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

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- Compensatory root water uptake models = more adequate description of soil water extraction by plant roots =Root water uptake from stressed parts of the root zone may be compensated by uptake from less stressed parts.

- Verification of such compensatory root water uptake approaches using field experiments with a higher measurement frequency and longer investigation periods.

- Analysis of a period from 2003-2004 with hourly ETr-rates and soil water contents measured at the boundary layer field site Falkenberg established by German Meteorological Service (DWD) at the Lindenberg Meteorological Observatory - Richard Aßmann Observatorium.

- Comparison of measured ETr and soil water contents with those simulated by using compensatory and uncompensatory root water uptake.

Measurements Falkenberg: 30 minutes time steps upscaled to hourly values

Types of measurements	Parameters	Measument height(+) and measurement depth (-) in m
10 m Tower	**Temperature (°C), rel. air humidity (%)**	0.5, 1, **2**, 4, 10
	Windspeed (m s^{-1})	0.5, 1, **2**, 4, 6, 8, 10
	Winddirection	11.5
	Air pressure (hPa)	1
	Precipitation (mm)	**1**
	Short- and longwave net radiation (W m^{-2})	**2**
Turbulence measurements, Eddy-Covariance	Momentum, sensible and **latent heat flux** (W m^{-2})	**2.4**
Soil measurements place	**Soil water contents in cm^3 cm^{-3} (measured by TDR) and soil temperatures (°C)**	**-0.08, -0.15, -0.30, -0.45, -0.60, -0.90**

(from Beyrich und Engelbart, 2006)

Soil type Falkenberg: Eutric Pozoluvisol: 150 cm depth

Layer	Depth (cm)	Sand	Silt	Clay	Bulk density ($g\ cm^{-3}$)
Ap	0-30	70	25	5	1.6
Ael	30-60	70	26	4	1.7
Bv	➢ 60	55	25	20	1.7

Lower boundary condition: Free drainage

Vegetation: Grass cover (Lolium perenne)

Annual precipitation 2003: 375 mm
Annual precipitation 2004: 488 mm

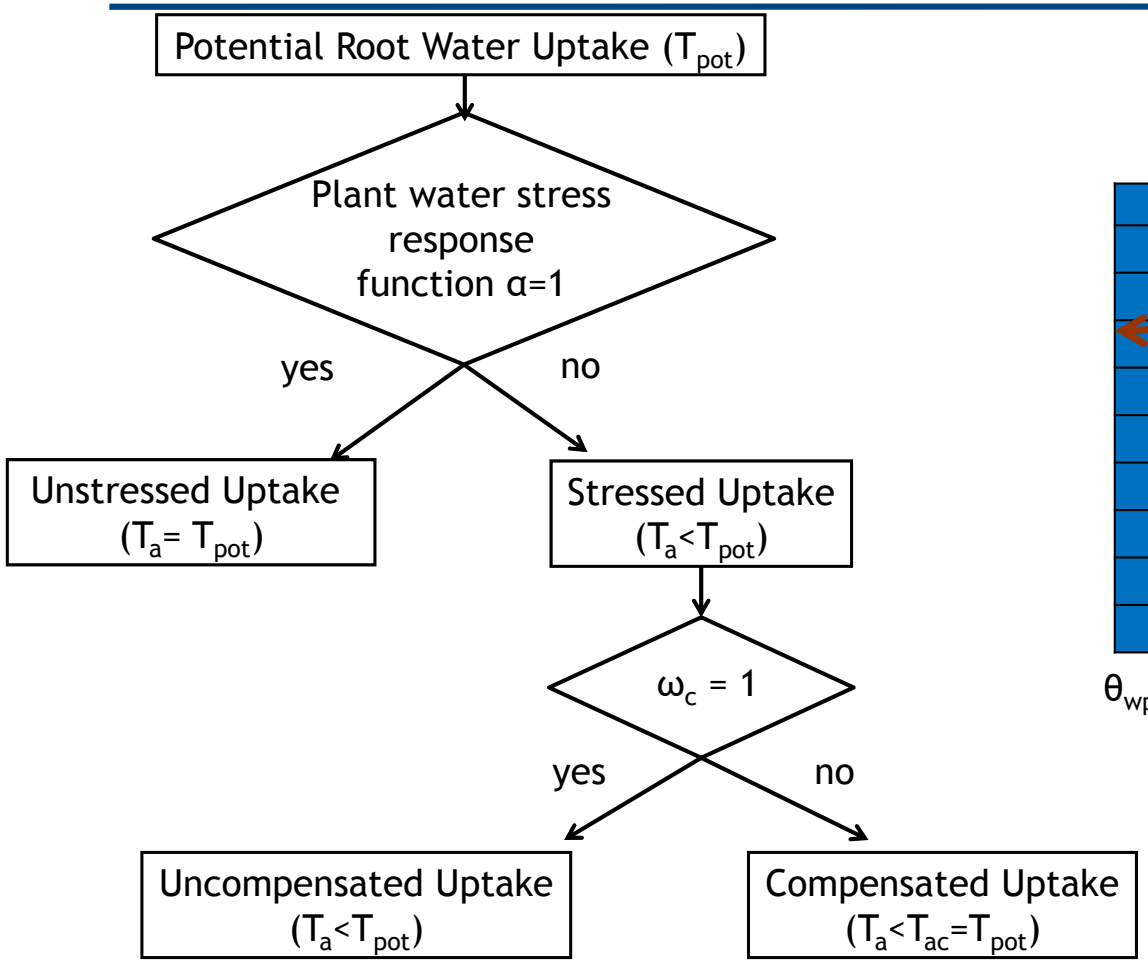
= 67% -88 % of long term mean annual rate of 556 mm for the period 1901-2010

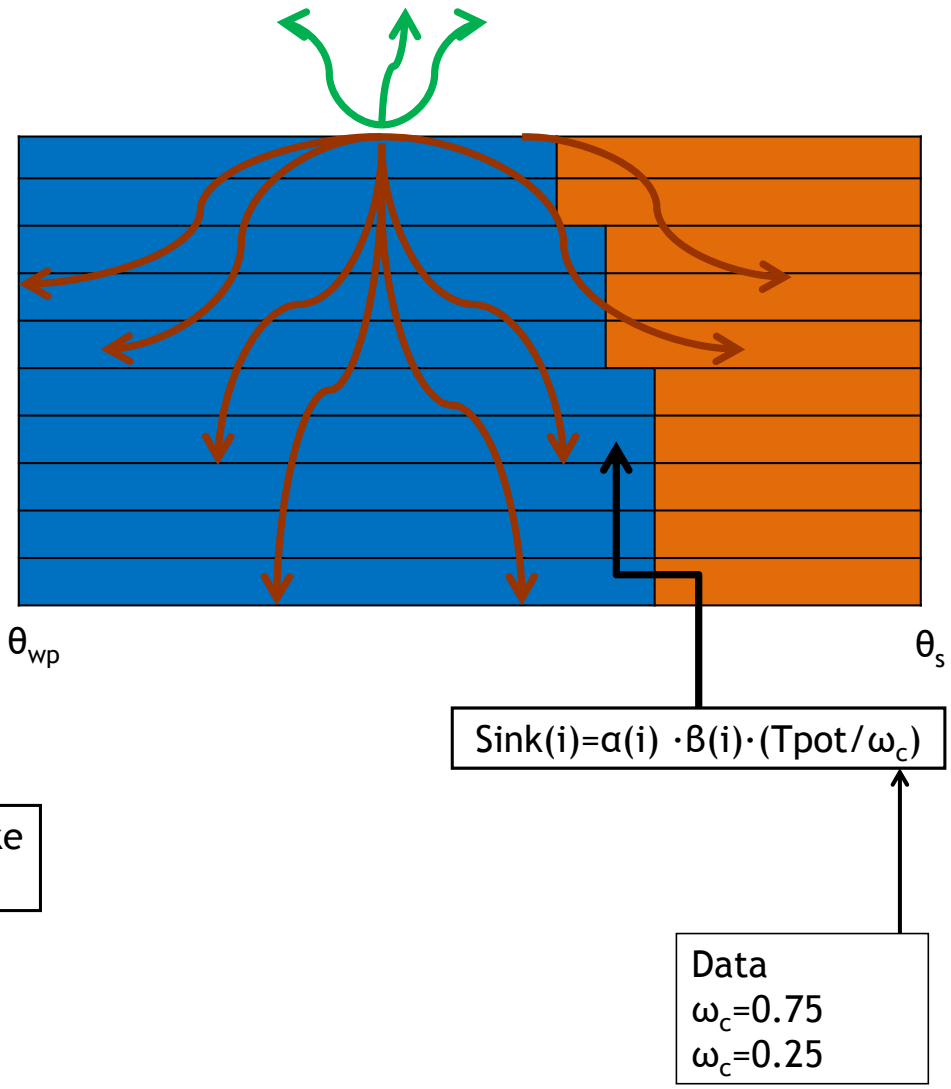
Modelling procedures:

- Hydrus (Simunek et al., 2008)
- Time step = 1h , Total simulation period: 17544 hrs = 2003 - 2004
- 150 cm depth of soil profile = 150 layers a 1 cm
- Soil hydraulic functions according Mualem (1976) and van Genuchten (1980) (vGM)
- Estimation of vGM-parameters θs, θr, α, n and saturated hydraulic conductivity K_{sat} by Neural Network pedotransfer functions using texture and bulk density based on the ROSETTA-database
- Root water uptake according to Feddes (1976) with parameters for grass cover
- Soil heat transfer using default parameters for soil heat conductivity and measured soil temperatures

Three simulation variants:

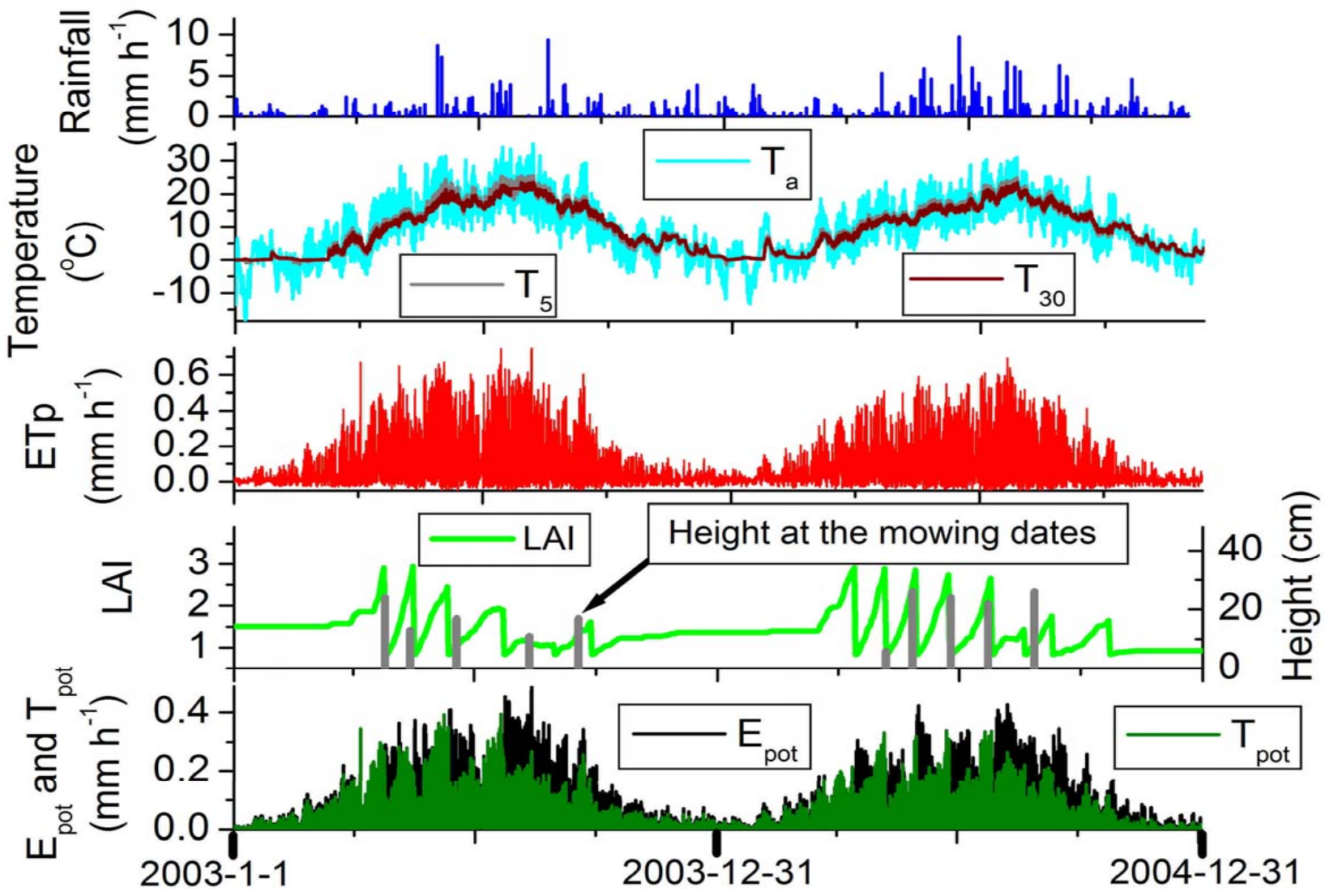
- 50 cm rooting depth, calibrated θs and θr using measured soil water contents.
- 50 cm rooting depth, calibrated θs and θr and root water uptake compensation with two different parameters for ω_c = threshold value for compensation



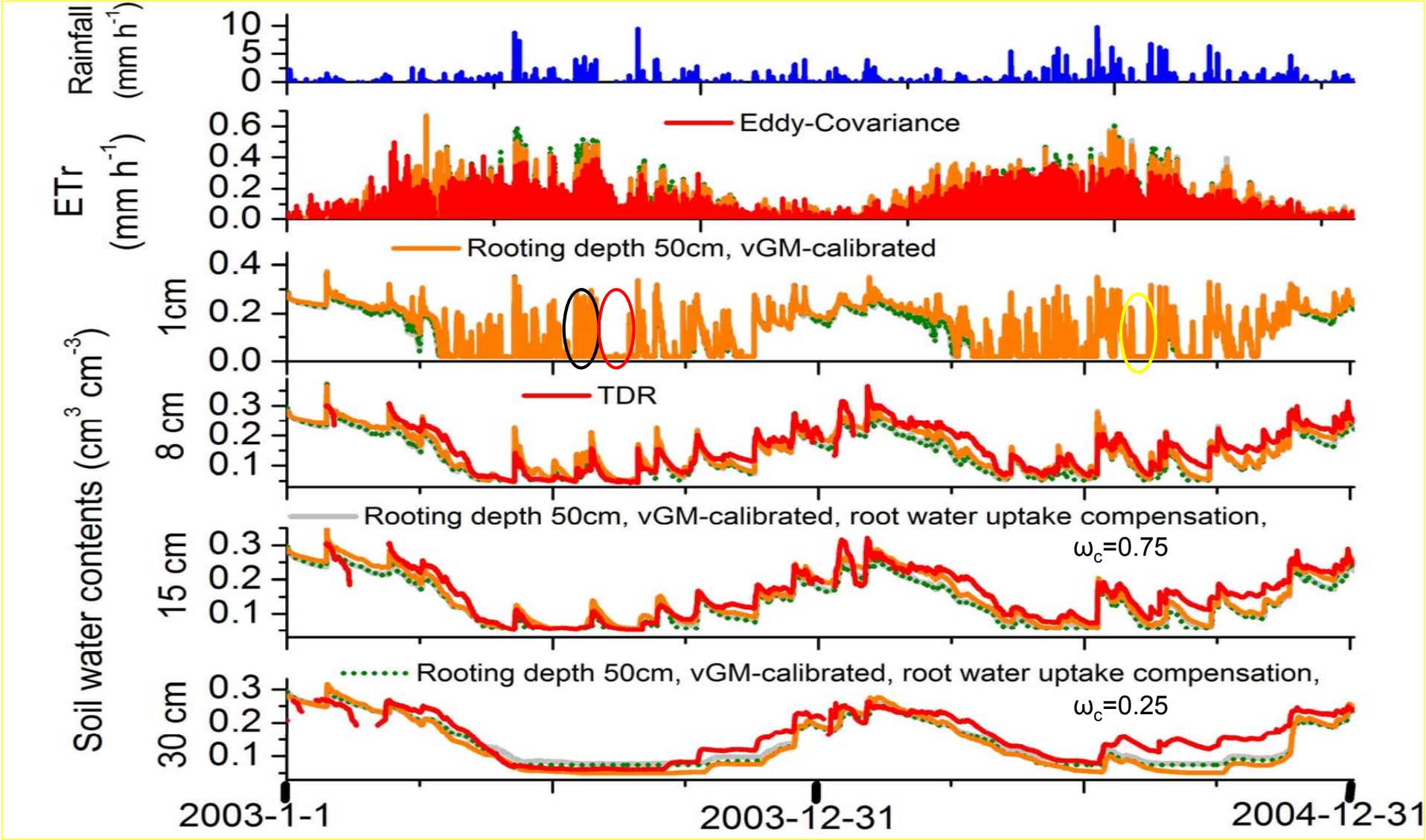


From Simunek and Hopmans (2008)

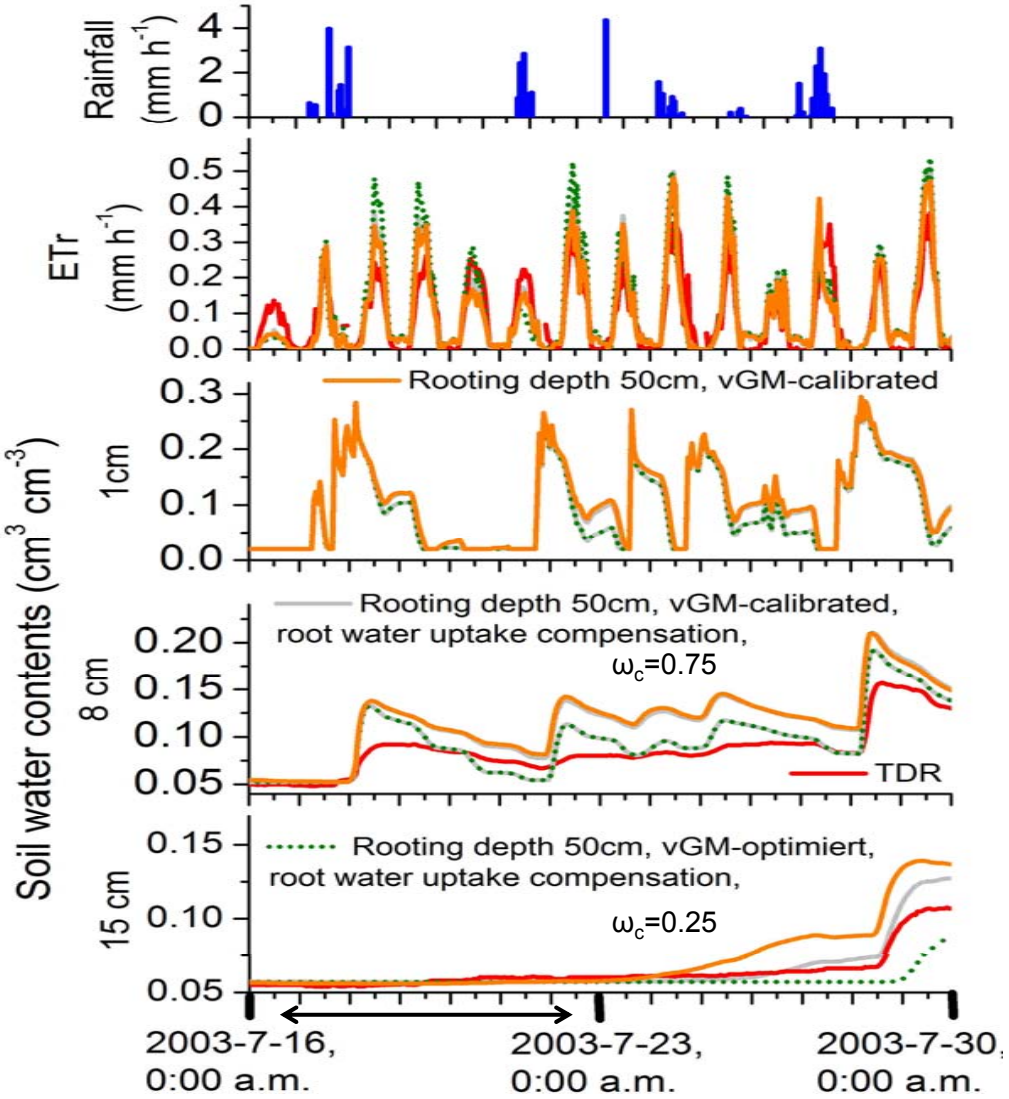
Input Hydrus: Hourly rainfall, air temperature 2m (T_a), soil temperature at in 5cm (T_5) and 30 cm depth (T_{30}), pot. grass reference evapotranspiration ETp, Leaf area index LAI (simulated by a grass cover growth model), pot. Evaporation (E_{pot}) and pot. Transpiration (T_{pot}), Falkenberg

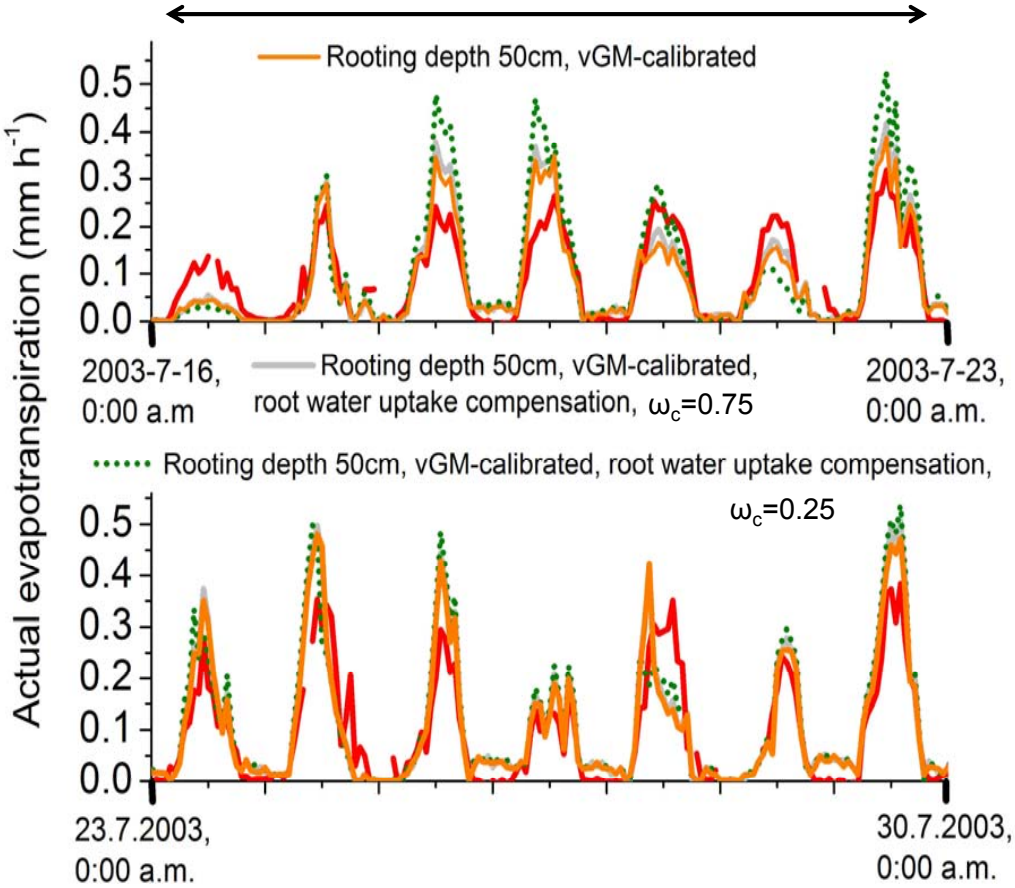


Hourly rainfall, measured and simulated hourly evapotranspiration (ETr) and soil water contents at 1 cm, 8 cm, 15 cm and 30 cm depth, Falkenberg

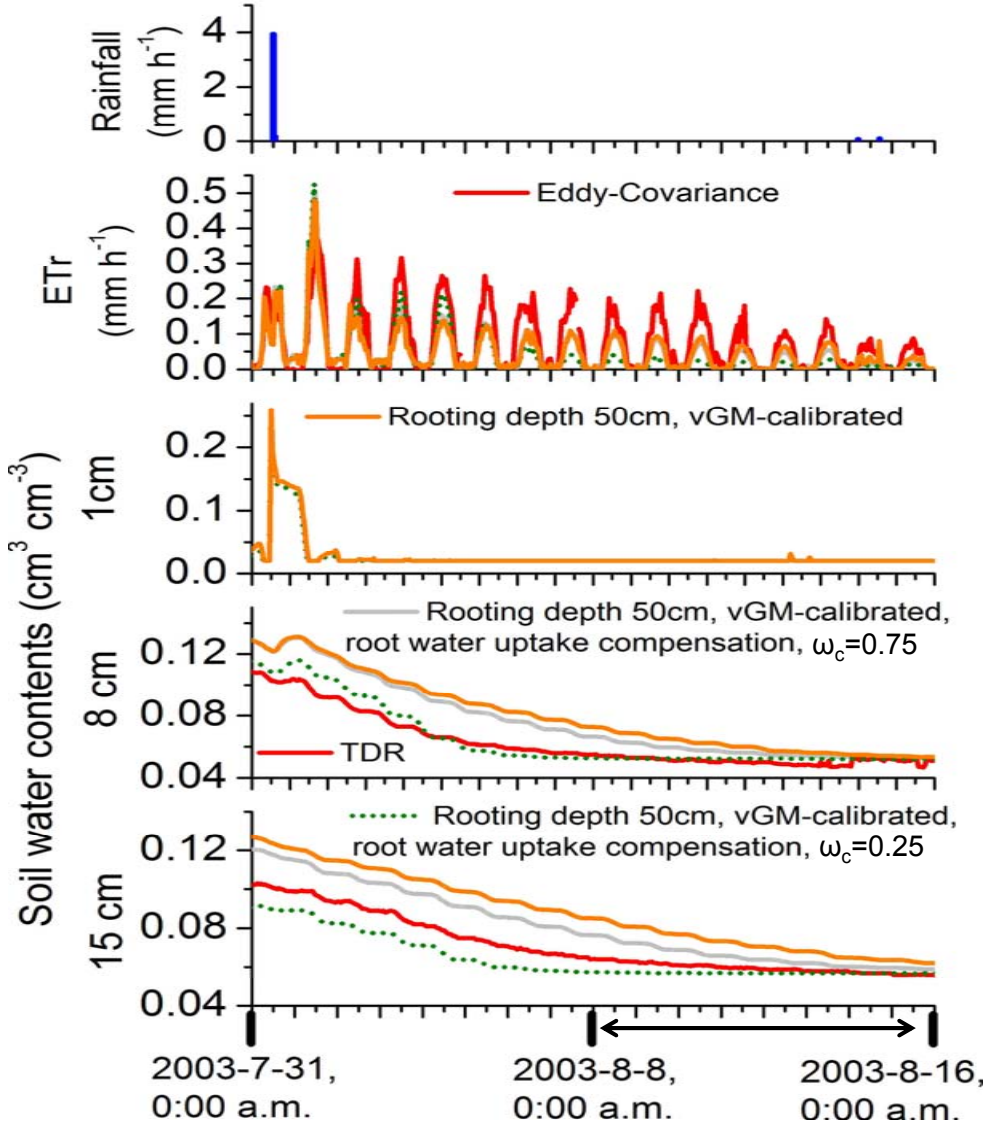


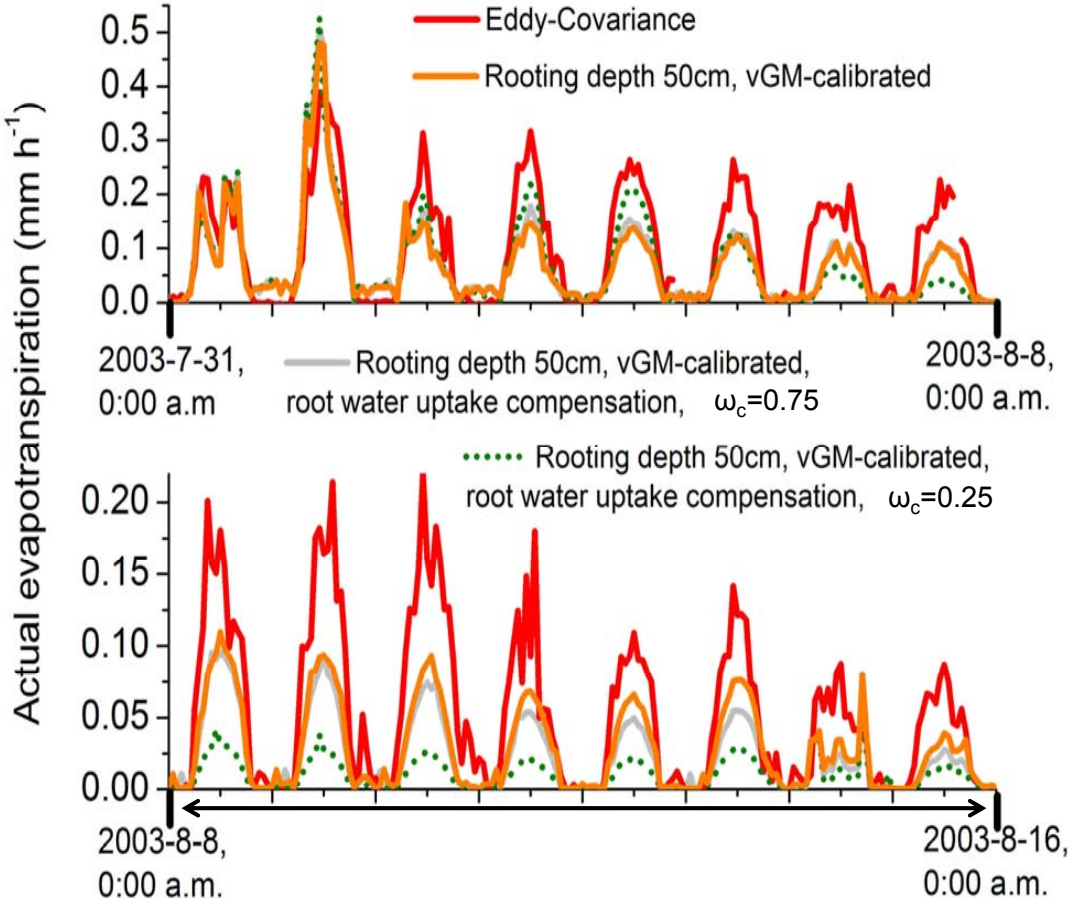
Horuly rainfall, measured and simulated hourly evapotranspiration (ETr) and soil water contents at 1 cm, 8 cm, 15 cm and 30 cm depth, Falkenberg, 2003-7-16 - 2003-7-30, 14 days = 336 hours



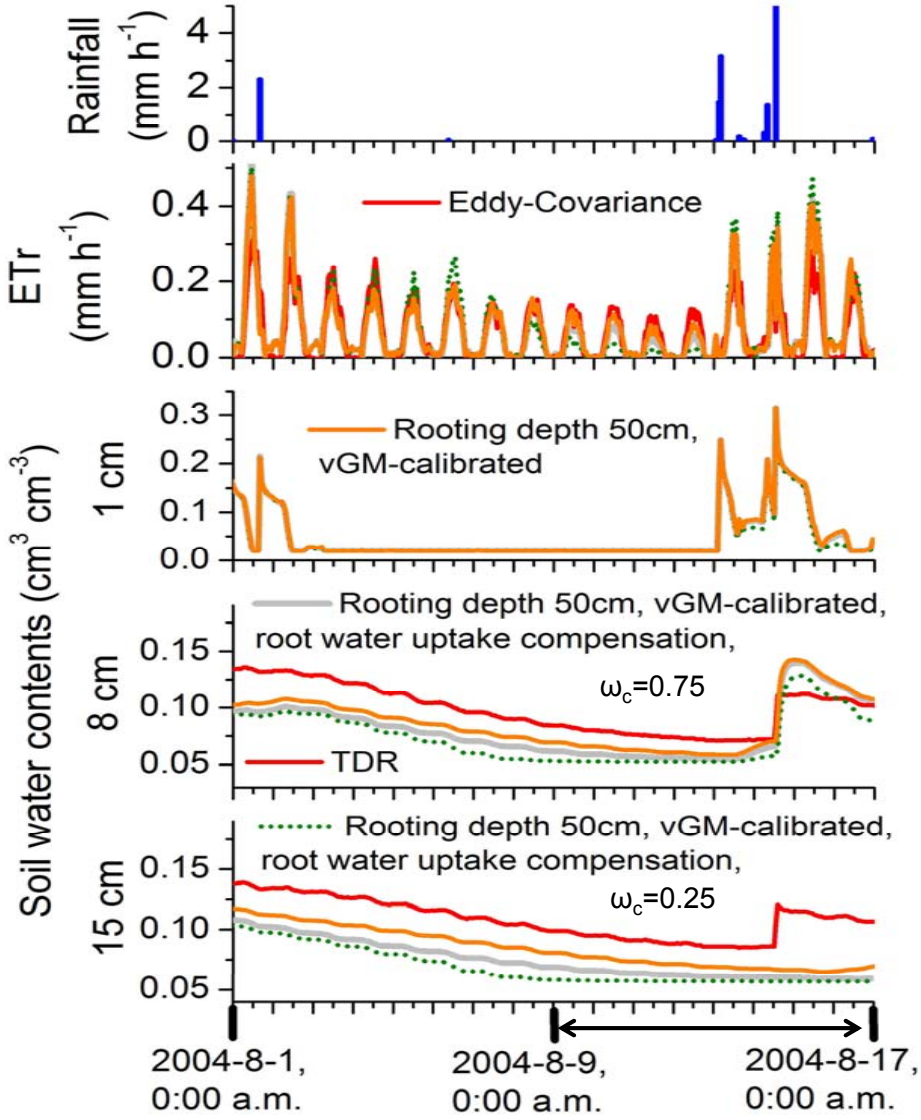


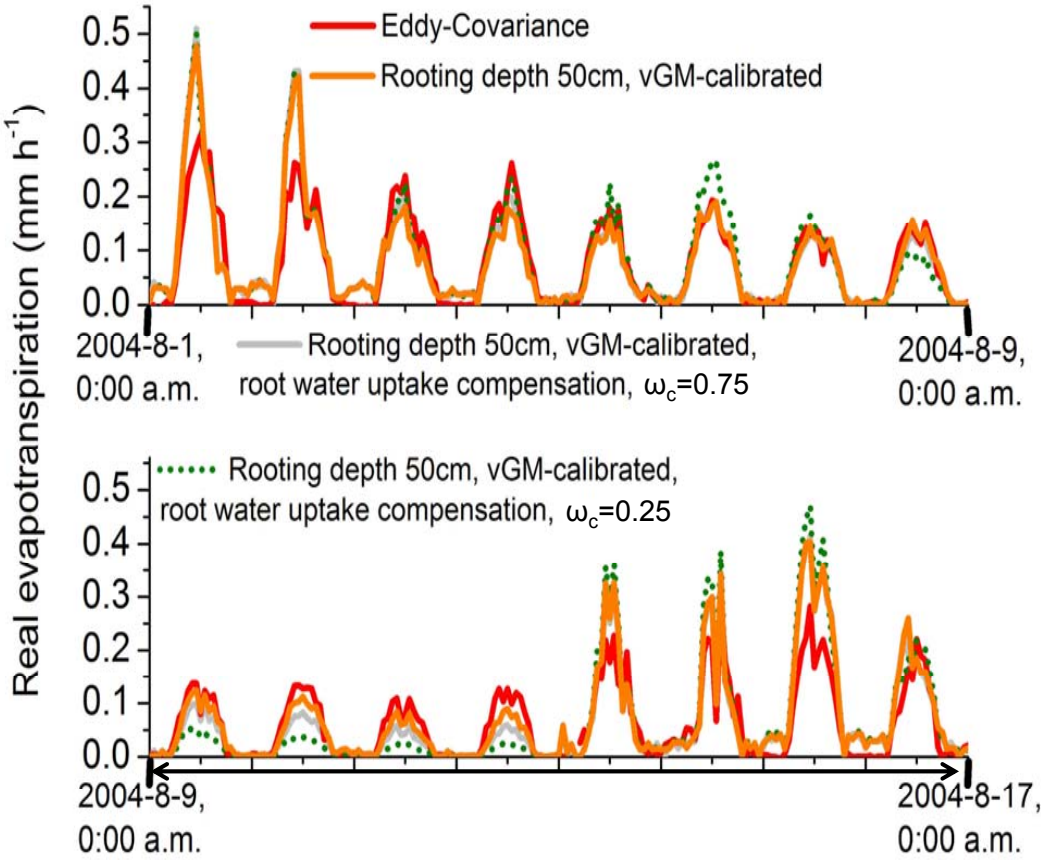
Hourly rainfall, measured and simulated hourly evapotranspiration (ETr) and soil water contents at 1cm, 8 cm, 15 cm and 30 cm depth, Falkenberg, 2003-7-31 - 2003-8-16, 16 days = 384 hours



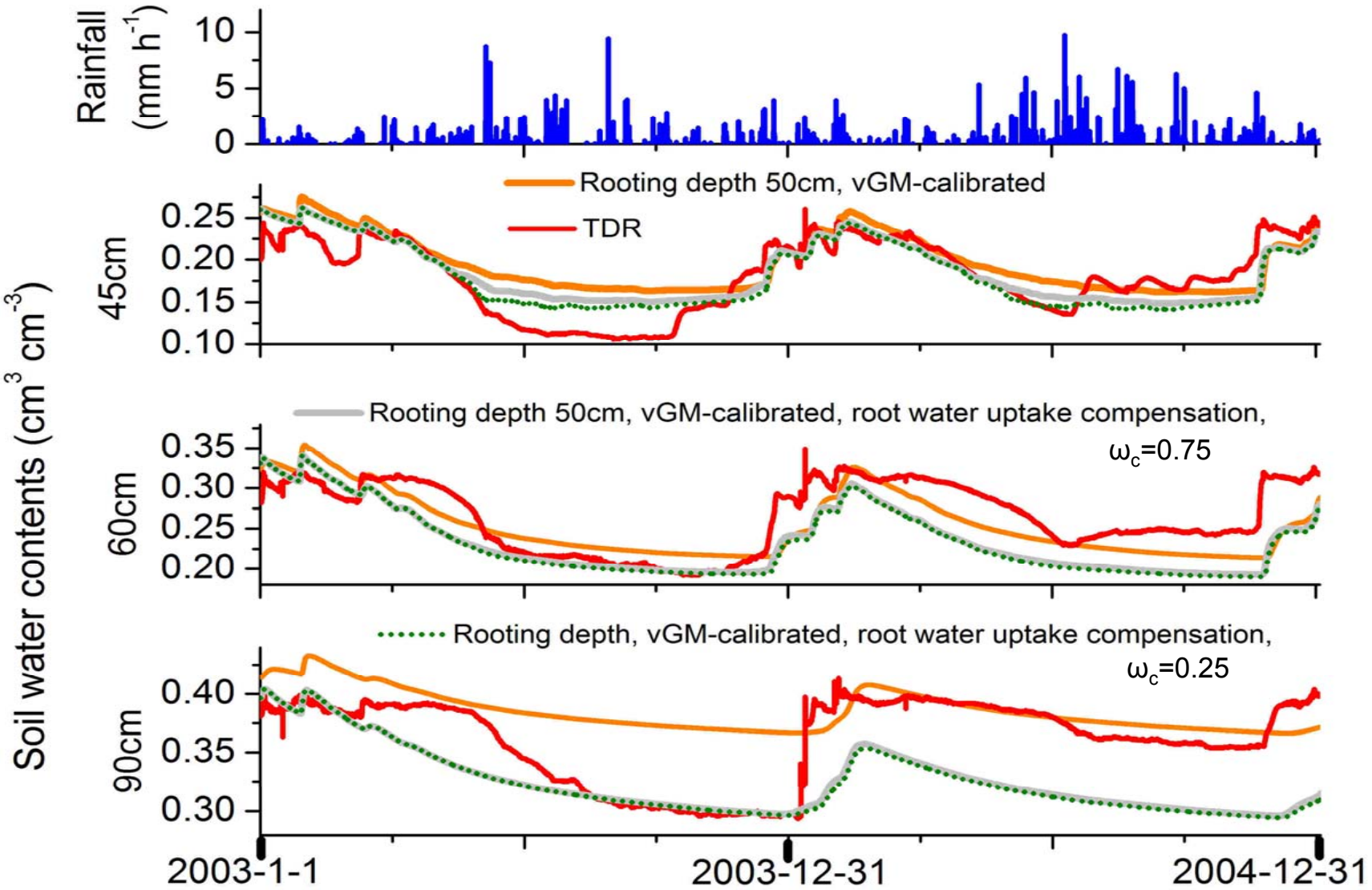


Hourly rainfall, measured and simulated hourly evapotranspiration (ETr) and soil water contents at 1 cm, 8 cm, 15 cm and 30 cm depth, Falkenberg, 2004-8-1 – 2004-8-17 , 384 hours





Hourly rainfall, simulated and measured hourly soil water contents at 45 cm, 60 cm and 90 cm depth, Falkenberg



Conclusions and Summary:

- Uncompensatory root uptake showed better model performance than compensated for the total period.
- Coefficient of determination R^2 for soil water contents at 8 cm, 15 cm and 30 cm depth (R^2=0.77-0.90), for soil water contents at 45 cm and 60 cm depth (R^2=0.55-0.71) and for soil water contents at 90 cm (R^2 < 0.35).
- Coefficient of determination R^2 for ETr (R^2=0.66-0.72).
- Root water uptake compensation using ω_c=0.25 resulted in the best fit of measured and simulated soil water contents, but in bad fit of ETr for dry periods 2003 - Triggering between compensated and uncompensated root water uptake in very dry periods such as 2003 ?.
- Different footprints of soil water contents measured by TDR (≈mm-cm) and ETr measured by Eddy-Covariance (> 100 m).
- Further analysis of longer periods 2003-2012.