How best to optimize a global carbon land surface model ?

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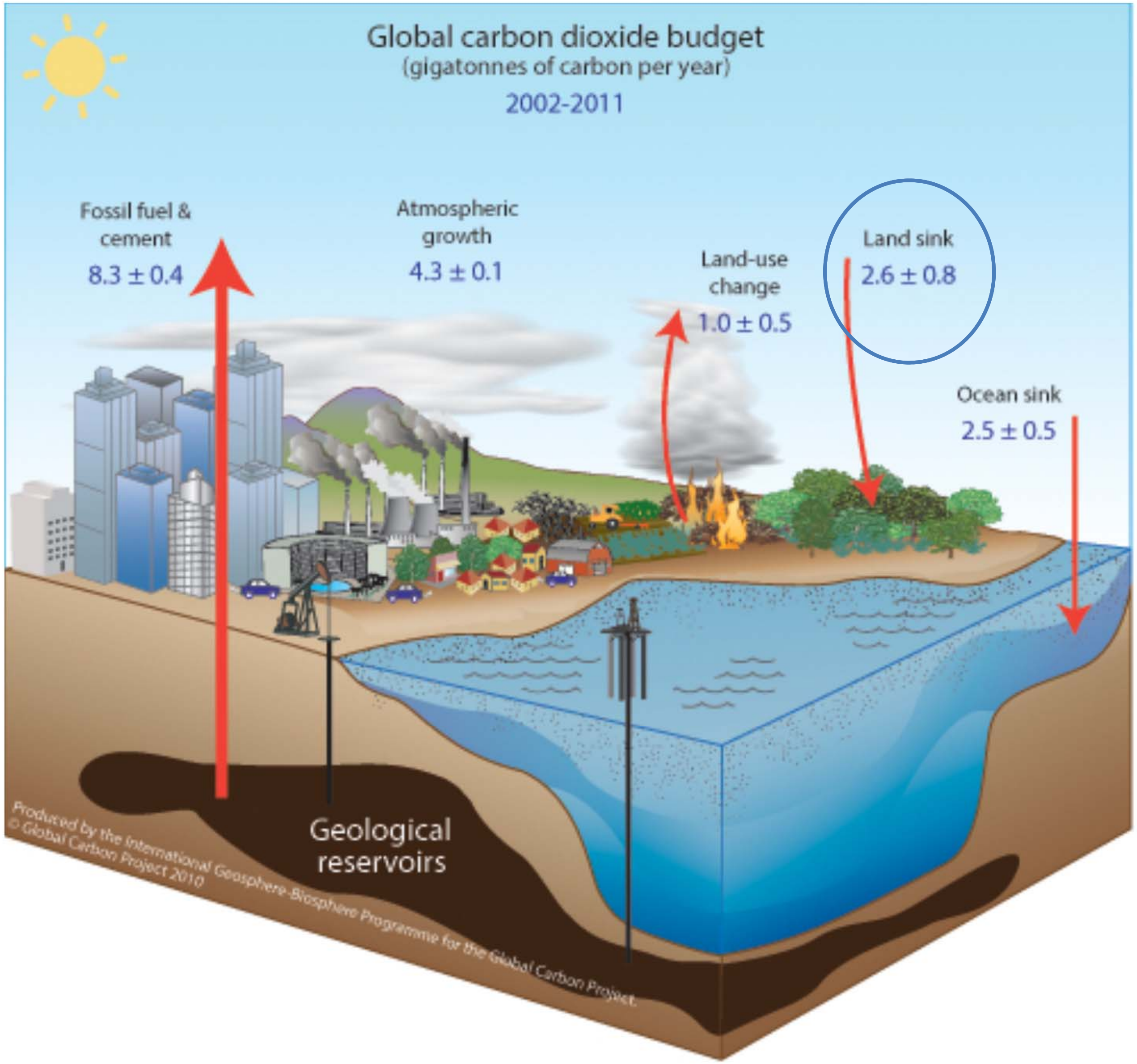
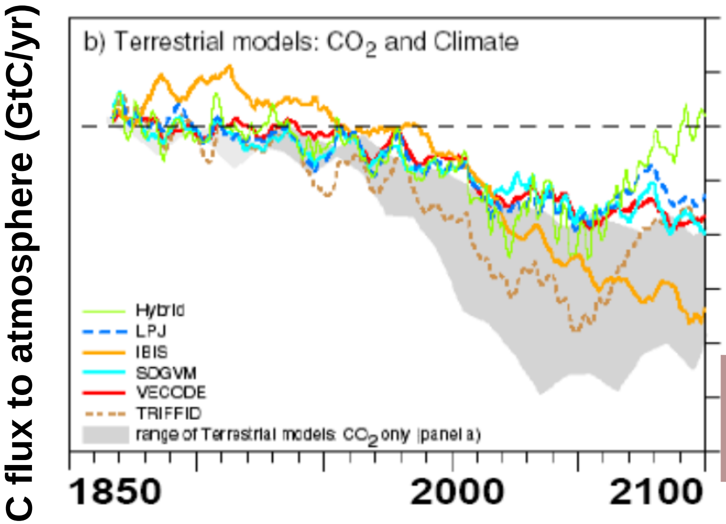
Closing the global carbon budget?

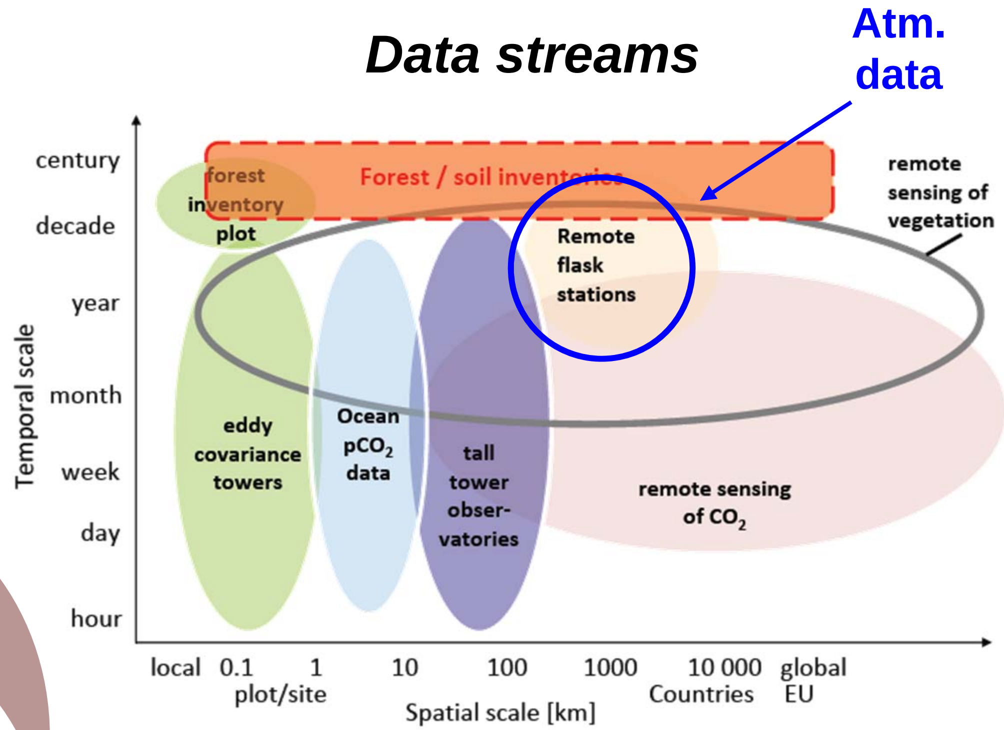


Needs for a **C**arbon **C**ycle **D**ata **A**ssimilation **S**ystem

Large uncertainty from land to predict global C-balance (C4MIP)



Data streams



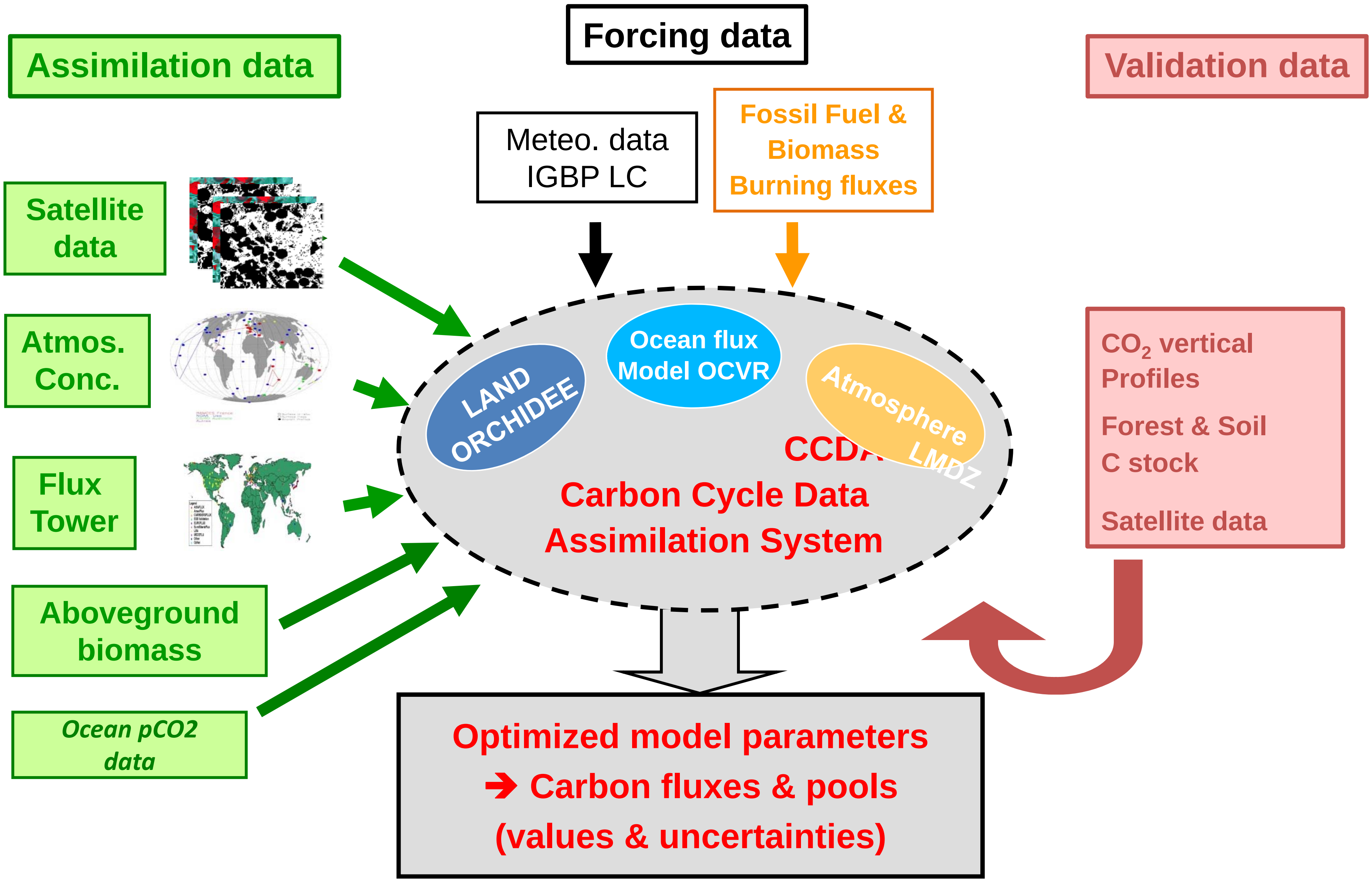
OPTIMISATION OF PARAMETERS
→ Data Assimilation

Optimized ecosystem models
➔ reduce the spread ?

Improve:

- **Uncertainty estimates**
- **C land budget estimates**
- **Future climate predictions**
- **Process understanding**

Structure of the LSCE CCDAS



Outline : Scientific points addressed

1) **Optimisation with biomass and in situ flux data**
   - **Site study: test of assimilation with different data streams**
   - **(Daily fluxes / annual biomass increment; 25 parameters)**

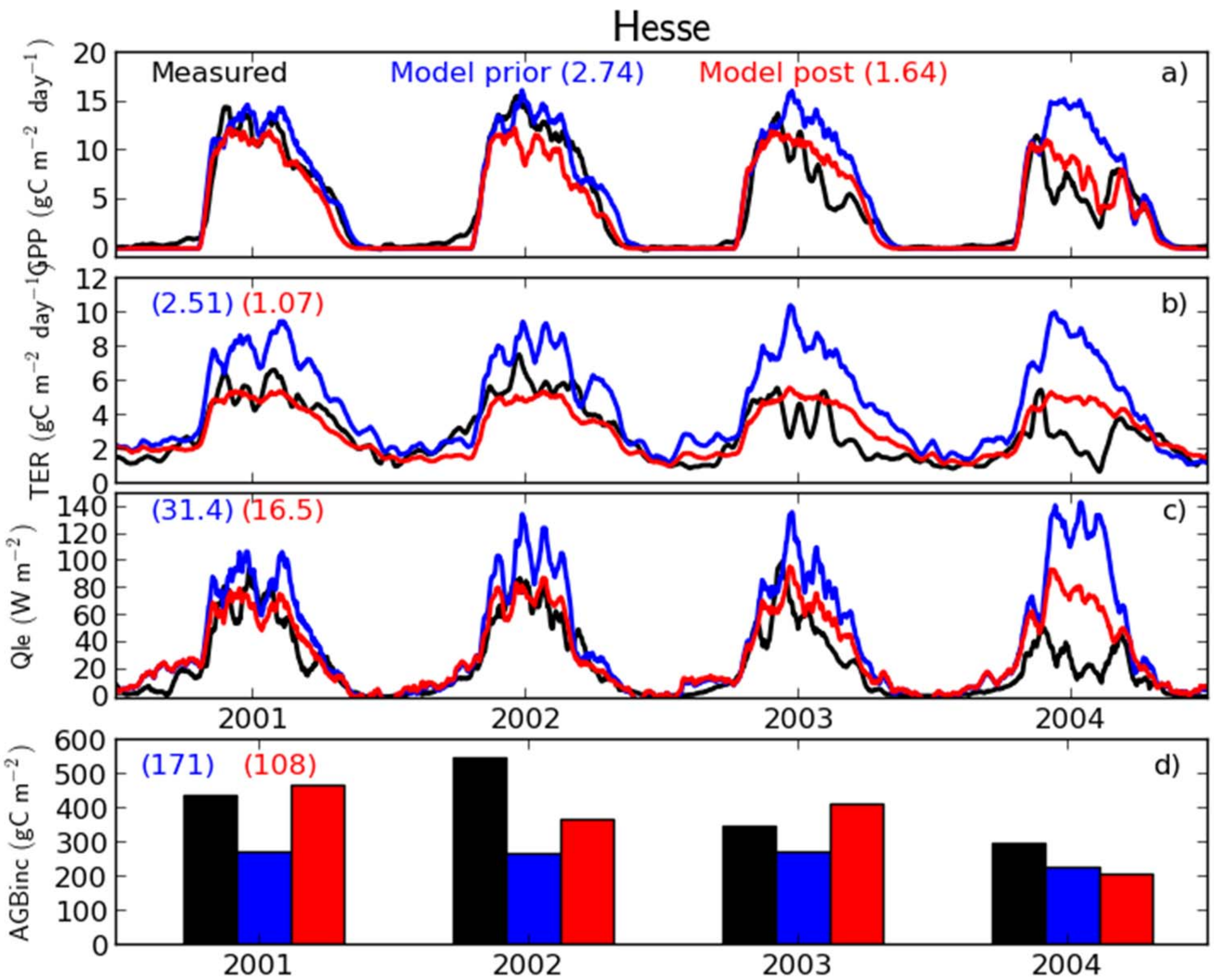
2) Complementarity between FluxNet and NDVI data
   - Site study: assimilation of one or both data streams

     (Daily fluxes / weekly NDVI ; up to 20 parameters)

3) Information brought by Atmospheric [CO2] data
   - Fit to the atmospheric data
   - Constraint on ORCHIDEE parameters & pools
   - Difficulties of the multi-data streams assimilation

4) Impact on prognostic simulations

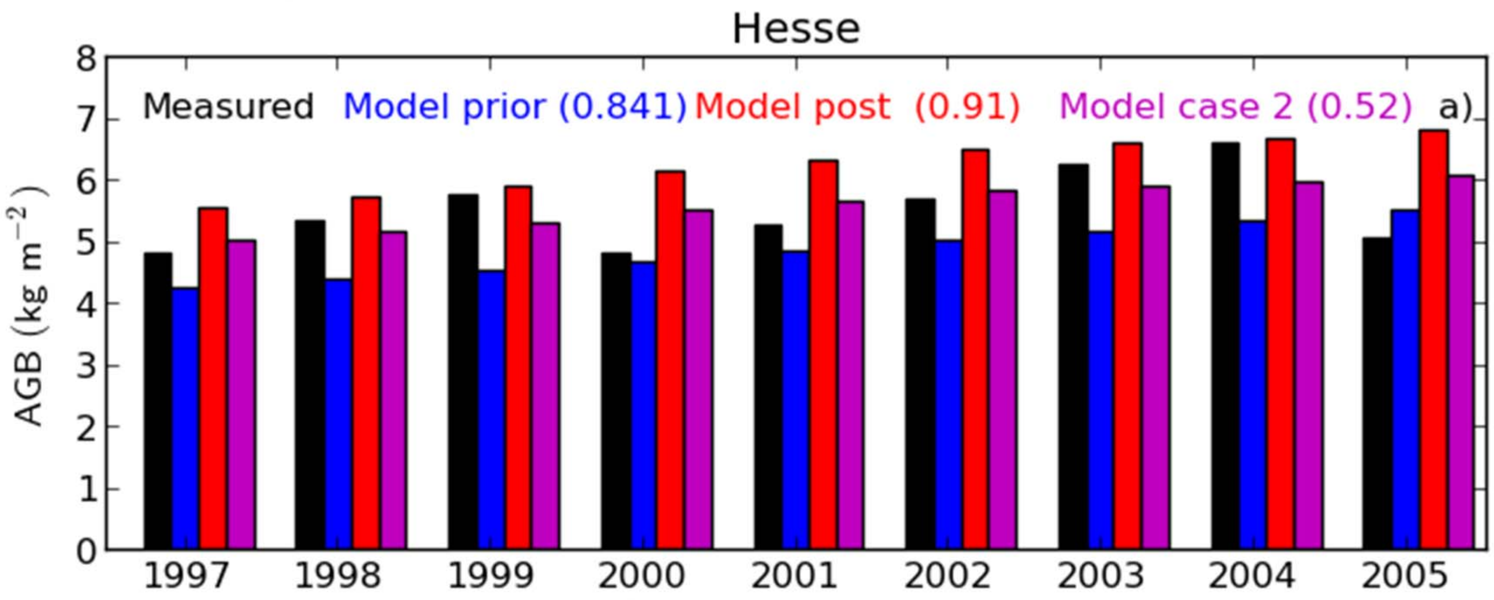
Joint assimilation of biomass and in situ fluxes



➔ Assimilate obs:
- GPP
- TER
- LE
- AGB increment

➔ Optimise params:
- photosyn
- resp
- energy balance
- soil water avail.
- phenology
- ***allocation***

Joint assimilation of biomass and in situ fluxes



- ➔ Assimilate AGB increment degrades fit to data
- ➔ Assimilate total AGB
- ➔ Optimise turnover rate
- ➔ *BUT missing model processes?*

Outline : Scientific points addressed

1) Optimisation with biomass and in situ flux data
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2) **Complementarity between FluxNet and fAPAR data**
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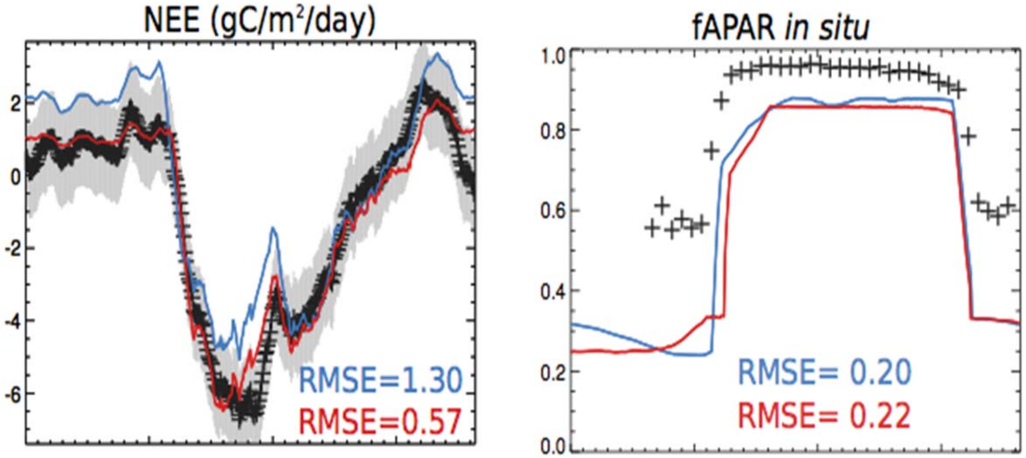
4) Impact on prognostic simulations

1) Impact of Flux data assimilation on fAPAR (20 params)

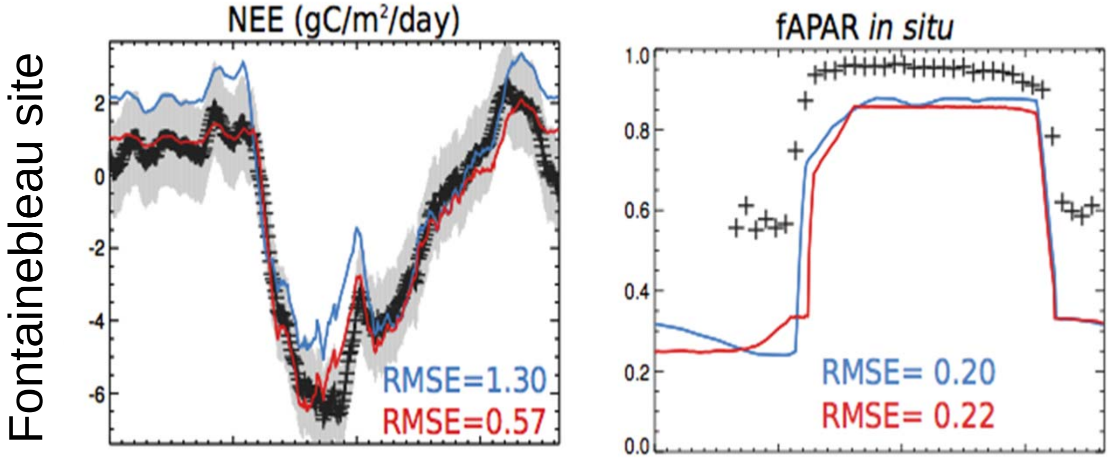
Fontainebleau site



➔No improvement on fAPAR

Bacour et al., in prep.

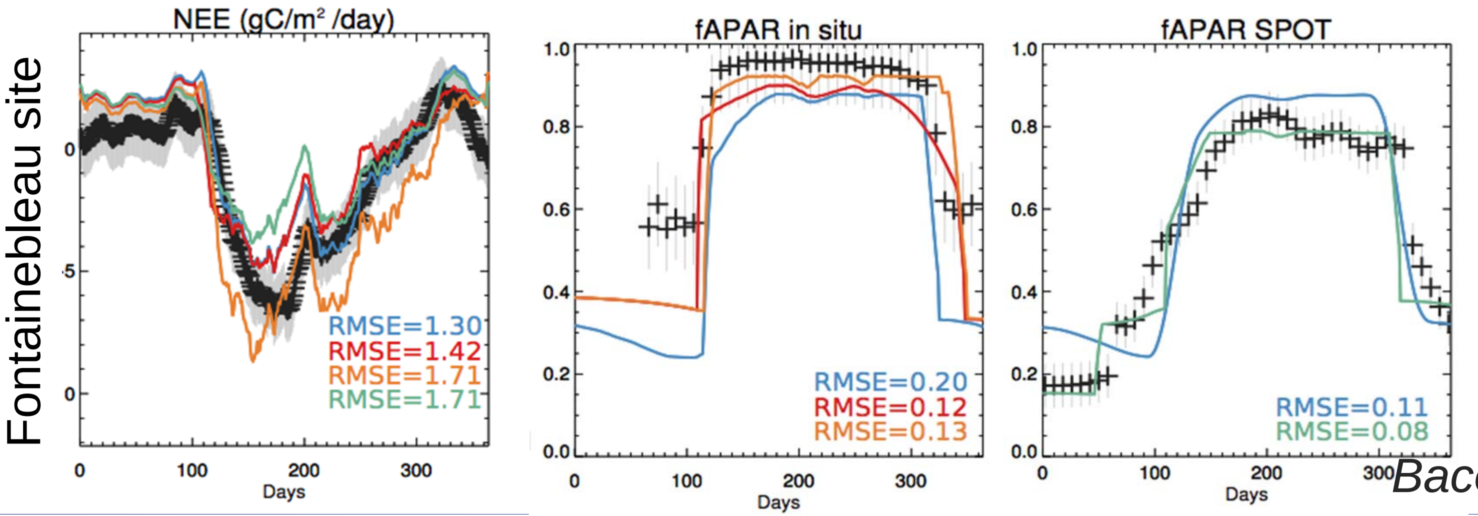
1) Impact of Flux data assimilation on fAPAR (20 params)



➔ No improvement on fAPAR

2) Impact of fAPAR data assimilation on fluxes (4/15 params)

Obs **prior** **post fA in situ** **post fA_ext in situ** **post fA SPOT**



➔ Degrade fluxes

➔ Need to use normalized fAPAR.

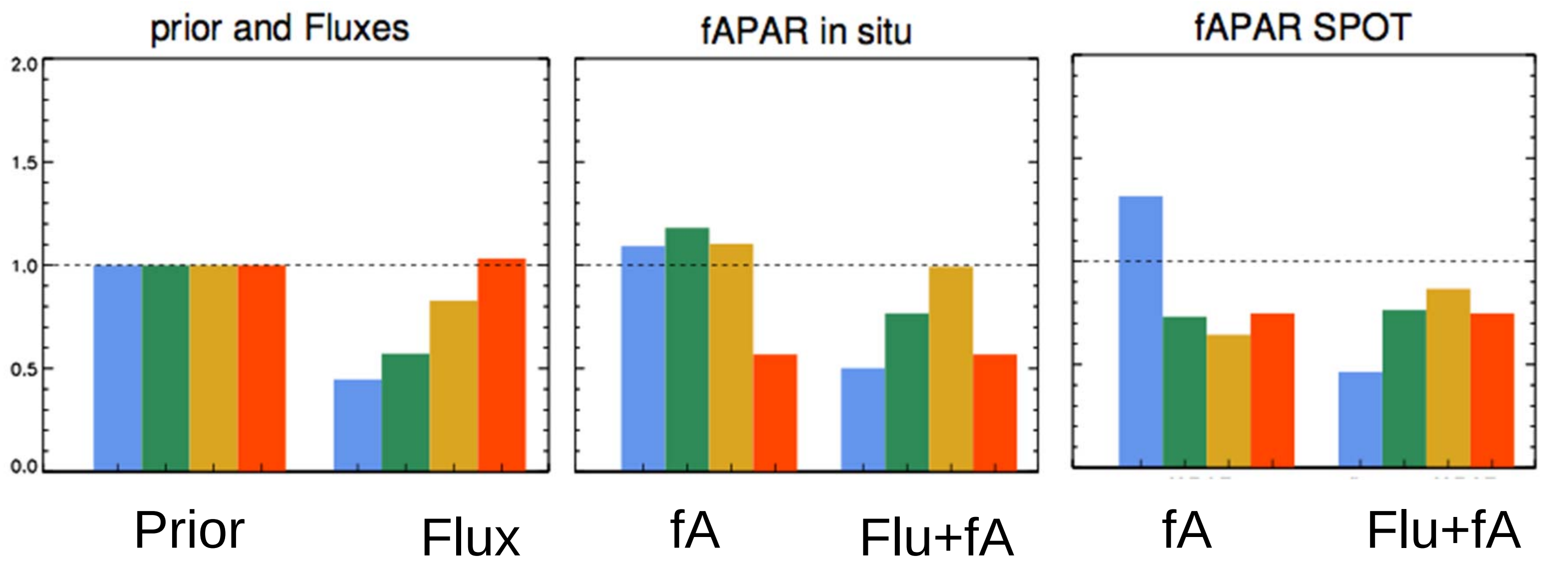
Bacour et al., in prep.

Joint assimilation of FluxNet and MODIS-fAPAR

➔ Fontainebleau (Oak forest) : RMSE_poste / RMSE_prior

Model degradation

Model improvement



Flu: Assimilation of only fluxnet data

fA: Assimilation of only fAPAR data

Flu+fA: Assimilation of both data

Bacour et al., in prep.

Outline : Scientific addressed

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   - **Fit to the atmospheric data**
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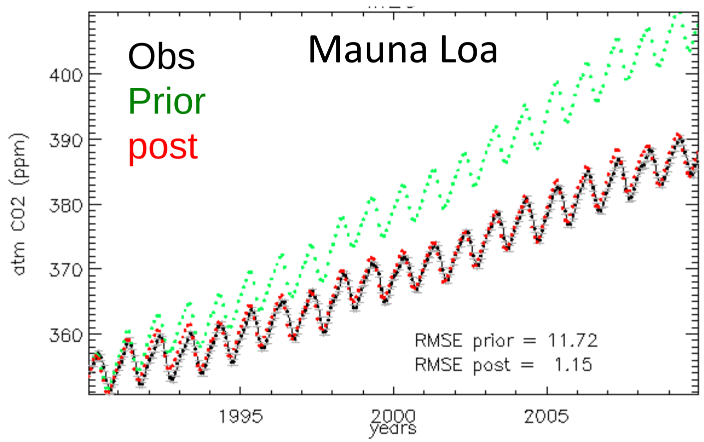
   - **Difficulties of the multi-data streams assimilation**

4) Impact on prognostic simulations

Assimilation of atmospheric [CO_2] data

Optimization of the CO2 trend

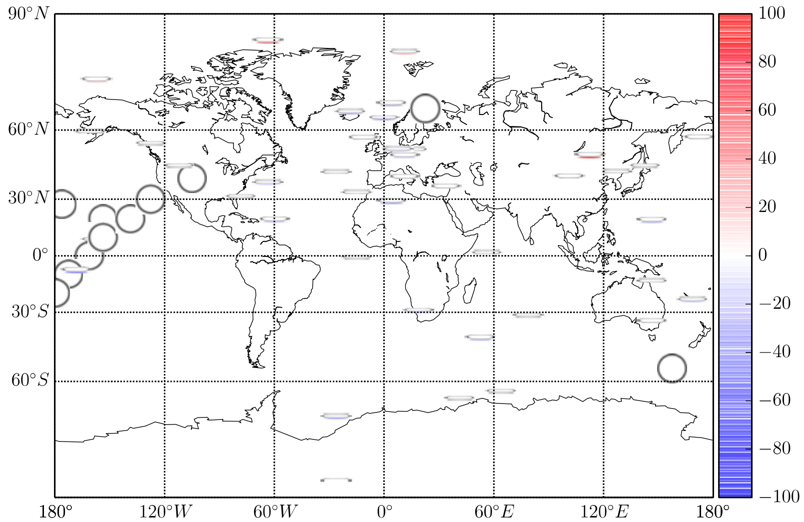


Signal decomposition:

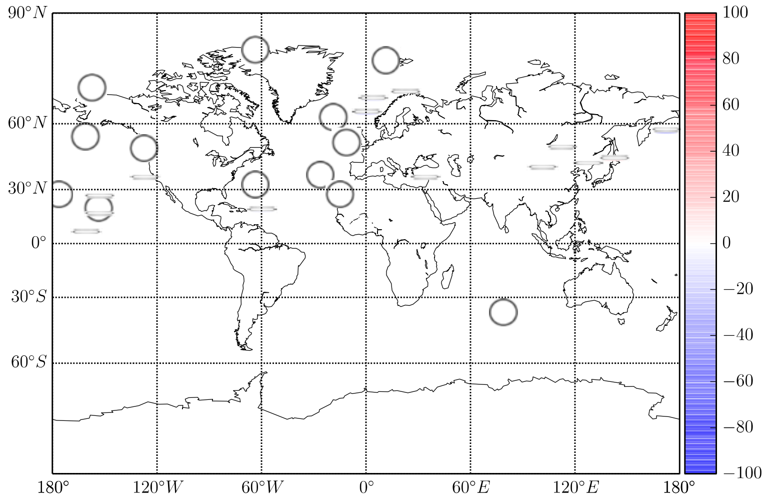
- Amplitude : max - min
- Phase : CPU

(1 – RMSE_poste / RMSE_prior)

Seasonal amplitude



Carbon uptake period length

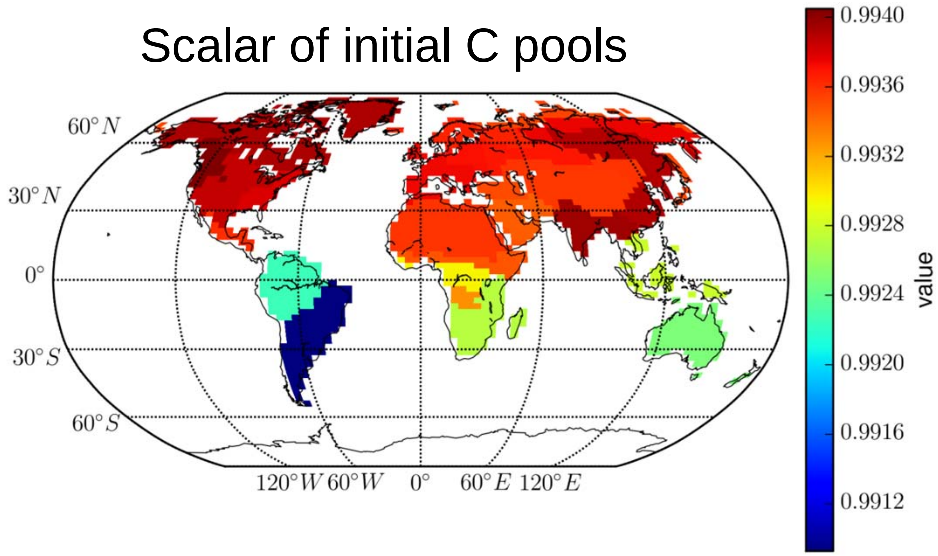


Assimilation of atmospheric $[CO_2]$ data

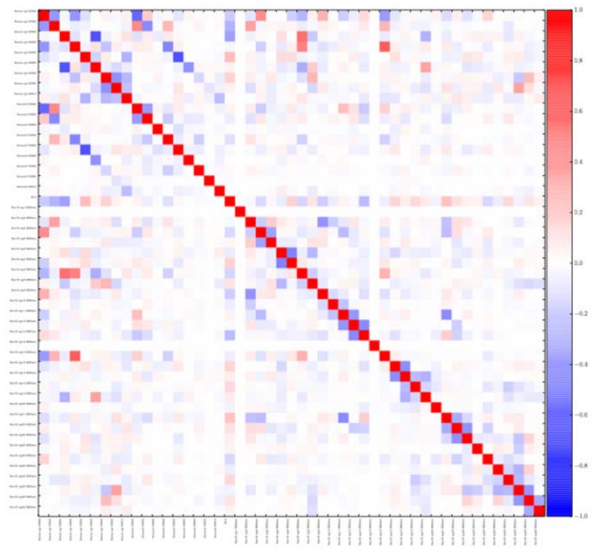
➔ Primary constraint on:

- Soil initial carbon pools..

Scalar of initial C pools

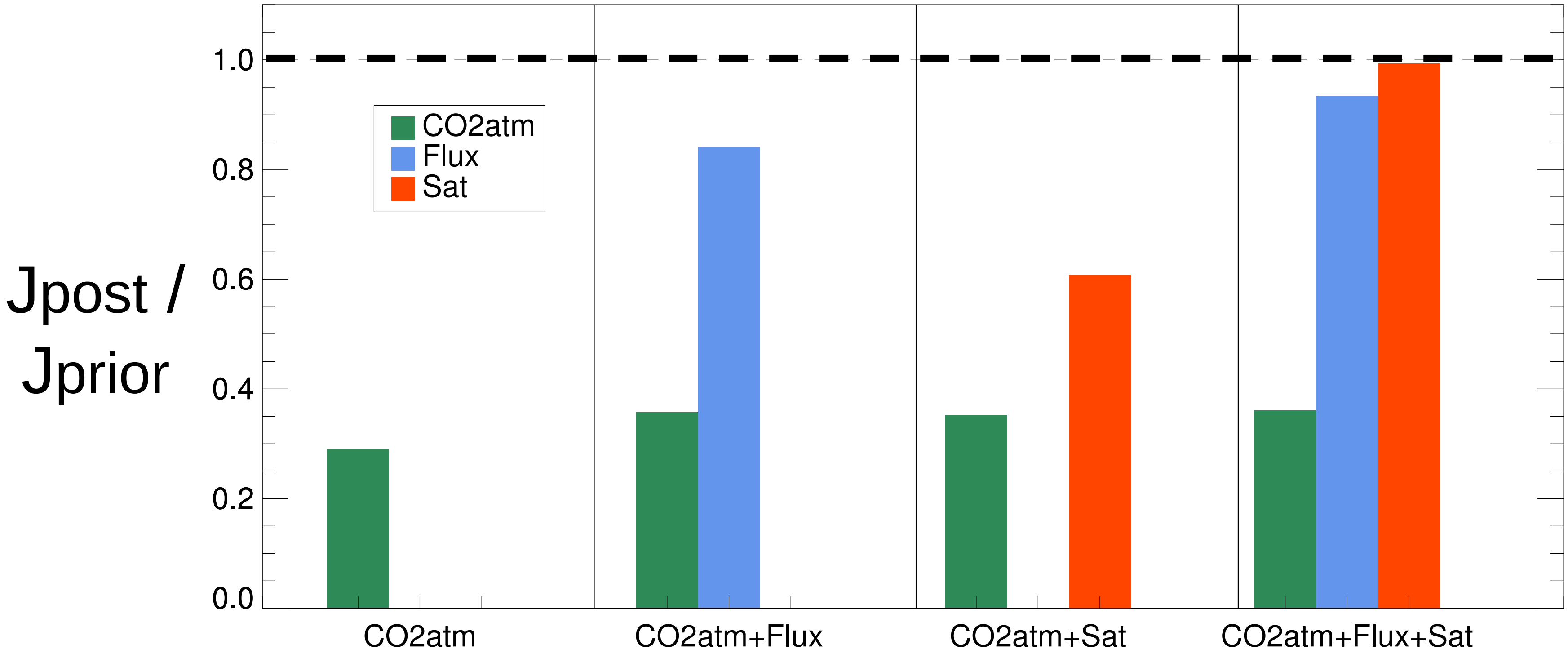


➔ But significant error correlations btw parameters



Joint assimilation of [CO2] and other data streams

➔ Reduction of the cost function : J_{poste} / J_{prior}



Atm. [CO2]
FLUXNET
MODIS-NDVI

Bacour et al., in prep.

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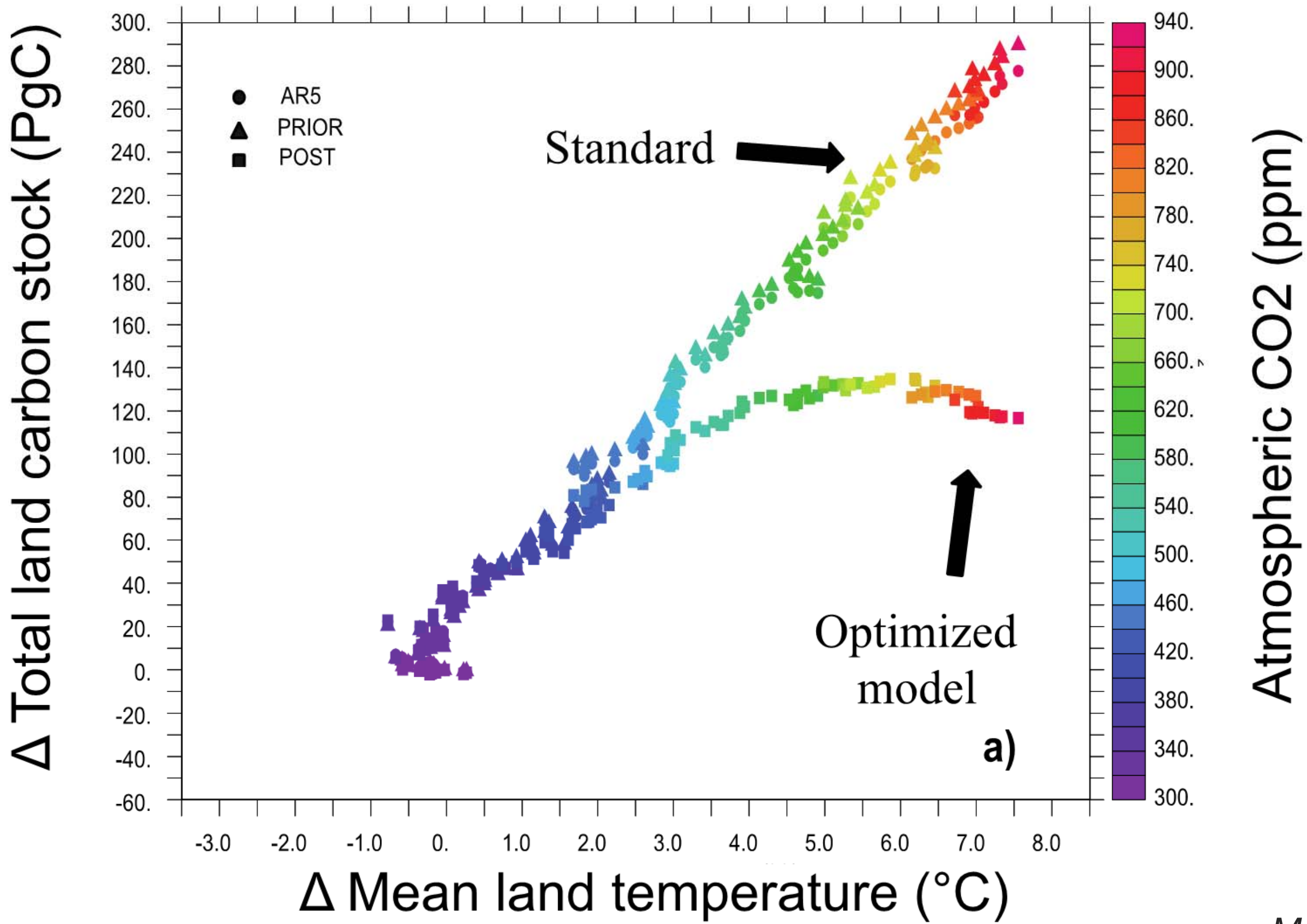
3) Information brought by Atmospheric [CO2] data
   - Fit to the atmospheric data
   - Constraint on ORCHIDEE parameters & pools
   - Difficulties of the multi-data streams assimilation

4) **Impact on prognostic simulations**

Impact on prognostic simulations (ISI-MIP protocol)

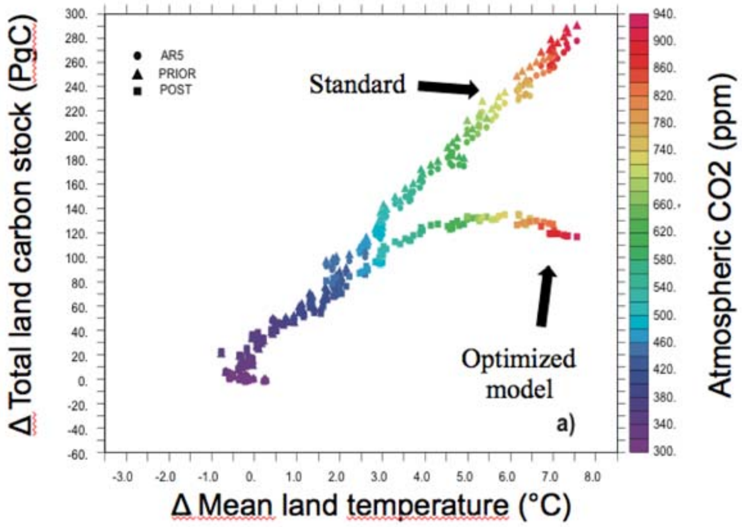
- Using CMIP5 climate scenario (HadGEM2) bias corrected with RCP8.5 CO2 concentration
- Run ORCHIDEE: Standard vs optimized parameters



MacBean et al., in prep.

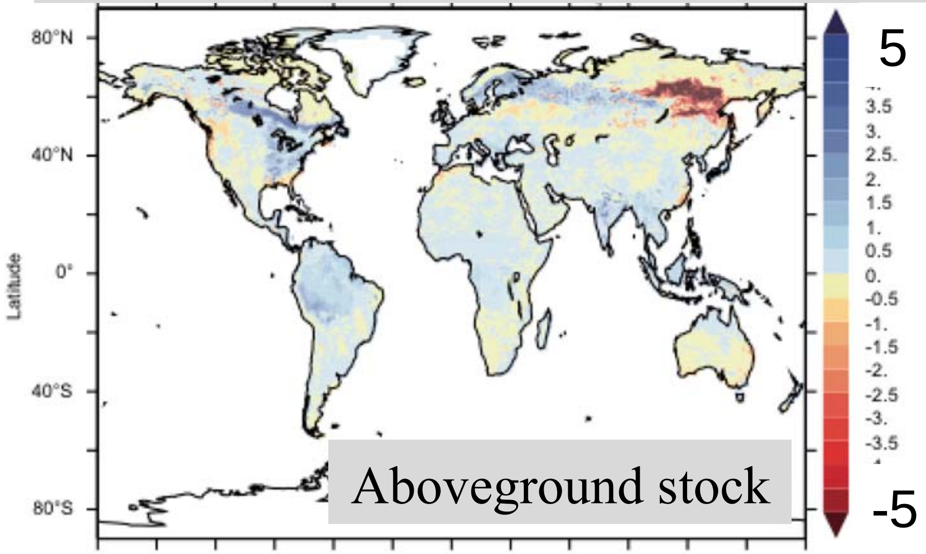
Impact on prognostic simulations (ISI-MIP protocol)

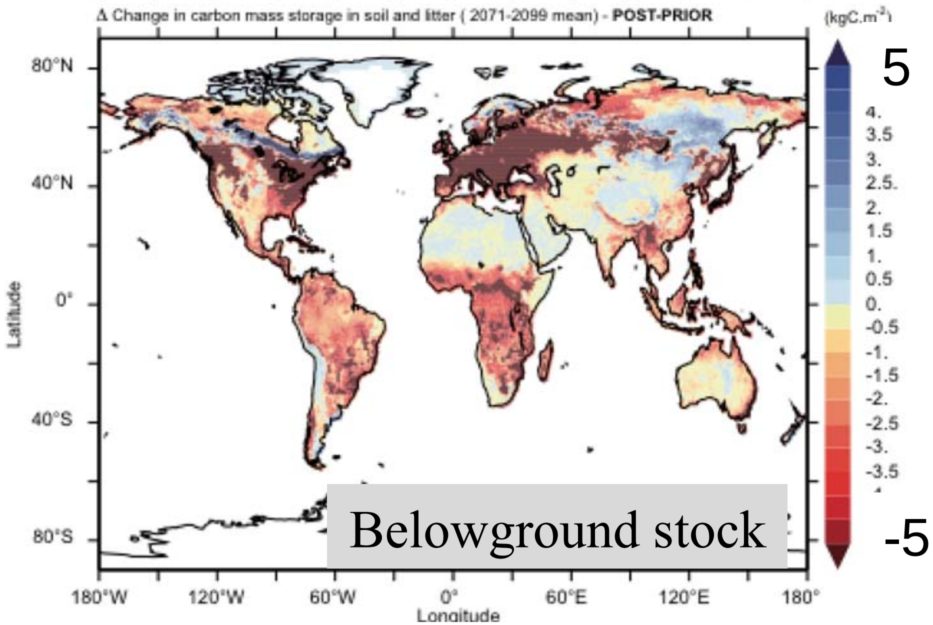
- Large decrease of soil carbon storage above + 3° (changes in input & mineralisation)
- Only small decrease of vegetation carbon stock



MacBean et al., in prep.

2100 minus 2000: Δ C (kgC/m2)





Summary and on-going work

- Using multiple data streams constrains different aspects of the model
- Simultaneous optimisation results in better fit overall
- BUT there are difficulties! → May be inconsistencies in model or between model and obs
- Need to account for different no. of obs/error correlations
- Important to get right! → impact on future predictions

Thank you!

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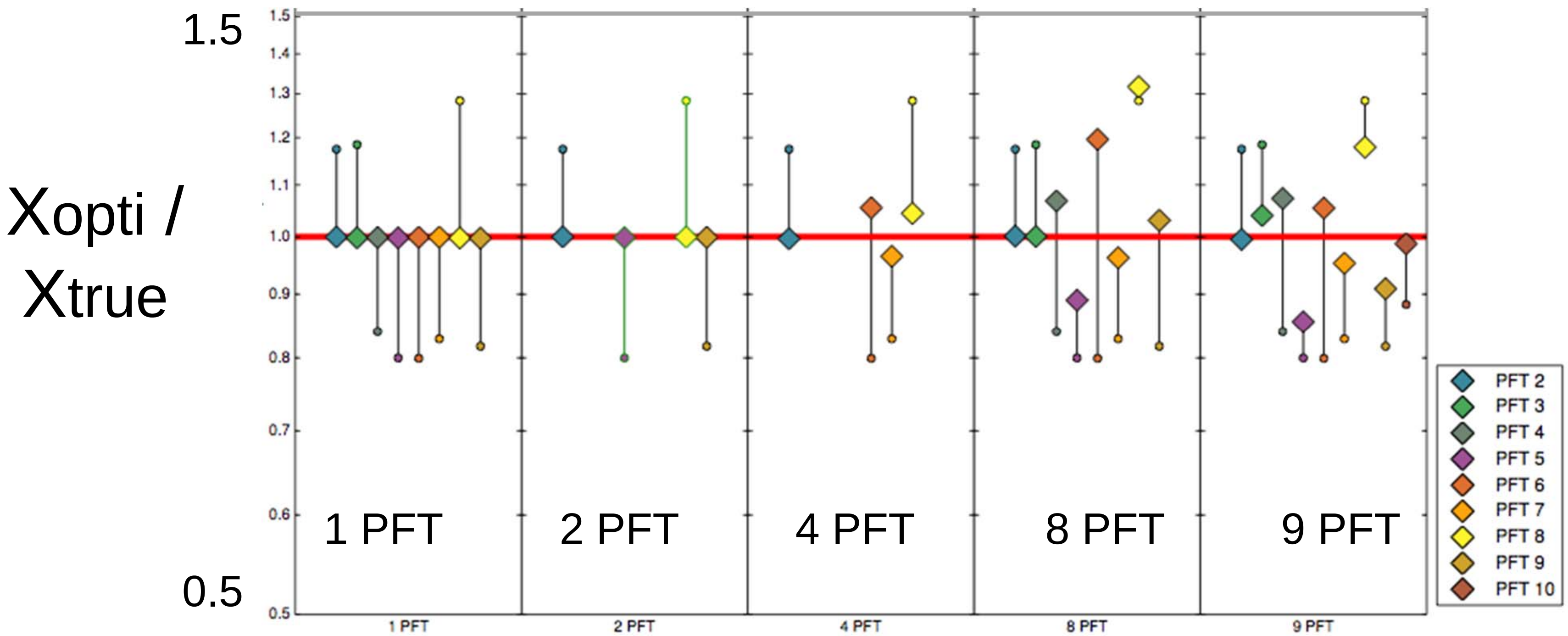
Work undertaken as part of

EU FP7-funded project:

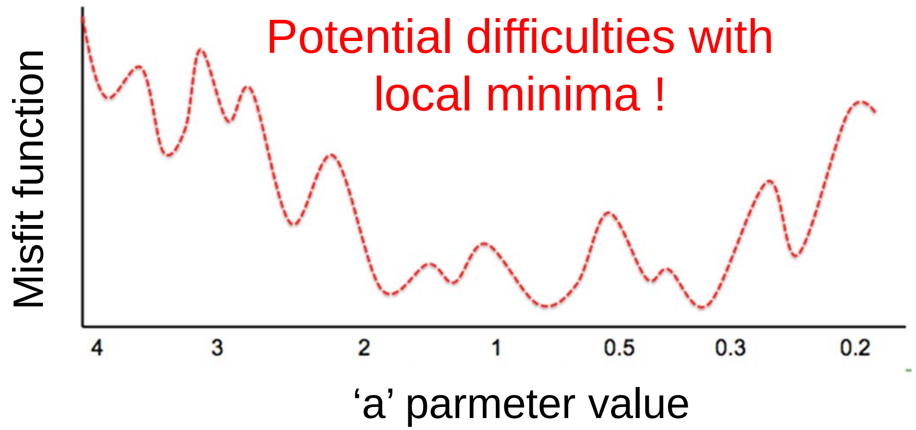
Warning: limited constraint by Atm. [CO2] data

- ➔ Tests with only Vcmax parameter (X) for several PFTs
- ➔ Pseudo data (created with perturbed parameters)
- ➔ Using either 1 / 2 / 4 / 8 / 9 PFTs
- ➔ Variational optimization



Leonard et al., in prep.

Ensemble versus Variational optimization method



Experiment with ORCHIDEE model:

- FluxNet sites: assimilation of daily NEE/LE with 20 parameters

- Create Pseudo-Data with randomly perturbed parameters (within 50% of allowed range)

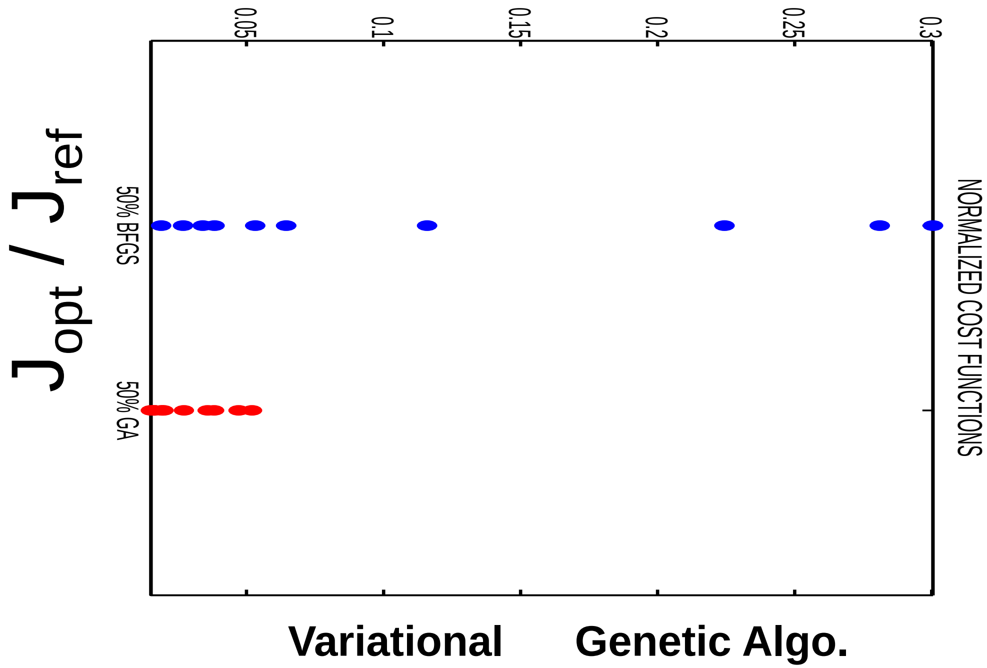
- 10 optimisations
  - Variational scheme : 10 different first guest X
  - Genetic Algorithm : 10 different experiments

- Compare J_{opt} to J_{ref} with ORCHIDEE standard param.

Genetic vs Variational algorithm

- One site: Hesse
  (Beach forest)
  20 parameters
  NEE/LE daily ;1 year

(Santaren et al, in press)



Genetic vs Variational algorithm

- One site: Hesse
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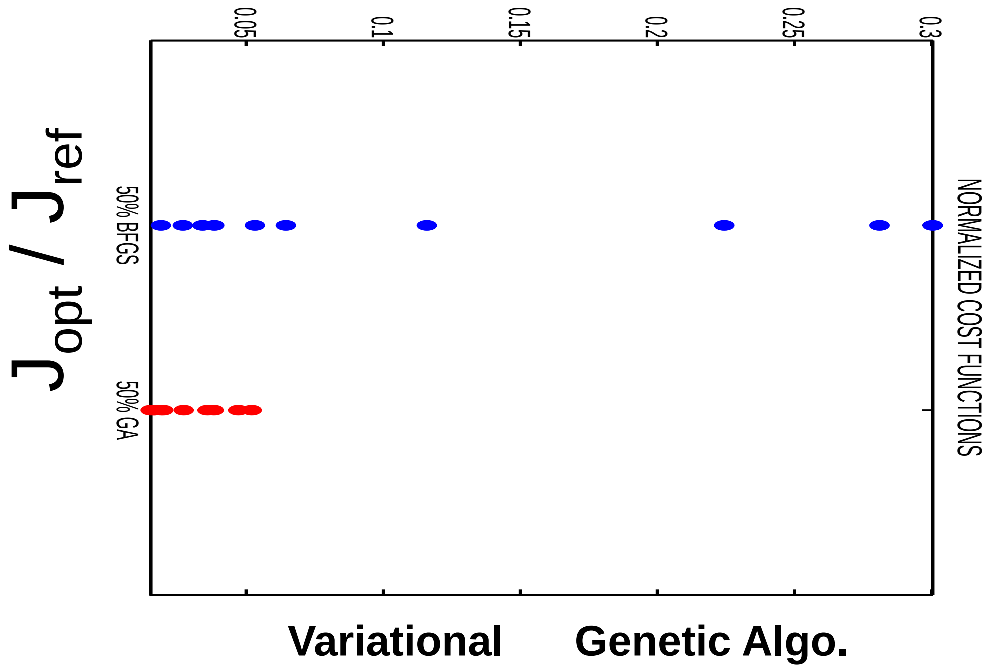
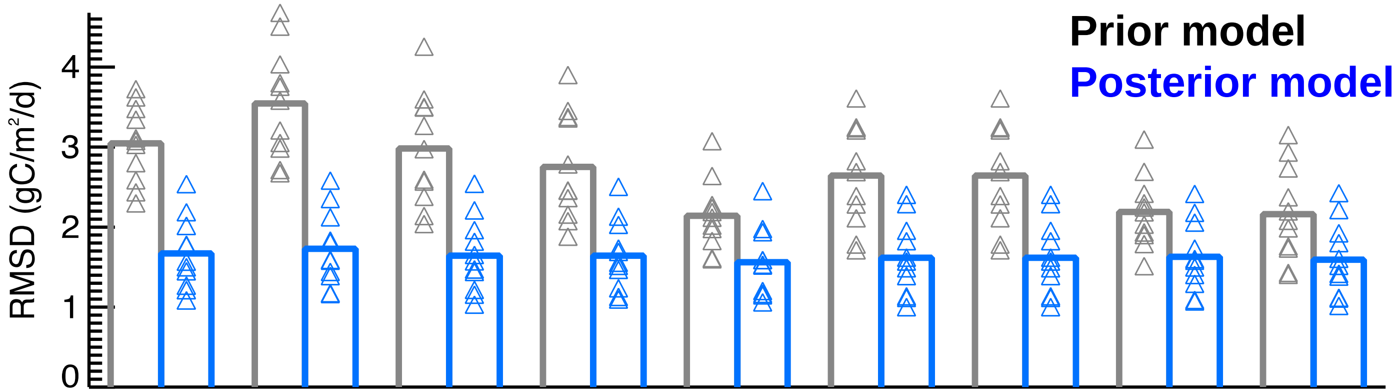
(Santaren et al, in press)



- Multi-sites simultaneously (12 DBF):

⇒ 10 tests with only variational

⇒ RMSD at all sites



Outline : Scientific & technical points adressed

1) Efficiency of the optimization with non linear models
   - Gradient method versus Genetic algorithm

2) Complementarity between FluxNet and NDVI data
   - Site study: assimilation of one or both data streams (Daily fluxes / weekly NDVI ; up to 20 parameters)

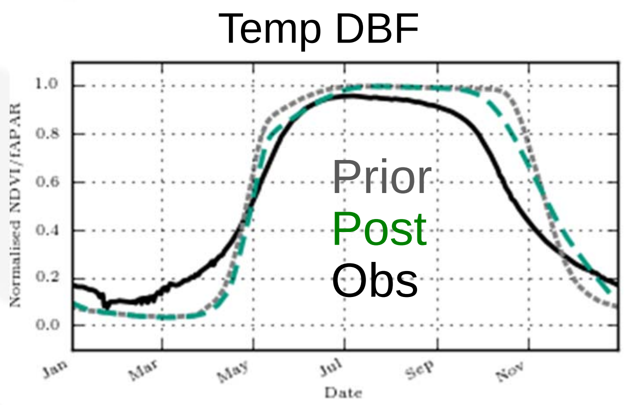
3) Information brought by Atmospheric [CO2] data
   - Fit to the atmospheric data
   - Constraint on ORCHIDEE parameters & pools
   - Difficulties of the multi-data streams assimilation

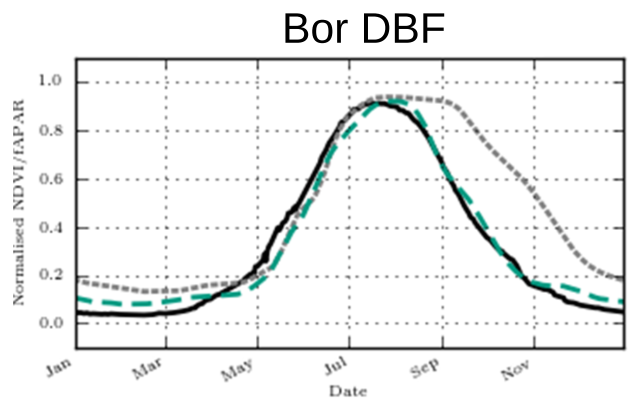
4) **Few results with a stepwise assimilation approach**
   - **Reanalysis of the pas 20 years C fluxes**

Stepwise approach (20 yr): a compromise!

Step 1:
MODIS-NDVI

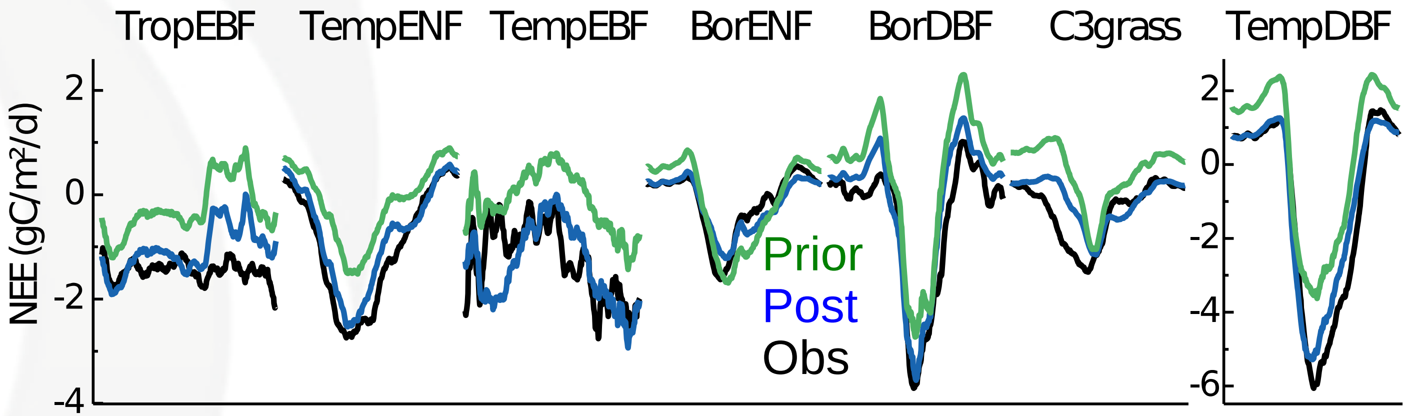
4 params /PFT





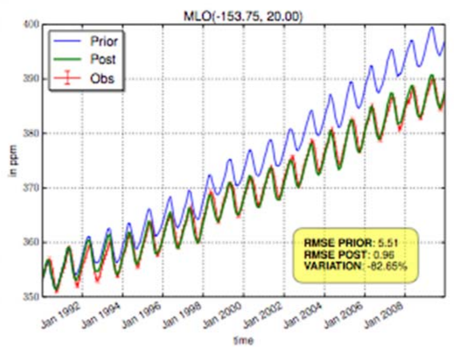
Step 2:
75 fluxnet data

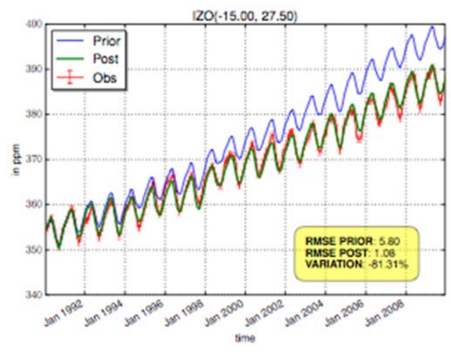
≈ 20 params /PFT



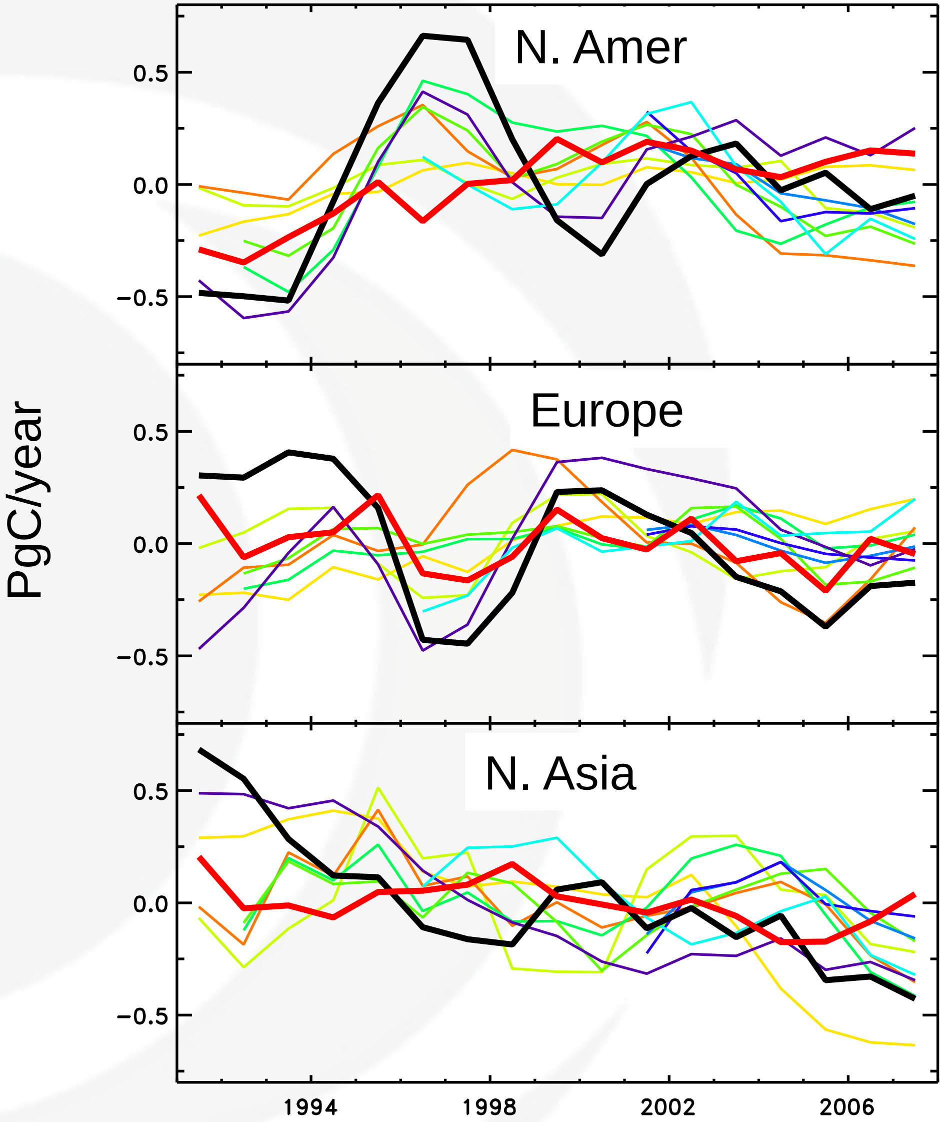
Step 3:
Atmospheric data

≈ 100 params total





Estimated land Carbon fluxes (anomalies)



Comparison with Atmospheric Inversions

CCDAS-Parameter optim

LSCE-flux optim

JENA_s96

LSCE_var

CTrac_US

CTrac_EU

C13CCAM

C13MATCH

TRCOM

RIGC

JMA

Assimilation of FluxNet NEE and LE **(STEP 2)**

- Improved fit of NEE for all 7 PFTs and modest improvement for LE
- Posterior misfit gives insights on missing model processes
- Improve fit to atm [CO_2] annual cycle, especially for Boreal regions
- Doesn't degrade fit to MODIS NDVI observations

Median correlation value	prior	post1	post2
PFT 6 temperate broad-leaved summergreen	**0.88**	**0.89**	**0.91**
PFT 8 boreal broad-leaved summergreen	**0.54**	**0.53**	**0.57**
PFT 9 boreal needeleaf summergreen	**0.36**	**0.91**	**0.91**
PFT 10 C3 grass	**0.53**	**0.59**	**0.59**

Still…

- Fit to atm [CO2] far from optimal
- Long-term trend not well captured
- IAV not improved at site-scale