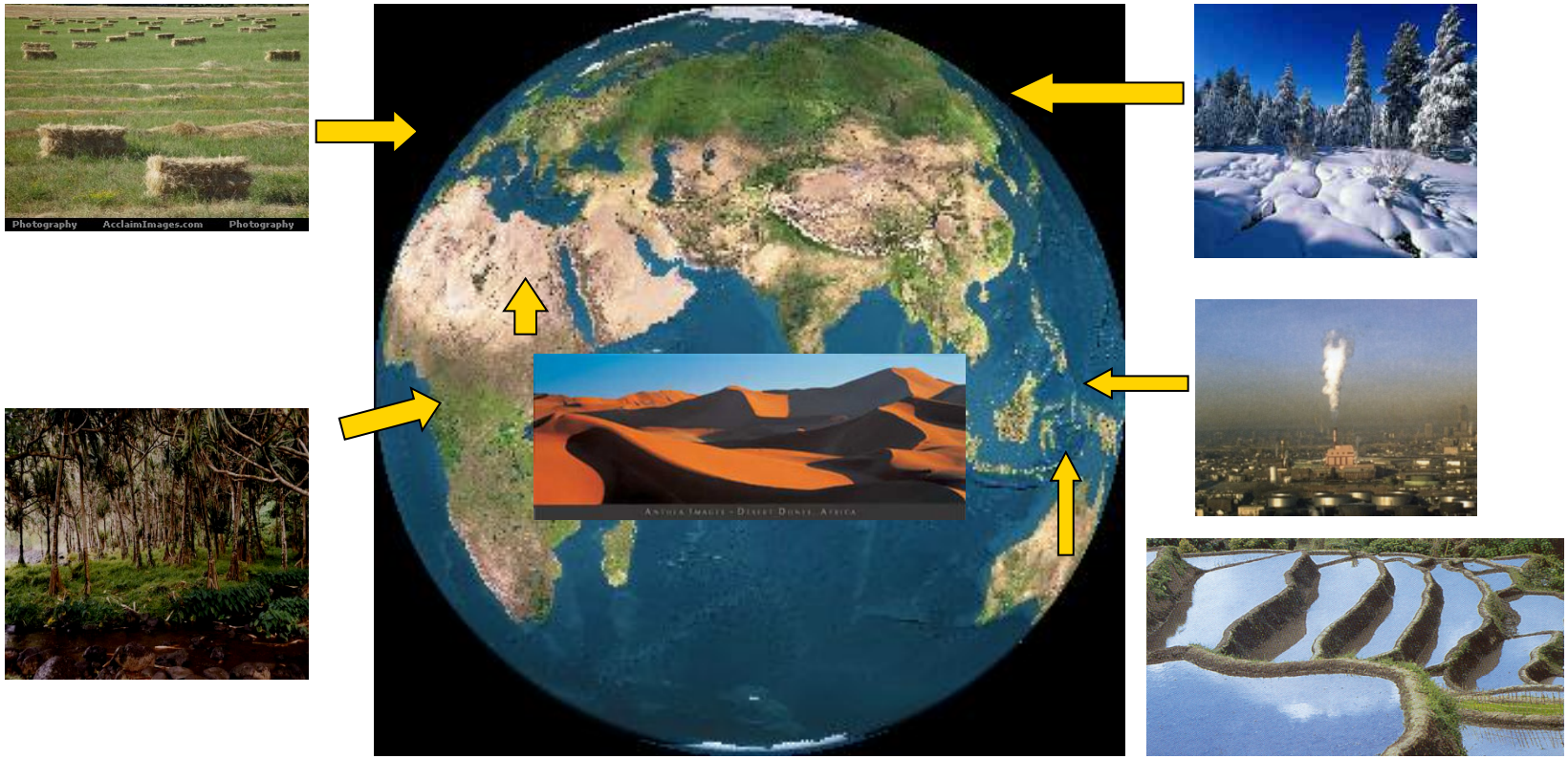
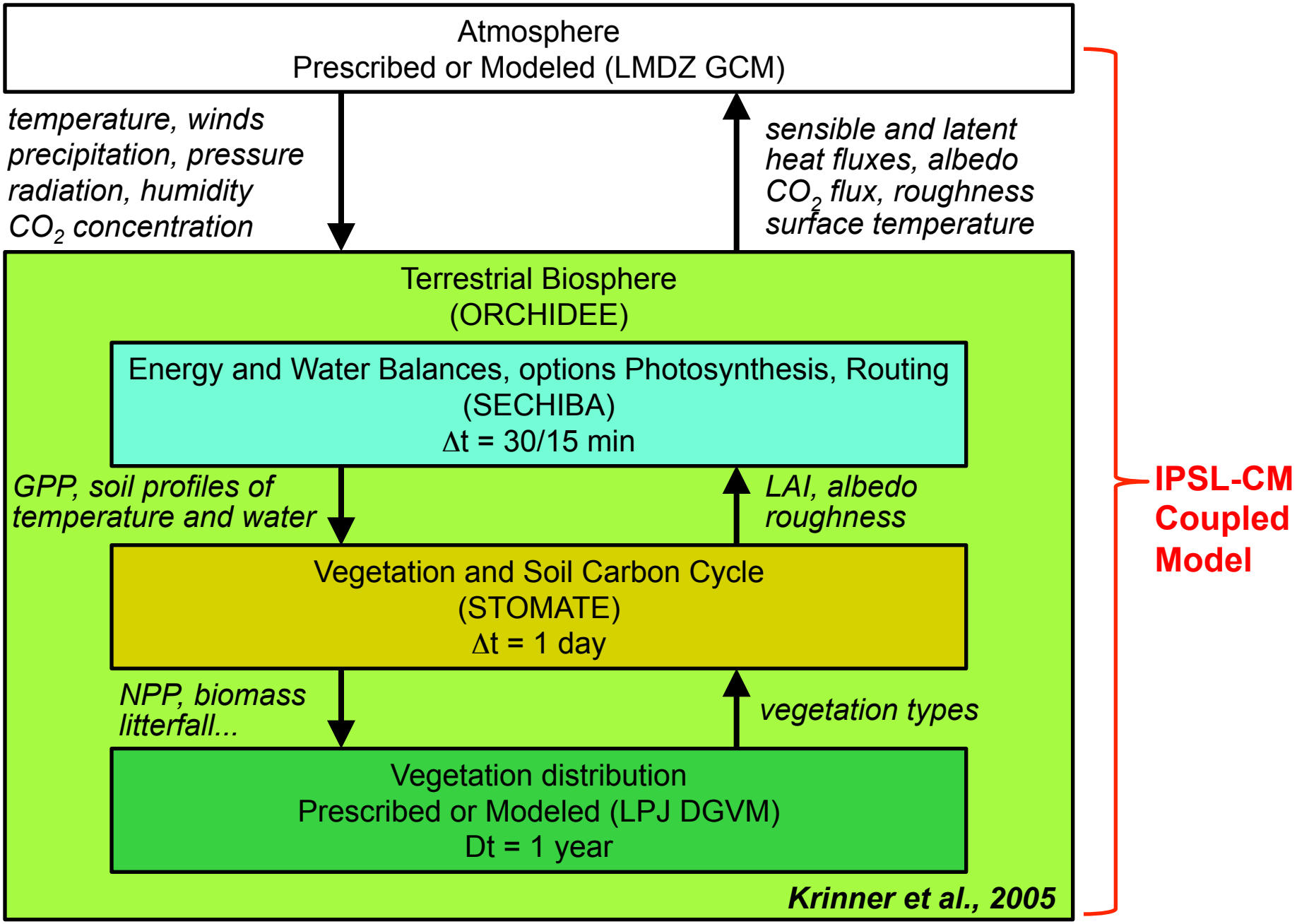
Dynamic Global Vegetation Model ORCHIDEE

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

Institut Pierre Simon Laplace



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

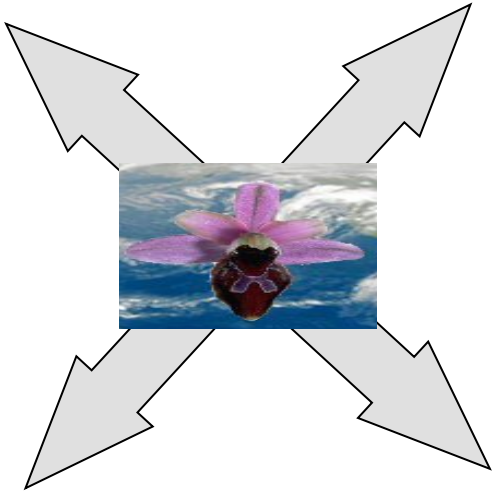
Why using ORCHIDEE

Climate impact & feedbacks: Energy & Water balances

- Impact of surface heterogeneity
- Global climate impact
- Regional climate impact
- Climate Change and Fires
- Climate extremes impact

Climate impact & feedbacks: Agrosystems

- Regional impacts
- Land sharing mitigation potential
- Food supply



Tipping Points

- Boreal regions: Permafrost melting…
- Amazon: possible die back

Attribution of global changes (GHG balances, run-off…)

- Carbon sink attribution (climate, N cycle, land use, forest management, fire)
- Change in run-off

More than 20 years of development

Model

SECHIBA

Carbon Cycle (STOMATE)

Dynamic Veg. (LPJ)

ORCHIDEE

+ New hydrology

+ River routing

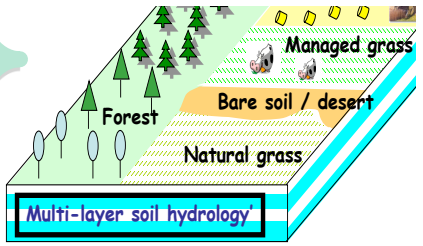
+ Forest management

+ Crops module

+ Permafrost

+ Nitrogen Cycle

Toward a single shared tool



(Laval et al., 1981) *(Ducoudré et al., 1993)* *(Viovy et al., 1997)* *(Polcher et al., 1998)* *(Krinner et al., 2005)*

80s **90s** **2000** **2009**

Project / Users

Few Scientists at LMD (3-4)

Small group btw LMD/LSCE (5-10)

Increasing number of developers & users (15-25)

LMD — organization LMD/LSCE → Specific "Project Group" across IPSL & few other labs.

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 Post-doc / PhD

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

Main features of ORCHIDEE

- **Vegetation defined as Plant Functional Types (13 currently)**
  A mosaic of vegetation in each grid cell

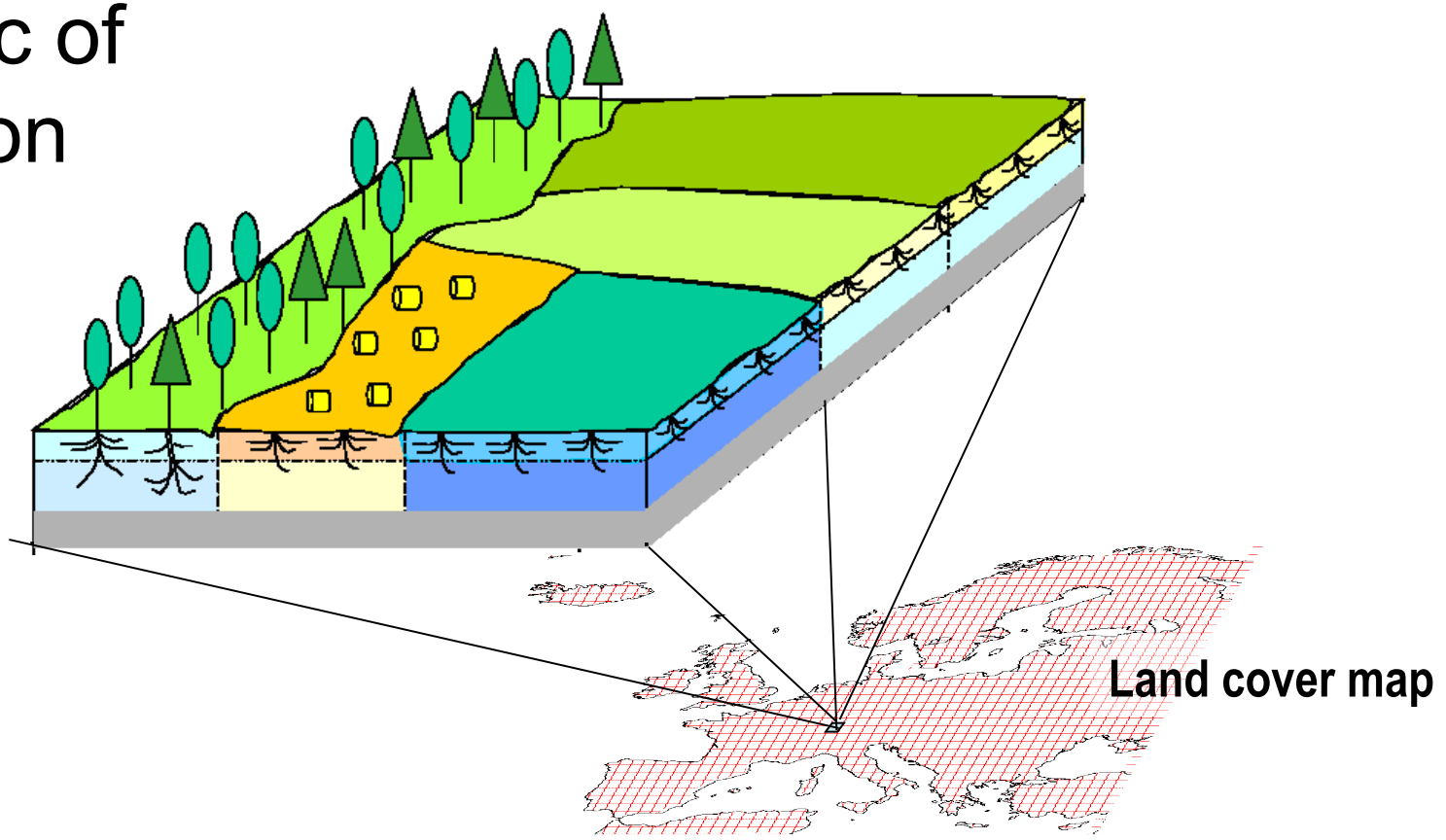
- **A "big leaf approach"**
  - One Energy budget for the whole grid box
  - Fully implicit coupling with the Atmospheric LMDz model
  - Coupled with snow & soil energy budget

- **Soil energy and hydrology**
  - Solve the Heat Diffusion Equation ; 7 layers ; up to 5.5m
  - Fully coupled with the calculation of surface temperature
  - "New" 11-layers soil hydrology scheme

- **Photosynthesis / Phenology**
  - Farquhar & Ball and Berry model
  - Computation a several levels (light decrease) ➔ integration

Surface description : a tile approach

- A mosaïc of vegetation



- 13 different Plant functional types

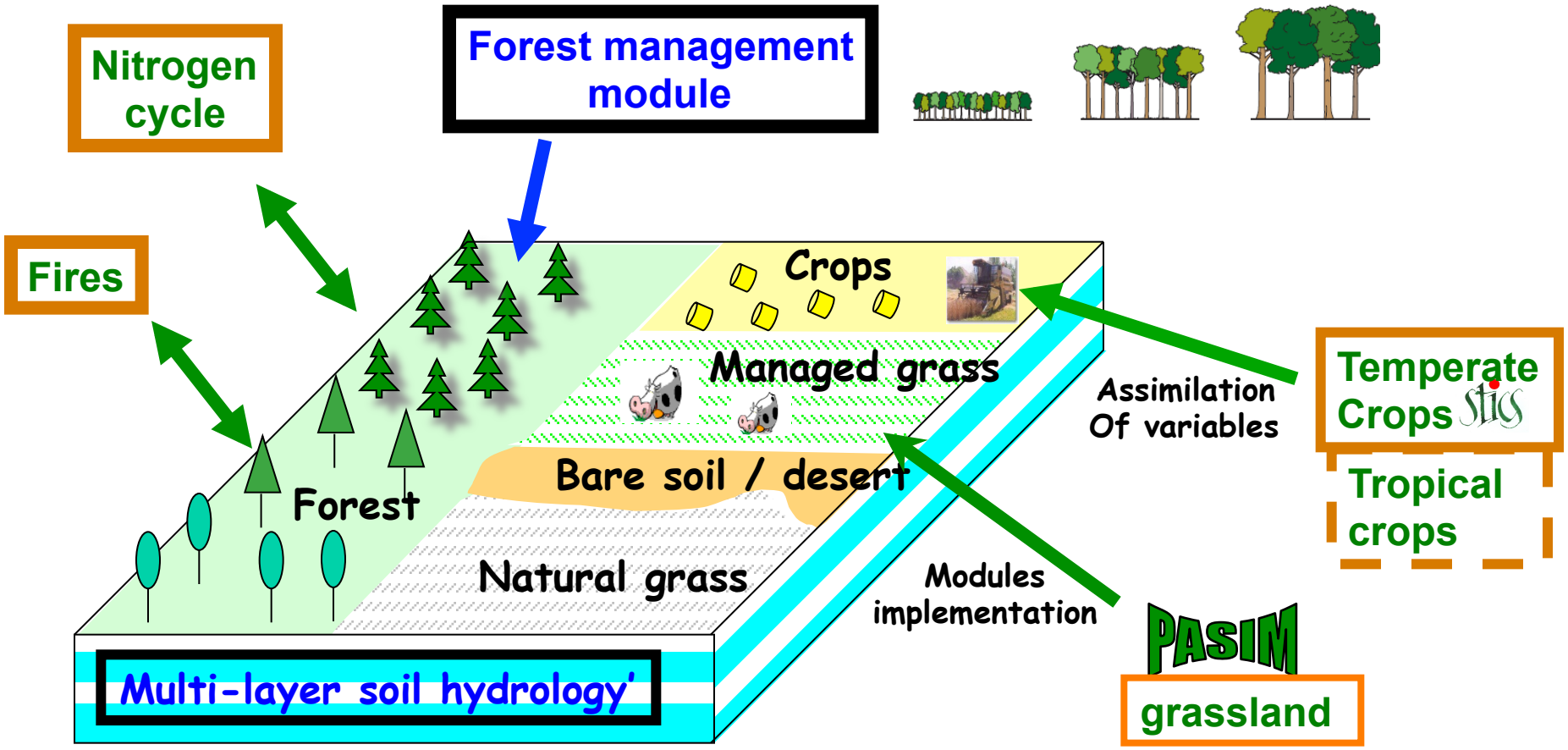
Hydrological Processes in ORCHIDEE

- Partition of throughfall between infiltration and runoff
- Water fluxes in soils (soil moisture and drainage)
- Routing of runoff into river discharge
- Human pressures, e.g. irrigation
- Interactions with floodplains (fluxes and storage)
- Wetlands
- Snow pack processes
- Permafrost (freeze/thaw in the soil)
- Interactions with groundwater tables (fluxes and storage)

“Slow biogeochemical” Processes

- Phenology - Budburst based on GDD, soil water...
- Senescence: Based on Leaf age, Temp...
- Carbon Allocation:
  - 8 pools of living biomass
  - 4 litter pools and 3 soil carbon pools (CENTURY)
- Autotrophic respiration: Maintenance & Growth
- Heterotrophic Respiration
- Fire module (SPITFIRE)
- Turnover : death of plants, etc.

Recent improvements of ORCHIDEE

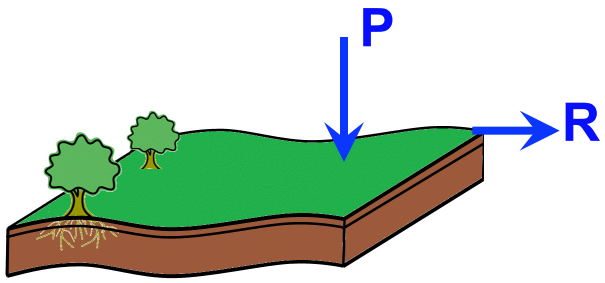


- Generalization of PFT concept (number not limited)
- A 11-layer hydrological scheme
- Scientific documentation

Two versions of the soil hydrology

Choisnel = ORC2

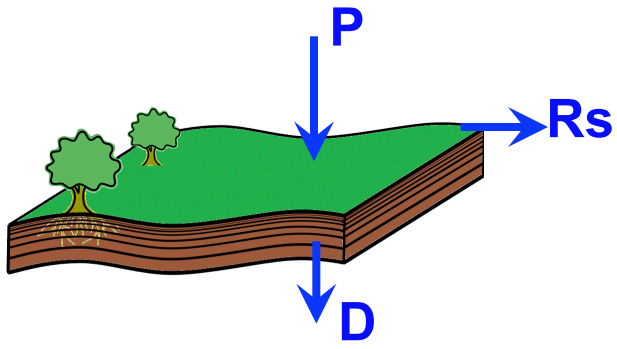
Ducoudré et al., 1993; de Rosnay et al. 1998



- 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

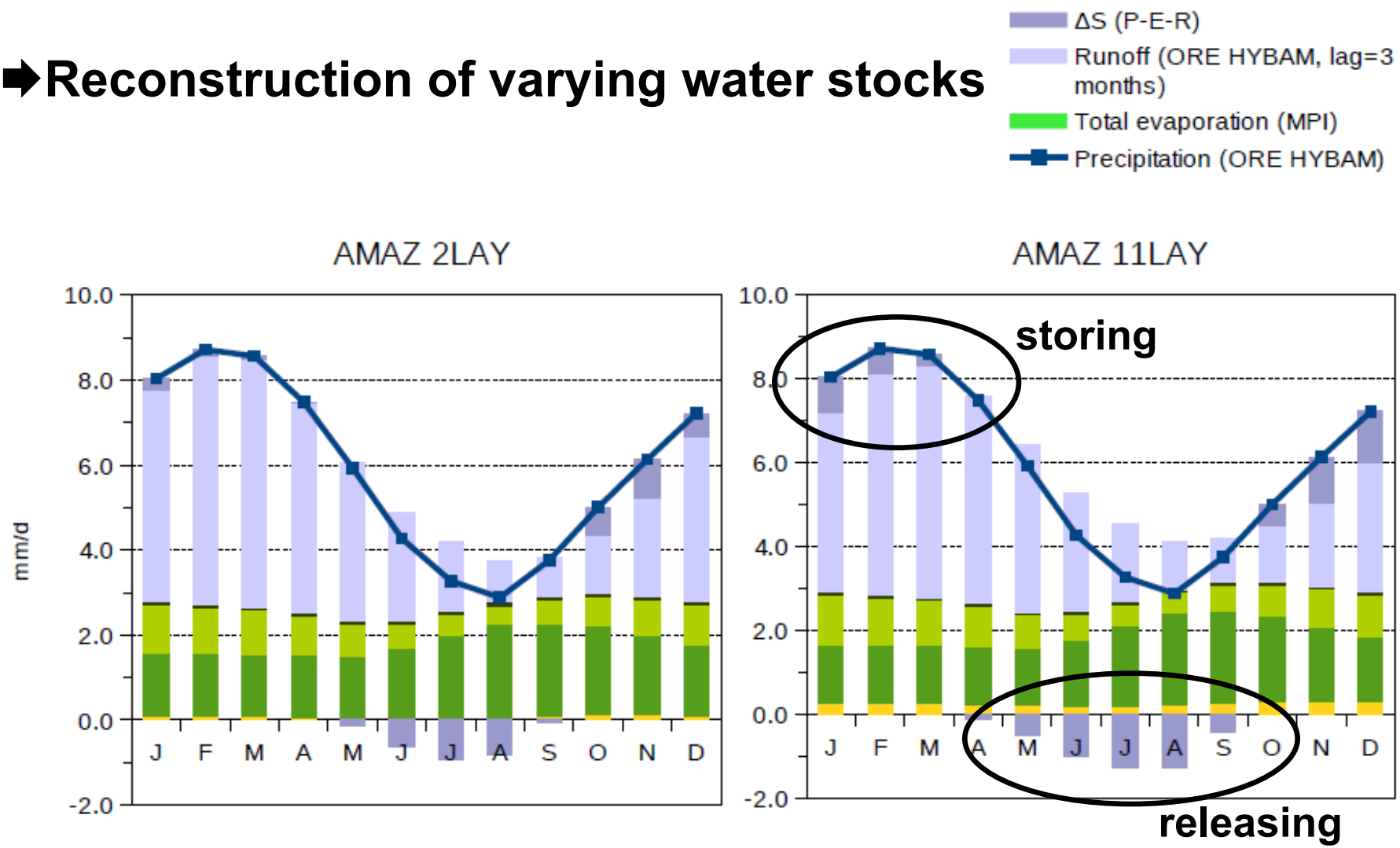
de Rosnay et al., 2002; d'Orgeval et al., 2008



- 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

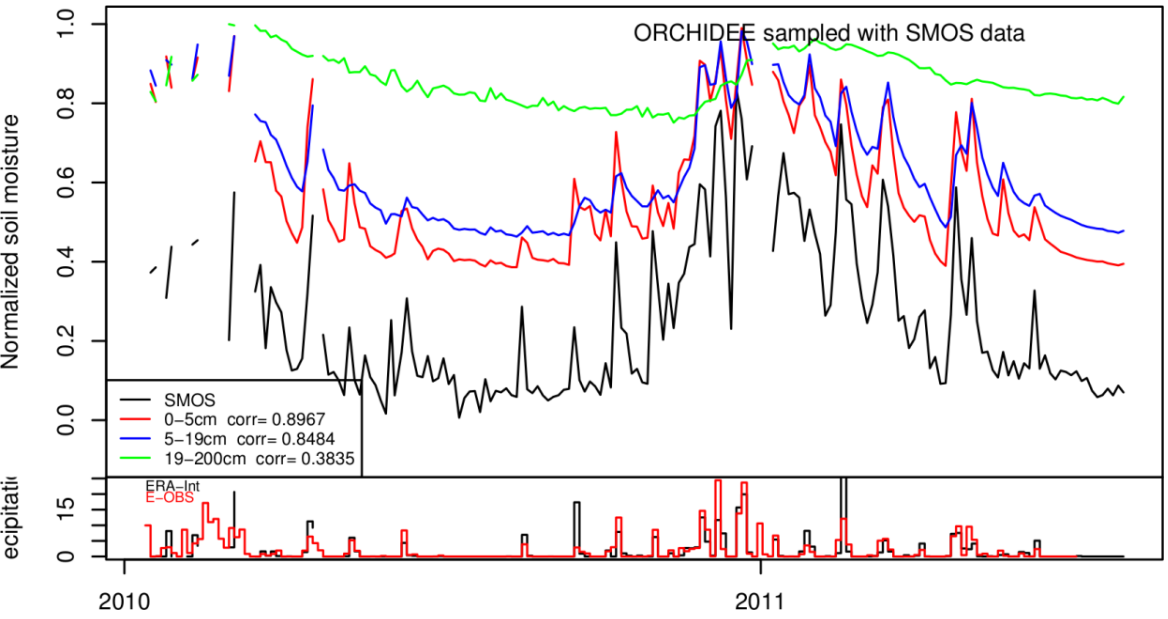
Test over the Amazon: 2 versus 11 layers

➡**Reconstruction of varying water stocks**



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

Comparison with SMOS: soil moisture evolution



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

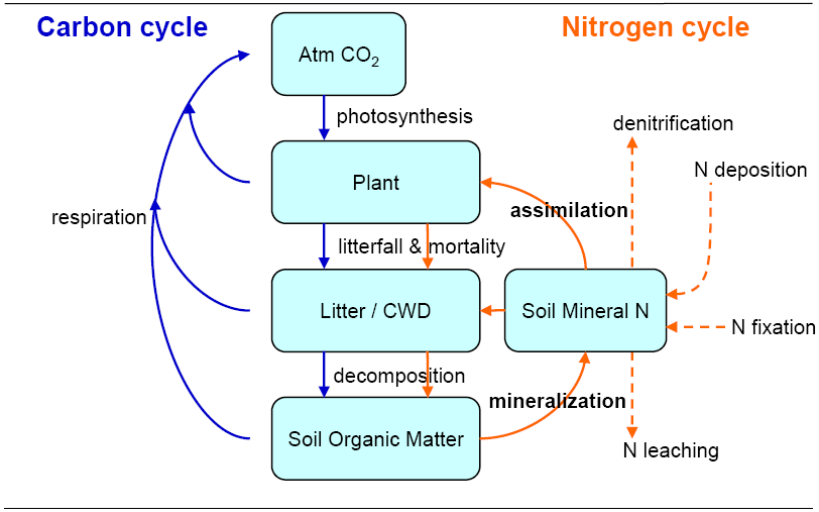
3 days average to reduce instrument noise

- 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.

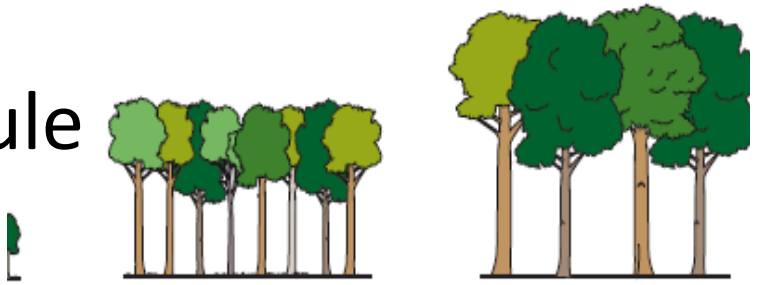
Recent developments to be merged

- High latitudes processes

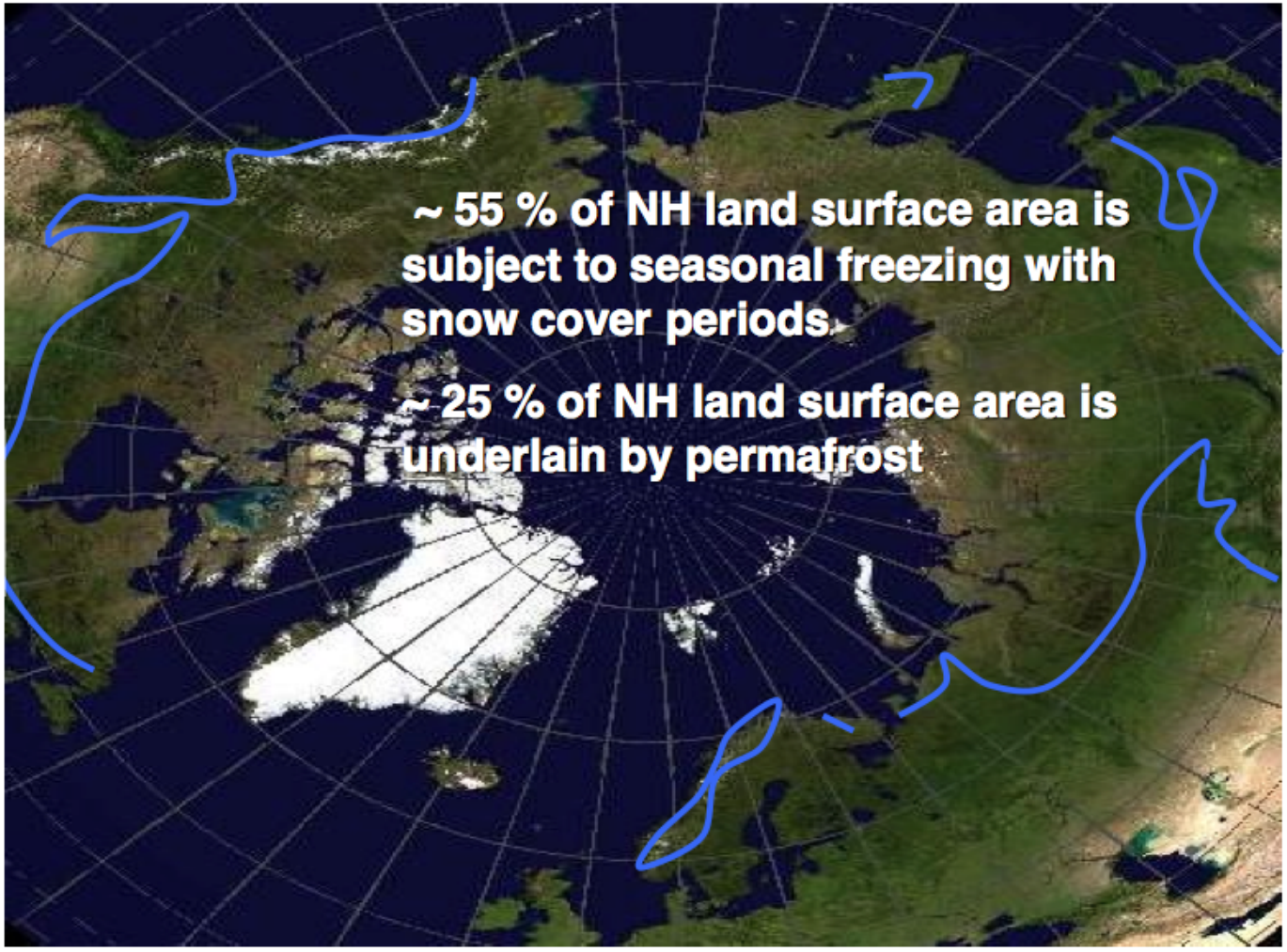
- Nitrogen cycling



- A Forest Management Module

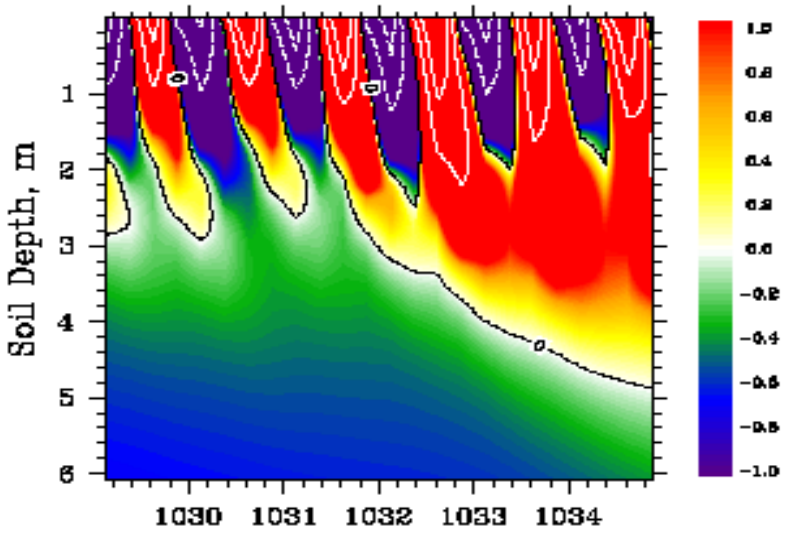


Climatic specificities of high latitudes and specific processes



High latitude Processes

- Permafrost & Climate change (soil heating)

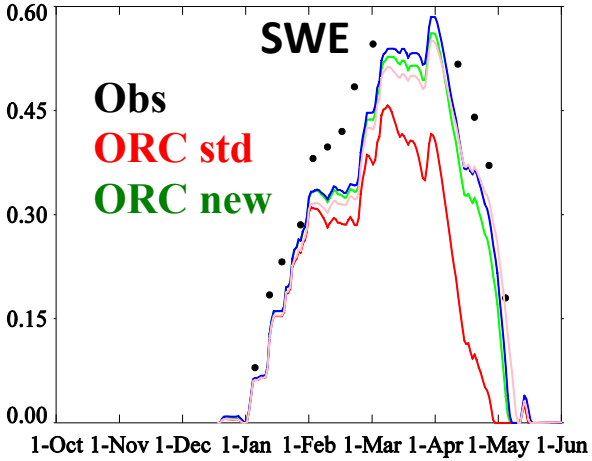


(a) Soil temperature (°C): talik formation when decomposition heat is 'On'. Contour interval is 4°C

- Wetlands hydrology
  ➔ CH4 emissions

- Snow: Adaptation of ISBA-ES
  + Soil freezing

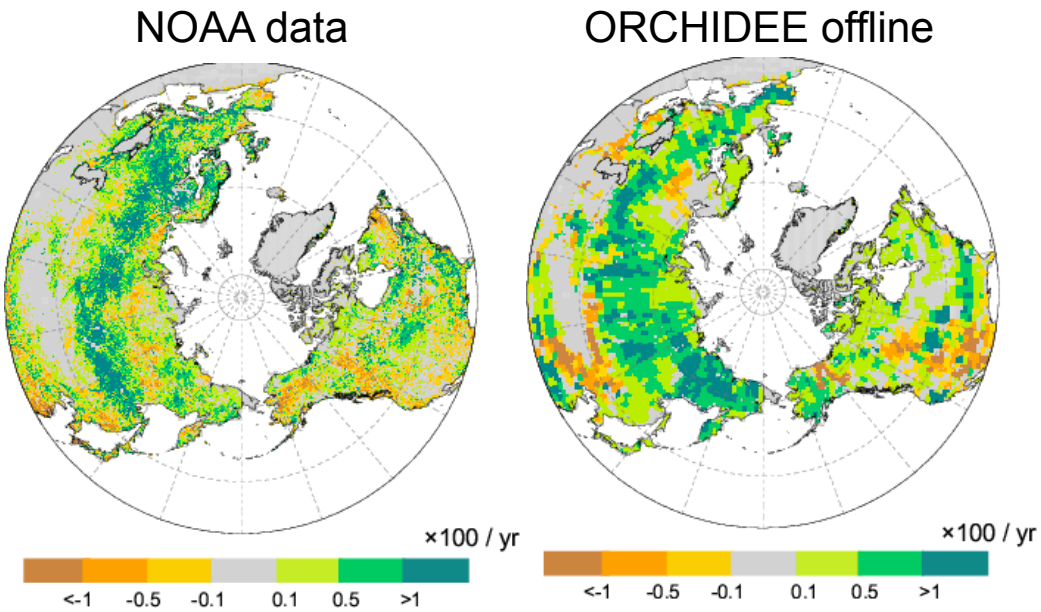
Col de Porte (1994-1995)



Change in Northern Hemisphere spring LAI

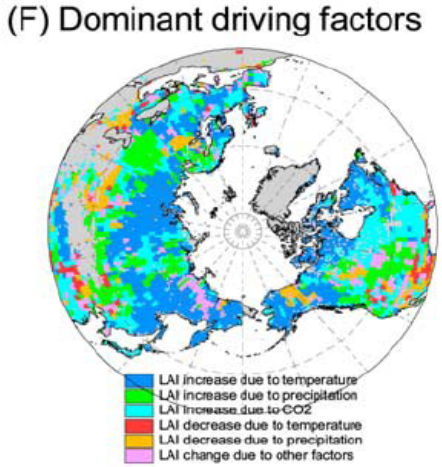
- A) Detection

LAI trend
(1982-2002)



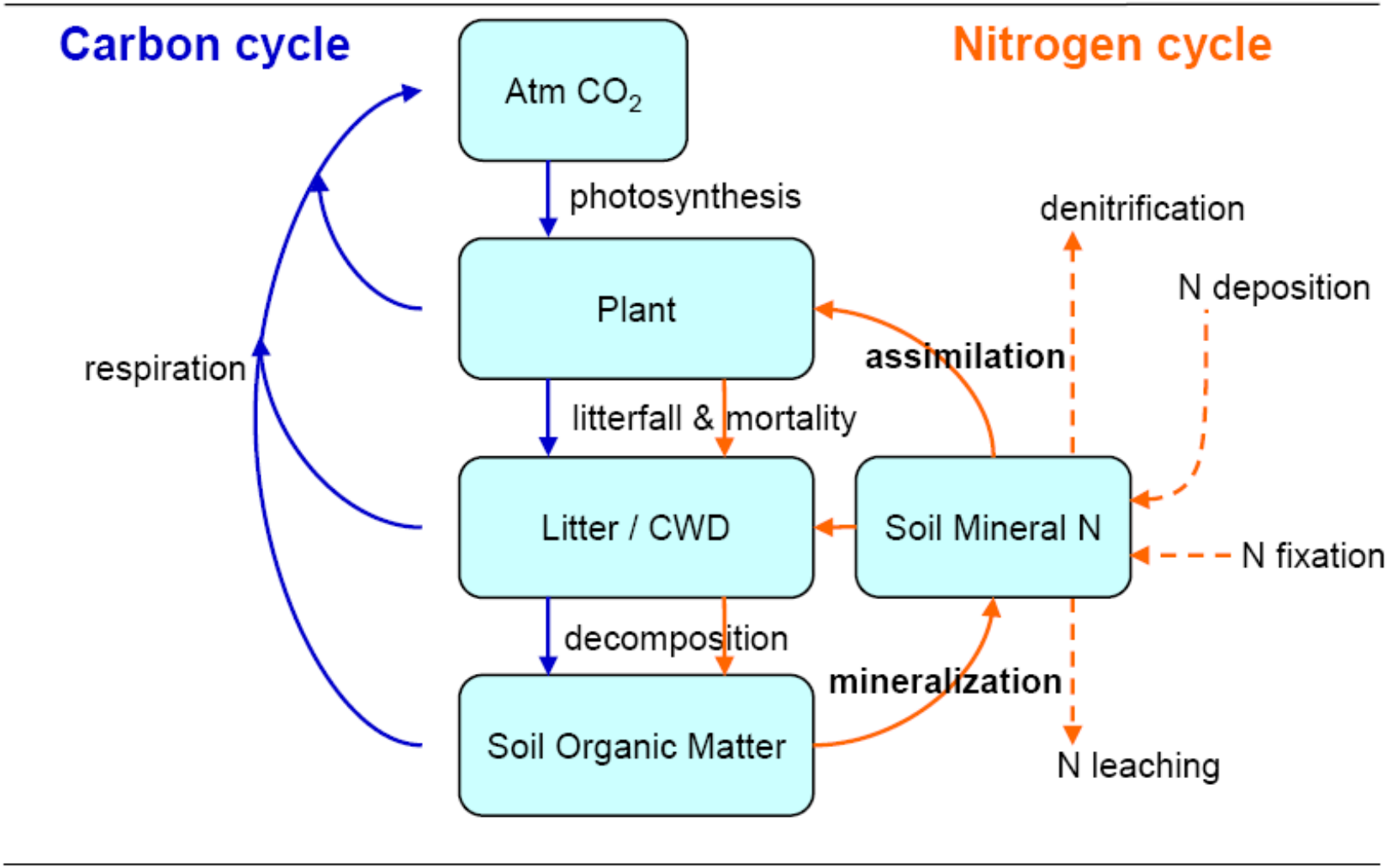
- B) Attribution

Factors:
Temperature is dominant
> CO2 > Precipitation



Piao et al., GRL, 2006

Nitrogen Cycling in ORCHIDEE

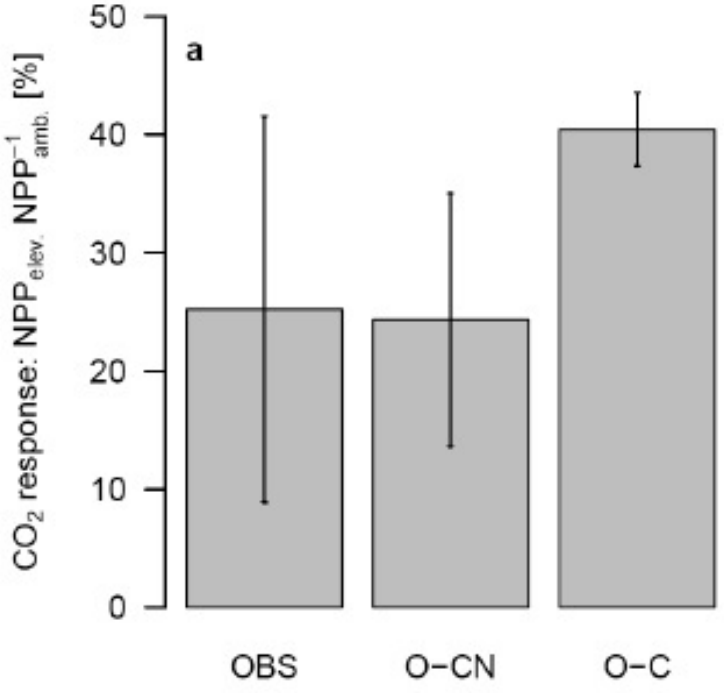


Nitrogen Cycling in ORCHIDEE

Sensitivity to elevated CO_2 (Duke forest: *Pinus taeda*)

- CO_2 enrichment since 1997 in 3 paired rings
- Control: ambient (~365 ppmv)
- Elevated: ambient + 200 (~565 ppmv)

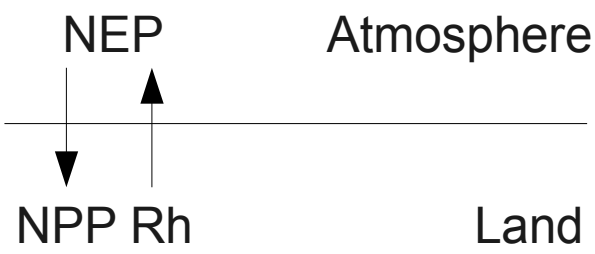
CO2 response (NPP): Elevate - ambiant



Obs **ORC + N** **ORC standard**

A Forest Management Module for ORCHIDEE

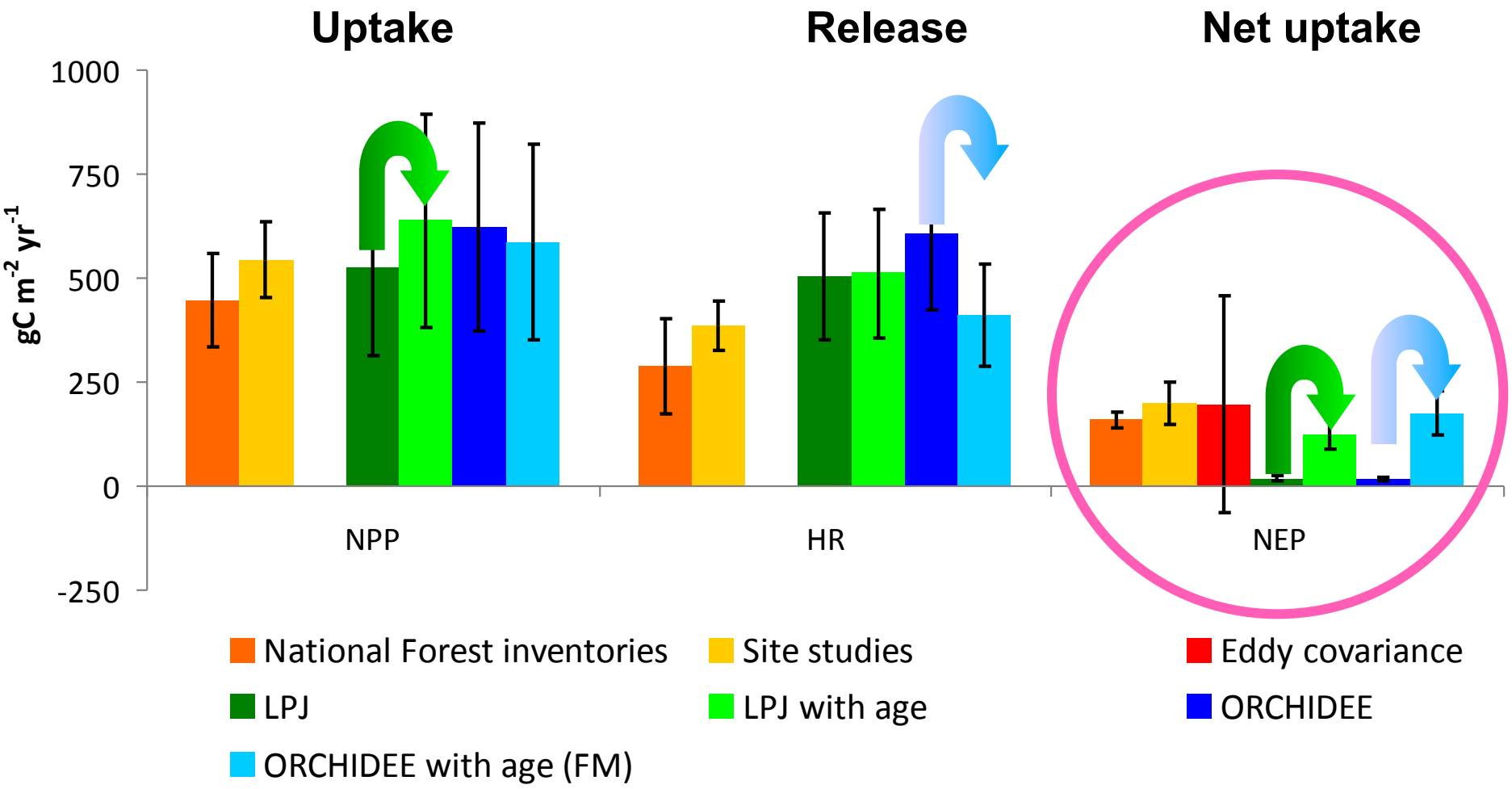
ORCHIDEE



ORCHIDEE - FM

- Age related decline in NPP
- Age related limitation of LAI
- Age related allocation between stem and roots
- Branch mortality
- Coarse woody litter compartment
- Individual growth of trees
- Generic management

Simulation of carbone fluxes for UE 25



Source: Luyssaert et al., 2010; Bellassen et al., in prep

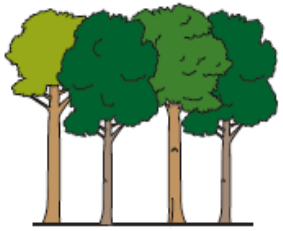
Current developments

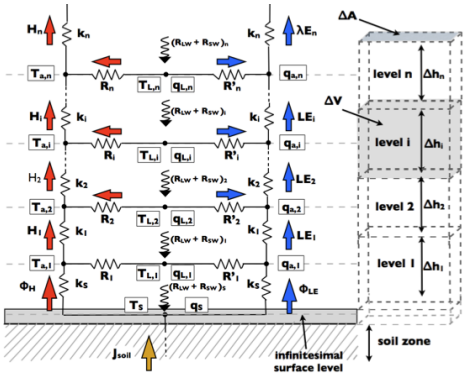
➔ ***Integration within 2-3 years***

- New multi-layers energy budget
- New radiative transfer scheme
- New plant functional types (PFTs)
- Coupling surface and ground water hydrology
- Coupling with WRF atmospheric model
- Isotopic module for Water and Carbon isotopes
- Vegetation and chemistry: coupling INCA-ORC

Mid term improvement (1-2 yr)

New energy budget

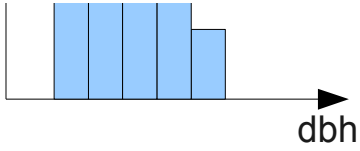


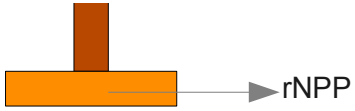


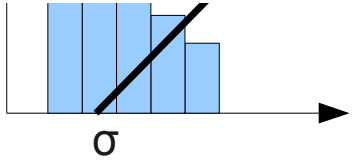
- Closed canopy (1.9.6)
- Prescribed radiation scheme f(LAI)
- Big-leaf energy budget (implicit)
- Prescribed snow albedo f(snow age)

- Open canopy (under development)
- Two way radiation scheme f(canopy)
- Multi-layer energy budget (implicit)
- Snow under the canopy f(snow age)

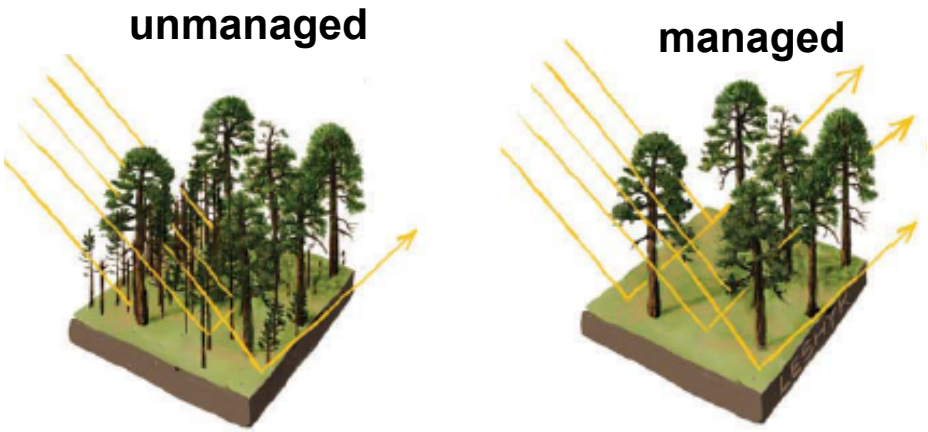
New C allocation scheme



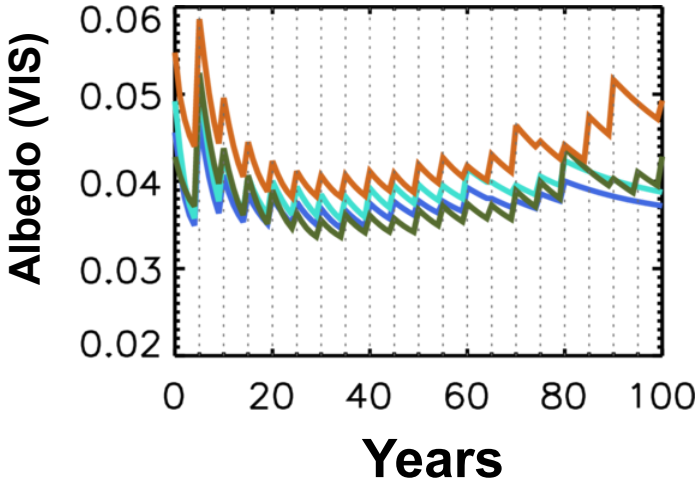




Forest Management and Climate



How does forest management affects
- **the surface albedo?**
- **subsequently the climate ?**



Interactions between the terrestrial biosphere and the atmospheric chemical composition

Coupling INCA and ORCHIDEE

Atmospheric Chemical Composition

HIGH REACTIVITY

Ozone, OH, aerosols,
GES lifetime

GLOBAL CHANGES ???

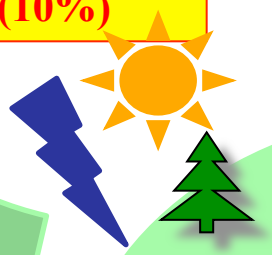
- Climate, land-use, chemistry, etc.

Biogenic Compounds :

- VOCs (80%)
- NOx (10%)

Deposition at the surface :

- O3: 25% of photochemical production
- Strongly linked to vegetation type



Terrestrial biosphere

- SIGNIFICANT SINK
- IMPACT ON ECOSYSTEMS (pollution)

ORCHIDEE

yesterday…

ORCHIDEE

tomorrow…