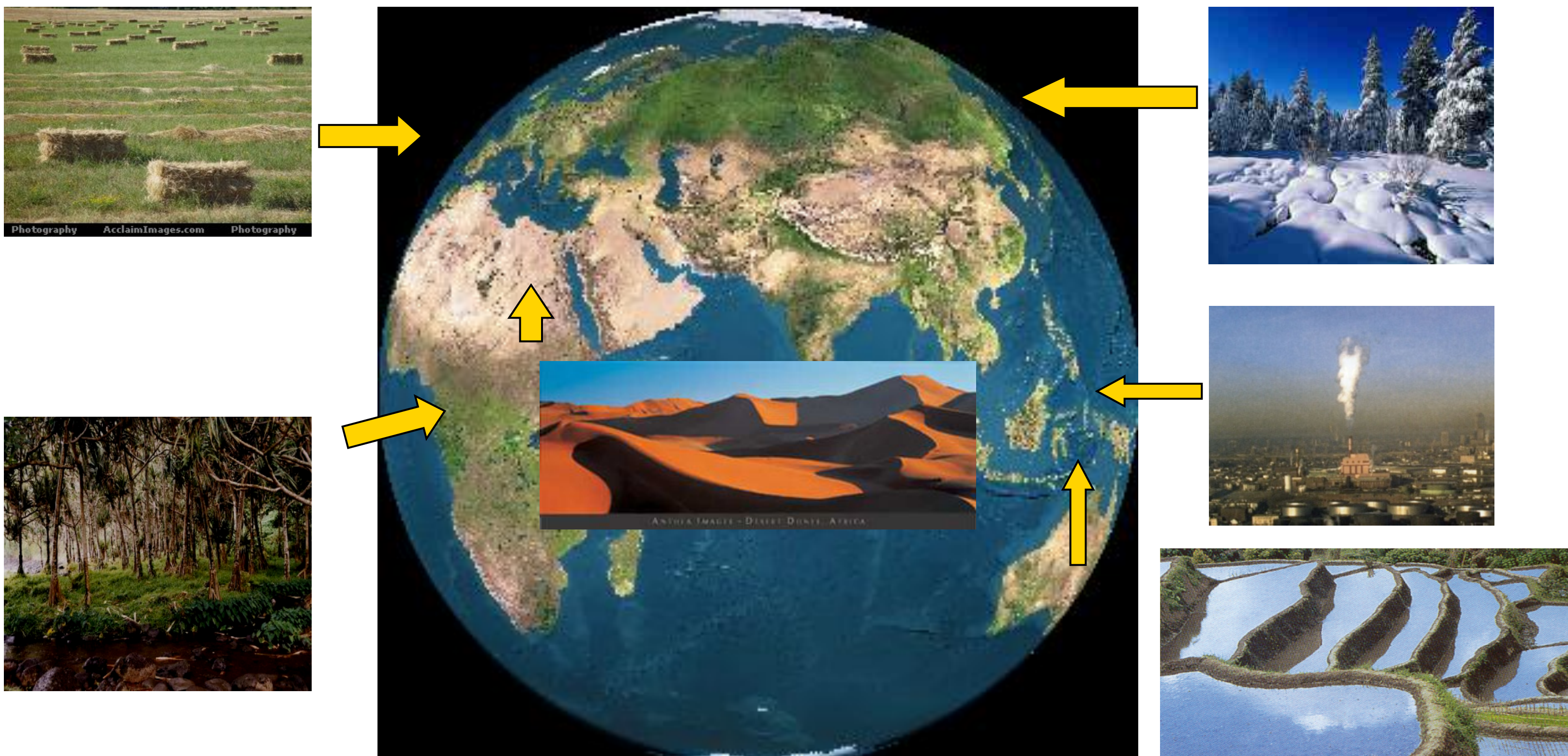
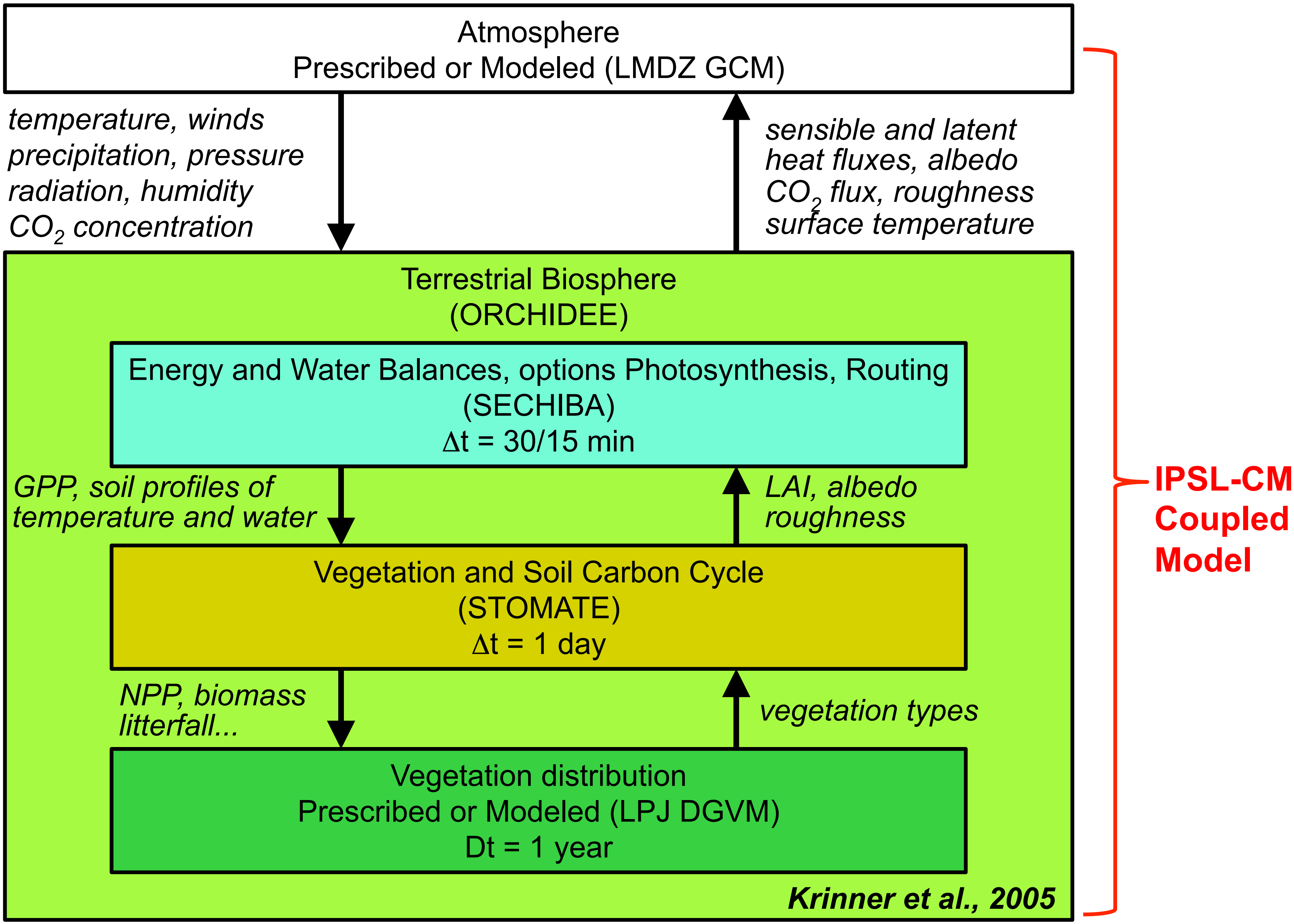
Dynamic Global Vegetation Model ORCHIDEE

Simulates the Energy, Water and Carbon balance
Land component of the IPSL Earth System Model



ORCHIDEE



Atmosphere
Prescribed or Modeled (LMDZ GCM)
temperature, winds
precipitation, pressure
radiation, humidity
CO_2 concentration
sensible and latent
heat fluxes, albedo
CO_2 flux, roughness
surface temperature
Terrestrial Biosphere
(ORCHIDEE)
Energy and Water Balances, options Photosynthesis, Routing
(SECHIBA)
Δt = 30/15 min
GPP, soil profiles of
temperature and water
LAI, albedo
roughness
Vegetation and Soil Carbon Cycle
(STOMATE)
Δt = 1 day
NPP, biomass
litterfall...
vegetation types
Vegetation distribution
Prescribed or Modeled (LPJ DGVM)
Dt = 1 year
Krinner et al., 2005
IPSL-CM
Coupled
Model

More than 20 permanents, Few laboratories

LSCE – Paris (Biogeochemistry and Biophysics): 10 permanents
P. Ciais, A. Cozic, N. De Noblet, J. Lathière, S. Luyssaert, F. Maignan, C. Ottlé, P. Peylin, N. Viovy, N. Vuichard ; 10-15 Post-Doc / PhD

IPSL (Engineering) : M.A. Foujols, J. Ghattas

LMD – Paris (Energy and Water balance):
F. Chéruy, J. Polcher, C. Risi ; 2-3 Post-Doc / PhD

SISYPHE – Paris (Water cycle):
A. Ducharne + 2 Post-doc / PhD

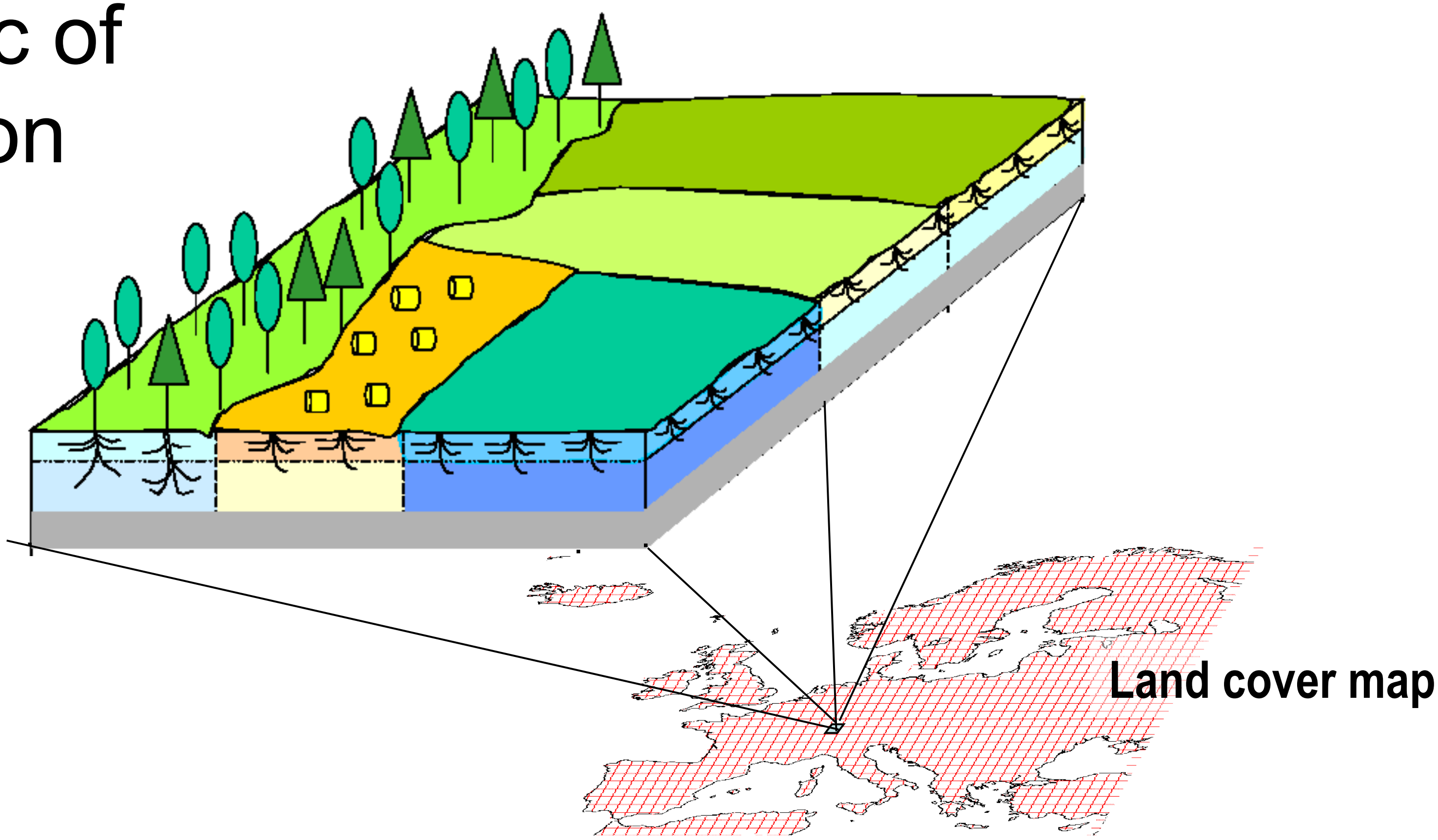
LGGE - Grenoble (High latitude processes):
G. Krinner ; 3 Post-doc / PhD

University of Peking – China (Biogeochemical cycle):
S. Piao; 5-10 Post-doc / PhD

University of Antwerp / Ghent – Belgium (Biogeochemical cycle):
I. Jansen, H. Verbeeck ; 3 Post-doc / PhD

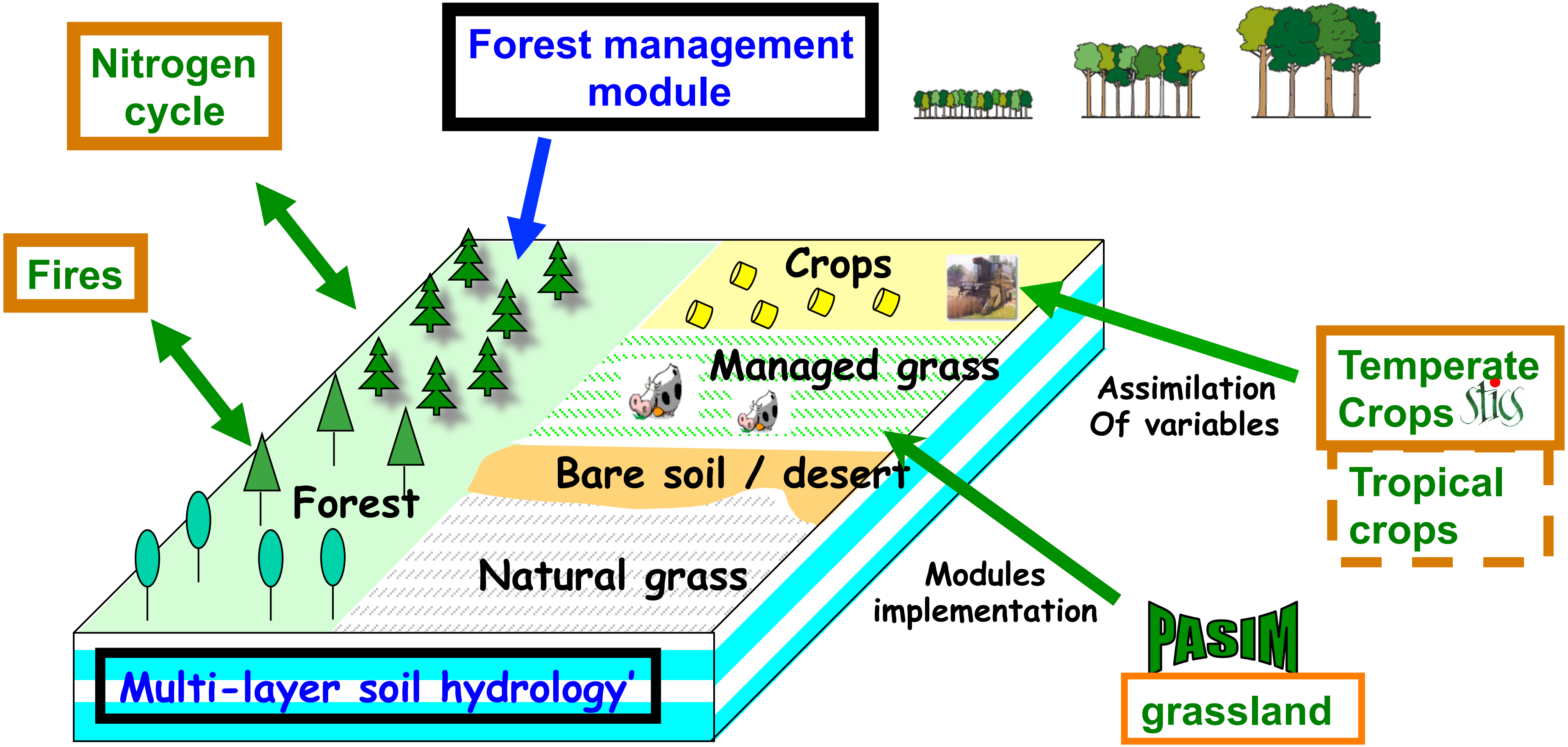
Surface description : a tile approach

- A mosaïc of vegetation



- 13 different Plant functional types

Recent improvements of ORCHIDEE

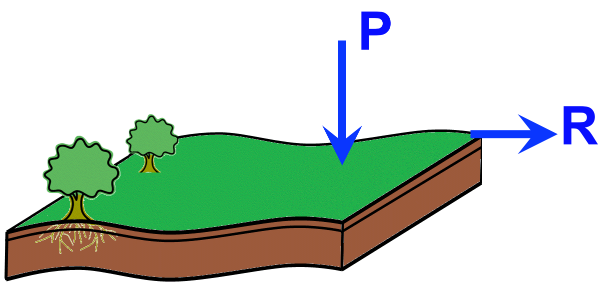


- Generalization of PFT concept (number not limited)
- A 11-layer hydrological scheme
- Scientific documentation

Two versions of the soil hydrology

Choisnel = ORC2

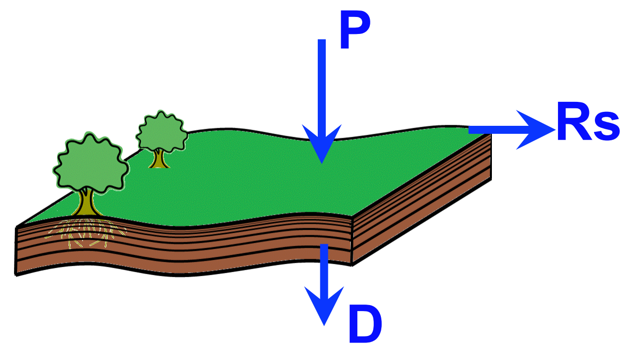
Ducoudré et al., 1993; de Rosnay et al. 1998



- Conceptual description of soil moisture storage
- 2-m soil and 2-layers
- Top layer can vanish
- Constant available water holding capacity (between FC and WP)
- Runoff when saturation
- No drainage from the soil
  We just diagnose a drainage as 95% of runoff for the routing scheme

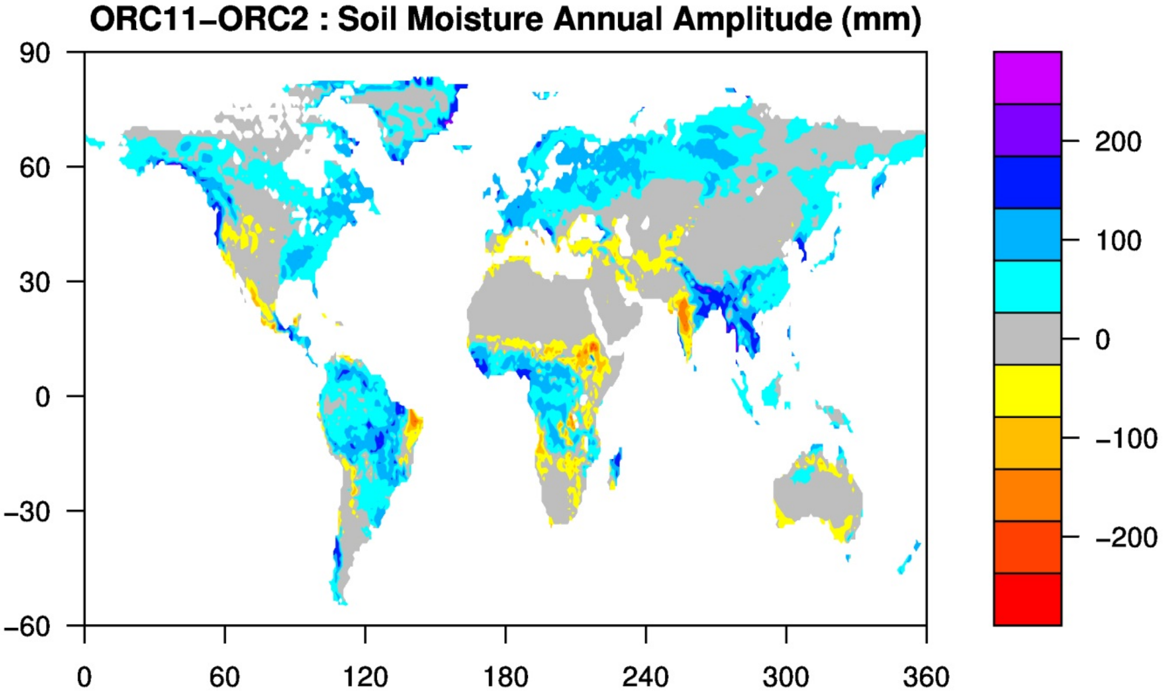
CWRR = ORC11

de Rosnay et al., 2002; d'Orgeval et al., 2008



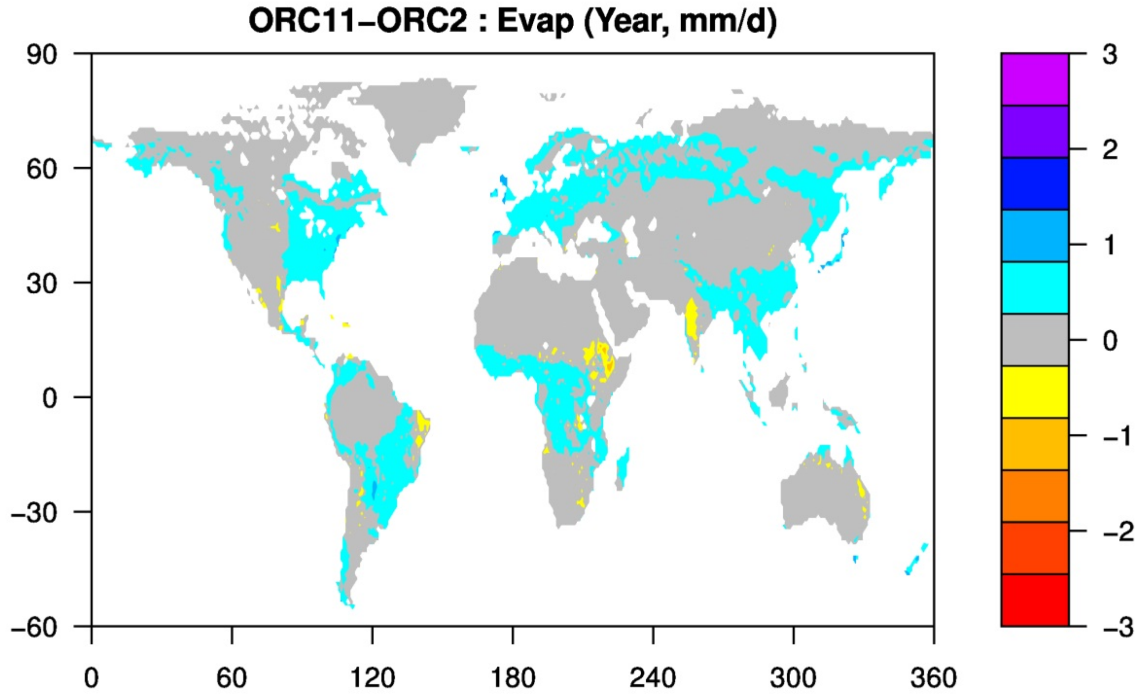
- Physically-based description of soil water fluxes using Richards equation
- 2-m soil and 11-layers
- Formulation of Fokker-Planck
- Hydraulic properties based on van Genuchten-Mualem formulation
- Related parameter based on texture (fine, medium, coarse)
- Surface runoff = P – Esol – Infiltration
- Free drainage at the bottom

Global scale: forced mode



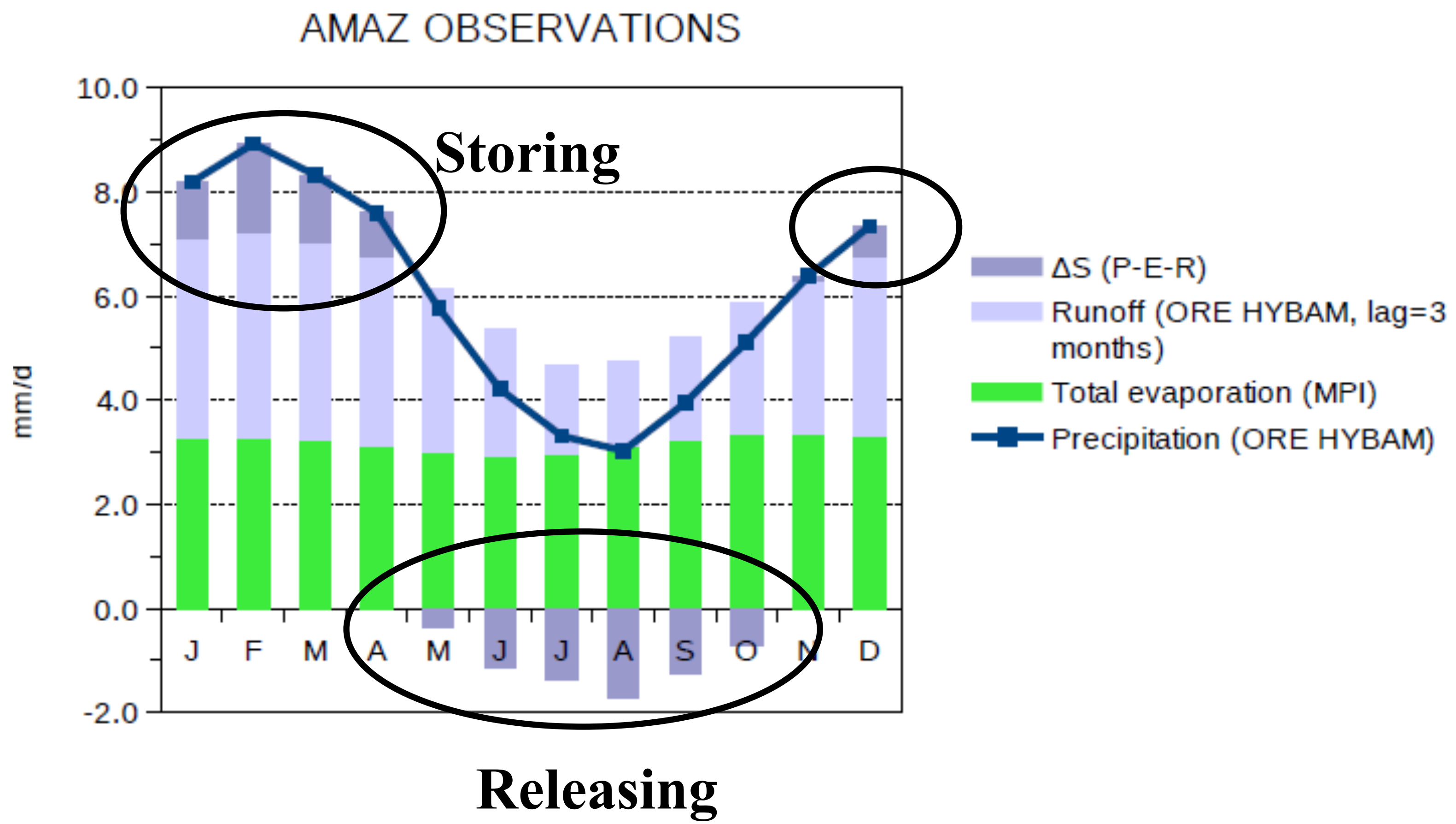
Amplitude of soil moisture variations is higher in ORC11 vs ORC-2

Evarpotranspiration increases in most rainy areas in ORC11



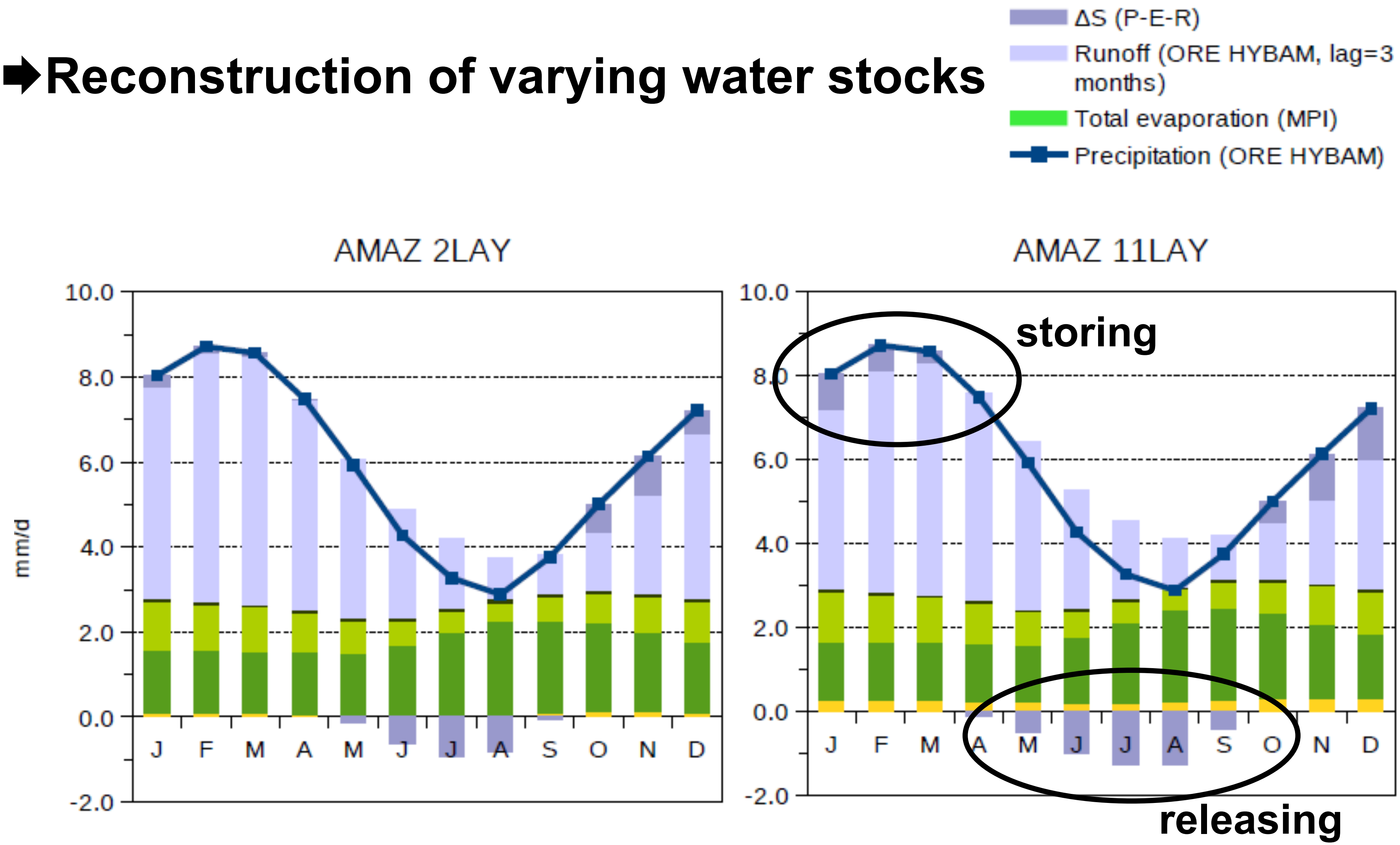
Test over the Amazon: 2 versus 11 layers

➡Reconstruction of continental water stock variations



Test over the Amazon: 2 versus 11 layers

➡ **Reconstruction of varying water stocks**



Larger amplitude of storing/releasing water in ORC-11LAY is more realistic.

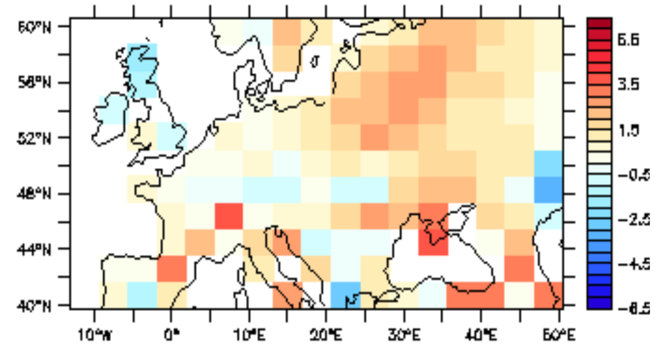
Global scale : coupled to LMDZ

➡ **Reduction of ORC11 warm bias in Europe in summer**

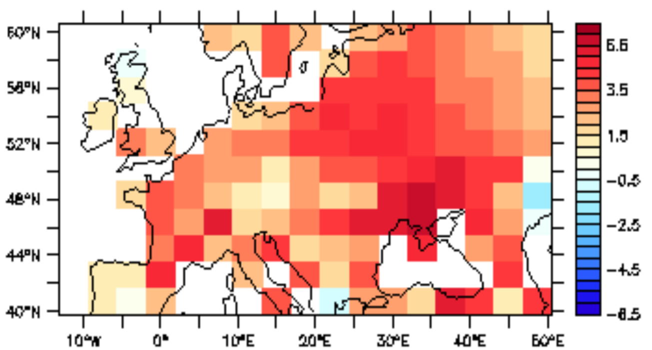
AMIP Simulations with CMIP5models

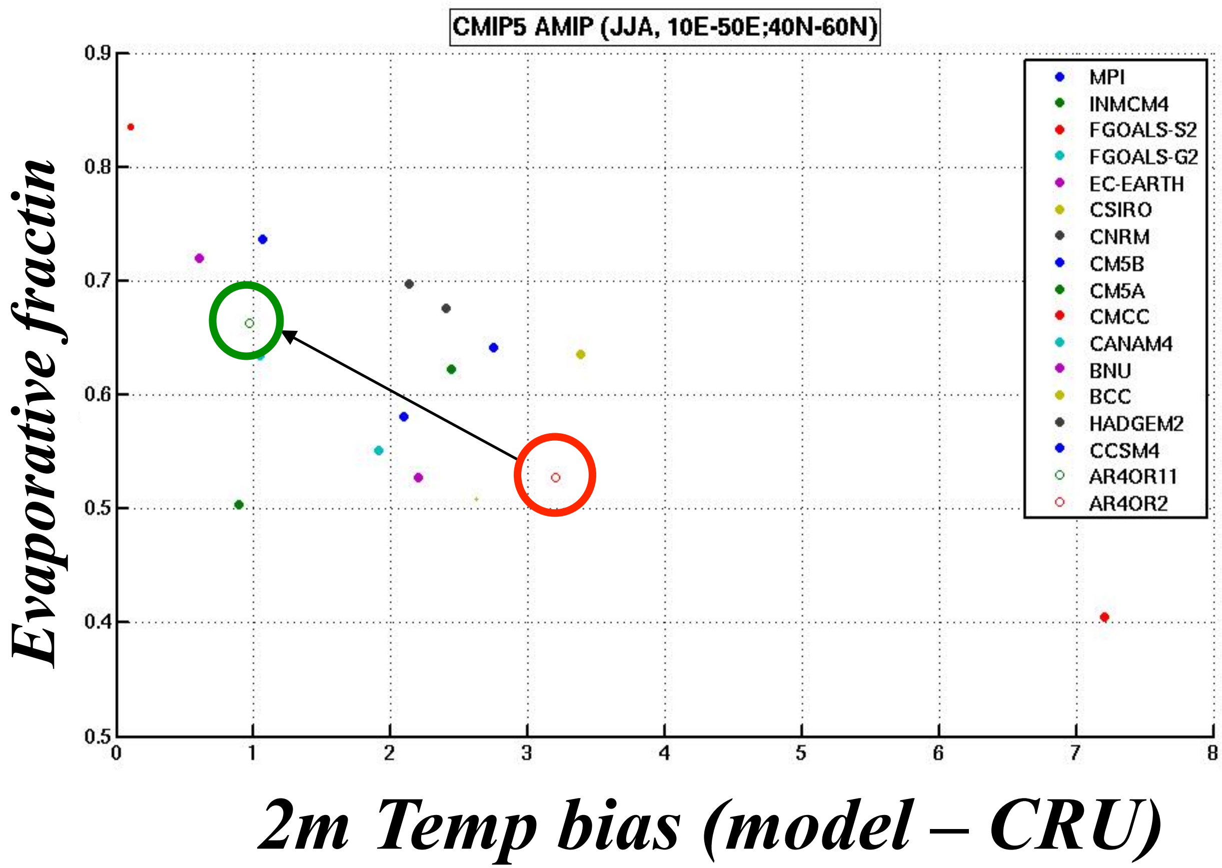
Bias Temp at 2m (compared to CRU data)

AR4-ORC11

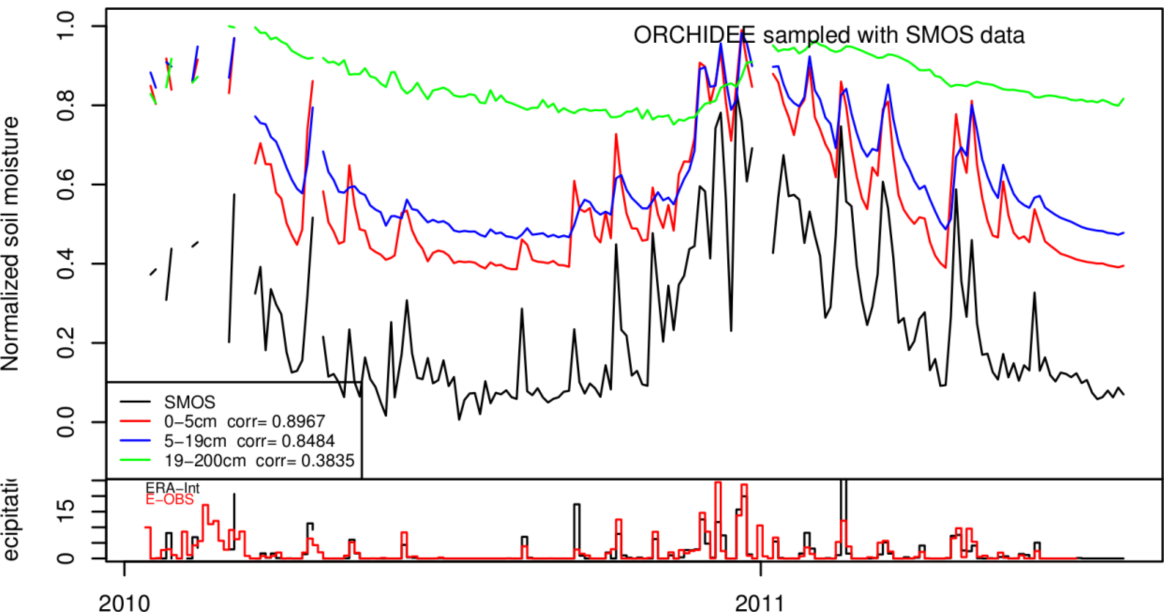


AR4-ORC2





Comparison with SMOS: soil moisture evolution



Guadalquivir area:

lon: -6:-4, lat: 37.2:38.

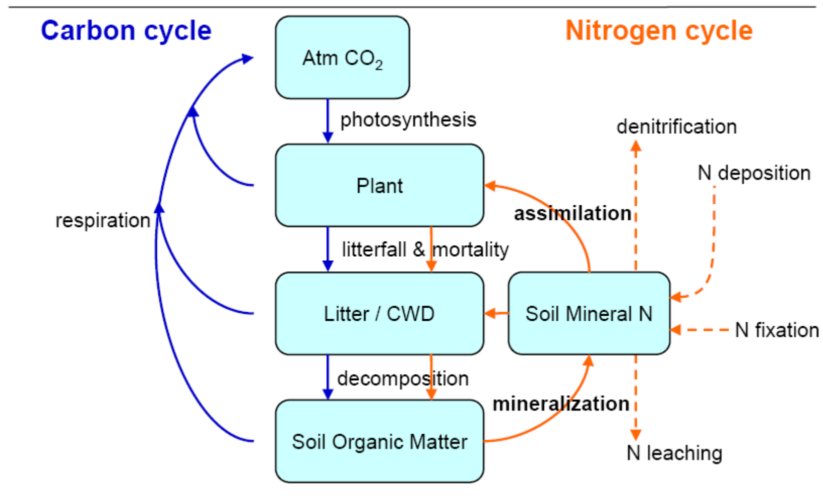
3 days average to reduce instrument noise

- The ERA-Interim rainfall forcing ORCHIDEE is rather good.
- The general annual cycle is rather well captured.
- The amplitude of the response to the rainfall events is more spiked in SMOS than the 0-5cm layer in ORCHIDEE.

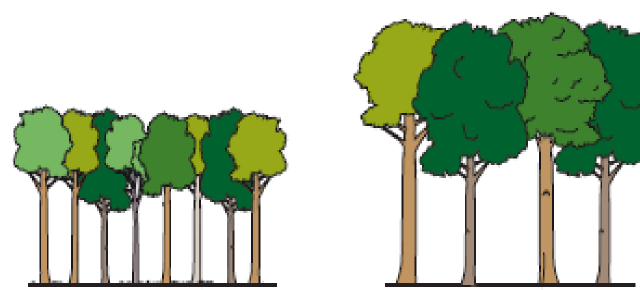
Recent developments to be merged

- High latitudes processes (MICT branch)

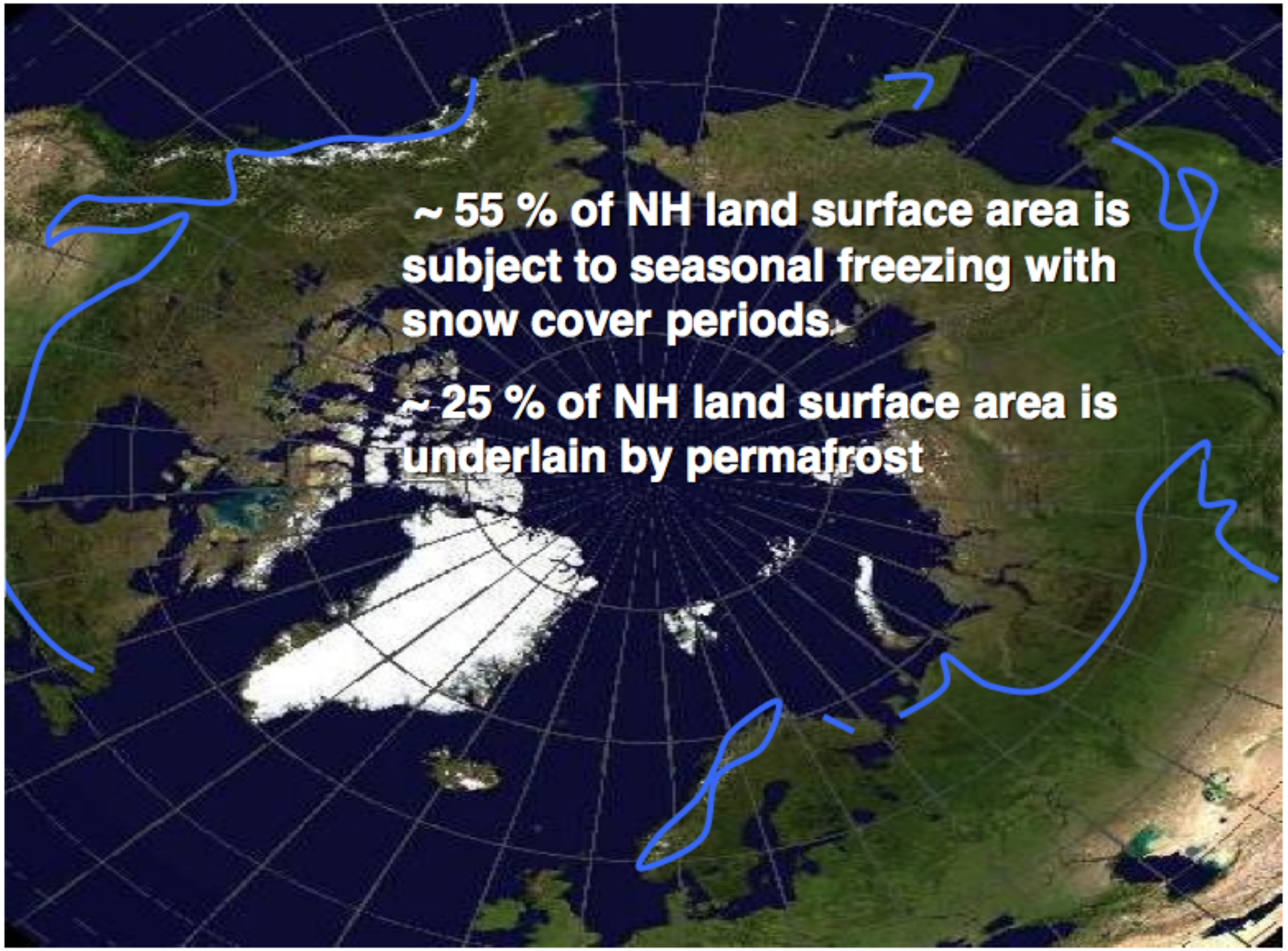
- Nitrogen cycling (new branch)



- A Forest Management Module (DOFOCO branch)

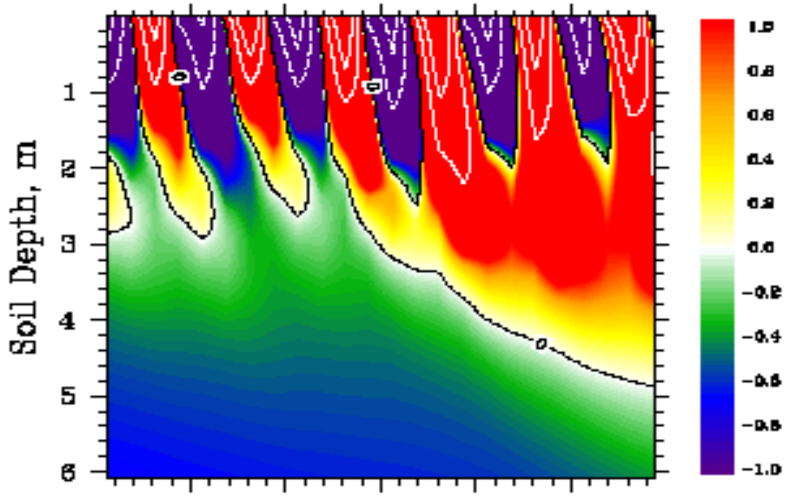


Climatic specificities of high latitudes and specific processes



High latitude Processes

- Permafrost & Climate change (soil heating)

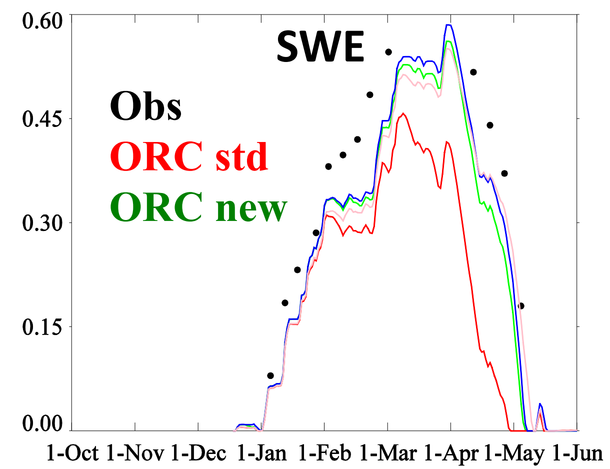


(a) Soil temperature (°C): talik formation when decomposition heat is 'On'. Contour interval is 4°C

- Wetlands hydrology
  ➔ CH4 emissions

- Snow: Adaptation of ISBA-ES
  + Soil freezing

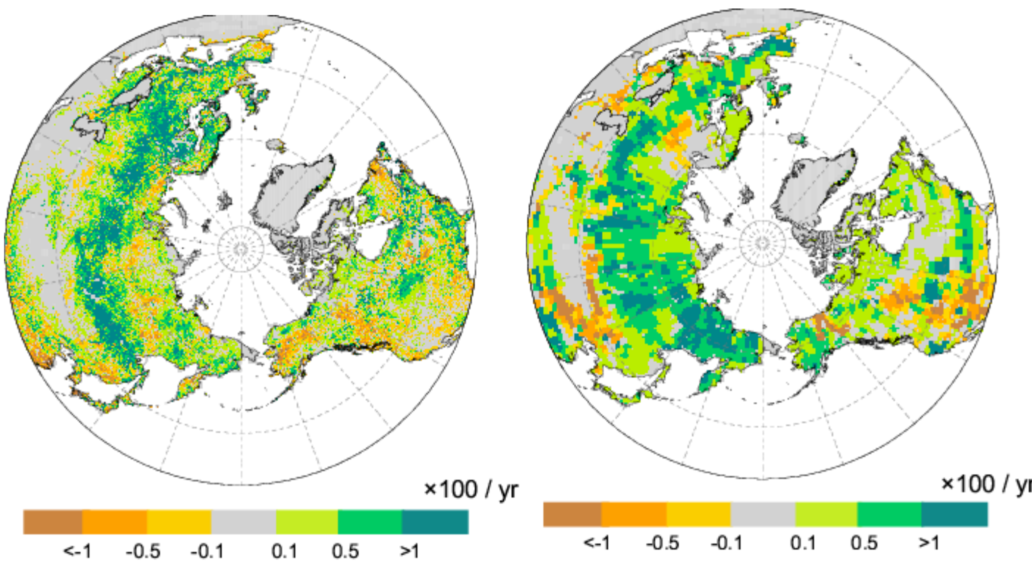
Col de Porte (1994-1995)



Change in Northern Hemisphere spring LAI

- A) Detection

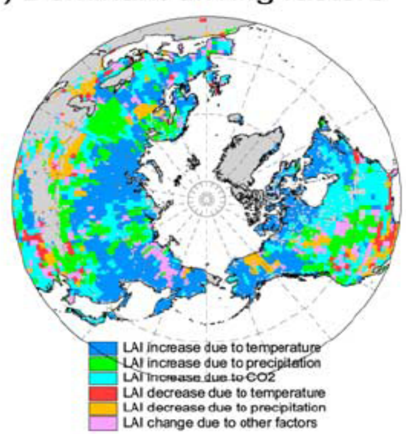
LAI trend
(1982-2002)



- B) Attribution

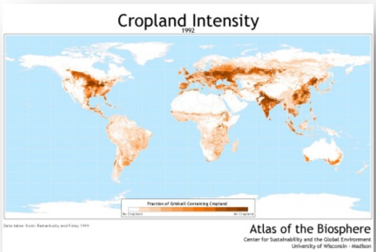
Factors:
Temperature is dominant
> CO2 > Precipitation

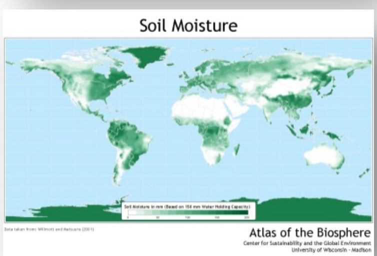
(F) Dominant driving factors

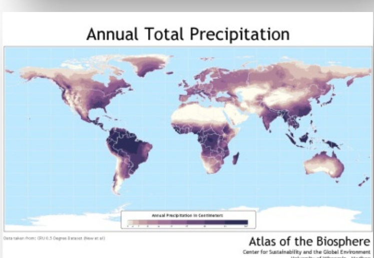


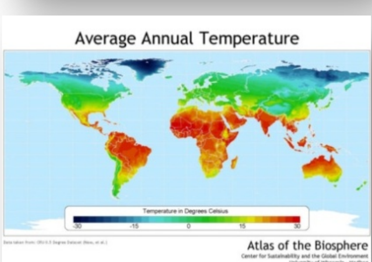
Piao et al., GRL, 2006

Nitrogen: O-CN biosphere model





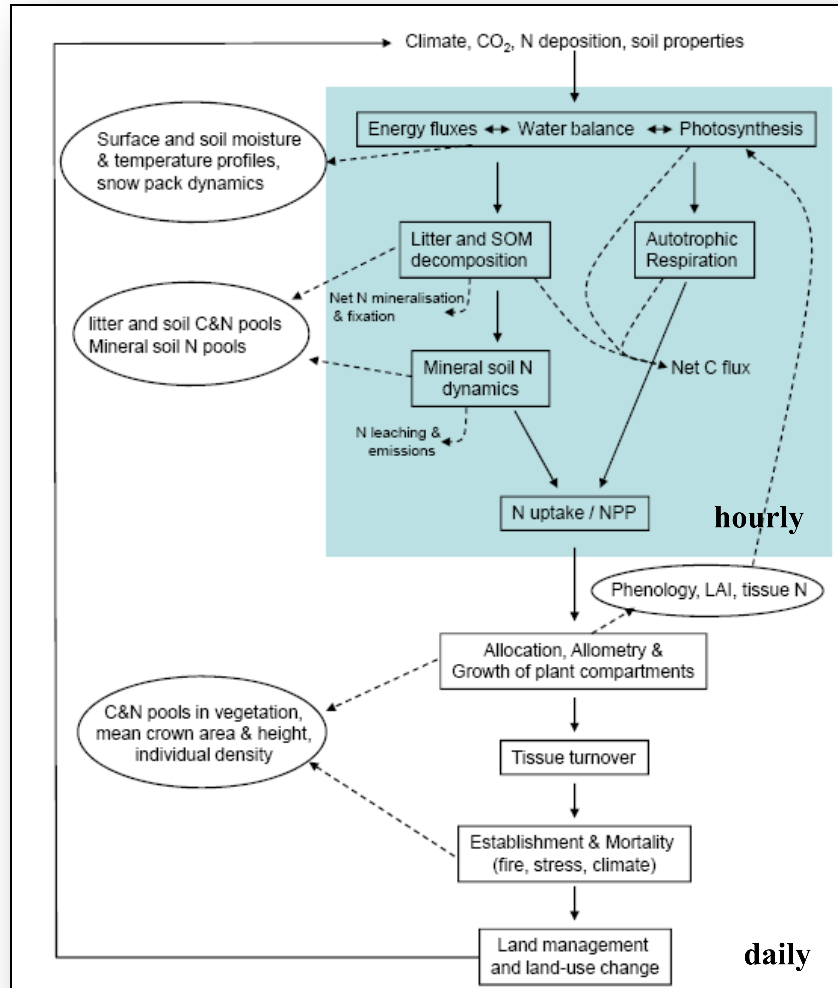




- Land cover maps
  time-variant
  - croplands, pasture ...
  - Fertiliser use

- Soil properties:
  - Water holding capacity
  - Soil texture, pH, color, albedo

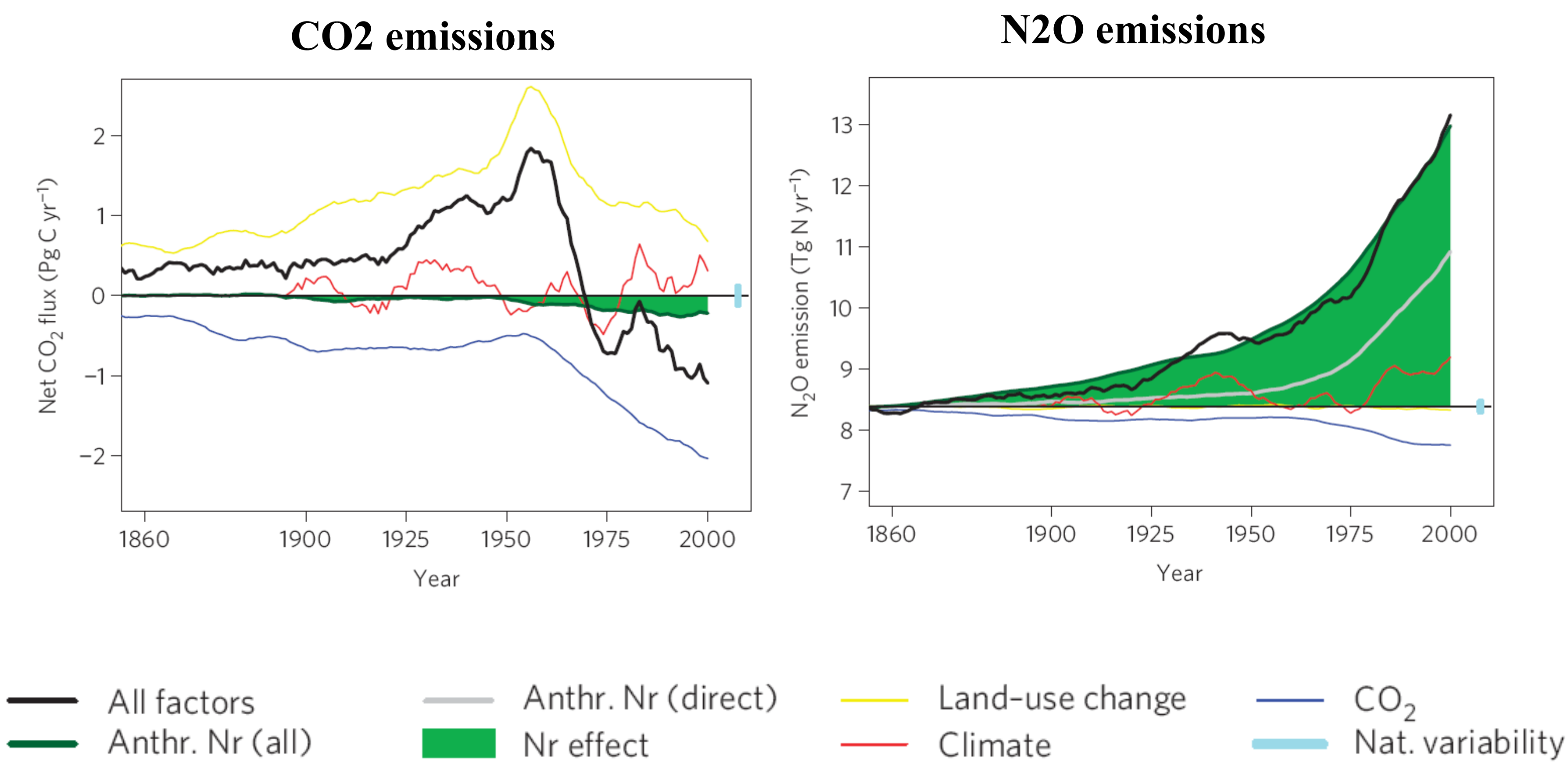
- Meteorology
  time-variant
  - Air temperature
  - Precipitation
  - atm. humidity
  - Radiation
  - wind speed
  - air pressure
  - N deposition
  - ...



Krinner et al. 2005, Zaehle and Friend, 2010; GBC

20th century net land CO_2 and N_2O exchanges

10 yr running mean fluxes



Zaehle et al. , 2011

A Forest Management Module for ORCHIDEE

ORCHIDEE

ORCHIDEE - FM

NEP

Atmosphere

NECB

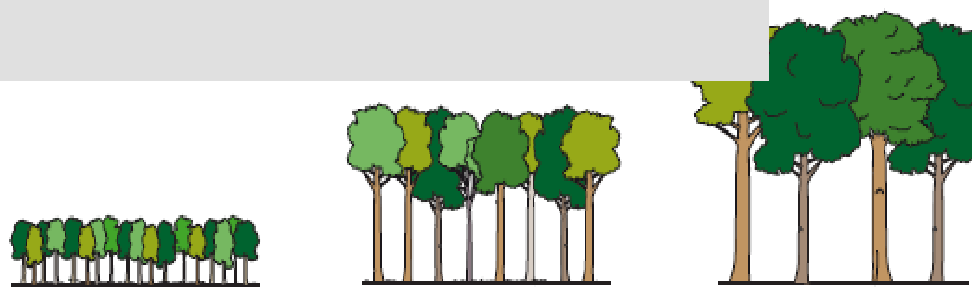
Atmosphere

NPP Rh

Land

See next presentation

- Age re
- Age re
- Age re
- Branch mortality
- Coarse woody litter compartment
- Individual growth of trees
- Generic management



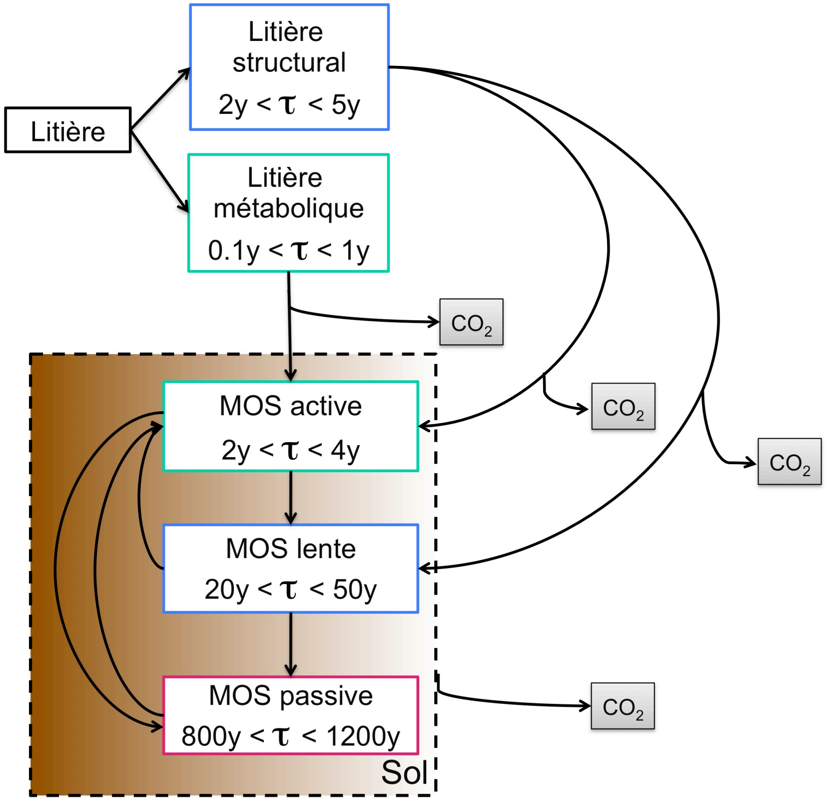
Current developments: **integration in *XX years?***

- Agrosystems : Crops & Pasture (J Chang, X Wu)
- New multi-layers energy budget (SL talk)
- New radiative transfer scheme (SL talk)
- New plant functional types (PFTs) (SL talk)
- Coupling surface and ground water hydrology
- Coupling with WRF atmospheric model
- Isotopic module for Water and Carbon isotopes
- Vegetation and chemistry: coupling INCA-ORC
- New soil carbon mineralization scheme

Soil Carbon in ORCHIDEE, past, present and future

(Bertrand Guenet)

Century model (present)

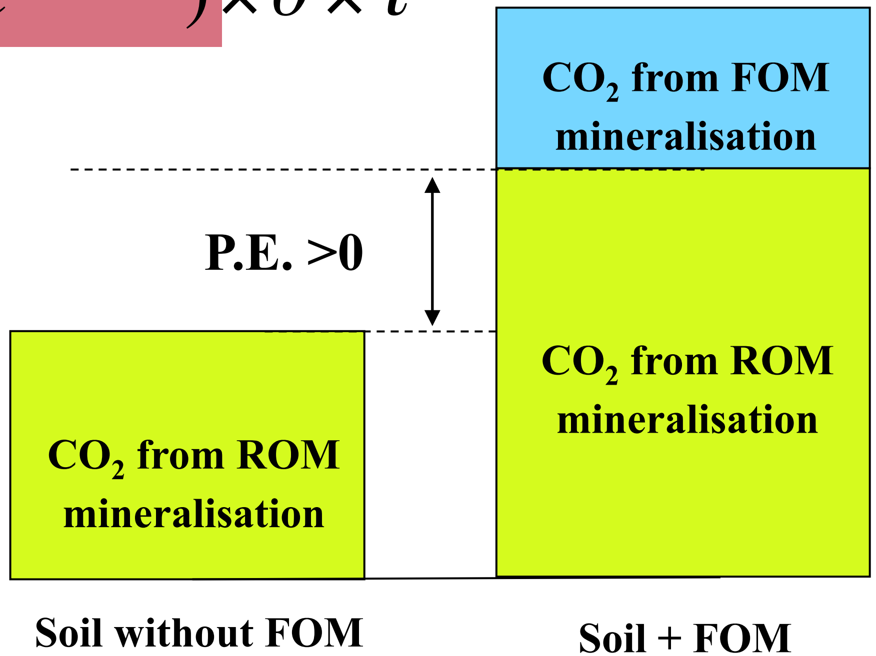


A NEW SCHEME OF DECOMPOSITION

- Based on Wutzler and Reichstein (2008) and adapted by Guenet et al., (2013)

$$\frac{\partial SOC}{\partial t} = I - k_{SOC} \times SOC \times (1 - e^{-c \times FOC}) \times \theta \times \tau$$

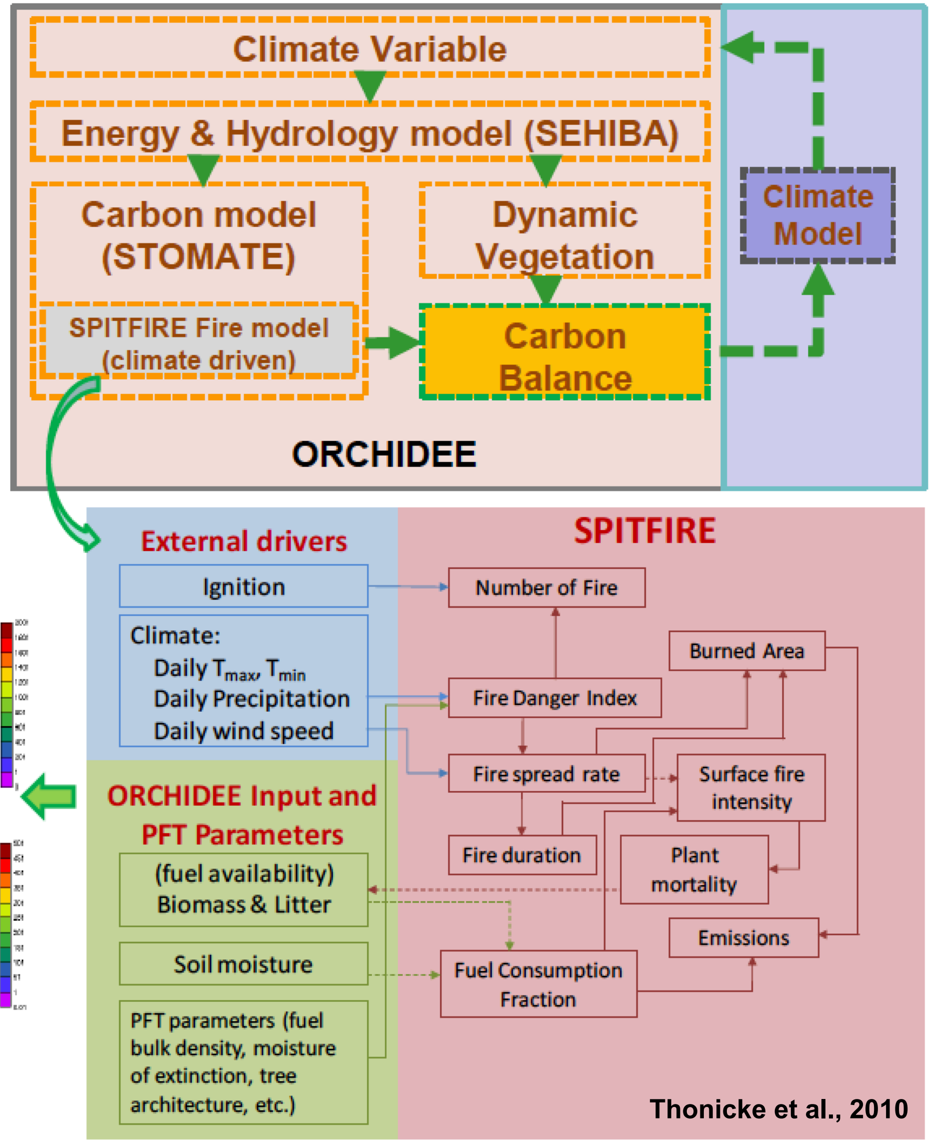
- Such approach is able to reproduce priming effect
- Assumes that microbial biomass is always in equilibrium with FOC (Xia et al., *In prep*)

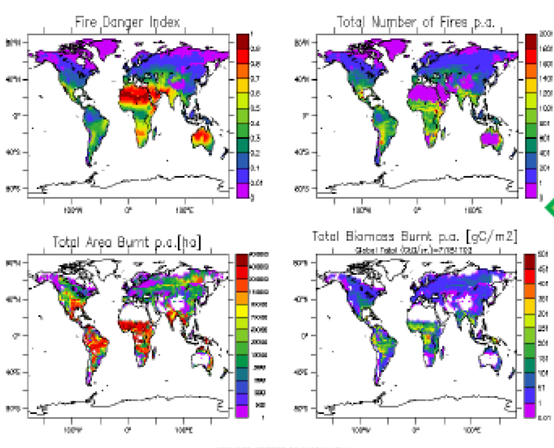


Adapted from Kuzyakov *et al.*, 2000

Spitfire: A fire model within ORCHIDEE

Use the ORCHIDEE-SPITFIRE model coupled with IPSL climate model to simulate future vegetation, fire and climate interactions.





The fate of African savanna : fire regimes and climate change

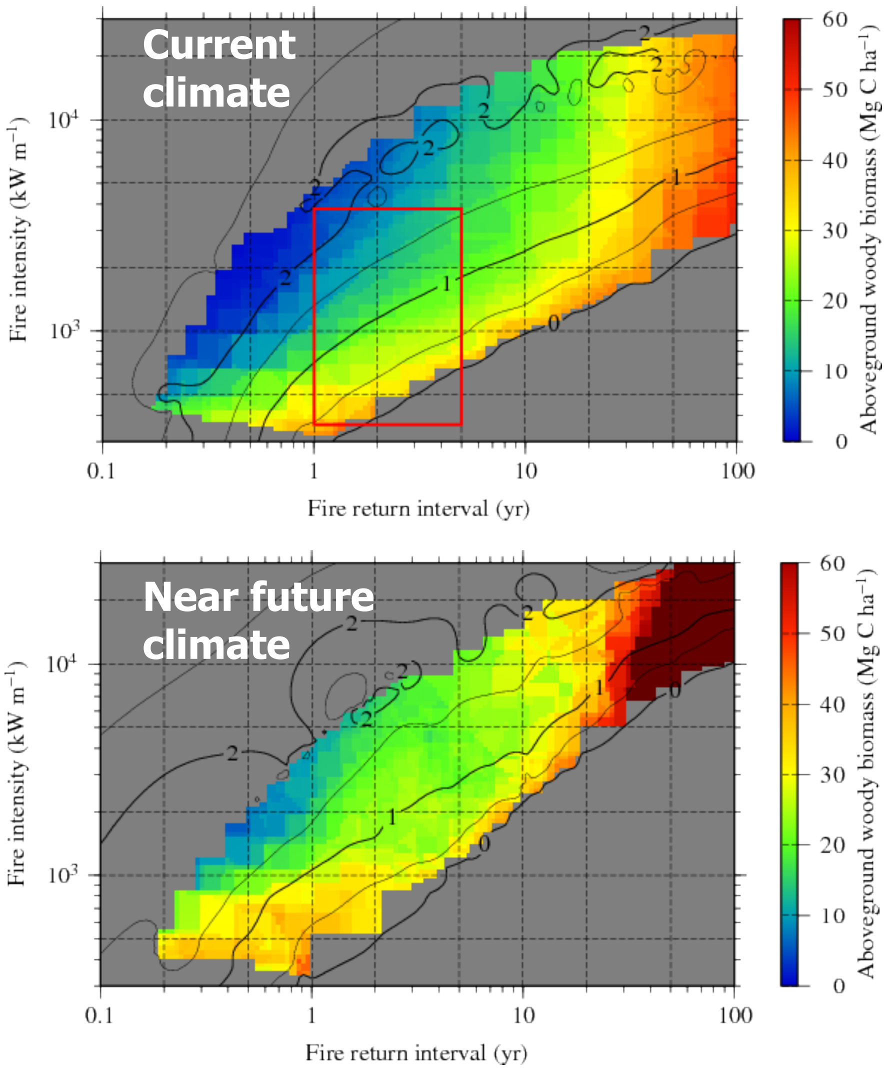


Fig. 3 Relationships between mean fire return interval (yr) and mean fire intensity (kW m^{-1}) over 500-yr simulations under (top) current and (bottom) near future climate (2100) conditions. Mean above ground woody biomass (Mg C ha^{-1}) is shown by colors. Contours show mean annual aboveground grass biomass (Mg C ha^{-1}).

Use of ORC-FM-SPITFIRE to test the impact of :
- fire frequency
- fire intensity

Key result:

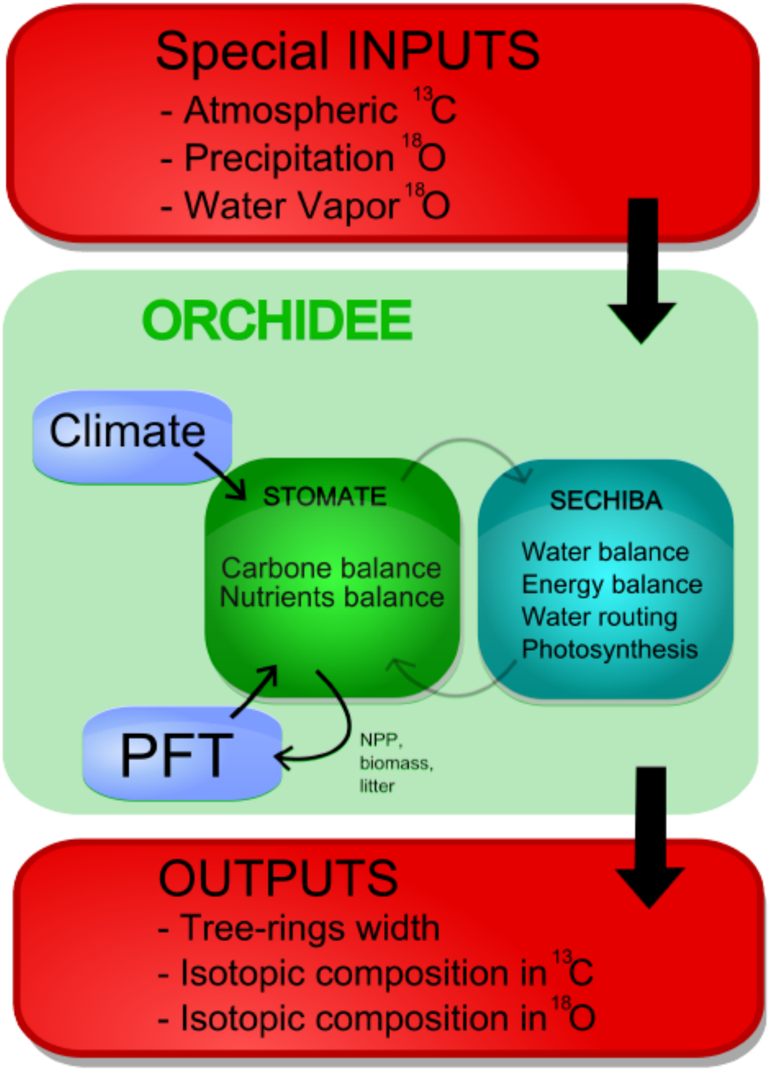
There are significant effects of fire regime and climate change on above ground woody biomass.

Fire works as a demographic bottle-neck in the growth of trees to mature stage (not shown).

High atmospheric CO_2 concentration and future climate may make above ground woody biomass less effective on fire disturbances.

Isotopes in ORCHIDEE

- ^{13}C of CO2 and carbon compounds
- ^{18}O in H2O
- ^{18}O in CO2 (futur)



^{13}C in ORCHIDEE

Ball & Berry
for conductance

$$g_s = m_1 \cdot \gamma_w \cdot A \cdot \frac{h_r}{C_a} + m_2$$

Hydric stress applied
to conductance

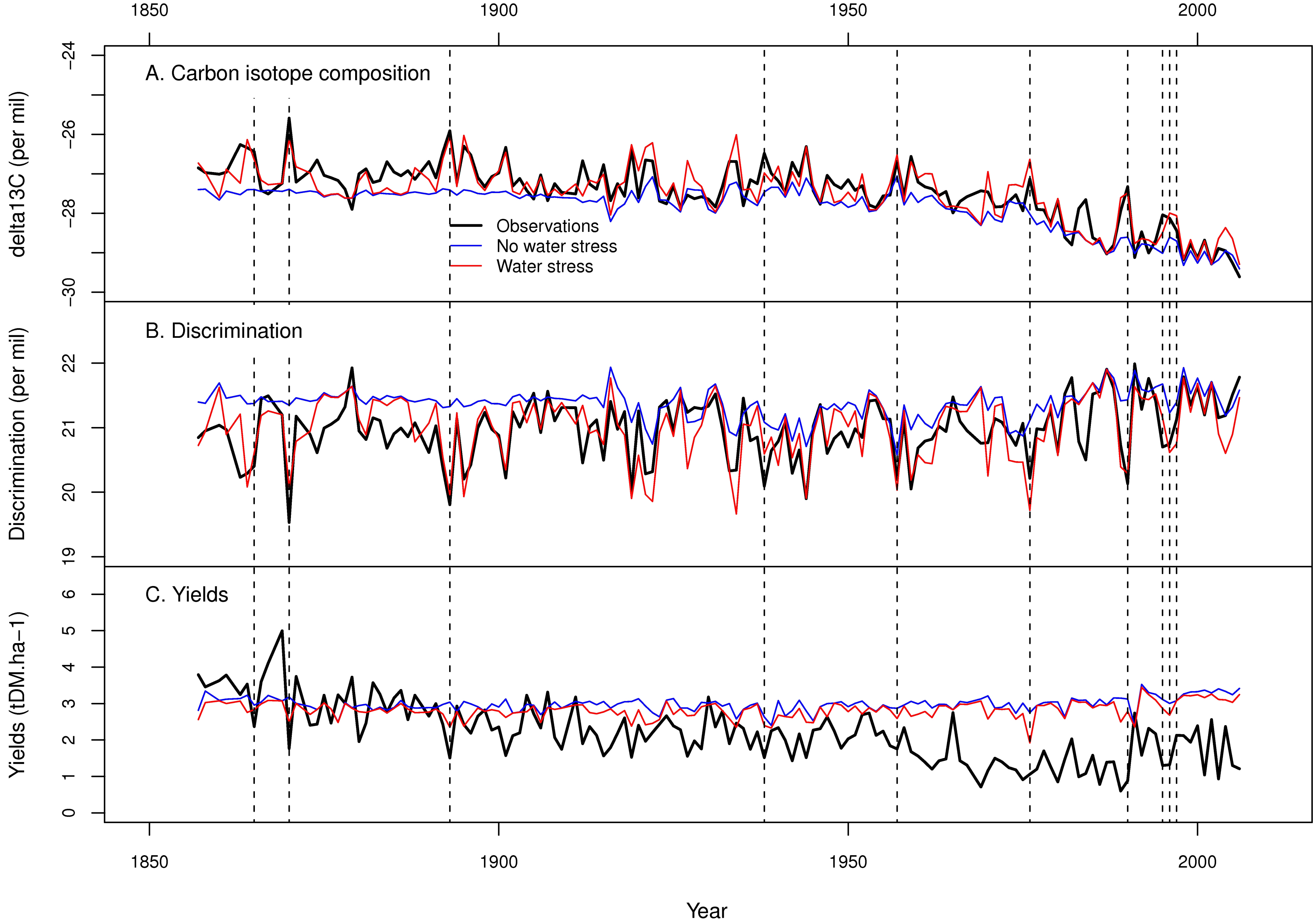
$$\gamma_w = \begin{cases} 1 & \text{if } \Theta > \Theta_1 \\ 1 - \dfrac{\Theta - \Theta_0}{\Theta_1 - \Theta_0} & \text{if } \Theta_0 < \Theta < \Theta_1 \\ 0 & \text{if } \Theta < \Theta_0 \end{cases}$$

Farquhar model
for 13 discrimination

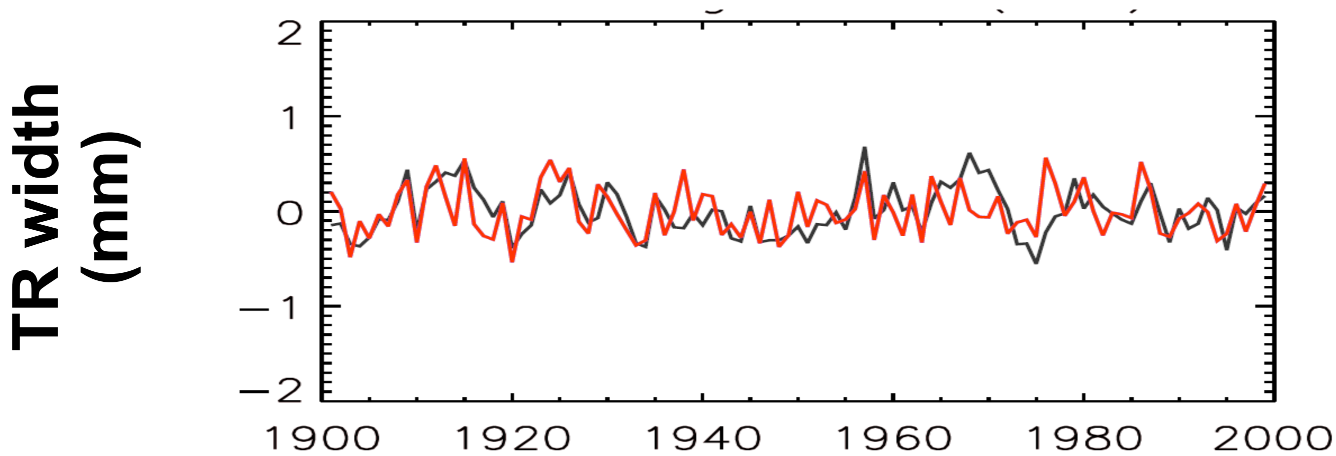
$$^{13}\Delta = a + (b - a)\frac{C_i}{C_a}$$

➔ Flow of 13C in the all C reservoirs without fractionnation

150 years of ^{13}C at Park Grass in UK (grassland : first cut in june)

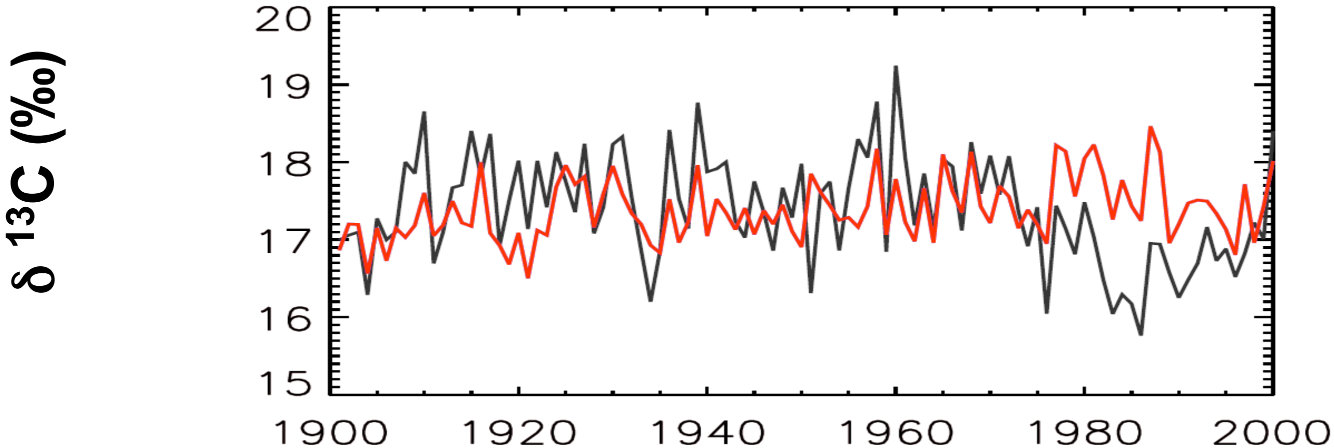


Results for oaks forest in Fontainebleau

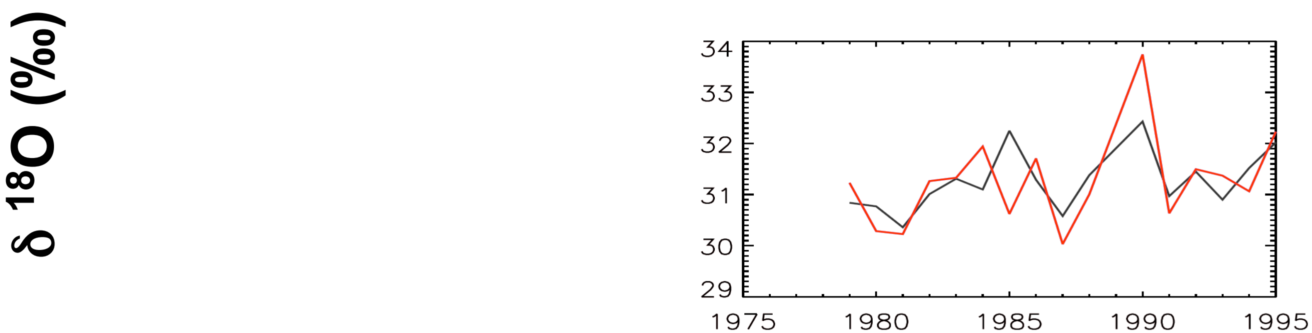


TR width
R=0,62
NSD=1,28

Observations
Model



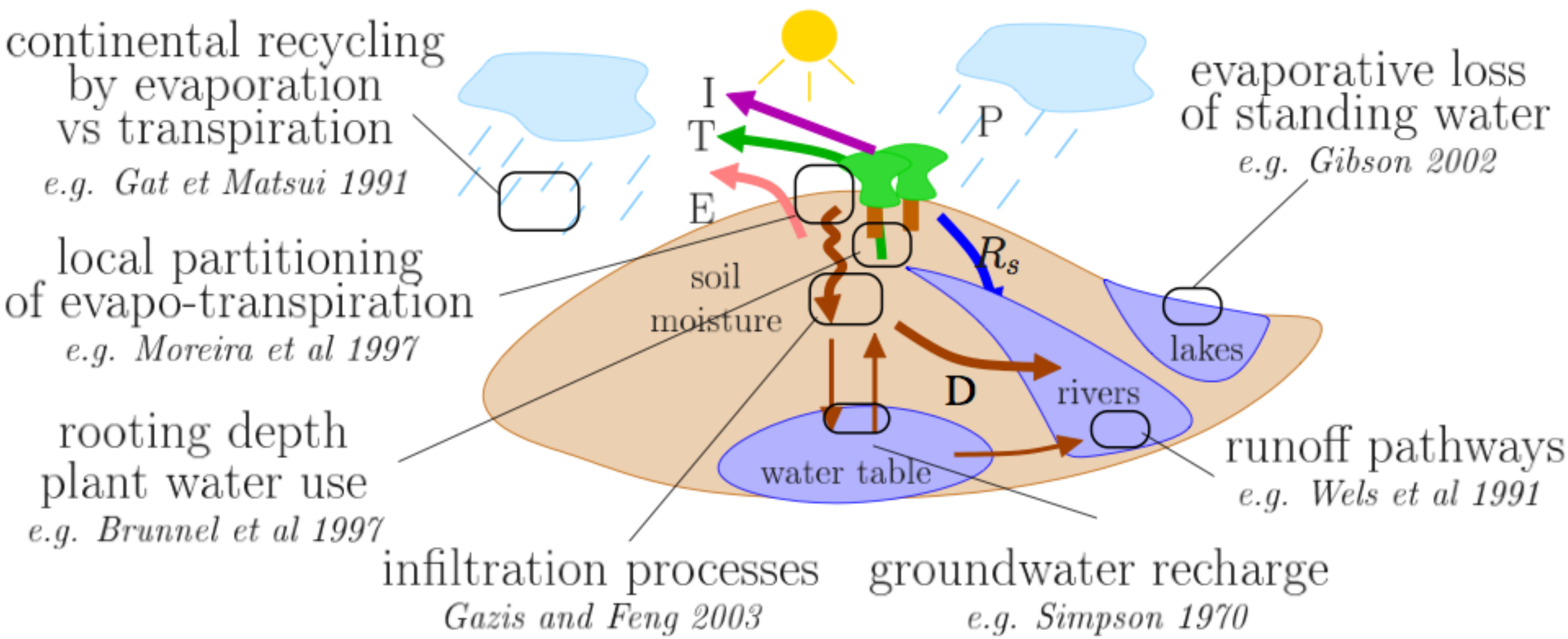
13C
R=0,35
NSD=1,37



18O
R=0,67
NSD=1,44

18O in H2O (ORCHIDEE – LMDz) : Motivations

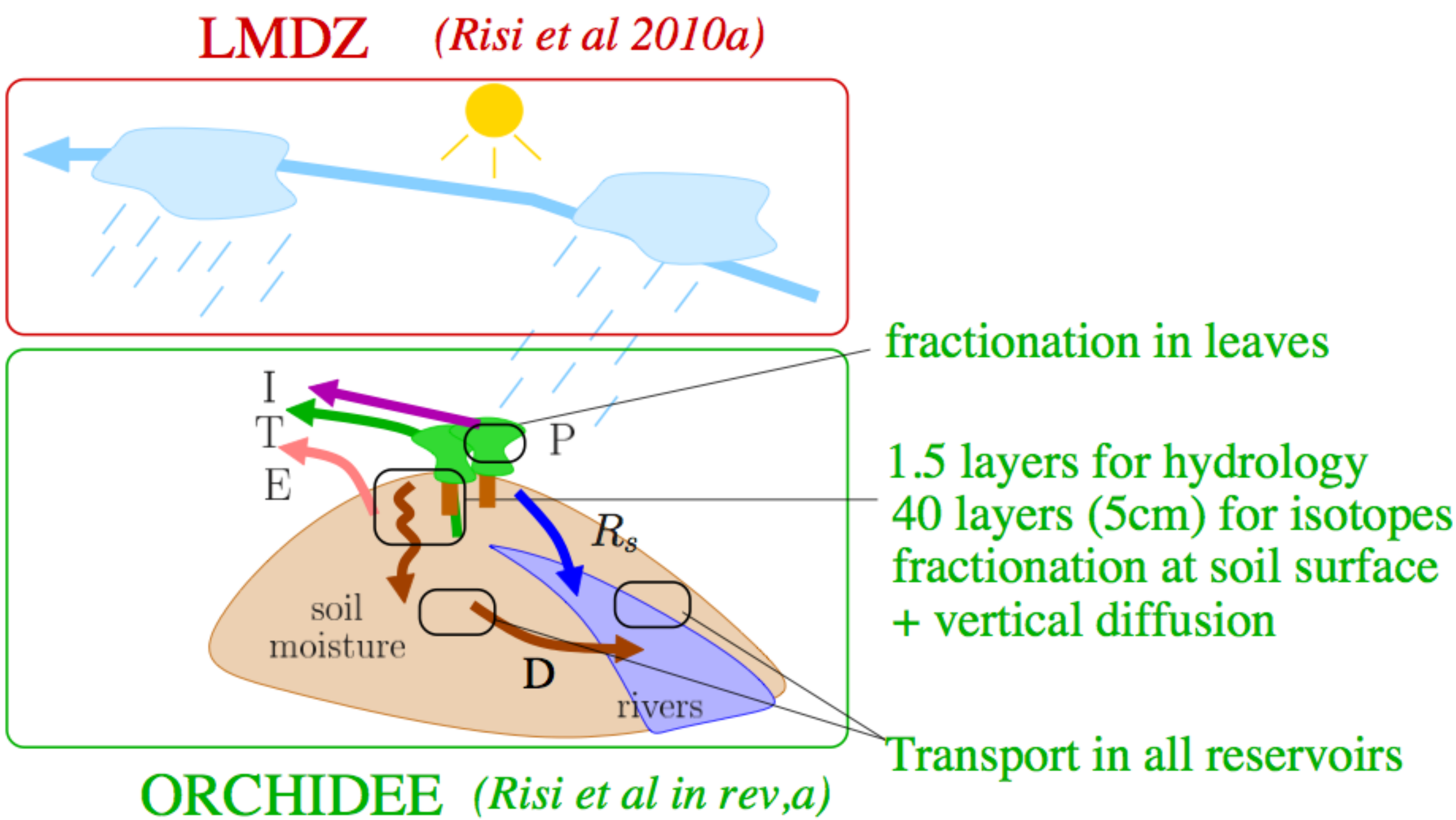
- isotopes to estimate budgets and study processes in nature



- to evaluate land surface models ? *(e.g. Henderson-Sellers et al 2006)*

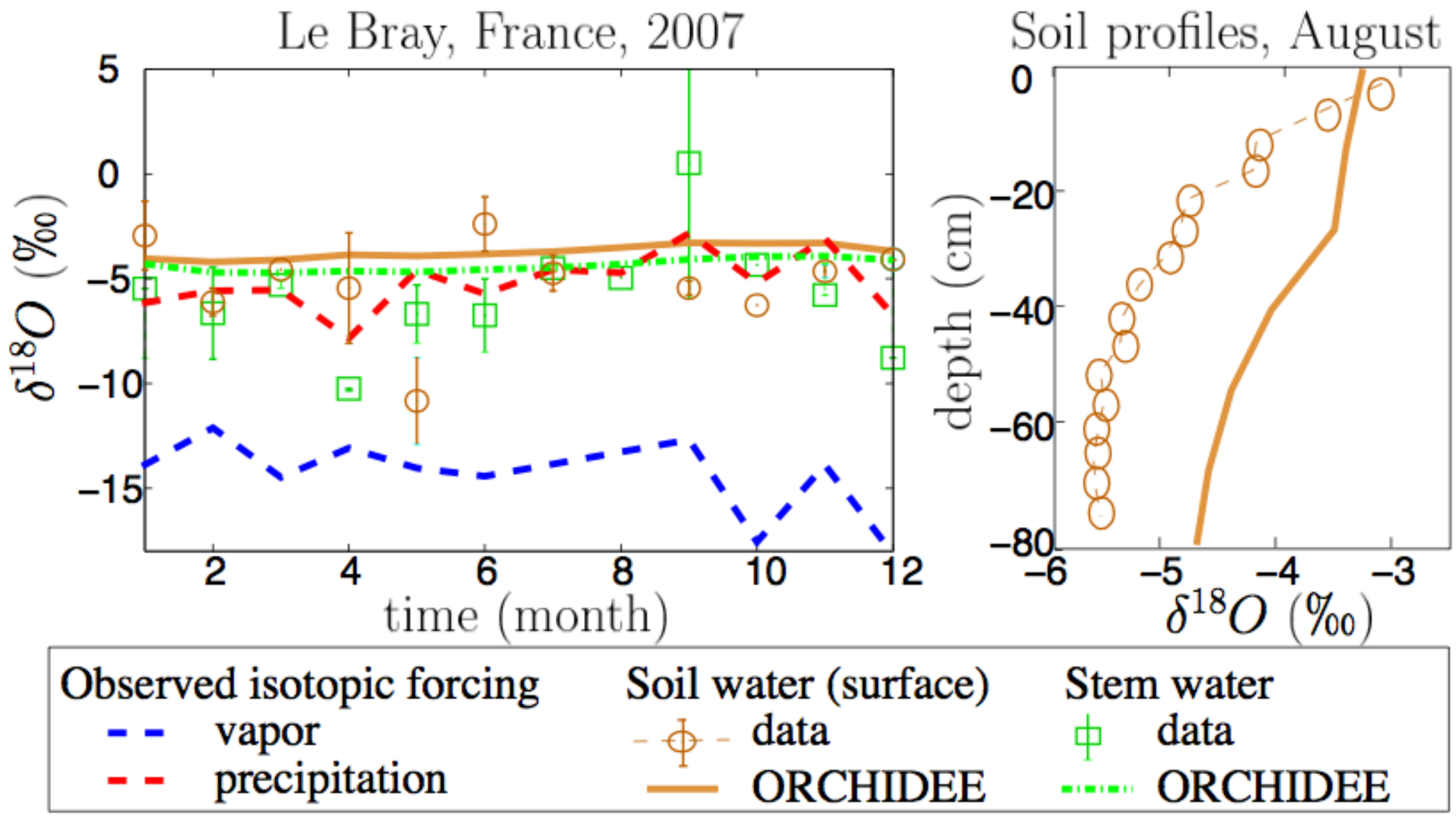
➔ *Developed by C. Risi*

Isotopes in LMDZ and ORCHIDEE

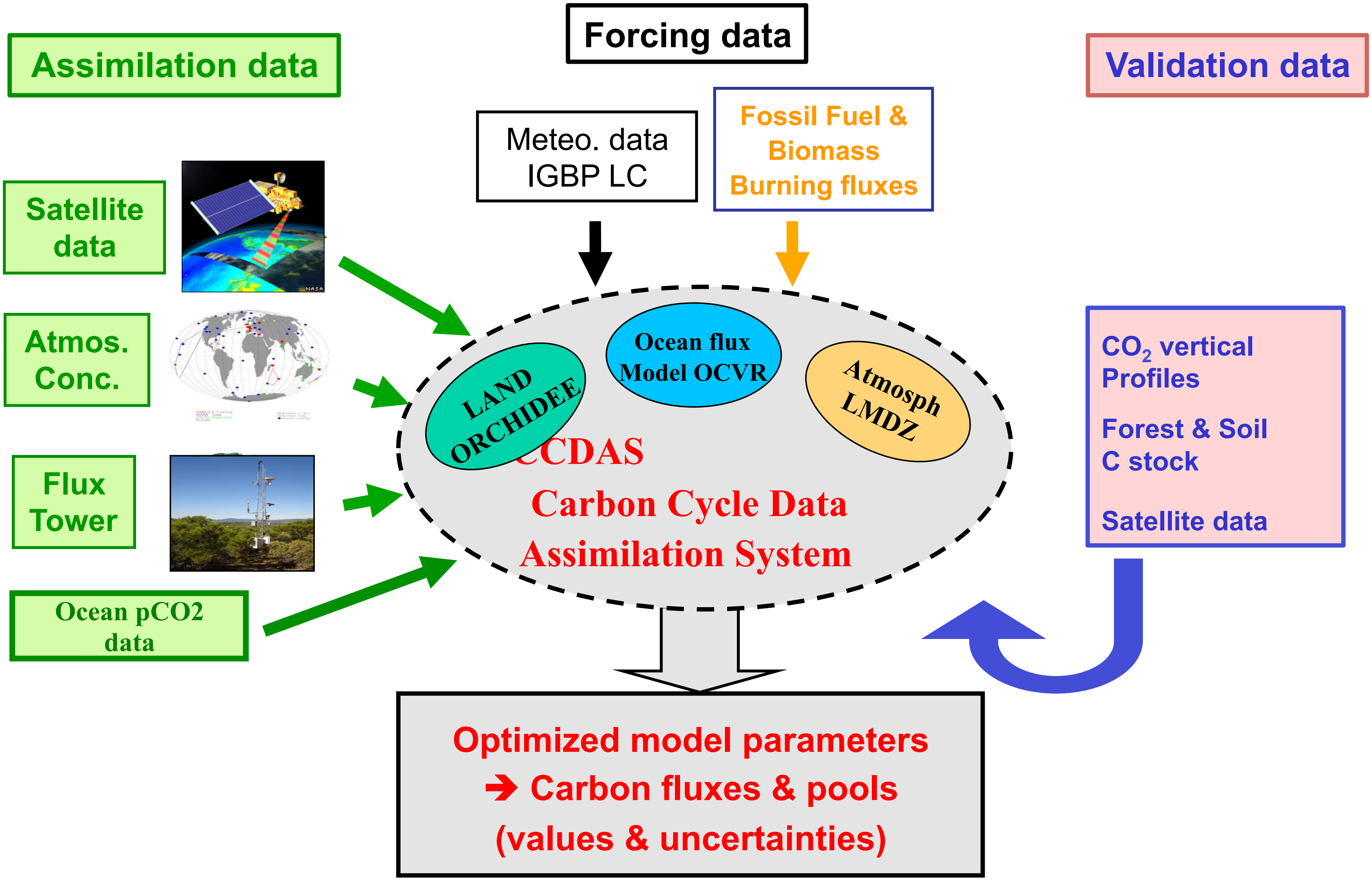


Evaluation of soil and biosphere isotopes

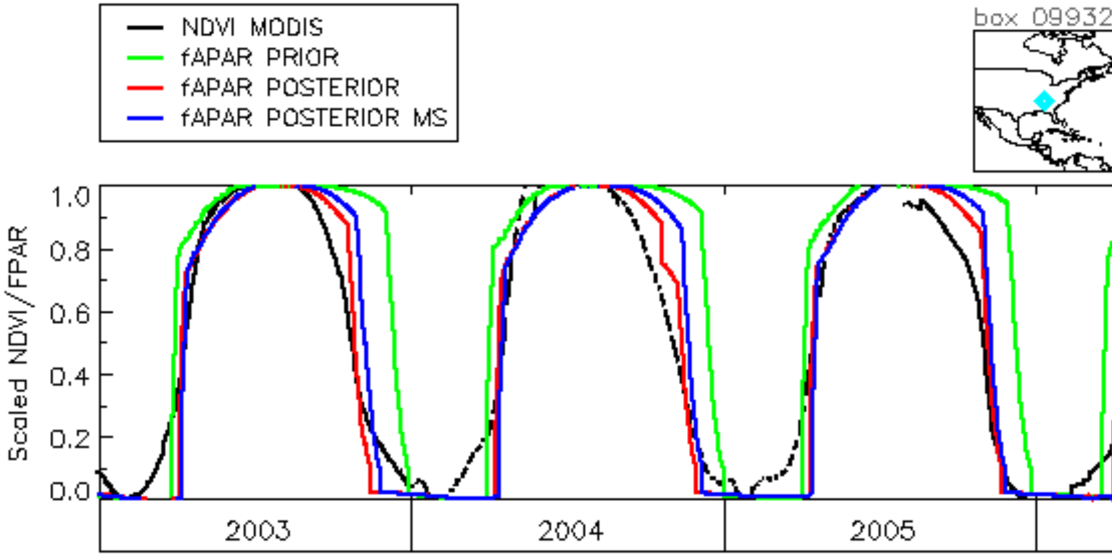
- 2 MIBA sites : Yatir (Israel, *Raz-Yaseef et al 2009*) and Le Bray (France, *Wingate et al 2009*, shown here)



Structure of the LSCE CCDAS



PFT : 'temperate broad-leaved summergreen'



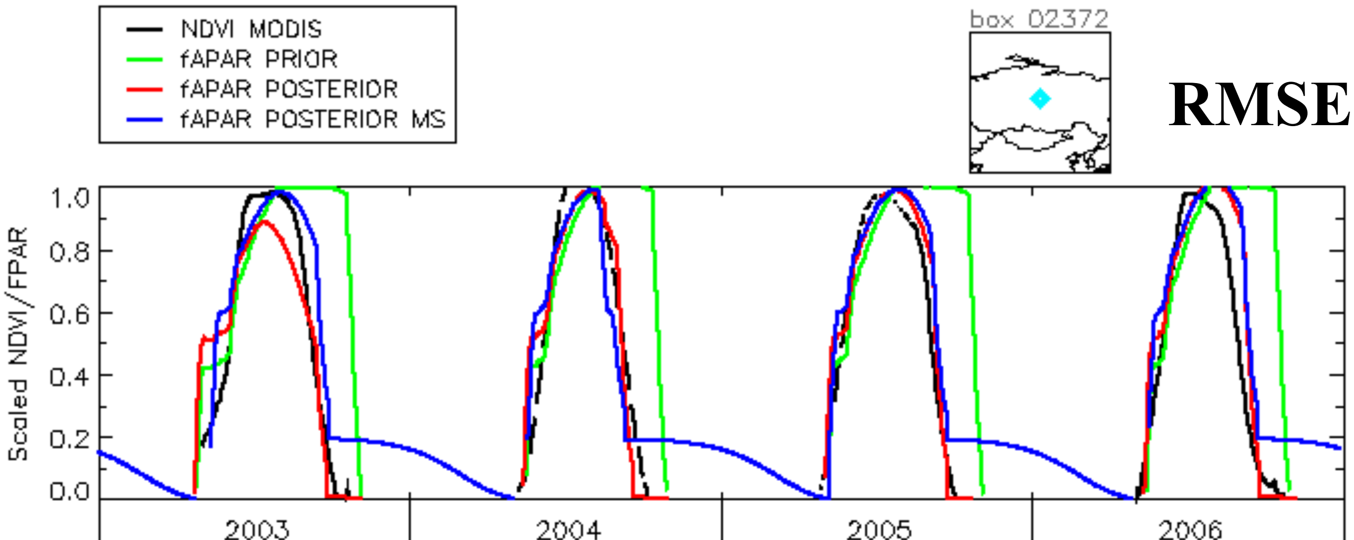
RMSE: 0.33 0.13 0.16

Prior

Posterior single-site

Posterior Multi-site

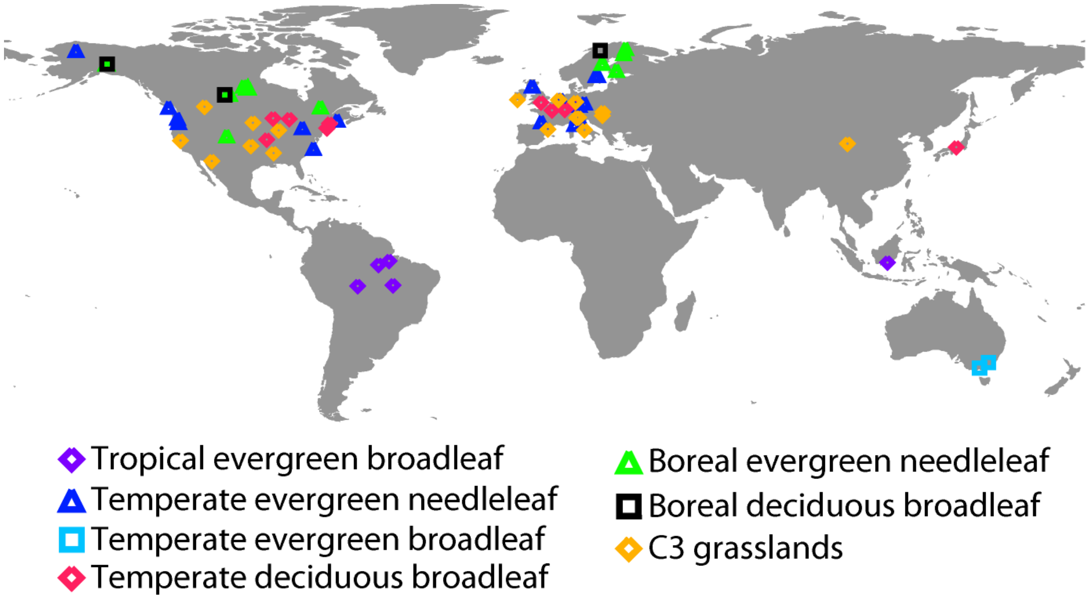
PFT : 'boreal needleleaf summergreen'



RMSE: 0.43 0.13 0.16

McBean et al. 2012

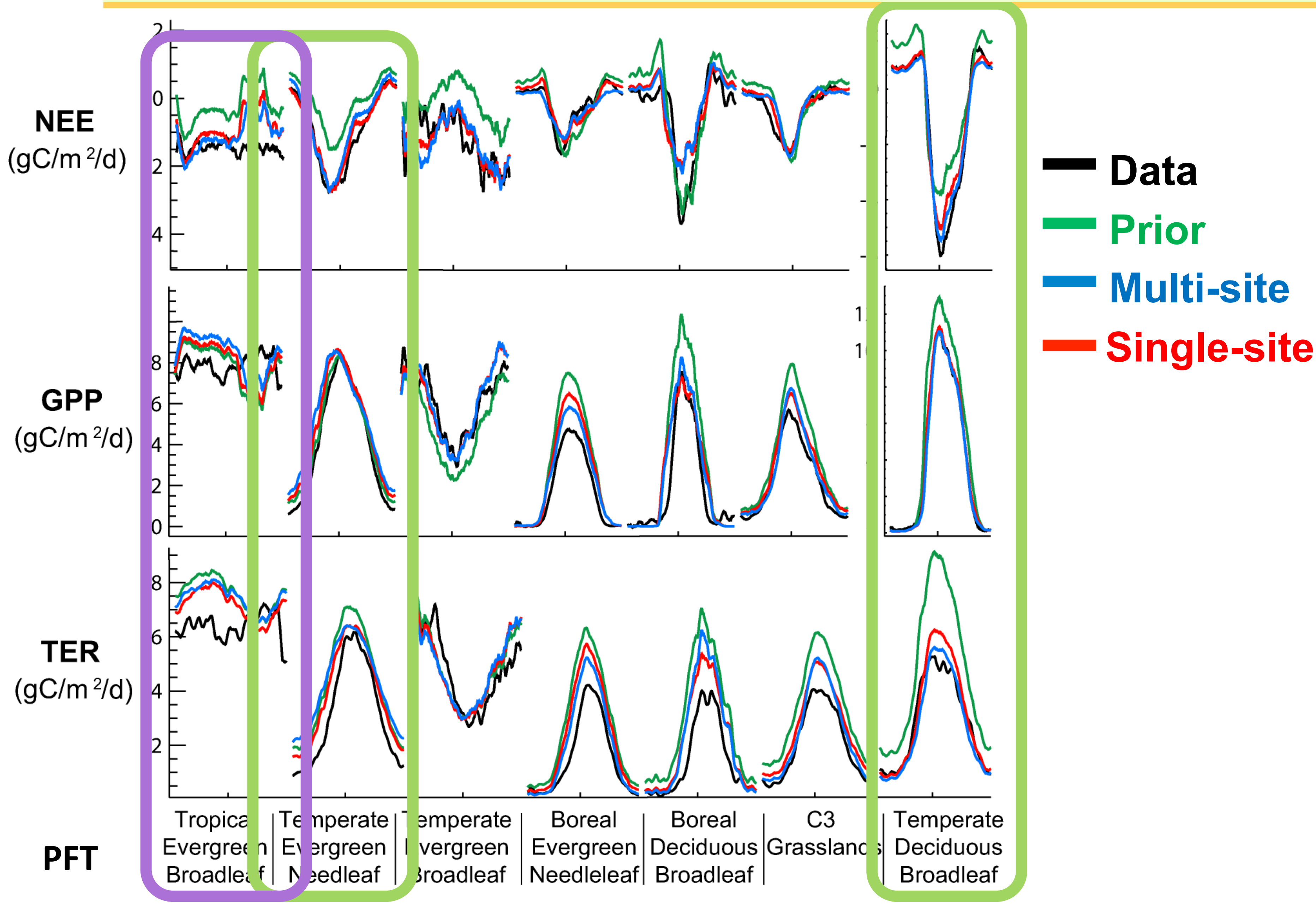
Assimilation of flux NEE & LE data



- ➔ **78 sites from the FLUXNET network**
- ➔ **Assimilation of daily-averaged NEE & LE**
- ➔ **Optimization of about 20 parameters per PFTs**

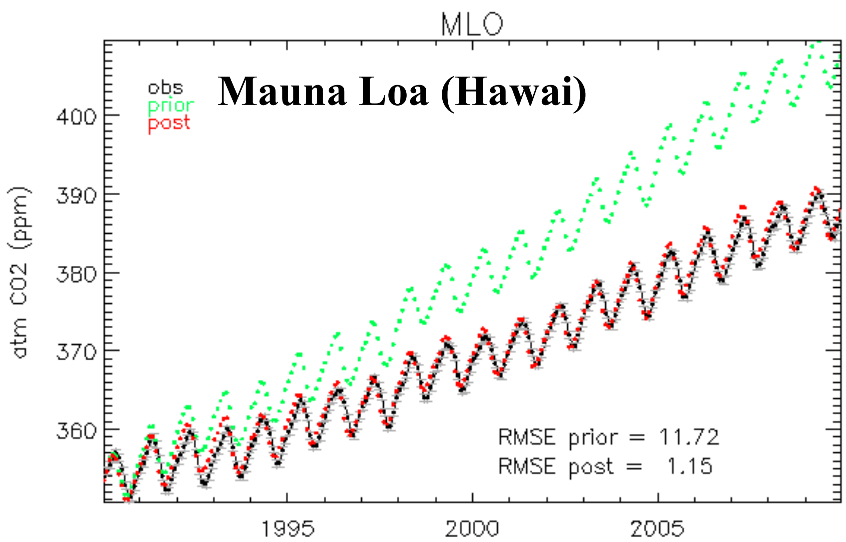
Parameter	Genericity
$V_{cmax,opt}$, $c_{T,min/opt/max}$, $L_{age,crit}$, $f_{stressh}$	PFT
$G_{s,slope}$	PFT
LAI_{MAX}, SLA	PFT
LAI_{init}	**Site**
$K_{lai,alloc}$	PFT
$K_{phenocrit}$, c_{senes}	PFT
MR_a, MR_b, GR_{frac}	PFT
Q_{10}, HR_b, HR_c, Z_{decomp}	PFT
K_{soilC}	**Site**
$K_{albedo,veg}$	PFT

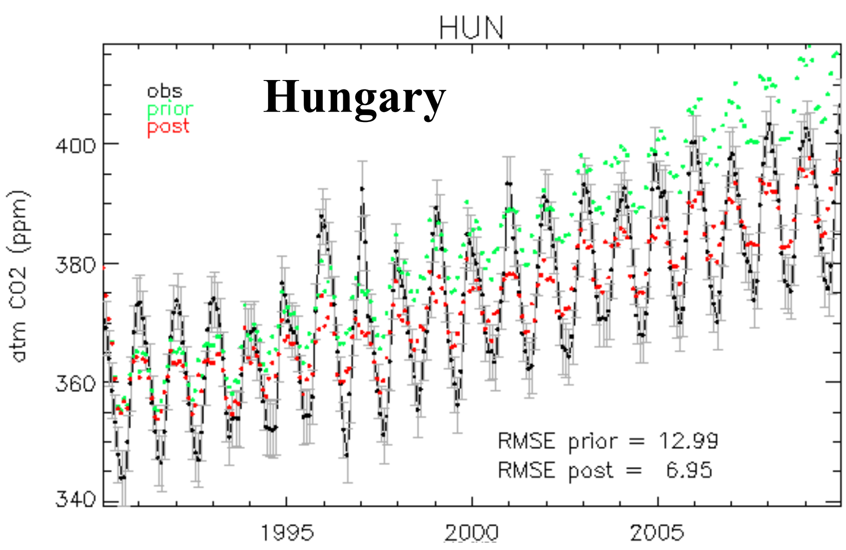
FluxNet assimilation: Mean seasonal cycles



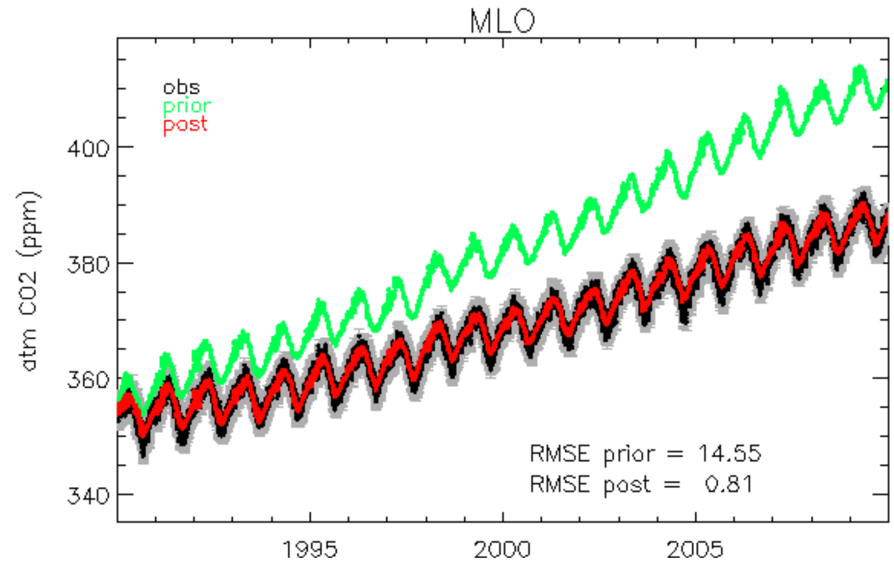
Assimilation of Atmospheric data

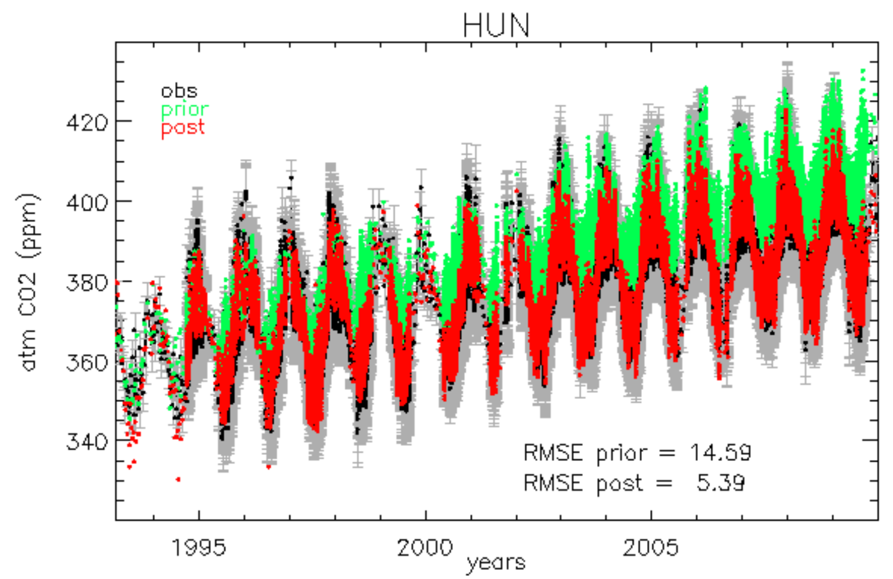
Parameter optimisation





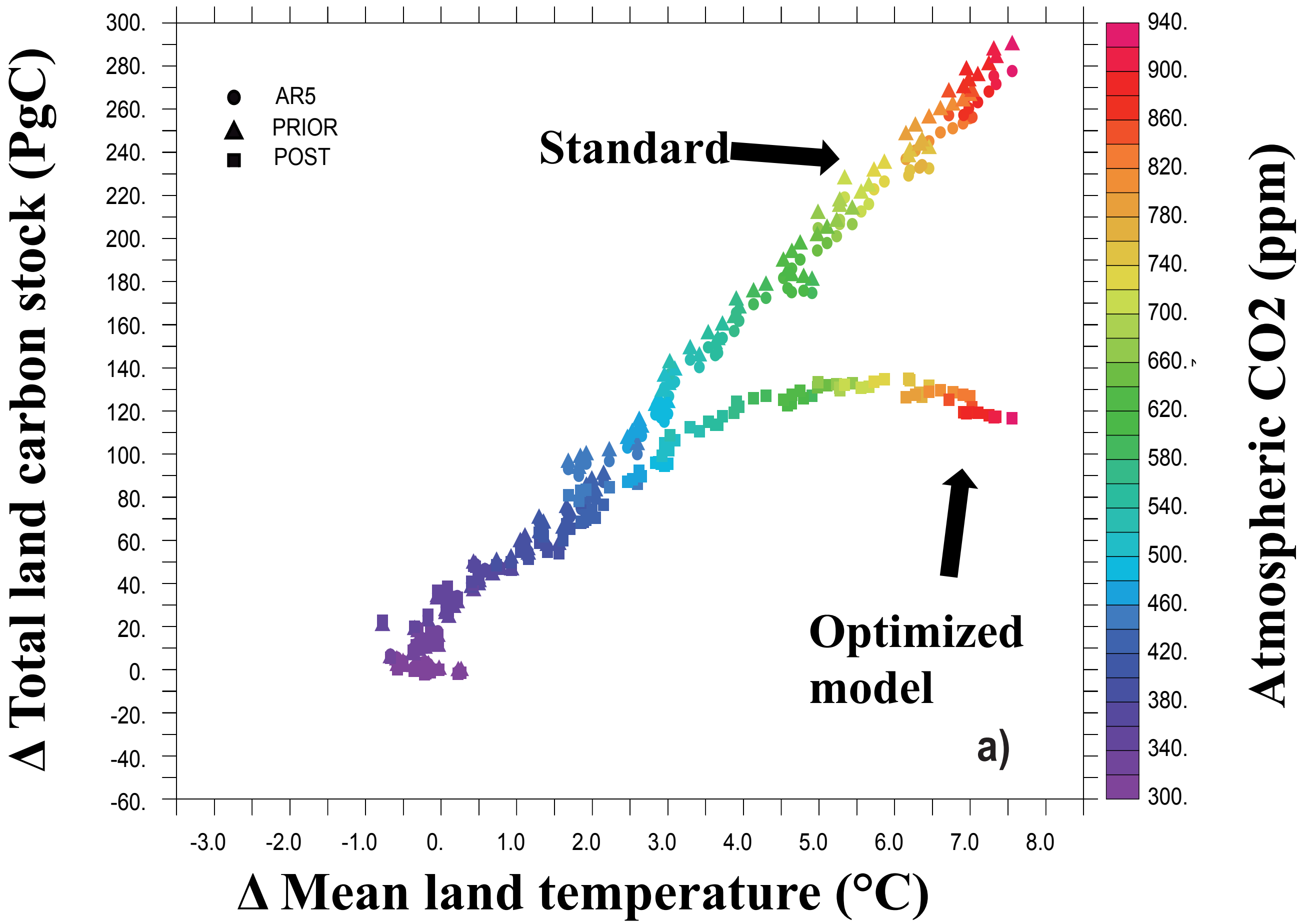
Flux optimisation





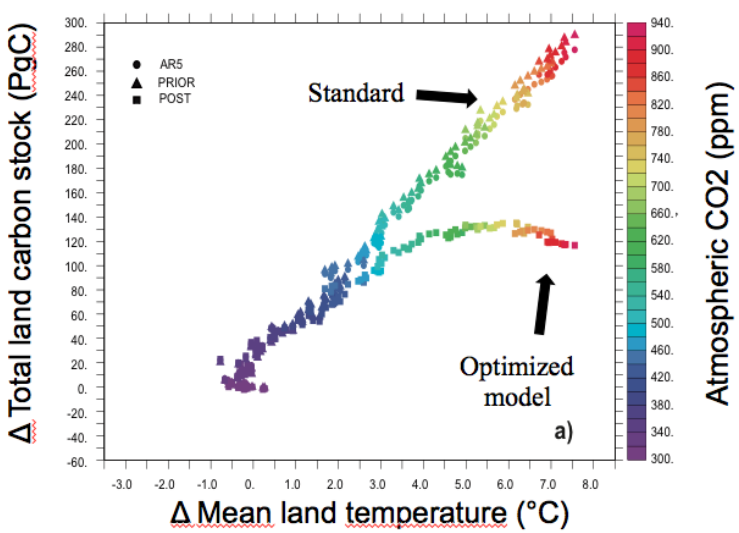
Impact on prognostic simulations (ISI-MIP)

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

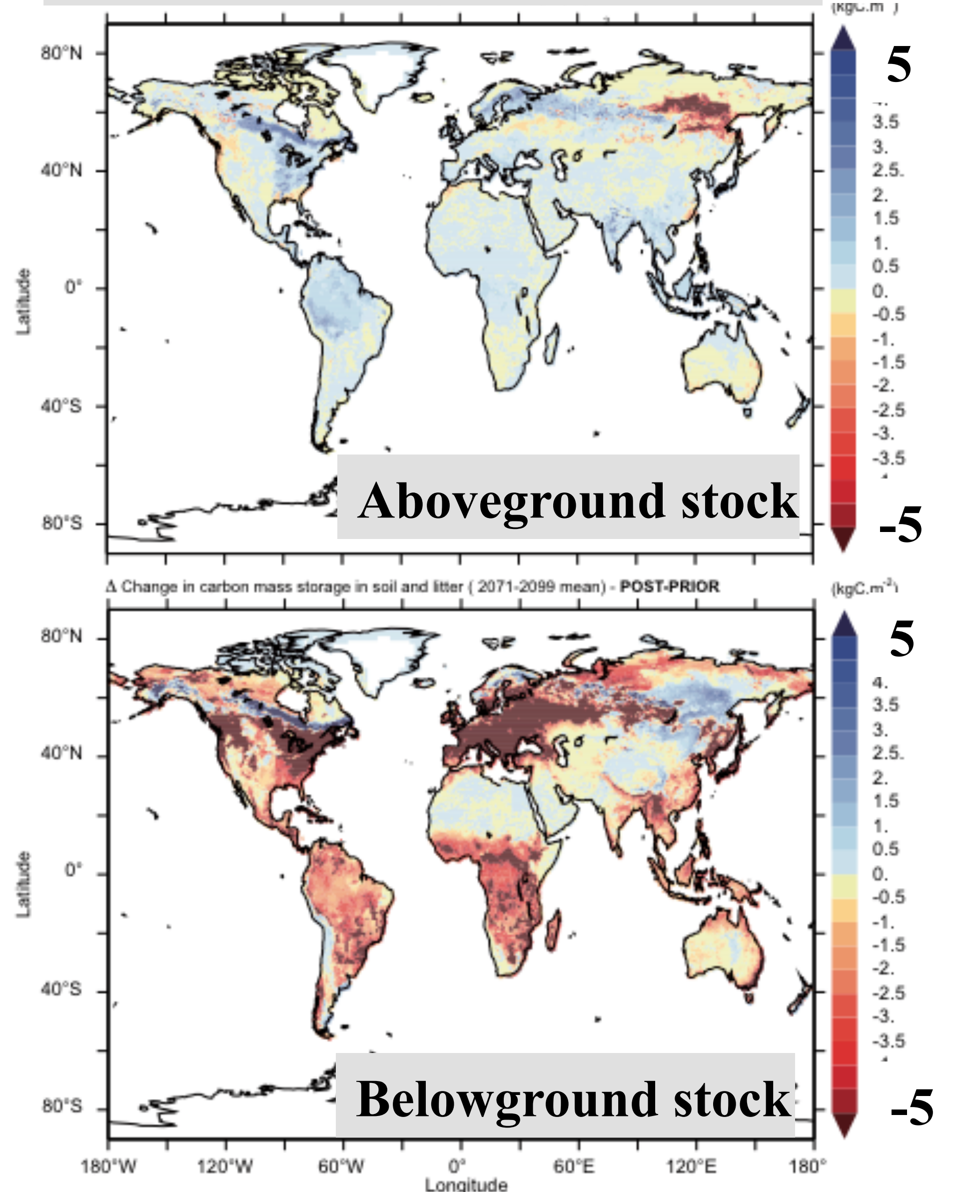


Impact on prognostic simulations (ISI-MIP)

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



2100 minus 2000: Δ C (kgC/m2)



ORCHIDEE today...

ORCHIDEE tomorrow...

Need strong scientific / engineer work