures. The implications and challenges of such measures will be presented and discussed.

K04

New insights into hydrochemical processes in lowland river systems gained from *in situ*, sub daily monitoring

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This talk will focus on the insights obtained from *in situ*, high-resolution hydrochemical monitoring in three lowland UK catchments experiencing different levels of nutrient enrichment. Between November 2009 and February 2012, the upper River Kennet, the River Enborne and The Cut, all located within the Thames basin, southeast England, were instrumented with *in situ* analytical equipment to make hourly measurements of a range of hydrochemical determinands. The upper River Kennet is a rural catchment with limited effluent inputs above the selected monitoring point. The River Enborne is a rural catchment, impacted by agricultural runoff, and septic tank and sewage treatment works (STWs) discharges. The Cut is a small river significantly impacted by urban discharges and water abstraction practices. On the upper River Kennet and the River Enborne hourly measurements of Total Reactive Phosphorus (TRP) were made using a Systea Micromac C. In addition on the River Enborne, a Hach Lange Nitratax was used to measure nitrate (NO_3). On The Cut both Total P and TRP were measured using a Hach Lange Phosphax Sigma. At all stations nutrient monitoring was supplemented with hourly pH, chlorophyll, dissolved oxygen, conductivity, turbidity and water temperature using YSI 6600 Multi-parameter sondes. Instream hydrochemical dynamics were investigated using non-stationary time-series analysis techniques.

The results reveal complex nutrient dynamics, with diurnal patterns which exhibit seasonal changes in phase and amplitude, and are influenced by flow conditions, shading and nutrient sources. The effect of sample collection time on Water Framework Directive classification was observed, and algal flow cytometry data were linked to the prevailing abiotic conditions to investigate biotic-abiotic interaction. Monitoring on the upper River Kennet highlighted the challenges associated with undertaking *in situ* analytical monitoring without mains electricity. Resampling of the data at lower sampling frequencies demonstrated that within the point-source dominated catchments, daily monitoring was sufficient for accurate load estimation in the River Enborne.

K05

Soil-atmosphere trace gas exchange: the importance of lateral water fluxes and groundwater as controlling variables

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Emissions of the greenhouse gases N_2O and CH_4 from soils are dominating their respective global atmospheric budgets. So far, most of the research has focused on assessing how land use and land management such as fertilization are affecting the sink and source strength of soils for CH_4 and N_2O. Little attention has given on elucidating how soil hydrology, e.g. groundwater fluctuations or lateral transport of nutrients, and its variability across landscapes and seasons is affecting soil-atmosphere exchange processes, thereby creating hotspots e.g. in riparian areas. That is surprising since soil moisture is a major controller of N_2O and CH_4 fluxes and neglecting soil hydrology at landscape scales might have led to a misjudgement of emission sources. Here we will present a literature review about the importance of topography, groundwater distance and lateral flows for soil ecological conditions, soil microbial processes (such as denitrification and methanogenesis) and associated soil-atmosphere GHG exchange processes and provide a conceptual framework describing how e.g. future changes in climate and soil hydrological conditions may feedback on soil-atmosphere GHG exchange.

K06

From Earth Explorers to Sentinels: ESA's Earth Observation Programmes - achievements, current status and plans for the future

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Explaining the complex processes of Earth remains a paramount challenge at the beginning of the third millennium. Earth observation satellites are important to improve the understanding of such processes. This knowledge forms the basis for the development of current and future measurement systems for science and applications.

ESA has more than forty years experience in developing and managing Earth observation satellites. With its flagship satellites ERS-1/2 and Envisat the Agency laid the foundations for a wealth of scientific studies and the development of many applications. Amongst others, their observations underpinned the trend of global change, having detected an accelerated trend of global warming and sea level rise.

With their successor satellites, the much smaller and scientifically more focussed 'Earth Explorer' Missions - dedicated to specific aspects of our Earth environment whilst demonstrating new technology in space - ESA continues to provide the scientific community with increasing insights on how the Earth functions as a system. Earth Explorer missions focus on the atmosphere, biosphere, hydrosphere, cryosphere and the Earth's interior with an overall emphasis on learning more about the interactions between these components and about the impact of human activity on natural Earth processes.

Distilling needs expressed in the international context, ESA is also developing a new family of missions called Sentinels specifically for the operational needs of the Copernicus Programme of the European Commission.

The presentation will not only sketch achievements as attained by its currently operating Earth Observation satellites, but also explain the status and prospects of ESA's Earth Observation programmes such as Copernicus and the suite of science-driven Earth Explorer missions.

K07

The impact of ecological pressures and pulses on the forest ecosystems in the Tatra National Park, Slovakia

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A natural Norway spruce forest dominates in the Tatra National Park (TANAP) in northern Slovakia. Several environmental and human-induced factors shaping the forest status and its dynamic have been monitored in a systematic way for several decades. Among the key factors are pollution and climate extremes. The impact of pollution culminated in the 1980-90s, but the alterations in the soil properties still endanger forest growth and its vitality. Despite a significant increase of pH in precipitation, the critical load for acid deposition is still exceeded. Further increase of nitrogen input into acid, nutrient poor soils poses a high risk for acidification, reduction of primary productivity and reduction of soil buffer capacity. More than 100 years of local meteorological observations confirm tendency of air temperature increase, especially during growing seasons. After longer rain free periods (> 10 days) drought symptoms were observed even in higher altitudes. Consequent bark beetle (*Ips typographus*) outbreaks occurred regularly, especially in combination with large windfalls.

An extremely severe windstorm hit the TANAP´ forest in 2004. A downslope bora-type wind laid down concentrated area of 12 000 ha (2.3 mil m^3) of mostly mature spruce forest with admixture of European larch and Scotch pine. Historical documents have confirmed that a large-scale destruction by downslope winds have periodically affected the same territory before. These events explain synchronous occurrence of tree species with contrast light demands; larch and pine versus spruce, in forest stands before the disturbance. Dendrochronological analysis confirmed a 40-50 year cycle of large windfalls. Roughly 10% of affected forest belonged to the core zone of TANAP and was intently left for natural development without any forestry intervention. Intensive research and monitoring of status and processes in the affected ecosystem was initiated by MPI Jena and the Research station of TANAP in 2005. Many institutions from Slovakia but also from abroad joined the collaborative research and monitoring programme in consequent years. The research sites, each approximately 100 ha, representing: managed, extracted windfall (EXT), and unmanaged (NEX), were chosen on localities with comparable site conditions (altitude, slope, geology, soil, vegetation, etc.). The forest unaffected by the windstorm was chosen as a reference site. Later, new sites representing fire and bark beetle impact areas became a part of long-term monitoring of natural disturbances in TANAP.

We summarize up to date results from an interdisciplinary research and monitoring of the dynamics of microclimate and vegetation parameters and processes (succession, energy and C fluxes) gained by both terrestrial and remotely sensed data. Beside a progressive trend of regeneration indicated by increasing diversity and primary production, we describe destructive impact of bark beetles, which, so far, destroyed more than 7000 ha of mostly natural spruce forest. The impact of subsequent windfall management on bark beetle infestation and a current forest status is discussed, as well as possible impact of projected climate change on future forest and forest pests. At the end we propose to apply some findings in adaptive forest management to keep TANAP´ forest more resilient and stable for provisioning of diverse ecosystem services in long term.

K09

Understanding hydrologic partitioning: Combining mechanistic modeling, global sensitivity analysis and signature exploration to understand controls on catchment-scale hydrologic behavior

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Headwater streams are the most abundant portions of the river network but the least monitored. As such, we have a limited understanding of headwater stream behaviors and how they are influenced by catchment properties such as topography, geology, and vegetation. Given the lack of runoff monitoring within headwater streams, improving an understanding of how catchment properties influence hydrologic behavior is necessary for transferring information from instrumented areas to ungauged sites. We utilize this concept to understand physical controls on similarities and differences in hydrologic behavior in the Tenderfoot Creek Experimental Forest catchment. We use a physically-based catchment-scale model, the Distributed Hydrology-Soil-Vegetation Model (DHSVM) combined with global sensitivity analysis to investigate modeled and actual controls on a range of model-predicted hydrologic behaviors (i.e. states) across multiple time scales. We want to improve our understanding of headwater catchment runoff behavior within this framework by directly relating physical properties of a given catchment to process-based predictions of hydrologic behavior, i.e. signatures. We find that across different hydrologic fluxes, including streamflow, evapotranspiration, and snow water equivalent change, only a few vegetation and soil parameters control the variability in hydrologic behavior in space and time. This framework has strong potential to inform how similarities and differences in headwater characteristics can influence the variability in spatially and temporally varying hydrologic signatures. It also allows us to understand the value of mechanistic models for hypothesis testing in the presence of potentially large uncertainties.

K11

State, challenges and options of pedogenetic modelling at pedon and landscape scales

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Pedogenetic modelling describes the co-evolution of various soil properties over time-scales of centuries to millenniums, and therefore is relevant for the assessment of past and future human impacts on soils (and vice versa). Although first modelling attempts date back to the 1970's, it is only since about 15 years that quantitative soil and landscape development models evolved beyond single purposes like assessments of erosion, biocide and nitrate leaching, soil acidification, etc. towards more integrated models. Reasons for this step forward are technical (improved computational capacity and algorithm development), data-related (development of parameterization and calibration methods) and knowledge-related (improved understanding of interactions and feedback mechanisms at various scales).

At present 2 schools of soil-landscape development models can be distinguished. One school typically addresses the pedon (1-D) scale, the other focuses on the landscape scale. A literature review reveals differences in (e.g.) process coverage and degree of empiricism in the models and in the degree of field verification, and indicates how the 2 approaches can benefit from each other. An overview of the achievements in pedon-scale modelling and of the challenges that still exist (regarding limitations caused by model assumptions, process coverage, parameterization and calibration and computational costs) informs about development issues. Additionally, experiences will be shared and options will be presented on to how to use pedon-scale models to obtain landscape-scale results. An overview of cases on pedogenetic modelling at the landscape scale informs that probably the major needed improvement is a higher process-coverage in a functional or mechanistic way. 3-D modelling of soil hydrology is an essential activity to allow flexible analysis of future climates on soilscape development, but is not yet commonly implemented in landscape-scale development models. These desired improvements invoke challenges of computational efficiency and of model parameterization. Pedon-scale models can serve as testing ground for process-modules to be finally included in 3D-landscape models. Thus, there are various motives for the 2 schools to interface more often.

One often neglected issue in model parameterization at pedogenetic timescales is the uncertainty associated with the boundary conditions imposed on the model. The effect of such uncertainty on simulated soil properties is still hardly known and should be a matter of research. Some tentative results will be shown. Adequate reconstructions of climate, vegetation and land use history are needed, for instance to be able to use today's measured soil data to calibrate model parameters in model runs of centuries or millenniums.

K12

Global Experimental Design using Critical Zone Observatories – the Update from Beijing

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Earth's Critical Zone (CZ), the thin surface layer from the top of the tree canopy to the top of unaltered bedrock that sustains human activity, is under intensive pressure from climate change and growth in human population and wealth.

Critical Zone Observatories (CZOs) have been established globally during the past seven years to intensively investigate the complex interactions of rock, soil, water, air and organisms that regulate CZ properties and determine the availability of life-sustaining resources. CZOs address a key component of emerging Earth Systems science with a defining focus on fundamental process understanding across spatial and temporal scales.

National funding councils of China, USA, UK, France and Germany jointly convened in May 2014 an international workshop in Beijing, China. The aim was to bring together these funders with international science leaders in order to advance the implementation of a coordinated, jointly funded, global programme of research that matches the urgency of major societal challenges and achieves international leadership in Critical Zone science advances and impact.

The workshop developed the following 4 thematic areas of critical zone research:

1. Mechanistic linkages in flows and transformations of energy, material and genetic information across the vertical and geospatial extent of catchments and aquifers as ecological-geophysical units,
2. Model hindcasting of CZ evolution, interpreting the present, and forecasting the future change and global impacts,
3. The Response, Resilience, and Recovery of the CZ to Perturbations of Environmental Change, and
4. Quantitative 3D characterisation of the critical zone including fluxes and reservoirs.

The workshop programme combined plenary presentations on current advances and future frontiers in Critical Zone knowledge with working group sessions. The workshop activities aimed to identify the key scientific questions, objectives and outline research methods, and the key features of required networks of CZOs to address the science questions.
The workshop outputs identified initial steps to establish methods for common observations, governance and data sharing and management. The funders confirm broad multi-national support for the science agenda and the aspirations to develop an international programme of CZO research. Actions were agreed to help develop international collaboration and funding. This includes dissemination of workshop outputs, popular and technical science articles, and continuing discussion between funders and the science community. It is the aim of the scientific community to have the framework for a multilateral CZ programme and a roadmap to deliver this, in place by the end of 2014.

K13

Hot spots and hot moments of biogeochemical cycling at aquifer-river interfaces

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The transport and transformation of carbon and nitrogen between surface waters and groundwater are significantly altered during their passage across aquifer-river interfaces. Recent investigations have substantially improved the understanding of controls of biogeochemical turnover rates, outlining a critical impact of exchange fluxes, temporal and spatial coincidence of reaction partners and streambed residence times. Still, there is little understanding of the drivers of the widely observed strong spatial and temporal variability of interlinked carbon and nitrogen turnover at aquifer-river interfaces, including hotspots (locations) and hot moments (time periods) of increased reactivity. Previous research, predominantly with a surface water perspective, has mainly focused on the impact of bedform controlled hyporheic exchange fluxes and the chemical transformation of surface solutes transported along a hyporheic flow path. While such studies may explain nutrient turnover in the hyporheic zones of low-order streams in rather pristine headwater catchments, they fail to explain observations of spatially and temporally more variable nutrient turnover in streambeds with higher structural heterogeneity and relevant concentrations of autochthonous carbon and nitrogen.

The “Leverhulme International Hyporheic Zone Research Network” has therefore developed an interdisciplinary combined experimental and model-based strategy to investigate physical controls on hyporheic exchange fluxes and residence time distributions, reactive solute and heat transport and implications on hyporheic and benthic fauna along a biogeographical and catchment gradient. Investigations combining smart tracer applications with distributed sensor networks in multi-scale nested monitoring schemes and numerical model studies to integrate process knowledge from mesocosms to artificial channels and stream reaches highlight the potential impact of small-scale streambed structural variability on spatial patterns of hyporheic exchange flow, residence time distribution and the development of hotspots of biogeochemical cycling in hyporheic zones. Physical manipulation studies proved the significance, sensitivity and resilience of biogeochemical, microbial and ecological functioning of identified hotspots to environmental change.

As an open and interdisciplinary project the network is striving to extend previous investigations to a wider range of streambed environments including ephemeral conditions and as well as the investigation of biotic feedback functions on solute transport and biogeochemical cycling.

K14

Modelling and evaluating long-term impacts on ecosystem services: experiences from LTER-site research

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Ecosystems generate a range of goods and services important for human well-being, collectively called ecosystem services. Over the past decades, progress has been made in understanding how ecosystems provide services and how service provision translates into economic value. Nonetheless, the losses of ecosystem services continue more rapidly than ever. Efforts have been made to define 'planetary boundaries' for the major impacts and changes (Rockström *et al.* 2009). Research in this field is also of great national science and strategic need regarding topics such as ecological restoration, ecological compensation and sustaining ecological security. It has still proven difficult to move from general pronouncements about the tremendous benefits nature provides to people to credible, quantitative estimates of ecosystem service values. Large efforts are currently devoted to develop methodologies for deriving spatially explicit values of ecosystem services across landscapes (Fu *et al.* 2013).

Sites belonging to national and international LTER (Long-Term Ecosystem Research) networks (www.lter-europe.net) provide excellent data and infrastructures for conducting process research and developing methods for developing ecosystem service concepts. The impacts of climate change on key ecosystem services at LTER sites in Finland have been studied (Forsius *et al.* 2013). The methods developed and used included remote sensing, derivation of impact scenarios, dynamic modelling, laboratory experiments, interactive workshops and expert judgment. The results clearly indicated not only complex interactions between the different ecosystem processes but also trade-offs between the ecosystem services. Climate change was predicted to have both positive and negative effects on key ecosystem services in Finnish conditions, the results being sector-specific and scenario-specific. Provisioning services like food and timber production would largely benefit from increasing temperatures and prolongation of the growing season in the cool Finnish conditions (with e.g. estimated increases in growth rates of trees up to 80% and the introduction of a wider selection of crops), although increasing occurrence of factors such as fungal diseases and insect outbreaks were estimated to cause increasing risks. On the other hand, climate change was predicted to pose a major threat to several endangered species, water and air quality, and tourism services dependent on present climate conditions. Goal conflicts between maximizing service production and meeting environmental quality objectives were also identified. Adaptation options and impact thresholds identified together with local enterprises and experts were also documented.

Vihervaara *et al.* (2013) conducted a literature study to evaluate the potential of the international LTER-network (ILTER, www.ilternet.edu) for studying and monitoring of environmental changes and ecosystem services at a global level. It was concluded that integrating and synthesizing the collected data should be prioritized for future cooperation, and integrated in decision-making. Standardized monitoring schemes and techniques should also be considered for future steering of ILTER collaboration.

Forsius, M. Anttila, S., Arvola, L. Bergström, I., Hakola, H., Heikkinen, H.I., Helenius, J., Hyvärinen, M., Jylhä, K., Karjalainen, J., Keskinen, T., Laine, K., Nikinmaa, E., Peltonen-Sainio, P., Rankinen, K., Reinikainen, M., Setälä, H., Vuorenmaa, J. (2013). Impacts and adaptation options of climate change on ecosystem services in Finland: a model based study. *Current Opinion in Environmental Sustainability* 5: 26-40. doi: http://dx.doi.org/10.1016/j.cosust.2013.01.001

Fu, B., Forsius, M. and Liu, J. (2013). Ecosystem services: climate change and policy impacts. Editorial overview. *Current Opinion in Environmental Sustainability* 5: 1-3. doi:http://dx.doi.org/10.1016/j.cosust.2013.02.003

Rockström J., Steffen W., Noone K., Persson A., Chapin F.S. III, Lambin E.F. et al. (2009). A safe operating space for humanity. *Nature* 461: 472-475.

Vihervaara, P., D'Amato, D., Forsius, M., Angelstam, P., Baessler, C., Balvanera,P., Boldgiv, B., Bourgeron, P., Dick, J., Kanka, R., Klotz, S., Maass, M., Melecis, V., Petřik, P, Shibata, H., Tang, J., Thompson, J., and Zacharias, S. (2013). Using long-term ecosystem service and biodiversity data to study the impacts and adaptation options in response to climate change: insights from the global ILTER sites network. *Current Opinion in Environmental Sustainability* 5: 53-66. doi:http://dx.doi.org/10.1016/j.cosust.2012.11.002

K15

Dynamic Soil Landscapes: the impact of agricultural soil erosion on soil functioning.

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Under natural conditions, soil systems are considered to be sustainable as the loss of soil material by erosion is approximately balanced by the production of soil as a result of weathering. A shift from natural to agricultural land use removes the protective natural vegetation and this typically increases soil erosion by one to two orders of magnitude, thereby accelerating physical erosion well over equilibrium levels.

Accelerated rates of erosion under intensive land use call into question the assumption that soil profile characteristics can be considered static. There is increasing awareness that accelerated erosion and deposition leads to the rapid evolution and significant heterogeneity of basic soil characteristics (eg soil thickness, horizon development, and hydrology) and that this should be accounted for when assessing the services provided by soils - e.g. storage and cycling of organic matter and nutrients, production and consumption of GHG and production of biomass. The evolution and significance of erosion-induced vertical heterogeneity is currently not well represented in soil biogeochemical models and state-of-the-art Earth System Models. This lack of attention to processes responsible for vertical and horizontal heterogeneity reflects both the perception that they can be ignored for short-term process investigation because of the long timescales (ie decades to centuries) over which they operate and the lack of models and data with which to explore the interactions.

There has been a growing interest in applying empirical quantitative techniques to predict soil properties from landscape attributes but few process-based models that allow a quantitative understanding of the dynamic processes described above are currently available. In this paper, we discuss the global significance of agricultural soil erosion in relation to soil functioning. We then present several case studies at different spatial and temporal scales where both empirical- and model-based approaches are used to understand the continuously evolving spatial heterogeneity of the soil system at the scale of landscapes in relation to weathering and soil carbon stabilization.

K16

Environmental monitoring based on palaeo-records

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The geological record contains long-term evidence for a variety of global environmental perturbations. Palaeoclimatological and palaeoecological studies use environmental 'proxies' to obtain information preserved within natural archives such as sediments, peat, tree rings, corals and ice sheets. During this presentation the focus will be on climate and environmental change during the Quaternary (last ca. 2.6 million years), but attention will also be paid to a review by Hönisch et al. (2012) about events of elevated atmospheric CO_2, global warming and 'ocean acidification' that occurred during the past 300 million years. Information on the amplitude, dynamics (rapidity) and ecological impact of abrupt climate and environmental changes in the past will be presented and potential driving mechanisms (among which greenhouse gasses and solar forcing) will be discussed. Some examples of the impact of past climate changes on human societies will be given.

As a first example the Paleocene-Eocene Thermal Maximum (PETM) will be discussed. The PETM, which occurred 56 million years ago, was an ocean acidification event that may well be comparable with changes that may happen in the ocean in the near future as a result of human-induced increases of atmospheric carbon. Within a relatively short period, 2000 - 6000 Pg of carbon was released into the atmosphere. As a consequence the sea surface temperature rose about 5 °C in the tropics and even 9 °C in the temperate zone. In the future, marine ecosystems may suffer from lowered pH values because the present increase of atmospheric CO_2 is faster than natural carbonate compensation.

An increasing amount of palaeo-records about the start and development of human impact on natural ecosystems, biodiversity, soils and atmospheric chemistry during the Holocene has become available. Such information can be taken into account as a reference for present and future environmental change.

As a second example the evidence for abrupt climate change that occurred 2800 years ago ('2.8 event') will be presented. It was triggered by a temporary decline of solar activity that caused an abrupt increase of precipitation and cooling in the temperate zone and dryness in the tropics. This 2.8 event had a strong impact on people living in areas that were marginal from a hydrological point of view.

Various palaeo-records point to hypersensitivity of the climate system to relatively small changes in solar activity, and the effects of the present decline of solar activity may interact with anthropogenic global warming.

Hönisch, B. et al., 2012. The geological record of ocean acidification. Science 335: 1058-1063.

K17

Challenges in Scaling Up Flux Measurements of Carbon Dioxide, Methane and Nitrous Oxide Emissions from Terrestrial Ecosystems

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Countries that have signed the United Nations Framework Convention on Climate Change (UNFCCC) have to report to the UN the magnitude of their greenhouse gas (GHG) emissions on an annual basis. As most inventory estimates are still highly uncertain, flux measurements are being collected at a wide range of spatial and temporal scales to improve the accuracy of these estimates. An overview of the strengths and weaknesses of commonly used micrometeorological techniques to measure the fluxes of CO_2, CH_4 and N_2O is presented. Using examples drawn from large and multi-scale biosphere-atmosphere flux measurement research projects, we examine some of the challenges in obtaining representative flux measurements across terrestrial ecosystems. We show the importance of determining the spatial and temporal variability of fluxes when quantifying the GHG exchange of an ecosystem and highlight the lack of homogeneity in GHG sources for various ecosystems. We found that when an area is flat, extensive and homogeneous, both tower and aircraft-based flux measurements agree very well. However, for heterogeneous ecosystems, we demonstrate that it is essential to use a combination of tower- and aircraft-based measurements to obtain representative and accurate fluxes. We use a footprint model to relate livestock information to aircraft-based flux estimates of CH_4 emissions for a mixed agricultural region and show that the observed discrepancy between bottom-up (inventory-based estimates) and top-down (aircraft-based measurements) estimates of CH_4 emissions could only be resolved by accounting for non-target source contributions such as wetlands. For N_2O emission estimates, the combination of aircraft- and tower-based measurement systems is also essential to obtain daily estimates at a regional scale. On a scale of approximately 50 km^2, similar N_2O emissions were measured on any one day from two similar agricultural regions 20 km apart. However, because of the unevenness of rainfall, large spatial differences in N_2O emissions are commonly observed. Finally, we demonstrate that biophysical models such as DNDC provide regional estimates of N_2O emissions from agricultural regions comparable to the combination of aircraft and tower-based flux measurements. This is important considering that fully tested and verified process-based models are essential to improve the accuracy of GHG inventory estimates.

K18

DROUGHT AND FLOOD MONITORING AND FORECASTING FOR SUB-SAHARA AFRICAN WATER RESOURCES AND FOOD SECURITY

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Of all natural disasters, droughts and floods arguably have the most impact in terms of the humanitarian and economic costs, and ecosystem stresses. Recent droughts and floods worldwide have caused severe problems for local populations such as food insecurity across the Horn of Africa, and lives lost and economic impacts in the Balkans. The expectation is that these extreme events will become more severe and frequent in the future under climate change. Mitigation of the impacts requires advance warning of developing conditions and enactment of plans to reduce vulnerability. A key element of this is an early warning system that monitors evolving hydrological conditions and water resources storage, and provides reliable and robust predictions at short time scales and out to several months, as well as the capacity to act on this information. This talk describes the development and implementation of a seamless monitoring and prediction framework for sub-Saharan Africa that allows consistent assessment of water variability from historic to current conditions, and from seasonal and decadal predictions to climate change projections. At the center of the framework is a water cycle monitoring and seasonal forecast system based on land surface hydrological modeling driven by satellite remote sensing precipitation to predict current hydrological conditions, flood potential and the state of drought. Seasonal climate model forecasts are downscaled and bias-corrected to drive the land surface model to provide hydrological forecasts and drought products out to 6-9 months. The system has been implemented and runs operationally in regional climate centers in West and East Africa. The multiple challenges for advancing our capability to provide both early warning at short-term to seasonal time scales and risk assessment under climate change, will be discussed as well as the challenges in translating forecasts into useable information by local institutions. In particular, many African regions suffer from lack of data and we discuss the use of low-cost environmental sensors and new satellite products for terrestrial hydrology and vegetation for improved monitoring and prediction.

K19

Mesoscopes for Hydropedology in the Critical Zone

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While landform and vegetation can now be mapped with high resolution (e.g., using LiDAR and IKONOS), we lack adequate tools and techniques for in situ, precision, continuous, and noninvasive mapping and sensing of the subsurface. This has hindered our understanding, modeling, and management of the hidden part of the Critical Zone. In this presentation, I will discuss some mesoscopes (i.e., devices or techniques that are between microscopes and telescopes) to shed light on subsurface complexity and related Critical Zone processes. I will then illustrate two mesoscopes that we have used in the Shale Hills Critical Zone Observatory for understanding hydropedologic processes: 1) a catchment-wide soil moisture sensor network that has revealed a hidden subsurface flow network, and 2) an enhanced time-lapsed GPR that can detect hillslope subsurface lateral flow network. Continued efforts are needed to further develop and enhance mesoscopes for mapping and sensing the complex hidden Critical Zone.

K20

Lake monitoring and recently observed limnological changes

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Lake monitoring at a few selected locations around the world has continued for decades. It serves to detect variation in seasonal and interannual patterns, long-term trends, and singular events that stand out by strong deviation from the norm. The information gleaned from these efforts has been instrumental in formulating the single most important theoretical framework in lake plankton ecology (the PEG model), in detecting large-scale spatial patterns driven by meteorology, and in evaluating impacts on lake ecosystems caused by both local and global drivers. Manual point measurements of physical and chemical variables characterizing lakes have been gradually replaced by increasingly automated records. The resulting high-resolution data provide unprecedented opportunities for detecting hitherto concealed patterns at fine and broad scales and for establishing a real-time ecology. This has prompted grass-root initiatives in Europe (NETLAKE) and worldwide (GLEON) aiming at cross-site coordinated analyses of lake monitoring data. Challenges new to aquatic scientists include handling of Big Data streams and extraction of useful information. New technologies now also facilitate capturing biological variables at high resolution. For example, bulk algal biomass can be routinely estimated by means of chlorophyll sensors, and species composition can be assessed at high taxonomic resolution by in-situ flow cytometry. Even determining photosynthetic rates may be possible in the near future based on in-situ measurements of delayed chlorophyll fluorescence, adding to continuous assessments of whole-ecosystem productivity and respiration derived from continuous records of oxygen concentrations. Further big leaps are expected when it becomes possible to measure gene activities with sensor technologies. Combined with modelling and large-scale experimental approaches, the future and recent technological advances in lake data acquisition and analysis promise to do no less than revolutionize current lake monitoring approaches.

K21

Hydrological ground measurements, remote sensing (,and models)

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There is a very good remedy against data scarcity, namely to go out and measure the phenomena one is interested in. The more unevenly distributed the phenomena of interest are over space and time, the more one has to measure to capture the variability. Unfortunately, often where variability is highest or most relevant, we have the fewest observations. Think of cities, mountainous areas, or arid regions. We see, however, that monitoring networks are in decline. We do so many projects and data campaigns, which is helpful, but we could use a better general strategy towards hydrological data stewardship.

Clearly, remote sensing plays an important role in data scarce areas. For example, in sub-Saharan Africa, outside South Africa, less than 200 weather stations report in an operational sense to international networks that feed weather predictions. Basically, satellite observations are often the only data available. Satellites are typically designed to provide data that are difficult to obtain on Earth's surface. There has been little effort, however, to develop systematically ground observation networks that enhance satellite observations.

Here, we present some early thoughts and results from the Trans-African Hydro-Meteorological Observatory (TAHMO,www.tahmo.org) with respect to observations that enhance satellite observations. TAHMO is an initiative to design, build, deploy, and operate 20,000 measurement stations in sub-Saharan Africa. Design follows a set of rules that serve easy deployment and operation, such as absence of moving parts and cavities, self- and cross calibration of sensors, and low cost. Operation focuses on the long-term financial sustainability of the network. Raw data will be made available for scientific use but value added products will be produced to financed maintenance and operation. This keynote will not so much focus on TAHMO as a whole but focus on sensors that are robust, affordable and add value to satellite observations.

K22

The Catchment Isoscape: A Meta-Model for Stable Isotope Tracers at the Shale Hills Critical Zone Observatory

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In this paper we use the concept of a catchment "isoscape" to interprete a 5 year (2008-2013) stable isotope experiment of δ^2H and $\delta^{18}O$ observations in precipitation, soil water, tree xylem water, groundwater and stream flow at the Shale Hills Critical Zone Observatory. The isoscape serves as a convenient framework for characterizing the space-time patterns of water isotopes in precipitation, vegetation, soil, groundwater and streamflow at the site. The paper first develops the conceptual-experimental framework of the Shale Hills experiment, interprets δ^2H and $\delta^{18}O$ observations in terms of the physical processes controlling the storage, pathways, exchanges and time scales of water in the catchment, and then develops a data representation or regression-model for mapping δ^2H and $\delta^{18}O$ across the catchment based on simple climatic (air temperature) and geomorphic variables. Evidence from δ^2H and $\delta^{18}O$ observations generally confirms the conceptual model for the hydrology of Shale Hills (Lynch, 1974), while extending our understanding of catchment flow pathways, the signature of soil-plant water storage, and the impact of gravity flow in macropores for recharge and lateral flow. The meta-model describes the rapid attenuation of isotope profiles with depth similar to thermal and soil moisture profiles, which results from mobile-immobile water exchange, water table rise and lateral groundwater flow and mixing. Seasonal dynamics of δ^2H and $\delta^{18}O$ show how cold-season processes dominate the annual baseflow runoff response, how vegetation interacts with a changing soil moisture signature, and tropical storms in late summer along with rain-snow dynamics contribute unique isotopic event signatures in runoff. The paper evaluates the prospect of the meta-model to support a comprehensive computational model for flow, transport, age and residence time of water operating in the catchment. The model is described and demonstrated.

K23

Overview of potential applications of cosmic-ray probe in hydrology

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Soils and water contained in soils participate in or control all processes that occur at and near the land surface, such as evapotranspiration, rainfall generation, partitioning of precipitation, water uptake by plants, partitioning of incoming energy into latent and sensible heat, biogeochemical processes, and nearly all life processes on earth. Many methods have been developed to measure properties of soils (for example hydraulic conductivity), and states and fluxes of water into and out soils (for example soil moisture and evapotranspiration). But most methods apply at small spatial scale (a point) that is not compatible with the resolution of land-surface models. What is needed are scale-integrating methods for measuring states and properties at the appropriate scale. The recently-developed cosmic-ray soil moisture probe has the footprint of hectometers and is therefore a good scale integrator, particularly in its mobile version.

The cosmic-ray method uses the response of cosmogenic fast neutrons hydrogen present in materials at the land surface. The fast neutrons that are produced in air and soil travel in all directions within the air-soil-vegetation continuum, and in this way an equilibrium concentration of neutrons is established. The equilibrium is shifted in response to changes in the water content of the soil. Adding water to soil results in more efficient moderation of neutrons by the soil, causing a decrease of fast neutron intensity above the soil surface, where the measurement is made. Removing water from the soil has the opposite effect. Thus, by measuring the fast neutron intensity in the air the moisture content of the soil can be inferred. The support volume is a cylinder with the diameter of a few hectometers and a depth of a few decimeters. Measurements can be made using stationary or roving probes. The former provide time series of moisture over the hectometer footprint, the latter gives moisture for swaths of land along driving routes.

The cosmic-ray method was originally designed for measuring soil moisture at a fixed location. Much progress has been made in the past five years. Recent work has shown that the probe can be used for measuring other pools of water, such as snow on the ground and on canopy, water in vegetation, and possibly water on canopy; that it can be used in a moving vehicle to map moisture over large areas; and that it can be used to measure hydraulic conductivities of variably-saturated soils at hectometer scale. These applications are discussed briefly below.

Biomass can be measured with cosmic rays because plants contain significant amounts of water whose presence near the land surface affect the moderation of neutrons and therefore their intensity. The proof-of-concept study involved measurements in a forest and a recently-deforested site nearby. The difference in neutron intensities between the sites was converted to biomass water equivalent, and then to dry biomass. The dry biomass was found consistent with allometric measurements at the forested site, showing that the cosmic-ray method is feasible.

Spatial mapping of soil moisture using a mobile probe, or rover, is possible with two recent advances: the development of a larger probe that has high count rate and is equipped with GPS to monitor position as the probe moves; and the development of a universal calibration function that permits conversion of neutron intensity to soil moisture without local calibration. Several rover surveys have been conducted in the past, including a year-long project in Tucson, Arizona, USA, which generated maps of soil moisture for a 1000-km2 at 22 different times, permitting mass balance calculations for the entire duration.

Hydraulic conductivity can be inferred from measured soil moisture and mass balance of water in soil. Following a precipitation event, soil moisture slowly decreases over many days. The drying curve provides information on changes of moisture with time, and its temporal derivative gives change of storage. That change is then used in a mass balance equation, which can be converted to infiltration and then to unsaturated hydraulic conductivity. Our first study showed that cosmic-ray derived effective hydraulic conductivity is consistent with an (upscaled) average of 36 point measurements, suggesting that the cosmic-ray method is feasible.

K24

From observation to prediction through model-data integration: the importance of multiple constraints

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There is a growing consensus that land surface models (LSMs) that simulate terrestrial biosphere exchanges of matter and energy must be better constrained with data to quantify and address their uncertainties. Ecosystem observation sites which measure the land surface exchanges of carbon, water and energy using the eddy covariance technique, but also ecosystem state variables, are one prime source of data for model improvement. Here we outline a multi-stage process for 'fusing' (i.e. linking) LSMs with ecosystem data to generate better models with quantifiable uncertainty. We then review the problem of equifinality, whereby multiple combinations of parameters can produce similar model output. Fusing multiple independent and orthogonal observation - in particular fluxes and pools provides a means to limit equifinality. We then show how parameter probability density functions (PDFs) from MDF can be used to interpret model validity, and to propagate errors into model outputs. We conclude by identifying five major model-data fusion challenges for the FLUXNET and LSM communities: 1) to determine appropriate use of current data and to explore the information gained in using longer time series; 2) to avoid confounding effects of missing process representation on parameter estimation; 3) to assimilate more data types, including those from earth observation; 4) to fully quantify uncertainties arising from data bias, model structure, and initial conditions problems; and 5) to carefully test current model concepts (e.g. PFTs) and guide development of new concepts.

K25

Global estimates of surface and root zone soil moisture from the assimilation of satellite microwave observations into a land surface model

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Satellite L-band (1.4 GHz) microwave observations from the Soil Moisture and Ocean Salinity (SMOS; launched in 2009) mission and the Soil Moisture Active Passive (SMAP; to be launched in November 2014) mission provide information on surface soil moisture and soil temperature. By merging these satellite observations into a land data assimilation system, estimates of root zone soil moisture can be obtained that combine the information in the satellite observations with that provided by the land modeling system and its surface meteorological forcing inputs.

This presentation will provide an overview of the soil moisture assimilation system developed for the SMAP Level 4 Surface and Root Zone Soil Moisture (L4_SM) data product. The product will provide global estimates of soil moisture and related land surface states and fluxes on a 9 km grid every three hours with a latency of a few days. The L4_SM system consists of a variety of components, including the NASA Catchment land surface model, an L-band microwave radiative transfer model (RTM), and an ensemble Kalman filter. Global soil and RTM parameter datasets were developed specifically for the L4_SM system using recent soil texture databases and advanced optimization techniques that ensure unbiased land model estimates to the extent possible. Residual systematic differences between the assimilated microwave brightness temperature observations and the corresponding model estimates are addressed through climatological rescaling.

The algorithm calibration and validation effort is based on a variety of approaches. In situ observations from dense networks play a key role as they permit validation at the spatial scale of the assimilation estimates. Furthermore, the assimilation system is verified by analyzing its internal diagnostics, including the observation-minus-forecast residuals and the analysis increments. We demonstrate the calibration and validation effort by evaluating a prototype L4_SM data product that is based on the assimilation of SMOS observations. This evaluation illustrates the challenges that result from inconsistencies in the complex set of ancillary system inputs (land model and RTM parameters, rescaling coefficients, and model and observation error parameters). Such inconsistencies are commonplace because of unavoidable changes in operationally produced, global surface meteorological forcing data in connection with the complex and costly process of generating a complete set of ancillary inputs for the soil moisture assimilation system.

K26

Ecosystem research: towards an integrated research infrastructures paradigm

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Terrestrial ecosystems represent a critical zone that provide key ecological services to human populations in the form of food, fibre and energy, climate protection and nutrient recycling, to name a few. In this critical zone, human activities are directly or indirectly generating major environmental pressures, such as pollution, global warming, and the destruction and alteration of natural habitats. Altogether, these global changes result in a rapid erosion of biodiversity and a major perturbation of ecological systems and services. It is therefore vital to understand how ecological systems respond and adapt to such pressures and perturbations and to test sustainable land use and innovative green technologies in order to address the main societal challenges we face today. Nowadays, a major focus in ecological and agricultural sciences is on the production of quantitative, experimentally reproducible and testable approaches using advances in our ability to characterize complex ecological systems from genes to ecosystem levels.

The talk will provide an overview of a new ESFRI FP7 distributed research infrastructure called AnaEE (Analysis and Experimentation on Ecosystems) as an integrated experimental approach to better understanding ecosystems functioning. Furthermore the need for complementary experimental (field studies/ ecotron facilities) that require sophisticated equipment and instruments, technological advances, and strong theoretical foundations through conceptualization and modelling of ecosystem functioning will be also addressed.

K27

On the use of lysimeters and ecotrons to study the fate of pollutants in soil plant ecosystems

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Terrestrial ecosystems are strongly affected by human activities and environmental changes. To understand how ecosystem functionning is impacted, and how it evolves with time there is a need for long term studies and pluridisciplinary approaches. Research has progressed on transfers, processes, including modeling aspects, at small and very small scales (micro- and nano-scales) and at large scales (higher than thousands of km), but the meso-scale (from the block of soil to the catchment scale) still requires investigation. The complexity of soil ecosystems, the spatial and temporal heterogeneity of what is called the « critical zone » for humans are still a challenge to be adressed. Lysimeters and ecotrons can be used as complementary tools to field and laboratory studies and are well adapted to that meso-scale and to study the critical zone. Lysimeters were initially used for measuring water balance in soil and ecotrons for studying ecosystem functionning, but now a large range of equipment are developed, from mesocosms to ecotrons, to study terrestrial and aquatic ecosystems and in France two ecotron plateforms are now recognized as national research infrastructures.

Lysimeters and ecotrons can be used to monitor the fate of pollutants in soil and soil-plant ecosystems, and their response to environmental stress. In the context of environmental changes, multiple contamination and multiple stress (for example salinity/heavy metal pollution, nutritionnal constraints and pollution) are more often encountered and should be considered. They can also be used to simulate natural and constructed ecosystems, to study the impact of environmental parameters such as pollution on soil and ecosystem processes, therefore being intermediate between laboratory controled experiments and less controled field studies. Finally, they can be used to study the retroaction of living organisms (interactions soil-plant-microorganisms) on soil functioning and property, and remediation or restoration techniques (ecological engineering). A few examples of such studies, from the GISFI experimental station at Homécourt (France) and other sites, will be presented. Some of the limitations of lysimeters and ecotron studies and need for developments will be underlined : sampling strategies and sensors, that should be further developped, the lack of coupled models (hydro-bio-geochemical processes, different scales), the data conservation, management and availability.

O01

TERENO observatories - valdiation sites for a sar-based soil moisture retrieval under vegetation cover

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ABSTRACT

Since 2006 four terrestrial environmental (TERENO) observatories have been established in different climatic regions across Germany to monitor vulnerable ecosystems and their environmental changes. They are fully equipped with in-situ/ground-based measuring instruments, which are constantly recording key variables of the atmo-, bio- and hydrosphere. The measurements within the observatories stretch from point, field to hill slope scale. They allow precise single-spot investigations as well as spatial pattern analyses of the different state variables. Moreover, the TERENO observatories are operated on a long-term basis (at least for a decade), in order to facilitate the determination and quantification of environmental changes. Hence, continuity is given to investigate fast and slow varying process in and between the different spheres.

Therefore these observatories represent ideal validation sites to evaluate remote sensing-based, geo-physical parameter retrieval algorithms of the different spheres. In this way, the calculated estimates from the remote sensing algorithms can be compared and validated with the in situ/ground-based measurements of the observatory for a quality assessment.

L-band fully polarimetric SAR data were acquired within several airborne flight campaigns of DLR's F-SAR sensor from 2011 to 2013 in all four TERENO observatories. The polarimetric SAR data are used for soil moisture estimation at high spatial resolution and under distinct agricultural vegetation cover. For this, a newly developed, iterative, generalized, hybrid decomposition and inversion approach is applied for a flexible soil moisture estimation [1]. In order to account for the temporally and spatially varying agricultural vegetation cover, an iteration-adaptive, generalized scattering model of the vegetation volume was implemented in the moisture retrieval algorithm. After inversion, the estimated soil moisture results are validated in detail with the available in situ soil moisture data of the respective observatories. For this, additional, intensive field measurement campaigns were conducted concurrently to the SAR acquisitions to measure soil moisture on different agricultural fields with varying crop types.

[1] T. Jagdhuber, I. Hajnsek & K.P. Papathanassiou, "An Iterative, Generalized Hybrid Decomposition for Soil Moisture Retrieval under Vegetation Cover Using Fully Polarimetric SAR," *Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, in minor reviews.

O02

Apparent Thermal Inertia for Soil Moisture Estimation in Agricultural Areas using Airborne Remote Sensing

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Soil Moisture Content (SMC) is one of the most important geophysical parameter needed by many scientific disciplines for example in the context of climate or hydrological modelling. Especially for agriculture it is the most important key variable that has directly impact on land use and agricultural yield. The direct determination of soil moisture is presently done by the interpolation of multiple point measurements that can be raised in different ways. This results in a very incomplete impression of the actual spatial distribution and is extremely time and cost consuming.

A wide range of approaches have been developed to derive soil moisture from remote sensing data offering the possibility to quantify the parameter soil moisture efficiently on different scales. The majority of the approaches rely on microwave sensors comprising microwave radiometers and scatterometers for global and regional scale and Synthetic Aperture Radar (SAR) for local scale applications. Besides these established approaches an increasing number of studies rely on the derivation of soil moisture using thermal infrared remote sensing. In this context the concept of Apparent Thermal Inertia (ATI), that is defined as the resistance of an object to its heating for 1 K, depending on four parameters: Firstly, the heat capacity, secondly the density of a material, thirdly the thermal conductivity and fourthly the albedo of the object. The variations of the temperature of materials ΔT are depending on its thermal inertia. Low thermal inertias indicate low resistance to temperature changes, resulting in a high ΔT (e.g. dry soils). The opposite applies for materials with a high thermal inertia, e.g. wet soils. The concept allows the exploitation of the impact of soil moisture on T and ΔT by analysing thermal infrared data acquired at different daytimes.

The objective of this study is to gather information on SMC in the agricultural area of the DEMMIN test site of the TERENO Northeastern German Lowlands Observatory based on the ATI approach. Therefore helicopter based thermal remote sensing data (VarioCam HR) have been acquire at 09.07.2013 at five different daytimes (3, 7, 11, 15, 18 UTC) and also airborne hyperspectral AISA data at the same day. The proposed method combines these two data source based on the adapted approach of Xue and Cracknell (1995) for ATI calculation. To investigate the potential for the SMC retrieval of thermal image data acquired at different daytimes and not covering the maximum ΔT of a material, all combinations of thermal image pairs were analysed with the approach.

The results show the great potential of the ATI approach for SMC retrieval, but are strongly related to acquisition times and conditions of the available data sets. The results will be presented and discussed in terms of validation, limitation and future optimisation.

O03

The Usage of a Crane Platform for a Hyperspectral Mixture Analysis - First Experiences and Results

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The detection of biophysical forest parameters as well as detailed tree-species information is of importance for monitoring ecosystem processes in woodlands. Especially floodplain forests play a crucial role in the storage of organic carbon as well as for preserving biodiversity. However, it is still difficult to interpret the spectral signal of a forest because the measured reflectance consists of a combination of different components, such as leaves, branches or understory vegetation. This relation of the components and the spectral signal is usually derived by a Spectral Mixture Analysis (SMA). SMA approaches model a mixed spectrum as a linear combination of pure spectral signatures of its constituent components (endmembers), weighted by their sub-pixel fractional cover. These endmembers and their corresponding spectral signatures can be used to generate sub-pixel cover distribution maps by model inversion. Due to the size of forests and the difficult structure, there are only few studies that were able to measure above crown signals and crown components. The presented study uses measurement of forest components from a crane platform to relate them to measurement of a portable spectroradiometer.

On the 23 of May 2011, as part of the TERENO project, the GFZ put into operation a crane in Drönnewitz, a town located close to Demmin in Mecklenburg-West Pomerania, Germany and belongs to the TERENO Northeastern Lowland Observatory. With a 45 meter long operating arm and a mast height of 45 meters, the crane can cover a forest area of approximately 6300 m². From this platform photographs as well spectral measurements were taken within the phenological period of 2012 (May to November). We evaluated 1,894 nadir images of different tree types (mainly Alder and Beech) along transects. The images were taken with a Canon EOS 5D (objective lens: Canon EF 85mm - f1.8 USM) approx. 10 meters above crown and approx. 40 meters above ground. Simultaneous, spectral measurements were recorded by an ASD FieldSpec4. Images as well as spectral information are measured at nine phenological stages between May and November 2012.

The images were reduced to the circular area matching with the measurement-area of the ASD sensor (foreoptics - 8° ~ 6 m²). They were processed in a semi-automatized knowledge-base using the software eCognition 8.9. The next step was the segmentation of the data, using the multiresolution segmentation algorithm (Scale Parameter: 40, shape: 0.1 / compactness: 0.5). The images were classified using the Nearest Neighbor approach for all crown components and direct thresholds for very bright and shadowed areas of the image. Training samples were selected for each class and include homogeneous and heterogeneous image objects spread over the entire images. For further processing of the SMA, the percentages of the crown components were calculated for all images.

The derived information on the crown components can be used to perform a hyperspectral mixture analysis in combination with the ASD-Fieldspec measurements, using linear and non-linear spectral mixture analyses. First tests indicated that the seasonal development of the crown components indicates a clear relation to the spectral signal and the acquisition date.

The object-based classification of forest crown components from nadir photographs is generally a valuable data-source to gain more information about the spectral mixture of a forest signal as well as about its phenological development. It is generally possible to derive information about the share of certain endmembers at a medium to high accuracy. However, accuracy could be increased by using a camera that includes near infrared information. The investigation on the seasonal development reveals more complex temporal pattern of the components (e.g. leaf types) than known before.

The study was connected to the “ForestHype” research project. The project is funded by the German National Space Agency DLR (Deutsches Zentrum für Luft- und Raumfahrt e.V.) on behalf of the German Federal Ministry of Economy and Technology based on the Bundestagresolution 50EE1025. The authors would also like to thank the TERENO (Terrestrial environmental Observatories) Northeastern Germany Lowland Observatory for facilitating the intensive field campaign.

O04

Multitemporal RapidEye-data analyses of semi arid natural vegetation in the Negev, Israel along an climate gradient to assess and monitor the land use changes

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Natural vegetation in semi-arid environment is very sensitive in relation to meteorological variability of precipitation and long term changes. Phenological shifts are connected with climate changes and have many applicative, economic, and environmental impacts. Monitoring and assessment of this vegetation type is very important as an indicator for land use changes. The availability of satellite data, like Rapid Eye with high repetition time capability and high spatial resolution as well as the red edge band offers new possibilities of change detection of this land cover types, characterized by highly heterogenous distribution and typical life time cycle. The Sentinel- and Enmap-Mission will open new fields in research and application in the future.

The test site is located in Shaked Park and is part of the Negev Long Term Ecological Research (LTER) site, Israel. It is a slightly hilly area and consist loessial soils. The long term annual average of rainfull of 200mm and occurs only in the winter season. The area is characterized by scattered perennial shrubs, and patches of annual plans. The soil surface is covered by biological soil crusts, lichens, and mosses, which are extremely sensitive to climate changes. The climatic changes are influencing heavily these ecosystems. Based on ground spectral measurements we could use a data set of RapidEye data for two different phenological season (2010/11, and 2012/2013) with clear differences in annual and distribution of rainfull. The paper shows the results of different indices, including crust index, and curvature indices as well as integration of the red edge channel. The results were discussed in relation to the meteorological differences (temperature, rainfull, and haze). The integration of phenological aspects enables the definition of the best time windows to detect the typical life cycle of the vegetation. So, we can separate between “seasonal variability” and “changes”. The results were integrated in a climatic gradient within the country and are the database for the assessment and monitoring of the land use changes of natural vegetation as well as agricultural sites. The developed algorithm can be transformed to long term satellite data sets from the past and continued in the future and will transformed to different scales. The results are an important database for hydrological modeling as well for the management, use and protection of the environment. The results are directly compared with the goals of the TERENO-MED program.

Needless to say how much impact these changes have on biodiversity, agricultural production, ecology, management, and the society in general. The models and tools developed in the proposed project are of a general nature, and can be also applied to issues relevant to many sectors. Data is important for planning of sustainable landscape management through choice of suitable species and provenances, and suitable management practices.

O05

Mitigating Climate Change in Brazilian Agriculture Sector: Carbon in Soil Monitoring.

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Introduction:

Brazil presented a set of voluntary actions to reduce GHG emissions during the performance of COP - 15 in Copenhagen, with the goal of reducing emissions by 2020 between 36.1 % and 38.9 %, or approximately 1.2 billion tons of CO2 eq. To do so a program of voluntary actions was implemented, defined as follows: i) reduction of close to 80 % in the rate of Amazon deforestation and 40% in the Cerrado area, resulting in reduced emissions of approximately 669 million tCO2e; ii) adopt methods for rehabilitation of degraded pastures; iii) promote the integration of crops, livestock and forest; iv) expand no tillage planting and v.) increase de biological nitrogen fixation in agriculture, actions that would entail cutting emissions between 133 million to 166 million tCO2e. On the other hand, the government proposed to increase the energy efficiency with the use of biofuels (sugarcane ethanol and alternative sources of biomass), wind , small hydro generators and use in steelmaking coal from planted forests, totaling a reduction in emissions ranging from 174 million to 217 million tCO2 eq. Proposals of one Plan for Mitigation and Adaptation to Climate Change aimed at consolidation of an Economy of Low Carbon in Agriculture (ABC Plan) began to take effect in December of 2010 and will last until 2020. This plan considers, besides the reduction in GHG, an increase in agricultural productivity as a result of new technologies. The recovery of degraded pastures through proper soil management and fertilization, as well as the adoption of crop-livestock-forest Integration (IAFP) systems, in an area of 19 million hectares, corresponding to emission reduction from 101 million to 132 million tCO2eq by 2020.

The plan considers also that there is an increase on carbon storage in plant biomass and in soil, with smaller losses to the atmosphere, while it promotes an increase in capacity of the pastures, from 0.4 AU/ ha (animal unit per hectare) to about 1.4 AU/ha. In this context, the objective of the project was to quantify carbon stocks in soil, as well as their net primary productivity (NPP) in areas with original degraded pasture, with crop-livestock integration (ILP), crop-livestock-forest integration (IAFP) and Agro forestry Systems (SAF) in all the states of Brazil.

Method:

As part of the plan, soil samples were collected at a depth of 0-30 and 30-60 cm in 198 points distributed in the country. The samples were collected in areas under degraded and cultivated pastures, crop-livestock Integration and crop-livestock-forest Integration. Samplings were collected also in areas with native vegetation (reference area) for further comparison of the results. Chemical and physical analyzes were performed in soil samples, as well as rates of NPP at each collection point.

Results and conclusions:

Some results showed that the replacement of the native vegetation handled by conventional grazing did not result in large losses of the soil C, confirming other studies where the amount of C not found in pasture degradation characteristics were well handled similar or greater amounts of C found in soil under native vegetation. The IAFP had the largest average C stocks accumulated throughout the soil profile, since the areas sampled were consolidated over two years with good management. The results demonstrate that crop-livestock integration and crop-livestock forest integration systems have the potential to store large amounts of carbon in the soil and in biomass, thus there is a real contribution to mitigate the emission of greenhouse gases, resulting in significant increase in biomass production and to raise the carrying capacity of pastures, reducing the pressure for conversion to

pastures new areas. Finally the great gain of the implementation of agricultural techniques recommended by the Low Carbon Agriculture Plan established in Brazil can be considered as an innovated technological method for agriculture. Monoculture joins the system, allowing continuous production and carbon assimilation, which is only possible in tropical environments. The results show that Brazil can reach the goals in controlling GHG emissions by agriculture established in Copenhagen during COP 15.

O06

LandscapeDNDC - A process based model for biogeochemical ecosystem simulations from site to the regional scale: Applications, uncertainty quantification on the regional scale, coupled hydraulic nutrient transport and ecosystem biogeochemistry at catchment scale

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Agricultural soils are the primary anthropogenic source of atmospheric N_2O. Greenhouse gas (GHG) emissions from soils like CO_2, N_2O and CH_4 are net result of all physicochemical and biological processes involved in production, consumption and transport. These processes have a strong dependency on environmental factors like temperature, moisture, soil and vegetation properties or the land management. Therefore emissions occur with a high spatial and temporal variability giving rise to hot spots and hot moments. Quantifying sources and sinks of GHG for natural, agricultural and forest ecosystems is crucial for our understanding of impacts of land management on the biosphere-atmosphere exchange of GHG and for the development of mitigation options.

Numerical simulation models are increasingly used to estimate greenhouse gas emissions at site to regional and national scales and are outlined as the most advanced methodology (Tier 3) for national emission inventory in the framework of UNFCCC reporting. Process-based models incorporate the major processes of the carbon and nitrogen cycle of terrestrial ecosystems like arable land and grasslands and are thus thought to be widely applicable at various spatial and temporal scales and they are considered useful tools for integrating our knowledge of the key processes and drivers to estimate carbon and nitrogen (C and N) trace gas emissions from soils.

The high complexity of ecosystem processes mirrored by such models requires a large number of model parameters. Many of those parameters are lumped parameters describing simultaneously the effect of environmental drivers on e.g. microbial community activity and individual processes. Thus, the precise quantification of true parameter states is often difficult or even impossible. For regional model applications such as GHG emission inventories spatial model input data for initialization and climate data to drive model simulations are required at various scales. Such data is often attributed with high spatial uncertainty. As a result model uncertainty is not solely originating from input uncertainty but also subject to parameter-induced uncertainty.

So far regional modelling studies have focused on the simulation of site specific fluxes neglecting the importance of landscape fluxes of water and nutrients for GHG emissions e.g. downwind or downstream the site of nitrogen fertilizer application. Open key questions with regards to C and N cycling and feedbacks concern the spatial distribution and magnitude of hotspots and hot moments of C and N losses and the pathways of C and N losses to the atmosphere and hydrosphere and the redistribution of nutrients in the landscape.

Coupling the LandscapeDNDC ecosystem model to the CMF (Catchment Modelling Framework) hydrology model creates a modelling system capable to assess the C and N cycling and their feedbacks to crop growth and microbial processes on the landscape scale. The coupled system enables the simulation of lateral exchange of nutrients with the soil water fluxes and therefore to assess the C and N cycling on the landscape scale. We present simulation results of crop growth, nutrient cycling and resulting nitrous oxide emissions in a catchment as a result of coupled C & N cycling on the landscape.

Besides model applications on the site and regional scale, we present results of a parameter uncertainty assessment (PUA) versus input data induced uncertainty assessment (IDUA) of GHG emission inventories on the regional scale from arable soils of Saxony (Germany). For the IDUA the spatial domain (represented by 4042) is set up with spatially explicit soil properties and climate data and a region-typical 3-year crop rotation consisting of winter wheat, rape-seed, and winter barley. Main

soil physical properties of the regional input data are assigned with uncertainties like soil bulk density (~ 20 %), soil organic carbon content (~ 100 %), pH values (~ 0.25) and hydraulic properties (~ 20 %). We have randomly sampled input data sets addressing these uncertainty ranges by Latin Hypercube Sampling resulting in 600 regional input datasets to calculate 600 individual realizations of the regional inventory. For the PUA we calculated regional inventories using joint parameter distributions for key parameters describing microbial C and N turnover processes as obtained by a Bayesian calibration study. We representatively sampled 400 different parameter vectors from the discrete joint parameter distribution comprising approximately 400,000 parameter combinations and used these to calculate 400 individual realizations of the regional inventory.

Average N_2O emission from arable soils in the state of Saxony using the default IPCC emission factor approach (Tier 1) for direct emissions reveal an average N_2O emission of 1.51 [kg N / ha] due to fertilizer use. The mean resulting from the PUA was 1.43 [kg N / ha] with a median value of 1.05 [kg N / ha] In the regional uncertainty quantification the 20% likelihood range for N_2O emissions is 0.79 - 1.37 [kg N / ha] (50% likelihood: 0.46 - 2.05 [kg N / ha]; 90% likelihood: 0.11 - 4.03 [kg N / ha]). Respective quantities were calculated for nitrate leaching.

The IDUA leads to lower emissions with smaller uncertainty bandwidths for N_2O emissions but for increased NO_3 leaching levels with wider bandwidths. The input data uncertainty mainly driven by the uncertainty of the soil organic carbon content emphasizes the increase in NO_3 leaching.

O07

Differentiated Disturbance Effects on Carbon Exchange of Forest Ecosystems

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Climate change is not only affecting ecosystems by gradual changes of environmental boundary conditions, but can also act by triggering extreme events such as storms, fire or insect outbreaks. On the one hand, these events are already occurring more frequently which is a development expected to continue (Coumou & Rahmstorf, 2012), on the other hand such events can seriously alter the long-term carbon balance of forests. The latter effect is not well represented in regional and global models leading to a large uncertainty about sink strength of vegetation (Reichstein *et al.*, 2013).

We therefore developed a new model routine for the ecosystem model LandscapeDNDC (Haas *et al.*, 2013) to investigate the impact of different disturbances (storms, fire, insect outbreaks, and clearcuts) on carbon exchange. The investigation shows the sensitivity of decadal carbon exchange on the kind of disturbance, i.e. if trees or fraction of trees are exported or left at the sites, how the nutrient and water cycle is affected, and to which degree new vegetation can gradually replace the old trees. The model has been partly evaluated with measurements from sites of the EUROFLUX network (forest management), the Bavarian forest (windthrow), and from the TERENO site Schechenfilz. Scenario analysis include plot- and regional scale simulations for pine stands to explore short- and long term impacts of different disturbance with respect to carbon exchange.

Considering that different disturbances are prominent at different regions and that they show a different sensitivity to climate change, we expect that regional application of this model will make a valuable contribution for future quantification of forest ecosystem services, including carbon sequestration, biomass provision, water retention, regional climate and air quality.

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O08

Spatial distribution of hydroxylamine and its role to aerobic N_2O formation in a Norway spruce forest soil

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Hydroxylamine (HA) is potentially involved in soil N_2O formation as a crucial intermediate in the oxidation of ammonium to nitrite. However, the determination of HA concentration in natural soil samples has not been reported until now. Here, we determined the HA concentrations in organic (Oh) and mineral (Ah) layers of 110 soil samples collected from a spruce forest (Wüstebach, Eifel National Park, Germany) using a novel approach, based on the fast extraction of HA from the soil at a pH of 1.7, the oxidation of HA to N_2O with Fe^{3+}, and the analysis of produced N_2O using gas chromatography (GC-ECD). In a second step, N_2O emission rates were determined by means of aerobic laboratory incubations of 3 g soil in 22-mL vials. Subsequently, the spatial distribution of soil HA concentrations and N_2O emission rates in the Oh and Ah layers of the whole sampling area were analyzed using a geostatistical approach. The correlations among soil HA, N_2O emission rate, pH, soil C, N, Fe, Mn and soil water content (SWC) were further explored. The HA concentrations ranged from 0.3-37.0 µg N kg^{-1} dry soil and 0.02-11.4 µg N kg^{-1} dry soil in the Oh and the Ah layer, respectively. The spatial distribution of HA was similar in both layers, with substantial spatial variability dependent on soil type, tree density and distance to a stream, e.g., HA concentration was greater at locations with a thick litter layer or at locations close to the stream. N_2O emission rates showed a similar pattern as soil HA concentrations, with higher rates in the Oh layer than in the Ah layer. N_2O emission rate exhibited the highest correlation with soil HA content in the Oh layer, while soil NO_3^- content explained N_2O emissions best in the Ah layer, along with SWC, Mn and C content. HA concentration was negatively correlated with pH and positively correlated with SWC in the Oh layer, while positively correlated with C and N as well as NO_3^- content in the Ah layer. Moreover, Mn content was the most important factor for HA recovery at the specific extraction conditions. The results demonstrated that HA is a crucial component for aerobic N_2O formation and emission in spruce forest soils. Mn may also play a key role to the aerobic N_2O emission due to the chemical reaction with HA. Further studies should focus to the relationships between HA, Mn and aerobic N_2O emission in other ecosystems.

O09

Is the dry zone of the land shifting poleward?

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The land is divided into the cold part (CP) and warm part (WP) by a threshold value of mean annual temperature 16^{o}C., which is dictated by a data-driven analysis of climate-carbon dynamics across FLUXNET research sites. The analysis of the FLUXNET data indicates that the CO_2 transfer from the atmosphere to terrestrial ecosystems in the WP is dominated by soil water availability. Climate data show that the WP has been expanded and the CP has been diminished since 1976. The poleward expansion of frontal boundary of the WP is coincident with the poleward extension of the Hadley Cell (HC) due to both have been driven by warming climate. It is well known that the northern descending branch of the HC in north hemisphere creates extreme dry conditions. The frontal boundary (or the shifted area) of the WP has been transformed by global warming into more vunerable regions where weather gradients are stronger, ecosystems are more sensitive to even slight increases in water deficit, crop yield is reduced by extreme heat waves, and vegitated land cover and pastroral population are reduced. An expansion of the global network monitoring CO2 flux to target the identified shifted areas would provide data that could improve our ability both to model these regions as they undergo further transitions and to assess the likely impacts on climate as a consequence of altered CO2 flux and increased soil aridity.

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O10

Real-time measurement of site specific N_2O isotopic composition above intensively managed grassland reveals controls on N_2O source process dynamics

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Nitrous oxide (N_2O) is a potent greenhouse gas (GHG) and the single most important stratospheric ozone-depleting substance. Since pre-industrial times, its atmospheric concentration has increased by 19% and at least 60% of anthropogenic N_2O emission can be attributed to food production. Thus, the growing human population and associated demand for meat will most likely accelerate the rate of atmospheric concentration increase, making efficient mitigation strategies a vital aim of research. N_2O is considered to be mainly produced by nitrification and denitrification, but the relative contribution of these processes to total emission is uncertain, hampering the development of efficient mitigation strategies. Measurement of the four main N_2O isotopic species ($^{14}N^{15}N^{16}O$ / $^{15}N^{14}N^{16}O$ / $^{14}N^{14}N^{18}O$ / $^{14}N^{14}N^{16}O$) has been suggested as a powerful tool to trace the biogeochemical cycle of N_2O and to allocate its emission sources as studies with microbial pure cultures and mixed population systems revealed characteristic isotopic signatures for the most important production processes. However, current studies suffer from limited spatial and temporal resolution due to the combination of discrete flask sampling in conjunction with laboratory-based mass spectrometric analysis. We recently demonstrated that a quantum cascade laser (QCL) based absorption spectrometer is capable of simultaneously measuring the three main N_2O isotopomers at trace levels.

Here we present results from the first long-term field measurement campaign conducted on intensively managed grassland in central Switzerland during three months. A modified state-of-the-art laser spectrometer (Aerodyne Research, Inc.) employing a mid-infrared cw-QCL (4.54 µm) and a novel astigmatic multipass cell with 204 m optical path-length was connected to a N_2O preconcentration unit. High analytical performance in combination with the applied calibration strategy resulted in excellent long-term precision of 0.20, 0.12 and 0.11‰ for $\delta^{15}N^{\alpha}$, $\delta^{15}N^{\beta}$ and $\delta^{18}O$ which was determined from repeated preconcentration and measurement of target gas from a compressed air tank. This instrumental setup allowed investigating responses of N_2O isotopic composition in soil-emitted N_2O to management events, soil temperature, soil water content, ammonia, and nitrate concentrations. Controls on N_2O isotopic composition will be discussed as well as the potential for partitioning of microbial source processes.

O12

More than just CO_2: Multiple trace gas exchange measurements at a temperate mountain grassland

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Question:Ecosystems exchange a large number of different trace gases to/from the atmosphere, however the vast majority of FLUXNET sites quantifies only the fluxes of carbon dioxide and when assessing the carbon or greenhouse gas balance neglect other carbon or greenhouse gas fluxes. This causes an overestimation of the role of carbon dioxid exchange for the ecosystem carbon and greenhouse gas balance, the magnitude of which is largely unconstrained

Methods: Here we use the eddy covariance method (and variants thereof) with a large variety of analytical methods to quantify the exchange of multiple trace gases to/from a mountain grassland. The monitored trace gas fluxes cover: carbon dioxide, methane, nitrous oxide, carbon monoxide and several volatile organic compounds.

Results: The main result of our study is that carbon dioxide is the major contributor to the gaseous carbon and greenhouse gas budget at this temperate mountain grassland, which however may be significantly modulated by other trace gases may, at least during some years. Differences between source and sink periods for the different trace gases and the underlying drivers are discussed and annual budgets, for some compounds covering multiple years up to decades, are presented.

Conclusions: Multiple trace gas flux measurements help to elucidate the importance of the exchange of carbon dioxide for the ecosystem carbon and greenhouse gas budget.

O13

Measurements of Surface Fluxes at City-Atmosphere Interfaces: Case Studies at High Residential Area and Urban Park in Seoul Metropolitan Area

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A city is using more than 70% of natural resources and more than 50% of world population lives in urban area in spite of its small land fraction. In this respect, cities make impacts on microclimate and weather and it is important to properly monitor turbulent exchanges of momentum, heat, and greenhouse gases from a city to the atmosphere. Particularly, like other Asian megacities, Seoul is vulnerable to climate change because of a combination of its rapid growth, geography, typhoons, heat waves and flood. The lack of our understanding of the city-atmosphere interaction hinders us from making adequate urban planning and mitigation in this area. For proper quantification of turbulent fluxes from the city to the atmosphere, two micrometeorological towers have been established at two typical land types (i.e., high residential area and urban park) in Seoul metropolitan area. We report observation data from the 1 year of surface flux measurements at these two sites. Surface energy partitioning at the high residential area shifted significantly after the town re-development. Vegetation in the urban park shows carbon uptake during sunny daytime but even during main growing season, the vegetation was a carbon source due to large nighttime ecosystem respiration. Net CO_2 release during summer season was about 5.8 gC day^{-1} and 2.8 gC day^{-1} in the high residential area and urban park, respectively. Our study confirms that not only traffic volume and local heating, but also urban vegetation play a role in controlling carbon balance in a city and urban park management must be carefully done for reducing greenhouse gas emission from the urban park.

O14

Importance of dissolved greenhouse gases leached from soil: insights from the lysimeter network TERENO-SoilCan

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Question

Measurements of climate-relevant trace gases from soils are frequently undertaken in contemporary ecosystem studies and substantially contribute to our understanding of greenhouse gas balances of the biosphere. While the great majority of such investigations builds on closed chamber and eddy covariance measurements, where upward gas fluxes to the atmosphere are measured, fewest concurrently consider greenhouse gas dissolution in soil water and leaching losses via the vadose zone to the groundwater. Here we present annual leaching losses of dissolved nitrous oxide (N_2O), carbon dioxide (CO_2) and dissolved organic carbon (DOC) from arable, grassland, and forest lysimeter soils from three sites differing in altitude and climate. We aim to assess their importance in comparison to direct N_2O emission, soil respiration, further leaching parameters of the C- and N cycle, and finally to the greenhouse gas balance.

Methods

The lysimeters are part of the Germany-wide lysimeter network initiative TERENO-SoilCan, which investigates feedbacks of climate change to the pedosphere on a long-term scale. Soil water samples were collected weekly from different depths of the profiles by means of suction cups. A laboratory pre-experiment proved that no degassing occurred under those sampling conditions. We applied the headspace equilibration technique to determine dissolved gas concentrations by gas chromatography.

Results

Soil solution and seepage water of all lysimeters were consistently supersaturated with N_2O and CO_2 compared to water equilibrated ambient air. In terms of N_2O, leaching losses increased in the ascending order forest, grassland, and arable soils, respectively. In case of the latter soils, we observed a strong variability of N_2O, with dissolved concentrations up to 87 µg N L^{-1}. However, since seepage discharge of the arable lysimeters was comparatively small and mostly limited to the hydrological winter season, leached N_2O appeared to be less important than direct N_2O emissions. Based on dissolved CO_2 concentrations, dissolved organic carbon, and seepage water discharge, our measurements revealed annual leaching losses of 6.8, 8.8, and 2.3 mg C m^{-2} from the forest, grassland and arable lysimeter soils, respectively.

Conclusions

In conclusion, the results of the first year of our investigations provide evidence that dissolved greenhouse gases should be considered in studies which aim to assess full greenhouse gas balances, particularly in ecosystems with small net ecosystem greenhouse gas budgets where hydrological conditions favor microbial activity and high leaching losses.

O15

The Agricultural Landscape Laboratories (AgroScapeLabs): a research platform to study relationships between biodiversity, ecosystem functions and land use at the landscape scale

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Biodiversity, including genetic, organismic, interaction, and landscape diversity, plays a central role in ecosystems functioning and in the provisioning of ecosystem services. This central role is increasingly threatened by ongoing changes in climate, biogeochemical cycles and land use causing a general decline in biodiversity. Current approaches that enable scientists to gain in-depth understanding of the interactions between biodiversity, land use, climate and ecosystem functions, focus primarily on extensively used, cultivated landscapes and protected areas, whilst large-scale investigations in agricultural landscapes are scarce. And yet only 25% of endangered species in Germany live in protected areas which make up only 2% of the country's territory. Thus, the majority of endangered species (i.e. 75%) occur in agricultural and forest areas (50% and 30% of the areas, respectively).

The Agricultural landScape Laboratories (AgroScapeLabs) intend to close this research gap. AgroScapeLabs is a research platform designed as a large-scale laboratory that offers scientists the opportunity to carry out large-scale experiments and manipulations within a multifunctional agricultural landscape. The 450 km² AgroScapeLabs study area, located north of Berlin in the TERENO North-East region of Germany, is mainly used for agricultural production. It is characterized by a continental/Atlantic transitional climate (annual average of 8.4°C air temperature and 486 mm precipitation) with long dry phases in the spring and with cold winters. Loamy soils enable intensive farming of mainly winter cereals, rape, sugar beet and maize.

The AgroScapeLabs are used as a platform for natural landscape experiments where drivers and consequences of biodiversity change are explored across various temporal and spatial scales bridging different trophic levels and different ecosystems (e.g. aquatic and terrestrial). In particular, the AgroScapeLabs allow to link land use and the corresponding dynamics of landscape structures with the dynamics of populations via the space and resource use of individuals. Thus, biodiversity research within AgroScapeLabs aims to explicitly link climate and spatio-temporal correlations of land use patterns with locomotion patterns of key groups of different taxa (e.g. mammals, birds, insects, vascular plants, micro-organisms, fungi), and their contribution to ecosystem functions and services. Ongoing research projects in the AgroScapeLabs range from plant-microorganism-interactions, and the interrelations between lyme-disease and landscape complexity, to movement ecology of mammals in temporally and spatially dynamic agricultural landscapes, the ecosystem services provided by insectivorous bats, or the relationship between plant diversity in habitat islands (kettle holes) and agricultural landscape structure.

O16

Linking biodiversity conservation and livelihood strategies: A new approach for sustainable rangeland management

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Rangelands play a significant role in sequestrating atmospheric carbon dioxide, conserving biodiversity and especially in providing livelihood benefits to pastoralists. Further, their biodiversity has contributed directly through provisioning (e.g., feed, food, fresh water, wood, fiber, genetic resources, and medicines) and regulating ecosystem services (e.g., climate *regulation,* flood and disease control, and water purification) and indirectly through supporting ecosystem services to many outcomes of livelihoods, including increased well-being, more income, reduced vulnerability, more sustainable use of rangelands and improved food security.

Pastoralists have lived within rangeland environments and have been able to more freely use the services and biodiversity that these ecosystems provide as well as adaptation to changes in ways that have improved their livelihoods. In other words, biodiversity at genetic, species and ecosystem levels has traditionally played an important role in reducing the vulnerability of production systems of pastoralists and improve their livelihood strategies. However, recently, the biodiversity of rangelands is under several serious threats resulted from climate change, invasive alien species, pollution, habitat change, habitat loss, fragmentation, over exploitation, population pressure, socio-economic pressures, unsustainable management practices, limited public awareness and lack of integration of biodiversity considerations into local land-use plans. These factors have further threatened the sustainability of livelihood strategies of pastoralists. On the other hand, biodiversity loss has been realized as one of the main causes for poverty of pastoralists and vulnerability of their livelihoods. Consequently, conserving rangelands biodiversity while sustaining pastoralists' livelihood has become a great challenge.

Recently, a set of livelihoods strategies for contributing to sustainable livelihoods (SLs) has been recognized, including livestock-based livelihoods, resource based livelihoods and supportive strategies. Achieving a balance between these strategies in order to approach sustainable rangeland management (SRM) *is essential, but a difficult task*. These strategies are increasingly threatened by a loss in fauna and flora, changing management practices and policy deficiencies in supporting pastoralists' livelihoods. All these have made the biodiversity conservation of rangelands difficult to achieve. In order to conserve rangelands biodiversity, livestock-based livelihoods must be supported while promoting resource-based livelihoods along with strengthening supportive strategies. This shows the need to integrate livelihoods strategies into principles of biodiversity conservation to ensure SRM.

Although the integration of rangelands biodiversity with other development and environment activities has been increasingly understood, the linkage between biodiversity conservation and livelihood strategies is not yet acknowledged. This gap demands for the application of integrated approach in development of the national strategy on preservation and sustainable use of biodiversity that could address livelihoods strategies as well. Even though biodiversity protection has been acknowledged as one of the actions proposed to improve social and economic conditions for rangeland inhabitants, there is little awareness on the important role of biodiversity conservation in livelihood strategies and vice versa. To fill this gap, the SLs approach should further be recognized as a superior framework that can link up livelihood strategies of pastoralists with rangelands biodiversity.

Accordingly, this paper first addresses factors threatening biodiversity. Secondly, the paper discusses SLs approach in SRM and reviews literature on factors affecting SLs by exemplifying the main (recent) challenges of SRM. Then, an effort is made to explain the link between biodiversity conservation and the *most important livelihood strategies* of pastoralists including ecotourism and payment for ecosystem services. Afterwards, the paper discusses some supportive strategies such as clear financial incentives and subsidies as well as certain specific legal considerations including appropriate

land tenure and a tax regime to protect rangelands ecosystem services as well as livelihood security that encourage pastoralists to conserve biodiversity. Finally, the paper draws some policy implications to conserve biodiversity.

Keywords: Biodiversity conservation, vulnerability, sustainable livelihoods, policy making, supportive strategies.

O17

Collecting Basal area information from field photography.

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This paper describes collaborative work conducted within Australia's Terrestrial Ecosystem Research Network (TERN) between the Ausplots and AusCover facilities and the Australian Centre for Visual Technologies (ACVT) to develop new photopoint collection methodologies for use by terrestrial ecologists. These photopoints are being collected at Ausplots survey sites throughout Australia along with a wide suite of environmental measures, including a range of soil, vegetation species and structure and genetics information, with currently around 402 sites out of 550 collected. These collections are intended to augment the ecological data collected at each site. Similar measures are also being collected at Auscover calibration and validation sites.

Our photopoints incorporate three sets of overlapping photographs, each collected from exposure points at the vertices of an equilateral triangle with sides of 2.5 m located around the centre point of the field site. The photos from each exposure point typically overlap by 50% and at least one photo in each series include a calibration target mounted on a pole at the centre of the exposure points. These photographs are then processed to create a range of data products.

Seamless photo panoramas and point clouds are also produced allowing a three dimensional view of the site and potentially allowing similar analysis, albeit at lower precision, to that of terrestrial Lidar systems. This is used to measure stem diameters, and calculate basal area, which are summed for the site, providing a measure of basal area per hectare when the visible distance is taken into account. This method is potentially more accurate than rapid techniques such as the use of basal wedges/prisms and significantly quicker and cheaper than accurate measures such as measuring DBH for all stems or utilising a terrestrial Lidar. Given that the method allows rapid collection (<30 minutes per site) of this information we anticipate that this method will be widely applicable.

Validation of this photopoint method against field measures and terrestrial lidar that was acquired coincidently is progressing and we look forward to further tests to quantify the accuracy of these methods and to account of the effect of occlusion. We are working on automating the extraction of this information and delivering these products freely online. A prototype should be available in time for the conference. We also hope to investigate the feasibility of the automatic extraction of growth form of species in the photographs to assist with site structural assessment.

O18

Farmland bird abundance in Central Germany: trend analysis based on species traits and land use

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The TERENO initiative (TERrestrial Environmental Observatoria; www.tereno.net) of the Helmholtz Association is aiming at long-term data sets covering abiotic and biotic parameters. This unique large-scale project aims to catalogue the long term ecological, social and economic impact of global change at the regional level. One focus of the Helmholtz Centre for Environmental Research is on birds in agricultural dominated landscapes within the Harz/Central German Lowland Observatory in Central Germany. Within an area of 50 x 90 km in Saxony-Anhalt farmland birds were monitored at six sites of each 4 x 4 km following the point-stop count method (20 points per site). Data have been collected in 2001, 2009, 2012, 2013 and 2014. We combine bird abundance data with species traits, land use, landscape composition and configuration to explain the changes in abundance of different ecological groups.

O19

Trait dependent responses and stability of bee communities as an indicator for the provision of pollination services

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There are a fair number of studies describing how bee communities respond to weather conditions and local land use, but not always with consistent results. We were especially interested if and how life history traits like body size, social status, nesting preference and food specialization level affect these responses to weather and land use. The findings allow conclusions about the pollination service provided by bee communities in the investigated test landscapes.

We used bee sampling data (with two seasons per year and three pan-trap sampling rounds per season) from three subsequent years within the long term monitoring initiative TERENO (TERrestrial ENviromental Observatoria). Within in a 50 x 90 km area in Saxony-Anhalt bees were sampled in six landscapes of 4 x 4 km varying in local weather conditions and land use, with 16 sampling locations per landscape (considering land use in 200 m radii buffer zones around each trap). We interpret the results with respect to the capacity of bee communities to provide pollination services within the selected landscapes in terms of abundance of individuals and the diversity of bee species traits relevant for pollination.

O20

Standardizing and maintaining micrometeorological long-term observations – First experiences from the ICOS approach

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The Integrated Carbon Observation System (ICOS) is a European research infrastructure that was created to improve our understanding of the carbon cycle and its driving factors and to verify the effectiveness of policies to reduce greenhouse gas (GHG) emissions. Standardized measurement protocols based on micrometeorological state-of-the-art techniques and central calibration facilities, as well as continuous and representative long-term observations of GHG concentrations and fluxes are the fundamental principles used in the ICOS network. Some specific challenges for the standardization of field measurements will be discussed using data examples from individual ICOS sites. Several examples of data products covering various surface and ecosystem types will also be shown. Observations made during the preparatory phase of ICOS indicate that a large part of the inter-annual variability in GHG exchange between the earth surface and the atmosphere is caused by ecosystem disturbance and/or management activities. Even when automated long-term measurements are successfully standardized and comparable to each other, a better understanding of the driving factors of GHG exchange requires also regular ground-based visual inspections of the field sites and additional biological observations and records of human activities.

O21

The Danish Hydrological Observatory HOBE

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The Danish hydrological observatory - HOBE - was established in 2007 based on funding from the private VILLUM FOUNDATION (http://www.hobecenter.dk). The Skjern catchment located in the western part of Denmark was selected as the site for the hydrological observatory.

The observatory was established with the overall purpose to obtain a better understanding of the water balance at catchment scale. Previous investigations have documented that water balance closure has been difficult to obtain based on independent measurements of in- and outgoing fluxes at catchment scale. This is due to both measurement and theoretical limitations.

Catchments are subject to a time-space variability of landscape characteristics and the hydrological processes occur and interact across a multitude of spatial and temporal scales. Often fluxes, process understanding and parameters are determined at a smaller scale and a pertinent problem is to scale findings and observations from one scale to another.

To address these challenges long-term observations, dedicated measurements and experiments of in- and outgoing fluxes as well as fluxes between the different hydrological compartments are carried out. Classic state-of-the-art measurement techniques in combination with novel sensor technologies are used to observe and measure the multi-scale spatial and temporal patterns of the land surface and subsurface systems. The project takes advantage of the recent developments within ground-based, air-borne and space-borne non-invasive geophysical, meteorological and remote sensing sensors. Also new instrumentation is used for easy and inexpensive measurements of stable isotopes. The collected data are integrated into a physically based and distributed hydrological model.

In the presentation a summary will be given of the results obtained so far and how the observatory has contributed to the development of a better understanding of catchment behavior and dynamics as well as the water cycle.

O22

The CRITEX program : a multidisciplinary equipment program for investigating the Critical Zone

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The Critical Zone of the Earth is defined as the thin veneer that the surface lying between the rocks and the atmosphere. It comprises many compartments, solid, gas and liquid phases that interact together at different timescales. The term “critical” non only mean that this zone is fundamental for the regulation of the Planet, it also means that, in response to global environmental changes, this zone, which is the life’s habitat and the zone from which food is produced, will have to be understood precisely so that we can predict its evolution in the Anthropocene.

Predicting the response of the Critical Zone as a whole needs in integrated approach. Because the Critical Zone is studied by many scientific fields (geological sciences, soil sciences, ecology), any holistic approach will need them to work together on common research questions.

While the different parts of the Critical Zone have been monitored for years in different long-term observatories, by different institution and for different aims, the CRITEX program is an attempt to foster a more integrated observational approach by coupling for example geochemical and geophysical and hydrological observations on well chosen Critical Zone Observatories. The Critex is a shared and centralized instrumental facility for the long-term monitoring and exploration of the Critical Zone, complementing and over-performing the existing site-specific equipments. CRITEX is organized according to two main challenging scientific objectives and 8 work packages divided into 22 work tasks. The first Objective is to develop high frequency monitoring in catchments (at the interface with the atmosphere, in the soil and at the outlet). Much information on the processes operating in catchments can be gained from refined temporal monitoring. High temporal monitoring of river catchments is also a prerequisite for closing energy, water and carbon budgets in selected catchments. The second objective is to develop multi-disciplinary monitoring of “hot spots” and during “hot moments” of the Critical Zone in catchments. CRITEX scientific approach is to investigate the Critical Zone across a wide range of spatial scales, ranging from the parcel to the whole catchment and coupling a process-based approach to an integrated holistic investigation using geophysical and geochemical techniques.

With 21 laboratory partners, 5 national institutions of environmental research (INRA, CNRS, IRSTEA, IRD, BRGM) and more that 20 universities, CRITEX is a major national French initiative, scheduled for a period of 10 years, embodying an unprecedented effort on the monitoring of rivers and catchments to foster a new style of scientific approach and to improve academic, societal, political and business partnerships with both operational and international spheres.

O23

Introducing Australia's Terrestrial Ecosystem Research Network; linking disciplines for better environmental outcomes

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A wealth of information about Australian ecosystems already exists, within university, industry, non-government organisations and government departments. The Terrestrial Ecosystem Research Network provides the resources to connect researchers in these areas and enable data to be efficiently discovered and retrieved.

TERN is helping fill in the fundamental knowledge gaps of terrestrial ecosystem science by providing a resource that enables data sets to be stored and shared. Indeed, TERN supports and highlights the need for data publication, sharing and citation which are critical for the advancement of ecosystem science. TERN first and foremost builds on established infrastructure and data sets, and relies on these large scale contributions to develop new research infrastructure and collection systems, expanding observation and monitoring programs into unrepresented ecosystems. The TERN network not only facilitates collaboration between ecosystem disciplines but creates a network for sharing ideas.

By providing the means to share data sets and develop collaborations as part of our data sharing processes, TERN is the catalyst for a culture shift to more open and collaborative ecosystem science in Australia. Our goal is to see more scientists working together, rather than in isolation, and being rewarded for sharing data and knowledge. Together, they will build knowledge more effectively to address key terrestrial ecosystem problems.

O24

Groundwater heads control catchment hydrological and hydrochemical response

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Nutrient export from agricultural areas strongly affects downstream water quality and ecosystem health. There is a need to understand the temporal variability of nutrient concentrations, discharge and resulting loads at the catchment scale. A general way to face that challenge is a top down analysis of catchments integrated response in the surface water to conclude on dominant processes controlling water quantity and quality. However, deconvolution of the strongly integrated signal at the catchment outlet bears the risk of equifinal combination of possible controlling processes. We assume that hydrological and hydrochemical processes are not independent from each other. To that end, a joint data-based approach was followed. The study combines the analysis of discharge and nutrient concentration from an agricultural managed headwater catchment with the assessment of groundwater head time series. The study site is the 1.4 km^2 sized Sauerbach catchment within the TERENO River Bode observatory. The Sauerbach catchment is characterized by a complex geological setup with Mesozoic sandstones and siltstones overlain by Tertiary and Quaternary sediments. Two aquifers are present within the catchment of which only the upper aquifer is discharging into the Sauerbach. Within the catchment 9 observation wells have been installed and equipped with automated dataloggers to measure groundwater heads at hourly intervals. The catchment outlet is equipped with a gauging station providing discharge at 10 min intervals. Sampling of water for quality analysis was conducted over a period of 1.5 years in the groundwater, spring water and tile drainages and over a period of 3 years in the surface water. The analysis aims at the dimensionality reduction of groundwater head time series by the use of principal component analysis. The resulting scores (temporal variability) and loadings (spatial differences) are used to determine their ability as predictors for catchment discharge and water quality. The principal component analysis was able to explain 96 % of the groundwater head variability by two components. The components represent two extremes in the groundwater level behavior of the catchment - a fast reaction and a slow and damped reaction to recharge forcing. The loadings of these components for the individual wells are a function of geological settings and depth to groundwater. In the upper aquifer feeding the Sauerbach discharge, a larger depth to groundwater results in higher damping of the recharge signal. The loadings were found to be correlated with the concentration of nitrate in the groundwater samples. Thus we assume that the passage of water through unsaturated zone is the dominant control of both groundwater level variability and nitrate turnover. The two principal components of groundwater levels are able to explain most of the variance in the catchment discharge (93 %) and large parts of the nitrate variance within the stream (84 %). Thus this analysis shows the tight connection of hydrodynamic and hydrochemistry in groundwater as well as surface water of headwater catchments. Here groundwater head variability where found to be the dominant control of seasonal discharge and nutrient export behavior.

O25

Nitrogen Load Estimates in Central Germany using Hydrological Water Quality Modelling and High Resolution Monitoring

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Hydrological water quality modeling is widely used for investigating runoff and nutrient transport processes as well as watershed management. For instance, a good estimate of nutrient load requires an accurate prediction of discharge and nutrient concentration. In addition, multi-regression modeling approach taking the effect of storm events on riverine nutrient dynamics into account can be used for load estimates. However, agood evaluation and understanding of the dynamical behaviour of surface water quality variables is mainly limited by the monitoring strategy and sampling frequencies.The aim of this study is to compare the riverine nitrogen load calculations using two different methods: Monitoring and modelling approaches. To this end, nitrogen load estimates using a semi-distributed hydrological water quality HYPE (Hydrological Predictions for the Environment) model and event response reconstruction approach were compared in central Germany.

In this study, the dynamics of riverine nitrogen and storms effects in two catchments with strongly deviating land use conditions in Central Germany were investigated through continuous high resolution measurements. In-stream 3 years of semi-continuous (15 min) measurements of nitrate and discharge were conducted at 3 gauging stations within the Selke catchment (463 km^2), which represents a catchment with moderate to low nitrate concentrations. The data were generated by the German's Terrestrial Environmental Observatories (TERENO). Additionally, 3 years of continuous data from the nitrate rich Weida catchment (99.5 km^2) were used. The Weida is characterized by high nitrogen leaching compared with the Selke catchment. Discharge-nitrate concentration data from the catchments show distinctive patterns, suggesting flushing and dilution responses. The nitrogen load estimates were improved by reconstructing the nitrogen concentration response to rainfall events using commonly available quantitative hydrological data. Preliminary results of this study will be presented and discussed.

O26

Kettle holes: Hot-spots of biodiversity, carbon dynamics and greenhouse gas emissions in an agricultural landscape

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The landscape in North East Europe, North Asia and North America is characterized by a great number of small ponds shaped by delayed melting of ice blocks of receding glaciers at the end of the last glaciation. These so-called kettle holes are depressional wetlands acting as hot-spots of biodiversity, carbon dynamics and greenhouse gas emissions in a landscape with predominant intense agricultural land use. They are a paramount example of the tight coupling between aquatic and terrestrial systems. Recent studies suggest that small ponds, in spite of the small fraction of the area they cover, might serve as a major carbon sink in agricultural landscapes.

Agricultural land use is the major driver of nutrient, contaminant, and carbon input into the kettle holes resulting in highly eutrophic systems. Drift from fertilizer or pesticide application, or surface runoff and erosion from adjacent arable fields can trigger the build-up of algae blooms in the pelagial, shifts between floating and submerged vegetation or can harm vegetation in the littoral zone of kettle holes. However, most effects are substantially delayed with respect to external triggers and depend on the boundary conditions. For example, many kettle holes undergo a wet-dry cycle, depending on the hydro-pedological boundary conditions, which in turn triggers enhanced mineralisation of organic carbon, shifts in dominant vegetation or oxidation of sulphides. Subsequent rewetting of the oxidized sediments then leads to mobilisation of nitrate and sulphate, and later, after re-establishment of anoxic conditions to mobilisation of phosphorus and elevated methane emissions. In addition, a complete cover of floating plants like duckweed can prevent algae growth and minimizes oxygen exchange with the atmosphere, which in turn affects phosphorus release from the sediment and carbon sequestration in the kettle holes. Consequently, kettle holes exhibit enormous geo-, bio-, physical and chemical process variability both in space and time.

To study the complex interplay of intertwined abiotic, biotic and anthropogenic processes, kettle holes are a focus of interdisciplinary research in the Quillow catchment, ca. 90 km north of Berlin. The catchment is part of the TERENO North East Germany region, is one of the LTER-D sites, and is the study area of the agricultural LandScape laboratories (AgroScapeLabs) initiative and of the joint LandScales project (Connecting processes and structures driving the **land**scape carbon dynamics over **scales**).

An interdisciplinary group of scientists produces extensive biogeochemical data by monitoring of selected kettle holes, ground- and stream water quality. The interplay between hydrological, geochemical and microbiological processes, carbon turn over in the kettle holes and the adjunct soil and vegetation carbon stocks, greenhouse gas emissions, and feedbacks of erosion are studied. Furthermore, within this project and combined with the AgroScapeLabs activities there are extended surveys of macrophyte vegetation as well as of hermatophagous arthropods, ticks, and mammal migration close to the kettle holes. We argue that such an integrated approach is urgently needed to reveal the complex interplay between terrestrial and aquatic systems, and between abiotic, biotic, and anthropogenic processes in this area.

O27

A multi-model uncertainty assessment of phosphorus transport using high-frequency data from the River Eden catchment, Cumbria

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Complex process-based models are increasingly being utilized to simulate nutrient transport processes in river catchments as a tool to inform water quality management strategies, with a recent attention focusing on phosphorus. When used at various temporal and spatial scales there are varying degrees of uncertainty associated with model predictions arising from errors in model structure due to lack of knowledge of the behaviour of key model parameters and processes. Uncertainties also exist where multiple different parameter sets can provide equally sufficient agreement with observed data, a concept known as equifinality. One key limitation in the calibration of such process-based models is insufficient input data to support and understand the behaviour of the large number of parameters. To address this issue, this study makes use of new high-frequency phosphorus and discharge data from the River Eden Catchment in the United Kingdom to perform a multi-model uncertainty assessment using the generalized likelihood uncertainty estimation framework (GLUE) framework. The GLUE methodology is employed to assess the ability of the models to reproduce the observed hydrology and phosphorus datasets. Identifying where the uncertainties are greatest will allow us to highlight areas where the models require further development.

O28

Changes in water storage and water quality in the largest freshwater lake (Poyang Lake) in China and effects of the Three Gorges Dam

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The unique and valuable functions of lakes and their flood mitigation roles are well recognized. Lake hydrological condition is fundamental to the maintenance of these functions. Climate variations and strong human activities may result in the alteration of lake water balances, causing significant changes in lake water storage, and subsequent water quality changes. A prominent example of hydrological modifications to lake functioning is the regime changes to Poyang Lake, the largest freshwater lake in China. The Lake is one of the few lakes that remain naturally connected to the Yangtze River. The lake surface expanses to 4000 km^2 for high water levels, and reduces to less than 1000 km^2 for low water levels, creating some 3000 km^2 vital wetland habitats for many birds. The Lake is also an important freshwater resource for local social-economical development. During the last decade, extreme low water levels were recorded in dry seasons, causing water supply crisis for 12.4 million inhabitants and irrigation problems for 3.9 million hectares of arable lands. Changes in lake hydrological regimes also affected wetland vegetations and water quality of the Lake. The onset of the low water level happened to be coincident with the initial operation of the Three Gorges Dam (TGD) in 2003, located upstream in the Yangtze River. Endless debates are being raised as how significant the TGD may have affected the Lake. This talk presented research outcomes to clarify some of the issues. It was found that the Yangtze River has significant drainage effect on the Lake. Operation of the TGD reduced the discharges in September-October, and lowered the water level in the Lake for autumn. The concentrations of total nitrogen and total phosphorus were also found to increase after the operation of the TGD, and this may be partly due to the reduced water volume in the Lake. Projections on changes of the Lake water level using comprehensive hydrological and hydrodynamic models show that the Lake may become even drier under future climate conditions, causing greater pressures on water resource and water quality management.

O29

Spatial patterns in hydrological modeling: Benchmarked by the human perception - Evaluating against real data - Diagnosing complex model defects.

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Recent advances in hydrological modeling towards fully distributed grid based model codes, increased availability of spatially distributed data (remote sensing and intensive field studies) and more computational power allow a shift towards a true spatial model evaluation. Traditionally models are evaluated against single spatially aggregated catchment scale observations, e.g. river discharge or hydraulic head data with the conviction that it features the correct simulation of catchment-inherent distributed processes. The need of this paradigm shift is demanded in literature; however no single spatial performance metric is identified yet that proofed suitable for comparing observed and simulated spatial patterns of hydrological variables, nor there exists an agreed procedure to do so. The goal of this study is to develop and test simple and flexible metrics that go beyond global statistics. These metrics, individual or collective are used to evaluate simulated land surface temperature (LST) patterns against observed data, by MIKE She, an integrated and fully distributed hydrological model and by the MODIS satellite respectively. This study promotes *FuzzyKappa*, a metric that combines elements of fuzzy set theory and kappa statistics: The typical confusion matrix of kappa statistics is extended by both, fuzziness of location and category to allow an advanced pattern comparison of two LST maps. The similarity space representing the fuzziness can be represented by a distance decay function, which requires a benchmark to be tuned. The human eye is well trained in pattern perception and can thus provide a reliable benchmark. Therefore, a web-based survey is set up to generate a similarity ranking of 12 synthetic perturbations of MODIS data following the perception of the probands (approx. 200). Simple global statistics like RMSE and mean error perform poorly in reproducing the similarity ranking from the survey. On the other hand a collective metric based on Pearson's correlation coefficient and *FuzzyKappa* could replicate the survey ranking satisfying. 38 LST maps with full coverage are available for a 6 year simulation period of the Skjern river, the HOBE hydrological observatory in western Jutland (DK). The spatial model performance is assessed following the optimal metric from the survey. Out of the 38 LST maps the top and bottom 10 in respect to simulation performance in LST patterns are selected to further diagnose possible model challenges and to reveal weaknesses and strengths of the model. It is identified that days showing a bad pattern match are significantly warmer than the ones with a good pattern match, causing a higher evapotranspiration yielding a general cooling of the land surface. This defect in the subsurface-surface-atmosphere transfer model was not detected in the multi-constrained calibration and validation, where traditional objectives functions were used, and was only revealed by a spatial model evaluation.

O30

From site measurements to spatial modelling - multi-criteria model evaluation

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Question

Hydrological models are traditionally evaluated at gauge stations for river runoff which is assumed to be the valid and global test for model performance. One model output is assumed to reflect the performance of all implemented processes and parameters. It neglects the complex interactions of landscape processes which are actually simulated by the model but not tested. The application of a spatial hydrological model however offers a vast potential of evaluation aspects which shall be presented here with the example of the eco-hydrological model SWIM.

Method

We present current activities to evaluate SWIM at the lysimeter site Brandis, the eddy-co-variance site Gebesee and with spatial crop yields of Germany to constrain model performance additionally to river runoff. The lysimeter site is used to evaluate actuall evapotranspiration, total runoff below the soil profile and crop yields. The eddy-covariance site Gebesee offers data to study crop growth via net-ecosystem carbon exchange and actuall evapotranspiration. The performance of the vegetation module is tested via spatial crop yields at county level of Germany. Crop yields are an indirect measure of crop growth which is an important driver of the landscape water balance and therefore eventually determines river runoff as well.

Results

First results at the lysimeter site show that simulated soil water dynamics are less sensitive to soil type than measured soil water dynamics. First results from the simulation of actuall evapotranspiration and carbon exchange at Gebesee show a satisfactorily model performance with however difficulties to capture initial vegetation growth in spring. The latter is a hint at problems capturing winter growth conditions and subsequent impacts on crop growth. This is also reflected in the performance of simulated crop yields for Germany where the model reflects crop yields of silage maize much better than of winter wheat.

Conclusions

With the given approach we would like to highlight the advantages and importance of a multi-criteria evaluation of eco-hydrological models. This approach appreciates the complex chain of processes in eco-hydrological models which are otherwise only tested at the integrated level of river runoff.

O31

Regional water balance analysis with an atmosphere to groundwater coupled hydrometeorological model for the pre-alpine TERENO region

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Complex, physically-based dynamic models of the terrestrial hydrosphere enable the analysis of cross-compartment interactions and facilitate a holistic representation of regional hydrometeorological systems. Dynamic regional atmospheric and climate models rely normally on a very general representation of hydrological processes above and below the land-surface. The movement of water is often restricted to the vertical direction and thus omitting mechanisms of horizontal redistribution. Moreover, the widely applied free drainage assumption for the lower model boundary leads to a violation of the model's intrinsic water balance. For longer integration periods such a configuration can lead to inconsistent conditions for storage bodies and for water and energy exchange at the land-atmosphere interface.

The Weather Research and Forecasting modeling system (WRF) with its hydrological extension (WRF-Hydro) permits horizontal redistribution of moisture for the sub-surface, the surface and the atmosphere and contains a one way coupled bucket representation of the groundwater storage.

We present anenhancedgroundwater configurationforWRF-Hydro. Theextensionaddsnon-linear feedback between saturated and unsaturated zone and the land-surface while maintaining the closure of theintrinsicwater balance.

After a stand-alone observation driven calibration, the coupled model is applied for the Ammer river catchment in Southern Germany, covering an area of around 700 km². Fully coupled and uncoupled simulations are compared and evaluated with observations from the pre-alpine TERENO observatory. The possibilities and limitations of such fully coupled modeling approaches are discussed and further observational requirements and opportunities are emphasized.

O32

A Physically-Based Modelling Approach to Assess the Impact of Climate Change on Surface and Groundwater Resources within the Grand River Watershed, Ontario, Canada

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It is now generally accepted within the scientific community that the climate is changing, and that future climate change may have significant impact on water resources in both quantity and quality. Alterations of base flow to rivers due to changing subsurface flow patterns, fluctuations in soil moisture and in the depth of the groundwater table, water levels in lakes and wetlands, and altered groundwater recharge/discharge patterns are examples of possible consequences of future climate change. Quantification of such impacts as driven by plausible climate-change scenarios is essential for policy makers and watershed managers. In this study, our physically-based model, HydroGeoSphere (HGS), is employed to simulate 2D surface water flow on the land surface together with 3D variably-saturated subsurface flow covering the entire Grand River Watershed (GRW). A globally implicit scheme used to solve the nonlinear surface and subsurface flow and transport equations simultaneously. The GRW covers 7,000 square kilometers, providing one million people their drinking water and irrigating one of Canada's most productive agricultural areas. We have assembled all currently available land cover/land use, climatic, hydrologic, digital elevation and subsurface hydrostratigraphic/hydraulic head data based on several decades of field-based investigations in order to characterize the GRW. The impact of global warming on the water resources within the GRW, including extreme event projections, is explored after calibration against historical meteorological, hydrological and hydrogeological data. An ensemble of dynamically-downscaled high-resolution climate projections is used to drive HGS in an attempt to quantify the uncertainty in the future climate projections and its consequences on the surface and subsurface water resources with the GRW. Due to the richness of the GRW datasets, it is suggested that the GRW could serve as a candidate watershed to enable inter-comparisons between comprehensive physics-based and lumped hydrologic models.

O33

Modelling the hydrological signatures of a complex landscape: The Quillow Catchment (TERENO North-East)

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Studying hydrological processes in the northeastern lowlands ofGermanyfaces substantial challenges. The deposits of the last glaciations resulted in an “immature” topography without a fully developed stream network. Consequently, many of the small streams are man-made. On agricultural waterlogged sensitive sites tile drainage can contribute to storm runoff. Besides, groundwater plays a dominant role for hydrological processes. The uppermost unconsolidated Pleistocene sediments of about 100 to 300 m thickness consist of a highly heterogeneous interbedding of permeable and impeding layers. The resulting number and thickness of aquifers and of leakages between them are rarely known in sufficient detail. Catchment boundaries derived from groundwater contour diagrams are not necessarily closely related to topography. In addition, groundwater flow direction and the associated catchment boundaries often are not stationary and depend on the hydrological conditions. Thus, due to generally fairly low groundwater recharge rates, even minor fluctuations of groundwater recharge can result in major changes of groundwater head, groundwater flow direction and transient desiccation of stream reaches which in turn affects the hydrological behaviour. This often includes transient desiccation of shallow lakes and wetlands that are very common in this landscape and subsequent reduction of evapotranspiration which then feeds back to the whole hydrological cycle. The hydrology of this region is considered highly sensitive to the predicted climate change. In fact, substantially decreasing groundwater and lake water levels have been observed during the last decades. In addition, the intensification of agricultural land use and changing water management after the reunification presumably cannot be neglected. Thus there is urgent need for models that can cope with the complexity of the landscape and the associated hydrological processes.

In light of the above assuming a homogeneous aquifer and fitting a lumped model to the observed hydrograph is not warranted. On the other hand even the most advanced geophysical prospection cannot provide the required detail for highly distributed catchment models. Instead a thorough analysis of the hydrological and hydrochemical signatures of the catchment can help considerably to assess the necessary degree of complexity of the model and to constrain the model structure. Examples will be presented from the Quillow catchment which is part of the TERENO North-East region.

The observed hydrological dynamics should to a certain degree reflect processes and even spatial patterns, e.g., of permeability, within the catchment. Consequently time series of soil water content, groundwater head and stream discharge from various sites in the Quillow catchment and in adjacent catchments were subjected a joint principal component analysis. In fact a confined aquifer could be identified, and the extent of the overlying non-permeable layer could be roughly assessed. In addition, the mean behaviour of the unsaturated zone with respect to transformation of the incoming precipitation signal could be assessed and could be used for parameterisation of hydrological models at a larger scale. Moreover, results from hydrographs for different catchments were used for a first quantitative assessment of the respective fractions of tile drainage.

Besides, hydrochemical signatures can provide valuable information about hydrological processes. The analysis of a large stream water and groundwater quality monitoring data set using the Isometric Feature Mapping approach was used to assess the contribution of deep groundwater to stream discharge accounting for spatial and temporal patterns. It could be shown that transient drying-up of the uppermost stream reaches resulted in a decoupling of stream discharge from shallow groundwater and increased the fraction of deep groundwater.

However, stream discharge comprises only about 15% of the output fluxes. The remaining 85% of the incoming rainfall is evaporated or transpired. Thus, spatial patterns of evapotranspiration based on remote sensing data are a paramount source of information for constraining and testing hydrological

models. Satellite data have been used at larger scales. Small areas like the transition zone between riparian wetlands and adjacent arable fields will be surveyed using an unmanned aerial vehicle. Here special interest is on the atmospheric lateral moisture exchange between sites with substantially differing evapotranspiration that seems to play a major role under certain boundary conditions.

O34

Seasonal Soil Moisture Patterns Control Transit Time Distributions in a Forested Headwater Catchment

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The Transit Time Distribution (TTD) of a catchment is frequently used for analyzing flow paths, storage characteristics and runoff sources. Despite previous studies, the connections between catchment characteristics and TTDs are still not fully understood. We present results from a two-year stable isotope tracer investigation in the forested Wüstebach headwater catchment (38.5 ha), including precipitation, stream and tributary locations. We used the gauged outlet to determine effective precipitation (p_{eff}), subdivided for wet and dry catchment state, and assumed it to be spatially uniform. We then calculated TTDs of 14 ungauged stream and tributary locations where stable isotope tracer information was available and compared them to respective subcatchment areas and the proportion of riparian zone within the subcatchments. Our approach gave insight into the spatial heterogeneity of TTDs along the Wüstebach River. We found that hydrological hillslope-riparian zone disconnection was an important factor, as the catchment shifted between two distinct, time-variant hydrological responses that were governed by seasonal changes of overall catchment wetness. The difference in hydrological behavior of the riparian zone and hillslopes could explain the often encountered 'old water phenomenon', where considerable amounts of old water quickly appear as runoff. TTD results showed a negative correlation between riparian zone proportion and Mean Transit Time (MTT), corroborated by the dense network of soil water content measurements. No correlation between subcatchment size and MTT was found.

O35

Using Spatial Data Infrastructure principles and services to improve management and availability of heterogeneous data for research and decision making on climate change and adapted land use in West-Africa - the case of WASCAL in West-Africa

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WASCAL is a Climate Service Center in West Africa focusing on Climate Change and Adapted Land Use for this region. A main task is to become a clearing house for climate change related matters and prepare research data on the climate-socio-ecological systems in the region for clients and translate feedback from clients to research questions. The development of a functional data structure is for this center thus a life line. The infrastructure, which should be able to handle heterogeneous environmental, economical and sociological data, as well as time series data. The management system for sensor data is being developed at the Research Center Jülich, Germany, which provides bio-physical data to the West African research community. Coupled to this system is a catalogue application for archiving and publishing file-based data of any type, covering thus the data forms of different scientific disciplines. The system furthermore provides comprehensive metadata management tools for individual data providers. The developed WASCAL Data Infrastructure (WADI) builds on the concepts and standards used in Spatial Data Infrastructures (SDI). The technical implementation builds on an self-defined organizational framework allocating tasks and responsibilities in data management workflows, and a data policy regulating data provision and access by protecting intellectual property rights and data privacy. Once WADI is completed, the Climate Service Center WASCAL will act as a knowledge hub in the region with the aim to integrate data providing partner institutions of WASCAL, step by step, into a data and knowledge sharing network to the benefit of research and policy advice on climate change and adapted land use in West Africa.

O36

Bottom-up capacity building for observations and measurements providers in RITMARE

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In the creation of a decentralized infrastructure for marine data in the context of RITMARE, Flagship Project funded by the Italian Ministry of Education, Universities and Research (Ministero dell'Istruzione, dell'Università e della Ricerca), a fundamental component is capacity building by data providers. This challenge has been tackled by providing the Starter Kit (SK), a comprehensive set of software components bundled as virtual appliance that exposes standard services for the environmental data.

The RITMARE Project aims at fostering data sharing among Italian data providers in the field of marine research. Our group, lead of subproject 7, is in charge of building the spatial data infrastructure that constitutes the underpinning technology of the project. The infrastructure is employed by the data providers (public research bodies and inter-university consortia) and also by a variety of other stakeholders (public administrations, private companies, and citizens). Major data providers are marine scientist belonging to different communities (e.g., oceanography, ecology, biogeochemistry, geophysics, etc.). As a consequence, they envisage a varied corpus of heterogeneous data, metadata, workflows and requirements. Moreover different degrees of maturity with regard to the solutions implemented for the provisioning of resources are present. In general, major effort is being devoted to capacity building on the observation providers-side, which is the facilitated by the SK.

SK has been developed to improve the capacity for sharing and discovery geospatial resources. SK lets manage observations, layers (e.g. shapefile, geotiff, etc.) and documents (e.g. pdf, doc, etc.) but is here described with focus on observations collected by the sensors. The objective of SK is to allow a new generation of researchers sharing their observations collected during the fieldworks within their and other communities in order to improve the overall knowledge.

O37

A generic data framework for processing and assessing heteregeneous observation data

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The rapid development of sensing technologies and observation networks had led to the creation of volumes of environmental observation data. Access to diverse web-enabled environmental sensors and their data is now possible using the standardized Sensor Web Enablement (SWE) framework. However, it is unclear how quality control descriptions of heterogeneous data can be systematically made available to user with the framework. Missing information on data processing and assessment can limit the use of the data. For example, data of good quality might be neglected, whereas data of low quality might be applied. Without quality control (aka. quality assessment) information, users may not be able to select data that would better suit their applications and make better interpretation of the data. There are several Sensor Web projects investigating different aspects of quality measures. Some express data uncertainties, e.g., EO2HEAVEN and UncertWeb. Others are usually application-specific and partially capture quality control information, e.g., SANY, NOAA's IOOS, and Q2O. Further, retrieval of observation data with respect to certain quality control aspects is not possible in the current SWE framework. Apart from the quality measures (e.g., accuracy, precision, tolerance, or confidence), an end-to-end aspect of the data quality assessment should also capture levels of observational series, the changes applied, and the methods involved must be specified. Representing the descriptions of operation and maintenance of sensors is also vital as these provide additional information about the causes for measurement variability.

Questions that call for clarification are: What are the end-to-end key aspects of quality control of observation data? How can they be modeled? How can they be associated with the observation data and other metadata? How can quality control information be made available along with the observation data via the SWE framework? This paper presents a common data quality assessment framework addressing these questions. The framework handles processing and assessment of heterogeneous environmental observation data. Starting with the way data are imported into the data infrastructure, custom workflows are developed. Data levels implying the underlying data processing, stages of quality assessment and data accessibility are defined. A tiered flag scheme is adapted to cater quality descriptors of different sensing applications. The observational data model and service from the SWE are modified to allow retrieval of observation data with respect to certain quality assessment aspects. The framework is evaluated with data from observatory infrastructure TERENO (TERrestrial ENvironmental Observatories) and data from external agencies hosted by the TERENO data infrastructure.

O38

Data Management and Long Term Archiving of Remote Sensing and In-situ Data at DFD - Status and Trends

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Within the last few years the situation of satellite and airborne supported remote sensing has changed fundamentally. The reasons can be explained among others by the following aspects:

- technical and technological developments and factors, such as the increase of the number of earth observation missions (e.g. multiple satellite missions on different or on one orbit), new advanced sensor technologies (e.g. SAR- and hyperspectral sensors of high spatial resolution), new storage media and storage technologies, and new improved data processing (e.g. automated interpretation algorithms and processing chains),
- market-oriented aspects (e.g. private remote sensing missions, such as QuickBird or RapidEye).

In addition to this the development was politically forced by European Union (EU) and European Space Agency (ESA) having established the program "Global monitoring for environment and Security" (COPERNICUS; erstwhile called GMES), which serves the development of an operative European Earth observation satellite fleet to combine earth observation monitoring with airborne remote sensing supported by terrestrial, maritime in-situ-measuring networks and additional data sources in operative process chains as well as services.

Besides the continuous provisioning of user friendly and reliable earth observation services e.g. to climate protection, for ecological survey, humanitarian assistance or for the reply to security-relevant questions the COPERNICUS initiative is aimed at the establishment of a European market for innovative remote sensing based services.

TERrestrial ENvironmental Observatories (TERENO) - Initiative of the Helmholtz community, operates on a temporal and spatial scale that make i.) integration of remote sensing technologies and ii.) the combination of these technologies with in-situ-measurement technologies urgently needed.

Both aspects require an advanced management and archiving design including appropriate technology and technological infrastructure to ensure a reliable long-term archiving. In the lecture, the DFD will present its solution the Data and Information Management System (DIMS) including its experience in archiving large data-massive. For a data provision to solute scientific questions in distant future additional aspects will be considered like data curation and interoperability in a service oriented environment.

O39

A Data Management Workflow for Verification, Integration and Visualisation of Heterogeneous Environmental Data

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We present a web-based framework for the management of heterogeneous environmental data. Datasets are partitioned based on their general structure (time series data, sampling data, etc.) and can be accessed and searched using a set of standardised keywords or search terms. A digital rights management scheme correlates individual data sets with user accounts in order to guarantee the protection of confidential data while still allowing an overview of the entire collection as well as access to open data for every user logged on to the web-portal. The database backend of our system is based on established standards and includes mandatory meta-data for each data set conforming to best-practice standards for geospatial data such as the INSPIRE directive and ISO 19115 ("Geographic Information - Metadata"). Apart from direct access via our web-portal, data may also be retrieved using a number of web services specified by the Open Geospatial Consortium, including the Web Map Service for spatial information or the Sensor Information Service for time series data, to allow access to data from any software or website implementing these services.

A wide range of additional software allows for the verification and integration of data sets. Visualization for time-series data is integrated directly into the framework and allows to assess the data of one or more sensors in order to detect sensor malfunction, artefacts or other potential problems. Basic functionality such as selecting ranges or zooming are integrated as well as the option to assign flags to indicate the quality of the data and mark invalid values. While basic, generally applicable filters such as thresholding are integrated directly into the framework, a more extensive analysis requires post-processing using established products such as *MatLab, R* or *Origin* with a subsequent re-upload of the modified data.

External software allows for the integration and visualization of heterogeneous spatial data. This includes commercial products such as *ArcGis* or the *GMS* as well as open-source frameworks such as the *OpenGeoSys Data Explorer* or *ParaView*. Incorporation of this software allows for interdisciplinary discussions on the data as well as correlation and error detection. It is also the basis for presentation of intermediate steps or project results to stakeholders or scientific audiences.

Our system currently includes more than 28 million data sets and approximately 170 million measurement values, including the observation and field data from the TERENO observatory "Harz/Central German Lowland", a modelling case study in the Middle East as part of the IWAS initiative and climate data gathered within the Global Change Experimental Facility (GCEF) project.

O40

Analyzing the Land Use /Cover Changes and Their Impacts on Ecosystem Services Using Vegetation Indices in Upper East Region of Ghana

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The capacity of different land use and land cover types to provide Ecosystem Services (ES) is highly differentiated, dependent on the spatial context and on temporal dynamics in the vegetation cover, so that the impact of land use and land cover (LULC) changes is difficult to assess and predict. The direct assessment based on field measurements would provide most detailed insight into both spatio-temporal dynamics of LULC changes and effects of management changes within land use. However, it is often not applicable due to high costs, or - in remote areas - due to difficulties of access and establishment of observation networks. Therefore, data from remote sensing are more promising in delivering proxies to assess the spatio-temporal dynamics of LULC and land management dependent ecosystem services provisioning variations.
In this presentation, we use satellite-derived vegetation indices (VIs) to calculate primary production (PP) as a proxy for some (provisioning) ES. Furthermore, primary production represents a measure of the solar energy captured by the system and is therefore recognized as a fundamental supporting service.
For the analyses, LULC maps derived from satellite data (MODIS, LANDSAT) will be used to identify LULC and detect changes. Subsequently, the Enhanced Vegetation Index (EVI) and the Normalized Difference Vegetation Index (NDVI) will be used to calculate the Primary Production. Finally, the sensitivity of the method will be tested for food provision as a representative service, using changes in crop yields derived from statistical services.

O41

A combined observational network and hydrological modelling to address water environmental services in watershed scale

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The current brazillian Forest Code law has enforced the consolidation of Permanent Preservation Areas (PPA) along rivers banks, steep and high slope areas, although not much has been effectively accomplished in the last years. We deployed a wireless hydroclimatic geosensor networks with 20 nodes (with measurements of air temperature and humidity, soil moisture and watertable) and 2 streamflow and precipitation gauges, over a 12 km2 watershed in the brazillian Atlantic forest biome, located in Extrema city at Posses river basin, which supplies water to Sao Paulo megacity. The cover area in the watershed comprises about 75% of pastureland, 20% primary and secondary forests, and 5% croplands. The network provide targeted measurements to be incorporated into simulations with a hydrological model (SWAT model), and their nodes were evenly distributed along the several types of vegetation across the spatial domain. With the field and modelling data, we have increased knowledge on how the hydrology responded to land use change, for a range of climate scenarios, and thus affected the water balance and water environmental services such as flood control and water availabity during the seasonal dry season and especially long dry spells. Streamflow and rainfall was measured since 2010, and network data (climate, soil moisture and aquifer) started to be measured in April 2014, which have been currently interpreted and discussed. The SWAT model was firstly calibrated using evapotranspiration measured in flux towers over forest and pastureland areas, and observed streamflow in the watershed. Model simulations were used to described land scenarios with varying extension of riparian reforestation and afforestation of steep areas basinwide. The scenarios with increasing reforestation showed a reduced mean surface runoff (24%) and a modest increased baseflow (2%). Preliminary results showed a substantial reduction of maximum streamflows, between 13% and 28% at the mouth and the head of the watershed. The results have highlited a substantial reduction of maximum streamflow events and a small increase of low flow which helps to keep the water availability during dry season.

O42

Integrated sensing, monitoring and modeling of low velocity flow fields in a constructed wetland for improving phosphorus removal

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Forecasting the low flow velocity field in a heterogeneous aquatic environment such as the Stormwater Treatment Areas (STAs) located at the northeast of the Everglades is extremely important in understanding the operation of the STA in its capacity to remove nutrient and functionality to serve as an effective wetland treatment system. Direct measurements of velocities at every single part of the STA are not always feasible. Integrated sensing, monitoring, and modelling technique can be a state-of-the-art tool to forecast the spatial and temporal distributions of flow velocity regimes in such dynamic aquatic environments. In this presentation, based on a few monitoring stations, comparison between two computational intelligence models including Genetic Programming (GP) and Artificial Neural Network (ANN) models was made possible to forecast the flow velocity and direction within a vegetative wetland area. First the local sensor network was established using Acoustic Doppler Velocimeter (ADV). Utilizing the local sensor data along with the help of external driving forces parameters, trained models of both GP and ANN were developed and validated to carry out the forecasting process of low velocity fields over time. The key finding of this research is the application of data driven artificial intelligence models for forecasting the hydraulic properties of a wetland system based on sparse monitoring sensors is reliable to some extent to discover insights of hydraulic residence time and to improve the overall understanding of possible nutrient removal in this constructed wetland.

O43

Five years of transition - atmospheric C-exchange dynamics of a coastal fen after rewetting

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Question: In which direction and how fast changes the atmospheric C-exchange of a coastal fen after hydrological conditions switched from moderately rewetted to flooded? The rewetting of drained peatlands is widely regarded as an adequate measure for the mitigation of greenhouse emissions. Therefore, especially in NE Germany, many peatlands are being rewetted. Our knowledge about greenhouse gas exchange associated with rewetting is mainly based on short-term experiments or space-for-time substitutions. These approaches do not consider the transient character of ecosystem acclimatization to flooding by rewetting. Here, we present more than 5 years of data on GHG (CO_2 and CH_4) exchange in a coastal fen after rewetting by flooding.

Methods: On the “Rodewiese” a coastal fen within the NSG “Hütelmoor und Heiligensee” in the Northeast of Rostock, NE Germany, we have established a long term research observatory addressing the atmospheric C-exchange. The site is part of to the TERENO Northeast network. Since summer 2009 we determine CH_4 fluxes with closed chambers distributed widely across the study site and CO_2-exchange with eddy covariance. Further, we record data on vegetation, hydrology, biogeochemistry, and microbiology.

Results: Gross photosynthesis as well as ecosystem respiration of the growing season both strongly decreased after flooding. However, because both decreased with the same magnitude, net carbon dioxide exchange (NEE) was almost constant at around 12 $t*ha^{-1}*a^{-1}$. The latter holds for the following years as well. Furthermore, flooding increased methane release rates to extremely high levels of up to 4.3 $t*ha^{-1}*a^{-1}$ for sedge stands and 2.7 $t*ha^{-1}*a^{-1}$ on average, which amounts to 67.5 $t*ha^{-1}*a^{-1}$ in CO_2 equivalents. Thereafter, the averaged annual methane emissions decreased asymptotically and where at an average of 0.4 $t*ha^{-1}*a^{-1}$ (10 $t*ha^{-1}*a^{-1}$ in CO_2 equivalents) in 2013. Factoring in the NEE of the growing season suggests that the system may be slightly above neutral with respect to the greenhouse warming potential of its atmospheric C-exchange 5 years after flooding. Analyses of peat and water biochemistry showed that the system had been destabilized in the first year following flooding and repeated vegetation analysis combined with remote sensing reveal strong and directed change in vegetation patterns.

Conclusions: Our data suggest that, when focusing on greenhouse gas mitigation, flooding should be avoided if possible. However, the successional development in vegetation, peat and water chemistry and atmospheric C-exchange we see in the 5 years after flooding hint at an adaptation of ecosystem functioning to the flooded conditions associated with reaching desirable annual rates of C-exchange and vegetation development during an acceptable time frame.

O44

Theory and practice of observing and manipulating grassland ecosystem services from the plot to catchment scale

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Agriculturally dominated catchments provide a wide range of ecosystem services. There is a need to understand the trade-offs and the multiple benefits that multifunctional agricultural land delivers. For example, intensively managed grasslands provide food and fibre, but also affect hydrological fluxes of sediment and macro-nutrients. It is increasingly realised that systems based approaches that take account of scale, connectivity and indicators of key thresholds in the delivery of ecosystem services are required.

In this presentation I will cover the theory and practice of monitoring grassland ecosystem services based on research that spans plot to catchment scale studies of temperate grasslands. These include understanding how grass cultivars can influence plot scale runoff generation, to the use of large (1 ha) lysimeters and field scale surface water drainage to understand grassland ecosystem services. There is a need for common and shared observatories to serve as coordinated cross-scale place based scientific platforms that enable interdisciplinary integration between empirical data collection through observation and experimentation, and modelling in support of ecosystem services and related integrative framings of land and water resources under environmental change.

O45

Tracking land-use changes from heterogeneous spatial data as tool for biodiversity and greenhouse gas monitoring in the nature park Drömling (Germany)

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Peatlands are important ecosystems for strongly specialized and endangered species but they are also hotspots of greenhouse gas (GHG) emissions when drained and used for agriculture and forestry. In Germany, most peatland rewetting projects have focused on biodiversity, but have nonetheless co-benefits for GHG emission reduction. Detecting changes in land-use and land-use intensity at adequate resolutions as proxy for GHG emissions (indicator: nutrient status, drainage depth or groundwater table) and biodiversity (indicator: vegetation) is an important prerequisite for assessing, and potentially monetizing multiple ecosystem services regained by peatland restoration. However, frequently no consistent time series of land-use products are available.

We introduce a soft translation key to construct consistent times series of land-use at the nature park Drömling at a 0.01 ha resolution. Two different fine-grained spatial products were used to create a time series of 20 years. Furthermore, the land-use datasets were analyzed to test whether they are useful as proxies for groundwater table by using data of 148 groundwater dipwells partially operating since 1992. The reduction of CO_2-emissions by rewetting from 1992 to 2012 was estimated by using the recent IPCC Wetlands Supplement of 2013.

A major loss of cropland and gain of grassland can be detected, while the area of shrubs and forests has been increased since 1992, mainly related to groundwater table depth. In contrast, the shift from grassland to cropland and vice versa is not always related to groundwater table. The information “wet” in spatial products can be useful, as well as detailed information of the groundwater table, but for making reliable statements both types of information are essential. Peatland rewetting in the nature park Drömling reduced the CO_2 emissions by 456 t $year^{-1}$, which is equivalent to 2.6% of CO_2-emissions of the peatland area.

It is impossible to distinguish between permanent and non-permanent land-use change based on the used diverse datasets.The groundwater table influences land-use and land-use intensity on organic soils in the nature park Drömling, so this can be used as proxy if available in good quality, but high uncertainties remain. Thus, detecting land-use change by fine-grained remotely sensed datasets could serve as a conservative method for monitoring biodiversity.

O46

Spatial and Temporal Patterns of Preferential Flow at the Catchment Scale

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There is abundant evidence that preferential flow is a common phenomenon, which stresses the importance of incorporating preferential flow processes at different hydrological scales. However, predicting the occurrence of preferential flow becomes troublesome when moving from the plot towards the catchment scale, as data coverage diminishes. A promising approach to identify the occurrence of temporal and spatial variability in preferential flow at the catchment scale is the use of soil moisture sensor response time. After determining the sequence of soil moisture response for different depths, the spatial occurrence of preferential flow and other flow regimes can be identified for single rainfall events. The aim of this study is to investigate the dominant controls on preferential flow at the catchment scale using data from the wireless soil moisture sensor network SoilNet installed at the TERENO test site Wüstebach. This data set consists of three-year long soil water content time series measured at three depths and more than a hundred locations. Separation and selection of rainfall event was based on a minimum period without rain and a minimum sum of precipitation. For all delineated precipitation events, the response time for all sensors was determined for each location. Subsequently, the order of the response times was used to assign one of the following classes for the particular location and event: (1) preferential non-sequential flow, (2) preferential flow based on flow velocity, (3) sequential flow, (4) no response, (5) no data. To understand the factors and processes that cause spatial variability in preferential flow, the results of this classification were related to site and event characteristics (e.g. precipitation characteristics, initial soil moisture content, soil type, bulk density, organic matter content).

O47

Estimation of the spatial distribution of soil hydraulic characteristics using apparent soil electrical conductivity as proxy data

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Precision irrigation management requires accurate information on spatial variation of field hydraulic properties and in-detail observations. Characterizing field scale soil hydraulic properties can be done by linking them to apparent electrical conductivity (ECa), which can be measured efficiently and inexpensively, so a spatially dense dataset for describing within-field spatial soil variability can be generated. Moreover, the soil ECa dataset can be used to guide sampling more effectively and efficiently. The objective of this study was to find a link between hydraulic properties and ECa and available ancillary information at our study site. We attemped to answer the following question: can theoretical and empirical relationships between field ECa data, hydraulic conductivity and soil water retention data be applicable to predict saturated/unsaturated hydraulic conductivity more accurately and effectively at the field scale.

Methods

The study site (10.5 ha) was located in a sandy agricultural area at the border between Belgium and the Netherlands (51°19′05″ N, 05°10′40″ E). ECa measurements were conducted with a DUALEM-21S sensor (DUALEM, Milton, ON, Canada) in 2011 and an EM38 (Geonics Ltd, Ontario, Canada) in 2013 at the field site with depths of explorations (DOE) of 50 and 100 cm for perpendicular receivers. The selection of sampling locations for the determination of soil hydraulic properties was done by combining a design-based (using ESAP software to select a full sample design i.e. 20 locations) and model-based sampling strategy (Fuzzme software to classify the ECa field data set) and 8 additional samples (traditional sampling along a transect) were taken to account for a maximum variation in soil properties based on a geophysical survey with a DUALEM-21S. Duplicate undisturbed (100 cm^3 Kopecky rings) and disturbed soil samples were taken at each of the 28 locations. Soil physical and hydraulic properties of samples were determined according to standard methods (*Ks* was determined using a constant head laboratory permeameter, the soil water retention curve, was determined using the sandbox method and the standard pressure plate apparatus. The bulk density was obtained by drying volumetric soil samples (100 cm^3) at 105 °C. Soil texture was determined using the pipette method for clay and silt fractions and sieving method for sand particles) and the parameters of the van Genuchten and Mualem conductivity model (MVG model) were fitted to the observed laboratory measurements. In a next step, the use of DUALEM and EM38 data with MVG parameters and Archie's laws was investigated to derive the predictive models of hydraulic properties.

Results

Results demonstrated the spatial variability and heterogeneity of ECa and soil hydraulic properties with K_s and α being the most variable parameters as compared to other MVG parameters. There are positive and significant correlations between $EM38_{v,100}$, $DUALEM_{p,50}$ and $DUALEM_{p,100}$($r \geq 0.84$). The greatest significant correlation of hydraulic properties and ECa occurred between K_s and EC_a of DUALEM ($r \geq -0.84$) while there is no correlation between α and all ECa values derived by different sensors. The correlations between log n and EM38 and DUALEM sensors at various depths were relatively strong ($r \geq 0.43$; $p \leq 0.05$).

A strong negative relationship between *log Ks* and ECa measured with DUALEM ($r^2 \geq 0.70$) and with EM38 ($r^2 > 0.46$) sensors was derived with a regression equation. The predicted results were tested vs measured data and confirmed that the performance of $DUALEM_{p,100}$-*Ks* model is relatively better than that of the same sensor with lower DOE and of the EM38 sensor (RMSE = 1.31 cmh^{-1}, R^2 = 0.55). It

must be noted that the EM38 and the DUALEM data were measured at different times with different field soil water status. Poor relationships between MVG shape parameters and ECa datasets were observed (0.052Ks and FF of first Archie's law and the negative relation between *Ks* and S_e of second Archie's law have achieved with different sensor at various DOE.

Conclusion

It can be concluded that the saturated hydraulic conductivity *Ks* can be estimated by using different equations of various ECa sensors such as EM38 and DUALEM. Poor relationships between MVG shape parameters and ECa data were observed. Therefore the prediction of MVG shape parameters from an ECa dataset is highly uncertain. The negative relationship between *logKs* and S_e of different sensors were obtained.

O48

Quantifying the uncertainties in the estimation of multilayered soil hydraulic properties at a catchment scale.

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Estimation of soil hydraulic parameters (SHP) is critical for modeling the coupled surface-subsurface processes at various scales, but the spatial variability of the parameters and insufficient data sets restricted its applicability at the catchment scale (Vereecken *et al.* 2008). Although extensive soil data is becoming more and more available at various scales in the form of digital soil maps, there is still a large gap between this available information and the input parameters needed for hydrological models. Inverse approaches using hydrological and crop model brought substantial improvement in the estimation of SHP from remote sensing observations, but this problem is still challenging. In particular, the soil layers and order/sequence of vertical heterogeneity of soil textures affect the uncertainty of parameter estimation due to complex nature of soil water in the layered soil profile (Shin et al., 2012). Several studies attempted estimating multilayered SHP by inversion of SVAT/crop model using LAI and evapotranspiration (ET) alone or in addition to SSM in model inversions (Sreelash et al., 2012; Shin et al., 2012). Though inversions with crop models provided better estimates of root zone SHP at plot scale, the large data requirements of crop model creates additional uncertainty in the estimated SHP via the uncertainty in the input data (non-estimated parameters) when applied at a catchment scale. To address this issue it is necessary to quantify the uncertainty associated with each of the input (non-estimated) parameters like agricultural practices, climate, soil parameters and vegetation parameters of a crop/SVAT model and their impact on groundwater refill.

The objective of this study is to perform such an analysis using remote sensing observations (LAI and surface soil moisture) and crop model inversion with different levels of precision to estimate the SHP and its uncertainty at a spatial scale in an agricultural catchment. The case study is provided by the Berambadi catchment (South India, www.ambhas.com), which is associated with the RBV network of Observatories of France (http://rbv.ipgp.fr/). The Stics crop model (http://www6.paca.inra.fr/stics_eng/) was calibrated for the main species cropped in the area. We consider three levels of uncertainty associated to the spatialization of the non-estimated parameters , according to the sources of data used: 1) a low level, by considering data obtained in field experiments; 2) a high level by considering the full range of values encountered on the site through a farmer survey for agricultural practices characterization and existing, poorly precise, maps and different pedotransfer functions for soil parameters definition; 3) an intermediate level by considering a smart use of field data, farmer survey, climate and soil data, in order to derive decision rules on agricultural practices. The applicability of remote sensing data for the estimation of SHP was tested by using LAI and surface soil moisture retrieved from RADARSAT-2 data. LAI was estimated from radar vegetation index (RVI) and surface soil moisture using the Water Cloud Model (Sreelash, 2014). The uncertainty associated to SHP estimates is therefore propagated to drainage fluxes estimates and allow to quantify the gain obtained from a better knowledge of crop management options in the watershed and adapted pedotransfer functions.

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O49

Soil moisture and water potential vertical profiles informationabout the rootzone: from the plot to the catchment scale.

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Since 1997 an experimental field with intensive soil moisture TDR measurements has been set. The site is sandy permanent meadow ina plain topography area, down to 2 meters depth. It is a midlatitude north-west Italy area.

During the first years also water potential was measured and the retention and conductivity curves have been estimated.

Several short time monitoring exercises in areas with similar climate but complex topography has been performed.

The link between time structure of rainfall and soil moisture dynamics has been studied. It was meaningful for upscaling the soil moisture in the other experiments, up to the catchment scale.

O50

Reconstruction of former lake levels of groundwater-fed lakes in northeastern Germany using RapidEye archive data

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Groundwater-fed lakes in northeastern Germany revealed massive fluctuations in their lake levels during the last decades. However, precise lake level measurements were only recorded for a small numbers of lakes. In this study we evaluate the use of multi-spectral images (RapidEye) to extract former water-land-boundaries and estimate the corresponding former lake levels. The main test area for the evaluation is lake Großer Fürstenseer See near Neustrelitz.

Lake Großer Fürstenseer See is characterized by a significant increase of its lake level since 2010. Its shore is heterogeneous with different topography and a variety of vegetation. The evaluation is based on selected subsets of the shoreline with different characteristics. After the pre-processing of the RapidEye images from 2009 to 2014, we extracted the water-land-boundary using a normalized difference water index (NDWI). The corresponding lake levels were estimated by merging the water-land-boundary with a high-resolution digital elevation model showing the terrain and the underwater topography of the lake. The evaluation of the data used and the methodology are based on DGPS measurements and in situ lake level records.

RapidEye images enable the monitoring of seasonal and annual variations of lake level changes of lake Großer Fürstenseer See. The extracted water-land-boundary showed a higher accuracy at shoreline subsets with shallow slopes and little vegetation than at steep and vegetated shorelines. As the accuracy of the estimated lake levels strongly depends on the accuracy of the extracted water-land-boundary, shallow and not vegetated shorelines are best suitable for the estimation of the lake level.

O51

Multi-decadal lake-level dynamics in north-eastern Germany as derived by a combination of gauging, proxy-data and modelling

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In the glacially formed, lake-rich territory of north-eastern Germany pronounced hydrological changes were detected in the last decades, leading to the general question how lake levels and related groundwater levels perform in a longer perspective, i.e. during the last century. But long-term gauging records are rare; most observations do not start before the late 20th century. Therefore the potential of historic hydrological data, comprising drowned trees (as a geo-/bioarchive) and aerial as well as map imagery (as a document archive) was tested in order to derive discrete-time lake-level stands. These data are contrasted with retrograde lake-level modelling, obtaining a record with continuous-time character.

Two small glacial lakes without surficial drainage (i.e. closed/endorheic lakes) were investigated in the Schorfheide area, c. 70 km north of Berlin. Both are dominantly fed by groundwater but differ in their hydrogeological and catchment characteristics. For one lake a c. 40 year-long gauging record is available, showing high lake levels in the 1980s followed by a lowering of c. 3 m till the mid-2000s. In both lakes submerged in situ tree remains were discovered and dated by dendrochronology, revealing low lake levels during the first half of the 20th century. One lake basin has been almost completely dry till c. 1960. Aerial photos provided data on lake levels since the 1930s which are corroborated by evidence of topographic mapping. Combining the empiric data with retrograde lake-level modelling, a well-proven lake-level record can be established for one lake that covers the last c. 90 years. The same general lake-level dynamics could be reconstructed by means of proxy data for the other lake. In both cases climate dominantly drives the lake level. Comparison with other multi-decadal lake-level records from the region shows that these differ, depending on the hydrological lake type which modifies water feeding and water level.

O52

Linking diatom deposition in Lake Tiefer See (NE Germany) with the spring temperature gradient

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The currently strongest link of instrumental and past time scales at Lake Tiefer See (NE Germany) is an inverse relation of the deposition of siliceous phytoplankton (diatoms) with the rapidity of spring warming.

The now fully implemented monitoring of weather and lake conditions and sediment deposition showed a much larger diatom deposition following the late ice breakup and rapid spring warming in April 2013 compared to that after the mild winter and gradual spring warming in 2012. Crucial for this response is the timing of nutrient supply (deep mixing) and light availability (stratification). The exemplified inverse relation of diatom deposition with the duration of spring warming (0 - 10°C) is verified for the annually averaged diatom Si in the recent varved sediment record (AD 1924 - 2010) using the Schwerin temperature series. We find 49% explained variability in a linear regression. This percentage increases when the period of intensive manuring and drainage in the catchment (1975 - 1995) is removed from the dataset.

This transfer function can be used to reconstruct the spring temperature development from the diatom Si permitted by the range of values covered in the recent period and measured in the long sediment core of Lake Tiefer See.

This study is a contribution to the Virtual Institute of Integrated Climate and Landscape Evolution Analysis -ICLEA- of the Helmholtz Association and uses TERENO infrastructure.

O53

Process-based modeling of daily growth as a function of environmental forcing in mixed temperate forests

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In spring 2012, an extensive monitoring site for tree growth and water relations was established within the framework of the Virtual Institute for Integrated Climate and Landscape Evolution Analyses (ICLEA) project using TERENO infrastructures in the lowlands of NE-Germany (Müritz National Park). Dendrometers and sap flow sensors were installed in mixed stands of mature pine, beech and oak growing along soil hydrological transects nearby a lake shore. This set up searches to evaluate the response of the species to changing climate and varying water availability. The climate at the study site is characterized by annual precipitation varying between 550 and 650 mm/year which has remained stable in the region over the last 115 years. In contrast, an increase in air temperature since the late 80s has been observed.

Process-based models are useful tools to properly investigate the impact that climate and environmental variability will have on forest growth dynamics. To this end, we will implement a process-based model to understand cambial activity at a daily time scale. We will analyze how carbon is allocated to the stem in relation to environmental variability from the monitoring data. The model aims to serve as a basis to link past climatic variability and tree growth to be used for predictive purposes.

O54

Climate reconstructions from tree-ring widths for the last 850 years and the need for new tree-ring proxies in northern Poland

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Tree-ring based temperature reconstructions form the scientific backbone of the current debate over global change, and they are the major part of the palaeo data base used for the IPCC report. However, long temperature reconstructions derived from temperate lowland trees growing well within their distributional limits in central Europe are not part of the IPCC report, which is an essential gap in the international data base. It appears that dendroclimatological analysis at temperate lowland sites was so far difficult to perform mainly for three reasons: diffuse climate-growth relationships, the lack of long chronologies due to absence of sufficient numbers of long-living trees and the potential loss of low-frequency signals due to the short length of the sample segments.

We present two robust multi-centennial reconstructions of winter temperatures and summer precipitation based on pine and oak tree-ring widths chronologies from northern Poland, where so far no long tree-ring based reconstructions were available. We compared the new records with global, hemispherical and regional reconstructions, and found good agreement with some of them. In comparison, the winter temperature of our reconstruction, however, did not indicate any modern warming nor did the summer precipitation reconstruction suggest any modern 20th century changes.

Then again, due to the short segment lengths of our individual series the resulting multi-centennial reconstructions suffered from the segment length curse inhibiting the preservation of low-frequency signals. Therefore, in a second step, we measured cell structures within the tree rings and developed chronologies of parameters such as cell wall thickness and cell lumen area for a period of several decades. We used our new method (Liang et al. 2013a,b) applying confocal laser scanning microscopy to increment core surfaces for efficient histometric analyses. We focused on samples covering the last century because meteorological data necessary for calibration studies were available for direct comparisons. It was demonstrated that the correlations with climate were strong and different from those found for tree-ring widths (e.g., N-Poland oak-vessel-lumen-area-chronology with previous September-to-December mean temperature r = 0,61 and N-Poland pine-tracheid-lumen-area-chronology with mean Feb-to-June temperature r = -0,66). Since the cell structure data did not contain age trends, there was no reason for detrending, thus we were able to use raw values. By using raw values low-frequency signals could be sustained in the chronologies. Currently, long chronologies of cell structure measurements are being developed to finally produce robust reconstructions for the temperate lowlands of Europe, which contain not only high- but also low-frequency climate information for the last Millennium.

O55

Evaluating the water fluxes from vegetation ecosystems along precipitation gradient in the dry Mediterranean region

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Quantifying evepotranspiration fluxes from vegetative surfaces in dry regions is critical to assess future plant survival and its effect on local hydrology and agriculture, as well as for large scale modeling efforts. This requires knowledge of the main flux components, of evaporation (E), interception (I), transpiration (T), runoff (R) and recharge. Dry lands ecosystems, especially Mediterranean ecosystems types, are characterized by a mosaic of a range of small and different vegetation types having different water uses strategies, resulting in different flux patterns. Large inter-annual variations in rainfall in dry regions further add complexity to the partitioning of the water fluxes in the soil-plant-atmosphere system to its components over a given region. Finally, traditional observation systems rely on sparse permanent flux tower sites, which further increase the difficulties in studying complex systems. To address the challenges noted above we developed a new measurement approach relying on a mobile observing system to quantify changes in water fluxes along a sharp south-north aridity gradient in Israel, and in both forests and nearby non-forested ecosystems in each case (Figure 1).

Our newly developed mobile observing system composed of three main core elements: First, it is a completely mobile and fast deployment unit fitted to rough terrains and independent of line power for extended periods. Second, it permits the traditional eddy covariance (EC) flux measurements, including radiations, in canopies ranging from grasslands to forests (using extendable mast up to 30 m). Third, it offers appropriate laboratory conditions for the deployment of any analytical instrumentation, for additional tracers and auxiliary measurements. This study extends the long-term study in the permanent FLUXNET site in Yatir, which indicate that the semi-arid forest ecosystem evapotranspiration (ET) is about 95% the annual precipitation, while tree transpiration is about 60% of ET, interception is ~11%, runoff is virtually zero, and the recharge to depth is 0-5% (Raz Yaseef *et al*., 2009). Both rain amount and rainfall distribution during the wet season have considerable effects on the water fluxes and carbon uptake by the forest ecosystem, and while the forest prevents soil erosion, over the non-forested area large rainfall episodes bring significant floods and erosions. These studies have shown that afforestation activities in the semi-arid zones could have significant effects on mitigating carbon raises in the atmosphere (Rotenberg&Yakir, 2010).

Measurements with the mobile system are on a campaign basis of about two weeks per site, repeated at different seasons, and include in addition to EC fluxes trees sap-flow and catchment runoff measurements. Four measurement sites were used from the Yatir area in the south, having long-term aridity index of 0.18, two intermediate sites in central Israel, and a wet site in Northern Israel with aridity index of 0.6 (Figure 1). At each location, measurements were made in a pine (Aleppo pine) forest site, and in a nearby un-forested ecosystem site (total of eight measurement sites). The system's quality of measurements was confirmed against a permanent EC site at the Yatir forest and was recently used for the first time to combine conventional and quantum cascade laser flux measurements (Asaf *et al*., 2013). Variations in fluxes between sites and between ecosystems at the same site where large and changed in magnitude over the seasons. For example, during winter, daily transpiration (and carbon uptake) patterns were similar at all pine sites (equivalent to about 50% of net radiation; Rn), but T become insignificant and constant during day at dry site (Yatir) during summer time (equivalent to 10% of Rn). At the wetter sites, winter activity patterns were sustained also throughout summer (with T equivalent to ~30% of Rn). This nonlinear response across the climatic gradient and across sites indicated that a single permanent observation site could not be used to predict the activities in the complex system. The water use by plant types, indicated by T/E ratio, were lower at the non-forested sites, which was reflected also in the reduced net carbon uptake by the non-forested ecosystems.

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O56

Evaporation measurements at the Dead Sea

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The Dead Sea area is a unique environment of great ecological and economic importance. The region is faced to various problems, especially the strong variability in water availability and the impact of climate change. Therefore, the understanding of the water cycle and the quantification of the water budget components of the Dead Sea are of great importance. Evaporation is a central component in this region, because it contributes directly to the water budget, but also indirectly by triggering precipitation. Models estimate the current evaporation at around 1200 - 1300 mm/year, but haven't been evaluated with measurements. Therefore a one-year field experiment was designed and energy balance stations were installed in spring 2014 in the framework of the HGF Virtual Institute DESERVE (DEad Sea Research VEnue).

At three characteristic sites (within vegetation, over bare soil, and directly at the coastline) eddy covariance measurements are performed to quantify evaporation. For westerly wind directions the wind is blowing from the land to the water and the bare-soil and coastline station measure the evaporation from the soil. So we have two comparable measurements of soil evaporation over a short distance. For northerly to southerly wind directions, the wind is blowing from the water to the land and the air over the water is advected to the energy balance station at the coastline. Thereby the instruments measure the actual evaporation from the water and the other energy balance station further inland still measures the evaporation from the soil. Due to predominant local wind systems, such as land and sea breeze, sufficient cases with wind directions from the water are guaranteed. Furthermore it is possible to investigate correlations and dependencies of the evaporation on various meteorological variables, such as wind speed, air temperature or radiation.

This measurements enable the calibration of models, which calculate the Dead Sea water budget, so that the accuracy of the results can be improved and future scenarios of water availability can be calculated to provide a basis for water resource management in this region.

O58

Data collection and visualization of water services: Applications for nexus governance in Africa

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Africa receives the third largest amount of global annual precipitation, which builds up the African water resources. Still, at the continental level, Africa´s renewable water resources only represent around 9 per cent of the world´s total freshwater resources, making it the second-driest continent. Moreover, in Africa the water resources are spatially-unequally distributed. In combination with varying population density, this results in wide differences in water availability and poses challenges for water supplies. (Semi)-arid regions have to deal with droughts, poor water quality, soil salinity, low agricultural production and limited water supply. Successfully coping with water-related problems and handling future water demands depend on effective water resource management. The management needs data about the actual and future state of the environment (including water resources) and socio-economics. The data assessment and management requires an integrated approach where spatial data is key for further system analysis and water management. However, the results of data assessment, complex system analysis and predictions need to be visualized making it understandable and useful for both, decision makers and the public. As an example of new data collection approaches for data-poor environments we introduce the water Point mapping system (WPMS) which is currently implemented in Tanzania as one of the Geo-information and communication technology tools for the management and presentation of information in a spatial context. It aimes at enabling planners, decision makers and other key partners to identify the geographic areas and communities in which to focus their efforts for maximum impact. UNU-FLORES is working with the Ministry of Water, Republic of Tanzania on a WPMS project based on a request to build capacity for evidence based decision making that advances the nexus approach. In addition to rural water supply, applications of WPMS in other sectors such as irrigation and livestock management are being explored in collaboration with governments elsewhere in Africa.

O59

Intermediate Scale Soil Moisture Surveys in TERENO with the Cosmic Neutron Rover

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Monitoring soil moisture with Cosmic Ray Neutron Sensors (CRS) is an emerging field of research, because the mesoscale footprint (~0.3 km² and 50cm depth, [1]) is of great interest for land surface models that usually work at resolutions ranging between point measurements (e.g. TDR) and remote sensing data. More than 20 stationary probes are already maintained all over the TERENO observatory.

We equipped a Land Rover vehicle with multiple CRS detectors that allow environmental neutron sensing with high temperal resolution on-the-fly. The so-called *Cosmic Neutron Rover* can be used to quickly capture large spatial patterns of soil moisture, biomass and snow in a whole catchment on demand. The measurements can be calibrated and compared with the high number of various soil moisture networks in the TERENO observatory, like stationary CRS, wireless point-sensor networks (SoilNet), TDR campaigns or remote-sensing/air-borne data. Since the latter method is lacking validation data sets at its large scale, the *Cosmic Neutron Rover* can be a unique and promising tool to provide soil moisture data at a comparable spatial scale.

The talk will give an overview about recent and upcoming studies with the new measurement technique in TERENO and TERENO-MED.

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O60

Cosmic-ray neutron intensities at a forest site - determination of soil moisture, biomass and canopy interception

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The water pooled above-ground (e.g. in snow, biomass, canopy interception) and in the shallow subsurface (soil and litter moisture) are controlling the exchange of water and energy between the land surface and the atmosphere. Therefore, measurements of the water stored within the interface of the shallow subsurface and the atmosphere are critical for the prediction of evapotranspiration and groundwater recharge. The scale of measurements is due to considerable spatial and temporal variability important to consider. At present soil moisture within the Ahlergaarde subcatchment (1055 km^2) of the Skjern River watershed (2500 km^2) (Danish Hydrologic Observatory - HOBE) are collected at point scale using Decagon ECH2O 5TE capacitance sensors (30 stations with sensors installed in three depths) and at larger scale (44*44 km) by SMOS satellite retrievals. Canopy interception is estimated from measurements of precipitation at a forest clearing and throughfall at three stations within the forest, each covering an area of approx. 3 m^3. However, calibration and validation of a hydrological model with a regular grid of e.g. 500 meter requires measurements at a corresponding scale. Upscaling of point measurements are possible but associated with uncertainties as a substantial amount of points were to be sensed to represent the heterogeneity of the area.

A cosmic-ray neutron probe continuously detects the cosmic-ray neutron intensity within a footprint of approximately 300 m at sea level and depths of 10-70 cm. The neutron intensity is inversely correlated to the hydrogen stored in the soil, biomass, litter layer, snow and/or canopy interception. Soil moisture constitutes in most cases the largest pool of hydrogen and it has in several studies been shown that the cosmic-ray neutron probe provides reliable estimates of soil moisture.

Lately, more attention has been given to use the cosmic-ray neutron probe for measuring other variables than soil moisture. At sites with extensive or considerable annual variation in vegetation cover, the signal is affected by the change in the biomass-water content of a cropped field (from sprout to harvest) as well as the canopy interception of a forested site.

Continuous cosmic-ray neutron intensity measurements are carried out at three land cover types to estimate intermediate scale soil moisture. Further, the potential of using the cosmic-ray neutron method to determine the water content of the biomass and the canopy interception are tested using multiple height measurements at a forest site and by neutron transport modeling using the extended version of the Monte Carlo N-Particle Transport Code (MCNPX).

Through 2013 and 2014 six cosmic-ray neutron probes were installed in the Ahlergaarde catchment at sites representing the three major land covers, i.e. agriculture (61 %), forest (17 %) and heath (14 %). Probes were at all three sites installed at 1.5 m above the ground surface. At the forest site probe installations were additionally conducted at the canopy surface at 27.6 m above the ground surface and probes detecting neutron intensity of lower energies were added to both detection heights. The probes at the ground surface were used for soil moisture detection. The difference in the count rates at the different energy levels and heights above the surface were detected to investigate the potential of using cosmic-ray neutron intensity measurements to estimate biomass-water and the canopy interception fluxes.

Modelling was conducted to simulate the response of different amounts of biomass, soil moisture and canopy interception on the neutron intensities and to test whether these responses could be seen in

the measurements. However, as both probes are contaminated by neutrons of either too high or too low energies additional field experiments were performed. Adding cadmium foil to the probes the neutrons of unwanted energies were shielded out leaving more distinct ranges to be detected, enabling the comparison of model results with measurements.

O61

Estimation of recharge using cross-borehole electrical resistivity tomography from long-term monitoring of saline tracer

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Recharge is one of the main components of the hydrological cycle. The direct measurement of recharge is difficult and it is, therefore, usually approximated based on the measurement of other water fluxes and mass balance considerations. Here we present results of a field experiment in which we estimate recharge using geophysical methods. The experiment was conducted at the agricultural field site, Voulund, within the Danish hydrological observatory in the Skjern river catchment, HOBE. At the field site a variety of instrumentation was installed to assist in estimating water fluxes and state variables, for example, eddy flux evaporation, potential evapotranspiration, precipitation, lysimeter recharge, soil moisture using TDR, Decagon 5TE probes, cosmic-ray intensity, and cross-borehole geophysics. In September 2011, a saline tracer was added across a 12 m by 12 m area at the surface within the field site, at an application rate mimicking natural infiltration. The movement of the saline tracer front was monitored using cross-borehole electrical resistivity tomography (ERT); data were collected on a daily to weekly basis and continued for one year after tracer application. The ERT data was subsequently inverted and corrected for temperature changes in the subsurface. Spatial moment analysis was used to calculate the tracer mass, center of mass and thereby recharge. The recovered mass was underestimated by the ERT data by up to 50% during the entire period. Such mass balance errors are widely recognized and are a result of variable measurement sensitivity and smoothing implicit in the regularization scheme of the applied inversion routine. Furthermore, it was not possible to calculate the center of mass after 7.5 months of measurements due to tracer mass loss through the bottom of the measurement domain, i.e. at the groundwater table. The results were nonetheless in very good agreement with porewater samples collected and analyzed from five cores extracted within the tracer application area. Recharge during the 7.5 months from September 2011 to the end of April 2012 was estimated to 585 mm using the ERT data. This value is in good accordance with recharge estimates made using buried lysimeters located only meters away from the cross-borehole ERT array.

O62

Combined satellite and proximal soil sensing approach for improved catchment characterization

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Recent developments in proximal soil sensing techniques offer unique opportunities to characterize the vadose zone across spatial scales, especially when combining these techniques with remote sensing approaches. Here, we link RapidEye satellite imagery and multi-depth-sensing electromagnetic induction (EMI) measurements of 20 ha arable land around Selhausen (Germany) and investigate one specific 1.1 ha plot using geophysical and conventional soil sampling methods. For the area, large-scale leaf area index (LAI) was estimated from the satellite images and compared to the lateral and vertical apparent electrical conductivity (ECa) distributions that were recorded using the multi-configuration EMI system. Increasing and decreasing ECa values with depth separated the area into the lower terrace (LT) and the upper terrace (UT), respectively. At the mainly gravelly UT, distinct LAI patterns coincided with higher ECa values that were measured with the deepest sensing EMI coil configuration. Soil analysis revealed higher subsoil clay content, related to higher water holding capacity, which enabled better crop performance under drought conditions. To extract depth information, we performed detailed investigations at the selected plot that showed UT sediments in the eastern part and LT sediments (loamy silt) toward the west. Here, we developed a dedicated quantitative EMI inversion scheme to obtain a three-dimensional (3-D) layered subsurface electrical conductivity model using multi-configuration EMI data. The smoothly changing lateral and vertical electrical conductivities were validated with grain size distribution maps and two previously measured 120 m long electrical resistivity tomography (ERT) transects. Overall, the 3-D subsurface model obtained with EMI inversions and the independent ERT inversions showed very similar subsurface structures. Small differences in absolute electrical conductivity values within certain layers were attributed to varying soil moisture states at different dates. Consequently, the combined sensor and data processing approach opens up new perspectives for an improved characterization of relatively large areas up to the km^2-scale and provided subsoil information that can improve models that aim at improved descriptions of catchment processes.

O64

Controls for multi-scale temporal variation in ecosystem methane exchange during the growing season of a permanently inundated fen

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Wetlands are the largest natural sources for atmospheric methane (CH_4). In wetlands with permanent shallow inundation, the seasonal variation of CH_4 exchange is mainly controlled by temperature and phenology. In addition, ecosystem CH_4 exchange varies considerably on smaller temporal scales such as days or weeks. Several single processes that control CH_4 emissions on the local soil-plant-atmosphere continuum are well investigated, but their interaction on ecosystem level is not well understood yet. We applied wavelet analysis to a quasi-continuous Eddy Covariance CH_4 flux time series to describe the temporal variation of ecosystem CH_4 exchange within the growing season of a permanently inundated temperate fen. Moreover, we addressed time scale-specific controls and investigated whether their impact changes during the course of the growing season. Water and-/soil temperature correlated with ecosystem CH_4 exchange at time scales of 6-11 and 22 days which exceeds the time scales that are typically associated with the passage of weather fronts. The low response time might be due to the high heat capacity of the water column. On a daily scale, shear-induced turbulence (expressed by friction velocity) and plant activity (expressed by canopy photosynthesis) caused a diurnal variation of ecosystem CH_4 exchange with peak time around noon. However, this pattern was apparent only at the beginning of the growing season (April/May). In the following, the daily cycle of convective mixing within the water column (expressed by the water temperature gradient) gradually gained importance and caused high night-time CH_4 emissions, thereby levelling off the diurnal CH_4 emission pattern. Our study highlights the need for multi-scale approaches that consider the non-stationarity of the underlying processes to adequately describe the complexity of ecosystem CH_4 exchange.

O65

Meso-scale eddies contribute to near-surface turbulent exchange: evidence from field measurements

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The eddy-covariance technique tends to underestimate the turbulent heat fluxes, which results in the non-closure of the surface energy balance. In this study, we show experimental evidence that meso-scale turbulent organized structures, which are inherently not captured by the standard eddy-covariance technique, penetrate down into thePrandtl layerand contribute to near-surface exchange.Using a combined setup of three Doppler wind lidars above a cropland-dominated area in the Eifel/Lower Rhine Valley Observatory of the TERENO program, we were able to detect convective coherent structures in the surface layer down to a few meters above ground. In order to assess whether these structures affect the eddy-covariance measurements, we analyzed data from two micrometeorological stations in the study area with respect to energy balance closure. In accordance with several studies before, our data confirm a strong dependence of the energy balance residual on friction velocity. In addition, we also found the energy balance residual to be positively correlated with the vertical moisture gradient in the lower atmospheric boundary-layer, but not with the temperature gradient. This indicates that meso-scale transport probably contributes more to the exchange of latent heat than of sensible heat, since we assume that the organized structures are the dominant transport mechanism between the surface layer and the outer layer.Moreover,we show that flow distortion due to tower mountings and measurement devices affects the energy balance closure considerably for certain wind directions and that a neglect of canopy heat storage can cause large residuals during the morning hours.

O66

Modelling of hourly evapotranspiration and soil water contents at the grass-covered boundary-layer field site Falkenberg, Germany

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1 Question

Real evapotranspiration (ETr) is a key variable for hydrology, agronomy and meteorology. In addition to atmospheric conditions, in particular global radiation, temperature, wind speed or air humidity, ETr is also influenced by vegetation type, phenology and soil water storage. Modelling of root water uptake by vegetation cover is an essential part of hydrological models and a prerequisite for an accurate simulation of ETr. In deterministic hydrological models, root water uptake is normally calculated by a sink term in the Richards equation with various parameterizations as functions of water stress. In the last years, new so called compensatory root water uptake models were developed for a more adequate description of soil water extraction by plant roots. Compensatory means that reduced root water uptake in upper stressed parts of the soil part is compensated by an increased uptake in deeper unstressed soil layers. However, only a few studies using experimental field data for the validation of such root water uptake models are published until now. Therefore, a further verification of such compensatory root water uptake approaches using field experiments with a higher measurement frequency and longer investigation periods was recommended in these studies.

2 Methods

In our study, we analysed a two-years period from 2003-2004 with hourly rates of ETr derived from Eddy-Covariance (EC)-measurements and soil water contents monitored by Time Domain Reflectometry (TDR)-probes at the grass-covered boundary layer field site Falkenberg of theLindenberg Meteorological Observatory-Richard-Aßmann-Observatory,operated by the German Meteorological Service (DWD). These ETr-rates and soil water contents were compared with the results of a modelling approach consisting of the Penman-Monteith equation and of the soil water balance model Hydrus-1D using an uncompensatory and a compensatory root water uptake model. One objective of our study was an analysis of the impact of the application of these two different root water uptake approaches on the model outputs to give a further experimental verification of root water uptake models. In contrast to experimental data with a daily time step, hourly measured data enable a more detailed analysis of the temporal dynamics of ETr and soil water contents near the soil surface, and, therefore, a more rigorous test of hydrological models.

3 Results

The comparison of soil water contents and ETr-rates simulated by our modelling approach with the measured ones suggested in general a satisfactory model performance. The calibration of soil hydraulic parameters and the estimation of an appropriate rooting depth of grass cover showed the highest impact on the simulation quality. In comparison with the results obtained from the other simulations, the application of compensatory root water uptake with a critical root water uptake index ω_c=0.25 led to a decrease in the model performance for the total investigation period. However, in the dry summer 2003, we found contradictory results in the model performance for ETr and for soil water contents. Corresponding soil water contents simulated by using compensatory root water uptake with ω_c=0.25 showed a better agreement with the measured ones than the other model applications in this period, whilst corresponding ETr calculated by this approach ranged significantly below those measured by the EC-system.

4 Conclusions

The recommendation of a possible model based triggering between the use of compensatory root water uptake in dry periods and the application of uncompensatory root water uptake in wetter periods was indicated by the comparison of simulated and measured soil water contents, but not by the comparison of calculated with observed ETr. Therefore, in the case of the application of such compensatory root water uptake models, the resulting impact on ETr-rates in dry periods should be analysed to identify unrealistic model outputs and to define an appropriate value of the critical root water uptake index ω_c.

In our study, simulated ETr-rates were typically higher with a mean of 20% than those measured by the EC-System. These differences might be related to the frequently reported inability of EC measurements to close the local energy budget.

We should finally remark that the investigation period 2003-2004 showed annual rates of precipitation below the longterm mean. Therefore, an application of compensatory and uncompensatory root water uptake models using experimental data obtained from years with higher precipitation at the GM Falkenberg should be the subject of a separate study.

O67

Integrated Climate and Hydrology Modelling - catchment scale coupling of a regional climate model and a hydrological Model

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Introduction

Observations and climate projections provide evidence that water resources are vulnerable and subject to a high potential impact by climate change with wide implications for human societies and ecosystems. An improved understanding of the hydrological feedback and interaction mechanisms between the atmosphere, the land-surface and the subsurface is therefore crucial. Previous modelling efforts primarily used each model in sequential steps whereas recent years have seen the emergence of studies coupling climate and hydrology models with the aim of directly including the atmosphere/land-surface/subsurface interaction. On the domain shared by the two models, the coupled system thereby utilize the higher temporal and geographical detail inherent in the hydrology land-surface scheme as well as the wider range of processes at the land- and sub-surface.

In the present study we investigate a dynamically coupled version of a comprehensive distributed hydrological modelling system, MIKE SHE, nested inside the DMI-HIRHAM regional climate model (RCM). A particular challenge in coupling a climate model to a hydrological model resides in the vastly different philosophies expressed by such codes. While RCM's generally implement primary physical equations, hydrological models are often greatly calibrated. Likewise, temporal and spatial resolutions are often quite different. Also, present versions of MIKE SHE are native only to the Microsoft Windows operating system, necessitating the development of a novel cross-platform model interface based on open-source OpenMI technology. The setup has proven stable and has been used for simulations of several years.

Method

The coupled model has been evaluated for a groundwater-dominated catchment in the western part of Denmark, Skjern River (2500 km^2 - 500 m grids), embedded within an RCM domain (4000 x 2800 km - 11 km grids). A two-way interaction between the atmosphere, land-surface and subsurface is enabled through and energy based (Shuttleworth-Wallace) land-surface model (SWET) within the shared domain. In this manner the simple land-surface model embedded in DMI-HIRHAM is effectively replaced by the superior land-surface component of the combined MIKE SHE/SWET model, which includes a wider range of processes at the land-surface and 3D distribued subsurface flows as well as higher temporal and spatial resolution. Outside the shared domain DMI-HIRHAM utilizes its own embedded land-surface model; however, the model nesting enables the detection of possible feedbacks (e.g. soil moisture and precipitation) from the improved surface/subsurface hydrology to the atmosphere even outside the shared domain. Simulations were performed for two different periods with differing aims: (i) 26 simulations were performed for a one-year period (1 May 2009 to 30 Apr 2010) to investigate the influence of the inter-model data transfer interval (varied from 12 to 120 min) as well as the influence DMI-HIRHAM coupled and uncoupled model variability. (ii) 8 simulations (ongoing and therefore subject to increase) were performed in selected periods from 2000-2010 having good observation data, evaluating the coupled model performance, as opposed to uncoupled, with regard to more severe events of drought, high precipitation and warm/cold periods.

Results

HIRHAM coupled output was assessed against distributed data sets of precipitation, air temperature, wind speed, relative humidity, global radiation and surface pressure. For the first batch of runs (i) the former four of these variables showed a statistically significant improvement in the coupled run root mean square error (RMSE) levels with a more frequent inter-model data transfer interval whereas the latter two variables were largely unaffected. In the current configuration, which is limited by transferring actual data files between the models due to security constrains, as opposed to memory transfer, an optimal transfer rate is seen in the order of 30 min. with regard to computation time vs. performance. Also, a significant regional variability is seen for precipitation for the coupled setup. In general however, the coupled performance is poorer compared to the uncoupled. The second batch of coupled simulations (ii) investigate the influence of including the more detailed land-surface scheme from MIKE SHE/SWET on the coupled performance in cases of more severe weather. In this manner we explore a possible reduction of the well-known climate model bias, e.g. for higher temperatures and high precipitation.

Conclusions

Presented here are the results from two full studies employing a fully dynamic coupling performed on several years with a sub-diurnal data exchange rate between the HIRHAM RCM and the MIKE SHE/SWET including full 3D subsurface flow, river flow and an energy based evapotranspiration scheme. The poorer results of the coupled setup, compared to uncoupled, is explained by the rigorous calibration and refinement of both models over a number of years, or even decades, to reproduce observations. These refinements however, are completely disregarded by imposing a new model over the shared domain which inevitably results in model deterioration. Therefore, an important issue for future studies is to pursue a strategy for calibrating the coupled model setup as a whole to overcome the danger of having the model calibration compensate for biases in other model. Further experiments should also include running on a larger shared domain and employing the setup for other regions. However, in the present study we emphasize the overall feasibility of the coupling tool and suggest that modelling studies of the future climate are likely to benefit from the coupled model setup.

O68

Investigation of connections between water budget components and soil water content distribution on a forested site

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The Wüstebach site represents a small catchment located in a low mountain range in the west of Germany that is entirely forested with spruce trees. All major water budget components are observed: precipitation, potential and actual evapotranspiration, as well as runoff. Evapotranspiration is determined from eddy covariance measurements made on at 40-m mast towering above the trees. The soil water content was monitored site-wide by a sensor network of 109 positions with sensors at three depths each. Precipitation is measured at various positions on and near the site and runoff is recorded by a gauge at the site outflow.
Comparison of the individual energy balance contributions suggests an energy flux closure of about 80%. The catchment water budget was found to be dominantly energy-limited, with the evaporation amounting to approximately 90 % of its potential value, but less than half of precipitation. Precipitation, evapotranspiration and runoff close the water budget with a residual of 2 % of annual precipitation. On the daily timescale, the residual of the water budget was larger and could be explained to a moderate extent by the ambient temperature.
The typical time scale of these processes was about 4 days and less. They were presumably dominated by unaccounted fast-turnover storage terms such as interception, as a major source of uncertainty. At weekly resolution, soil water content explained more than half (R^2 = 0.62) of the water budget residual. In the spatial domain, two slightly different spatial patterns of soil water content could be identified that were associated with mean soil water contents values below and above 0.35 cm^3/cm^3, respectively.

O69

Land surface energy partitioning explained by maximum convective power: evaluating the effects of vegetation and weather conditions at three eddy covariance sites in Germany

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Absorbed solar radiation heats the surface while the emission of thermal radiation and the convective heat exchange with the atmosphere both cool the surface. Considering that convective exchange can be regarded as a Carnot heat engine which transforms heat into convective mass exchange, the radiative-turbulent partitioning can be predicted by assuming that the atmospheric heat exchange operates at a limit of maximum power (Kleidon and Renner, 2013). This state corresponds to strong surface-atmosphere interactions and predicts that 50% of the absorbed solar radiation R_{sn} is used by convective fluxes. Further, we indirectly infer heat storage fluxes from the requirement that a certain part of the heat absorbed during daytime is released by radiative loss during nighttime. Hence the heat storage considerations directly effect the net long wave radiative exchange at the diurnal time scale.

This simple model provides a testable Null hypothesis which we evaluate for locally driven summer conditions. Specifically we explore alternative hypotheses on turbulent-radiative partitioning which include effects of land use and weather conditions for three neighboring Eddy-Covariance sites of TU Dresden between 2007-12.

Generally the simple partitioning predicts both, the net longwave R_{ln} and the total convective fluxes J = H+LE very well for the grass (R_{ln}: r^2 = 74%, mean error ME = -1 W m^{-2}; J: r^2 = 88%, ME = 9 W m^{-2}) and the crop site (R_{ln}: r^2 = 69%, ME = 4 W m^{-2}; J: r^2 = 85%, ME = 10 W m^{-2}). However, at the forest site the observed convective partitioning J/R_{sn} = 0.6 is much larger than derived by our simple model which biases our predictions (R_{ln}: r^2 = 73%, ME = 27 W m^{-2}; J: r^2 = 78%, ME = -50 W m^{-2}). This significant difference in energy partitioning of tall vegetation highlights an important biophysical mechanism which is, however, not represented in our simple model and may be linked to canopy effects which increase land-atmospheric interaction.

With respect to weather conditions, the strongest effect was found to be related to atmospheric moisture conditions, with reduced convective cooling and increased radiative exchange during and after rainfall as well as low vapor pressure deficit. It appears that these mostly large scale driven moist conditions strongly reduce the vertical temperature difference which can be thought of the driving heat gradient of the convective heat engine.

We conclude that strong surface-atmosphere interactions shape the energy partitioning at the land surface and that thermodynamic limits provide useful constraints on convective exchange. Our top-down approach highlights that tall vegetation effectively increases the convective exchange and that the inclusion of atmospheric moisture in the simple energy balance framework will further improve predictions.

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O70

Leaf area and soil controls of boreal forest water, energy and carbon fluxes - a modeling study over a stand rotation

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Boreal coniferous forests in Northern Europe are extensively managed for timber, fibre and to greater extent for bioenergy production. Depending on site fertility, climatic conditions and production goals a typical stand rotation period ranges from 60 to 120 years, during which one to three commercial thinnings are performed before final clear-felling and subsequent planting of a new stand. During rotation, forest structure and species composition are modified by natural succession and forestry practices, which in turn affect within-canopy microclimate and leaf- and stand scale mass and energy exchange. To understand dynamics of stand-scale water (H2O), energy and carbon (C) fluxes and their partitioning over rotation period, a multi-layer soil-plant-atmosphere model APES is used in combination with eddy-covariance (EC) fluxes from Fennoscandic coniferous forests.

The APES couples canopy microclimate and leaf-scale, field layer and soil H_2O, C, and energy exchange using biophysical theory. Here the model is first parameterized for a boreal coniferous forest using literature values and field measurements from a Scots pine stand at Hyytiälä SMEAR II -station in Southern Finland. Then, it is used to upscale component processes to a stand scale, and shown to well reproduce i) above and sub-canopy EC fluxes, ii) forest floor C and H2O exchange and iii) soil heat and water balances. The changes of leaf-area density and shape, species composition and field layer properties over a stand rotation are derived from a statistical forest growth model, incorporated into the multi-layer model and the structural and physiological controls on growing-season H2O, C and energy fluxes and their partitioning are considered. Finally, coupling of leaf-scale and forest floor processes with stand water budget enables assessing how the stand scale fluxes and their partitioning are mediated by site properties and water availability.

O71

Modeling soil CO_2 production and transport to investigate the intra-day variability of surface efflux and soil CO_2 concentration measurements in a Scots Pine Forest (Pinus Sylvestris, L.)

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Soil CO_2 efflux (F_s) is one of the most important components of the C cycle to elucidate because of its impact on the atmospheric CO_2 loading. F_s results from two main processes: the CO_2 production and its transport within the soil. Both processes should be considered to improve the mechanistic understanding of F_s, especially its temporal variation at short-time scales. In this study, a measurement campaign of F_s and vertical soil CO_2 concentration [CO_2] profiles was conducted in a Scots Pine Forest soil in Hartheim (Germany) and used to investigate, through modeling, which process among the CO_2 production and its transport is responsible for observed intraday variation of both variables. A reference model taking into account a purely diffusive CO_2 transport and a temperature-dependent CO_2 production is compared to models with more complex description of either the CO_2 production or CO_2 transport. For the transport, the introduction of the advection and the dispersion is investigated. For the production, the emergent hypothesis of the phloem pressure concentration wave influence is tested. We conclude that the intra-day variation of Fs and [CO_2] are better represented when the more complex CO_2 production expression is taken into account compared to the more detail description of CO_2 transport.

O73

Quantifying the effect of model scales with the inclusion of groundwateron simulated surface-energy fluxes

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Non-linear interactions between landcover and soil moisture affects the partitioning of surface energy fluxes. On the other hand, spatial-temporal variability of soil moisture is dependent on: 1) Variability of meteorological conditions and precipitation events, and 2) Spatial heterogeneity of landcover, geology and topography. For numerical models, heterogeneity is a deterministic source of variability related to model scales (grid cell size) of the numerical domain. Modeling scales becomes important as one moves from column models (related to modeling vertical fluxes) to physically based models with integrated surface-groundwater flows, adding a new dimension of spatial complexity. This study tries to examine how the model scales effect the soil moisture variability and surface-energy fluxes with the inclusion of a ground water model. We use the hydrological component of the newly developed Terrestrial System Modeling Platform (TerrSysMP) over a subcatchment of Rur in Germany. The hydrological component of TerrrSysMP (TerrSysMP-Hydro) consists of NCAR Community Land Model (CLM) coupled with 3D variably saturated ground water model ParFlow. Results are presented based on the yearly simulations at multiple modeling scales (960m, 480m, 240m, 120m and 90m).

O74

Sensitivity of soil moisture initialization for decadal predictions under different regional climatic conditions in Europe

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The impact of soil initialization is investigated through perturbation simulations with the regional climate model COSMO-CLM. The focus of the investigation is to assess the sensitivity of simulated extreme periods, dry and wet, to soil moisture initialization in different climatic regions over Europe and to establish the necessary spin up time within the framework of decadal predictions for these regions.

Sensitivity experiments consisted of a reference simulation from 1968 to 1999 and 5 simulations from 1972 to 1983. The Effective Drought Index (EDI) is used to select and quantify drought status in the reference run to establish the simulation time period for the sensitivity experiments. Different soil initialization procedures are investigated. The sensitivity of the decadal predictions to soil moisture initial conditions is investigated through the analysis of water cycle components' (WCC) variability. In an episodic time scale the local effects of soil moisture on the boundary-layer and the propagated effects on the large-scale dynamics are analysed.

The results show: (a) COSMO-CLM reproduces the observed features of the drought index. (b) Soil moisture initialization exerts a relevant impact on WCC, e.g., precipitation distribution and intensity. (c) Regional characteristics strongly impact the response of the WCC. Precipitation and evapotranspiration deviations are larger for humid regions. (d) The initial soil conditions (wet/dry), the regional characteristics (humid/dry) and the annual period (wet/dry) play a key role in the time that soil needs to restore quasi-equilibrium and the impact on the atmospheric conditions. Humid areas, and for all regions, a humid initialization, exhibit shorter spin up times, also soil reacts more sensitive when initialised during dry periods. (e) The initial soil perturbation may markedly modify atmospheric pressure field, wind circulation systems and atmospheric water vapour distribution affecting atmospheric stability conditions, thus modifying precipitation intensity and distribution even several years after the initialization.

O75

How best to optimize a global process-based carbon land surface model?

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Global process-based land surface models are used to predict the response of the Earth's ecosystems to environmental changes. However, the estimated water and carbon fluxes remain subject to large uncertainties, partly because of unknown or poorly calibrated parameters. Assimilation of *in situ* data, remote sensing products, and/or atmospheric trace gas concentrations into these models is a promising approach to optimize key parameters, providing that all major processes are well represented. So far, most of the studies have focused on using one single data stream, either remotely sensed estimates of the vegetation activity (fAPAR or NDVI) to constrain the modeled plant phenology, *in situ* measurements of net CO_2 and latent heat fluxes (NEE, LE at FluxNet sites), in situ above ground forest biomass data, or atmospheric CO_2 concentrations (through the use of a transport model) to provide constraint on the net carbon fluxes at hourly to inter-annual time-scales. However, the combination of these data streams is expected to provide a much larger constraint on ecosystem carbon, water and energy dynamics.

At LSCE we have constructed a global Carbon Cycle Multi-Data Assimilation System (CCDAS) to assimilate i) MODIS-NDVI observations (selected points), ii) *in situ* NEE and LE fluxes at around 70 FluxNet sites, iii) specific forest biomass data (total or yearly increment) and iv) atmospheric CO_2 measurements at more than 80 sites. We used different methods of data assimilation (including a 4D-Var approach), depending on the number and type of data streams that are considered, in order to optimize the main parameters of the global vegetation model ORCHIDEE (around 15-20 parameters per PFT).

Using such a CCDAS, we investigated several questions: What is the additional information brought by the measurements of above ground biomass data on the top of eddy covariance fluxes to constrain the C allocation within ORCHIDEE? What is the level of constraint brought by the global atmospheric CO_2 data compared to FluxNet NEE/LE and satellite-derived NDVI data? What is the impact of the multi-data stream assimilation on the projected global land carbon balance at the horizon 2100 using future climate scenarios?

In order to answer these questions we have conducted several studies over a 3-year period with the assimilation of i) each data stream separately and ii) several combinations of them in both a step-wise and simultaneous mode. The estimated parameters from each experiment will be compared together and the corresponding land carbon fluxes/stocks (and to a lesser extend the land water fluxes) will be analyzed in terms of seasonal and inter-annual variations at site level or continental scale. These estimates will be compared against independent datasets/approaches in order to highlight the benefit of Carbon Cycle Data Assimilation Systems.

Keywords: data assimilation, carbon, CCDAS

O76

Assimilation of four-dimensional soil moisture response to assess the saturated hydraulic conductivity at the Landscape Evolution Observatory: a sensor failure analysis

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The Landscape Evolution Observatory (LEO) at Biosphere 2 (University of Arizona) consists of three identical, sloping, 333 m^2 convergent landscapes inside a 5,000 m^2 environmentally controlled facility. The one-meter depth soil that covers each of these engineered landscapes is equipped with a dense sensor network measuring the spatial distribution of soil moisture, energy, and carbon states and fluxes. The water mass balance on the hillslope is completely controlled by measuring the changes in system mass (thanks to ten load cells embedded into the structure), the water outflows at the lower boundary of the hillslope, and the imposed rainfall evaporation rates at the landscape surface. This real-scale landscape allows for data collection at spatial and temporal scales that are impossible in natural field settings. For this reason the experiments at LEO are perfect benchmarks to validate hydrological models and, eventually, data assimilation techniques. In particular, in this presentation the water dynamics is simulated with the physically-based hydrological model CATHY, that couples surface and subsurface water flows. The data collected during the first LEO experiment (22 h of rainfall at ~12 mm h^{-1}) show that, although carefully put in place and compacted, the soil at the first landscape is characterized by heterogeneous hydraulic properties. Thus, assimilation of the measurements of the whole sensor network is necessary to calibrate the numerical model and characterize the spatial distribution of the soil hydraulic properties. An ensemble Kalman filter with state augmentation technique is employed for the estimation of the soil saturated hydraulic conductivity assimilating the soil moisture content at 496 5-TM Decagon sensors distributed over 5 different depths. To asses the reliability of the assimilation procedure in CATHY, we consider a synthetic scenario reproducing the first experiment. We explore the sensitivity of the parameter estimation under scenarios of heterogeneity (different correlation lengths of the prior distribution) and varying degrees of sensor failure.

O77

Estimating Vegetation Transpiration and Soil Evaporation Sequences with a Dual Source Variational Data Assimilation Scheme

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Recently, a number of studies have focused on estimating surface turbulent heat fluxes via assimilation of sequences of land surface temperature (LST) observations into variational data assimilation (VDA) schemes. Using the full heat diffusion equation as a constraint, the surface energy balance equation can be solved via assimilation of sequences of LST within a VDA framework. However, The VDA methods have been tested only with total evapotranspiration (ET). The estimated vegetation transpiration (ETc) and soil evaporation (ETs) are not validated with real data. Hence, in this study, dual-source (DS) VDA schemes are tested at Daman site located in middle reach of Heihe River Basin (HRB). The ground-measured meteorology data are used as model forcing data. The DS-VDA estimated ET is validated with observation derived from eddy covariance (EC) instrument. Moreover, the ETs and ETc are measured by stable isotope instrument, and the data used to validate model estimates. The DS-VDA scheme is compared with two source surface energy balance model (TSEB) proposed by Normal et al., [1995]. The results indicate that the DS-VDA outperforms TSEB at Daman site.

O78

Future scenarios of soil water availability at managed grassland ecosystems in the Austrian Alps

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Available soil water is a major constraint for numerous ecosystem functions and is likely to be considerably affected by projected shifts in temperature and precipitation. Quantifying likely future changes in soil water content is therefore essential for assessing impacts of climate change on ecosystem functions.

We present a data fusion approach addressing changes in soil water content of temperate grasslands in the Austrian Alps under future climate scenarios. We use a simple soil bucket model, characterized by an efficient structure and minimal requirements regarding meteorological inputs (solar radiation, precipitation and air temperature). The model is therefore suitable for the analysis of a wide range of ecological datasets. Model parameter were constrained by up to three different datasets (soil water content, evapotranspiration and snow water equivalent) using a Bayesian inversion scheme.

Given a repository of data collected at ten sites in the Eastern Alps as well as a set of downscaled and error corrected (quantile mapping) regional climate scenarios, developed for the years 1961 - 2050 with 5 different regional/global climate models (CNRMRM, AITCCLM, KNMIRACMO, DMIHIRHAM, ETHZCLM) we simulated soil water content conditions under these future climate scenarios.

Despite the simple model structure calibrated model runs do show a very good performance at the majority of investigated sites. Results show that if any trend can be found, the investigated ecosystems tend to higher soil water contents on average, associated with a distinct decrease in snow cover duration under future climate conditions. Regardless of these average trends some climate models cause an increasing frequency and a longer duration of extreme dry soil water conditions under future climate scenarios.

O79

MODIS Land Surface Temperature Assimilation and Verification at Rur Catchment

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The 1 km remote sensing products of Land Surface Temperature (LST) are available operationally from MODIS (Moderate-resolution Imaging Spectroradiometer). There are four measurements per day from MODIS Terra/Aqua sensors with low measurement error (around 1 K). In this study, MODIS LST products were assimilated into the Community Land Model (CLM) to improve the soil moisture, soil temperature, latent and sensible fluxes estimation. Remote sensing of soil moisture has severe limitations for the Rur catchment given the spatially highly variable landuse distribution and coarse resolution of passive microwave remote sensing; LST assimilation could be an alternative for the improvement of soil moisture simulation given the coupled water and energy balances at the land surface. In this study the assimilation algorithm Local Ensemble Transform Kalman Filter (LETKF) with the state augmentation method is used. Vegetation and soil properties are also updated in some simulation scenarios. Besides soil temperature, also soil moisture is explicitly updated by LETKF on the basis of the LST-measurements. The atmospheric forcing data, vegetation properties (leaf area index, etc.) and soil properties (sand and clay fraction, etc.) are randomized to represent the model uncertainties. The assimilation results were evaluated against measured soil moisture, soil temperature and latent and sensible heat fluxes obtained for the Eifel/Lower Rhine Valley Observatory of TERENO.

O80

Advanced microwave forward operator for the Naoh-MP land surface model

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From local to global scales, microwave remote-sensing techniques can provide temporally and spatially highly resolved observations of land surface properties including soil moisture and temperature as well as the state of vegetation. These variables are critical for agricultural productivity and water resource management. Furthermore, having accurate information of these variables allows us to improve the performances of numerical weather forecasts and climate prediction models. However, it is challenging to translate a measured brightness temperature into the multiple land surface properties because of the inherent inversion problem. In this study, we introduce a novel model forward observation operator for microwave remote sensing to resolve this inversion problem and to close the gap between land surface modeling and observations. It is composed of the Noah-MP land surface model [1] as well as new models for the dielectric mixing [2] and the radiative transfer.

For developing a realistic forward operator, the land surface model must simulate soil and vegetation processes properly. The Noah-MP land surface model provides an excellent starting point because it contains already a sophisticated soil texture and land cover data set. Soil moisture transport is derived using the Richards equation in combination with a set of soil hydraulic parameters. Vegetation properties are considered using several photosynthesis models with different complexity. The energy balance is closed for the top soil and the vegetation layers, respectively. The energy flux becomes more realistic due to including not only the volumetric ratio of land surface properties but also their surface fraction as sub-grid scale information (semitile approach). Radiative transport is calculated for the bare soil and the vegetated components of the grid box using a two-stream radiative transport model. These model characteristics provide all relevant information needed for a simulation of the microwave emission from the land surface with unprecedented realism.

A case study will be provided to investigate how well the simulation of the observation operator matches to the real world. L-band microwave remote-sensing measurement over the Schäfertal region in Germany have been used for this case study. Furthermore, we discuss the future extension of this operator for thermal infrared radiation (TIR).

The novel observation operator integrated into Noah-MP will be able to simulate an anisotropic scale brightness temperature measurement with isotropic computation of the effective dielectric constant. In other words, in the data assimilation scheme the measured brightness temperature can then be ingested into the subgrid scale model properties of Noah-MP. Finally, this operator can be implemented in a consistent land-surface-atmosphere data assimilation system, e.g., Noah-MP can be coupled with the Weather Research and Forecasting (WRF) model system.

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O81

Evaluation of plants effect on the mobility of heavy metals in a phytoremediation action of the ancient zinc mine the Avinières (St Laurent le Minier, France)

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This study was conducted in the frame of the SYMETAL project (ANR CESA) and aimed at evaluating the mobility and retention of three heavy metals, Zinc, lead and Cadmium, in ore residues stabilized with metallicolous plants. An experimental approach combining laboratory columns and field lysimeters leaching was developed. Ore residues of the ancient zinc mine “The Avinières” (St-Laurent-le-minier, France), stored in tailing ponds, were collected and homogenised before filling the columns and lysimeters. These setups were unplanted (controls) or vegetated with three plant species: Anthyllis Vulneraria (metallicolous plant), Festuca arvernensis and Koeleria vallesiana, alone or mixed. A. Vulneraria was mycorhized with Mesorhizobium metallidurans in order to improve its growth through nitrogen fixation. Rain simulations were performed every month or 6 months on the columns and lysimeters, respectively. Water balance was controlled to be equivalent in both situations. Physical and geochemical factors were monitored all along the period and especially during the leaching experiments (water flux, pH, heavy metal content, ionic mass balance…). These factors were shown to be quite constant during each leaching experiment but evolved significantly with time and also between the different vegetation conditions. Plant growth was shown to highly modify water infiltration and metal concentrations in the leachates. The temporal increase of water flux observed in the columns and lysimeters along the infiltration experiments was attributed to the rhizophere development, which is supposed to modify the spatial structure of the ore residue, thus improving water infiltration. In columns and lysimeters vegetated with A. vulneraria only, high nitrate contents were measured in the leachates, in relation with nitrogen fixation. On the contrary when A. vulneraria was associated with F. arvernensis alone or with K. vallesiana, nitrate was directly consumed by the latter two plants and further undetected in the leachates, demonstrating the advantage of plant associations for phytoremediation actions. Furthermore compared to unplanted columns or lysimeters, the leaching of cadmium and zinc in vegetated ore residues was significantly and variably decreased depending on the number of plant species. On the contrary, lead mobilization from the ore residues was very low in relation with its low water solubility, and seemed unaffected by plants introduction. Our results showed that plant species introduction modifies both the physical properties of the ore residue and also its geochemistry, with strong benefits in terms of plant growth and heavy metal retention. Modelling of these results with a combined hydro-geochemical approach is ongoing and will help better understanding the processes involved in metal transfer limitation. These results thus demonstrate the benefit of mixing grass and metallicolous plants to stabilize ore residues from mining activities.

O82

ClimAgro- understanding the anthropogenic and natural drivers of water balance in changing alpine grasslands using a network of small-scale lysimeters

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Technological and social development, land-use strategies and environmental changes strongly affect the degree of utilisation in alpine agro-ecosystems. Equally, the functioning of these systems and the services they provide are also subject to the same set of drivers. Patterns of biodiversity, productivity, nutrient and water cycling vary distinctively along the gradients of agricultural intensity and environmental characteristics. Hence, defining the interplay of the anthropogenic and natural drivers which influence the different components of the water balance in alpine ecosystems is essential for informing long-term projections concerning the provision of freshwater from mountain regions. Employing a network of small-scale lyismeters, the ClimAgro project seeks to investigate how management intensity and environmental change may affect the ecological components of water cycling in grasslands of two contrasting regional alpine climates. The data gathered within ClimAgro, comprising also manipulations of temperature, precipitation and agricultural intensity, will characterise changes in the individual players of ecological water cycling and allow decomposing the hydrological coupling of the soil-plant-atmosphere system. The combination of *in situ* manipulation and transplantation of vegetation monoliths will further allow outlining methodological differences in the two major approaches used to investigate climate change effects on vegetation properties. Here, we present the details of the ClimAgro project with respect to experimental design, sampling strategy and research infrastructure. A comprehensive summary of the small-scale lysimeter approach, field site characteristics and measurements scheme as well as preliminary results will visualise how ClimAgro seeks to investigate the eco-hydrology of alpine grassland ecosystems under climate and management change.

O83

Impacts of climate change on carbon and nitrogen cycling of (pre-) alpine grassland ecosystems under intensive and extensive management - a climate sequence lysimeter study

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Due to cool and moist climatic conditions alpine grassland soils of moderate elevation are rich in soil organic carbon and associated nitrogen. In the framework of an in-situ climate change experiment we test the hypothesis that soil organic carbon and nitrogen are either volatilized (GHG emissions) or leached with seepage water due to increase in temperature. Field investigations are carried out in the (Pre-) Alpine TERENO Observatory covering several research sites in South-Bavaria, Germany. IMK-IFU has installed 36 lysimeters with undisturbed intact grassland soil cores (diameter 1m, depth 1.4m) and is operating them at three sites differing in altitude (Graswang 850m, Rottenbuch 750m, Fendt 600m). Lysimeters were partly translocated from higher elevation to sites at lower elevation and other soil cores still staying at the sites as controls. Along the altitudinal gradient maximum mean annual temperature differences are ð 2.5°C (850-600m) and slightly lower mean annual rainfall with decreasing altitude. In addition to the space for time in-situ climate change approach the total of 36 lysimeters are split into treatments of intensive (up to 5 cuts and manure applications) and extensive (2 cuts and 1 manure application) grassland management.

The different components of the water balance i.e. precipitation, evapotranspiration and groundwater recharge of each lysimeter are measured by precision weighting of the lysimeters and a separate container for collection of seepage water at the lower boundary condition (1.4m). Soil moisture and temperature are measured in 10, 30, 50, 140 cm soil depth. Soil water in 10, 30, 50 and 140 cm soil depth is sampled by under pressurized suction cups. Water samples are collected regularly every 2 weeks and at higher frequency (e.g. 3 times a week) after fertilization and cutting events, and analyzed for concentration of DOC, DON, NH_4^+ and NO_3^-. Greenhouse Gas (GHG) emissions (CO_2, N_2O and CH_4) were measured by the static chamber technique mostly with automatic chambers with a new developed robot systems and QCL laser analytics in high temporal resolution. In addition to water, nutrient and GHG fluxes measurements also focused on plant biomass, N_2-emissions, nitrogen turnover processes and dynamics and activity of soil microorganisms.

Climate hange, generally stimulated plant growth and soil C and N turnover leading to increased soil CO_2 emissions and an increased uptake of atmospheric CH_4. Increases of DOC losses were only of minor importance. N_2O emission were generally low and slightly increased in spring, summer and autumn but significantly decreased during the winter period under global change conditions, the latter due to lower intensity and frequency of frost-thaw events. The main gaseous nitrogen component emitted from the (pre-) alpine grassland ecosystems was N_2 which also showed a much stronger increase with climate change than N_2O. Furthermore, climate change lead to a significant increase in nitrate leaching, whereas leaching of ammonium and DON remained unaffected. Climate induced changes in the GHG balance of (pre-) alpine grassland ecosystems are mainly triggered by increased CO_2 emissions since magnitude of CH_4 and N_2O exchange, even regarding their much higher global warming potential (GWP) are only of minor importance. Overall, impacts of climate change on ecosystem C and N losses seem to be more severe under extensive management.

O84

Nitrate leaching and soil N_2O emissions and their responses to different nitrogen management options in a rainfed wheat-maize rotation system, Southwest China

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Overuse of nitrogen fertilizer is severely impacting the regional and global environment due to unintended losses of reactive nitrogen to surface and groundwater bodies and the atmosphere. However, studies quantifying gaseous and hydrological nitrogen loss pathways are scarce. In this study we provide results from a multi-year field lysimeter experiment in southwest China, where we simultaneously quantified NO_3^- leaching and soil N_2O emissions from a rain-fed wheat-maize rotation. NO_3^- leaching losses were the main N loss pathway in our study region, though leaching events only occurred during the summer maize growing season. The seasonal NO_3^- leaching losses ranged from 28.0 to 53.3 kg N ha^{-1} (mean: 32.8 kg N ha^{-1}), which corresponds to 12.7% to 35.5% (mean: 21.9%) of applied N in maize growing seasons. Annual N_2O fluxes from the N fertilized treatments ranged from 1.9 to 6.7 kg N ha^{-1} yr^{-1} (N_2O emission factor: 0.12- 1.06%; mean: 0.61%). A significantly exponential decaying relationship between NO_3^- leaching loss and soil N_2O emissions was found, indicating that the tradeoff between NO_3^- leaching and N_2O emission exist in the investigated wheat-maize rotation system. Thus, our findings suggest that developing agricultural N management practices towards reductions of reactive nitrogen losses needs to carefully consider the tradeoff between NO_3^- leaching and N_2O emissions.

To meet the challenges of guaranteeing crop yields while reducing environmental impacts of nitrogen use due to associated losses of nitrate leaching and N_2O emissions, we conducted another field experiments on rainfed wheat-maize rotation by using large-scale field lysimeters (each size: 8 × 4 m^2) at the same study site. One control and three same total rate of N application (280 kg N ha^{-1} yr^{-1}) were included: control; synthetic N fertilizer (NPK); synthetic N fertilizer plus pig manure (OMNPK) and synthetic N fertilizer plus crop residue (RSDNPK). Crop grain yields, NO_3^- leaching and greenhouse gas (GHG, CH_4 and N_2O) were simultaneously measured for one year. As compared to NPK treatment, the treatments of OMNPK and RSDNPK tended to reduce NO_3^- leaching by 36% and 22%, respectively. The N_2O emissions from RSDNPK treatments were significantly lower than those for NPK and OMNPK treatments. Linking crop grain yields with NO_3^- leaching and GHG emissions, either the OMNPK or RSDNPK treatments tended to decrease both yield-scaled NO_3^- leaching and yield-scaled GWP as compared to NPK treatment. Our study shows that it is possible to reduce the negative environmental impacts of NO_3^- leaching and N_2O emissions without compromising crop productivity through minimal adjustments of fertilization practice options.

P1 - 01

The Hydrosphere section of the Helmholtz Alliance on Remote Sensing and Earth System Dynamics: Enhancing the understanding of hydrological processes by remote sensing

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The Earth system comprises a multitude of geophysical processes that are intimately meshed through complex interactions. In times of accelerated global change, the understanding and quantification of these processes is of primary importance. Spaceborne remote sensing sensors are predestined to produce geophysical data products at the global scale. The Helmholtz Alliance will therefore complement the high degree of innovation in radar remote sensing technology, which has been successfully implemented with TanDEM-X, and will establish a unique chain from satellite technology, mission operation to information extraction and integration into local, regional and global models.

The overall goal of the hydrosphere-related Alliance activities is to enhance the understanding of hydrological processes by optimally exploiting the observations of current (e.g., SMOS, TerraSAR-X) and planned (e.g., SMAP, Tandem-L) satellite missions. Therefore, we are developing and improving remote sensing derived data products, such as soil moisture from active and passive microwave sensors, the combination of radar and hyperspectral sensors, and the determination of sea surface currents velocity by SAR along-track interferometry. Moreover, we are establishing algorithms for validation and building up ground based observation infrastructures for the accuracy assessment of remotely sensed data products. Methods with larger footprints such as GNSS reflectometry, cosmic-ray neutron probes and geophysical measurement techniques serve as an improved reference for spaceborne observations compared to point-scale measurements. Satellite-based as well as in-situ observations are integrated in numerical models by data assimilation methods to allow for a quantitative understanding of dynamic processes in the hydrosphere.

Scientific questions that are addressed in this research consortium include:

- Does the assimilation of soil moisture and freeze/thaw states help to minimize parameter uncertainty of hydrological models?

- To what extent does the assimilation of subgrid-scale (e.g. 50-500 m) variability of state variables contribute to the derivation of effective parameters at larger scales (e.g. 1-5 km) in order to characterize hydrological processes?
- Does the assimilation of high-resolution synchronized observations of soil moisture and snow water equivalent help to reduce the predictive uncertainty of hydrologic models?
- Is Tandem-L with the high spatial resolution of the soil moisture product able to improve the regionalization of land surface models?
- Can the global operational geodetic GNSS ground network contribute to a global soil moisture monitoring and validation system in conjunction with remote sensing products?
- Can the improved land surface model enhance our understanding about soil-vegetation - atmosphere water fluxes and coupled plant water/carbon dynamics?

P1 - 02

Radar altimetry backscattering signatures at Ka-band over West Africa

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This study presents an analysis of radar signatures acquired over West-Africa at Ka band using the first one year and a half of Saral nadir-looking altimeter data. The backscattering coefficients time series are generated over regional transects and local sites. Meridian transects from the wet tropics to the arid regions of the Sahara desert point out the spatial and temporal changes of the radar response at Ka-band over the West-African bioclimatic gradient in terms of surface roughness, land cover and soil wetness. Comparisons with radar responses at Ku- and C- bands using nadir-looking altimeters (35-day orbital period ENVISAT RA-2 over 2003-2010 on the same orbit as Saral and 10-day orbital period Jason-2 since mid-2008) will be presented. Comparisons with time-variations of in situ soil moisture measurements will also be presented for a study site located in Senegal.

P1 - 03

Evaluation of standard pre-processing techniques for X-Bandradar using hydrologic modeling

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Precipitation is the key driver of hydrological processes on the land surface; like runoff, infiltration, and evaporation. A standard device for measuring precipitation are rain gauges which exhibit a relatively good measurement accuracy but only provide point measurements. The estimation of areal precipitation by interpolating rain gauge data is a big challenge because of the high spatial variability and intermittency of precipitation. Weather radar data provide a promising addition to rain gauge measurements for the estimation of areal rainfall. They are able to better resolve the spatial variability of precipitation at the expense of measurement accuracy.

In this study, the impact of different precipitation products obtained separately by rain gauge and radar data on hydrologic fluxes like runoff is going to be assessed. The study domain covers the Selke river catchment located in the TERENO Harz observatory. The study period encompasses the calendar year 2013. Hourly rain gauge data is made available by the German Weather Service (DWD), which is interpolated using external drift kriging. The radar data is obtained from the TERENO rain scanner located within the observatory. Raw reflectivity data from this X-Band radar is corrected for ground clutter and attenuation as well as transformed to precipitation rates using standard procedures available from the literature. Both precipitation products are then used to force the mesoscale hydrologic model (mHM) to produce river discharge.

It is expected that the precipitation products will generate different streamflow discharges. Preliminary comparisons of the two precipitation products highlight that the discharge produced by the rain gauge interpolation show a closer match than the one obtained from the radar to the observed one. This study provides the first insights on the potential utility of assimilating discharge data to improve radar based precipitation estimates.

P1 - 04

Installation and operation of sensors for automated optical measurements at two eddy covariance sites

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We installed multispectral 4-channel and hyperspectral sensors at eddy-flux measurement sites monitoring two different vegetation types, grasland and deciduous forest. Spectral measurements are taken with dual-field-of-view systems continuously and automatically. Radiances and irradiances are measured in order to derive diurnal and seasonal reflectance dynamics. These measurements are compared with airborne hyperspectral data from a flight campaign, ground measurements with a field spectrometer, a RGB-camera to observe changes in phenology and the micrometeorologicaland ecophysiologicaldatameasured at the eddy-covariance sites.

Our main goals are:

(1) the retrieval of fluorescence and calculation of vegetation indices to estimate GPP from eddy-flux-measurements

(2) the retrieval of other biophysical parameters, such as phenology, LAI and chlorophyll content to validate of satellite products, especially for SENTINEL-2.

Here we present our measurement concept and technical set-up as well as first results.

P1 - 05

Spatio-temporal Dynamics of Land-use and Land-cover in the Mu Us Sandy Land, China, using the Change Vector Analysis Technique

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Sandification refers to land degradation in sandy areas. Considerable attention has been given to sandification processes in China since vast areas of sandy deserts are located in the north of the country within arid and semi-arid climatic zones. The current paper is aimed at assessing the land-use/land-cover spatial and temporal dynamics over the Mu Us Sandy Land, China, via change detection methodology based on spaceborne images. Two biophysical variables, NDVI, positively correlated with vegetation cover, and albedo, positively correlated with cover of exposed sands, were computed from a time series of merged NOAA-AVHRR and MODIS images (1981 to 2010). Generally, throughout the study period, NDVI increased and albedo decreased. Improved understanding of spatial and temporal dynamics of these environmental processes was achieved by using the Change Vector Analysis (CVA) technique applied to NDVI and albedo data extracted from four sets of consecutive Landsat images, several years apart. Changes were detected for each time step as well as over the entire period (1978 to 2007). CVA created four categories of land-cover change - vegetation, exposed sands, water bodies, and wetlands. The CVA's direction and magnitude result in pixel-based maps of the change rather than broad qualitative classes, such as slight-, moderate-, or severe land degradation that previously presented for this region. Each of the four categories has a biophysical meaning that was validated in selected hot-spots, employing very high spatial resolution images (e.g., Ikonos). Careful selection of images, taking into account inter and intra annual variability of rainfall, enables differentiating between short-term conservancies (e.g., drought) and long-term alterations. NDVI and albedo, although comparable to tasseled cap's brightness and greenness indices, have the advantage of being computed using reflectance values extracted from various Landsat platforms since the early 1970s. It is shown that, over the entire study period, the majority of the Mu Us Sandy Land area remained unchanged. Part of the area (6%), mainly in the east, was under human-induced rehabilitation processes, in terms of increasing vegetation cover. In other areas (5.1%), bare sands were found to expand to the central-north and the southwest of the area.

P1 - 06

Multitemporal soil pattern analysis with multispectral remote sensing data at field Borrentin in testsite Demmin, TERENO Northeast Germany

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For (1) general issues of policy-making, land resource management and environment-monitoring as well as for (2) more precise applications in precision agriculture, hydrological modelling and soil landscape studies soil maps should provide qualitative and quantitative soil information at different scales (landscape-, field-level). In the early 1990´s evolved the philosophy of "site-specific (crop) management" (SSM) in precision agriculture. Nucleus is the identification of (crop) management zones as relatively homogenous sub-units of farm fields, considering temporal-spatial variability of soil and crop characteristics at scales finer than soil mapping units. Because of large coverage as well as detailed spatial and spectral information multispectral imagery offers excellent capability for detection of homogenous surficial soil patterns due to existing relationships between soil (colour/brightness) reflectance and specific soil properties (e.g. organic content, texture, $CaCO_3$, soil moisture). This implies a great potential for identifying management zones at low costs. Because of different land use and vegetation conditions, monotemporal analysis with one single remote sensing dataset always contains heterogeneous spatial reflectance pattern without any temporal dimension. Regarding agricultural land use, static soil pattern persist beside temporal pattern characterized by crop type, vegetation phenology and land management practices. To eliminate the disturbing influence of temporal pattern a multitemporal approach is needed. This also allows evaluating the stability of soil reflectance pattern and categorizing them into static and temporal pattern. As (additional) spatial-precise basic soil information identified static soil pattern can be used for delineating management zones and mapping functional soil property units in several SSM-models of application maps generation.

We present a model for functional soil mapping at field scale for precision farming based on multitemporal remote sensing data analysis and GIS spatial data modelling. The objective is (i) to demonstrate the potential of multitemporal soil pattern analysis in comparison to monotemporal analysis and (ii) to generate functional soil maps based on identified static homogenous soil pattern and related soil property. The most important step in soil pattern analysis is the separation between static pattern and temporal reflectance pattern, influenced by (vital and senescent) vegetation and land management practices. By using the high spatial and temporal resolution of multispectral RapidEye satellite imagery in standardized principal component and per-Pixel-analysis static spatial soil pattern could be derived and allowed to produce a highly significant functional soil map respective to organic matter for field Borrentin, Northeast Germany. Due to existence of archive data and data availability, this model might be more rapid, less time-consuming and at lower costs than proximal sensing techniques.

P1 - 07

Remote Sensing of Forest 3-D Structure by Means of Synthetic Aperture Radar Systems: Status, Potentials and Challenges

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The next generation of spaceborne Synthetic Aperture Radar (SAR) remote sensing missions will enable systematic monitoring of dynamic processes on the Earth surface with high quality and resolution providing a unique data source to significantly advance our understanding of the Earth system and its dynamics. At the same time, the development of a new generation of SAR techniques combined with the evolution of radar technology and the implementation of innovative SAR measurement configurations have the potential to change the way forest monitoring, management and modelling is addressed today. Indeed, today it is already possible to accurately estimate critical (horizontal and vertical) forest structure parameters such as forest height and vertical forest layering with a high spatial resolution. At the same time, the next generation of spaceborne SAR configurations will be able to measure these parameters with a high temporal resolution (on a weekly to monthly basis) opening the door to estimate natural and anthropogenic changesof these parameters and provide a better understanding of theircauses andeffects.

In this presentation, we critically review the current state-of-the-art in forest parameter estimation by means of SAR, specifically forest height, forest structure and forest biomass. We identify potential forest products and the challenges associated with their integration into the existing framework of forest ecosystem research and management. These issues are being investigated within the Biosphere Topic in the "Alliance on Remote Sensing and Earth System Dynamics" established by the Helmholtz Association, Germany's largest scientific research organization.

Regarding forest height and forest structure estimation, radar remote sensing applications have been developed in the last decades. Indeed, the polarimetric-interferometric (PolInSAR) combination of multiple SAR images acquired in spatial diversity (i.e. multi-baseline) was a decisive step in order to estimate forest height and structure with high resolution and large coverage. PolInSAR forest height estimation matured and developed from a pre-operational to an operational PolInSAR product that has been validated in a series of airborne and spaceborne experiments over a variety of natural and managed temperate, boreal, and tropical test sites characterized by different stand and terrain conditions. The overall obtained estimation accuracy is on the order of 10% or better. In addition to forest height, the availability of multiple PolInSAR interferograms at a low electromagnetic frequency (e.g. L-band) makes it possible to determine not only forest height, but also a full profile of the backscattered power (reflectivity) along the vertical dimension for each spatial resolution cell, which depends on the horizontal and vertical structure of the vegetation. Contrarily to forest height inversion, the use of the 3D radar reflectivity for forestry applications is still in a very early stage.

An underdeveloped element is the physical interpretation of the vertical radar reflectivity profiles. Efforts are still to be provided to clearly assess how and how accurately structure-related SAR observables can be translated into geophysical information of interest. Also, the benefits of shifting from 2-D to 3-D observation capabilities have to be evaluated and new forest products that could result from this have to be identified. The aim of the research activities currently being carried out in the Alliance Biosphere framework is to bridge this gap. In the scope of this presentation, progresses in two specific applications will be shown. The first one concerns forest classification and characterization of the forest stages from the 3D structure information derived from SAR after mapping this information in a space of quantitative horizontal and vertical structure descriptors. The second one concerns biomass estimation. It will be shown that more accurate biomass distribution maps can be obtained from SAR, not only considering forest height estimation, but also accounting for the vertical structure information derived from the reflectivity profiles. Preliminary validation is performed through comparison with available terrestrial data.

P1 - 08

Spatio-temporal downscaling of passive microwave soil moisture product using active microwave

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SMOS (passive microwave) mission provides the soil moisture product with a fine temporal resolution (approximately 3 days), but with a relatively coarse spatial resolution (approximately 50 km) (Kerr, Y.H. et al., 2001). On the other hand, the active microwave satellites are capable of providing fine spatial scale (less than 100 m) soil moisture products but with a poor temporal resolution (around 3 weeks) (Moran, M.S. et al., 2004). There exists a good potential to merge data from both the sensors to provide the soil moisture products at a higher spatial and temporal resolution, which would be helpful in various applications like agriculture, hydrology, atmospheric sciences etc. The current study presents a methodology for the spatio-temporal downscaling of the SMOS retrieved soil moisture product with the help of active microwave data (RADARSAT-2), and the methodology is tested in an experimental watershed, Berambadi, South India. The watershed is being studied under the Indian AMBHAS project (http://ambhas.com/) and French RBV network of observatories (http://rbv.ipgp.fr/).

First, a non parametric algorithm based on the Cummulative Distribution Function (CDF) transformation was developed to retrieve the soil moisture from RADARSAT-2 data sets. The developed algorithm was validated using the 28 satellite images of RADARSAT-2 and field data collected in 50 agricultural fields spanning over 3 years. The developed algorithm provided a good estimate of the surface soil moisture with a RMSE of 0.05 (v/v). Then the surface heterogeneity (soil texture, land use and SMOS mean antenna patterns) was analysed by up-scaling and comparing the validated RADARSAT-2 soil moisture maps with the SMOS retrieved soil moisture. It was observed in the study area, that up-scaling based on the land use outperformed the other approaches. Further, considering the significant effect of land cover on up-scaling, a model was developed to downscale the soil moisture from SMOS based on a combination of the statistical downscaling of variance observed at large scale (Blöschl, G. et al., 2009) and spatial patterns obtained from the RADARSAT-2 derived soil moisture. First, the model was calibrated using the 14 RADARSAT-2 images, and then it was validated using the separate 14 RADARSAT-2 images and field data. The developed methodology showed the promising results with a RMSE of 0.05 (v/v).

P1 - 09

Long term estimation of evapotranspiration over Kabini basin at 250 m spatial resolution using MODIS data

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Knowledge about evapotranspiration (ET) over a long time period is critical for proper understanding of the hydrological cycle. In India, though streamflows and ground water levels are observed periodically, reliable data on the quantity of water reaching the atmosphere through ET is not available. This lack of data causes high uncertainties in closing the water budget and estimating the quantum of water available for human consumption. Remote Sensing (RS) sensors like MODIS and AVHRR are providing datasets for estimation of ET over a long time period, however only at a spatial resolution of 1000 m. The 1000 m spatial resolution may be too coarse to capture the field level variation (~100 m) in ET in the Indian context. Hence there is a need to generate a reliable and consistent ET product with a spatial resolution of few hundreds of metres over Indian river basins.

Kabini, originating in the Western Ghats is a tributary of the river Cauvery in south India. The Kabini river basin has a unique climatic gradient and contrasted landuse/landcover. The basin is a part of French network of observatories and some of the sub-watersheds of the Kabini basin are monitored for several hydrological, meteorological and geochemical studies. The objectives of this study are (i) to estimate ET at 1000 m resolution over the Kabini basin in South India using MODIS data from 2002-2013 and (ii) to develop a spatial disaggregation algorithm to bring down the ET at 1000 m resolution to 250 m.

In this study, ET was estimated as a product of Evaporative Fraction (EF) and net available energy (Difference of net radiation and soil heat flux, hereinafter abbreviated as NAE). The triangle method was used for estimation of EF and a simple clear sky radiation model was utilized for NAE estimation. No ground data was used in ET estimation. The adopted approach for ET estimation was validated at five different sites in India using data from Bowen Ratio Energy Balance (BREB) towers. The final day-time averaged ET product at 1000 m resolution had RMSE and bias of 47 Wm^{-2} and 12 Wm^{-2} respectively for all the five sites put together. Since the approach adopted for ET estimation was found to perform with reasonable accuracy at different sites, the same approach was applied over the Kabini basin to estimate ET at 8 day interval at 1000 m resolution.

For disaggregation of the ET product, a disaggregation model called DEvap using the relationship between ET and a vegetation index (VI) was developed in this study. In order to find the VI that gives a better disaggregated ET product, three different VIs NDVI, FVC and NDWI were tested and compared for their use in the DEvap (hereafter referred as $DEvap_{NDVI}$, $DEvap_{FVC}$ and $DEvap_{NDWI}$) model. Since NDWI is available is available from MODIS only at 500 m resolution, testing was done by disaggregating ET at 1000 m to 500 m. When compared with the BREB tower estimates, the day-time averaged disaggregated ET had RMSE of 49 Wm^{-2}, 49 Wm^{-2} and 63 Wm^{-2} for $DEvap_{NDVI}$, $DEvap_{FVC}$ and $DEvap_{NDWI}$ variants respectively. Similarly the bias in the disaggregated product was 9 Wm^{-2}, 9 Wm^{-2} and 27 Wm^{-2} respectively for $DEvap_{NDVI}$, $DEvap_{FVC}$ and $DEvap_{NDWI}$ variants. The $DEVap_{NDWI}$ variant produced higher errors than the original 1000 m ET estimate. It was observed that $DEvap_{NDVI}$ and $DEvap_{FVC}$ performed very similar to each other and both were superior to the $DEvap_{NDWI}$ variant. Furthermore, disaggregation using $DEvap_{NDVI}$ and $DEvap_{FVC}$ variants captured the sub-pixel level ET variability that is otherwise averaged out at 1000 m resolution.

After the initial performance assessment, NDVI was chosen for use in the DEvap model. MODIS 8-day surface reflectance product at 250 m was used for computing NDVI at 250 m. This 250 m NDVI was combined with 8-day 1000 m ET product to produce 8-day ET product at 250 m over the Kabini basin for the period 2002-2013. It was observed that the ET time series at 250 m was able to capture the seasonal trends in ET. However there were gaps in the ET product due to cloud cover in the summer

monsoon season (June-September). Future study will focus on filling this gap and producing a time continuous ET product over the Kabini basin at 250 m spatial resolution.

P1 - 10

Ground surface response to groundwater level changes in Neustrelitz region, Germany: Insight from Terrasar-X interferometry analysis

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Monitoring of surface deformation and landscape changes associated with water level fluctuations in lakes could provide important constraints on rheological properties of the crust and lithosphere. The extent and complexity of surface motion in unstable areas is also important for designing preventive and remedial measures in regions subject to surface loading and unloading.

In this work, we have investigated the capability of X-band (wavelength ~ 3.1 cm) SAR Interferometry (InSAR) for monitoring ground surface deformation in response to groundwater level changes in Großer Fürstenseer See of Neustrelitz region in Germany. The data include 82 SAR data acquired by German TerraSAR-X from September 2008 to August 2010, which we process using the time-series technique of Persistent Scatterer (PS) Interferometry (PS-InSAR). Although challenging for classical InSAR processing because of the dense vegetation cover, the preliminary results show that time-series analysis of X-band SAR data from TerraSAR-X satellite with a repeat interval of 11 days is promising in providing important insight into possible response of the ground surface deformation to sub-surface hydrological processes operative in Neustrelitz.

P1 - 11

Natural and Drained Temperate Bog-Forest Ecosystems: Carbon Sink or Carbon Source?

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About 30% of the worldwide soil carbon is stored in peat-soils. However, this long-term carbon storage is threatened by climate- and land use change. Most of these climate sensitive areas are used for agriculture and forestry. The impact of these processes on the greenhouse gas (GHG) balance of peatlands is still far from being unraveled. Studies of carbon exchange of peatlands, and in particular of peatland forests, are still rare. Furthermore, reported GHG-balances of peat-forests are highly variable and strongly depended on climate, nutrient supply and tree population. Until now, there is still no full agreement whether peatlands drained for forestry are net GHG sinks or sources.

This study aims to shed more light on the GHG exchange of peatland forests in the temperate, pre-alpine region of southern Germany. Therefore, we compared the GHG-exchange of a classically managed, drained spruce forest (Mooseurach) with a near-natural bog-pine ecosystem (Schechenfilz), by eddy covariance measurements. The sites are separated by only a few kilometers, thus weather conditions and peat-formation history are the same, and differences in the GHG exchange can be entirely attributed to differences in land use and management. We can present results of four years of CO_2measurements from both sites, and data of almost two years of methane exchange from the natural site. Annual net budgets of CO_2 exchange indicate currently about three times stronger CO_2 uptake at the drained site compared to the natural ecosystem. Furthermore, considering the methane emission at natural site, the bog-pine ecosystem is still a small GHG-sink, but the CO_2 uptake induced climate cooling effect is reduced by about 80%. Consequently, the measurements show that the drained spruce forest is a much stronger GHG-sink than the natural bog-forest ecosystem. However, the measurement period of a few years can only reflect the current stage of the observed ecosystems. For an unbiased interpretation of the flux measurements at the drained site, we need to validate the impact of drainage and spruce afforestation on the long-term carbon balance. Therefore, peat loss-induced carbon emissions, as well as the net carbon fixation within the spruce life-cycle have to be considered. This rough estimate indicates a strong net carbon loss that could not be compensated within one spruce rotation period. In contrast, the natural bog-pine ecosystem has likely been a small but steady GHG-sink for decades, which our results suggest is very robust regarding short-term changes of environmental factors.

P1 - 12

Methane and nitrous oxide emissions from rice and maize production in diversified rice cropping systems

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Traditional irrigated double-rice cropping systems have to cope with less water availability. To quantify the shift in CH_4 and N_2O fluxes when changing from traditional to diversified double cropping- systems, an experiment including flooded rice, non-flooded “aerobic” rice and maize was conducted at the international Rice Research Institute in the Philippines. Two automated static chamber-GC systems were used to measure CH_4 and N_2O fluxes continuously in the three cropping systems combined with three fertilizer treatments (N=3): zero-N (no fertilizer), conventional (130 kg ha^{-1}) and site-specific (180-190 kg N ha^{-1}). Turning away from flooded cropping systems leads to shifts in greenhouse gas emissions from CH_4 under wet to N_2O emissions under dry conditions. The global warming potential (GWP) of the non-flooded crops was lower compared to flooded rice as high CH_4 emissions under flooded conditions override the N_2O emissions. The yield-scaled GWP favored maize over aerobic rice, due to low yields of aerobic rice. Significant ($p<0.001$) lower CH_4 emissions from non-flooded systems implements high greenhouse gas mitigation potential for the diversification of double-rice cropping systems with aerobic rice or maize in the dry season. Furthermore, subsequent measurements indicate lower CH_4 emissions from diversified rice systems during flooded rice production in the wet season and further reduction of CH_4 emissions from aerobic rice production in the following dry season.

P1 - 13

The influence of meteorological variability on the seasonal course of pre-Alpine managed grasslands

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The seasonality of pre-Alpine grasslands is controlled by a combination of environmental drivers and management. The variability in environmental drivers originates from climate, weather and topographic effects, with management interacting through adaptive behavior, policy and traditions. The topography in the pre-alpine regions, with elevation and exposure differences in particular, introduces heterogeneity in environmental drivers, which in turn controls grassland productivity.

We investigated the seasonal and spatial variability of exchange fluxes at the start and end of the growing season in relationship to environmental controls and management. Of particular interest were the timing and duration of snow cover. In the pre-Alpine region, precipitation as snow is common. But the amount and persistence of the snow cover varies. The resulting time line of exposure of the surface influences the re-growth dynamics after winter. Further, meteorological variation leading to shifts in the start and end of a season are not always accounted for in the timing of management, and we quantified that effect.

We show first results of a comparison of plant-atmosphere carbon and energy fluxes for TERENO pre-alpine managed grassland sites that are situated in close proximity but at different elevations in the River Ammer catchment in the South of Germany.

P1 - 14

Up-scaling of greenhouse gas source strengths for spatial inhomogeneous soil emissions

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1. Background & Objectives

Emissions of greenhouse gases as nitrous oxide (N_2O) from soils are commonly characterized by huge spatial variability so that the measurement results are scale dependent. An up-scaling of classical small-scale chamber measurements may add uncertainty to emission inventories or emission factors. Also urban - rural exchange process studies require such data. Further, the development of non-intrusive micrometeorological flux measurement methods is necessary because such techniques are available for CO_2, CH_4 and H_2O only, i.e. they are yet not applicable for the greenhouse gas N_2O and other trace gases.

In this presentation a flux gradient method utilizing a non-intrusive path-averaging measurement method is described.Measurements in two heights (0.5 m and 2.7 m, respectively) are performed by anopen-path Fourier Transform Infrared (FTIR) spectrometerfor the N_2O concentrations (100 m average) and by three-dimensional (3D) ultrasonic anemometers for the three orthogonal wind components. The significance of measured concentration gradients and turbulence statistics are investigated to get reliable flux data.

Since micrometeorological techniques are limited by stable atmospheric conditions, we used a closed tunnel equipped with an open-path FTIR spectrometer to (i) evaluate its feasibility for measuring field-scale N_2O fluxes from an unfertilized grassland soil and (ii) compare those results with small-scale fluxes obtained from closed chambers.

Further improvements of these methodologies are underway which are of relevance for TERENO.

2. Materials & Methods

The investigations were conducted from June 2006 until June 2008 in the flat catchment area of the Fuhrberger Feld aquifer on a permanent grassland with Festuca rubra as the predominant species.

Open-path flux-gradient method:

While there is relatively high confidence in flux measurements made under unstable atmospheres with mean winds greater than 1 m s^{-1}, there is great uncertainty in flux measurements made under free convective or stable conditions. Different approaches for calculating the flux data were applied using the empirically-derived turbulence parameters and using those following the Monin-Obukhov similarity theory with stability corrections. Additionally, the N_2O fluxes were calculated with the concentration gradient and the diffusivity as exchange coefficient.

Measuring tunnel:

The measuring tunnel, consisting of a 99×5×0.6 m aluminium liner structure, was closed with a commercial plastic cover prior to each measurement. The cover was sealed at the frame and the soil using sand-filled hoses. Based on those measurements, we used a non-steady-state approach to calculate thepredeployment N_2O flux (q_0) by taking into account diffusive gas transport between soil

and tunnel atmosphere. We estimated q_0 inversely using measured concentration courses at the FTIR beam height.

N_2O fluxes from concurrent static chamber measurements were calculated using the non-steady-state diffusive flux estimator (NDFE).

3. Results & Discussion

Open-path flux-gradient method:

During two measurement campaigns (16 - 17 October 2007 and 17 - 18 June 2008) the mean N_2O emission rates differed considerably between the applied methods.

Measuring tunnel:

During twenty-four measuring campaigns the tunnel systemwas generally feasible for calm and dry weather conditions. Therefore, we restricted the measurements to the evening hours.

4. Conclusions

The application of flux-gradient methods is difficult because there are either (1) low wind speeds with poorly defined wind speed gradients and typically high vertical concentration gradients or (2) high wind speeds with small concentration gradients. The FTIR spectrometer must routinely provide the necessary precision and detection limits.

The tunnel evaluated here can be applied to heterogeneous field conditions or to reveal difference in emissions among treatments so that it can fill an experimental gap between small-scale chamber and ecosystem-level micrometeorological methods.The extension of the application of the tunnel could be achieved by an improved, solid, double-walled cover or a mechanical system, that facilitates tunnel closure, and by using mirrors for the FTIR radiation beam to change the tunnel length and thus the covered soil area.

P1 - 15

Modeling the influence of atmospheric parameters on N_2O-Emissions

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The trace gas N_2O, mainly produced by microorganisms in agricultural soils, is a very stable and thus potent greenhouse gas and is the main contributor for the recent depletion of ozone in the stratosphere. Therefore N_2O-emissions need to be mitigated and thus much effort has been made to reveal the causes of N2O-formation in soils. At present some crucial drivers for N_2O-fluxes are known, but underlying processes of N_2O-fluxes are not yet understood or described adequately. An important shortcoming is the description of the upper boundary layer at the soil-atmosphere interface.

Therefore, the aim of this study is to develop a mechanistic simulation model, which considers both the formation of N_2O in agricultural soils, and the impact of the atmospheric conditions on the transport of soil-born N_2O into the atmosphere. The new model simulates N_2O-flux as a function of meteorological values instead of a model that just releases the whole amount of N_2O into the atmosphere.

For this purpose the modular ecosystem model framework Expert-N, which allows to simulate the formation of N_2O in the soils will be extended to a model with a more detailed description of the upper boundary condition at the soil-atmosphere interface. In detail, this is realized in the form of a resistance approach, where N_2O-fluxes are constrained by resistances analog to Ohm's law.

The newly developed model will be validated using Eddy Covariance measurements of N_2O-fluxes. Measurement device for the N_2O concentrations is a Quantum-Cascade-Dual-Laser produced by Aerodyne Research Inc. (Billerca, Mass., USA). The measurements are conducted on an intensively managed field at the TERENO research farm Scheyern (Germany), which is part of the TERENO Bavarian Alps / Pre-Alps observatory.

P1 - 16

Impact study on spatial and temporal variability of greenhouse gas emissions of an agricultural landscape conducted with different farming systems since 22 years

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In order to achieve a reduction of greenhouse gas emissions, management practices have to be adapted by implementing sustainable land use. At first, reliable field data are required to assess the effect of different farming practices on greenhouse gas budgets. Our long time field experiment covers and compares two main aspects of agricultural management under same site conditions, namely an organic farming system and a conventional farming system, implementing additionally diverse tillage systems and fertilisation practices. Furthermore, the analysis of the alterable biological, physical and chemical soil properties enables a link between the impact of different management systems on greenhouse gas emissions and the monitored cycle of matter.

Measurements were carried out on long-term field trials at the Research Farm Scheyern located in a Tertiary hilly landscape approximately 40 km north of Munich (South Germany). The organic and conventional farming system trials were started in 1992 on comparable fields (similar physical and chemical soil properties). Since then, parcels in the fields (each around 0,2-0,4 ha) with a similar interior plot set-up have been conducted. So the 20 years impacts of different tillage and fertilisation practices on soil properties including trace gases were examined.

Emissions of CH_4, N_2O and CO_2 are monitored since May 2007 for the integrated farming system trial and since February 2012 for the organic farming system trial using an automated system which consists of chambers (per point: 4 chambers, each covering 0,4 m^2 area) with a motor-driven lid, an automated gas sampling unit, an on-line gas chromatographic analysis system, and a control and data logging unit (Flessa et al. 2002). Each chamber is sampled 3-4 times in 24 hours. Physical, chemical and biological soil properties (i.a. texture, mineral nitrogen and soil organic carbon) were monitored weekly and event-based to aggregate the parameters and processes influencing the greenhouse gas emissions. Weather data, i.d. air temperature and precipitation were recorded by on-field weather stations.

The main outcomes are the temporal and spatial dynamics of greenhouse gas emissions as influenced by management practice events (fertilisation and tillage) and weather effects (drying-rewetting, freezing-thawing, intense rainfall and dry periods) in both established systems and the creation of an impact study comparing the conventional farming system trial with the organic farming system trial over a time period of one and a half year. Annual emissions are calculated as the mean of measured values. Moreover, to take the economical interests of farmers into account emissions per product yield are assessed. Furthermore, to understand processes leading the greenhouse gas emissions, additional experiments under laboratory conditions (e.g. soil potential for trace gas formation) are included. Net global warming potential of the two different management systems are calculated. In addition, potential trade-offs between soil carbon sequestration (ascertained in certain time steps) and greenhouse gas emissions will be assessed.

P1 - 17

Estimation of N_2O emissions using LandscapeDNDC in Poland, during the period 1960 - 2009

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The aim of this work was to estimate the quantity of nitrous oxide (N_2O) fluxes simulated by the process-based biogeochemical model known as LandscapeDNDC in Polish conditions. The model was calibrated based on the data of N_2O fluxes measured by static chambers method at Brody Copland sites in the vegetative period of 2012. It is located on the soil which is classified by FAO as Albic Luviosols (Typic Hapludalfs according to the USA Soil Taxonomy), with pH = 6.0 and the content of fraction below 0.02 mm in the amount of 12 % on average. The calibration was based on measurements conducted in four experimental plots where, during 2003 - 2012, the following crops were grown: alfalfa, potatoes, winter wheat, rye, spring barley and winter triticale. With the accurate data available, as far as management is concerned, the main emphasis was placed on the period from 28th March 2012 to 13th of August 2012 because of measurements of nitrous oxide emission conducted then in particular plots. Additionally, the results of measurements of soil water content and soil temperature at the depth of 10 cm were compared with modelled quantities. Thus calibrated model was used for developing simulations of N_2O emissions from arable lands in Poland in the years 1960 - 2009 for two major areas of Poland, located in the East and West of the country, respectively. The former is characterized by a higher level of farming technology, whereas the in the latter, farms are typically small and dispersed. These differences stem from historical events that occurred in Poland for the past 200 years. Daily values of meteorological parameters from thirteen meteorological stations as well as annual data as regards the land exploitation were used for modelling. The following crops were considered for simulations by LandscapeDNDC model: cereals (winter wheat, winter barley, oat), beetroots, potatoes, rape and maize. Estimated crop values obtained by the model were compared with real quantities, which allowed to prove the accuracy of the model. The results obtained from 13 areas mentioned above were extrapolated for the whole country for the years 1960 - 2009.

P1 - 18

Soil greenhouse gas fluxes under conditions of climate-induced drought and heavy rain from agricultural soils in the Pannonian area

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IPCC models for the development of the precipitation in the Pannonian area in Austria predict increasing drought periods due to an overall reduction of precipitation. The remaining amount of precipitation is thought to be concentrated to a few heavy rain falls. However, there is a lack of understanding of how altered precipitation and thus soil moisture regime affect changes in greenhouse gas (GHG) emissions and underlying processes. The objective of the present study, which was part of the project LYSTRAT, was, therefore, to determine the effects of climate-induced droughts and heavy rain on GHG fluxes (CO_2, N_2O and CH_4) and to identify potential drivers.

For this purpose, the GHG fluxes from three soils typical of the Pannonian area was determined biweekly in a field trial with controlled irrigation using the closed-chamber method from March 2011 to December 2013. The field trial is located at the lysimeter facility Hirschstetten, Austria, which consists of 18 backfilled gravitation lysimeters (six replicates per soil type). Three replicates of each soil type (calcic chernozem, calcaric phaeozem and gleyic phaeozem) were watered according to the precipitation pattern predicted for the period from 2071 to 2100 simulating drought periods and heavy rain events (variant prog.rain). The remaining nine lysimeters (control; variant curr.rain) were irrigated with respect to the 30 year mean of rainfall (amount and distribution) in Großenzersdorf, Marchfeld, Austria. To identify potential drivers of GHG fluxes in the soils investigated soil samples were taken at least four times per year and analyzed for important chemical (pH, NH_4^+ and NO_3^- concentrations) and microbiological properties (e.g. microbial biomass C and N).

The GHG fluxes from all three soils types responded to changes in the precipitation patterns. Compared to the calcaric and gleyic phaeozem, the response of the calcic chernozem was delayed. However, no general trend can be derived from the data. For the whole experimental period no significant effect of precipitation patterns was found. Soil temperature and, to a minor degree, air temperature were identified as the most important factors controlling GHG fluxes from the control and the prog.rain treatment of the three soils investigated. Other potential controlling factors such as soil water content, available N and the amount of microbial biomass present were not related to GHG fluxes. Overall, an alteration in the precipitation pattern as simulated in the LYSTRAT experiment will not result in distinct changes of GHG fluxes and potential controlling factors in major soil types of the Pannonian area in the short term.

P2 - 01

Data Publication in TERENO-Northeast (NE)

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The contributions to TERENO by the participating research centers are organized as observatories. The challenge for TERENO and its observatories is to integrate all aspects of data management, data workflows, data modeling and visualizations into the design of a monitoring infrastructure.

TERENO Northeast is one of the sub-observatories within TERENO and is operated by the Helmholtz Centre Potsdam German Research Centre for Geosciences (GFZ). This observatory investigates geoecological processes in the northeastern lowland of Germany by collecting large amounts of environmentally relevant data. The success of long-term projects like TERENO depends on well-organized data management, on data exchange between the partners involved and on the availability of the captured data. Data discovery and dissemination are facilitated not only through data portals of the regional TERENO observatories but also through a common spatial data infrastructure TEODOOR (TEreno Online Data repOsitORry). TEODOOR bundles the data provided by the different web services of the single observatories and provides tools for data discovery, visualization and data access. The TERENO Northeast data infrastructure integrates data from more than 200 instruments and makes data available through standard web services. Geographic sensor information and services are described using the ISO 19115 metadata schema. TEODOOR accesses the OGC Sensor Web Enablement (SWE) interfaces offered by the regional observatories.

In addition to the SWE interface, TERENO Northeast also publishes data through DataCite. The metadata required by DataCite are created in an automated process by extracting information from the SWE SensorML to create ISO 19115 compliant metadata. The GFZ data management infrastructure panMetaDocs is then used to register Digital Object Identifiers (DOI) and preserve file based datasets. A DOI uniquely identifies an object, such as an electronic document or data set, by giving it a persistent identity while its location on the internet may change. In analogy to DOI, the International Geo Sample Numbers (IGSN) is used to uniquely identify research specimens. GFZ is in the process of implementing an infrastructure to register IGSNs.

P2 - 02

The climate and soil moisture network TERENO Northeastern Lowlands Observatory - DEMMIN®

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The goal of the TERENO initiative is the long-term monitoring and documentation of proposed climate change, changes in land use, social-economic developments and anthropogenic influences on terrestrial ecosystems. Therefore long-term observations of multitemporal environmental parameters at different scale are the basis for gathering information on changes of the available water resources, material flows, or further ecological changes.

The Durable Environmental Multidisciplinary Monitoring Information Network (DEMMIN®) located in the North-east of Germany was installed by German Aerospace Center in 1999 for Calibration and Validation of Remote Sensing data at agricultural areas. Due to its physiographic composition and typical agricultural management the area is a perfect test site for monitoring of relevant environmental parameters. Since 2009 the DEMMIN® test field of 50 x 50 km is part of the Northeastern German Lowland Observatory (TERENO-NE), which is coordinated by Helmholtz Centre Potsdam - GFZ German Research Centre for Geosciences.

Within the TERENO project the existing 28 climate stations (DLR) are supplemented by DLR with an automated lysimeter hexagon station (TERENO SoilCan), and by GFZ with additional 20 climate stations and 63 soil moisture stations below agricultural used fields. That enables to analyse variations of: air temperature / air moisture, wind speed /wind direction, WET leaf wetness, incident and reflected solar radiation, incident and emitted thermal radiation, barometric pressure, precipitation, soil temperature (different depths) and soil moisture (different depths) at local scale. The in-situ-measurement component is completed by an information technology infrastructure, that allows the near-real time storage and processing of the measured in-situ data. Because of the remote sensing focus of the DEMMIN® test site it is a perfect area to evaluate the potential of linking ground based in-situ data with remote sensing data analysis with view to the COPERNICUS initiative of the European Union (EU) and the European Space Agency (ESA).

The study presents an approach for the retrieval of area based environmental parameters based on the local data of the climate and soil moisture network in combination with Digital Elevation Model and Vegetation Information retrieved by remote sensing data. Therefore multitemporal remote sensing (RS) data of different sensors, reaching from optical multispectral and hyperspectral data, over thermal data up to microwave data are analysed concerning vegetation type and status and also soil parameters. The following data products have been developed or are under development:

- Air Pressure → climate stations + DEM

- Precipitation → climate stations

- Air Temperature / air moisture → à climate stations + RS data

- Wind Speed → climate stations + RS data

- Soil Moisture → climate stations + soil moisture stations + RS data

The results will be presented in terms of validation, limitation and future developments.

P2 - 03

The Observatory for Climate and Environment in Luxembourg

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The Centre de Recherche Public - Gabriel Lippmann (CRP-GL) operates a dense hydro-climatological measurement network in Luxembourg in cooperation with public authorities (Administration de la Gestion de l'Eau and Administration des Services Techniques de l'Agriculture). Since the establishment of the first two limnigraphs in 1995, the Observatory has continued to expand and now manages data from 35 permanently installed meteorological stations, 67 pluviographs, 25 piezographs and 57 limnigraphs in the Grand-Duchy of Luxembourg. In addition to operating and maintaining the hydro-climatological monitoring network, the Observatory also hosts a comprehensive repository of historical data. This includes daily precipitation, air temperature and discharge data series going back to 1838. The currently operated limnigraphs of the CRP-GL are mainly located in headwaters and tributaries of the Alzette River basin and are complementary to the stations operated by the public authorities on the main rivers. The network includes catchments of various sizes (0.44-1176 km^2) and physiographic characteristics. The instruments mainly provide data with a time resolution of 15 minutes. The Observatory is in charge of establishing and maintaining stage-discharge relationships for the stream gauge stations of the CRP-GL. Besides operating the stations, the Observatory's mission is to validate, centralize, archive and manage acquired field data, including those of the public authorities. Consequently, a series of automated quality control chains are developed and implemented to provide validated data. The Observatory also offers a range of services associated with the management and processing of geographic information and is responsible for the implementation of a data base management system. The acquired data provide a basis to study the interactions between hydrosphere, ecosystems and atmosphere and support the realization of projects in fundamental and applied research. The data help to improve the understanding of rainfall-runoff transformation processes and to study the spatial and temporal variability of the components of the water cycle (e.g., DFG-FNR CAOS project). The measured data are also crucial for the validation of perceptual models of hydrological systems, e.g. identifying and reducing the uncertainties in the modelling of flood events, and to foster major progress and developments in flood management.

P2 - 04

OPE-Andra ecosystem monitoring stations in forest, crops and grasslands in the eastern part ofFrance

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The French authorities have mandated Andra (The French National Radioactive Waste Management Agency) to assess the feasibility of a deep underground nuclear waste repository in eastern part of France. If authorized by the government, the preparation, construction and further operation phases will last more than 100 years. After the operation phase, the observation phase will also last at least an additional 100 years. Within this framework, Andra has set up a long term environmental observatory, the OPE, to survey and monitor the quality of the environment in a 900 km2 area around the site of investigation in the eastern part of France. The OPE territory is situated in a sparsely populated area, covered by agricultural fields (~50%), forests (around 30%) and grassland (11%). The area, reaching 400m altitude, is located on the eastern part of the Parisian Basin. The climate is a transition between oceanic and continental, with an annual mean temperature of10°Cand annual precipitation of 1000mm. The main objective of the observatory is to collect data from the atmosphere, biosphere/geosphere and biodiversity/population in order to establish a baseline of ecosystems functioning and vulnerabilities to natural (mainly climatic) and anthropogenic forcing in the study area. Data on biodiversity, air and water quality, vegetation and agricultural practices are generated through the survey of several gridded (for soil monitoring for example) or ecologically stratified network (for bird or forest monitoring for example) as well as atmospheric, water and ecosystems instrumented field stations. These data will contribute to define the reference state of the environmental conditions before the start of the construction phase and then to monitor the operational phase and the observation phase. An environmental specimen bank has been built to archive the environmental samples collected (soil, flora, fauna, …).

In order to monitor and understand the ecosystems functioning and in particular, the vegetation growth in relation to the agricultural/forestry practices and the biotic and abiotic conditions, three atmosphere-vegetation-soil flux monitoring stations (i.e. eddy covariance flux towers) have been setup inside the OPE. Those sites allow to assess ecosystem functioning under very close pedoclimatic conditions, and to monitor CO2 and water fluxes, meteorological and phenological conditions as well as energy exchanges (radiation, latent and sensible heat fluxes and soil heat fluxes. The forest site is equipped with a 45m flux tower located at the center of a 2000ha beech forest (around 55 years old). The crop site is located on an 18ha crop field and is adjacent to the 6ha grassland site. Regular biomass samplings and observations as well as soil inventories will complement the instrumented monitoring. The measurements at the stations and inventories are performed according to ICOS protocols and recommendations.

The observation systems set up has started mainly in 2011 and first data has been generated. The observation time is however not sufficient yet to draw definite conclusions. Here, we like to show the aims of the OPE long term observatory, the flux stations design and some preliminary results.

P2 - 05

The TERENO Northeastern German Lowland Observatory: studying Earth surface processes and structures in a glacially formed landscape

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Since 2008 a network of Terrestrial Environmental Observatories (TERENO) has been established in Germany by the Helmholtz Association as a long-term interdisciplinary research platform, focusing on the impact of climate and land-use change on terrestrial ecosystems and on related process understanding. This observation network consists of four main observation areas that extend across Germany from the Alps to the lowlands, forming in the latter area the Northeastern German Lowland Observatory (TERENO-Northeast). TERENO-Northeast, located in a glacially formed and intensively used landscape, investigates four subject groups and is supported by a central data management. These closely cooperating subject groups work on geoarchives (lake sediment formation, dendrochronology), geopedology (present-day and historic soil carbon redistribution, soil formation, trace gas balances of peatlands), hydrology (lake-groundwater interactions, water balances of lake and river catchments), and remote sensing (soil moisture retrieval, soil mapping). Combining geoarchives (lake sediments, trees, soils) with monitoring enables us to distinguish short-time fluctuations from long-term climatic and anthropogenic trends and to extend time series into the unobserved past. Instrumentation of TERENO-Northeast started in 2011and will be completed in 2014. The observatory comprises five research sites that differ significantly in area size (from a few hectares to several thousands of hectares) and landscape structure (e.g. geology, hydrology, land cover) including intensity and history of land use. Within TERENO-Northeast one of the study sites was chosen for the future establishment of a Critical Zone Observatory, comprising a forested and lake-rich part of the Müritz National Park (CZO Fuerstensee). Several partner organizations are involved in TERENO-Northeast, forming a regional network of non-university research institutions and universities. Further information, publications and data are available via the central TERENO portal: http://teodoor.icg.kfa-juelich.de/overview-de. (Remark: The authors named represent the coordination board of TERENO-Northeast and the main partner organizations, respectively. Several further persons are involved in TERENO-Northeast.)

P2 - 06

Long-term, multi-scale documentation of the hydrologic cycle and vegetation dynamics in West Africa: the AMMA-CATCH observation system.

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AMMA-CATCH is a multi-scale observation system dedicated to long-term monitoring of the water cycle, the vegetation dynamics and their interactions with climate and water resources in West Africa. In the context of the global change, long-term observations are required to i) gain understanding in eco-hydrological processes over this highly contrasted region, ii) help their representation in Earth System Models, and iii) detect trends and infer their impacts on water resources and living conditions.

It is made of three meso-scale sites (~ 1°x1°) in Mali, Niger and Benin, extending along the West African eco-climatic gradient. Within this regional window (5° by 9°), each of the three sites comprises a multi-scale set-up which helps documenting the components of the hydrologic budget and the evolutions of the surface conditions over a range of time scales: raingages, piezometers, river discharge stations, soil moisture and temperature profiles, turbulent fluxes measurements, LAI/biomass monitoring,...This observation system has been continuously generating datasets for 10 to 30 years depending on the datasets. It is jointly operated by French and African (Mali, Niger and Benin) research institutions. The data-base is available to the community through the internet (www.amma-catch.org).

AMMA-CATH already participates to several global or regional observation networks, such as Flux-Net, Carbo-Africa, International Soil Moisture Networks (ISMN), ... and to calibration/validation campaigns for satellite missions such as SMOS (Europe/France/Spain), or MEGHA-TROPIQUES (France/India). AMMA-CATCH fills a gap over a region, West Africa, where environmental data are largely lacking, and thus, it can usefully contribute to the international networking effort for environmental monitoring and research.

P2 - 07

The North Wyke Farm Platform, a national capability for research into sustainability of temperate agricultural grassland management: data & modelling opportunities

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The North Wyke Farm Platform (NWFP) at Rothamsted Research in the South-West of England, is a large, farm-scale experiment for collaborative research, training and knowledge exchange in agro-environmental sciences; with the aim of addressing agricultural productivity and ecosystem responses to different management practices. The 70 ha NWFP site, captures the spatial and/or temporal data necessary to develop a better understanding of the dynamic processes and underlying mechanisms that can be used to model how agricultural grassland systems respond to different management inputs. Here, via beef and sheep production, the underlying principle is to manage each of three farmlets (each consisting of five man-made, hydrologically-isolated sub-catchments) in three contrasting ways: (i) improvement through use of mineral fertilisers; (ii) improvement through use of legumes; and (iii) improvement through innovation.

The connectivity between the timing and intensity of the different management operations, together with the transport of nutrients and potential pollutants from the NWFP is evaluated using various data collection and data modelling exercises. The primary data collection strategy involves the use of a ground-based, wireless sensor network, where in each of the fifteen sub-catchments, water characteristics such as flow, turbidity and chemistry are measured at a flume laboratory that captures the sub-catchment's water drainage (via a system of directed French drains). This sensor network also captures: precipitation and soil moisture data at the centroid of each sub-catchment; greenhouse gas data (N_2O and CO_2) across three of the fifteen sub-catchments; and meteorological data (other than precipitation) at a single site only (which is assumed representative of the NWFP site, as a whole). Such high temporal resolution data sets (but with limited spatial resolution) are coupled with a secondary data collection strategy, for high spatial resolution data sets (but with limited temporal resolution). These latter data sets include (multi-spectral and hyper-spectral) remote sensing data, together with more traditional field studies that provide information on soils nutrients and biodiversity. Both the primary and secondary data collection strategies are complemented by a dedicated geodatabase for the geographical layout of the NWFP site that includes soil class and LiDAR data.

We describe all such NWFP data sets and introduce some of the modelling opportunities that are possible. Models can stem from a mathematical, a hydrological, a process-based, or a statistical viewpoint; where various hybrid model forms are also possible. Models may need to account for: (a) data quality; (b) data support; (c) sample configuration and interval; (d) data distribution; (e) data relationships; (f) spatial, temporal and scale dependencies; (g) data heterogeneities; and (h) discontinuities and barriers (such as roads and hedges). Clearly, the modelling strategy is expected to be a challenge, but must be designed so that the key research objectives are met (i.e. those focused on sustainability with respect to high productivity coupled with low environmental damage). Thus to rationalise the modelling tasks, an inter-linked, four-stage programme of analysis is proposed; consisting of: (1) Quality Assurance; (2) Exploratory Data Analysis; (3) Interim Model Fits; and (4) Full Model Fits. Stages (1) to (3) will tend to investigate data sets in isolation; relate just a few of them at a time; or relate many data sets very simply. These outputs will feed into and direct the more complex models of stage (4), where many data sets will be used. All model results should be presented in both advanced and basic forms, depending on the target audience. The use and development of simple, but powerful visualisation techniques are promoted in this respect.

P2 - 08

The North Wyke Farm Platform, a national capability for research into sustainability of temperate agricultural grassland management: Infrastructure and instrumentation

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The North Wyke Farm Platform (NWFP) at Rothamsted Research in the South-West of England is a large, farm-scale experiment for collaborative research, training and knowledge exchange in agro-environmental sciences; with the aim of addressing agricultural productivity and ecosystem responses to different management practices. The 70 ha NWFP site, captures the spatial and/or temporal data necessary to develop a better understanding of the dynamic processes and underlying mechanisms that can be used to model how agricultural grassland systems respond to different management inputs. Here, via beef and sheep production, the underlying principle is to manage each of three farmlets in three contrasting ways: (i) improvement through use of mineral fertilisers; (ii) improvement through use of legumes; and (iii) improvement through innovation. Each of the farmlets is equipped with a range of state of the art, in situ, environmental monitoring equipment, sensing in real time: the quantity and quality of run-off; a range of soil variables; meteorological parameters and greenhouse gas emissions.

The three farmlets are further sub-divided into five (15 in total) hydrologically-isolated sub-catchments through a combination of the existing topography, the impermeable nature of the clay soils and through the introduction of French drains bounding the perimeters. The drains, dug to 0.8m, containing a perforated pipe and backfilled to the surface with stone, intercept surface and subsurface flow and channel it to one of 15 H-Flumes. Flow rates are calculated using a combination of primary and secondary flow measurement devices. The primary devices, the H-flumes, restrict the run-off from each catchment through a known geometry, while the secondary devices, bubbler-flow meters, use compressed air and a pressure transducer to calculate the head of water within the flume and convert to a flow rate (Litres per second, LPS). Providing there is sufficient flow (>0.2 LPS), a 13 litre by-pass cell is filled and emptied on a 15 minute cycle by a bi-directional peristaltic pump. The cell contains a suite of sensors that measure the following parameters: Ammonium; Dissolved Oxygen; Turbidity; pH; Conductivity; Temperature; Nitrate N and Dissolved Organic Carbon. In addition, Total P is measured at one site within each farmlet. An auto-sampler is also located at each of the 15 flume sites allowing for the physical collection of water samples for lab analysis of unmeasured parameters or for sensor validation. Each sub-catchment also contains a soil moisture station, measuring soil moisture at 3 depths (10, 20 and 30 cm), soil temperature at 15 cm, and precipitation using a tipping bucket rain gauge. The NWFP also has a fully equipped, centrally located automatic weather station.

All of these instruments are connected to a UHF radio telemetry network (www.adcon.com) consisting of remote telemetry units (RTUs) in the field which communicate with a centrally located base station. This station manages the network, receiving and storing the data before passing it to the Adcon AddVantage-pro software which collects, stores, processes and displays the data via its intergraded web server. At present the NWFP has a network of 45 RTUs, connected to 108 instruments collecting data on 198 parameters every 15 minutes.

In addition to the water, soil and meteorological instrumentation, the NWFP also has 3 automatic long-term chamber systems that are used on a campaign basis to measure N_2O and CO_2 fluxes from the soil on each of the farmlets.

P2 - 09

Modelling of historical hydrological conditions in the Mol area, Campine region, NE-Belgium: possibilities and limitations

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Usually, hydrological models are calibrated and validated using instrumental data, thereby limiting the modelling time window to the last few decades. However, as such short time windows do not capture the full variability of hydrological conditions and their driving forces, it seems necessary to test model performance also for historical periods, using reconstructed parameters and historical or proxy data. Furthermore, modelling of past conditions would allow to identify different drivers of environmental change (climate, human activities) and their influence on the hydrological cycle. By testing our ability to simulate what happened in the past few hundreds years, this type of study also may provide insights into the confidence we have in climate change and land use predictions and simulated impacts for the future.

The study aims at the reconstruction of present and past hydrological conditions in a small interfluve area (18.6 km^2) in NE Belgium. We compare the current state with four reference time periods in the past (1500 AD, 1770 AD, 1880 AD and 1940 AD) representing the main stages of landscape evolution in the study area. Historical information and proxy data were used to derive conceptual model features such as topography, surface water geometry (lakes, canals, drains…), as well as land cover, soils and vegetation distribution. We then used this information to parameterize a coupled vadose zone - groundwater model of the study area. The groundwater model is implemented in MODFLOW-2000 (Harbaugh et al. 2000) and unsaturated zone processes are treated by the HYDRUS package (Seo et al. 2007) for MODFLOW.

A limitation of this work concerns the comparison of simulated past hydrology with relevant data derived from validation paleo-records. The potential of a few indicators (recharge, groundwater table depth, seepage zones) for the validation of paleohydrological studies is discussed.

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P2 - 11

Adaptive Wireless Ad-hoc Sensor Networks for Long-term Ecosystem Research

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Environmental systems are often characterized by their high heterogeneity and dynamic, so individual measurements for their complete representation are often not sufficient. The application of wireless sensor networks in terrestrial and ecosystems offer significant benefits as a better consideration to the local test conditions, due to adapting the sensor distribution, the sensor types and the sample rate. Another advantage of wireless ad-hoc sensor networks is their self-organizing behavior, resulting in a major reduction in installation and operation costs and time. A concept and realization is given in the field monitoring of micrometeorology and soil parameters for the interaction of biotic and abiotic processes. This long term analyses are part of the Global Change Experimental Facility (GCEF), a large field-based experimental platform to assess the effects of climate change on ecosystem functions and processes under different land-use scenarios. This network includes 250 sensor nodes with one photosynthetic active radiation sensors and three soil und air humidity/temperature sensors in 3 depths and heights per node. Additionally precipitation and global radiation (incoming and surface reflected) is monitored at specific points. Regarding to the adaptive behavior of the network, the development of new sensor types and methods are under investigation to derive secondary parameters. This work will also present first test results of developed low cost radiation and photogrammetric sensors for detecting plant activity and leaf area index.

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Monitoring of Ecosystem Development at the Constructed Catchment Chicken Creek

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The constructed catchment Chicken Creek was established in 2005 as an experimental landscape laboratory for ecosystem research. The 6 ha area with clearly defined horizontal as well as vertical boundary conditions was left for an unrestricted primary succession. The developing ecosystem offers the opportunity to study most processes occurring at the interface of bio-, pedo-, geo- and hydrosphere. Particularly interactions and feedbacks between different evolving compartments as well as the establishment of ecosystem functions and services can be investigated during the ongoing ecosystem development. The catchment is extensively instrumented since 2005 in order to detect transition stages of the ecosystem. Comprehensive data recorded with a high spatial and temporal resolution include hydrological, geomorphological, pedological, limnological as well as biological parameters.

This site offers the unique situation of an early stage ecosystem with highly dynamic system properties. The first years of development were characterized by a fast formation of geomorphological structures due to massive erosion processes at the initially non-vegetated surface. Hydrological processes led to the establishment of a local groundwater body within 5 years. In the following years the influence of biological structures like vegetation patterns gained an increasing importance. Feedbacks between developing vegetation and e.g. hydrological features became more and more dominant. As a result, different phases of ecosystem development could be distinguished until now.

This observatory offers manifold possibilities to identify and disentangle complex interactions between ecosystem compartments in situ under natural conditions. The originally low complexity of the system is growing with time facilitating the identification of influences of newly developing structures on ecosystem functions. Thus, it is possible to study effects of small-scale processes on the whole system at the landscape scale. In addition, the highly dynamic initial system properties allow the observation of multifaceted changes of ecosystem properties and functions within short periods of time.

P2 - 13

Consequences of climate change on ecosystem functions, water balance, productivity and biodiversity of agricultural soils in the Pannonian area - project LYSTRAT

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Regional climate change scenarios for 2050 predict fewer but heavier rainfall during the vegetation period without substantial changes in the total annual amount of rainfall for Eastern Austria (Pannonian region). An experiment was carried out at the lysimeter station of the Austrian Agency for Health and Food Safety (AGES), comprising the three main soil types of the pannonian agricultural area (Calcaric Phaeozem, Gleyic Phaeozem, Calcic Chernozem) with six replications of each. The lysimeter station was covered by a greenhouse whose ventilation panels are automatically regulated in synchronization with rain, wind and temperature sensors. Precipitation rates have been modified according to the predicted scenario for the second half of this century in comparison to the current precipitation pattern.

The overall aim of the project was to obtain more information on possible changes in the soil-plant system due to lasting droughts and heavy rain events.

Different cultivation and irrigation during three years showed differences in the crop yields, the abundance and diversity of soil arthropods (Collembola, Oribatid and Gamasid mites), greenhouse gas measurements, analysis of mycorrhization, weed invasions and analysis of phospholipid fatty acids.

The analysis of Phospholipid Fatty Acids (PFLAs) and greenhouse gas (GHG) dynamics should highlight possible responses of the microbial community.

From March 2011 to November 2013 gas samples were taken regularly in the field to gain insight into the dynamics of the GHG CO_2, CH_4 and N_2O. Gas sampling using the closed-chamber method was carried out biweekly from April to October and monthly from November to March. At each sampling date, soil samples were taken from all lysimeters to determine the gravimetric water content and soil temperature in 5 cm depths was measured.

Phospholipid Fatty Acids (PFLAs) are essential structural components of microbial cellular membranes. Phospholipids are present in all cell membranes, except accumulations, and are broken down very quickly after cell death in the soil. Therefore, they are excellent indicator molecules for soil microorganism. Functional groups of microorganisms are characterized by specific phospholipid fatty acids - the basis of this "pattern" can thus be used as a "fingerprint" of the microbial community structure of a soil sample. PLFA´s have been monitored within the project for three years, three times a year (spring, summer and autumn).

Already after the first few months, a response of the PLFA´s could be detected. Whereas at the beginning of our experiment (in May) no difference between the precipitation treatments occurred, only after 3 months higher biomass levels were measured following the change of precipitation.

P2 - 14

Rainfall-runoff mechanisms on a hill island

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A number of studies have indicated that the hydrological system of stream valleys on the outwash plains in western Denmark is often complex. Here the flow paths between stream and aquifer may be quite diverse because of superficial semi-permeable layers. Only little is known about the second major geological element in this region - the hill islands - in which we concentrate our study in the relatively small Abild catchment (65.8 km^2) on Skovbjerg hill island. Existing discharge data comprise a few summer measurements while there are no time series of stage or discharge. Abild stream joins with the upper Vorgod which is only marginally larger than the Abild stream. The hydrograph from a discharge station in the Vorgod shortly downstream the confluence of the two streams present a paradox since it appears to be strongly influenced by quick flow indicating that shallow control by low permeable sediments is important. Nevertheless irrigation is intensive in the Abild catchment which indicates that the soil and shallow sediments are permeable. The topography of the watershed is characterized by gently rolling hills with wide valleys (25-80 MASL). The upper 0-20 m consists of Quaternary meltwater deposits and tills underlain by clay, quartz sand and lignite of Miocene age.

The objectives of this study are to investigate what are the dominating processes and what are the flow paths and fluxes for groundwater-surface water interaction on a hill island.

Stream flow is measured quarterly (ADCP and propeller) at 11 sites and monthly at five sites along the stream representing different spatial scales. Stream stage is measured continuously at seven sites with pressure transducers. Early April 2014 we installed temperature loggers in pairs of two at 10 sites in the downstream part of the stream. One at streambed and one close below water table at both sides of the channel. Furthermore we have mapped topography, soil types, geomorphology, ditches, drains and land use through field observations and digital maps. The shallow subsurface geology has been mapped using logs from a large number of old wells and geophysical data (airborne TEM).

To further investigate the spatial hydrogeological variation and its influence on stream discharge within the catchment we will:

- establish Q-h relationships at the five gaging stations

- qualify flux components at representative stream sections through temperature method

- map the shallow subsurface in more detail

- choose appropriate locations for further monitoring of discharge at different spatial scales

- monitor hydraulic head variations and quantify hydraulic parameters

- build a model for analysis of rainfall-runoff processes in this particular hydrogeological environment

We will present a short overview of the initial investigations with focus on either the Q-h relationships or the results from the temperature loggers (poster).

P2 - 15

Highly resolved long-term 3D hydrological simulation of a forested catchment with litter layer and fractured bedrock

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Soil water content plays a key role in water and energy balance in soil, vegetation and atmosphere. According to Wood et al. (2011) there is a grand need to increase global-scale hyper-resolution water-energy-biogeochemistry land surface modelling capability. However, such a model scheme should also recognize the epistemic uncertainties on the characteristics and processes of a grid element, as well as the nonlinearity and hysteresis in its dynamics. Unfortunately, currently it is not clear how to parameterize hydrological processes as a function of scale and how to test deterministic models with regard to epistemic uncertainties. In this study, funded by the BMBF research programme “MiKlip”, high resolution long-term simulations were conducted in a highly instrumented TERENO hydrological observatory (Wüstebach catchment). Soil hydraulic parameters were derived using inverse modeling with the Hydrus-1D model using the global optimization scheme SCE-UA and soil moisture data from a wireless soil moisture sensor network. The estimated parameters were then used for 3D simulations using the integrated parallel simulation platform Parflow-CLM. The simulated soil water content, as well as evapotranspiration and runoff, were compared with the field observation to illustrate how well the model was able to reproduce the water budget dynamics. With variable model setup scenarios, we investigated how depth-to-bedrock and lateral flow processes above the underlying fractured bedrock affects the simulation results. Furthermore, we also explored what role the litter layer of the forest soil plays in the simulation of water flow processes. Method of empirical orthogonal function (EOF) was also used for analysis on spatial patterns of simulated and observed soil water content.

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P2 - 16

Periglacial Slope Deposits and the CZ - on their genesis and influence on soil water content by a case study from the Bavarian Forest, Germany (TUM-CZO)

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Periglacial slope deposits (PSD) are widespread in mid latitudes' Pleistocene non-glaciated areas. In the mid-mountainous regions of Germany like the Bavarian Forest these sediments appear as characteristic layered material on any slopes. Typically, the PSDs consist of three different layers: Upper, Middle and Lower Head. Their properties are governed by their genesis at different climates and according to periglacial morphodynamics. Additionally, bedrock lithology and source of strata are influencing factors. The PSDs are crucial part of the critical zone as the uppermost layer between surface and the lowest groundwater level and responsible for layer-characteristic soil water movements. The latter are hydrological processes, like interflow and storage, depending on the PSDs.

In this investigation selected profiles of the Otterbach catchment are analysed in consideration of the pedological and sedimentological properties. Stratigraphical features and numerical dating techniques (OSL) help to interpret landscape evolution and genesis of its critical zone. In addition, soil water measurements within the single PSDs show the influence of the layers on soil water movement and the importance of the periglacial slope deposits as part of the critical zone.

P2 - 17

Effects of Climate Change on Groundwater Budget, Water Quality and the Local Water Supply in crystalline headwater areas in south-eastern Germany

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The main groundwater reservoirs in the crystalline complexes of the Moldanubikum (Bavarian Forest) and the Saxothuringikum (Fichtelgebirge) are concentrated within the weathering zone, with numerous springs forming the headwater regions of the adjacent river systems. Local water suppliers depend, to a high degree, on water originating from these spring systems draining the predominantly shallow aquifers. In context of climate change, the local water resources as well as the water quality are therefore vulnerable to the projection of a drier and warmer climate in the future. This makes it necessary to customize the public water supply structure to periods of water shortages, especially during summer when water demands are highest.

To increase our knowledge about the effects of climate change on the water budget, case studies in the Ilz catchment, situated in the Bavarian Forest, as well as in the headwater areas of the Saale, Eger and Oberer Main River in the Fichtelgebirge in the north-east Bavarian crystalline (NOBYK) were conducted to investigate the present and future yield of groundwater. These areas can be considered to be representative for a variety of similar crystalline low mountain ranges in Germany and Europe. To this end, water balance models (ArcEGMO-PSCN, Ilz catchment and WaSiM-ETH, NOBYK) were applied in high resolution to quantify the mean and inner-annual effects of climate change (WETTREG 2006 and 2010 scenarios, based on ECHAM5-OM1 A1B) on river and spring discharge in the near (2021 - 2050) and distant future (2051 - 2100). The meteorological input parameters for the model regions, based on weather stations from the DWD (German Meteorological Service), were regionalized and validated with the time period from 1980 - 2008 for the Ilz catchment and from 1971 - 2000 for the NOBYK. The water balance models were calibrated at 13 river gauges, snow cover gauges as well as measured soil temperature and -moisture in the Ilz catchment and at 29 river and spring gauges in the NOBYK area. Similar to their geology, elevation and land cover, the two study areas exhibit an analog hydrological response to the climate scenarios: In winter, higher mean temperatures and an increase in precipitation result in increasing evapotranspiration (ET) rates alongside an earlier occurrence of the yearly river runoff peaks due to a change in snowmelt dynamics. In summer, a decrease in precipitation leads to a partly significant decrease in ET, which can be explained by the lack of total available water during drought periods. Groundwater recharge is therefore limited or even negative during summer. As a consequence, total river discharge is going to decline during spring, summer and autumn for both scenarios with extending low flow periods. Generally, the simulated spring discharge pattern shows no clear inner-annual trend in the near and distant future.

Additionally, a water quality case study in the Lehstenbach catchment, within the NOBYK area, was realized in cooperation with the University of Bayreuth, Department of Soil Ecology and the Department of Hydrology. The chosen catchment represents typical forested mountain ranges with fens in saturated areas around open water bodies. Here, the focus was on the trend and the dynamics of the dissolved organic carbon (DOC) and Nitrate export. In many forested regions in Europe and northern America, increasing DOC and Nitrate concentrations have been observed over the last decades. Both compounds have the capability to deteriorate the drinking water. To get insight into the DOC and Nitrate export dynamics, a high resolution measurement period was conducted: Following precipitation events, DOC in fen areas is quickly mobilized by fast runoff components after the groundwater level increased to surface near levels. As the DOC production is closely linked to temperature, DOC concentrations peaked during summer. However, the highest total DOC export takes place during winter when discharge is highest. The dynamic in Nitrate export behaves conversely; low concentrations were measured during summer runoff peaks, while higher concentrations were measured during winter, indicating slow runoff pathways in deeper groundwater. The simulated future increase in discharge during winter is accompanied by an increase in total DOC export, while the overall summer export remains stable despite a decrease in summer discharge due to frequent heavy rainfall events resulting in increased DOC export rates.

P2 - 18

Quantification of denitrification via N_2 balances provides unique insights to the in-stream nitrate cycle

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Nitrate can be removed from aquatic (lotic) systems in various ways eg. assimilatory uptake, adsorption or intermediate storage in sediment and wetland. Amongst these, denitrification, the microbial reduction of NO_3 to N_2 (g), is the only process which eternally eliminates Nitrate from the system. Unfortunately, due to methodological limitations, the quantification of in-stream denitrification is so far hardly assessed.

Long time monitoring in form of mass balances in the Lower Bode indicates that nitrate is processed in the run of this river. Our objective is to disentangle the different processes leading to this reduction. It is of particular interest to quantify the proportion of removed nitrate attributed to denitrification. In order to do so, we measured in situ dissolved N_2 (the end product of microbial nitrate reduction) in a Lagrangian approach. Due to the poor reactivity and high background of nitrogen in water and atmosphere, commonly used methods (GC, head- space MS) fail to deliver usable data. Sufficiently accurate results can up-to-date exclusively be achieved measuring N_2/Ar concentrations on a membrane inlet mass spectrometer. An assessment based on a complex set-up and the determination of various side parameters.

Here we demonstrate how this approach especially in combination with the investigation of solute exchange to the interstices, provides unique insights in the in-stream nitrate cycle.

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Modeling Carbon Dynamics for Small Ponds in the North-East of Germany

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Due to the complexity and the large number of the biogeochemical processes in small ponds and their adjacent arable areas, any modeling of carbon dynamics in kettle holes should take into account interactions between multiple elements, e.g. carbon, nitrogen, phosphorus, oxygen and other chemical elements. A significant fraction of these elements originate from agricultural areas and are transported to the ponds via wind or water erosion. This input is processed by phytoplankton, macrophytes, bacteria and fungi which are the key players for biomass production and decomposition. For this, a complex eutrophication model was developed for the Rittgarten kettle hole which is surrounded by arable fields located in eastern part of Germany to get an insight into the substantial short-term variations of these processes, assessing carbon budget and to best understand their eff ects on water quality as well. The model combines phytoplankton as a single group and describes its interaction with duckweed and submerged macrophytes. We also considered the incorporation of the nutrients, organic and inorganic matters in the overlying water as well as in the sediment bed. In addition, the model takes into consideration the phosphate-iron and dissolved inorganic carbon-calcium interactions. Model calibration is performed using data derived from time series of water quality and monitoring data of the LandScales project.

P2 - 20

High Resolution Monitoring of Hydrogeochemical Gradients Across the Dynamic Soil-Groundwater Interface in a Riparian Landscape

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Riparian zones are important buffer zones for non-point groundwater contaminants like nitrate. Shallow water tables favour denitrification, as nitrate rich groundwater comes into contact with anoxic, organic rich layers in hydric soils. To date, riparian research has focused on influences of groundwater-surface water interactions on nitrate removal mechanisms, but little is known about processes occurring at the interface between the saturated and the unsaturated zone during groundwater table fluctuations. Strong groundwater level fluctuations are a typical feature of riparian zones, caused by the tight response to surface water-level fluctuations and influences of rainfall forcing and evapotranspiration. Therefore, the objective of this study is to identify hydrogeochemical gradients across the soil-groundwater interface and monitor their response to groundwater table changes. High-resolution multi-level monitoring wells will be installed in the riparian corridor of the Selke TERENO field site in the Harz Mountains with sampling ports both in the unsaturated and the saturated zone. We expect that dynamic conditions in the vicinity of the groundwater table play an important role for matter turnover processes as increased dispersivities enhance solute transport and thus increase potential mixing of rate limiting reactants. By resolving processes at the intended small scale, hot spots and hot moments of biogeochemical turnover processes can be identified and their relevance for overall degradation processes can be estimated. This leads to a better prediction and improved management strategies for buffer mechanisms in riparian zones.

P2 - 21

Spatial and temporal links between DOC and NO_3^- in a forested mountainous headwater catchment in the Eifel, Germany

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The spatial and temporal variability of the concentration of dissolved organic carbon (DOC) and nitrate (NO_3^-) was studied by means of weekly grab samples over a 4-year period (2009-2013) in a forested headwater catchment (Wüstebach, Germany).

Stream water DOC values varied between 0.8 and 7.4 mg/l, with a mean value of 2.7 mg/l. NO_3^- concentrations ranged between 2.8 and 12.2 mg/l, with a mean value of 5.7 mg/l. The stream water DOC values were negatively correlated to NO_3^- concentrations (highest R^2=0.54). Hence, low DOC and high NO_3^- concentrations were measured during summer in stream waters. Generally, surficial water exhibited high DOC, low NO_3^- concentrations and high variability while ground waters were characterised by low DOC, high NO_3^- values and low variability. The data confirmed observations by others, which suggest the existence of a negative nonlinear relationship between NO_3^- and DOC occurring along a hydrologic continuum from soils over to streams and lakes. However, we also wanted to test the hypothesis whether or not this correlation between DOC and NO_3^- depends on the time-point of observation. Cross wavelet analysis were performed and time lags quantified on stream and groundwater monitoring data. The wavelet analyses revealed negative cross correlations with a three month shift of NO_3^- compared to DOC. The strongest correlations occurred at the range of 6-7 months, especially for the surface water (up to an R^2 close to 1). The study did therefore confirm a direct correlation between DOC and NO_3^- in surface waters, but only when short term random effects are neglected.

Within the whole catchment, general spatial differences in annual trends in DOC and NO_3^- concentrations in tributaries and various superficial components were found. This most likely reflects the localized differences (soil, hydrological and bedrock conditions) in the relative contributions of surface and ground water to the stream water, probably in response to prevailing weather conditions.

P2 - 22

Assessing the imbalance between sediment rating curve options and spatial scales - reducing uncertainties in water quality modeling

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Suspended sediment generated at catchment outlet using sediment rating curves strongly depends amongst other factors on: (i) rainfall event intensity and amount; (ii) land surface state in terms of physical surface characteristics, seasonal vegetation stages, land use/management; and (iii) catchment sizes, on which depend the increase or decrease in the complexity of land surface states, the measurement strategy so the sediment rating curve options. This study aims to clarify the suitability of the classical Sediment-Discharge Rating Curves (SDRC) compared to Sediment-Turbidity Rating Curves (STRC) for a given catchment size to provide reliable time-series data for water quality and soil degradation modeling. Thus, SDRC and STRC were computed and compared over two consecutive years 2004-2005 at three different catchment scales of 16.5 km^2, 586 km^2 and 2,324 km^2 in the upper Ouémé catchment in Benin. For that, sub-hourly turbidity measurements were considered together with sub-daily suspended sediment concentration and water discharge data. The SDRC were fitted using a Generalized Reduced Gradient Nonlinear approach. The results suggested that the SDRC approach behaves poorly but improves with increase catchment size. In opposite to that, the STRC approach provides acceptable results at all scales. This can be explained by complex behavior at the small scale due to landscape and rainfall patterns. With increasing size of the catchments, variability smoothes out caused by mixing processes as well as erosion and sedimentation within the river system. Therefore, the SDRC approach is only suitable for large catchments but does not allow analyzing the rainfall-erosion patterns.

Keywords: Sediment; turbidity; water discharge; rating curve; spatial scale; land surface state.

P2 - 23

Effects of temporal and spatial resolution of calibration data on integrated hydrologic water quality model identification

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Hydrological water quality modeling is increasingly used for investigating runoff and nutrient transport processes as well as watershed management but it is mostly unclear how data availability determines model identification. The objective of this study is to investigate the impacts of temporal and spatial resolution of calibration data (discharge and nitrate-N concentrations) on integrated hydrologic water quality modeling performance, parameter identification and predictive uncertainty. The HYPE (HYdrological Predictions for the Environment) model, which is a process-based, semi-distributed hydrological water quality model, was applied in a nested meso scale catchment Selke (463 km^2) located in central Germany to simulate discharge and inorganic nitrogen (IN) transport. The Bayesian inference based approach $DREAM_{(ZS)}$ was combined with the HYPE model to conduct parameter calibration and uncertainty analysis. Split-sample test was used for model calibration (1994-1999) and validation (1999-2004). Both dynamics and balances of water and IN load were well captured with NSE greater than 0.83 during validation period. IN concentration and daily IN load were found to be highly correlated with discharge, indicating that IN leaching is mainly controlled by runoff. Multi-site calibration was able to improve model performance at internal sites, decrease parameters' posterior ranges and prediction uncertainty. The impacts of multi-site calibration on parameter optimization and prediction accuracy depend on the variability of catchment characteristics. Nitrogen-process parameters calibrated using continuous daily averages of nitrate-N concentration observations produced better and more robust simulations of IN concentration and load, lower posterior parameters' ranges and IN concentration prediction uncertainty compared to the calibration against non-continuous biweekly nitrate-N concentration measurements. This study helps us to understand the realism of model structure and design reasonable hydrological water quality sampling campaigns.

P2 - 24

CHARACTERIZATION OF STREAM-AQUIFER INTERACTIONS IN CARBONATE ROCKS

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Groundwater - surface water interactions play a fundamental role in terms of quantity and quality of water and in terms of ecological quality of rivers. Moreover, the hyporheic zone influences the mobilization and degradation of many pollutants. Despite many research efforts and the necessity to better understand such interactions in order to reach effective management of water resources, stream-aquifer exchanges remain poorly understood, in particular in fractured carbonate environments.

In this context, the overall objective of the project is to identify, characterize and quantify groundwater - surface water interactions in carbonate rocks, to assess the impact of these interactions on the ecology of the stream and to better understand the nitrate pathway from surface to the river (soil - vadose zone - groundwater - hyporheic zone - river). Carbonate systems present a high variability of fluxes because of groundwater flow inside fractures and karstic networks. This leads to transport and dispersion of pollutants and to localized groundwater inflows in the river with high variations in time. The heterogeneities and the impact of flows are difficult to emphasize in such systems. Therefore, the monitoring setup has to be adapted to be able to catch the dynamic of these environments. This implies the need for increasing the number of spatial and temporal measurements.

In order to accomplish this objective, two main observation scales are considered. First, a portion of a stream is studied in quantitative and qualitative ways via a dense instrumentation and monitoring. Electrical resistivity tomography (ERT) identifies fractures and characterizes their geometry by contrast of resistivity. Streaming potential (SP) locates groundwater fluxes in the banks via an electrical signal induced by the polarization of the water. These measurements allow locating groundwater inflows in the stream that are then characterized for the temporal approach by a distributed temperature sensing (DTS). This technique measures shifts of temperatures (0.1°C by 1m) resulting from the mix of groundwater (constant temperature: 12-13°C) and surface water (16-17°C during summer, 4-5°C during winter). Incoming groundwater fluxes, previously located by geophysics, modify surface temperature and are recorded by DTS. Repetitions of DTS measurements allow characterizing temporal variations of groundwater incomes.

Furthermore, nitrate pathway is studied on an experimental site where different depths piezometers are drilled. Tracer and infiltration tests are performed to assess mechanism and time of transfer in the unsaturated and saturated zone.

Second, a global analysis is foreseen. The selected watersheds are mainly covered by agricultural activities with some influence from inhabited areas. Detailed enquiries regarding the agricultural practices are performed. Soil samples are taken on hundreds of parcels to quantify the nitrate content on the 0-90 cm depth. The agricultural practices as well as the hydrological behavior of the catchments will be modelled in order to assess water flows and nitrogen transfer to surface water and groundwater using the EPICgrid model.

The impact of the hyporheic zone on the degradation of nitrate is studied by different techniques such as hydrochemical analyses in groundwater and in the stream and by conservative and non-conservative tracer tests. In-stream nitrate concentration, along with other parameter, is monitored at high temporal resolution by multiparameters probes. Moreover, key aquatic communities are studied in detail, in order to identify indicators of the groundwater - surface water interactions that may have significant impacts, possibly leading to alteration of the ecological status of the surface waters.

It is expected that the results from the combined experimental setup will provide an improved characterization of the variability of stream-aquifer interactions in carbonate rocks and a better understanding of the nitrate dynamics.

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Application of isotopic tracers and hydrochemical data for the investigation of groundwater flow in a young moraine area

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Decreasing groundwater and lake levels over the last 30 years have been observed at many locations in northeastern Germany. However, the precise reasons for this decline are still unclear. Our investigation aims at a better understanding of the hydrodynamic behavior of a shallow aquifer using isotopic tracers and hydrochemical data. Focus area is the domain of Lake Hinnensee, which is located in a young moraine area in Mecklenburg-Vorpommern. The research area consists of the Pommeranian main terminal moraine in the north and the outwash plain in the south. The unconfined aquifer in the Lake Hinnensee area is mainly composed of glacial medium sands.

Little knowledge about groundwater flow directions and dynamics is available for the Lake Hinnensee region. However, as we are looking at a purely groundwater controlled lake system (no surface inflows or outflows), this information is essential for a better understanding of the ongoing processes controlling both lake and groundwater levels.

First field campaigns were carried out in 2012. The establishment of seventeen observation wells and a groundwater level monitoring system, electric resistivity tomography measurements as well as the investigation of subsurface characteristics such as hydraulic conductivity supplied important first insights into the structures and properties of the hydrogeological system.

From recharge to discharge, groundwater is subject to different chemical reactions and physical changes. Information on water chemistry is used to analyze groundwater residence times, flow paths and origin. The stable isotopes oxygen-18 and deuterium and the radioactive radon are used as tracer. In addition, the ion content and the physico-chemical parameters temperature, electrical conductivity, pH, oxygen content and redox potential are measured. For this purpose the observation wells were pumped every six weeks between May 2013 and November 2013 and every eight weeks from November 2013 to May 2014. From analyses of isotope and radon contents as well as of physico-chemical parameters spatial patterns of different groundwater regions can be determined. The regions may indicate areas of different groundwater origin, flow paths and residence times, which amongst others are determined by subsurface properties, structures and boundaries. The highest water levels are monitored in April and May, the lowest in October and November. In general the hydrographs of the seventeen observation wells are relatively similar in their seasonal dynamics. However, they show slightly different trends, possibly pointing at different groundwater origins or flow paths. First results of the isotope and radon measurements as well as an overview of the ion content, the spatio-temporal distribution of the physico-chemical parameters and the water level developments in the area are presented.

P2 - 26

Evaluation of trends in nutrient concentrations

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Water quality measurement analysis and modeling are combined to monitor and evaluate the nutriënt concentrations in catchments. The developed method resulted in more and better information than achieved from the measurements before. The results have been used to contribute to the evaluation of the Dutch fertilizer policy. With the knowledge gained it is possibleto improve the use of the measurements as wel as to optimize the design of the measuring networks.

P2 - 27

Physically-based modeling in an experimental alpine catchment

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Mountain regions are particularly sensitive to climate change and at the same time they represent a key water resource not only locally but as well for lowland areas. Therefore, there is a strong need to improve the capability of hydrological models to quantify changes of the water cycle components, considering interactions and feedbacks with climate and vegetation. Process-based hydrological models represent promising tools for addressing those needs. However, their inherent complexity sometimes limits their applicability for operational purpose, but they offer great potential in terms of tools to test hypotheses, which can be verified in the field.

GEOtop is a hydrological model that calculates the energy and mass exchanges between soil, vegetation, and atmosphere, accounting for land cover, water redistribution, snow processes, glacier mass budget and the effects of complex terrain and thus is one of the few models that was built with this complexity in mind. Recently, it has also been coupled with a dynamic vegetation model in order to simulate alpine grassland ecosystems.

In this contribution, we want to present an application of the GEOtop model in simulating above ground biomass (Bag) production, evapotranspiration (ET), soil moisture (SM) and snow water equivalent (SWE) for the emerging LTER area of Matsch/Mazia, located in the Venosta/Vinschgau valley in the European Alps. In this area an intensive hydrological and ecological monitoring activity with ground observations and remote-sensing products has been established in the last five years.

Simulations results underlines the capability of the model to predict the observed changes on the water budget components along the altitudinal gradient, as well its potential in terms of predicting future changes. However, detailed observations are needed to parameterize the model.

In this contribution we want to highlight the role of the experimental observations for a multi-scale and multi-process evaluation of the model. Plot scale observations of evapotranspiration, soil moisture and snow cover, combined with remote sensing observations help to discriminate between uncertainties in input data and model parameterization. Moreover, we want to show how, when the model is used in combination with detailed experimental campaigns, a more coherent and accurate estimation of the catchment hydrological behavior is possible with respect to the one that is possible with simpler lumped models.

P3 - 01

High resolution analyses of partially varved sediments from Lake Tiefer See (NE Germany) for the last ca. 10,000 years - a multi proxy study

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Annually laminated (varved) lake sediments represent unique archives in continental areas providing both, precise chronologies and seasonally resolving proxy data. Lake Tiefer See in NE Germany provides such an archive for an integrated multi-proxy study based on high-resolution sediment analyses and monitoring of modern deposition processes forming subannual laminae.

Lake Tiefer See is located within the terminal moraine belt of the Weichselian glaciation and is part of the Klocksin Lake Chain which has been formed as a subglacial gully system. Coring campaigns at the deepest part of the lake (62 m depth) yielded 7 sediment profiles, 3 of which reached glacial sand deposits at the base. From these individual profiles a ~10.5 m long continuous composite profile has been compiled by means of identifying macroscopic and microscopic correlation layers. The chronology of the core sequence is based on varve counting, AMS ^{14}C dating of terrestrial plant remains and identification of cryptotephras including the Laacher See Tephra originated from the Eifel region. The position of the Laacher See Tephra suggests an onset of lake sedimentation in the late Allerød at ca. 13,000 years BP.

A combined approach of sediment microfacies analyses using large-scale thin sections, µ-XRF element scanning of split sediment cores, geochemical analyses of the bulk sediment and pollen analyses for the complete composite profile and diatom analyses for certain intervals has been carried out. First results include a distinct increase of the endogenic calcite contents at ca. 5,000 years BP and the appearance of poorly varved or homogeneous intervals starting ca. 4,000 years BP. Poorly and non-varved intervals are characterised by higher Ti and K count rates indicating increased detrital matter flux into the lake by surface runoff and/-or aeolian transport. Results of pollen data imply increased forest opening and agricultural activity during these intervals with poorly preserved varves.

Possible mechanisms for the abrupt changes beginning at ca. 5,000 years BP include local influences (e.g. lake level fluctuation, anthropogenic disturbances on the vegetation in the lake vicinity) and increasing maritime influences of the North Atlantic related to changes in atmospheric circulation patterns and wind strength.

The data from the Lake Tiefer See sediment record are compared with the varved lake record from Lake Czechowskie, located ca. 400 km to the East in central northern Poland in a similar geomorphologic position, based on independent and high precision chronologies. The aim of this comparison is to test the hypothesis of decreasing North Atlantic maritime influences towards more continental regions in the East.

This study is a contribution to the Virtual Institute of Integrated Climate and Landscape Evolution Analysis -ICLEA- of the Helmholtz Association and uses TERENO infrastructure.

P3 - 02

Hydrological and sedimentological processes of flood layer formation in Lake Mondsee

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Detrital layers in lake sediments are valuable recorders of extreme river floods and are increasingly exploited to establish continuous flood chronologies reaching several millennia back in time. The annually laminated sediments of Lake Mondsee (486 m a.s.l., Upper Austria) contain a seasonally resolved flood layer chronology over the past 7100 years. Despite the great potential especially of varved lake sediments for reconstructing long flood time series, there are still some confinements with respect to their interpretation due to a lack in understanding the complex chain of processes leading to the formation of detrital layers.
For this purpose, a comprehensive monitoring network was set up at Lake Mondsee recording hydrological and suspended sediment dynamics from the catchment to the lake. Precipitation, runoff and suspended sediment concentration are monitored continuously at the outlet of the main tributary to the lake, the Griesler Ache River; water samples were taken automatically during runoff events. Within the lake, sediment is collected continuously in 3- to 12-day intervals by sediment traps, one located close to the river inflow and one in a more distal position where the long sediment record was retrieved.
Our monitoring data cover the period from January 2011 to November 2013 including 26 floods of different amplitude (10 to 110 m3/s) which triggered variable fluxes of catchment sediment to the lake floor (4 to 758 g/(m2*d)). The detailed comparison of runoff and sediment data revealed (i) empiric thresholds for triggering significant sediment influx in the proximal (20 m3/s) and distal lake basin (30 m3/s), (ii) a relation between the amplitude of flood discharge and the amount of sediment flux and (iii) a variable spatial sediment distribution during high magnitude floods. The latter is mainly due to the role of (i) flood duration, (ii) the existence of a thermocline and (iii) local sediment sources which episodically contribute additional detrital material. Monitoring floods of very different intensity and seasonal occurrence shows a complex relation between flood amplitude and sediment signal. This helps to identify uncertainties in the Lake Mondsee flood layer record and demonstrates the potential for a closer link of instrumental and sediment-based flood time-series.

P3 - 03

Colluvial Sediments and Bogs in the Ammer Mts. as GeoArchives: Predicting Soil Stability under Land Use and Climate Change (TUM-CZO)

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Soils represent the central part of the complex interaction system of the Critical Zone. As such, soil loss causes serious, irreversible loss of vital ecosystem services. Hence, deter- mining risks of soil degradation and soil loss is a major task within the Critical Zone research. As an example for recent research within the Critical Zone Observatory of the Technische Universität München (TUM-CZO), located in the Ammer Mountains of the Bavarian Alps, we present a project which deals with the investi- gation of possible soil loss triggers and dyna- mics in alpine landscapes by reconstructing mineral colluvial deposits in peat bogs.

Within the Ammer catchment, we investigate a total of twelve peat bogs distributed across an altitude gradient from alpine to subalpine and lowland landscapes. Represented are the study sites investigated so far with special focus on the southern alpine part of the catchment. Three sites within the northern prealpine catchment are still to be prospected.

The investigation of colluvial deposits in peat geoarchives provides perfect conditions for the reconstruction and interpretation of past soil erosion events. In particular we intend to : evaluate peat geoarchives with regards to soil morphodynamics (caused by former climate and land use changes) assess frequency and amplitude of disturbances (system stability/lability) give a valuable risk assessment on the threat/loss of ecosystem, define management strategies for forestry, agriculture and conservation validate existing szenarios (proxy data).

P3 - 04

A spatial reconstruction of European droughts from an isotope-climatenetwork approach

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A well-verified spatial reconstruction of European moisture variability back to 1600AD was established from a network of tree-ring stable isotope records (C+O). Principle component regression and change point detection techniques have been applied and revealed strong coherences among the tree ring isotope records, convincing congruence with isotope theory and a powerful climate-proxy relationship with the summer Standardized-Precipitation-Evaporation-Index (SPEI; July-August). The presentation will outline and discuss trends in the spatial extent of drought events, coherences with atmospheric regimes (SNAO) and comparisons with other European climate reconstructions.

P3 - 05

Climate and tree growth in TERENO West & Northeast

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The TERENO Coordination Team Geoarchives (http://teodoor.icg.kfa-juelich.de) aims to improve the understanding of the long-term climate-growth relationships since this is the crucial link between soil, vegetation and atmosphere. Tree rings allow for high-resolution and long-term analyses, especially in conjunction with lake sediment records. Since one of the major aims of TERENO West and Northeast is to combine tree rings and lake sediments, it is important to first identify differences and commonalities in the climate-growth relationship in West and Northeast. The insights will sharpen our comprehension concerning the impact of climate change in different TERENO regions spatially and temporally.

Tree-ring width chronologies of oak from two different regions (W= West and NE=Northeast) were developed and correlated with monthly precipitation, temperature and Palmer Drought Severity Index (scPDSI) of the previous and current vegetation period using Pearson´s correlation coefficient. Additionally, as a discontinuous approach, an extreme year analysis was conducted in order to concentrate on the climate growth relationships for selected extreme years.

Correlations between tree rings and climate data reveal a stronger common signal in NE than W. Oaks from both regions are correlated significantly with spring and early summer precipitation, whereas less significant temperature signals were found. Tree growth of oak from NE responds stronger to moisture deficits.

In total, 18 years of extreme growth anomalies were detected for the period from 1901 to 1996. More negative than positive extreme years were found in both regions. Only negative extreme years are shared between both regions but no positive extreme years were found at the same time. Tree growth in NE responds stronger to extreme events. Analyses revealed that extreme years of tree growth are also characterised by severe deviations from the long-term (1901-2006) monthly temperature and precipitation means.

Overall, the analyses indicate similar climate-growth relationships in TERENO W and NE, with stronger correlations in NE. The results suggest that more reliable climate reconstructions are likely to be achieved with oak in TERENO NE, probably due to the more continental climate in TERENO NE. On-going investigations comprising studies on quantitative wood anatomy and stable isotopes will increase our know-how of the complex climate-growth relationships and lead to comprehensive reconstructions. Since living oak trees in TERENO NE can grow to several hundred years and in addition a lot of archaeological oak wood is available, a regional moisture-sensitive oak chronology of more than 1000 years will be achieved, thereby opening doors to new multi-proxy reconstructions.

P3 - 06

Finding proxies for historical groundwater table depth in a flat and sandy landscape: examples from the Campine area, NE Belgium

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Hydrological modelling is usually applied to predict the state of a specific hydrological variable (channel flow, peak run off, groundwater head) for the present and the future. Model calibration and validation is then based on instrumental measurements of variables in the recent past, usually the last few decades. However, this inherently limits the evaluation of model performance because this timeframe is usually too short to encompass the full variability of the hydrological system and its response to driving forces (climate, land use, human activities). Extending the modelling timeframe to historical periods (several centuries) allows to test model performance for different conditions than today, encompassing a wider range of hydrological variables. However, verification of the model output for historical periods requires the acquisition of palaeohydrological proxies describing the state of a specific variable for a given point in time in the past.

In this presentation, we discuss several proxies for historical groundwater table depth and methods to derive them. The study area is a small interfluve within the Nete catchment, Campine area, NE Belgium. Surface altitude ranges between ~ 23 m TAW (Tweede Algemene Waterpassing; m a.s.l.) in the floodplains and ~ 28 m in the dune areas. At present, the groundwater table is on average 1-2 m below the surface and can be recognized as a subdued replica of the topography. Outside the small floodplains, a so-called drift sand landscape developed during the last few centuries, witnessing the strong human impact on the landscape. Other impacts on the landscape can be seen, like the numerous drains that were constructed during the 19th century to expand the arable land, or the straightening and deepening of small rivers and brooks. With respect to soils, the introduction of plaggen agriculture in the 16th century has led to the development of thick Anthrosols, while enhanced soil erosion in the 17th-18th centuries has led to the transformation of typical Podzols into Arenosols.

Redoximorphic features in OSL-dated soil-sediment profiles suggest that, compared to the current situation, the groundwater table was significantly higher (around 1.5 m) ca. 1650AD and even higher between ca. 1000AD and 1600AD. Furthermore, geomorphological investigations showed that the altitude of blown-out surfaces, dated to ca. 1600AD and regarded as an upper bound for the groundwater table, are closely related to the position of redoximorphic features observed in cross-sections cut into the dunes (Beerten et al., 2014a).

Historical maps point out that part of the interfluvium was occupied by shallow pools, at least around 1780AD and 1850AD. Today such pools are much less numerous and artificially fed by water from the mid 19th century established canal that crosses the interfluvium. Field work and DTM-analysis indicates that the groundwater table must have been 1-2 m higher in order to sustain the existence of such pools.

During the 19th century, the Kleine Nete river was straightened and deepened. This must have led to a significant groundwater table lowering in the floodplain. The evidence for a shallow river is derived from the investigation of a section cut across an 18th century palaeo-channel, while information on the geometry is derived from historical maps (Beerten et al., 2014b).

Finally, historical maps, field work and detailed DTM-analysis suggest that around the end of the 19th century, the higher parts of the interfluvium were (still) experiencing high groundwater table conditions as ditches were cut to sustain the newly established pine plantations in the area. An imaginary profile line connecting the bottom of the ditches mimics the position of a groundwater table.

Despite the fact that the nature of the investigated archives is highly discontinuous, and their examination yields temporally and spatially discontinuous information on groundwater table depth in

this specific sandy landscape, it seems that a period of high groundwater table can be identified that started probably already before 1600AD and lasted until around 1900AD. Land use and vegetation changes are held responsible for the groundwater table lowering, although the role of climate change and increasing water demands should be considered as well.

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P3 - 07

Challenging a process-based agro-ecosystem model with the impact of erosion on short-term carbon dynamics within an undulating landscape

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Measuring carbon (C) fluxes towards a complete C balance in a soil-crop-atmosphere system allows a faster and more precise evaluation of climate and land use effects than common field experiments. However, it requires the help of process-based modelling in cases where some relevant C fluxes cannot be separated using measurements and to predict hypothetical states of the system which are beyond the power of field experiments. In this context, little has been done to quantify the role of erosion on the function of soil as a C sink or source so far. In a field manipulation experiment (CarboZALF-D) on the C budget at different erosion-induced transient states of soils in the undulating landscape of North-eastern Germany (hummocky ground moraine) high-frequency data of C fluxes gross primary production (GPP), ecosystem respiration (R_{eco}) and net ecosystem exchange (NEE as the difference between GPP and R_{eco}) were available for a maize crop. We used the MONICA model to analyse the C fluxes. MONICA has been successfully tested for maize yield predictions across a range of different environments and against long-term soil carbon dynamics in various crop rotation experiments. From the conceptual point of view, MONICA should be able to reflect the influence of soil properties and weather on actual CO_2 fluxes and crop growth and successfully predict cumulative CO_2 fluxes, CO_2 budgets and biomass yields at three different landscape positions: hill top (Albic Cutanic Luvisol, erosion neglectable), slope (Calcic Cutanic Luvisol, slight erosion and Calcaric Regosol, strong erosion), and hill foot (Endogleyic Colluvic Regosol, deposition). In this exercise we show that MONICA reproduces NEE as GPP − autotrophic respiration - heterotrophic respiration) of a maize stand in the range of the measured values, although at a small temporal resolution considerable differences are noted for the individual CO_2 fluxes. However, in a method intercomparison the lack of prediction accuracy is compensated by the additional information provided by the model on C fluxes in times when measurements were limited. The prediction of biomass production at the different landscape positions, however, did not live up to the expectations, which is due to several limitations: A point model, MONICA lacks important input information on laterally in- and outflowing sub-surface water into the soil column whose water dynamics is additionally influenced by fluctuating groundwater levels at the hill foot position. Secondly, at strongly inclined positions, where strongly eroded soils exist, nutrient deficiency beyond nitrogen (magnesium, potassium, phosphorus) additionally add to the growth-reducing factors which are not captured in the MONICA model. In summary, it seems that the unsatisfying model results are explained by the insufficient acquisition of growth-relevant soil properties and their three-dimensional distribution rather than the incapable model which was not constructed for this level of detail in the first place. However, to start with, we are able to show that the observed soil water contents at the different positions - if provided as an input to MONICA - may explain a considerable part of the yield differences across the landscape and that stepwise integration of growth-relevant soil properties and their consequences for different processes in the soil-plant-atmosphere system gradually improves the model performance.

P3 - 08

Limitations of two energy balance closure parametrizations

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Tower-based eddy-covariance (EC) measurements usually do not close the energy balance, because they underestimate the turbulent heat fluxes. We tested two energy balance closure parametrizations that were suggested to correct the measured EC fluxes. For this purpose, we used tower data from three sites of the Bavarian Alps / pre-Alps Observatory of the TERENO programme and surface-layer airborne measurements from the Canadian Twin Otter research aircraft. The non-closure of the energy balance of the aircraft data was estimated from the flux contributions of turbulent structures larger than 2 km. The first parametrization approach, by Huang et al. (2008), is based on large-eddy simulation and was developed for horizontally homogeneous convective boundary layers. It is neither applicable to our tower-based EC measurements nor to the aircraft data, because its grid resolution is not sufficient for modelling surface-layer turbulence. However, for two of the three sites, we could at least confirm the suggested dependence of the energy balance closure on friction velocity. The second approach, by Panin and Bernhofer (2008), is empirical and focuses on landscape-level roughness heterogeneities that are expected to induce secondary circulations. It only gives a rough estimate of the energy balance closure, because besidessurface roughness it does not consider any other feature of landscape-scale heterogeneity, such as surface temperature, surface moisture or topography. Moreover, the meteorological conditions are not taken into account. Nevertheless, the parametrization of Panin and Bernhofer (2008) works better for the sites considered here and clearly shows that the non-closure of the energy balance is related the heterogeneity of the surrounding landscape.

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P3 - 09

Eddy covariance CO2 and CH4 fluxes in a rewetted fen in NE Germany

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Carbon dioxide (CO2) and methane (CH4) are the most abundant greenhouse gases after water vapor (H2O). Considerably high emissions of CO2 are known from drained and degraded peatlands. Restoring degraded peatlands is expected to reduce their greenhouse gas contribution to the atmosphere in the long term although CH4 release may increase, especially in the first years after rewetting. To inform and improve management decisions, the effect of restoration has to be quantified and greenhouse gas dynamics following re-wetting have to be understood.

Using the eddy covariance (EC) technique we investigate methane and carbon dioxide flux dynamics between the atmosphere and a highly degraded minerotrophic fen grassland, which was flooded in 2004/2005. The study site is located in the Peene River valley (53°52´N, 12°52´E), NE Germany, and part of the Terrestrial Environmental Observatories Network (TERENO) spanning across Germany. Water table fluctuates between 30-80 cm and the area is densely covered by several helophytes and hydrophytes typical for this stage of rewetting. We used the LI-7200 enclosed CO2/H2O and LI-7700 CH4 analyzers. The usual biometeorological data were logged continuously.

We will present flux data covering one year since the system was newly established. Previous measurements at the study site by a steady state flow-through chamber system revealed continuing high methane release, especially during warm periods. Thus, the climate impact of the fen is still not declining after 9 years of rewetting.

P3 - 10

Foehn is snow-eater: numerical analysis of snowmelt and CO_2 exchange processes at pre-alpine grassland sites

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The timing of snowmelt plays an important role in determining the variability of CO_2 exchanges over the growing season. Snow physics exhibit a high level of complexity and therefore a sophisticated process-based snow model is needed to obtain realistic results. In the present study, an existing multi-layer atmosphere-SOiL-VEGetation model (SOLVEG) developed by the authors was modified to simulate snow and frozen soil processes. Heat and liquid water transported within a multi-layer snow structure scheme, and freeze-thaw process of soil water was incorporated into the model. The modified model was applied to two pre-alpine grassland sites named Graswang and Fendt in TERestrial ENvironmental Observatories (TERENO) networks in Germany and compared to observational datasets during the wintertime. The modified model reproduced the overall temporal changes in observations of momentum, surface energy, and CO_2 fluxes, albedo, physical snow depth and surface temperature, and soil temperature and moisture. Our simulations demonstrated that foehn winds, a southern warm and dry downslope wind of the Alps, strongly enhanced snow melting due to large negative sensible and positive latent heat fluxes. Soon after the snow melted due to foehn winds, CO_2 assimilation immediately occurred even in the middle of winter season. The overall wintertime Net Ecosystem Exchange (NEE) was estimated and the part of NEE can be attributed to increased growing season length due to enhanced snow-melting under foehn conditions.

P3 - 11

On the benefit of driving Large-Eddy Simulation with spatially resolved surface fluxes derived from environmental response functions

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Large-Eddy Simulation (LES) is well-suited for studying turbulence in the atmospheric boundary layer under controlled conditions. However, for LES studies in heterogeneous terrain it is important to accurately prescribe the surface conditions. Environmental response functions (ERF) allow a spatially explicit regionalization of the surface heat fluxes from airborne or tower-based flux measurements. The surface data from the ERF have high spatial resolution (100 m) and exhibit temporal variation during the course of the day, compared to the static and more coarsely resolved surface data obtained from satellite measurements. We run a series of virtual LES experiments, driven by the ERF-derived surface fluxes, and compare the results with LES driven by MODIS surface temperature and enhanced vegetation index data. We evaluate our simulations with vertical profiles of temperature, humidity and eddy-covariance data from the tall tower in Park Falls, Wisconsin, at measurement heights of 30, 122, and 396 meters.

P3 - 12

Coupling of Carbon and Water Cycles over Multiple Time and Spatial Scales in Australian Savannas

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In light of recent concerns of climate change, it is important to conserve natural ecosystems such as savannas that contribute to binding the increasing additional carbon dioxide in our atmosphere due to anthropogenic activities. Because of the vast spatial extent of savannas, they account for approximately 25% global productivity (GPP), this makes them a key terrestrial biome since they play a crucial role in the sequestrian of additional carbon (C) from the anthropogenic emissions into the future and are an important source of carbon storage. Therefore, there is a current need to quantify and model that carbon capture and storage capacity accurately since it is vital in predicting the evolution of the savannas, weather and climate. The efficiency of savannas is estimated by land surface models, such as Australia's CSIRO Atmosphere Biosphere Land Exchange Model (CABLE) and the Soil-Plant-Atmosphere (SPA) model, that include many factors regulating productivity and these models of primary production in terrestrial ecosystems cannot rely on a single limiting factor but instead must consider multiple potentially limiting coupled processes on multiple time and spatial scales. Spatial heterogeneity assures that exchange processes and concentration gradients commonly exhibit a complex three-dimensional structure. Driving mechanisms of climate dynamics and landscape evolution operate on a variety of time scales from diurnal to season to yearly but instrumental measurements do not capture the full range of time scale variability and so the models have limitations in the uncertainty of climate representations in the data. The models are validated against observed field flux measurements of productivity to seven OzFlux sites on a spatial sub-continental scale rainfall gradient of more than 1100km in length, known as the North Australian Tropical Transect (NATT) in Australia.
The aim of the research is to reduce uncertainty and promote precision of land surface models (using CABLE and SPA as a representative) in predictions of heat, water and CO_2 fluxes between the atmosphere and vegetation. There is a need to understand the dynamic relationship between meteorological climate variables and the savannas in order to accurately estimate savanna GPP and to contribute to better savanna data inputs into capable models that focus on estimating global GPP values. We also aim to increase the soundness of land surface models in simulation of plant future responses to climate change and CO_2 increase. To assess the possible future states of Australian savanna landscapes we will use output from the CSIRO climate model (Mk2) as input for the models. The CSIRO Mk2 model is a fully coupled atmosphere/ocean model that includes dynamic sea ice and soil-canopy models and has been shown to provide good agreement with historic Australian rainfall dynamics. We will use several IPCC climate change scenarios from Global Circulation Model outputs for the future projected climate (IPCC Special Report Emissions Scenarios, 2000) such as the business-as-usual IS92 scenario., the best case scenario (B2), and worst case scenario (A2) then input these projections into the modified CABLE to evaluate how the present savanna landscape may respond to projected changes in future climate.

This justifies the direction and scope outlined in this research, as this project will identify the gaps in present models used to project climate and improve them to ultimately dynamically generate current, past and future savanna vegetation patterns and responses. Not only would this work improve and validate the models against observations over fine spatial and temporal resolutions (NATT) of the key processes of carbon and water fluxes, but it also improves the model's capability in simulating and predicting the interactive effects of climate change and CO_2 increase on the savannas function. Hopefully the models will provide robust future estimates of carbon and water that will aid our management of savannas to ensure viable water resources and carbon sequestration, to provide tools for land managers to account for the consequences of climate change and elevated atmospheric CO_2 concentrations on ecosystem viability and hopefully inform the policy decision makers on the importance on conserving the savannas natural ecosystem. As this project deals with the environmental sustainablity of Australian ecosystems, it will be of considerable social benefit for Australia.

P3 - 13

Interactions between climate, soil, vegetation, animals in a sahelian rangeland. Impact on organic matter mineralisation and natural NO emissions to the atmosphere

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The Nitrogen (N) cycle is closely linked to water and carbon cycle, and participates to surface-atmosphere interactions. Modelling studies aim to simulate the various processes involved in these exchanges, by linking hydrology, vegetation, and biogeochemistry, in an integrated model.
Natural (biogenic) emissions of nitrogen oxide (NO) from soils to the atmosphere result from biogeochemical processes in the soil and at its surface. These processes are governed by temperature and moisture conditions, directly linked to precipitations, and by the quantity of organic matter, linked to the quantity of vegetation, the presence of livestock or not, and the fertilization. In the Sahel particularly, where the soil moisture content is very low at the end of the dry season, NO emissions depend strongly on soil moisture. When the first rains fall at the beginning of the wet season, soil moisture increases sharply, until reaching a threshold value above which the microbial population can develop, and the microbial activity generating nitrogen within the soil is reactivated. NO emissions to the atmosphere result from the microbial decomposition of organic matter, and present important peaks at the beginning of the wet season (Delon et al., 2012)
In Sahelian soils, the organic matter decomposition is very efficient at the onset of the wet season because part of the litter has been buried during the dry season by livestock trampling, and is rapidly decomposed when soil moisture is sufficient

This work is an attempt to provide seasonal variation of biogenic NO emission fluxes in a sahelian rangeland in Mali (Agoufou, 15.34◦ N, 1.48◦ W) for several years (2004 - 2008).
The link between NO production in the soil and NO release to the atmosphere is investigated in this study, by taking into account vegetation litter production and degradation, microbial processes in the soil, emission fluxes, and environmental variables influencing these processes,
using a coupled vegetation-litter decomposition-emission model. This model includes the Sahelian-Transpiration- Evaporation-Productivity (STEP) model (Mougin et al., 1995) for the simulation of herbaceous, tree leaf and fecal masses, the GENeral DEComposition (GENDEC) model ((Moorhead & Reynolds, 1991) for the simulation of the buried litter decomposition, and the NO emission model (Delon et al., 2007) for the simulation of the NO flux to the atmosphere.
The integrated model takes into account the interaction between climate and vegetation growth and decay, animal impacts on aboveground herbage mass variation through ingestion and trampling, and NO emissions. Furthermore, N uptake by plants during the wet season is simulated and related to the decrease of NO emissions from soils at that season.
The several years of simulation allow the quantification of seasonal and yearly variation of biogenic NO variations, with a strong insight in the coupling between different processes involved in the N cycle at the soil-atmosphere interface in semi arid regions.

P3 - 14

Water as dominant driver of heat impacts in black locust and Douglas-fir trees

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Heat induced droughts are increasing globally, impacting productivity and survival of trees. However, most of our process knowledge on the effects of heat waves originates from single-driver experiments focusing on the effects of soil drought, but largely neglecting changes in temperature and vapor pressure deficit. This study, therefore, investigates the combined effects of heat and drought on tree water and carbon dynamics.

Douglas-fir and black locust trees were grown in large pots under ambient temperature and humidity conditions and watered according to the long-term monthly average in two environmentally controlled compartments of a greenhouse facility. Two heat waves (H1 and H2) were simulated (+10°C; 14-16 days), followed by two recovery phases (R1 and R2) during summer 2013. To study the effects of water availability, watering was reduced by 40-60% for half of the trees per species (drought and heat-drought treatment).

The dominant effect of heat on plant water status was confirmed by large increases in transpiration rates when relative extractable soil water content (RSW) was > 40%. Black locust trees quickly depleted soil water resources (RSW < 30%), causing pronounced tree water deficits and photosynthetic rates to decrease by up to 95% compare to the control. During the recovery phases, tree water storage refilled quickly and photosynthetic rates reached the control values in R1, however, lasting damaging effects became apparent during R2, with photosynthetic rates remaining 20-40% below the control. In Douglas-firs, coupled heat-drought caused mild soil water stress (RSW > 60%) that resulted in significant tree water deficits only during H2, when daily temperature maxima were > 40°C and VPD > 4 kPa, along which photosynthesis declined by 60% in the heat-drought and by 40% in the heat treatment.

In summary, heat stress significantly affected tree water relations and caused a linear decline in water-use-efficiency (WUE = assimilation / transpiration; R^2 = 0.61), which was similar overall treatments and species. This indicates that the impact of heat waves may largely depend on tree water demand and the related depletion of soil water resources.

P3 - 15

Isolating the effect of groundwater dynamics on subsurface-land surface interactions

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In the terrestrial hydrological cycle, the land surface acts as the interface between the subsurface and atmosphere. It is important to study the interconnections between different processes associated with these compartments (i.e., subsurface, land surface, and atmosphere) to understand the overall mechanisms of the coupled water and energy cycles. A new concept of dual-boundary forcing for the land surface processes is proposed to explain and quantify the interactions between compartmental mass and energy balance components at different space-time scales. According to this concept, atmosphere and groundwater act as the upper and lower boundary conditions, respectively, for the land surface mass and energy balance components. The space-time patterns of land surface mass and energy fluxes can be explained by the variability of the dominating boundary condition for the exchange processes, which is determined by moisture and energy availability. In order to substantiate this concept, a fully coupled subsurface-land surface model ParFlow.CLM is applied over the Rur catchment, which is located in western Germany and has an area of ~2,400km^2. A comprehensive comparison between observed and simulated fluxes and states demonstrates the model's capability to represent adequately the processes of the coupled water and energy cycles. Geostatistical and spectral analysis of the model results show the coherence between different processes of the coupled water and energy cycles at various space-time scales, which supports the proposed dual-boundary forcing concept. In order to isolate the influence of temporal dynamics of the lower boundary condition on hydrological cycle, subsequently a spatially distributed, temporally constant groundwater table is prescribed to ParFlow.CLM. The comparison of different fluxes from these two model runs illustrates the effect of the lower boundary condition on the coupled water and energy cycles. The results demonstrate that groundwater table depth modulates the influence of the temporal dynamics of lower boundary condition on land surface processes (e.g., latent heat flux). Using wavelet transform analysis it is shown that the temporal variability of land surface processes (e.g., soil moisture and surface runoff) increases at different time scales (on the order of 10^0-10^1days) in case of the temporally constant lower boundary condition. Cross wavelet transform suggests that this enhanced temporal variability of land surface processes can be attributed to atmospheric forcing (e.g., precipitation). From these results it appears that the influence of atmospheric forcing (i.e., the upper boundary condition) on land surface processes increases in the absence of temporal dynamics of the groundwater table (i.e., the lower boundary condition).

P3 - 16

The influence of dynamic vegetation models including harvest on the energy fluxes and the feedback effects between weather and land surface models

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Recent studies show that uncertainties in regional and global weather and climate simulations are partly caused by inadequate descriptions of the soil-plant-atmosphere system. Particularly relevant for the improvement of regional weather forecast are models which better describe the feedback fluxes between the land surface and the atmosphere, which influences surface temperature, surface air pressure and the amount and frequency of precipitation events.
Aim of this study was to examine the influence of different management strategies and the use of dynamic vegetation models to energy fluxes at the land surface boundary layer.
For this study the land surface model Expert-N was used, which is fully coupled to the "Regional Climate and Weather Forecast Model" (WRF). Where the standard model NOAH distinguish between vegetation class specific monthly changing soil cover values (leaf area index) and defined soil characteristics, Expert-N is an ecosystem model that allows the application of more mechanistic soil and plant sub-models including the management of soil and vegetation and effects of water and nutrient availability on plant growth are considered.
The influence of different harvest scenarios on the energy fluxes is discussed. The simulation shows the high impact of vegetation management on the energy fluxes which caused significant differences between weather characteristics such as the simulated surface temperatures and precipitation events on the regional scale. Therefore, we conclude that weather forecast on the regional scale could be significantly improved by modeling approaches that better describe the dynamic of vegetation growth.

P3 - 17

Improvement of forecasts of pollen emissions by birches on regional scale.

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Patient targeted medication could be improved if forecasts of the allergenic potential of pollen emissions and the actual allergenic potential are precise on regional scale. The allergenic potential is determined by the biochemical composition. In plant tissue the biochemical composition may change within hours due to resource availability for plant growth and plant internal nutrient re-mobilization, and the organ specific demand.

These processes highly depend on both, the environmental conditions and the development stage of a plant.

Therefore, dynamic plant models that consider the dependence of the chemical composition of tissue on the development stage of the plant embedded in process-based ecosystem models seem promising tools to improve forecasts of pollen emissions; however, today dynamic plant growth is widely ignored in simulations of atmospheric pollen loads.

In this study we analyze to which extent frequently applied temperature sum models could simulate onset of flowering of birches on regional scale in Bavaria. Temperature sum models integrate average temperatures above a base temperature below which no further bud development is assumed. In this study we achieved the best simulation results using base-temperatures below 0°C, which is much lower as frequently used base temperatures. A more regional calibration of the models to sub-regions in Bavaria with comparable climatic conditions further improved the simulation results indicating the need for a more local adjustment of birch phenology models. The simulation results may be biased if the base temperatures are assumed constant for all birches and are transferred to other regions with different climatic or environmental conditions, or when applied to extrapolate birch pollen seasons to future climate conditions.

P3 - 18

Implementation of Spaceborne Canopy Height Data in the High Resolution WRF Model

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Vegetation canopy regulates weather and climate by modifying roughness, albedo, and longwave radiation at the surface. In particular, vegetative surface is a major source to reduce wind speed and so it is important to provide surface roughness parameters such as zero-plane displacement height and roughness length to climate and NWP models for better reproducing wind and its related divergence of air flows. Recently, airborne canopy height data has been released and these data has been implemented into the high resolution WRF model. WRF version 3.5 is used to investigate impacts of inclusion of observed canopy height data on reproducing rainy season over Korea and South America continent. The physics package used in this study employs the WRF single-moment 6-class (WSM6) microphysics scheme, the new Kain-Fritsch cumulus parameterization scheme, the Yonsei University planetary boundary layer (YSUPBL), a simple cloud-interactive radiation scheme, and Rapid Radiative Transfer Model (RRTM) longwave radiation schemes, and Noah-MP land-surface model. The implementation of spaceborne canopy height data decreases latent heat fluxes over Korean peninsula and thus reducing excessive orographic precipitation which have been generally reported in the NWP models and GCM.

P3 - 19

Modelling climate change impacts on crop growth and yield quality based on explicit simulation of plant internal transport processes

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The yield of agricultural plants will be influenced by future climate change as well as by the changing composition of the atmosphere. In order to better estimate these effects new, mechanistic plant growth models are needed. It is desirable that these models dynamically reproduce the plants' reactions to modified climate state variables like water availability, temperature and atmospheric CO2-concentration. In particular, to better describe the crop response to more strongly changing water availability an explicit simulation of plant-internal water and solute transport processes in xylem and phloem has to be executed.

Our existing water transport model uses two coupled 1-D Richards equations to calculate water transport in the plants and in the soil. This model has already been successfully applied to single *Fagus sylvatica L.* trees. At present it is adapted to agricultural plants such as maize.

The simulation of the water transport in the plants requires a representation of the plants' architectures, i.e. the flow paths. Aboveground plant structures are obtained from terrestrial laser scan (TLS) measurements at different development stages. These TLSs have been conducted at the TERENO research farm Scheyern and at the lysimeter facilities of Helmholtz Zentrum München. Additionally, an L-system model, which produces plant architectures at different growths stages, is used to simulate the aboveground part of the plants. In a next step this model will be extended to belowground plant architectures.

Furthermore, the quality of the explicit water flow model has to be evaluated with measurements. Therefore, the Heat-Ratio-Method has been employed to directly measure sap flow in larger maize plants during a two-months-period in summer 2013 with a temporal resolution of 10 minutes. Thus, the plants' transpiration can be assessed. Water losses from soil are determined by weighing lysimeters, which allow for the calculation of evapotranspiration.

Plant growth, including transpiration and evapotranspiration is also simulated with the modelling system Expert-N. This framework facilitates the combination of different models and sub-models to simulate plant growth and crop management as well as water, heat, nitrogen and carbon dynamics. Two different sub-models (CERES and SPASS) are used to simulate plant growth, which includes plant transpiration. Modeled and measured actual transpiration and evapotranspiration are compared and discussed.

Measured sap flow rates show clear diurnal cycles and are strongly controlled by the particular weather, especially by temperature, radiation and relative humidity. CERES and SPASS are only partly suited to model plant water dynamics as measured. This confirms the importance of explicit water transport and transpiration models.

P3 - 20

A new method for continuously measuring the $d^{13}C$ of soil CO_2 concentrations at different depths by laser spectrometry

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The transfer mechanisms of carbon in the soil-plant-atmosphere continuum, in particular for soil CO_2 production, have yet to be identified. Nor are the processes linking these transfers fully understood. To partially address this lack of information, one approach is to simultaneously measure soil CO_2 concentrations in the air-filled pores, soil CO_2 efflux and their respective isotopic signatures ($\delta^{13}C$-CO_2). To quantify soil air $^{13}CO_2$ and $^{12}CO_2$ concentrations, we adapted a method based on CO_2 diffusion from soil pores. Tubes with a highly gas-permeable membrane wall were placed horizontally at different depths in the soil. Air was sampled automatically from the tubes and injected through a diluting system into a tuneable diode laser absorption spectrometer. The CO_2 and $\delta^{13}C$-CO_2 vertical profile was thus obtained at hourly intervals. Our tests proved the absence of fractionation in the membrane tubes for $\delta^{13}C$-CO_2. Subsequently, we set up field experiments for two forest soils which showed that natural soil CO_2 concentrations and $d^{13}C$-CO_2 were not significantly affected by the system. While $d^{13}C$-CO_2 in air-filled pores below 5 cm was constant over three days, we observed large diurnal variations in $d^{13}C$-CO_2 efflux. However, the average difference between the two measurements was close to -4.4‰, which supports steady-state diffusion. This new method seems to be a very effective way to measure the $d^{13}C$-CO_2 profile of the soil atmosphere, and reveals that fractionation during diffusion is the main process that affects the $d^{13}C$-CO_2 of the soil CO_2 efflux on a daily timescale while advection may account for within-day variations.

P3 - 21

Horizon Partitioning of Soil CO2 Sources and their Isotopic Composition (13C) in a Pinus Sylvestris Stand

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The Flux-Gradient Approach (FGA) allows the vertical distribution of gas turnover and production in thesoil to be calculated. This approach has been used successfully for greenhouse gases, such as CO2, CH4 and N2O but not yet for the stable isotope composition of soil CO2 (□13CO2), although this subject has become increasingly important. In this study, an innovative experimental set-up, based on the MEmbrane TubeTechnique (METT) and adapted to C stable isotope recording, was used to carry out in situ measurements in a Scots pine forest soil in Hartheim, Germany. Continuous measurements of soil CO2 and □13CO2 efflux and of soil air CO2 and □13CO2 concentration were combined with the FGA to investigate the vertical distribution and temporal variability in CO2 production (P) and its isotopic signature (□13P). The FGA gave consistent values for P and □13P in each soil horizon, except for the Ol horizon where diffusive transport seemed to be affected by atmospheric turbulence. The results showed that P was subjected toa significant vertical stratification, whereas no significant □13P vertical variation was found. The surfacesoil water content (SWC) was reported to be critical to the accurate partitioning of P between the topsoillayers. In addition, significant temporal P and □13P variations were found in the most productive horizon,the first being best explained by the soil temperature, the second depending on the moisture conditions. No visible □13P climatic dependence was visible in the measured surface flux isotopic composition (□13Fs). Finally, in the litter layer (Ol), a significant correlation was found between P and friction velocity. This was attributed to the predominance of non-diffusive transport in the litter layer.

P3 - 22

Modelling water flow in beech trees based on 3D plant architecture derived from laser scans

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We apply a functional-structural model of tree water flow to single old-growth trees of a temperate broad-leaved forest stand. Roots, stems and branches are represented by connected porous cylinder elements that are divided into the inner heartwood cylinders surrounded by xylem and phloem.

Xylem water flow is simulated by applying a non-linear Darcy water flow in porous media driven by the water potential gradient according to the cohesion-tension theory. The flow model is based on physiological input parameters such as the hydraulic conductivity, stomatal response to leaf water potential and root water uptake capability and, thus, can reflect the different properties of tree species.

Actual root water uptake is calculated using a Darcy law based on the gradient between root xylem water potential and rhizosphere soil water potential and by simulation of soil water flow using Richards equation.

A leaf stomatal conductance model is combined with the hydrological tree and soil water flow model and a spatially explicit three-dimensional canopy light model. The structure of the canopy and the tree architectures are derived by applying an automatic tree skeleton extraction algorithm from point clouds obtained by applying a terrestrial laser scanner allowing an explicit representation of the water flow path in the stem and branches. The high spatial resolution of the root and branch geometry and connectivity makes the detailed modelling of the water use of single trees possible and allows for the analysis of the interaction between single trees and the influence of the canopy light regime on the water flow inside the xylem.

The model can be applied at various sites and to different tree species, allowing the up-scaling of the water usage of single trees to the total transpiration of mixed stands.

Examples are given to reveal differences between diffuse- and ring-porous tree species and to simulate the diurnal dynamics of transpiration, stem sap flux, and root water uptake observed during the vegetation period at different sites.

P3 - 23

Interception and resulting below canopy patterns in a mixed beech forest in central Germany

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Water can reach the forest floor through several pathways, as stemflow and throughfall, both being the source of substantial heterogeneity in water input at the soil surface. So far there have been only few combined measurements, to assess at the same time the creation of heterogeneity by stemflow and throughfall and their relation to soil moisture patterns.

We investigate in a beech-dominated forest in central Germany the dynamics throughfall, stemflow and topsoil water content. The site belongs to the Terrestrial Environmental Observatories (TERENO), Harz/Central German Lowland Observatory. We measured net precipitation on an event basis, and separated it into subplots covered with oak and beech. We also assessed soil water content using a wireless sensor network (SoilNet) at over 130 locations. The measurement points were arranged at increasing distances from the tree trunks. Data were collected over a nine months period, including 10 weeks of intensive event based throughfall and stemflow monitoring.

Interception loss did not differ substantially between locations under oak and beech, although the partitioning between stemflow and throughfall varied substantially, particularly during larger precipitation events. During most of the observed precipitation events, the correlation length of throughfall was on the order of the average tree distance. The degree of organization decreased with interception: Larger events, with smaller interception, were characterized by short correlation lengths. These were at the same time the events with a larger proportion of stemflow.

Stemflow also modified patterns of soil water content near the trees compared to further away. However, this influence was only of short duration, particularly during in the growing season, probably due to root water uptake and/or preferential flow paths.

Our results indicate that while canopy type does not appreciably change interception, it may strongly modify the degree of heterogeneity in patterns of net precipitation and hence available water for infiltration.

P3 - 24

Implementation and validation of high-resolution and plant-specific physiological parameterizations in a terrestrial systems modeling platform

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Vegetation is the interface layer between the soil and atmosphere compartments of the terrestrial water, energy, and matter cycle. It exerts a major impact on both climate and weather dynamics by modifying the radiative, momentum, water, and energy balance between the land surface and the planetary boundary layer. In Earth system modeling platforms, the vegetation is classified by defining plant functional types that do have measurable leaf physiology and carbon allocation. In such representation, agricultural crops are commonly classified as corn, wheat, and soybean by setting time-invariant physiological properties based on estimates published in literature. In this work, a new set of physiological parameters describing the photosynthesis, optical, and aerodynamic properties of two crops, sugar beet and winter wheat, were included in the parametrization of the land surface component of a novel terrestrial modeling platform (TerrSysMP). These leaf-level plant parametrizations were based on a synthesis of extensive field measurement campaigns carried out over several sites located in an agricultural district of the North Rhine-Wesphalia region in Germany. The new set of crop-specific parameters were validated using eddy covariance technique (latent heat and sensible heat) at three measurement sites and over multiple years. In addition, to evaluate the impact of such high-resolution information on the evolution of the planetary boundary layer, a series of land surface-atmosphere coupled experiments were performed. The numerical simulations consist of 2-days hindcast semi-idealized runs over the North Rhine-Westphalia domain where a generic crop functional type was replaced with region-specific sugar beet and winter wheat parametrizations.

P3 - 25

Is an accurate description of local carbon fluxes in soil-vegetation-atmosphere system from large scale climate data possible?

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SEVER dynamic global vegetation model (DGVM) was run for 14 Euroflux sites with the large scale NCEP daily climate data as an input for years 1997-2000 and net ecosystem exchange (NEE) calculated and observed were compared. It was shown that daily local NEE flux can be feasibly described by SEVER, using large scale climate data as an input. Possible combinations of linearly-interpolated and not interpolated monthly temperature, precipitation, shortwave radiation and ratio of sunshine hours were tried in order to get a feasible accuracy in NEE values. We found that daily temperature and shortwave radiation data are most essential for reproduction of daily NEE at the Euroflux sites, precipitation and ratio of sunshine hours can be linearly interpolated from their mid-month values. Running means (1 to 30 days) were calculated for simulated and observed values of NEE and correlated for each Euroflux site. The most visible improvement in both the averaged correlation coefficient and the averaged slope of regression for the set of Euroflux sites was seen for 5 days running mean. SEVER DGVM was compared for monthly time step with the Lund-Potsdam-Jena DGVM with an incorporated stochastic weather generator. The test showed that LPJ DGVM has better performance in description of NEE only for three Euroflux sites and for the other ten sites SEVER DGVM outperforms it. This was attributed to the weather generator of LPJ DGVM.

P3 - 26

Separating evaporation from transpiration in winter wheat using high-frequency eddy covariance data

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Evapotranspiration has (ET) declined globally, but it is unclear if transpiration (T), evaporation (E), or both are driving this response. T and E must be quantified to understand the mechanisms driving changes to ET, but are difficult to measure at the plot scale. Here, we apply the method of Scanlon and Kustas (2010, Ag. For. Met 150: 89-99) to estimate T and E from eddy covariance observations of ET using high frequency data and expectations of similarity theory. We find that ET in a Montana wheat field is almost entirely (>90%) attributable to T during the peak growing period and that the ratio E:T is a function of crop growth stage with predictable changes after harvest. T is maintained in this dryland cropping system by progressive root growth until seed is set, after which a rapid shift in E:T favoring E is observed. Opportunities to extend these analyses to TERENO study ecosystems in the Ammer Basin are discussed.

P3 - 27

A Concept for the Development of Spatially Resolved Measurements for Soil Moisture with TEM Waveguides

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Soil water content plays a leading role in partitioning water and energy fluxes at the land surface. Furthermore, soil moisture is an important store of water for vegetation. The information about water content in the soil would be very useful in overcoming the challenge of managing water resources under conditions of increasing scarcity in Southern Europe and the Mediterranean region. For collecting data about the water content in soil, it is possible to use remote sensing and groundwater monitoring, built wireless sensor networks for water monitoring. Remote sensing provides a unique capability to get the information of soil moisture at global and regional scales. Wireless environmental sensor networks enable to connect local and regional-scale soil water content observations.

There exist different ground based soil moisture measurement methods such as TDR, FDR, electromagnetic waves (EW), electrical and acoustic methods. Among these methods, the time domain reflectometry (TDR) is considered to be the most important and widely used electromagnetic approach. The special techniques for the reconstruction of the layered soil with TDR are based on differential equations in the time domain and numerical optimization algorithms. However, these techniques are time- consuming and suffering from some problems, like multiple reflections at the boundary surfaces. To overcome these limitations, frequency domain measurement (FDM) techniques could be used. With devices like vector network analyzers (VNA) the accuracy of the measurement itself and of the calibration can be improved. For field applicable methods the reflection coefficient is mathematically transformed in the time domain, which can be treated like TDR-data and the same information can be obtained.

To develop an improved method for determining the soil moisture distribution, a combination of FDM techniques with an increased amount of data is applied. The basic idea is to use four sets of data provided by VNA: the reflection from both sides and the transmission through the transmission line in both directions. However, if the increased information content with three instead of one frequency-dependent value constitutes the input for a layer inversion algorithm, the results are supposed to have a better accordance with the control measurement or the computing time should decrease. Following up the approaches described in the preceding sections a model for the propagation of an electromagnetic wave along transmission line needs to be developed. The model has to contain an expression for the reflection and the transmission coefficients. There are already existed some experiments using the frequency domain data directly as an input for inversion algorithms to find the spatial distribution of the soil parameters. The model that is used represents an exact solution of the Maxwell's equations. It describes the wave propagation in a multi-layered medium, assuming the wave to be transverse electromagnetic (TEM). In the particular case of transmission lines with perpendicularly arranged layer transitions this assumption is very close to reality. Such waveguides and their frequency domain measurements in layered media are promising concerning a development ways working with soil moisture detection.

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Assessment of a Multi Model Ensemble to Forecast the European 2003 Drought

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Agricultural droughts are considered among the most catastrophic natural disasters because they have the potential to diminish crop yields causing economic damage or threatening the livelihood of societies (e.g., the European 2003 drought and the 2010/11 Horn of Africa drought, respectively). An agricultural drought occurs if a soil moisture index is falling below a threshold (typically, a quantile that is equaled or exceeded 20% of the time). The capabilities of current drought monitoring systems are two-fold. First, they provide an estimate of current drought (i.e., soil moisture deficit) conditions. Second, they provide a seasonal forecast of drought development. Being able to correctly forecast the extent and intensity of agricultural droughts can help to mitigate their negative effects on the society.

Several drought monitoring and forecasting systems exist for the regional and the continental scale, for instance, the U.S. Drought Monitor (USDM), the European Drought Observatory (EDO), and the African Flood and Drought Monitor (AFDM). These systems combine information from various observational data sources such as ground based meteorological measurements and satellite based remote sensed products to provide the best possible estimate of current drought conditions. Additionally, some of these systems (e.g., AFDM) also incorporate seasonal meteorological forecasts such as CFSv2 to estimate future drought conditions. Meteorological forecasting skill, however, in particular that of precipitation, is limited to a few weeks because of the chaotic behavior of the atmosphere. Ensembles of meteorological forecasts are typically employed to increase the drought forecasting skill because the uncertainty associated with single model simulation outweighs the model capability to correctly estimate the actual evolution of the atmospheric processes. One of the most important challenges in drought forecasting is to understand how the uncertainty in the atmospheric forcings (e.g., precipitation) is further propagated into hydrologic variables such as soil moisture, and from them to forecast variables such as the soil moisture index.

A large atmospheric ensemble has the potential to overcome the aforementioned challenge. The North-American Multi-Model Ensemble (NMME) is the latest collection of a multi-institutional seasonal forecasting ensemble with global coverage. It encompasses more than 100 meteorological data sets from different Numeric Weather Models developed by several institutions. The NMME allows testing the hypothesis that a large meteorological ensemble increases drought forecasting skill at various lead times. In particular, it is investigated if the ensemble is already large enough for achieving a robust drought forecasting by subsequently selecting different sub-ensembles from it and evaluating their forecasting skill. Sub-ensemble selection methods are readily available and have already been successfully applied in the evaluation of ENSEMBLES regional climate models (RCMs) to reproduce observed extreme meteorological indices.

The aforementioned hypothesis is tested for the European 2003 drought event. The modeling period encompasses the period from January 1st to September 30th 2003. The study area ranges roughly from 10°W to 40°E and 35°N to 55°N and covers large parts of the Pan-European domain. The seasonal NMME forecasts are provided at a spatio-temporal resolution of 1° horizontal resolution and monthly values. These are bias corrected and downscaled to daily values and 1/4° resolution to force the mesoscale hydrological model (mHM). Previous research has shown that historic drought events in Germany could be successfully reconstructed by mHM soil moisture fields at approximately 1/32° resolution.

Preliminary results indicate that the full NMME leads to more robust drought statistics than those obtained if only limited (e.g., CFSv2) forecasts are considered. Based on the fact that sub-ensemble selection has proven to be beneficial for increasing the skill of RCMs to reproduce extreme indices, it is expected that a subset of the full NMME ensemble could be found that exhibits at least the same fidelity to forecast the European 2003 drought event as the full ensemble. This would be highly

beneficial because a sub-ensemble will drastically reduce the computational cost of the hydrologic modeling. Overall, the experiences gained within this study will provide useful information to enhance the capabilities of current drought forecasting systems such as AFDM and to develop a first seasonal drought forecasting system over Europe.

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Investigating wintertime hillslope hydrological and snow cover dynamics using a wireless soil moisture and temperature monitoring network and time-lapse digital photography

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In mountainous catchments, snowmelt may be an important component of the water balance. We apply data from a wireless soil moisture and temperature monitoring network in combination with time-lapse photographs collected over a two-weeks period during winter 2014 from a hillslope in the Schäfertal catchment, lower Harz mountains, to investigate interactions between hillslope-scale snow cover, soil moisture and soil temperature. The time series of digital photographs is evaluated using an automatic algorithm that estimates snow height at the position of several snow stakes placed along the hillslope using the green value of the RGB color cube. Snow heights are then applied to interpret near-subsurface soil moisture and soil temperature dynamics from the same time period including snow accumulation and melt. Even though snow cover was extremely low (less than 10 cm) during winter 2014, the combination of time lapse digital photography, soil moisture and soil temperature monitoring clearly shows the strong influence of the snow cover on subsurface soil moisture and soil temperature dynamics. The shallow snow cover has a strong insulating effect on near-subsurface soil temperatures leaving the soil unfrozen even at air temperatures reaching down to less than -10 °C. The time-lapse photographs, soil moisture and soil temperature observations also show the different snowmelt behavior of the north- and south-exposed slopes, with faster snowmelt on the south-exposed slope being snow-free one day earlier than the slope exposed towards the north. All these observations are important information for future modelling of hillslope and catchment-scale hydrological dynamics.

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Species specific temporal patterns of throughfall and stemflow in the north-eastern German Lowland Observatory (TERENO)

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Rain falling on forests is redistributed in the canopy: it is intercepted by the canopy and later evaporated, it falls through canopy gaps or drips from leaves and branches once the interception storage is filled (throughfall (TF)), or it is channeled to the tree stems and delivered to the soil as stemflow (SF). Throughfall is usually the largest fraction, followed by evaporation or stemflow. The amounts and spatial patterns of rainfall redistribution by forest canopies vary for different tree species and can play an important role for soil moisture distribution and subsequently for groundwater recharge. Therefore we quantified the fractions of TF and SF on gross rainfall for different forest types and for different meteorological parameters and rainfall characteristics. This will improve our ability for predicting future impacts of climate and forest structural changes on the water balance of forest stands.

TF was measured at 7 monitoring sites covering different tree species and ages: young and old beech, young oak and young and old pine as dominantly occurring trees. The investigated 2000m²-plots are situated in the TERENO observatory in the Müritz-Nationalpark / Germany. TF at each site was collected with 5 trough systems, each consisting of 3 troughs connected to one tipping bucket. The total collecting area per plot was 6.6m². Gross precipitation, i.e. rainfall above or outside of the forest, was evaluated in a nearby forest clearing with an identical setup of 3 troughs. Stemflow was measured for 5-10 trees per site with PVC-collars wrapped around the stems. The collars were connected to tipping buckets.

Canopy structure is likely to have a major influence on TF distribution. The forest structure was characterized by mapping the tree species, stem positions and stem diameters. Seasonal variations of leaf coverage were monitored by ground-based leaf-area index (LAI) measurements. Spatial LAI patterns within a site and possible relations to TF distribution were assessed.

The storage capacity of the canopy can be estimated based on the cumulative precipitation between the onset of rainfall and the onset of TF. Rainfall events were grouped depending on time elapsed since the previous event as a proxy for storage depletion through evaporation, and correlations to delay in TF initiation were examined. The effect of rainfall intensities on these tree species specific time lags was also investigated.

As one of the next steps the TF, SF and soil moisture data from the same sites will be implemented in a hydrogeological model to test several groundwater recharge scenarios.

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Development of Inexpensive Radiation Sensors for Ecosystem Research

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The observation and monitoring of ecosystem processes are great challenges in environmental science, due to the dynamic and complexity of such procedures. To describe and understand biotic and abiotic processes and their interaction it is necessary to acquire multiple parameters, which are influencing the natural regime. Essential issues are: the detection of spatial heterogeneities and scale overlapping procedures in the environment. To overcome these problems an adequate monitoring system should cover a representative area as well as have a sufficient resolution in time and space. Hence, the needed quantity of sensors (depending on the observed parameters or processes) can be enormous. According to these issues, there is a high demand on low-cost sensor technologies (with adequate performances) to realize a delicate monitoring platform. In the case of vegetation processes, one key feature is to characterize photosynthetic activity of the plants in detail. Common investigation methods are based on optical measurements. Here photosynthetically active radiation (PAR) sensors and hyperspectral sensors are in major use. Photosynthetically active radiation (solar radiation from 400 to 700 nanometers) designates the spectral range that photosynthetic organisms are able to use in the process of photosynthesis. PAR sensors enable the detection of the reflected solar light of the vegetation in whole the PAR wave band. The amount of absorption indicates photosynthetic activity of the plant. Hyperspectral sensors observe specific parts of the solar light spectrum and facilitate the determination of the main pigment classes (Chlorophyll, Carotenoid and Anthocyanin). Due to absorption of pigments they producing a specific spectral signature in the visible part of the electromagnetic spectrum (narrow-band peaks). If vegetation is affected by water or nutritional deficience the proportion of light-absorbing pigments is reduced which finally results in an overall reduced light absorption. The resulting spectral signature then differs from usual reflectance patterns and can be used as stress indicator. Hence, reflectances between 550-700 nm are extremely sensitive regarding changing Chlorophyll contents. Both kinds of sensors based on semiconductor technologies whereby the material input can kept on low level. This work presents the development and testing of a practical, rugged, and inexpensive PAR and hyperspectral sensor. The sensors were made from a gallium arsenide phosphide (GaAsP) photodiodes and silicon photodiodes with different interference filters. The testing of the cosine correction and spectral response of the sensors features optimal measuring characteristics in relation to industrial produced sensors. In addition results of recorded long term in-situ data and linear regressions (in comparison to commercial products) show extremely high performances (coefficient of determination higher than 0.99) of the PAR sensors simultaneous to the cost cutting.

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Potentials, Challenges and Applications of Mobile Wireless Ad-hoc Sensor Networks for Environmental Monitoring

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To characterize environmental systems it is necessary to detect individual processes with suitable monitoring methods. Due to the natural heterogeneity of ecosystems, single point measurements are insufficient for an adequate representation. The application of mobile wireless sensor networks in terrestrial and aquatic ecosystems offer significant benefits, because of the simple adaption (e.g. sensor distribution, sensor types and sample rate) to the local test conditions. This can be essential for the monitoring of heterogeneous and dynamic environmental systems. A significant advantage in the application of mobile ad-hoc wireless sensor networks is their self-organizing behavior. In combination with the localization via satellite a major reduction in installation and operation costs and time is possible. In addition, a point measurement with a sensor is significantly improved by measuring at several points. It is also possible to perform analog and digital signal processing and computation in the sensor nodes close to the sensors. Hence, a significant reduction of the data to be transmitted can be achieved which leads to a better energy management of nodes. Furthermore the miniaturization of the nodes and energy harvesting are current topics under investigation. First results of field measurements are given to present the potentials and limitations of this application in environmental science, especially for the monitoring of the interaction of biotic and abiotic processes, soil atmosphere interaction and the validation of remote sensing data.

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A non-invasive microwave method using microstrip antennas to measure soil moisture in the profile of a rhizobox

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New tools or approaches are considered important to investigate and evaluate soil-water-plant interactions in the plant phenotyping investigations (Fiorani; Schurr, 2013). A central parameter determining root system response to water availability is that water is usually not homogenously distributed in the soil and the heterogeneity significantly increases when drought stress occurs. Thus the development of non-invasive instruments and sensors to measure soil moisture distribution would open up new approaches to investigate plant strategies to deal with low water content or, in particular, heterogeneities in water availability of soils during periods of drought cycles.

To explore the use of scattering parameters (S-parameters) at microwave frequency range close to 5.0 GHz we developed a system with microstrip antennas, placed on both sides of a rhizobox, to non-invasively measure soil moisture in the box. The variation of water content profiles over time was monitored under laboratory conditions. Rhizoboxes are normally used to study root growth during plant development and can be applied in the investigation of critical zone impact on root performance.

The antenna was simply designed as a λ/2-resonant microstrip antenna (Cataldo et al, 2009) and realized on a circuit board with a thickness of 1.5 mm and a dielectric constant, $\varepsilon_{r,sub}$, of 4.4. The antenna was 15.7 mm in width and 15.2 mm in length. A Vector Network Analyzer (ZNB 8, Rohde & Schwarz) was used to measure changes of the transferred high frequency parameter, S_{21}, and the reflected high frequency parameters, S_{11} and S_{22}, with a resolution of 6×10^{-3} dB. This was applied to measure non-invasively soil moisture in rhizoboxes made from Plexiglas and PVC. The boxes had a length of 315.0 mm, a width of 200.0 mm, about 5 mm thick walls and were filled with soil. There were two different sizes with an internal thickness of either 20 or 40 mm. The antennas were moved with steps of 5.0 mm every 4.0 s in the vertical direction (length) of the rhizoboxes. The distance between the microstrip antennas was 33.5 mm and 61.2 mm for the 20 mm and 40 mm thick rhizoboxes, respectively. We used a soil with an organic matter content of 19.1% for which a moisture calibration curve was obtained by measuring S_{21}. Six samples of the soil were prepared differing in volumetric moisture content, Θ_V(%), with 0.0%, 6.7%, 13.4%, 20.1%, 26.8% and 33.4%. The bulk densities (ρ_b) of the soil samples were $\rho_b = 0.597 \pm 0.009$ g/cm^3. To investigate changes of water distribution in the soil, 40 ml of deionized water was spread uniformly on the top of dry soil of one rhizobox which was then scanned with microstrip antennas every 5 to 30 min over a time period of 2 days. The experiments were made in the laboratory conditions with a temperature of about 25^{0}C and a relative humidity of approximately 30%.

The calibration curve of the soil moisture (S_{21} vs Θ_V(%)) for the thin rhizoboxes filled with 20 mm soil in thickness was obtained as:

$$\Theta_V\ (\%) = -83.443 - 11.356 \times S_{21} - 0.277 \times S_{21}^2 \quad (R^2 = 0{,}9521)$$

Table 1. Measures of S_{12} for pure water in the thin rhizobox and for soil in the differently sized rhizoboxes.

Substrate	Internal thickness of rhizobox	
	20 mm	40 mm
	S_{12} (dB)	
Deionized water	- 26.369	---
Soil with ρ_{ds} = 0.593 ±0.008 g/cm^3 and Θ_V = 33.4%	-18.666	-35.231

With the measured temporal change in soil water profile it was possible to evaluate the permeability of the soil. At the beginning of the experiment, the volumetric soil moisture Θ_V, at 40 mm below the top of the soil was 31,8% and at 110 mm it was 3,8%. After 2 days, Θ_V was similar (3,6%) at both positions. At 40 mm the equation fitted to the data over time was a polynomial of 3rd order and, at 110 mm, the equation was just linear. Using the data from this experiment, the permeability was calculated as about 0.156 cm h^{-1}. Refering to Soil Survey Staff, (1999) and Vogel, (2000) the permeability class of this sample can be considered slow.

From the measured results it is possible to conclude that the developed non-invasive microwave method, using microstrip antennas, is an innovative sensing method to measure the water status in rhizoboxes filled with soil. This can be used to investigate the growth of plant roots together with soil physics properties. Such kind of approach gives an opportunity to apply it to study the critical zone and to use it to monitor 2-D soil moisture distribution in rhizoboxes.

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Calibrating cosmic ray neutron sensors for soil moisture measurements in deciduous forests

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Cosmic ray neutron sensors are still a relatively new measurement technique to determine soil moisture at the intermediate scale (within a 300 m radius). Using them means moving from point measurements provided by individual soil moisture sensors towards larger footprints. The neutron sensors have to be calibrated once, therefore, in order to make them universally applicable it is indispensable to agree on a calibration procedure that yields consistent soil moisture values independent of the time of calibration. We repeated the calibration of a cosmic ray neutron sensor that was permanently installed in a deciduous forest eight times within one year. These calibrations included one winter calibration, five spring calibrations that covered the trees' leaf-out and two summer calibrations (one during relatively wet conditions and one during relatively dry conditions). We applied all the common corrections for air pressure, background neutron flux and humidity. For each of the calibrations we obtained slightly different count rates of cosmic ray neutrons over dry soil (N0, which is the calibration parameter). This resulted in 8 soil moisture time series with differences of over 10% in volumetric water content. We approached the problem of determining the correct N0 value from different angles: averaging count rates over longer time periods, accounting for changes in aboveground biomass, accounting for water in the higher atmosphere (clouds above 300 m). We also looked at the changing soil moisture patterns throughout the 8 calibration time periods and whether this variability had an influence on the calibration.

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A new approach to investigate soil moisture dynamics by radio waves

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The large scale mapping of soil properties, particularly of soil moisture is eminent for the estimation and management of water resources. There are various methods for soil moisture measurements, but none of them is able to provide continuous, integrated estimates of the soil moisture content over an area of typically 10-50 km and a depth of 1-2 m.

The principle of the new approach is based on the correlation between propagation characteristics of low frequency radio surface waves and soil moisture. The propagation of the wave depends on the electric conductivity of the media, which is beside others a function of the moisture content. Hence the resulting phase and amplitude changes of the surfaces wave, is a measure for the soil moisture content in the monitored area.

The radio signal used, is the DCF77-time signal from Mainflingen, Germany. Between Edingen, near Heidelberg and Karlsruhe in Southwest Germany, three stations are lined up at intervals of 20 km, to measure the phase transition of the surface wave. The GPS time signal is used as a reference for the phase transition. Nine soil moisture stations and the data of numerous ground water monitoring stations along the measurement section are used to calibrate and to evaluate the data.

The analysis of a two year period of measurements show a depicted dependence of the phase measurements on the soil moisture evolution in the monitored soil layer.

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Observation of soil moisture variability in agricultural and grassland field soils using a wireless sensor network

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Soil moisture dynamics is a key factor of energy and matter exchange between land surface and atmosphere. Therefore long-term observation of temporal and spatial soil moisture variability is important in studying impacts of climate change on terrestrial ecosystems and their possible feedbacks to the atmosphere. Within the framework of the network of terrestrial environmental observatories TERENO we installed at the research farm Scheyern in soils of two fields (of ca. 5 ha size each) the SoilNet wireless sensor network (Biogena et al. 2010).
The SoilNet in Scheyern consists of 94 sensor units, 45 for the agricultural field site and 49 for the grassland site. Each sensor unit comprises 6 SPADE sensors, two sensors placed at the depths 10, 30 and 50 cm. The SPADE sensor (sceme.de GmbH, Horn-Bad Meinberg Germany) consists of a TDT sensor to estimate volumetric soil water content from soil electrical permittivity by sending an electromagnetic signal and measuring its propagation time, which depends on the soil dielectric properties and hence on soil water content. Additionally the SPADE sensor contains a temperature sensor (DS18B20).
First results obtained from the SoilNet measurements at both fields sites will be presented and discussed. The observed high temporal and spatial variability will be analysed and related to agricultural management and basic soil properties (bulk density, soil texture, organic matter content and soil hydraulic characteristics).

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Soil moisture and shallow groundwater monitoring at the pre-Alpine TERENO site Peißenberg-Fendt

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The TERENO initiative aims at the detection of environmental changes at the regional level. In this context, the influence of climate on water resources depicts an important question.

Near surface soil moisture states and shallow groundwater dynamics are a major regulator for the vertical exchange of water and energy between the land-surface and the atmospheric boundary layer. Due to the spatio-temporal heterogeneity of subsurface moisture transport and surface partitioning, it is difficult to obtain representative observations that qualify for an evaluation with physically-based, distributed complex hydrometeorological models. Moreover, to enable also spatial applicability at the respective model scales, the local observations need to be related to remotely sensed data.

In order to increase process understanding and to provide multi-scale observations of soil-moisture, the pre-Alpine critical zone grassland observatory at Peißenberg-Fendt, Southern Germany will be equipped with a wireless soil-moisture sensing network. Hydraulic head measurements are carried out for the shallow saturated zone and for the deeper main aquifer. The interrelation between surface and sub-surface compartments is studied through stable isotope and hydrochemical analysis. A cosmic ray soil moisture observation probe, with a horizontal footprint of several hundreds of meters, will be used to bridge between small scale variability and model resolution. Moreover, observations from satellite and air-borne remote sensing become comparable and scaling issues can be addressed. The on-site eddy-covariance and climate station provide the observational link to the atmospheric boundary exchange. With this overarching observational setup, cross-compartment hydrometeorological model studies can be conducted, thereby overcoming temporal and spatial scales.

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Surface ground penetrating radar full-waveform inversion to characterize soil texture and soil water content at the Selhausen test site

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Ground penetrating radar (GPR) measurements can be performed quickly and effectively to map electromagnetic properties to characterize the subsurface at the field-scale and can be applied to a wide range of applications such as geophysical engineering, environmental studies, infrastructure characterization and agricultural engineering. The method provides two subsurface properties: the dielectric permittivity and electrical conductivity. The permittivity is highly correlated with soil water content and porosity, whereas the conductivity depends to soil properties such as ion concentration, soil texture and clay content. Therefore, GPR is well suited to characterize and to improve our understanding of dynamic processes that are taking place in the soil. Permittivity and conductivity can be obtained from common midpoint (CMP) or wide-angle reflection-refraction (WARR) measurements. The permittivity is commonly estimated by applying ray-based techniques such as ground-wave travel-time picking, whereas the conductivity can be estimated by fitting far-field amplitude decay functions to the picked first-cycle amplitudes. Nevertheless, these methods can contain errors because only small parts of the information present in the GPR data are considered and simplified models are used. In contrary, full-waveform inversion of GPR data uses significant parts of the wave field and is able to provide a reliable and quantitative estimate of the permittivity and the conductivity. The method uses an exact forward model based on a 3D frequency domain solution of Maxwell's equation and assumes a layered earth model, whereas a sequential optimization is performed of the effective source wavelet and the subsurface parameters.

Here, we employed this surface full-waveform inversion to characterize the TERENO test site Selhausen that is located close to Juelich in the Lower Rhine Embayment, Germany. The soil type of the test site consists of silty loam with a transition from coarse to fine textured soils from east to west. The field campaign in 2012 was perfomed along a 120m long transect and included GPR WARRs, GPR profiles, EMI measurements, theta probes and soil sampling. The WARR GPR data was acquired every 5 m using a 200 MHz antenna and an antenna step size of 0.05m. The WARR data is inverted using the full-waveform inversion and is able to provide permittivity and conductivity values, whereas the GPR profiling is able to map stratigraphy and lateral changes in the near surface. The inverted permittivity results are transformed into soil water content using the 4-phase CRIM model and compared to soil samples and Theta probe measurements that are available for every 10 m and 5 m, respectively, whereas the obtained full-waveform conductivity results are compared with inverted large-scale EMI data.

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Predicting the variability of soil water content using unsaturated flow stochastic analysis and pedotransfer function

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Understanding the variability of soil water content (σ_θ) and the relationship with its mean ($<\theta>$) plays an important role in hydrological research. Such $\sigma_\theta(<\theta>)$ behavior can be considered as a fundamental property of a heterogeneous soil, which is related to the spatial variability in soil water retention characteristic. The existing stochastic models of unsaturated flow are based on the simple Gardner-Russo or Brooks-Corey constitutive relationship. In this study we developed the stochastic model with the more complex van Genuchten-Mualem model of steady state, gravity dominated unsaturated flow. The stochastic model was expressed as a closed form between σ_θ and the van Mualem Genuchten (VGM) parameters. A sensitivity analysis was performed to identify the effect of VGM parameters on the shape of the $\sigma_\theta(<\theta>)$ curve. We found that the n parameter strongly influenced the shape of the $\sigma_\theta(<\theta>)$ curve and specifically the occurrence of the maximum. The closed form equation was combined with the PTFs from Rosetta to estimate $\sigma_\theta(<\theta>)$ curve for seven different locations with varying textural composition. Five out of seven locations showed a very good agreement between observed and predicted $\sigma_\theta(<\theta>)$ curve. We demonstrate that the closed form expression can be used to derive the soil hydraulic properties and their variability from field measured $\sigma_\theta(<\theta>)$ curve. These results give us an important insight in the interpretation of observed soil water content variability in the field and potentially lead to a better understanding and a more fundamental interpretation of the soil water variability in land surface processes across scales.

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Field-scale prediction of soil moisture patterns by means of a fuzzy c-means clustering algorithm, digital elevation data, and sparse TDR measurements

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Soil moisture is a key variable of the hydrological cycle. For example, it controls partitioning of rainfall into a runoff and an infiltration component and modulating physical, chemical and biological processes within the soil. For a better understanding of these processes, knowledge about the spatio-temporal distribution of soil moisture is indispensable. For the field to the small catchment scale with survey areas up to a few square kilometres, there are numerous new and innovative ground-based and remote sensing technologies available which have great potential to provide temporal information about soil moisture patterns.

The aim of this work is to design an optimal soil moisture monitoring program for a low-mountain catchment in central Germany. In a first step, the fuzzy c-means clustering technique (Paasche et al., 2006) was used to identify structure-relevant patterns in a set of different terrain attributes derived from a DEM. Based on these patterns optimal measurement locations were identified to conduct in-situ soil moisture measurements. To consider different wetting and drying states in the catchment, several TDR measurement campaigns were conducted from April to October 2013. The TDR measurements have been integrated with the structure-relevant patterns obtained by the fuzzy cluster analysis to regionally predict soil moisture. In this study, we outline the conceptual framework of this integrative approach and present first results from field measurements.

The results of the project are expected to improve the monitoring and understanding of small catchment-scale hydrological processes and to contribute to a better representation of soil moisture dynamics in physically-based, hydrological models operating at the field to the small catchment scale.

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Integrating data assimilation techniques and Passive Distributed Temperature Sensing for high resolution soil moisture measurements

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Soil moisture plays a pivot role in hydrology and water resources management. For many hydrological applications, the resolution of remote sensing data is too coarse. To maximize the use of remote sensing data products, it is essential that we can account for spatial variability within the footprint. This involves using measurement techniques to bridge the observation gap from traditional point scale in-situ measurements to footprint-scale measurments from remote sensing.
Distributed temperature sensing (DTS) is an innovative tool for high resolution temperature measurements (spatial < 1m, and temporal < 1min) along fiber optic cables which can extend up to kilometers in length. Previous studies demonstrated the feasibility of using DTS to measure soil moisture using active and passive DTS. The Active DTS method involves providing a heat pulse to the cable, and inferring soil moisture from the temperature change in the cable during and after the pulse. Passive DTS uses measured soil temperature at multiple depths, and estimates soil thermal property by inverting the soil heat transfer equation. Finally, moisture is estimated using the relationship between soil moisture and thermal diffusivity. Compared with Active DTS, Passive DTS requires no artificial energy input, which is preferable in field implementations. However, Passive DTS is affected by many sources of uncertainty, and can be difficult when solar radiation is low.
Here we will present results from a new approach to soil moisture estimation using Passive DTS. We compare results from different data assimilation approaches used to combine temperature observations from Passive DTS with a physical model of the soil column. This gives us a unique perspective on the potential value of the passive DTS data. We will use synthetic experiments to illustrate the sensitivity to different sources of uncertainty and error.

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Parameter and state estimation for catchment scale carbon flux simulations with the Community Land Model (CLM)

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Until now the land surface model CLM was mainly applied for global scale simulations without detailed consideration of within-catchment variability of carbon fluxes. However, the information gained from small scale (high resolution) CLM simulations is valuable e.g. in terms of understanding the interactions of carbon fluxes and hydrology within a catchment. We used CLM version 4.5 (CLM4.5) at 1 km^2 resolution to simulate the net ecosystem exchange of CO_2 (NEE) for the 2454 km^2 Rur catchment located in the border region of Belgium, Germany, and the Netherlands. After an initial sensitivity analysis, eight key parameters controlling the carbon uptake and respiration in CLM were calibrated against observed data to mimic as accurately and consistently as possible the observed variations in NEE. Parameter estimation was performed for individual grid-cells using $DREAM_{(ZS)}$, an adaptive Markov Chain Monte Carlo (MCMC) method (Laloy and Vrugt, 2012; Ter Braak and Vrugt, 2008). The data used for calibration consist of NEE time series measured by eddy covariance towers at different sites within the Rur catchment. To improve the consistence of modeled and measured NEE, CLM state variables were estimated using an Ensemble Kalman Filter with the Data Assimilation Research Testbed (DART) (Anderson et al., 2009). With DART-CLM we assimilated remotely sensed leaf area index from the Moderate Resolution Imaging Spectroradiometer in addition to NEE and latent heat flux observations.

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Testing of four data assimilation algorithms including parameter estimation at the TERENO-site Rollesbroich

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Ensemble Kalman Filtering (EnKF) and Particle Filtering (PF) are two popular data assimilation methods, which are both based on the Monte Carlo approach. In this work, the performances of two variants of each method were investigated. Two approaches of joint estimation of states and parameters in EnKF are compared: state augmentation and dual estimation. In the state augmentation approach, the state and parameter vector are combined into a single joint state vector and the states and parameters are estimated simultaneously. In the dual estimation approach, states and parameters are stored in two vectors. Parameters are updated first and then the updated parameters are used to update states. For the particle filter we tested the sequential importance resampling Particle Filter (SIR-PF) and the Markov chain Monte Carlo particle filter (McMC-PF). In McMC-PF, after resampling, a move step is added on particles, creating a proposal distribution. A Metropolis ratio is calculated to judge whether the proposal particle is accepted or not. If the proposal particle is accepted, it replaces the corresponding particle. The PF estimates states and parameters in the same step. When particles are resampled, the parameters generating the particles are also resampled.

The four different algorithms were tested for the TERENO-site Rollesbroich, assimilating measured soil moisture data at 5, 20 and 50cm depth measured by SoilNet during a period of six months. The next six months served as verification period. The assimilation experiments were carried out with the Variable Infiltration Capacity (VIC) model. We considered uncertainty with respect to soil hydraulic parameters, meteorological forcings and model structural error. Results showed that all data assimilation algorithms resulted in better predictions for the verification period if parameters were updated. However, nearly all algorithms were not able to significantly improve soil moisture predictions at 50cm, which was related to the parameterization of groundwater drainage in VIC.

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Monitor Water and Energy Fluxes by Jointly Assimilation of Land Surface Temperature and Soil Moisture

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Water and energy fluxes are the sensible and latent heat fluxes between the land surface and atmosphere boundary layer. Accurate estimation of water and energy fluxes is very important in many fields such as meteorology, hydrology and agronomy. Data assimilation is a new method that can integrate observation data from different sources with models, and produce accurate land surface states. Therefore, a large number of data assimilation scheme has been developed to estimate land surface states including water and energy fluxes. Land surface model is the principle part of a land data assimilation scheme, and can produce land surface states continuously. Water and energy fluxes are diagnostic variables in land surface models, and the estimate accuracy is affected by model uncertainties from the parameterization scheme, soil and vegetation parameters, model states, and forcing data. With data assimilation technique, the observations are used to reduce uncertainties of land surface model. Recently, the observations from multiple platforms and the developed data assimilation techniques promoted the evolution in improving predictions water and energy fluxes. The soil moisture and LST are both important to water and energy fluxes and cannot replace role of each other. But by now, there is no efficient way to improve water and energy fluxes by jointly assimilating both of them. The aim of this study is to develop a data assimilation scheme that can efficiently improve predictions of water and energy fluxes with the assimilation of both soil moisture and LST observations.

HiWATER (Heihe Watershed Allied Telemetry Experimental Research) was initialized in 2012 and will last four years until 2015, which include airborne mission plans, flux observing matrix, eco-hydrological wireless sensor network, and so on. HiWATER can provide adequate data (in-situ measurements and airborne remote sensing data) to do the data assimilation experiments and improve model performances. The HiWATER dataset of in-situ measurements (meteorology, leaf area index, soil texture data, and eddy covariance data, etc.) and satellite data (land surface temperature and leaf area index from MODIS, soil moisture from SMOS) are used in the data assimilation experiment.

In this study, the jointly data assimilation experiments are conducted at two different temporal and spatial scales with the in-situ measurements (with high temporal resolution and small spatial scale, soil moisture data from cosmic-ray and LST from radiometer) and with remote sensing data (with low temporal resolution and large spatial scale, SMOS soil moisture and MODIS LST products). The assimilation results of water and energy fluxes are compared with eddy covariance measurements. And the results show well agreement with the in-situ measurements.

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An improved characterization of riverbed heterogeneities and river-aquifer exchange fluxes with the normal score ensemble Kalman filter

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Interactions between surface water and groundwater play an essential role in hydrology, hydrogeology, ecology, and water resources management. A proper characterization of riverbed structures is important for estimating river-aquifer exchange fluxes. The ensemble Kalman filter (EnKF) is commonly used in subsurface flow and transport modeling for estimating states and parameters. However, EnKF only performs optimally for multi-Gaussian distributed parameter fields, but the spatial distribution of streambed hydraulic conductivities often shows non-Gaussian patterns which are related to flow velocity dependent sedimentation and erosion processes. In this study, we assumed a riverbed with non-multi-Gaussian distributed hydraulic parameters as a virtual reference. The synthetic study was carried out for a 3-D river-aquifer model with a river (conceptualized as a flow domain with eight lines consisting of each out of 51 river nodes) in the middle of a homogeneous aquifer. Next, in a series of data assimilation experiments two different scenarios were studied. In the first scenario stochastic realizations of non-multi-Gaussian riverbeds were inversely conditioned to state information, using EnKF and the normal score ensemble Kalman filter (NS-EnKF), which honors the non-Gaussian distribution of states and parameters. NS-EnKF builds a normal-score transformation of states and parameters, updates these normal-score transformed states and parameters and then back-transforms the scores. In the second scenario, the stochastic realizations of riverbeds have multi-Gaussian distributed hydraulic parameters and are conditioned to state information with EnKF. It was found that better results were achieved for non-multi-Gaussian stochastic realizations, especially for the characterization of river-aquifer exchange fluxes. In addition, it was concluded that both EnKF and NS-EnKF improve the characterization of non-multi-Gaussian riverbed properties, hydraulic heads and exchange fluxes with assimilation of piezometric heads. NS-EnKF outperforms EnKF when only parameters are normal-score transformed but states are not transformed.

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Assimilation of cosmic-ray soil moisture observations into an integrated land surface-subsurface model

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The coupling of land surface and subsurface models might improve the overall predictive accuracy of hydrological and atmospheric models. In general, predictions with such highly parameterized models are associated with a considerable degree of uncertainty due to the uncertain initial conditions and the poorly known subsurface and vegetation properties. An important variable of such systems is the soil moisture content which influences the partitioning of energy fluxes at the land surface and is highly variable in space and time. Information on soil moisture contentis therefore essential for improving the prediction capability of integrated models, e.g., with respect to the estimation of latent and sensible heat fluxes from the land surface, regional water budgets and river discharge, and for constraining the associated uncertainties of these variables. Soil moisture data canbe derived from a variety of sensor types which operate at different spatial scales ranging from point measurements like TDR sensors (dm scale) over medium range measurements like cosmic ray probes (ha scale) to large scale measurements like satellite remote sensing products (km scale).Especially cosmic ray soil moisture data are well suited for medium scale distributed hydrological models because their footprint closely matches the typical spatial discretization of such models. We will present first results on the assimilation of cosmic ray soil moisture data into an integrated hydrological model of the Rur catchment (Germany). The integrated model consists of the land surface model CLM and the groundwater model Parflow which are coupled via state and flux variables by the coupling software Oasis-MCT. Soil moisture data for assimilation are available from 10 cosmic ray stations which are distributed over the whole catchment area. These data are assimilated into the subsurface model (Parflow) with the Ensemble Kalman Filter and the value of this assimilation is monitored through cross validation with surface flux measurements and discharge data.

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The development of water balance components under different groundwater regimes on sites with shallow water tables

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Sites with shallow groundwater tables constitute a great proportion of German lowlands. These sites can be natural wetlands or unused nature protection areas. But most commonly inGermanyand Middle Europe, they are drained and used for agriculture or forestry. Few decimetres higher or deeper water levels decide on the vegetation development and determine the fate of peatlands, i.e. if they grow or degrade. Therefore these sites are often in the centre of conflicts between different interest groups, especially between farmers and conservationists. The understanding of the complex water balance of sites with shallow groundwater tables, including knowledge of the effects that different water regimes exert on the water budget, is a precondition to find compromises acceptable for both groups.

Nature protection groups ask for higher water levels in winter and spring, especially in regions that receive few precipitations but have a high evapotranspiration demand during the summer months. The measure is believed to slow down the water level lowering in spring and early summer, leading to higher groundwater levels during the summer months and therefore limiting the need for sub-irrigation during that time. However, the farmers are concerned that the measure may cause a higher overall water demand and decrease the yield as well as the forage quality of the growing grass.

To quantify the effect of different groundwater regimes on the water balance components, we conducted experiments with weighable groundwater lysimeters. The lysimeters are situated in the Spreewald wetland, amid an extensive used grassland site. A special system for automatic control of the lysimeters was developed and applied to enable a realistic simulation of the different groundwater regimes. Between 2012 and 2014 the impact of different groundwater levels on evapotranspiration and the groundwater development was investigated during spring. Three variants were tested. The basic variant (variant 1) simulated the groundwater level of the surrounding area. For the other two variants the groundwater levels were set few centimetres below the surface (variant 2) and few centimetres above the surface (variant 3) at the starting point of the investigations in April. Afterwards the groundwater levels could freely develop and all variants were compared with each other.

The results show that the water balance components of the three variants behaved differently. The variants with higher groundwater levels showed a higher demand for evapotranspiration, partly caused by their vegetation which adapted better to the wetland conditions. In 2012 and 2013 the values of the variant 3 were 40% higher than those of the basic variant. The additional evaporated water originated mainly from the higher water storage. No additional water was withdrawn from the aquifer, which in the Spreewald wetland is supplied by the streams and channels. The values of variant 2 lay in between both variants.

The groundwater levels of the variants 2 and 3 developed differently. For variant 2, they dropped down relatively fast. After reaching the level of the basic variant, both variants showed nearly the same behaviour. In contrast, the groundwater level of variant 3 decreased very slowly as long as it was above the surface, resulting from the higher specific water storage. As soon as the water level dropped below surface, it decreased very fast and reached the level of the other variants in few days.

We conclude that higher groundwater levels in spring and the joined higher water storage can compensate the higher evapotranspiration for some weeks. However, due to its time-limited effect, the measure is not sufficient to stabilize the water balance in the most critical phases in July and August.

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A lysimeter study to assess the evolution and the environmental impact of excavated clay materials

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Research on a suitable geological formation for long term disposal of nuclear waste has led to the construction of a deep underground research laboratory in easter France. The target formation, the Callovo-Oxfordian argillite, is a stable and homogeneous clay rock with very low permeability situated between 400-600m depth. The development of the laboratory has generated in the last 15 years a large amount of excavated material. In this study we are investigating the behaviour through time of the excavated material from the Callovo-Oxfordian formation when exposed to surface conditions. In the oxidising conditions prevailing in surface environment, complex alteration processes are known to affect the mineralogy and/or the organic matter associated with the clay. Characterising the extent of these changes and their potential impact on the quality of the environment is important to help define the repository conditions of the specific excavated material. The changing climatic conditions and the biological activities may by instance induce a release of saline elements and/or trace metals due to the alteration of the bearing phases, like pyrites.

Within the framework of the Long-term Environmental Observatory (OPE - Observatoire pérenne de l'environnement - www.andra.fr/ope) of the French Agency for Nuclear Waste Management (Andra), a lysimeter station was installed to specifically study the water flows in the excavated material and the chemical composition of the leaching water. Taking advantage of more than 10 years of research on the underground laboratory, lysimeters were filled with 10 years old and recently excavated clay material and with a natural soil developed on Callovo-Oxfordian bedrock. Several sensors were placed in each lysimeter at 20, 50, 100, 150cm depth to measure continuously the water content and the temperature in the clay material as well as the volume of leaching water. Regular water samples were collected to measure the anions and cations concentrations at different depths in each lysimeter. This experiment is allowing us to follow the changes of the chemical composition of the water interacting with either old or recent clay through time. These can be compared to the measurements in the natural soil that correspond to the future evolution of the excavated material after a long period of pedogenesis. Hydrological flux model combined with the characterization of the speciation in solution will be used *in fine* to determine the potential amount of chemical species released in leaching water over several decades of disposal.

The preliminary results of the study highlight a release of ionic species inherited from the marine origin of the clay rock. Large amounts of sulfates (up to 5 $g.L^{-1}$), sodium, calcium, magnesium and potassium (1 to 600 $mg.L^{-1}$) were measured in the collected water samples, while chloride and nitrate were found in lower concentrations (< 25 $mg.L^{-1}$). The increasing water conductivity with depth in both old and recently excavated clay suggests a relatively fast leaching of these elements throughout the lysimeter column. However, low concentrations of metallic elements (Al, Mn, Ni, Co, Zn) were measured, and As, Cd, Cu, Cr, Pb, Sb were not detected which imply that the release of these potentially toxic elements due to mineral alteration is buffered by the alkaline pH of the water circulating within the argillite (pH 7.5 - 8.0). The lysimeter survey will be run for at least 10 years to provide more consistent results on the physico-chemical evolution the clay. It will be complemented by lab based experiments (e.g. batch and columns), field works (runoff water measurements, revegetation…) and mineralogical analyses (XRD, microscopy, XAS…) to achieve a better understanding of the alteration processes occurring in the excavated clay material.

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Soil water dynamics inside and outside of small-scale lysimeters in extreme conditions

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While lysimeters allow the direct measurement of water fluxes through the soil-vegetation system, the realistic representation of natural soil water conditions is always a critical aspect in lysimeter research. The risk of deviations from the conditions of the undisturbed soil compartment increases for smaller lysimeters and in extreme conditions. As part of a study aimed to investigate the effects of spring and summer droughts on the productivity and water balance of an irrigated mountain grassland in the Vinschgau/Val Venosta region in northern Italy, we measured the soil water characteristics inside and outside of three small-scale lysimeters. Inside the lysimeters soil water content and matrix potential were measured at 5 and 20 cm depth. The lower boundary condition at 30 cm depth was adjusted to outside conditions measured with a tensiometer using a vacuum pump which allowed the removal but not the addition of water through a ceramic plate at the bottom of the lysimeter. Outside the lysimeters soil water content and matrix potential were measured at 5, 20 and 30 cm depth in six profiles with increasing distance to the lysimeters. The measurements were taken during the 2013 growing season which included experimental drought periods induced with foil tunnels from mid-April to mid-June and from end of July to beginning of September but also periods with natural precipitation as well as three irrigation events of 40 to 50 mm within four to six hours. Here we will present the effects of excluding capillary rise and lateral water flow on the soil water dynamics in small lysimeters in very dry conditions as well as during intense precipitation/irrigation. Our results will provide insights on the limitations of lyimeter studies and hints on how to improve the design of small lysimeters.

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ClimGrass - An experiment to quantify and understand effects of warming, elevated CO_2 and summer drought on productivity and biogeochemical processes in permanent grassland

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Climate change is expected to occur at a rapid pace during the coming decades, involving a doubling of atmospheric CO_2 concentration, a warming by 3°C or more, and an increase in the frequency and severity of extreme climatic events. The Alpine region has experienced above average warming over the last century and is considered particularly vulnerable to global change. While there is already considerable knowledge on the responses of plants and ecosystems to individual climate factors, the combined and interactive effects of multiple climate drivers on ecosystem processes in real world ecosystems are much less known. ClimGrass is a multifactorial experimental approach testing effects of multiple levels of air temperature (ambient, +1.5°, +3°C), atmospheric CO_2 concentrations (ambient, +150, +300 ppm) and extreme summer drought on a managed grassland at AREC Raumberg-Gumpenstein in the Austrian Alps. Such managed grasslands are a highly relevant land cover type in many parts of Austria and other European mountain regions. In addition to 32 plots (4x4m with a core zone of 3 m²) arranged in a response surface design for warming and elevated CO_2 and an additional factorial design for testing effects of extreme summer drought, six large lysimeters will be exposed to key combinations of warming and elevated CO_2 to obtain high resolution information water and nutrient fluxes under future climate conditions. In addition, 48 grassland monoliths (30 cm diameter, 60 cm depth) will permit a testing of how altered fertilizer regimes modify ecosystem responses to climate change. This presentation will outline the experimental setup and testing of the unique ClimGrass facility and its potential as an experimental platform for testing complex climate interactions on the productivity and biogeochemistry of managed grassland.

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Towards an approach to validate filter methods to separate precipitation signal from noise in high frequency weighing lysimeter data

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High precision weighing lysimeter allow a more reliable water flux estimation across the upper- and lower boundary of soils [1]. In recent years, much work has been done on lysimeter design [2, 3] and on the processing of lysimeter weight records affected by noise [4-9]. Noise prone measurements prevent a direct estimation of water fluxes from lysimeter weight changes as each small increase or decrease of weight change will be interpreted as precipitation or evapotranspiration. Therefore the estimation of precipitation and evapotranspiration from high resolution lysimeter data depends on the appropriate use and functionality of the noise reduction method (filter-algorithm). However it is still unclear how to validate the procedure of individual state of the art filter-algorithms [10] on lysimeter observations, as long as noise affect the change of the lysimeter weight. The lack of a known noise free reference water flux on the upper lysimeter boundary (e.g. precipitation) makes it impossible to validate and to compare the impact of different filter-algorithms on the estimation of precipitation or evapotranspiration from lysimeter measurements.

In order to define the impact of different filter-algorithms on the separation of water exchange between the soil-plant-atmosphere continuums, we will present an experimental lysimeter set-up with a predefined upper boundary condition for several precipitation events. Within our experimental approach, we will apply a known input “precipitation” signal from a permanently weighted (high resolution 1 g) water reservoir on the lysimeter upper boundary. The lysimeter surface will be covered to omit weight changes due to evaporation or transpiration processes and the irrigation water will be collected in a tank which will be installed on the top of the lysimeter. Three different irrigation events which can be distinguished by its irrigation intensity will be used to measure parallel the noise free (irrigation) and the noise affected weight change of precipitation on the lysimeter.

The experimental set-up enables us to validate the performance of different state of the art filter-algorithms by a comparison of the derived goodness of fit between the observed (irrigation) and processed precipitation (filter-algorithms) data’s.

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