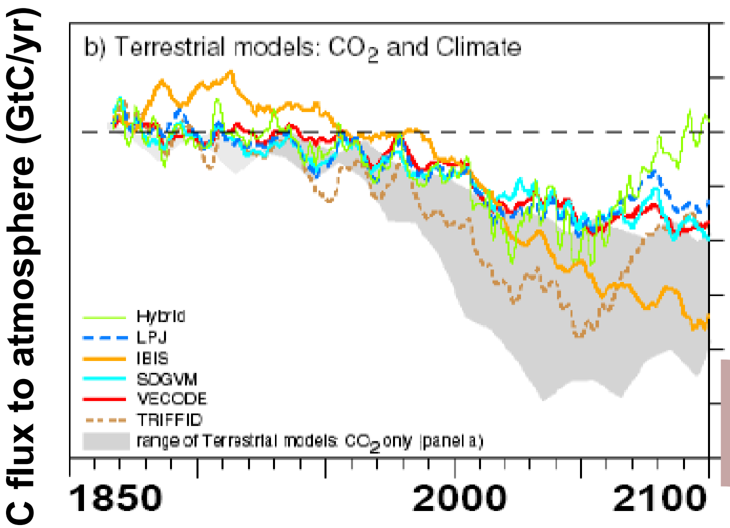
Principle and example of parameter optimisation with ORCHIDEE : the application to Tibetan grassland ?

Philippe Peylin, Hui Yang, Sushi Peng, Natasha MacBean, Cédric Bacour, Vladislav Bastrikov, Tea Thum, Fabienne Maignan, Sylvain Kuppel, Frédéric Chevallier, Philippe Ciais, Shilong Piao

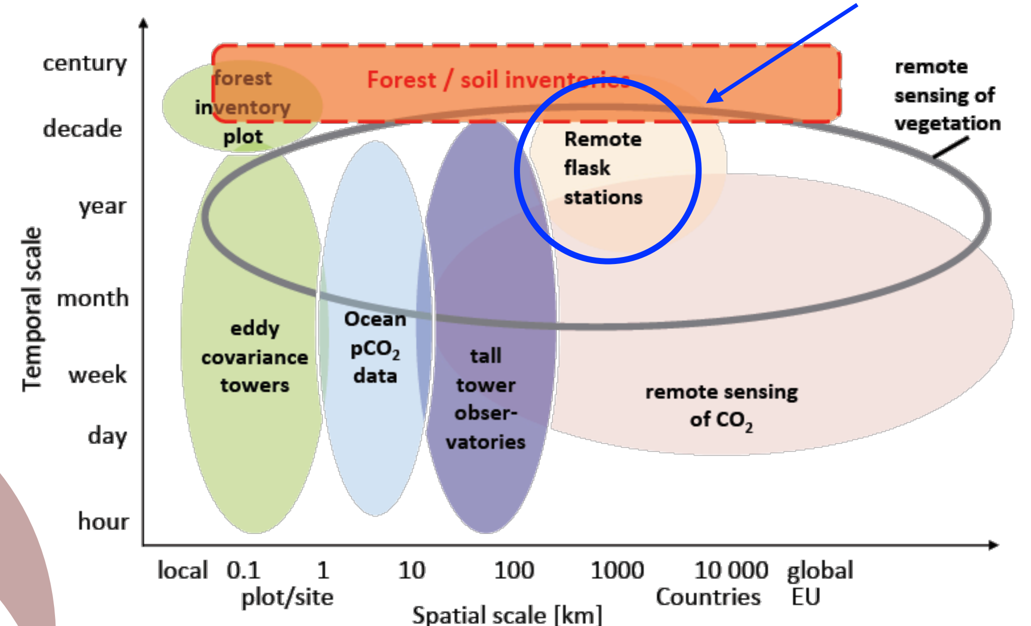
Laboratoire des Sciences du Climat et de l'Environnement (LSCE), France

Needs for a Carbon Cycle Data Assimilation System

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



Data streams



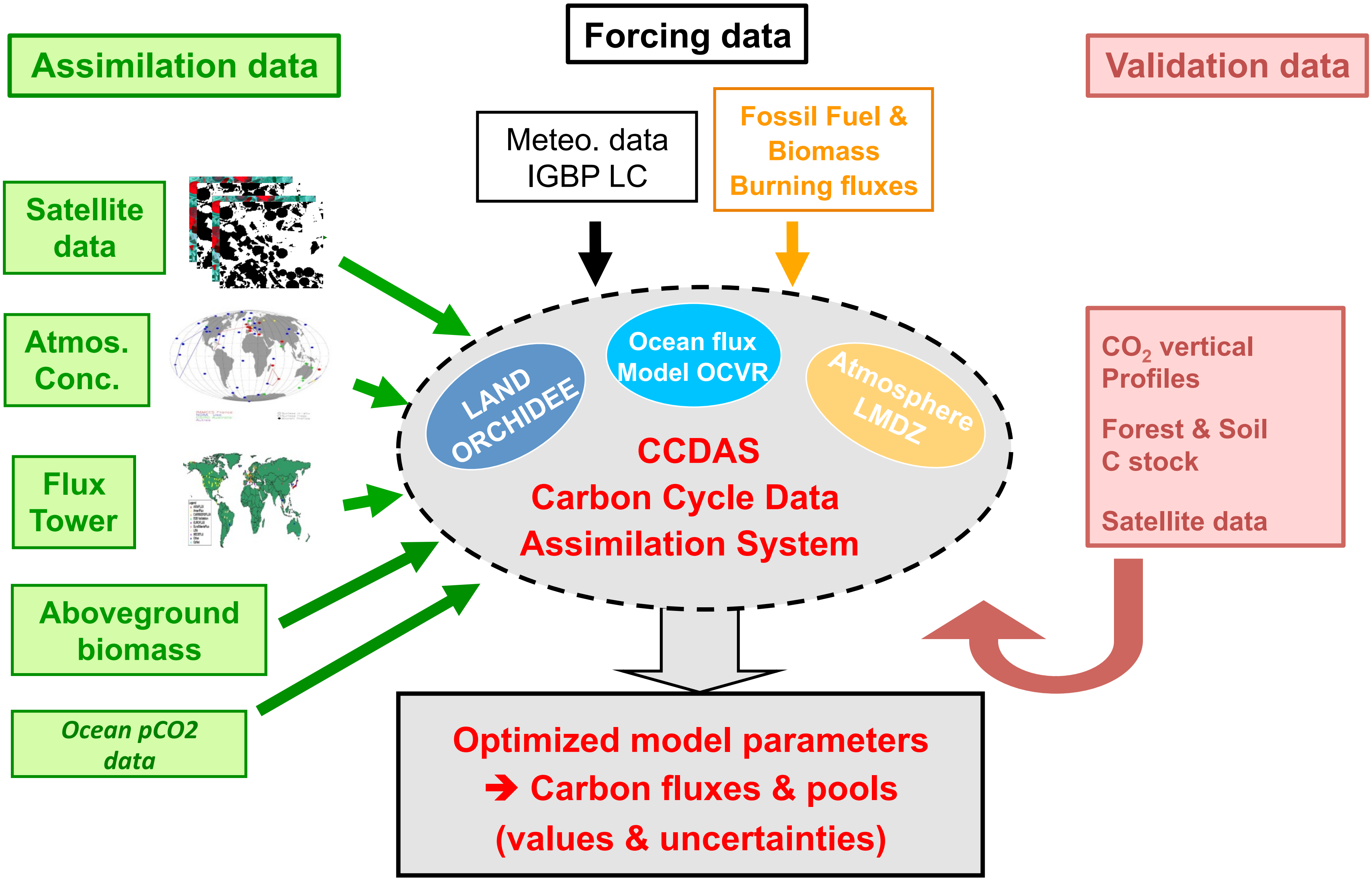
OPTIMISATION OF PARAMETERS
→ Data Assimilation

Optimized ecosystem models
➔ reduce the spread ?

Improve:

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

Structure of the LSCE CCDAS



ORCHIDEE data assimilation systems…

- Several systems have been developed at LSCE….

- Effort around CARBONES project lead to a system that :
  - Can optimize many ORCHIDEE parameters
  - Work at local scale or global scale
  - Assimilation of many data stream separately or together: FluxNet, satellite NDVI, [CO2], Biomass,..
  - Use 2 different approaches to minimize a cost function:

$$J(\mathbf{x}) = (\mathbf{x} - \mathbf{x}_b)^{\mathrm{T}}\mathbf{B}^{-1}(\mathbf{x} - \mathbf{x}_b) + (\mathbf{H}\mathbf{x} - \mathbf{y})^{\mathrm{T}}\mathbf{R}^{-1}(\mathbf{H}\mathbf{x} - \mathbf{y})$$

    - Variational approach based on BFGS algorithm
    - Monte Carlo approach based on Genetic algorythm

Outline : specific points addressed

1) **Example of optimisation with different data streams**

   Optimisation with biomass and in situ flux data

   Complementarity between FluxNet and NDVI data

   Information brought by atmospheric [CO2] data

2) **Preliminary results for Tibetan grassland sites**

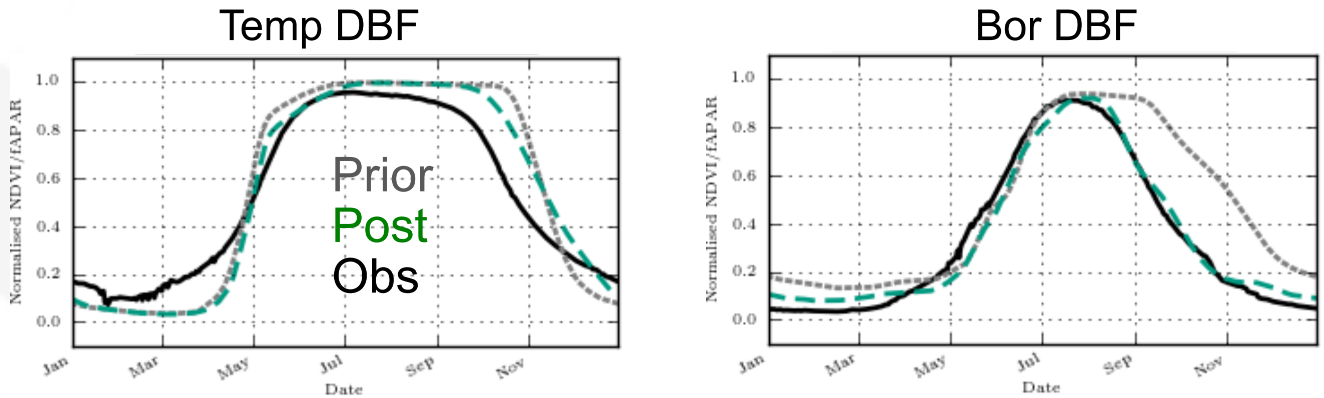
   Single site optimisations

   Multi-site optimisations

Stepwise approach (20 yr): a compromise!

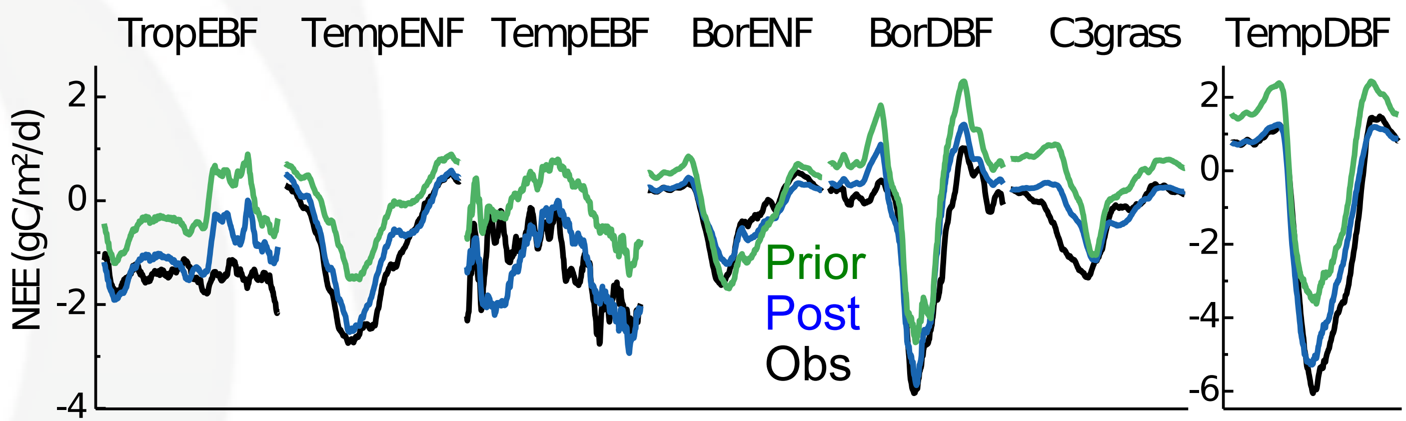
MODIS-NDVI

4 params /PFT



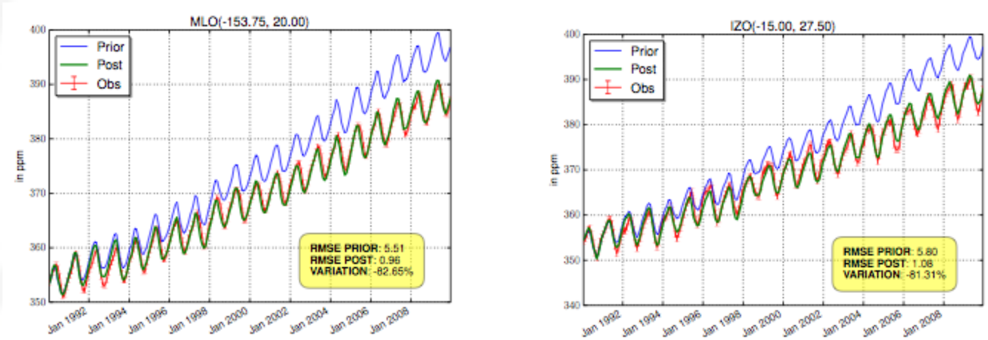
75 fluxnet data

≈ 20 params /PFT



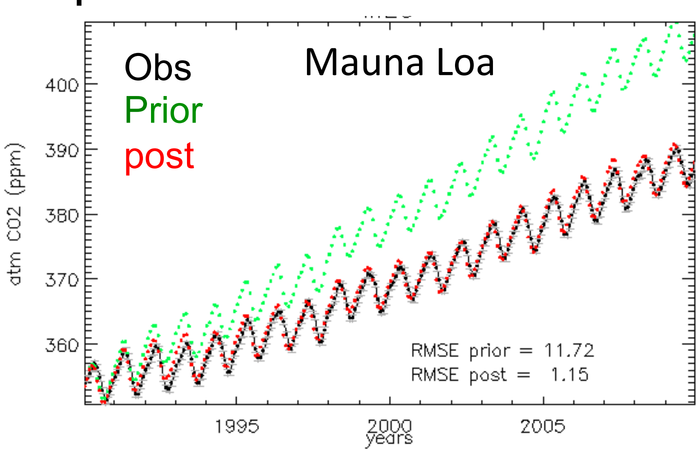
Atmospheric data

≈ 100 params total



Assimilation of atmospheric [CO_2] data

Optimization of the CO2 trend

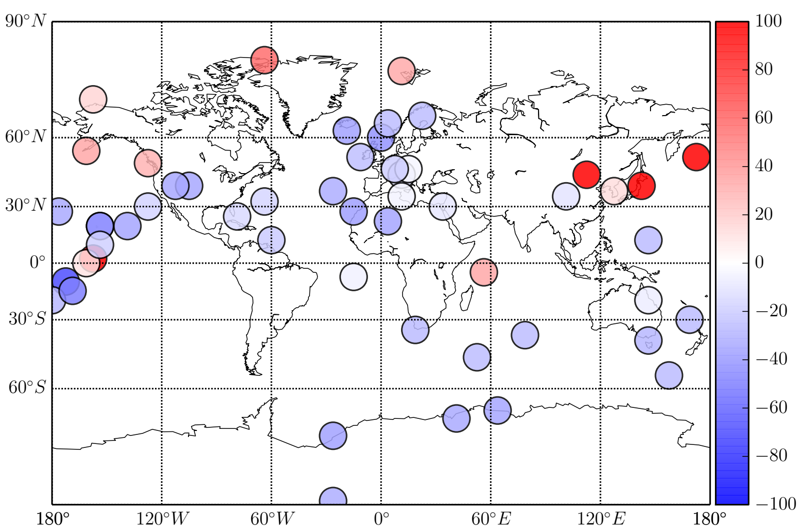


Signal decomposition:

- Amplitude : max – min
- Phase : CPU

(1 – RMSE_poste / RMSE_prior)

Seasonal amplitude



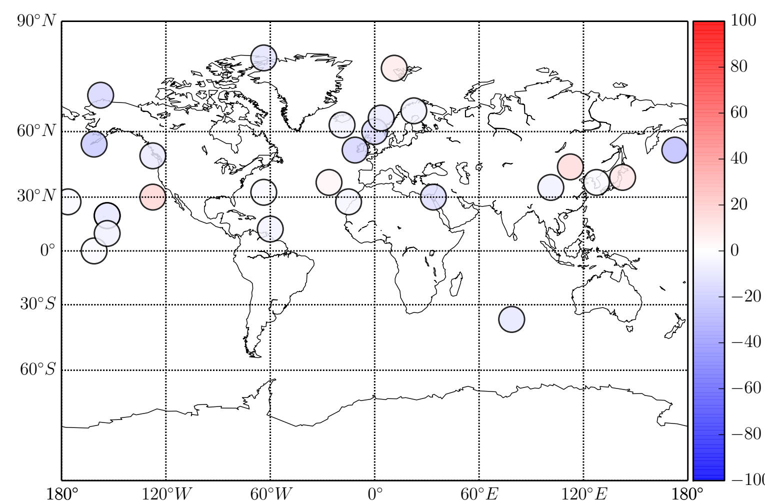
100%

Degradation

Improvement

- 100%

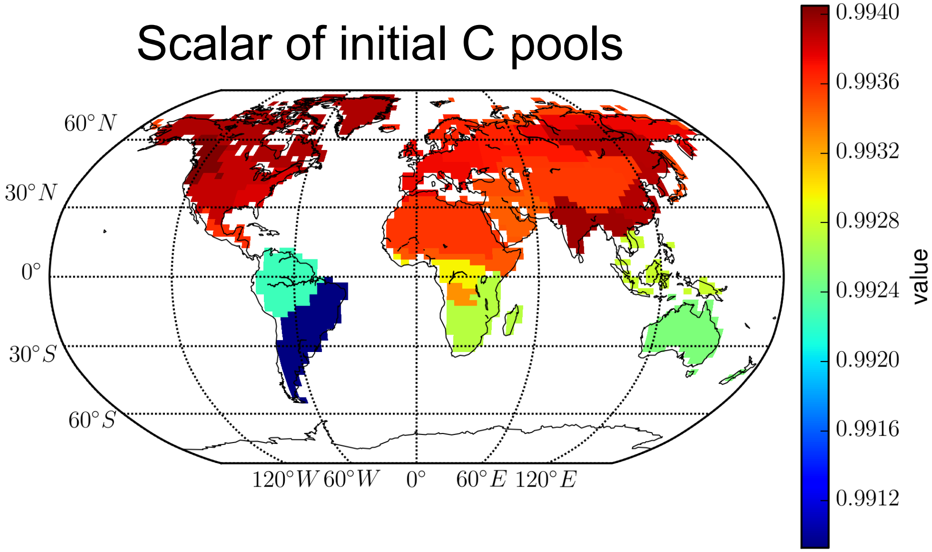
Carbon uptake period length



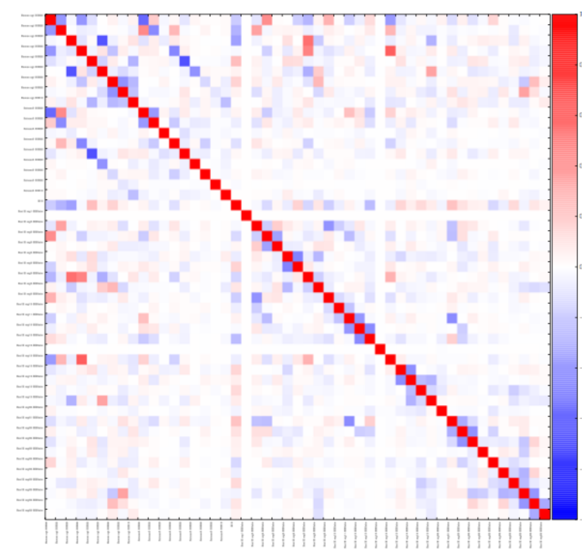
Assimilation of atmospheric [CO_2] data

➔ Primary constraint on:

- Soil initial carbon pools..



➔ But significant error correlations btw parameters



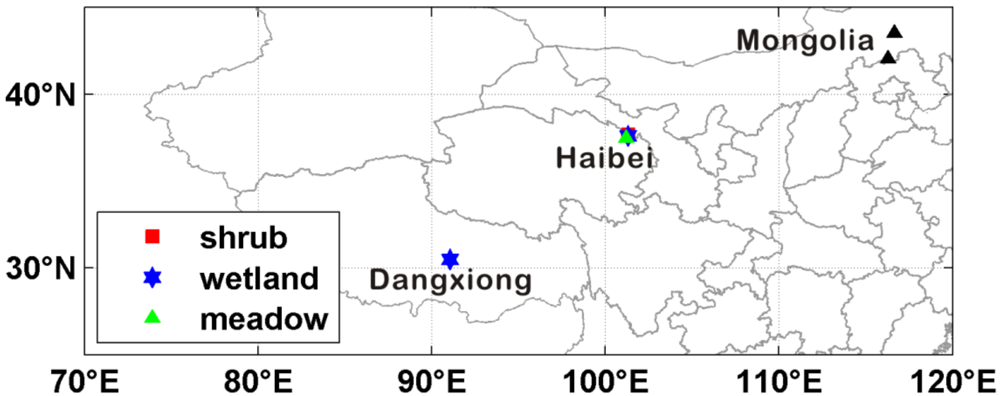
Grassland in ORCHIDEE….

➔ One PFT (unique set of params) for very different ecosystems…






Parameter Optimiztion in the Tibetan Plateau



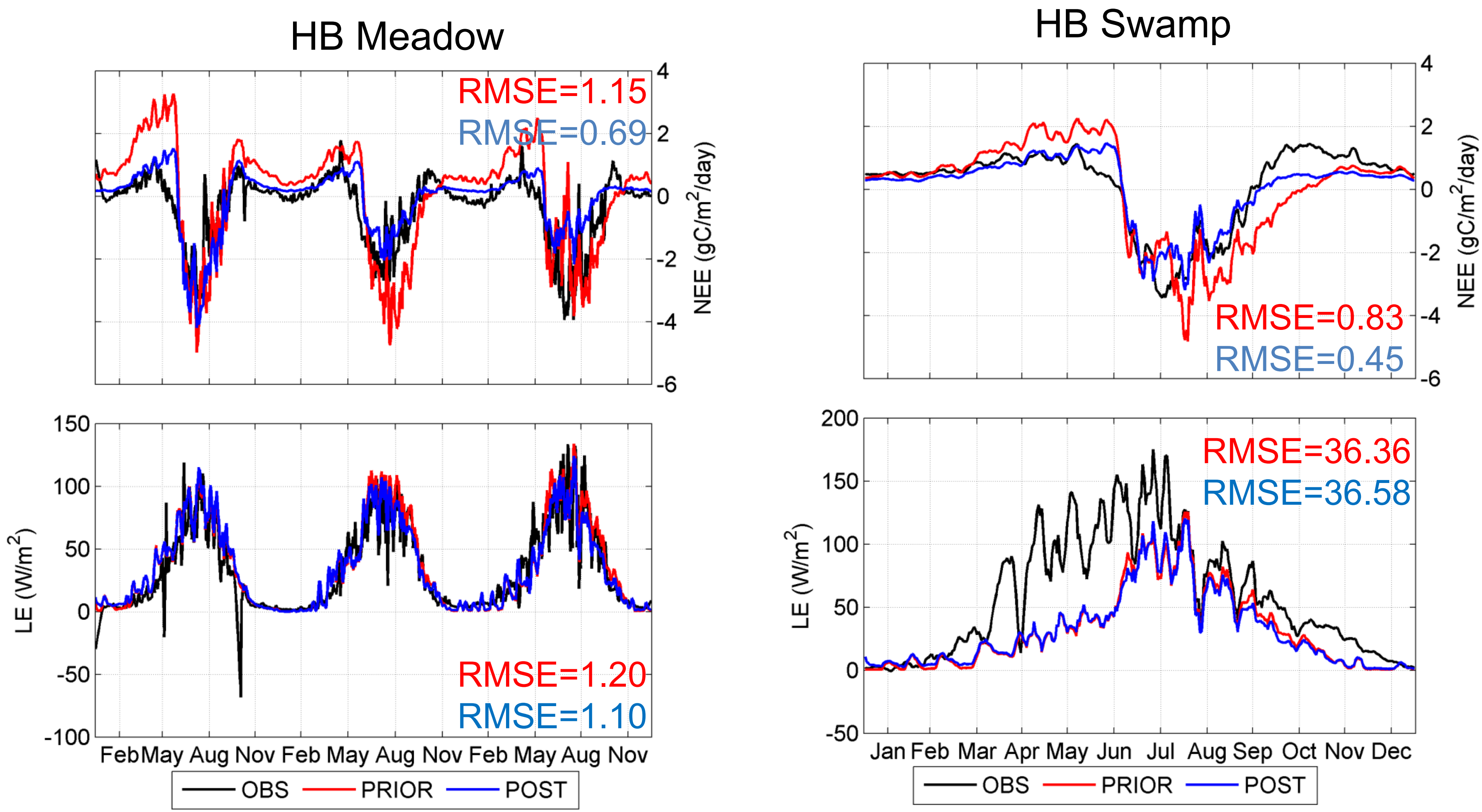
Site	Location	Altitude (m)	Vegetation type	Period
HB-meadow	37.610°N, 101.310°E	3148	Kobresia meadow	2002-2004
HB-shrub	37.670°N, 101.330°E	3293	Alpine shrub meadow	2004-2005
HB-SW	37.610°N, 101.330°E	3160	Swamp meadow	2004
DX-SW	30.470°N, 91.060°E	4286	Swamp meadow	2010-2012

- 11 Grassland sites
- Meteorological data (Temperature, Precipitation, Radiation, Wind, Humidity)
- Flux data (NEE, GPP, LE, H)

→ Selection of 4 sites

→ Optimisation of 29 parameters

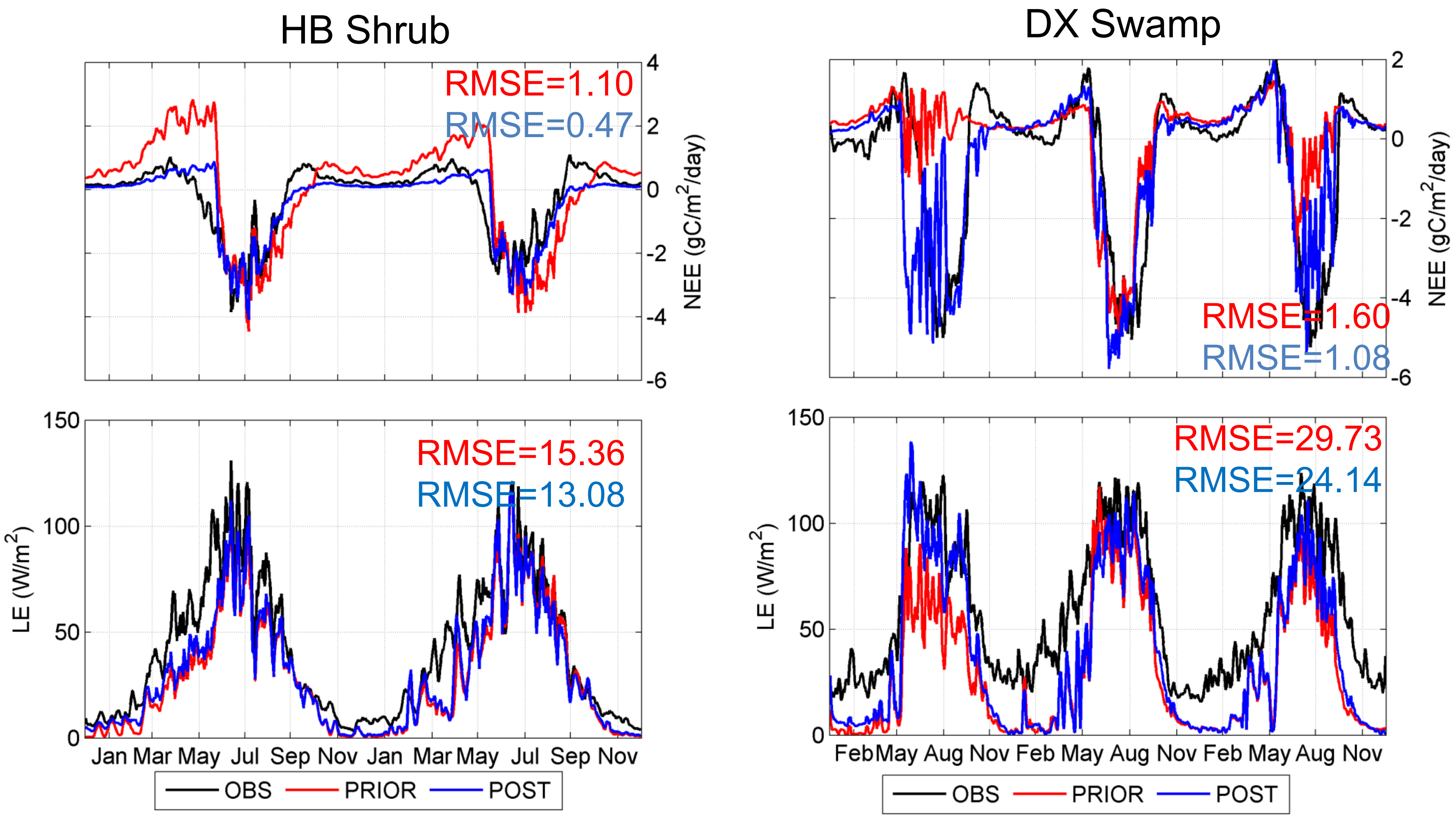
Part 1. Single Site Optimization



1. Recurrent overestimation of the winter carbon release
2. Overestimation of the summer carbon uptake
3. Significant phase shift at some sites (onset and senescence)
4. Recurrent underestimation of the latent heat

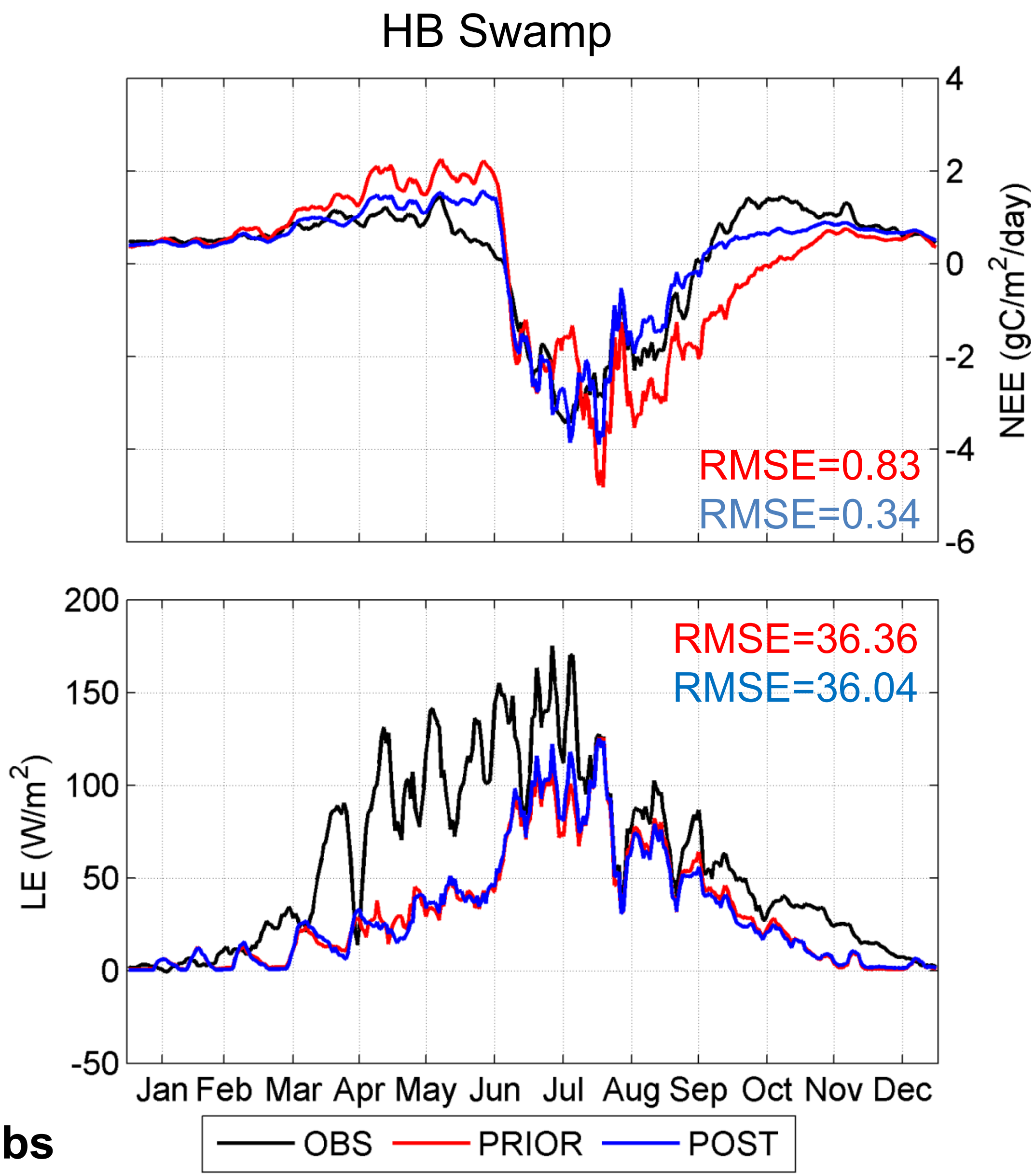
Obs
Prior
Post

Part 1. Single Site Optimization



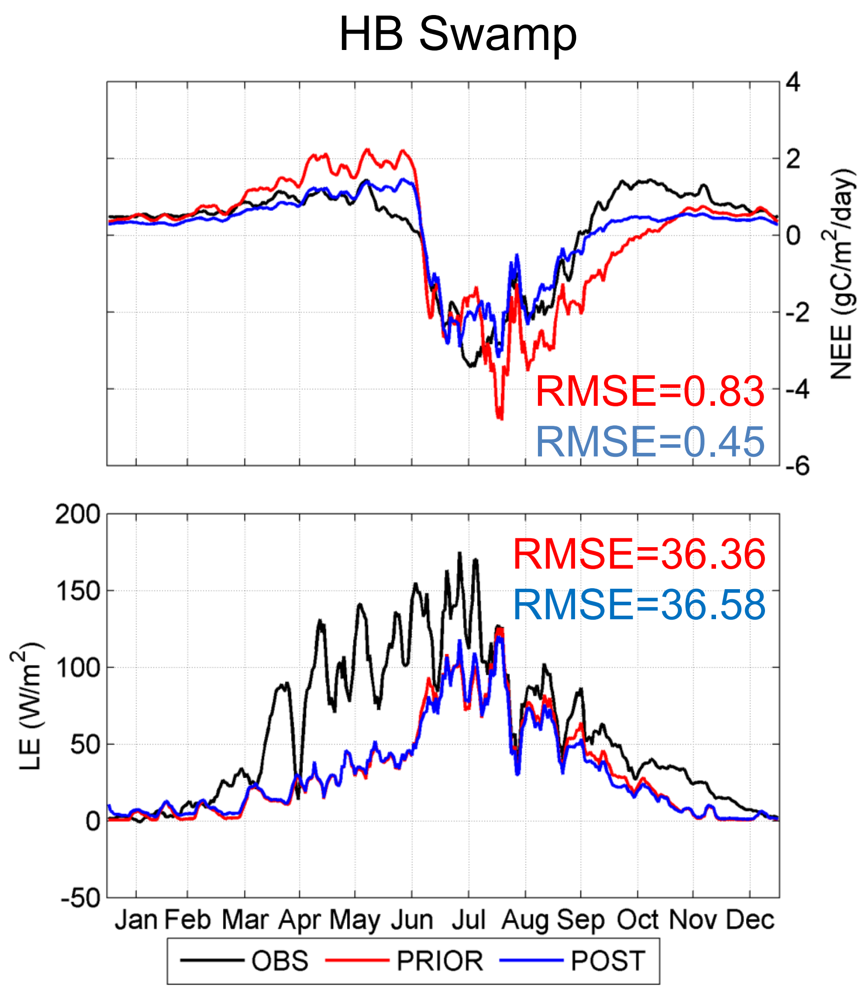
1. Recurrent overestimation of the winter carbon release
2. Overestimation of the summer carbon uptake
3. Significant phase shift at some sites (onset and senescence)
4. Recurrent underestimation of the latent heat

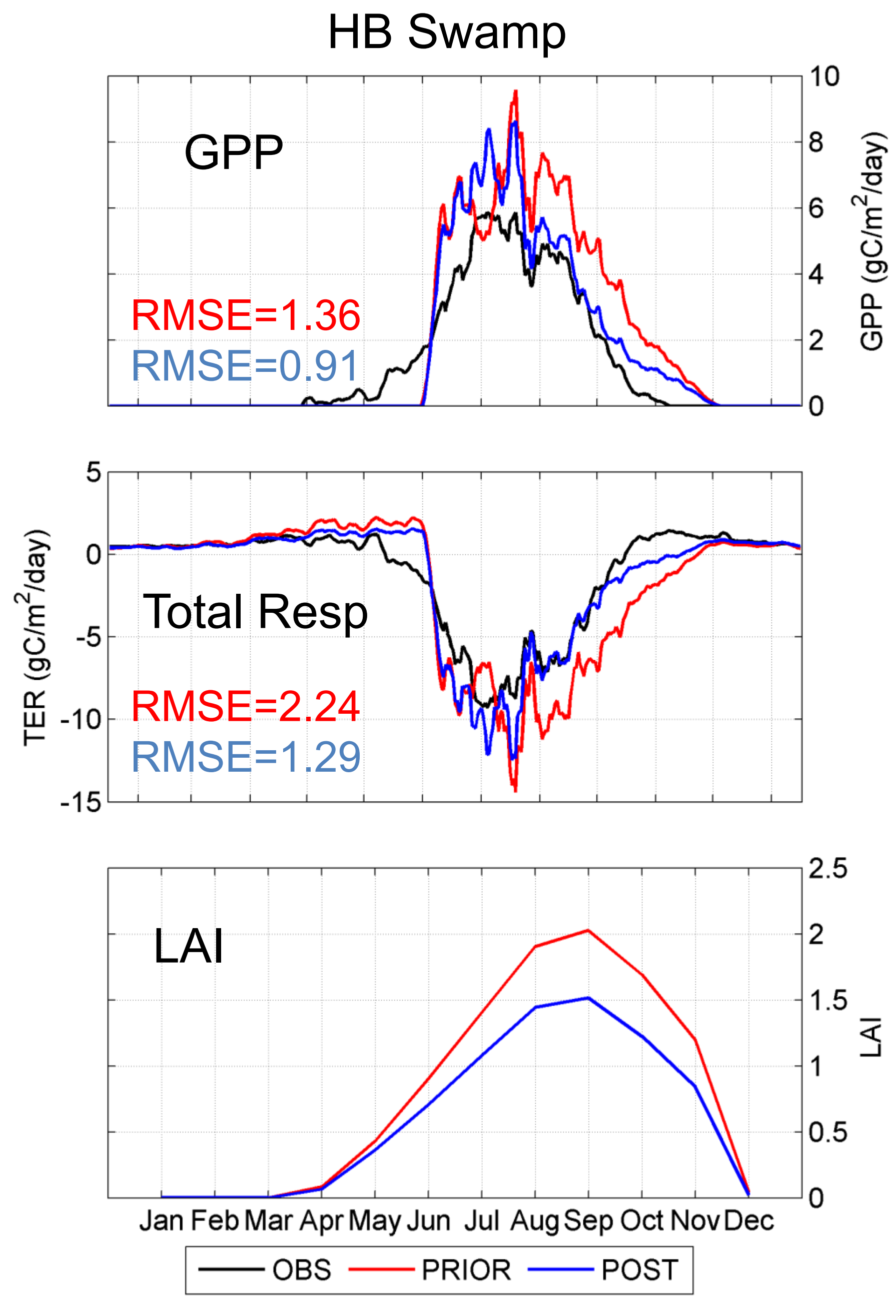
Obs
Prior
Post



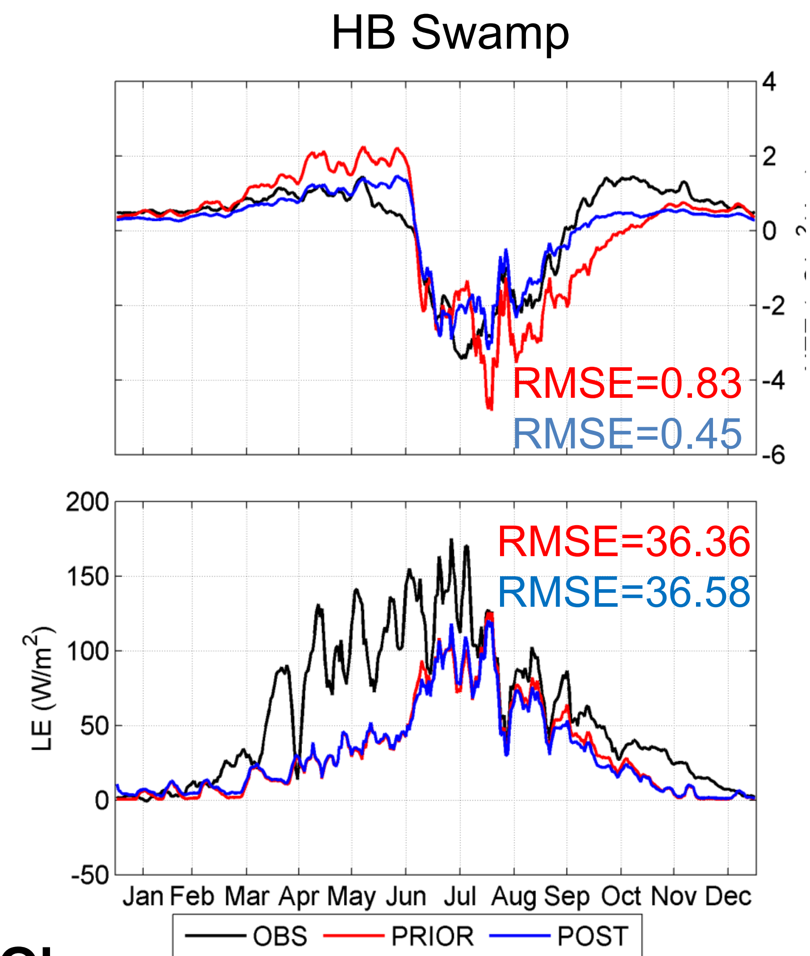
Obs
Prior
Post

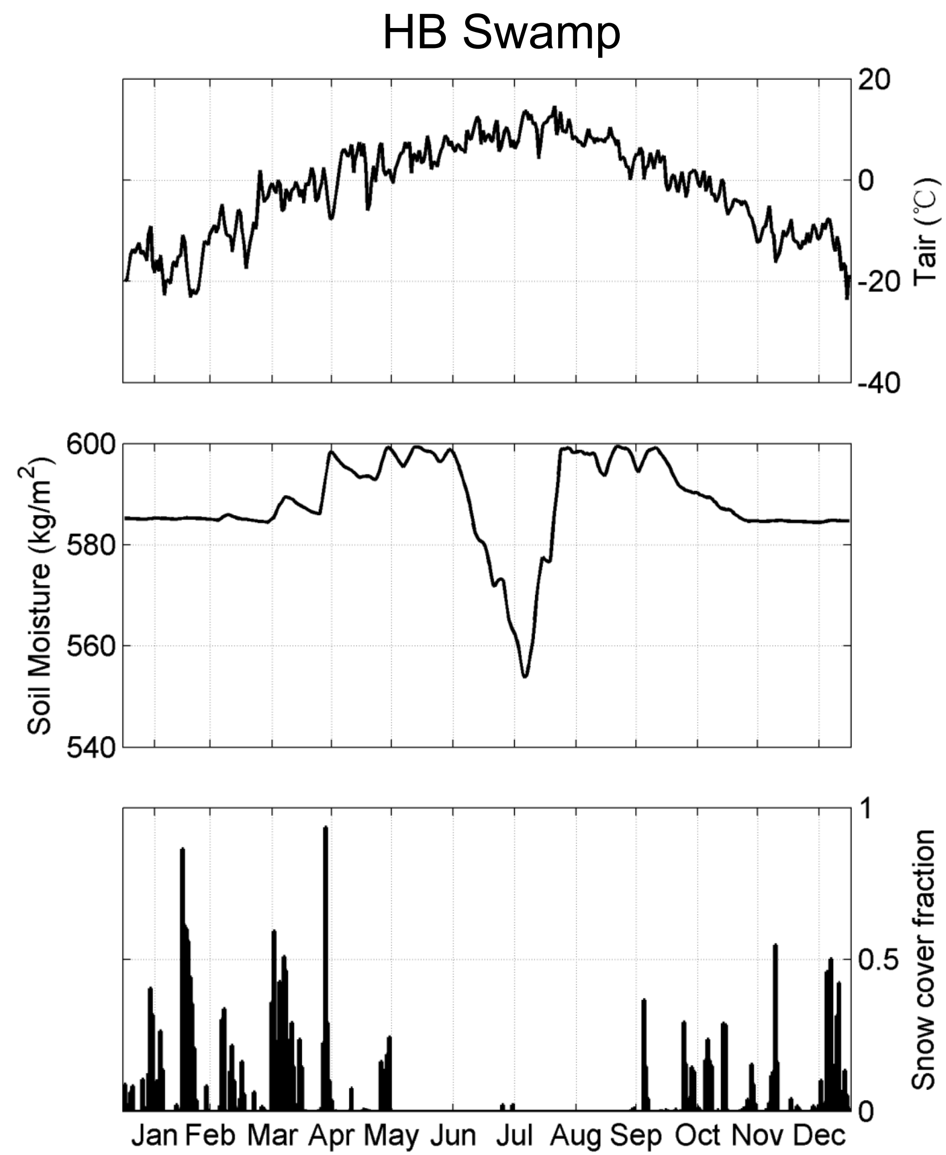
Variables	PRIOR	POST
Vcmax_opt-PFT10	70.0	75.93
Humcste-PFT10	4.0	1.0
Tphoto_min_c-PFT10	-4.0	-4.0
Tphoto_max_c-PFT10	55.0	55.0
Senescence_temp_c-PFT10	-1.375	-1.375
LAI_MAX-PFT10	2.5	2.77
SLA-PFT10	0.026	0.021
Leafagecrit-PFT10	120.0	88.43
Klaihappy-PFT10	0.5	0.56
Tau_leafinit-PFT10	11.0	10.07
Z0_over_height	0.0625	0.048
So_capa_dry	1.8	2.07
So_capa_wet	3.03	3.47
Q10	1.99	1.93
Moistcont_a	-1.1	-1.19
Moistcont_b	2.4	2.31
Moistcont_c	-0.29	-0.38
Z_decomp	0.2	0.71
Hcrit_litter	0.08	0.10
Maint_resp_c	1.4	1.81
Maint_resp_slope_c-PFT10	0.16	0.18
Frac_growthresp-PFT10	0.28	0.30
Dpu_cste	4.0	4.38
Residence_time-PFT10	0	30.0
R0	0.3	0.43
S0	0.3	0.40
Rsol_cste	3.3	1.75
Qsintcst	0.1	0.08
Defc_mult	1.5	1.5





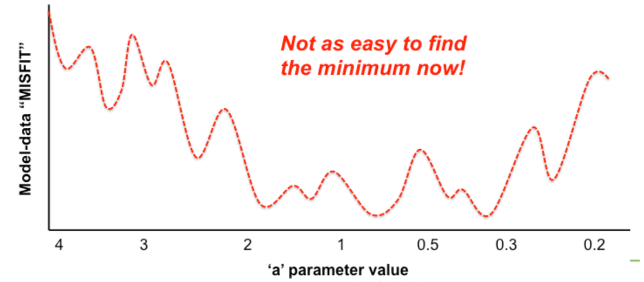
Obs
Prior
Post



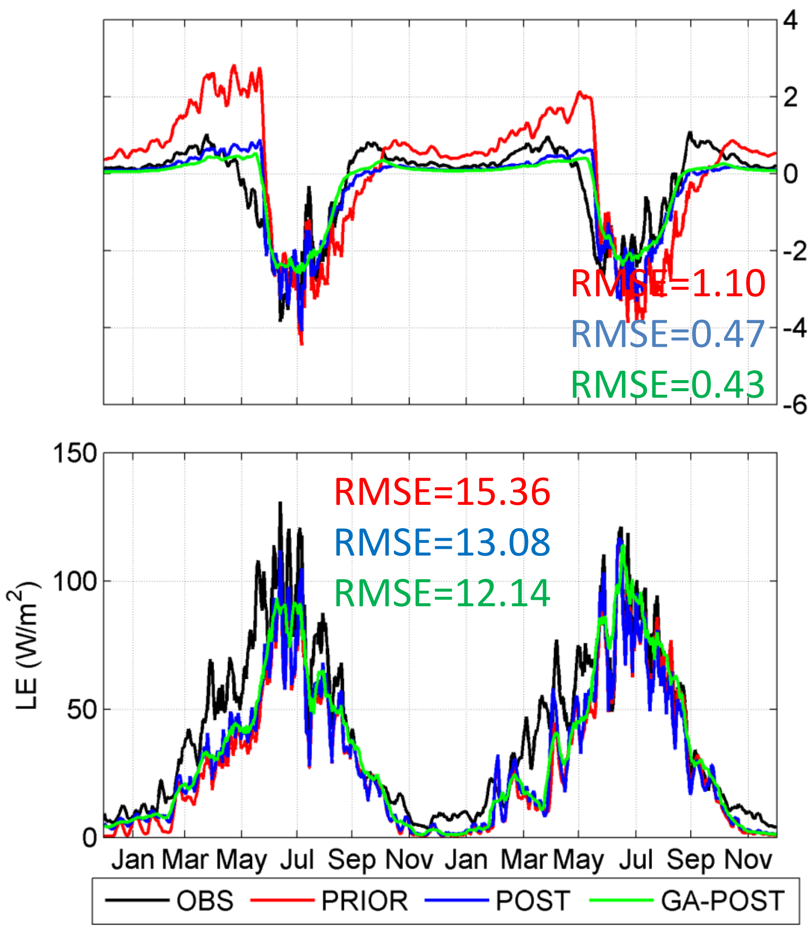


Obs
Prior
Post

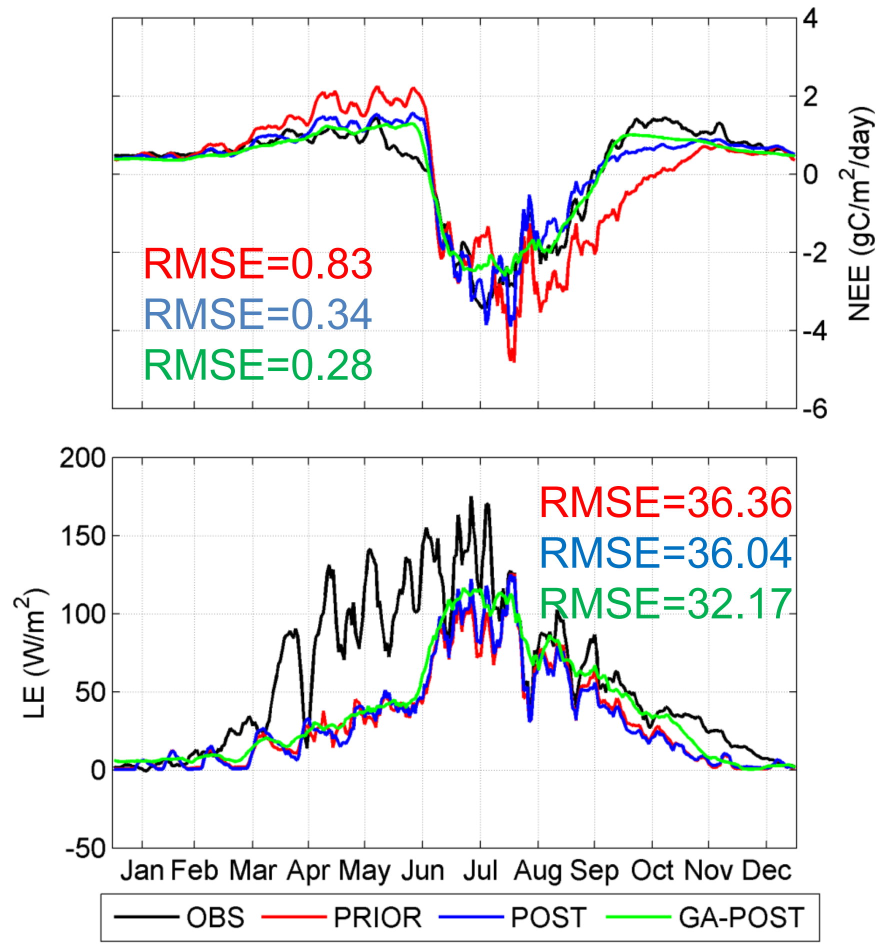
Variational versus Monte-carlo (Genetic Algo.) optimisation

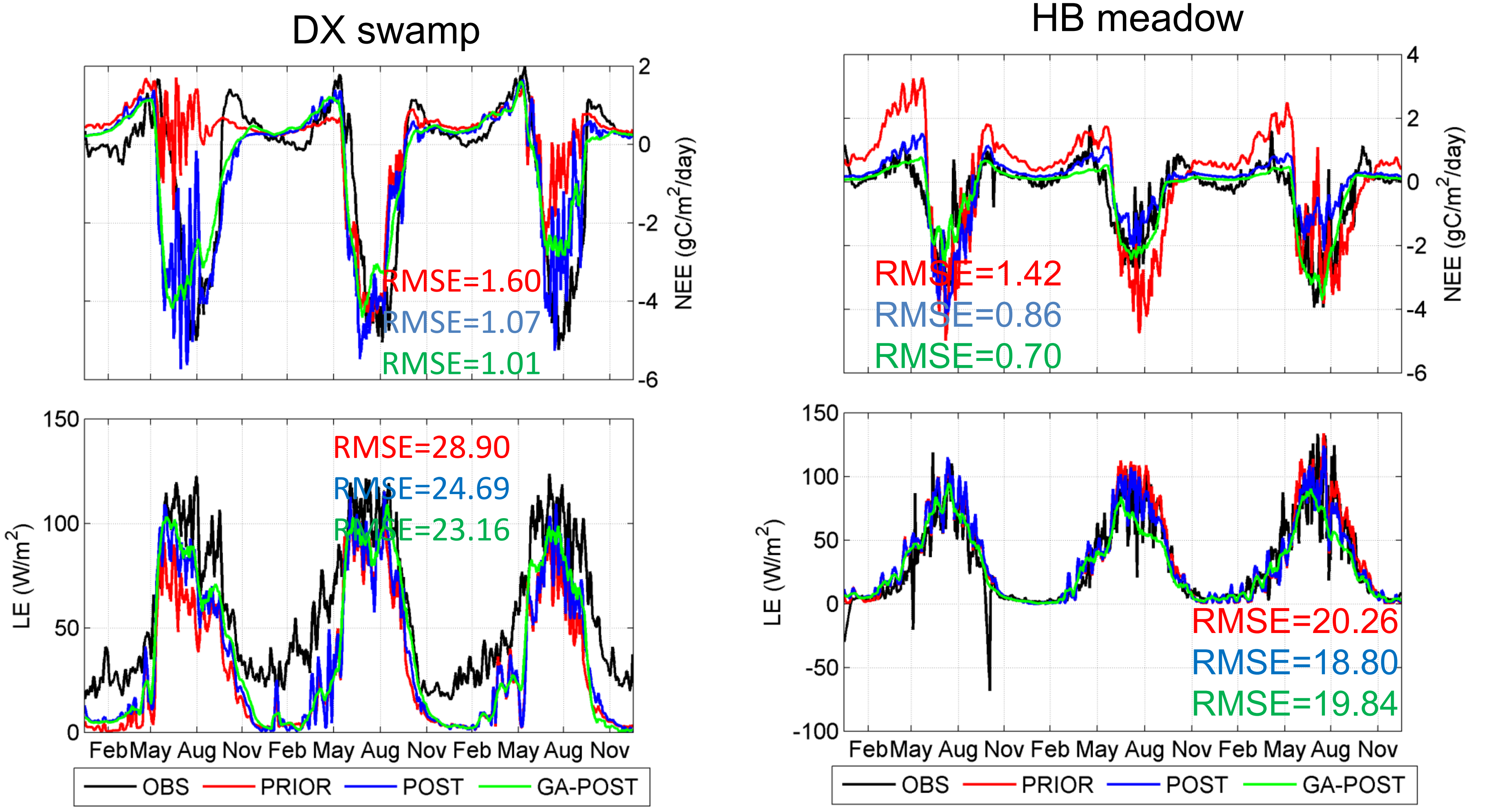


HB Shrub



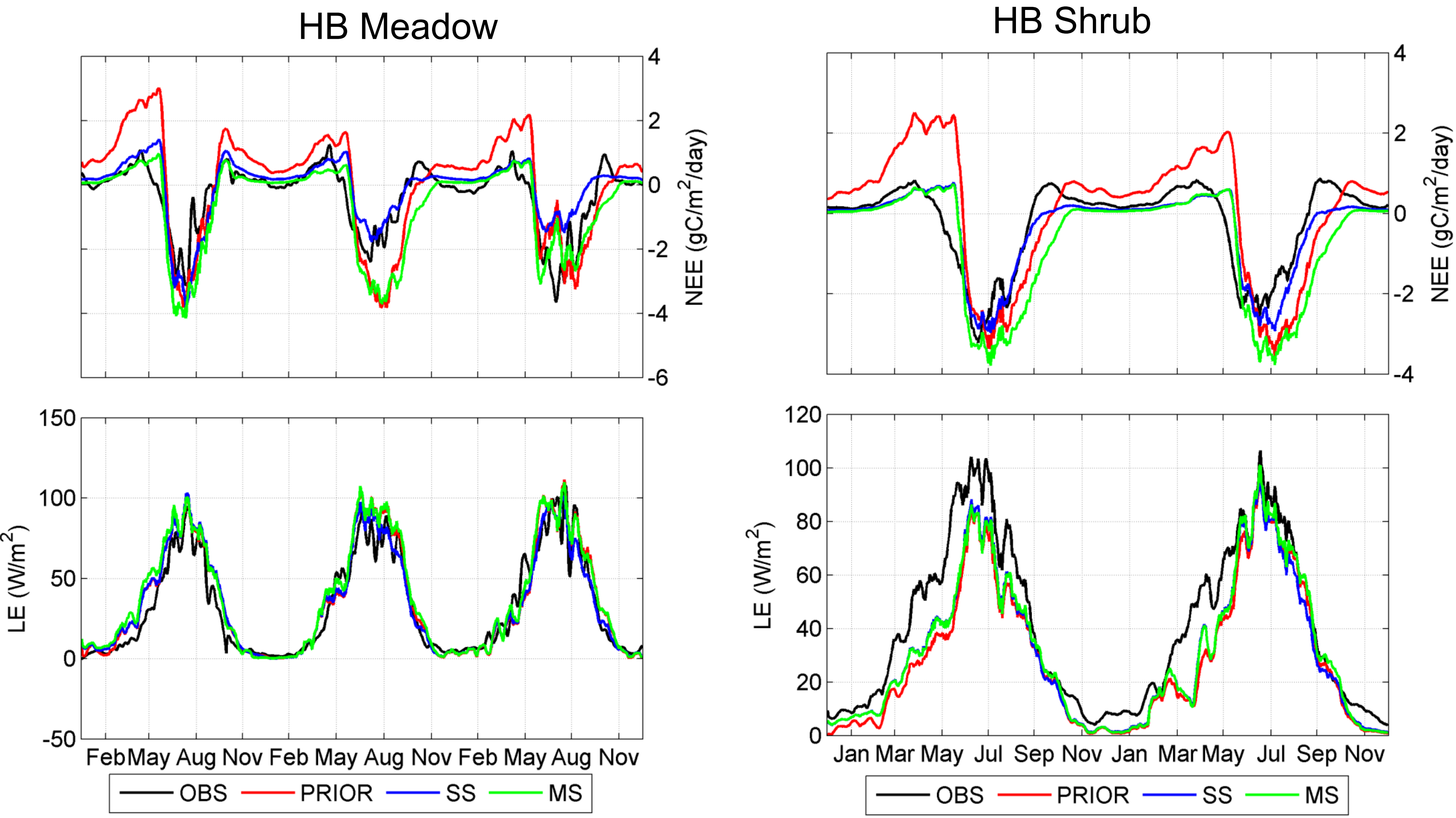
HB Swamp





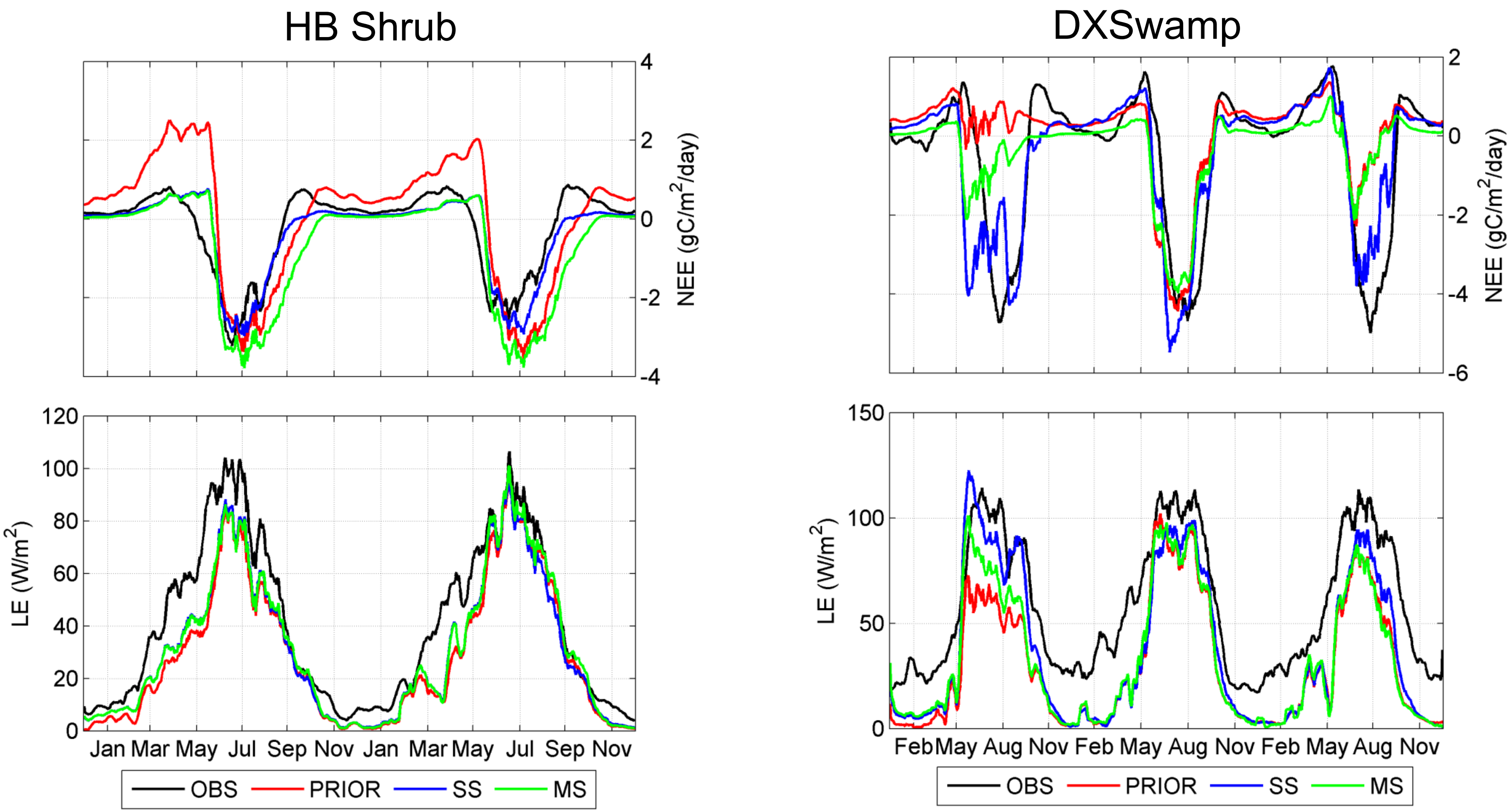
The optimization using Genetic Algorithm is generally better!
But this optimization increase computing time, and only improves a little.

Single Site optimization vs. Multi Site optimization



1. the MS parameter set significantly improves the model-data fit at most sites
2. The results of the MS optimization are often comparable to those of the SS optimizations

Single Site optimization vs. Multi Site optimization

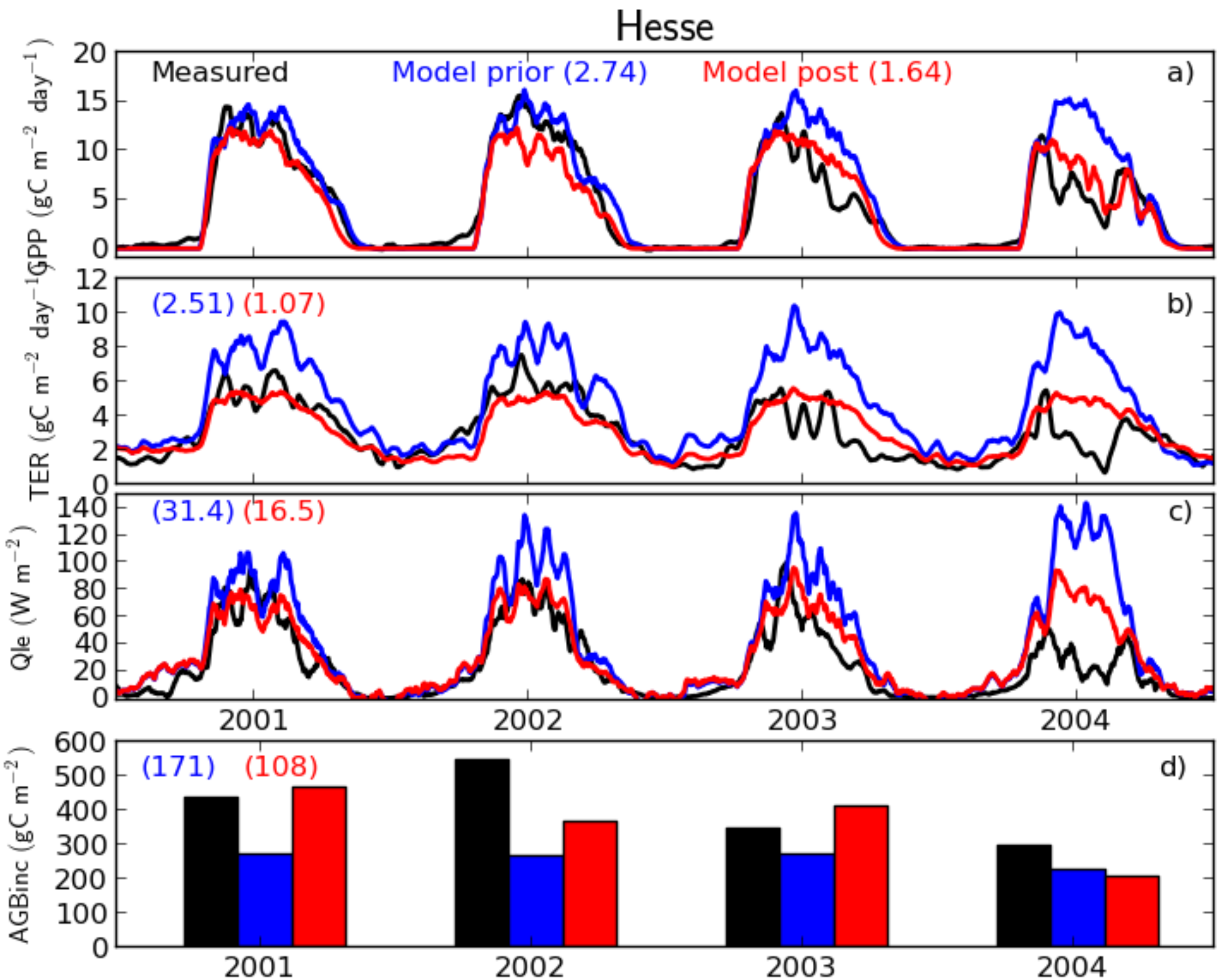


1. the MS parameter set significantly improves the model-data fit at most sites
2. The results of the MS optimization are often comparable to those of the SS optimizations

Summary and on-going work

- Preliminary results with Tibetan grassland sites
  - Optimization ➔ significantly improve NEE simulation
  - Promising appraoch to improve ORCHIDEE for « high altitude » grassland ecosystems
- 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

Joint assimilation of biomass and in situ fluxes

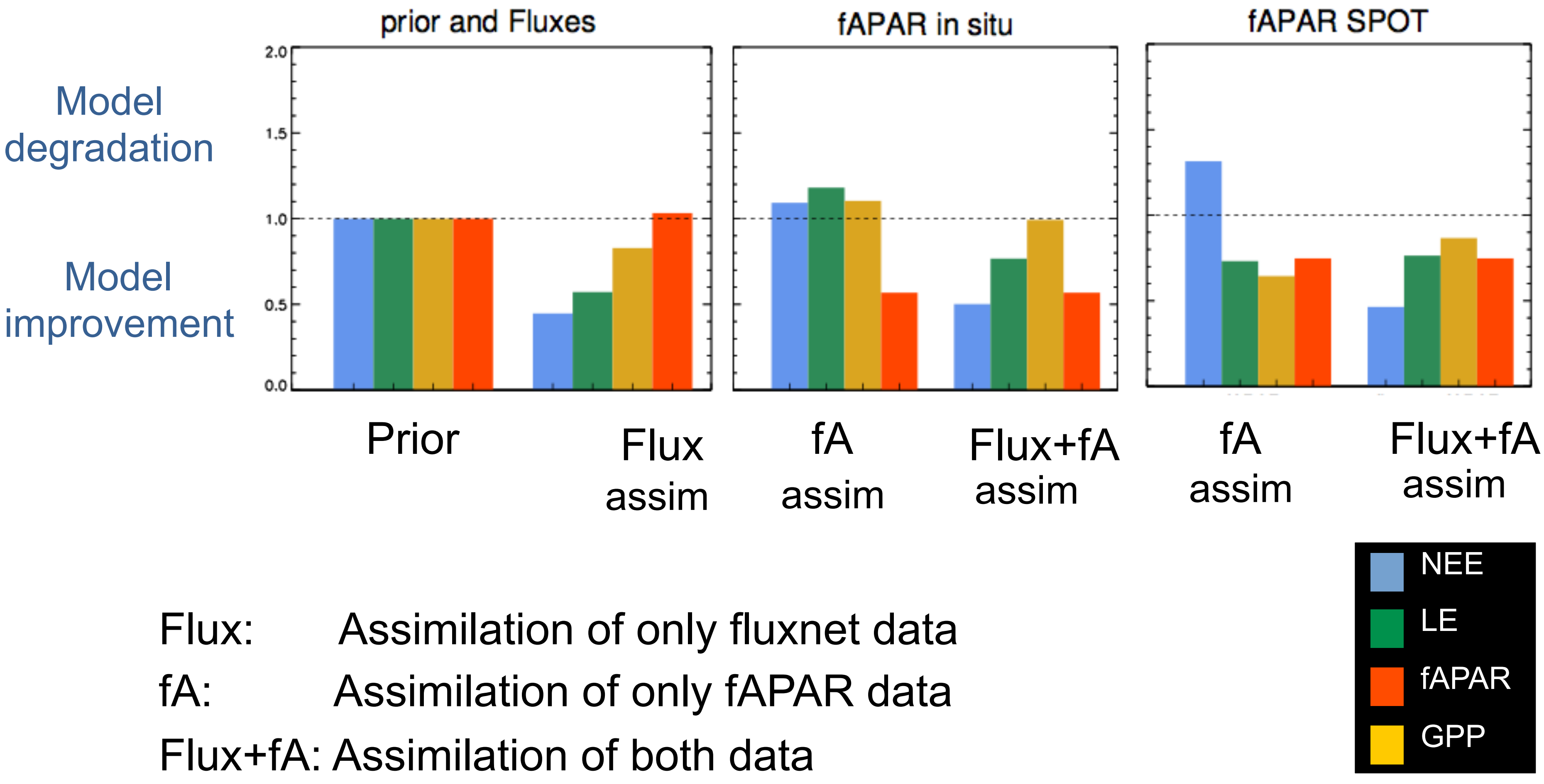


➔ Assimilate obs:
- GPP
- TER
- LE
- AGB increment

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

Joint assimilation of FluxNet and MODIS-fAPAR

➔ Fontainebleau (Oak forest) : RMSE_poste / RMSE_prior



Flux: Assimilation of only fluxnet data

fA: Assimilation of only fAPAR data

Flux+fA: Assimilation of both data

Bacour et al., in prep.

Thank you!

NOVELTIS

CLIMMOD

LSCE

orchidas.lsce.ipsl.fr

Work undertaken as part of several projects:

Carbones

GEOCARBON

Name	Description	Value	Name	Description	Value
- Carbon					
Vcmax_opt	Maximum carboxylation rate		Senescence_temp_c	Temperature threshold for senescence	
Tphoto_min_c	Minimal photosynthesis temperature		Leafagecrit	Average critical age for leaves	
Tphoto_max_c	Maximum photosynthesis temperature		Qsintcst	interception reservoir coefficient	
Senescence_temp_c	Temperature threshold for senescence		Maint_resp_c	Maintenance respiration coefficient	
LAI_MAX	Maximum LAI per PFT		Maint_resp_slope_c	slope of maintenance respiration coefficient	
SLA	Specific leaf area		Rsol_cste	Evaporation resistance	
Dpu_cste	Total depth of soil water pool		Residence_time	residence time of trees	
S0	sapwood allocation		So_capa_dry	Dry Soil Capacity	
Z0_over_height	Characteristic rugosity length		So_capa_wet	Wet Soil Capacity	

Name	Description	Value
-Energy and Hydrology		
Klaihappy	LAI threshold to stop carbohydrate use	
Tau_leafinit	time required to develop a minimal LAI	
Frac_growthresp	fraction of GPP which is lost as growth respiration	
Humcste	Root profile	
Defc_mult	Constant in the computation of surface resistance	
Q10	Temperature dependence of heterotrophic respiration	
Z_decomp	Maximum depth for soil decomposer's activity	
Moistcont_a	Soil moisture coefficient	
Moistcont_b	Soil moisture coefficient	
Moistcont_c	Soil moisture coefficient	