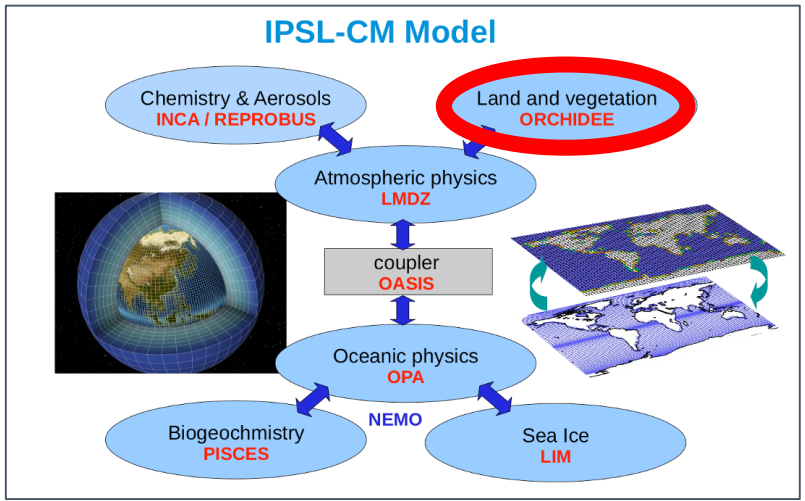
The ORCHIDEE global land surface model

Philippe Peylin for the whole ORCHIDEE project group



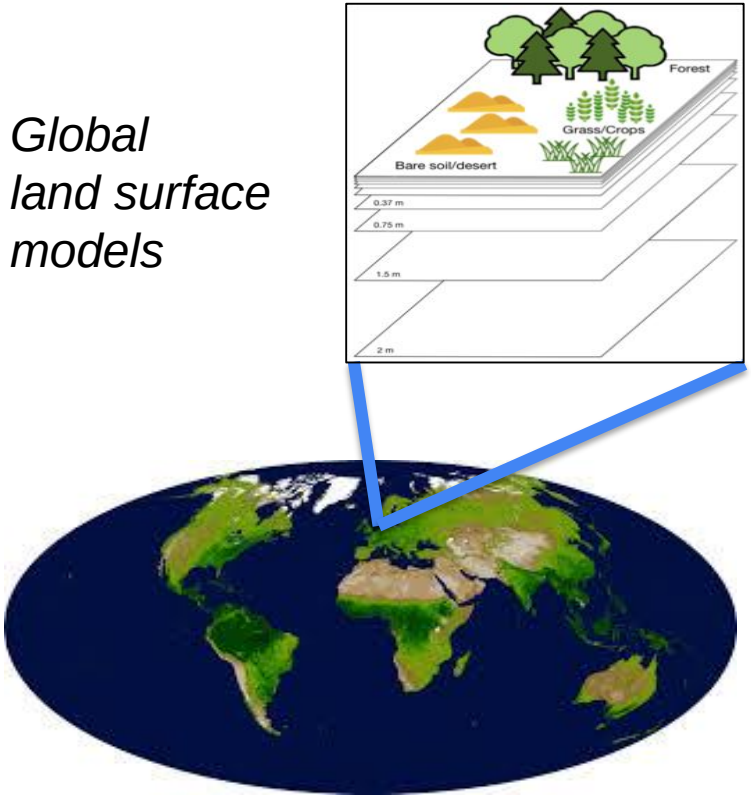
⇒ From site-level to global applications !

⇒ Component of IPSL/CNRM climate model

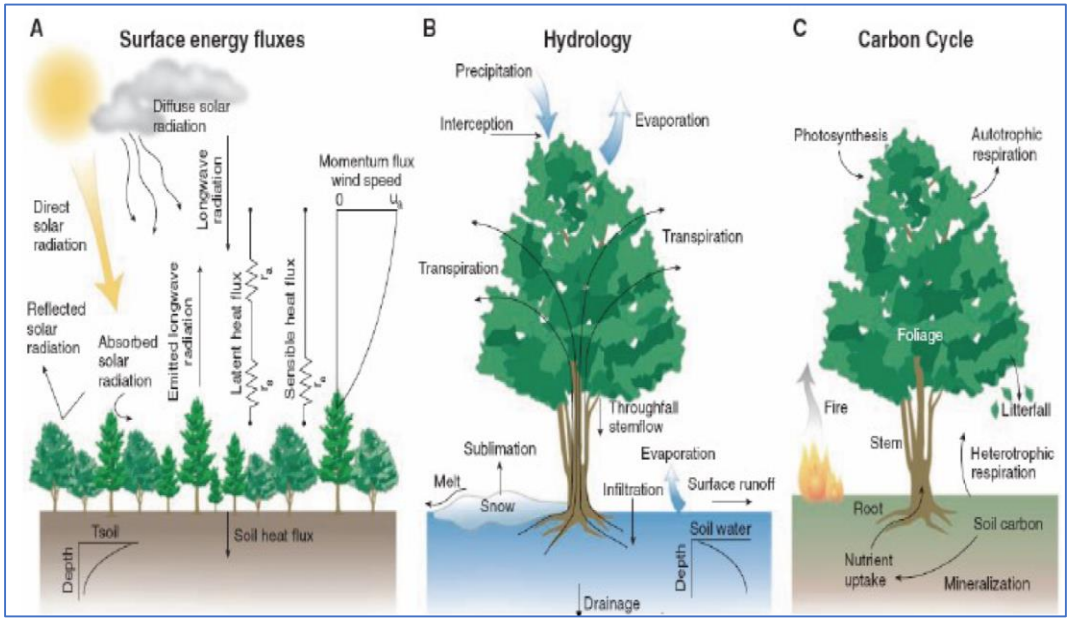
Land surface model

⇒ Solve for Energy / Water / Carbon / Nitrogen budgets

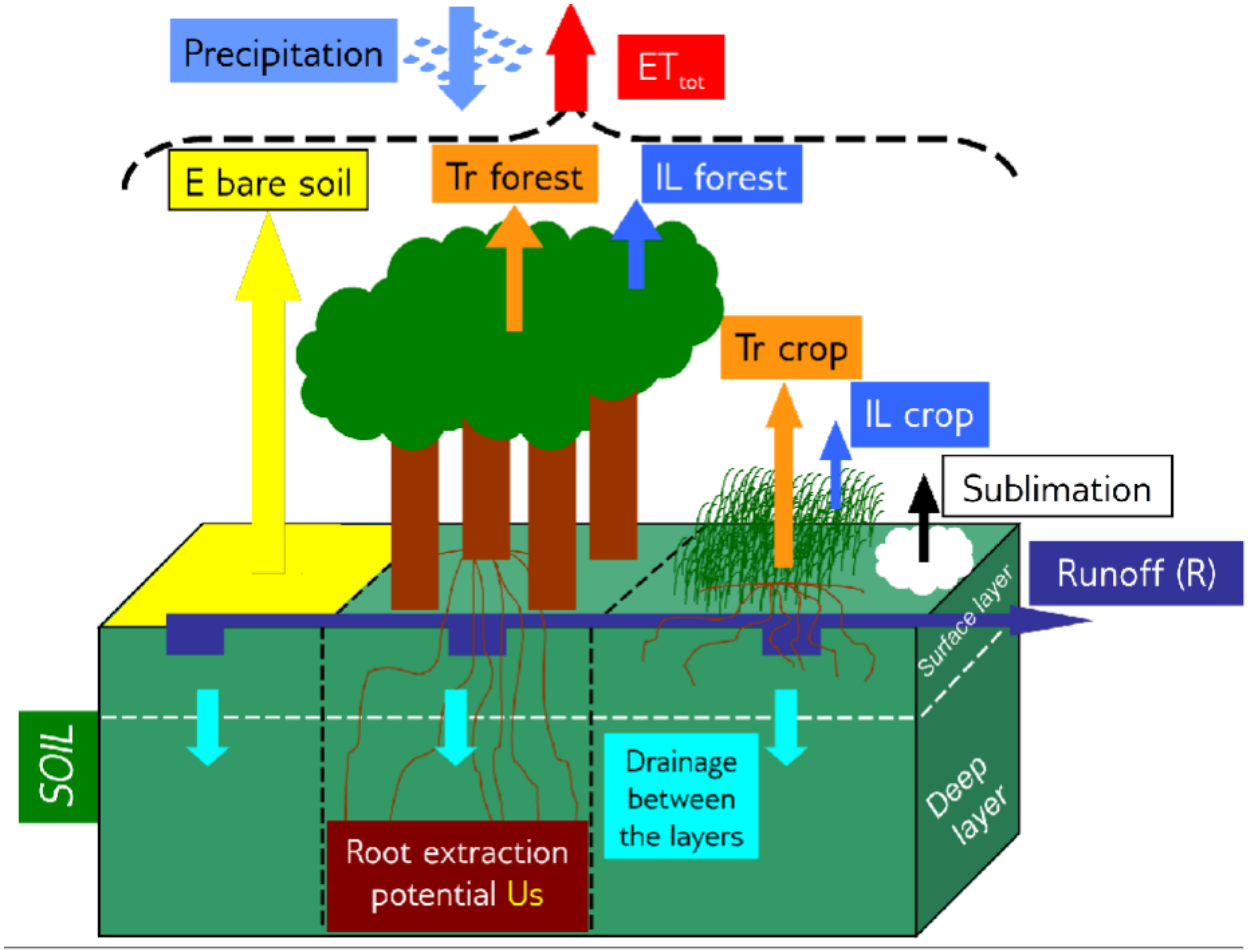
Global land surface models



Process-based land model

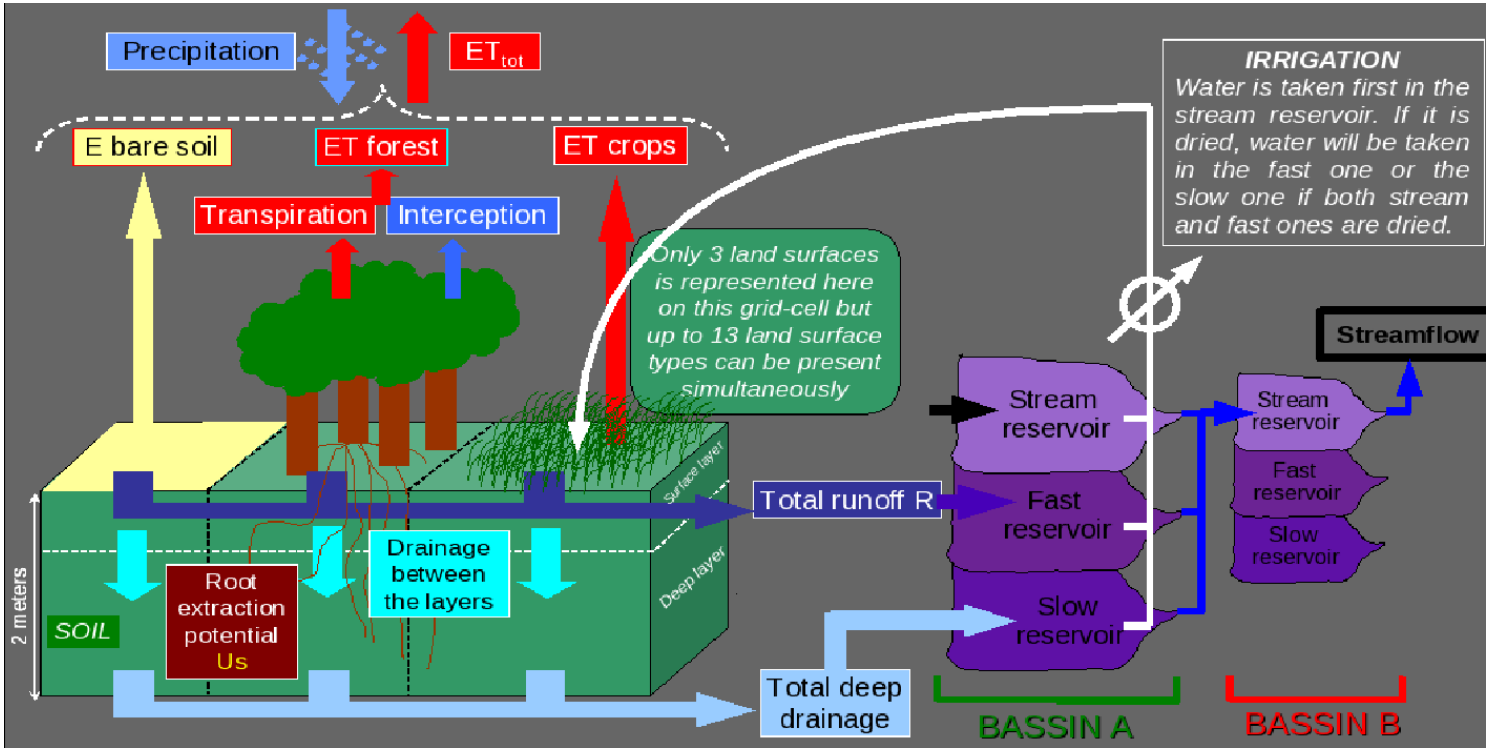


Hydrological modelling



Routing / Irrigation

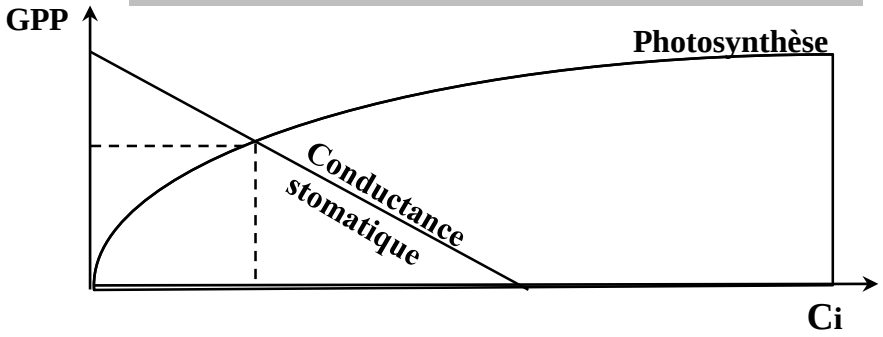
⇒ Routing parametrization to calculate water discharge to river



From Guimberteau (thesis, 2010)

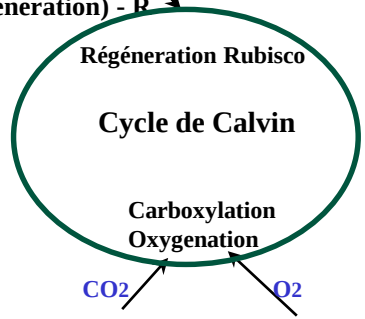
Photosynthesis: “Farquard, Ball & Berry model”

Leaf carbon assimilation



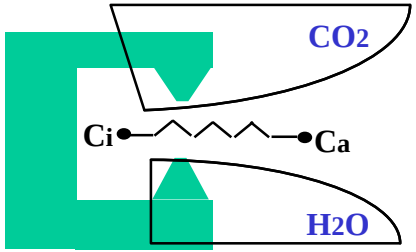
Photosynthesis (Farqhuar et al.)

An = f (Vcarbox , photons
Vregeneration) - R

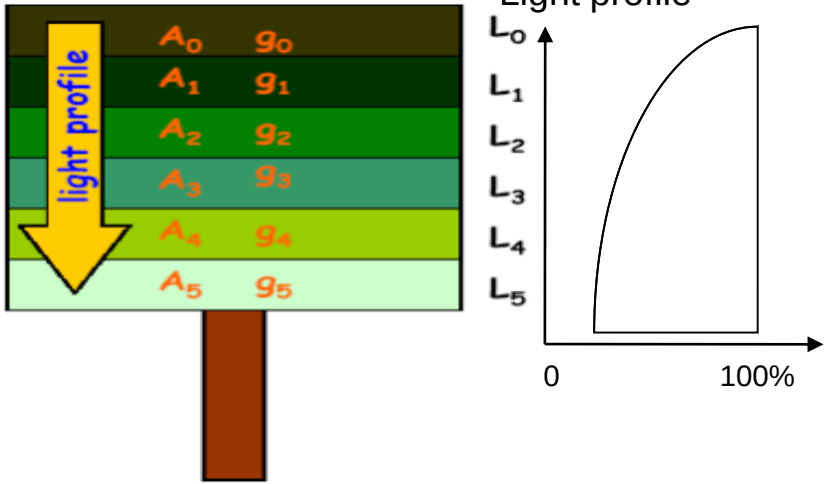


Stomatal conductance (Ball et al.)

Gs= m An*Hr/Ca
An = gs(Ca-Ci)



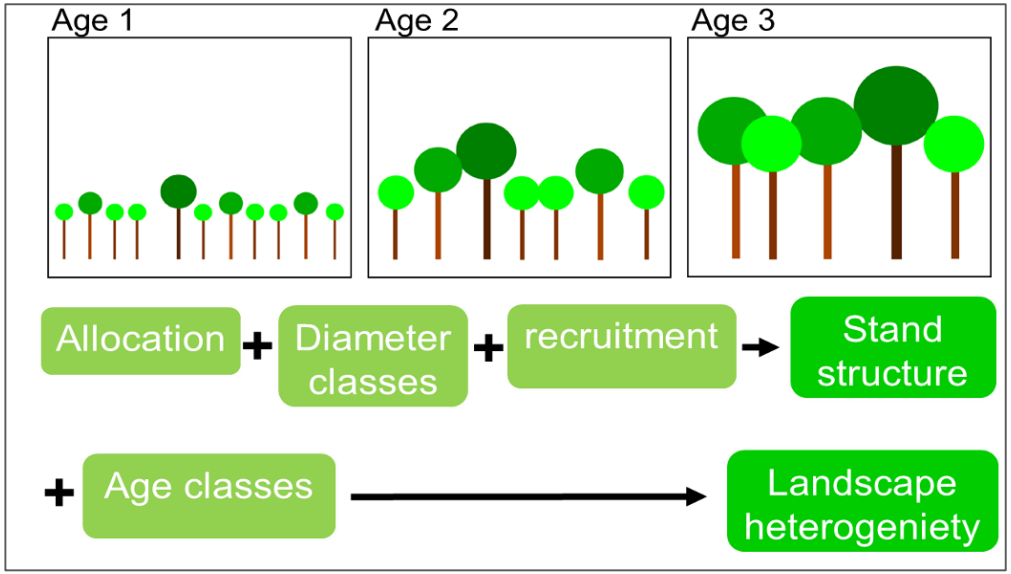
From the leaf to the canopy



ORCHIDEE : Forest AGB dynamics

⇒ include diameter & age classes

⇒ recruitment & mortality processes

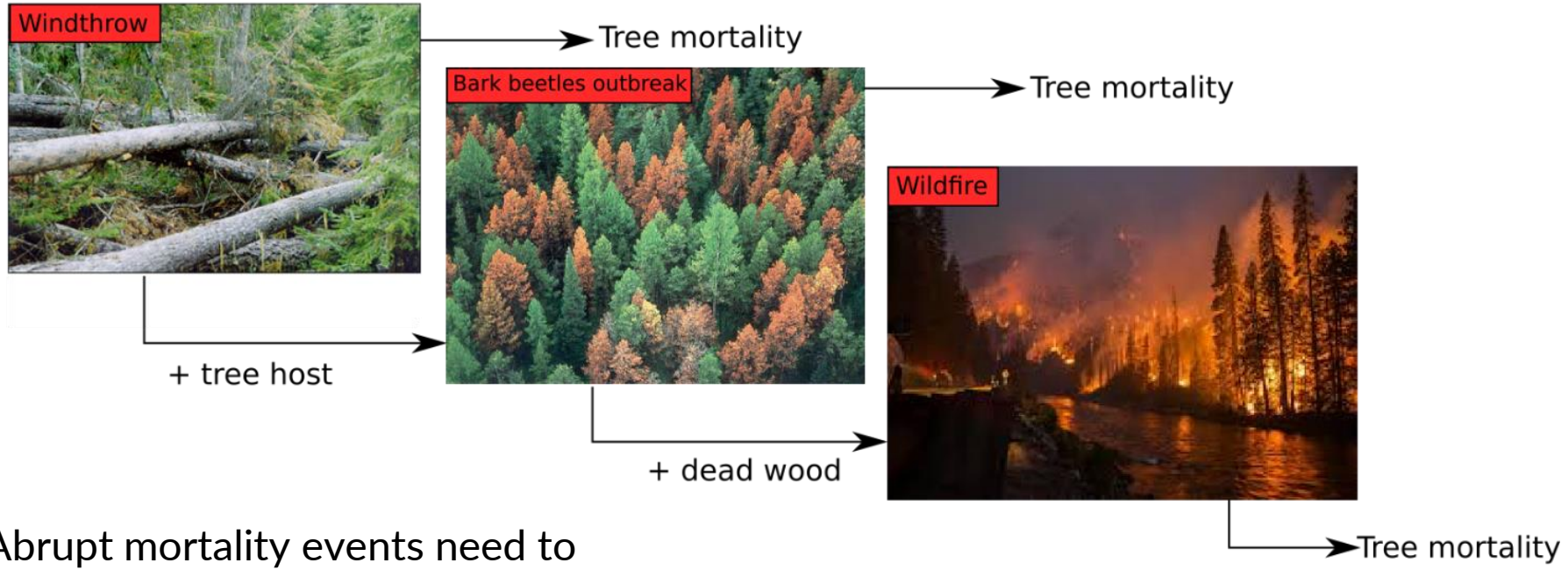


Key processes

- 2 stream Radiative Transfer
- Dynamic LAI
- Hydraulic architecture to calculate water stress + 11 layers soil water
- Potentially multi-layer energy budget (+ intra-canopy climate)
- Mortality from (wind, fires, bark-beetles)
- N cycle impact on C allocation
- ....

Mortality cascade is key to model ecosystem stability

An example of mortality cascade we would like to implement.

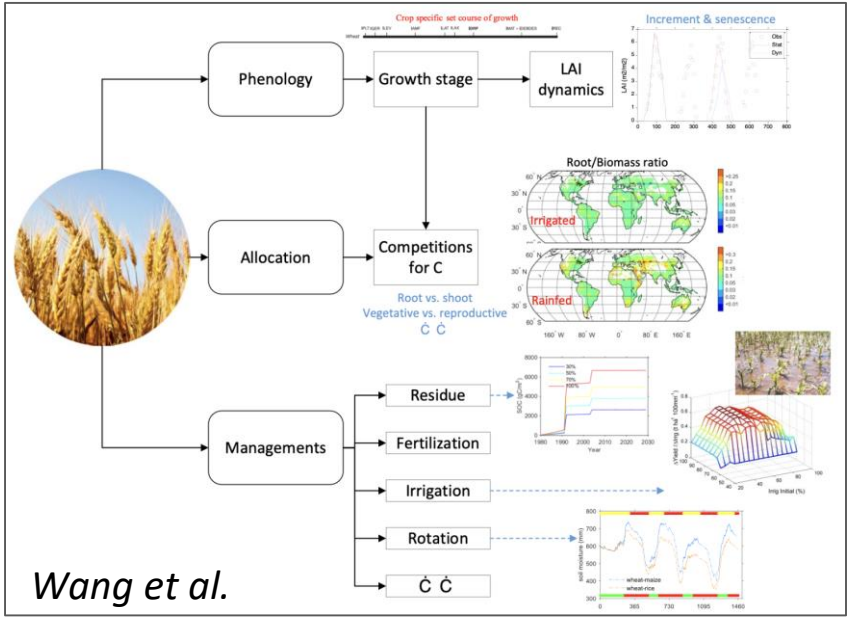


Abrupt mortality events need to be linked together in order to model mortality cascade

Developments by S. Luyssaert, G. Marie, ….

ORCHIDEE : Crop / grass dynamics

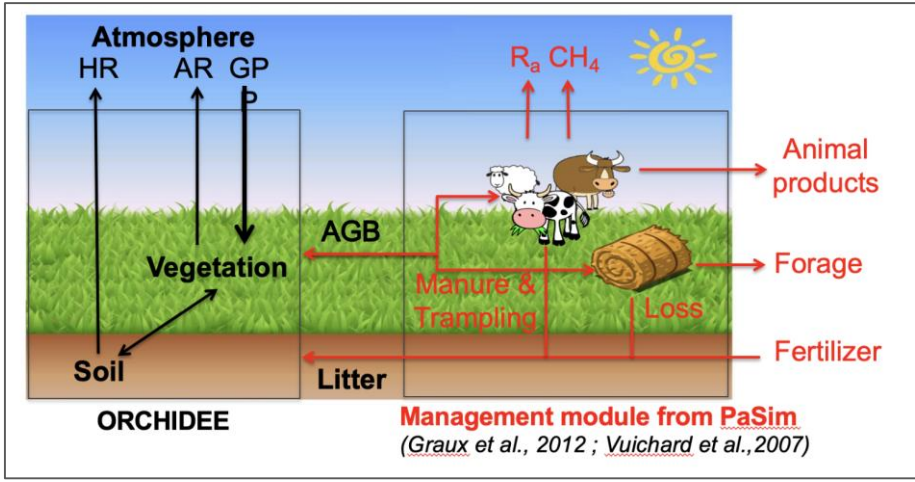
ORCHIDEE-Crop
(based on STICS modules)



Wang et al.

ORCHIDEE-GM
(based on PaSim modules)

⇒From intensive pasture to rangeland

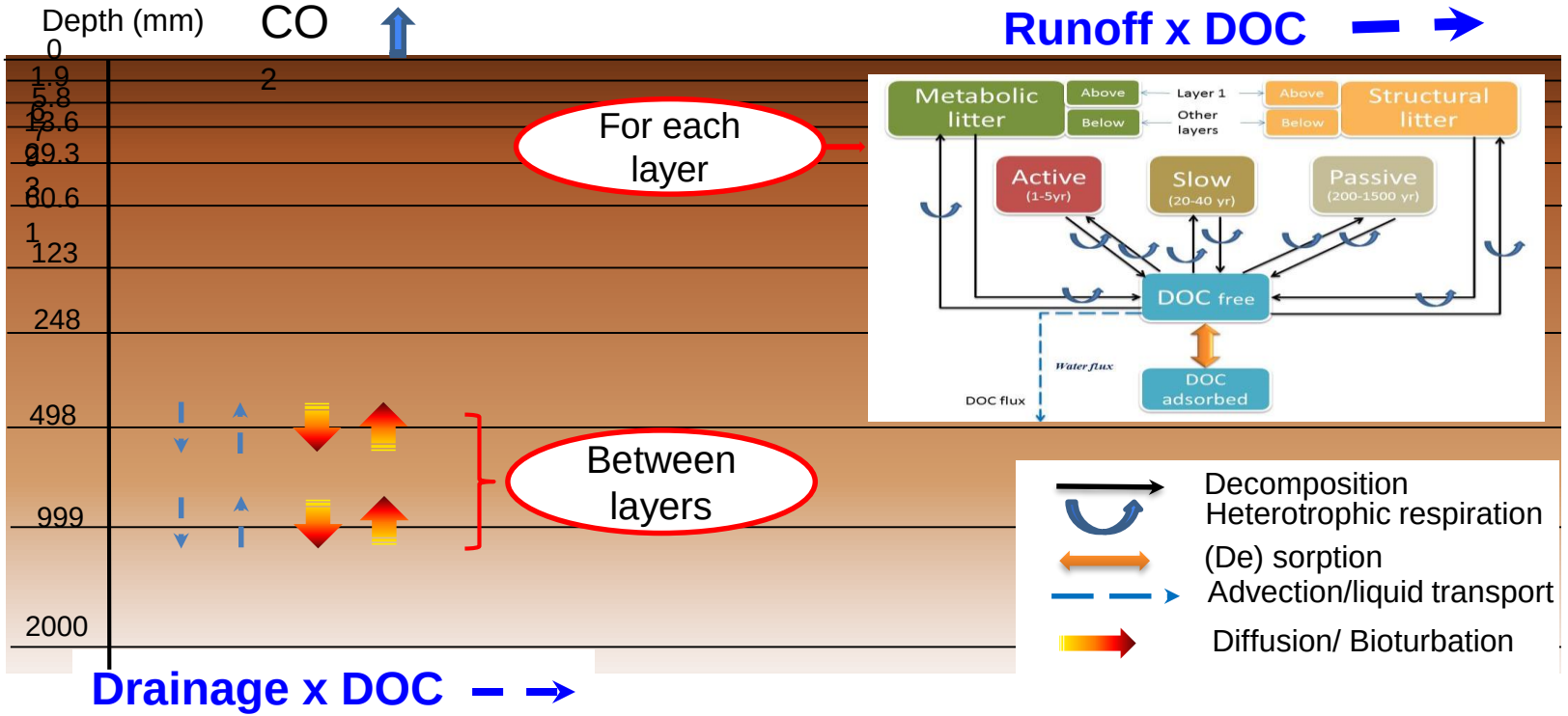


Chang et al. 2017

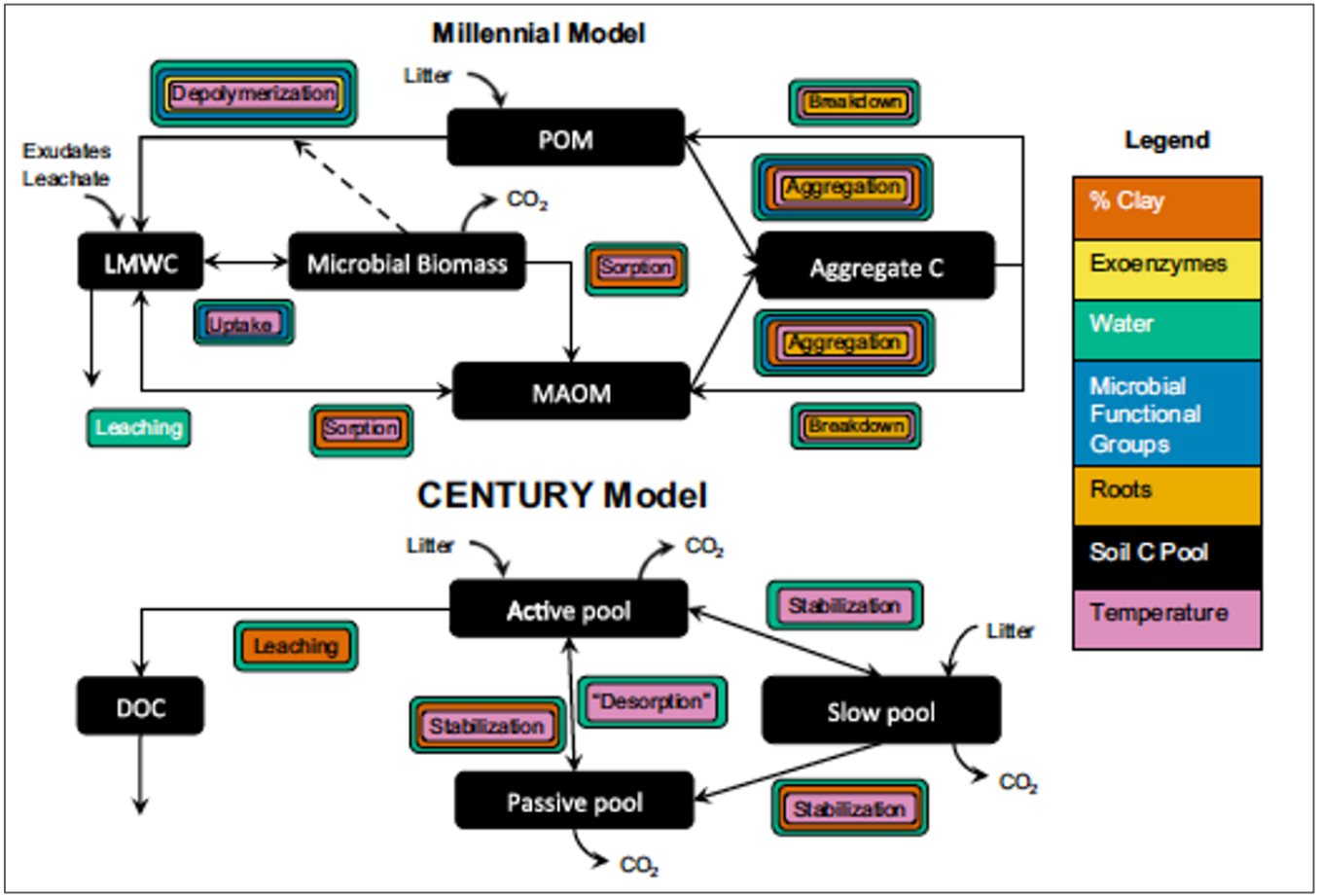
⇒ On-going merge of Crop / Grass branches into Trunk with N cycle

ORCHIDEE : Soil C dynamics

- Discretized soil carbon (11 layers) + new pools introduced (DOC)
- New decomposition scheme (priming): $\frac{\partial SOC}{\partial t} = I - k_{SOC} \times SOC \times (1 - e^{-c \times FOC}) \times \theta \times \tau$



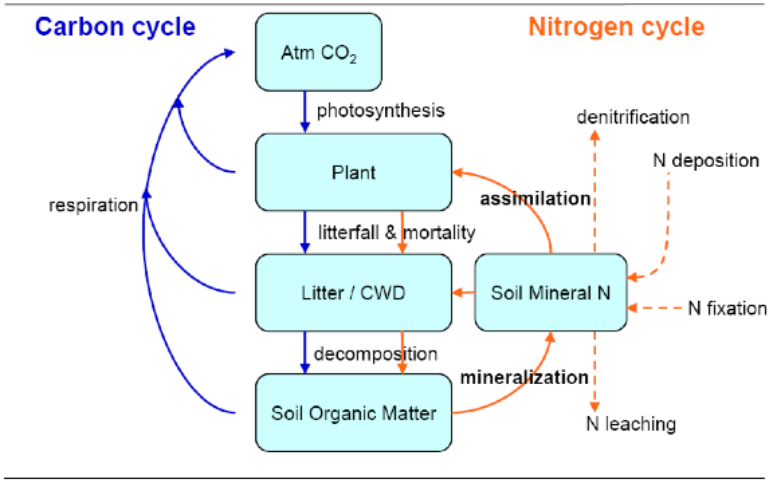
Soil Carbon model: on-going developments



⇒ Accounting for soil Microbial biomass

Abramoff et al., 2018

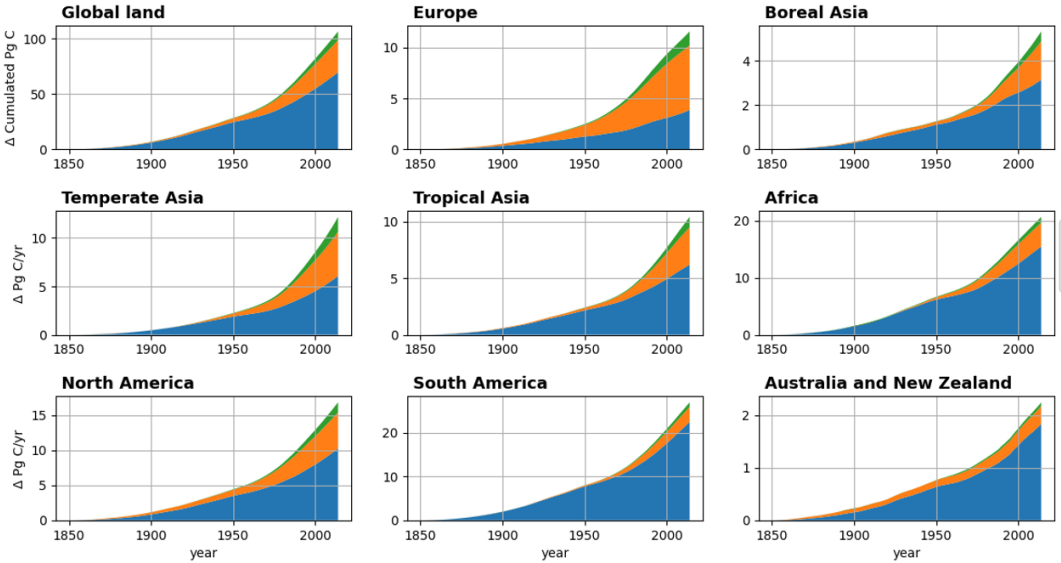
Accounting for the N cycle impact on the C cycle



Vuichard et al., 2019

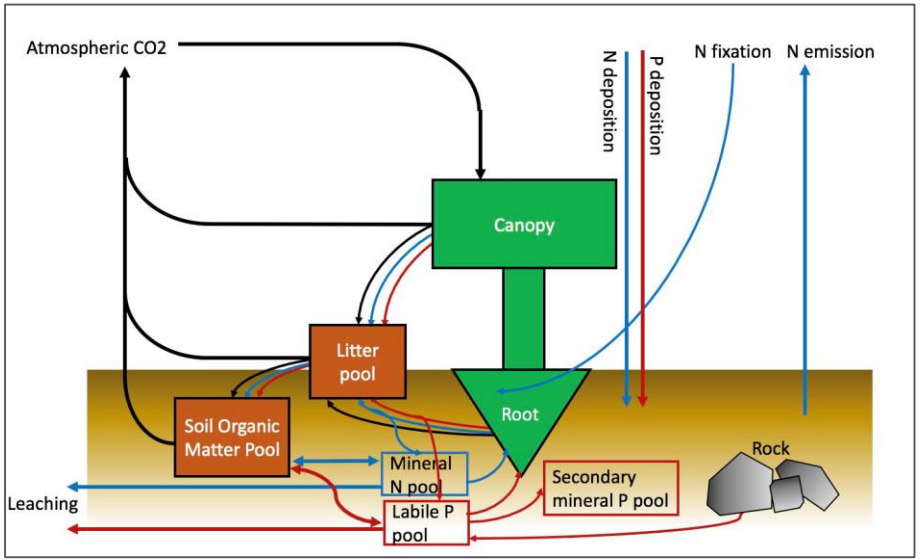
Respective contributions of CO2 and Ndep to cumulated NBP

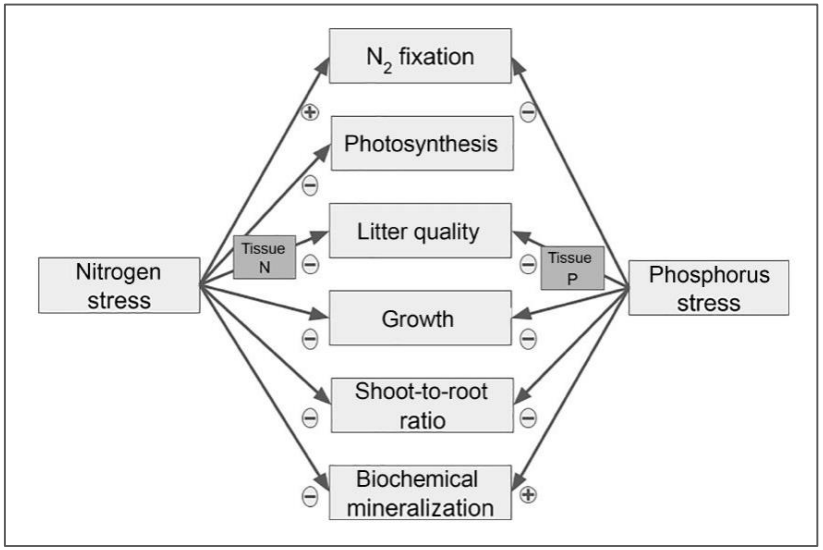
CO2 only / Ndep only / Covarying effect



Raino Sanchez et al., in rev.

Accounting for the P cycle impact on the C cycle





Goll et al., 2017

- ORCHIDEE - CNP version that accounts for both N and P nutrient limitations; Significant impact of P cycle in Tropics
- Ongoing effort to include back the P cycle in ORC - Trunk

The terrestrial biosphere and atmospheric chemistry

J. Lathière

Ozone

Aerosols Lifetime

Oxidizing capacity

Isoprene

Alcohols Acids

Monoterpenes

NO

NO_2

Volatile Organic Compounds (1000 TgC/yr)

80% of global emissions

Methane

30% of global emissions

Nitrogen oxides

10% of global emissions

O_3

NO_x

Isop.

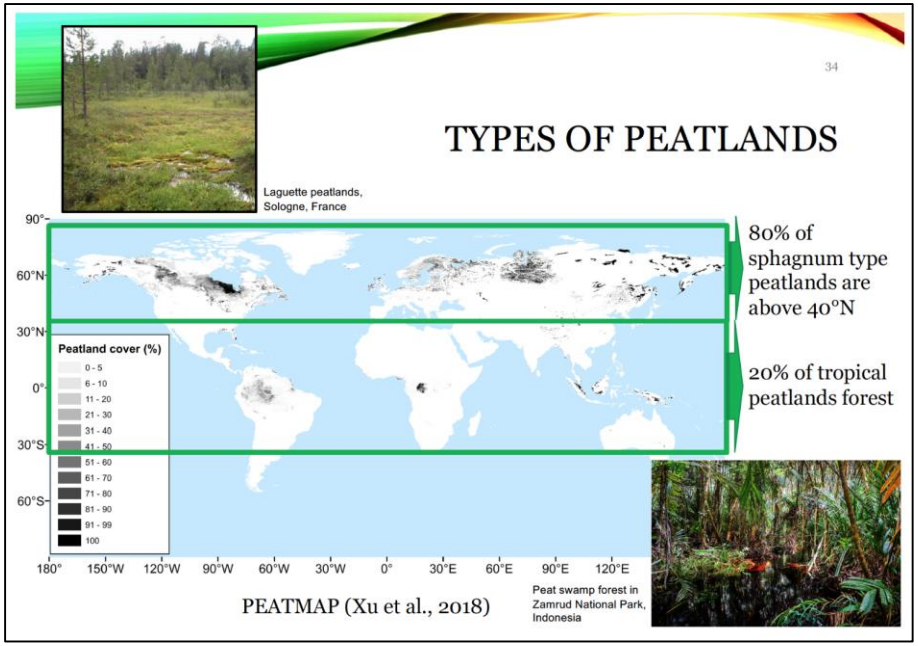
OH

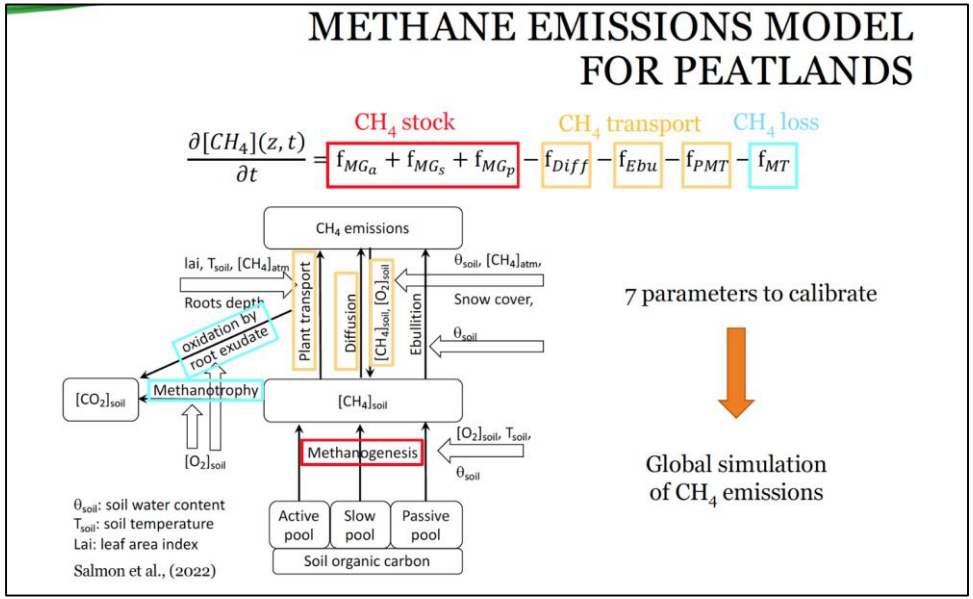
Vegetation

Wetlands

Soils - Cultures

Peatland and CH4 modelling in ORCHIDEE





Several branches of ORCHIDEE (PEAT, LEAK, ...)

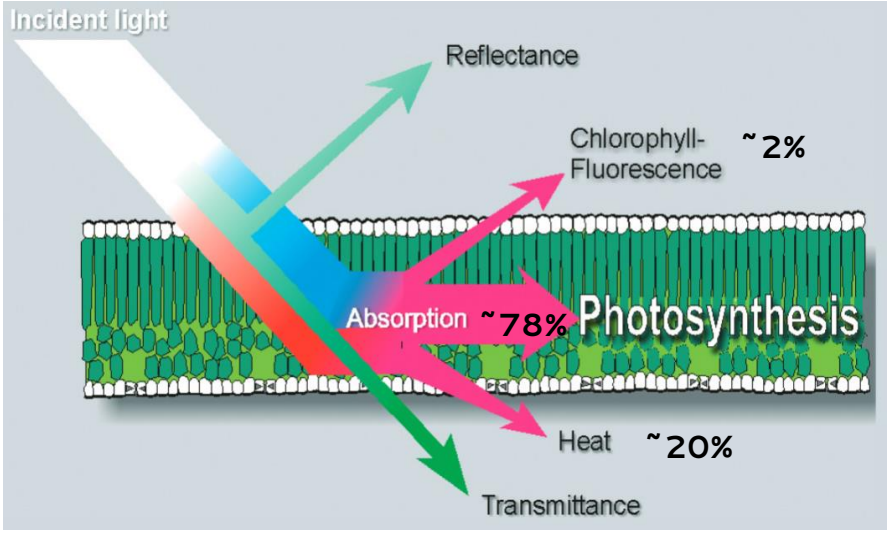
⇒ On going merge in the TRUNK

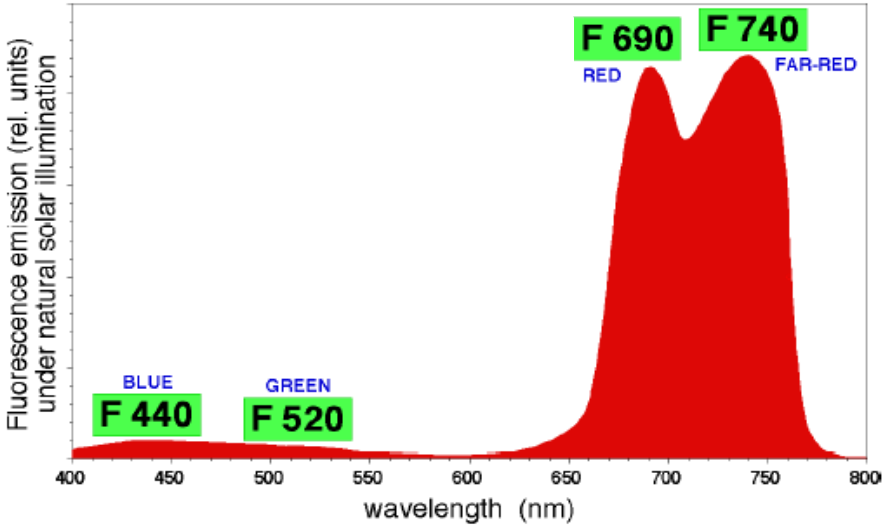
⇒ Contact E. Salmon

What makes SIF so interesting for vegetation monitoring?

Solar-Induced Fluorescence (SIF)

- Chlorophyll fluorescence is an electromagnetic signal emitted by the photosynthetic machinery of green plants that can be linked to **instantaneous photosynthesis**
- SIF can be retrieved by atmospheric spectrometers with the required spectral and radiometric resolution





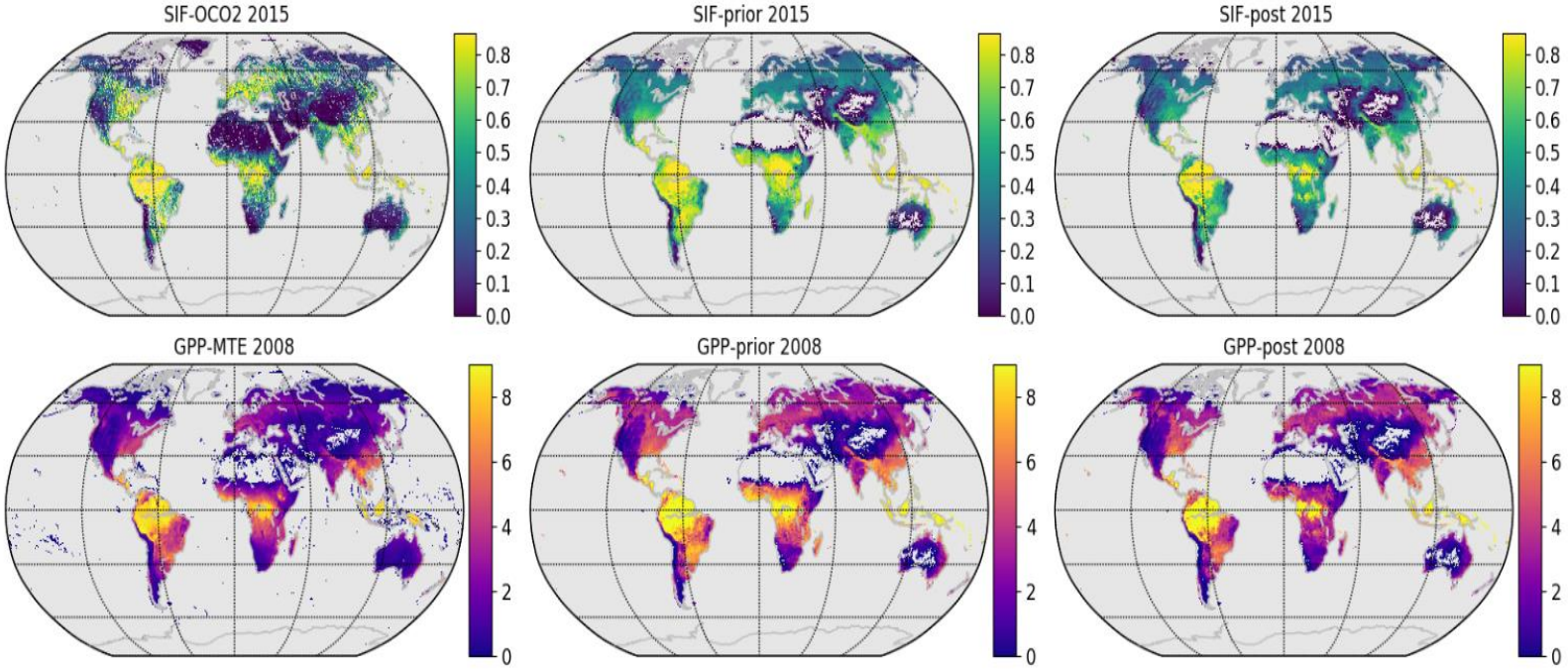
⇒ Development of a process-based SIF model in ORCHIDEE

Assimilation of Space-borne SIF (parameter optimization)

Application with OCO-2

SIF (2015)
"Assimilated"

GPP (2008)
"validation only"

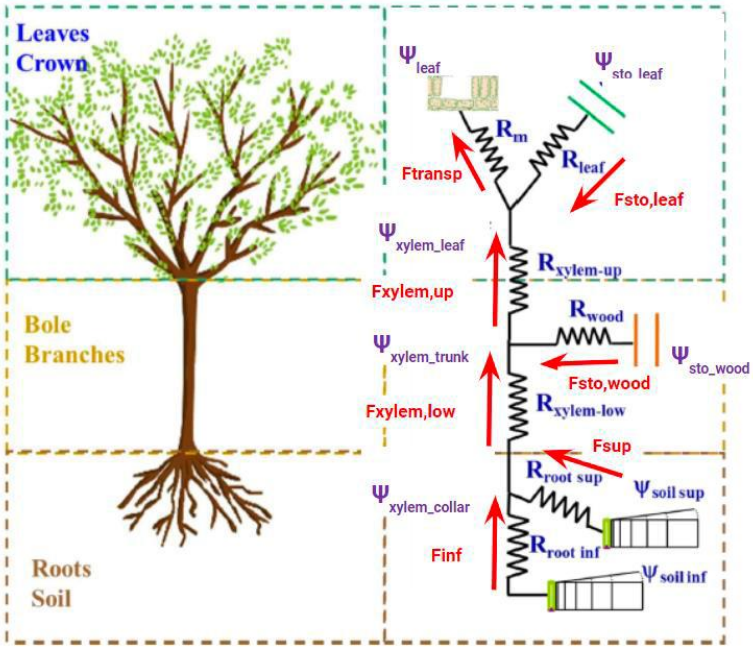


⇒ Improvement of GPP magnitude and seasonality & large reduction of total GPP

Bacour, Maignan, MacBean et al. (2019)

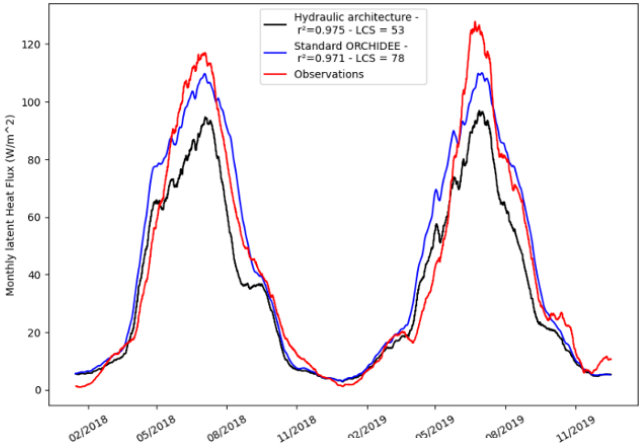
Optimisation of a new hydraulic architecture

- **New physical scheme linking soil water potential to leaf potential !**

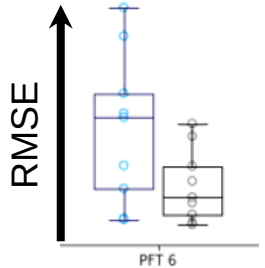


- **Optimisation of the STD vs NEW scheme with FluxNet latent heat fluxes at site level !**

Hydraulic architecture:
r^2=0.975 / LCS=53
Standard ORCHIDEE:
r^2=0.971 / LCS=78
Observations



⇒ **Higher capability to model temporal flux variations especially during droughts!**

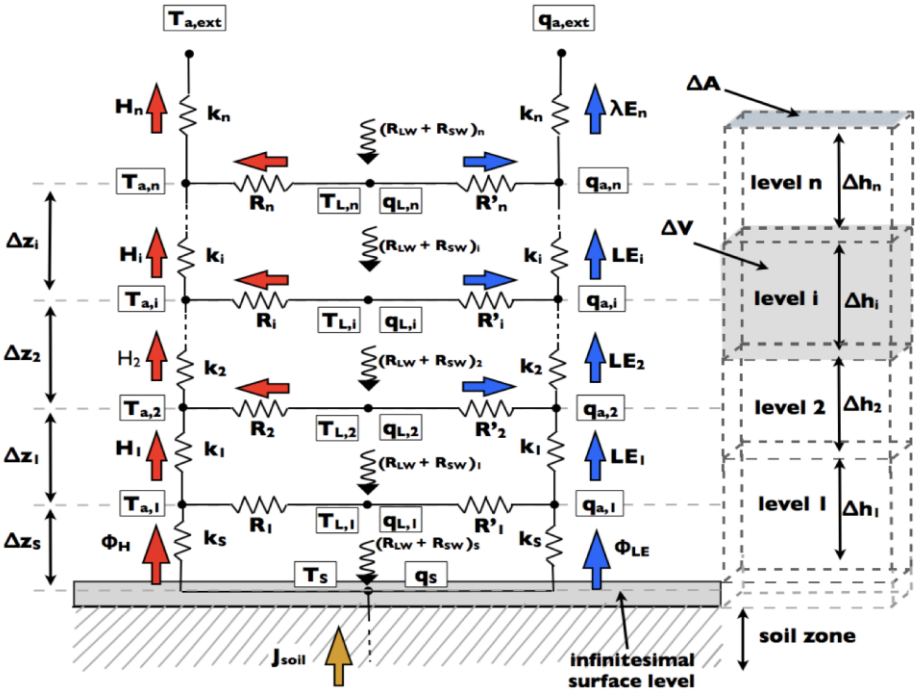


Broadleaf Dec Forest

@Alleon et al. (in prep.)

Vertical multi-layers scheme..

- Free number of layers
- E / W / C exchange at each level
- Turbulance mixing within air canopy
- Light penetration following Pgap model



Implementation constraints :

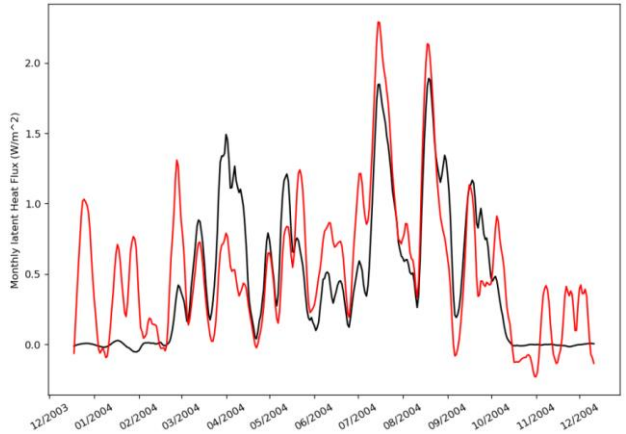
- Coupling with plant growth / harvesting module (variable plant height)
- Implicit coupling with Atmospheric model (30’ step)
- Parametrisation of intra-canopy turbulence

Vertical multi-layers scheme..

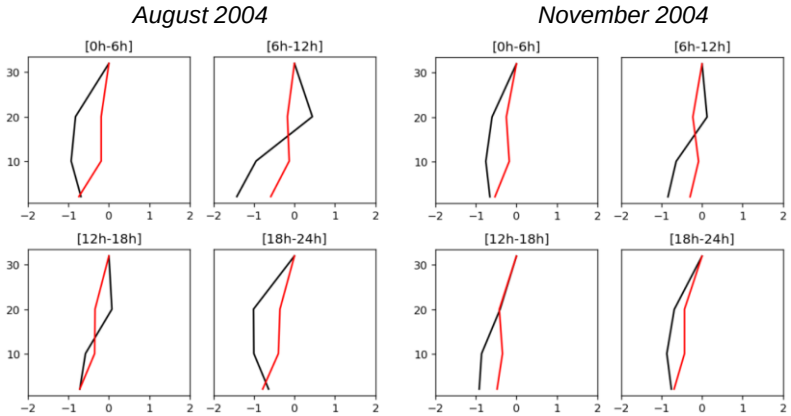
Multi-layer energy budget: Local results (DE-Hai – 2004)

Multi-Layer EB
Observations

Temperature difference between top canopy and surface in 2004



Normalized intra-canopy temperature gradient



- **Overall canopy temperature gradient dynamics** well represented during the year;
- **Intra-canopy climate well reproduced** most of the time;

Other Mature/Ongoing developments

Biophysical

Biogeochemical

Lake model (FLAKE)

Irrigation

Termokarst lake

DOC – DIC transport by river

New boreal PFTs (Mosses, lichens, shrubs)

Nitrogen – **Phosphorus** - Carbon coupled cycles

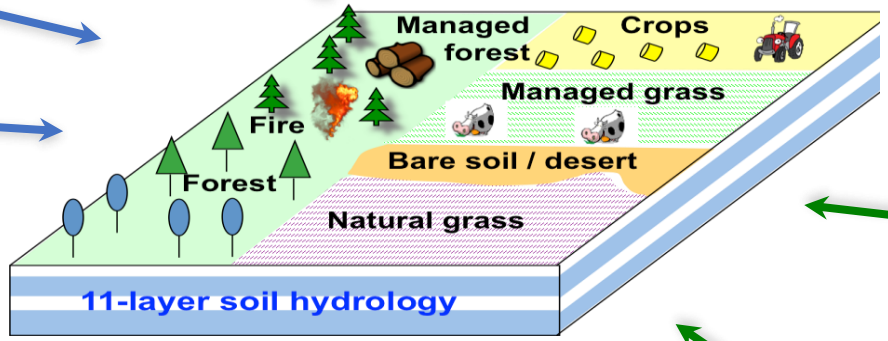
Crop model (wheat, corn, rice,…)

Grassland management

Peatland model (CH4)

Herbivory (large herbivore)

Plant Traits

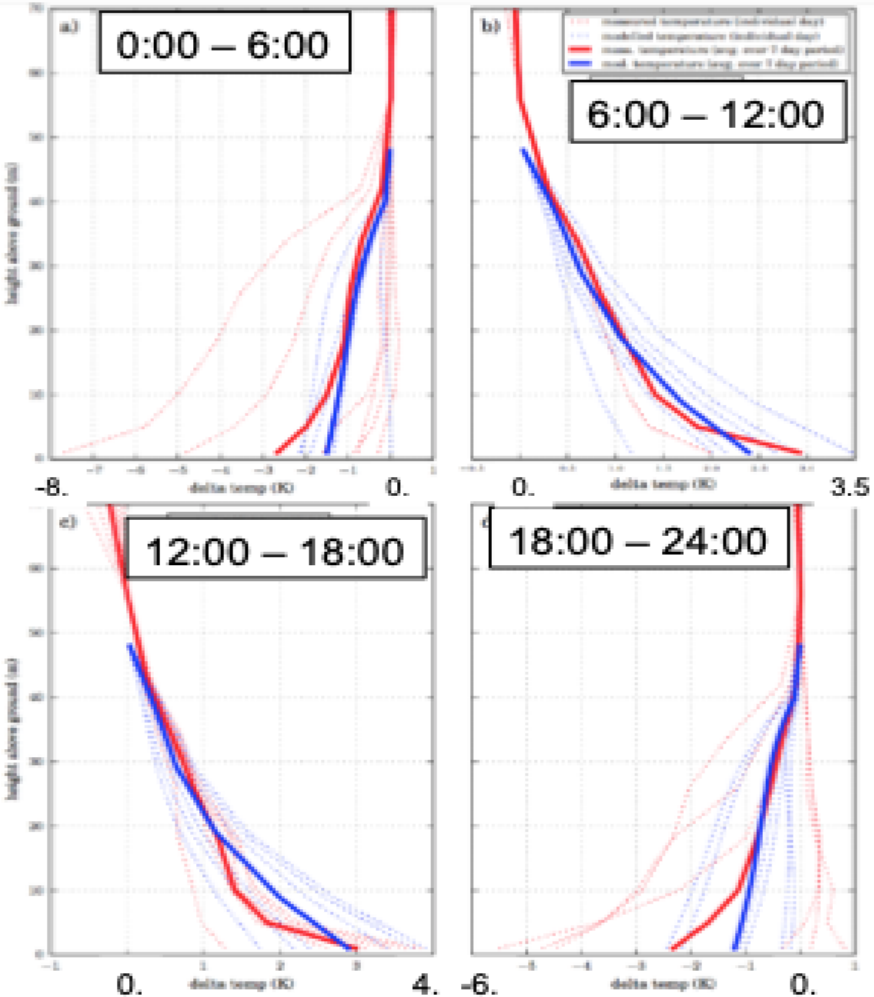


Le comité de pilotage d'ORCHIDEE

⇒ Un groupe regroupant des expertises multiples et variées !

⇒ Nombreuses personnes au LSCE !

Thank you...



Daily temperature

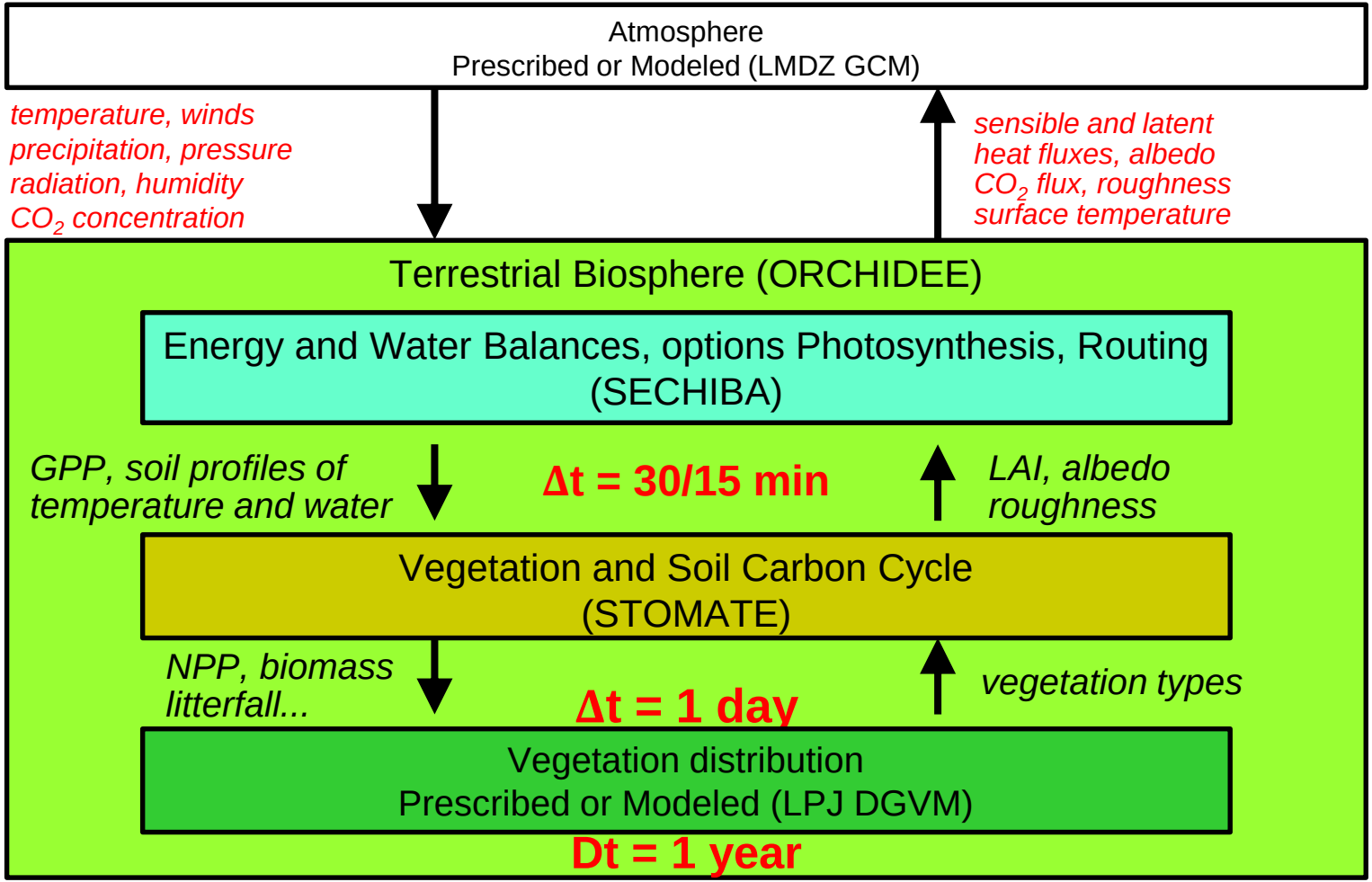
Temperature profile at Tumbarumba site

Observations

Model

Ryder et al., 2015

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)
GPP, soil profiles of
temperature and water
Δt = 30/15 min
LAI, albedo
roughness
Vegetation and Soil Carbon Cycle
(STOMATE)
NPP, biomass
litterfall...
Δt = 1 day
vegetation types
Vegetation distribution
Prescribed or Modeled (LPJ DGVM)
Dt = 1 year