# ORCHIDEE
# a global terrestrial ecosystem model

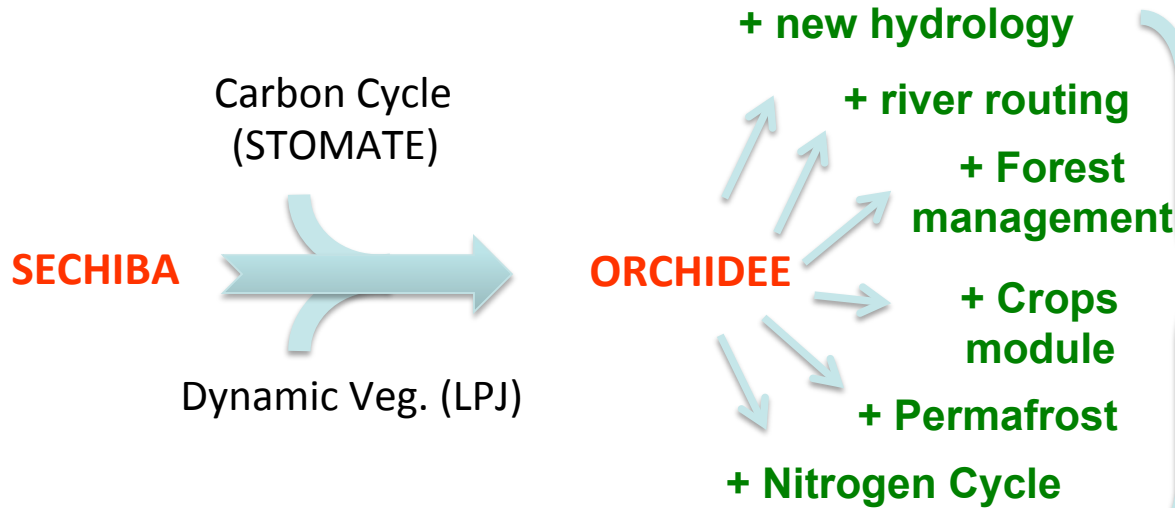(ORganizing Carbon and Hydrology In Dynamic Ecosystems Environment)

# Plan

- Models objectives, structure and interface

- Strategy of evaluation

- Ongoing development

# A brief history

**Model**

Carbon Cycle (STOMATE)

**SECHIBA** → **ORCHIDEE**

Dynamic Veg. (LPJ)

**+ new hydrology**

**+ river routing**

**+ Forest management**

**+ Crops module**

**+ Permafrost**

**+ Nitrogen Cycle**

*Toward a single community tool*

Managed grass

Forest

Bare soil / desert

Natural grass

Multi-layer soil hydrology'
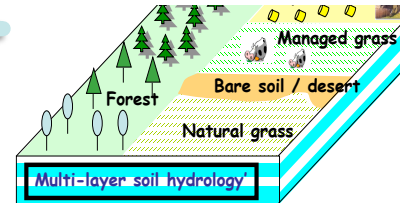
*(Laval et al., 1981)*  *(Ducoudré et al., 1993)*  *(Viovy et al., 1997)*  *(Polcher et al., 1998)*  *(Krinner et al., 2005)*

**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.**

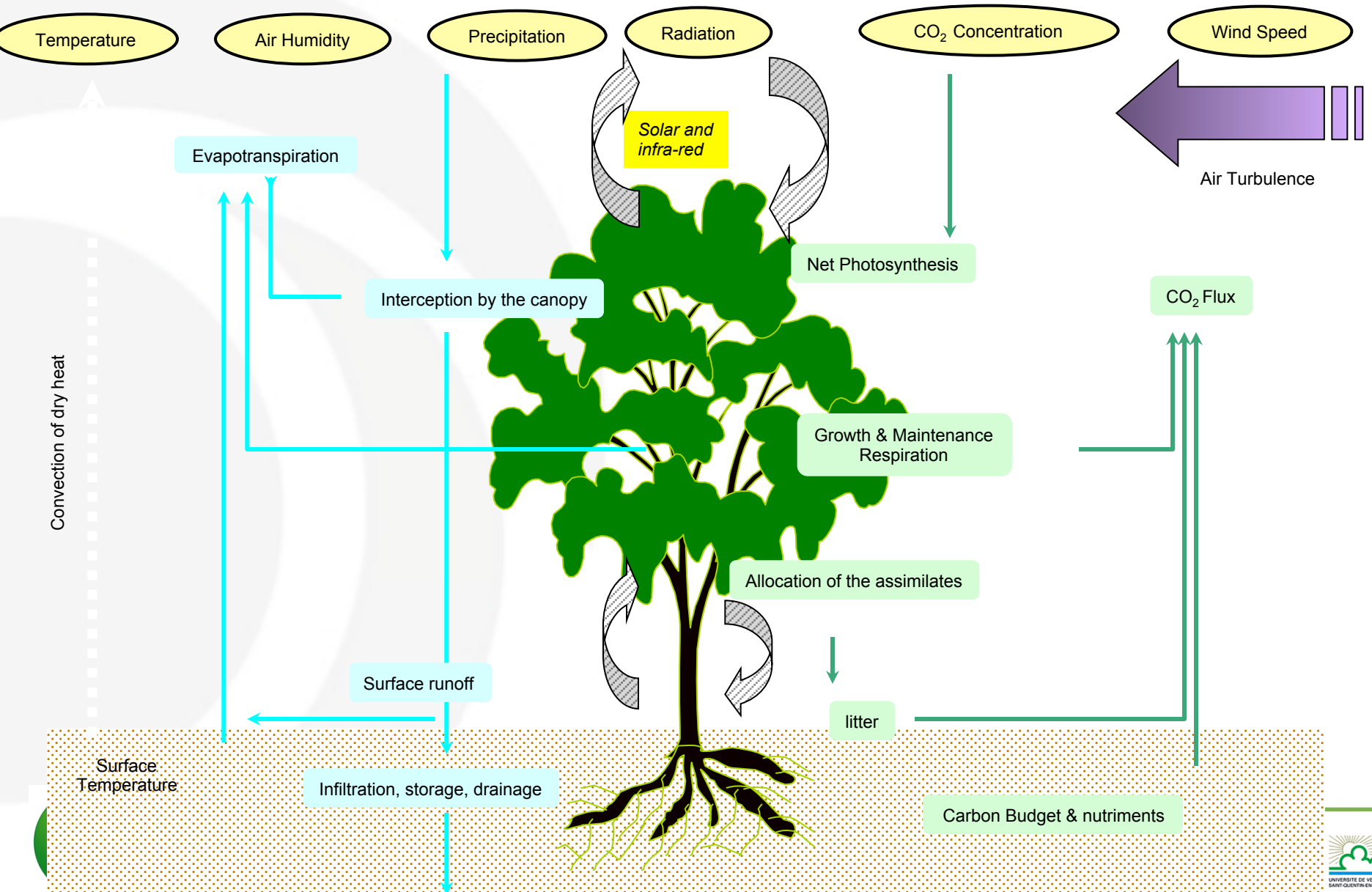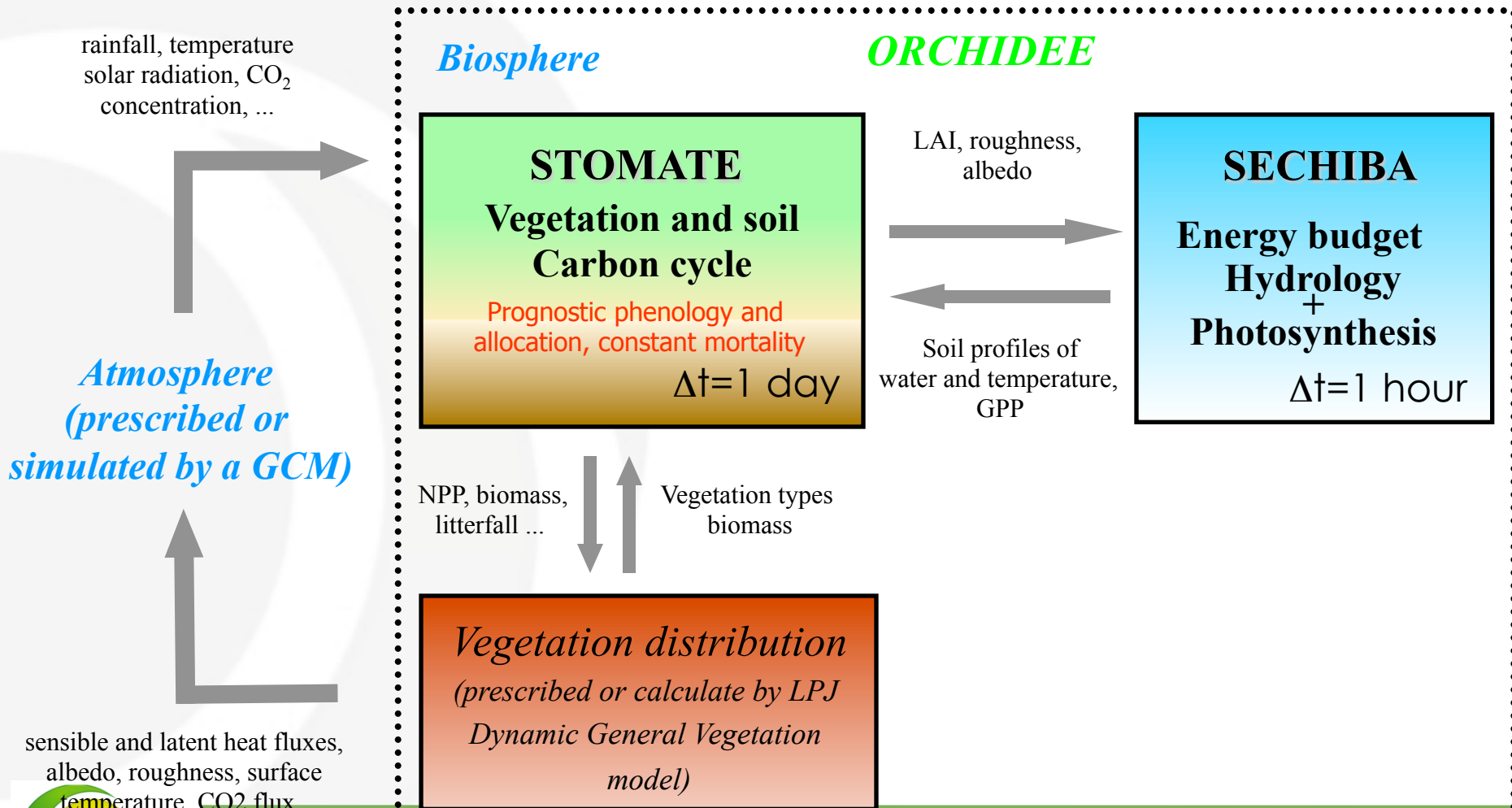UNIVERSITE DE VERSAILLES
SAINT-QUENTIN-EN-YVELINES

# Objectives

- To simulate energy, water and carbon fluxes at the land/atmosphere interface
  - To be the 'Land Surface' component of Earth System Model (ESM, IPSL-CM5)
    - ✓ Global => to account for the major biomes at global scale
  - For past, present-day and future climate conditions
    - ✓ A vegetation dynamic module
    - ✓ Process-based modelling

# Processes

Temperature

Air Humidity

Precipitation

Radiation

CO$_2$ Concentration

Wind Speed

Evapotranspiration

*Solar and infra-red*

Air Turbulence

Net Photosynthesis

CO$_2$ Flux

Interception by the canopy

Convection of dry heat

Growth & Maintenance Respiration

Allocation of the assimilates

Surface runoff

litter

Surface Temperature

Infiltration, storage, drainage

Carbon Budget & nutriments

UNIVERSITE DE VERSAILLES
SAINT-QUENTIN-EN-YVELINES

# ORCHIDEE standard version



rainfall, temperature solar radiation, $CO_2$ concentration, ...

**Atmosphere (prescribed or simulated by a GCM)**

sensible and latent heat fluxes, albedo, roughness, surface temperature, CO2 flux...

*Biosphere*

*ORCHIDEE*

**STOMATE**
**Vegetation and soil Carbon cycle**
Prognostic phenology and allocation, constant mortality
$\Delta t = 1$ day

LAI, roughness, albedo

Soil profiles of water and temperature, GPP

**SECHIBA**
**Energy budget Hydrology + Photosynthesis**
$\Delta t = 1$ hour

NPP, biomass, litterfall ...

Vegetation types biomass

*Vegetation distribution (prescribed or calculate by LPJ Dynamic General Vegetation model)*

# Vegetated lands

- Concept of 'Plant Functional Types' (PFT)
- Defined according to systematic, physiological, phenological, climatic conditions
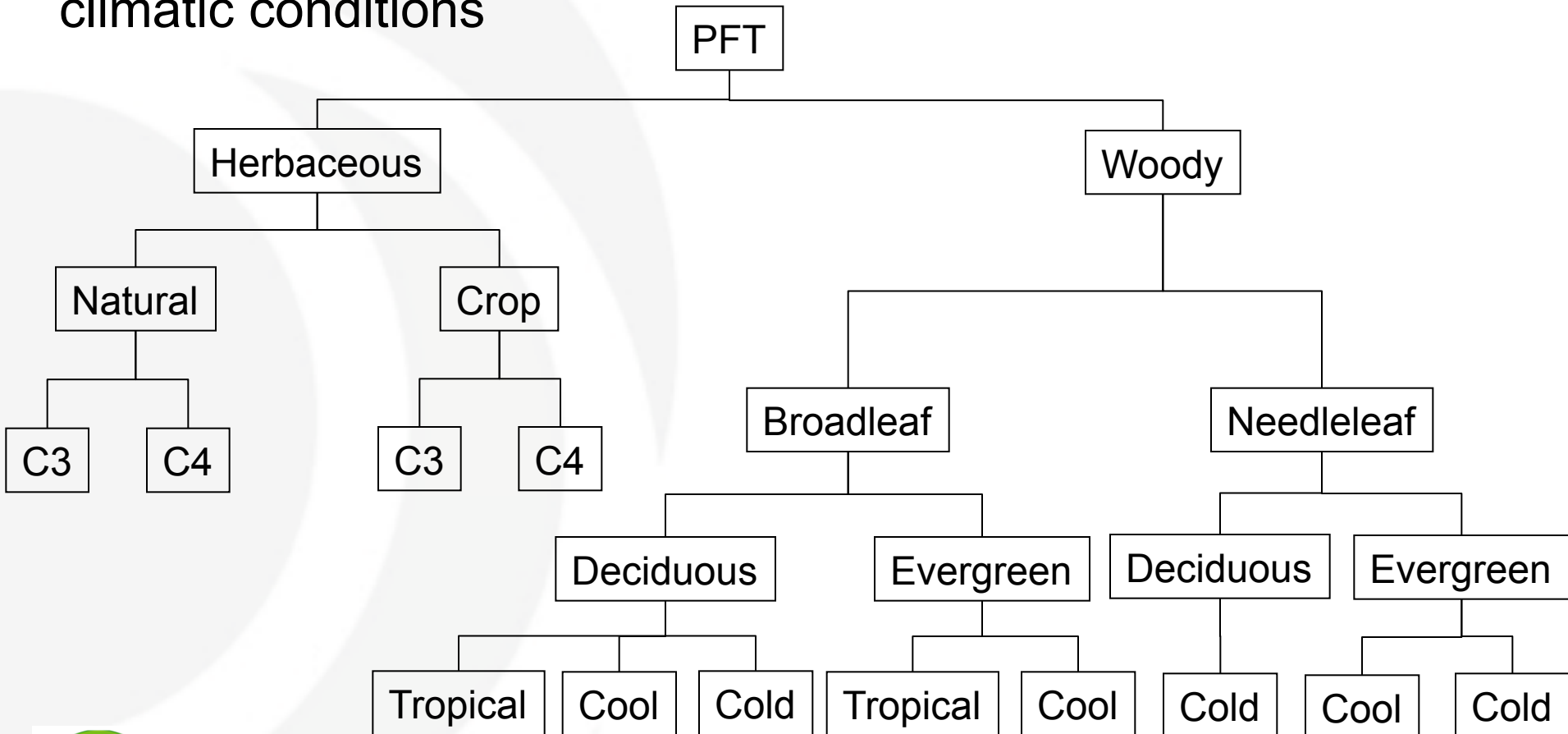
# How the surface is represented ?

- A mosaïc of vegetation



**Land cover map**
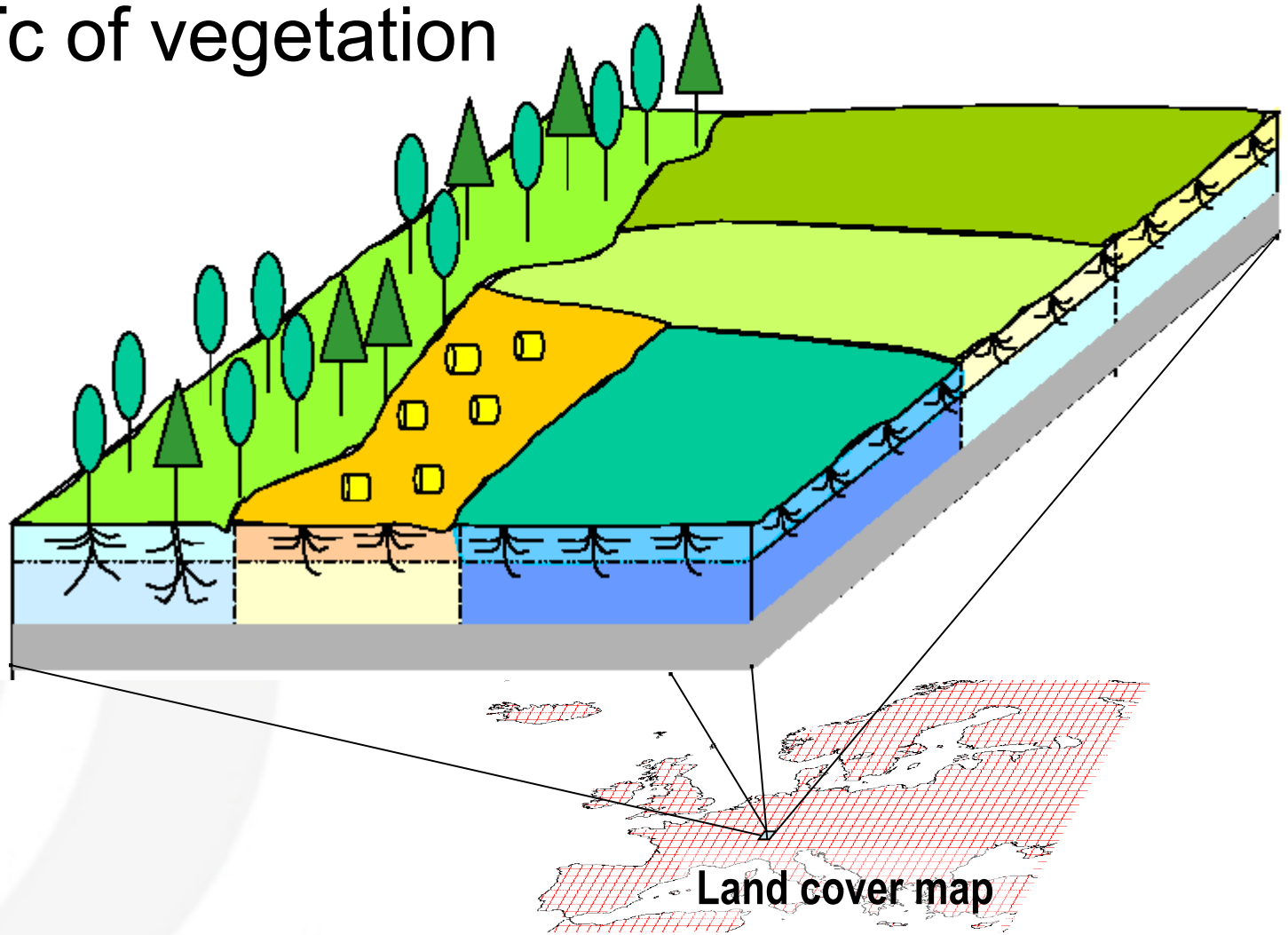
# Plant Functional Types

- A same set of equations governs C dynamic
- But parameter values differ among PFT's

| PFT | $V_{cmax,opt}$ | $T_{opt}$ | $\lambda_{max}$ | $z_{root}$ | $\alpha_{leaf}$ | $h$ | $A_c$ | $T_s$ | $H_s$ |
|-----|----------------|-----------|-----------------|------------|-----------------|-----|-------|-------|-------|
| TrBE | 50 | 37 | 10 | 1.25 | 0.12 | 25 | 910 | - | 0.3 |
| TrBR | 60 | 37 | 10 | 1.25 | 0.14 | 25 | 180 | - | 0.3 |
| TeNE | 37.5 | 27 | 5 | 1. | 0.14 | 15 | 910 | - | - |
| TeBE | 37.5 | 32 | 5 | 1.25 | 0.14 | 15 | 730 | - | - |
| TeBS | 37.5 | 28 | 5 | 1.25 | 0.14 | 15 | 180 | 12.5 | - |
| BoNE | 37.5 | 25 | 4.5 | 1. | 0.14 | 10 | 910 | - | - |
| BoBS | 37.5 | 25 | 4.5 | 1. | 0.14 | 10 | 180 | 5 | - |
| BoNS | 35 | 25 | 4 | 1.25 | 0.14 | 10 | 180 | 7 | - |
| NC3 | 70 | $27.5 + 0.25T_l$ | 2.5 | 0.25 | 0.20 | 0.2 | 120 | 4 | 0.2 |
| NC4 | 70 | 36 | 2.5 | 0.25 | 0.20 | 0.2 | 120 | 5 | 0.2 |
| AC3 | 90 | $27.5 + 0.25T_l$ | 6 | 0.25 | 0.18 | 0.4 | 150 | 10 | 0.2 |
| AC4 | 90 | 36 | 3 | 0.25 | 0.18 | 0.4 | 120 | 10 | 0.2 |

# Response to environmental conditions

**Température**

**Light**

**C3**

**C4**

**[CO2]**

0 °     32°     45°

Ci

Ci

1000 ppm

350 ppm
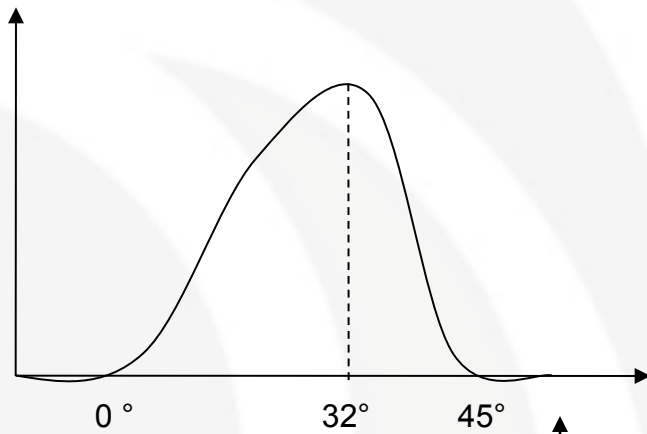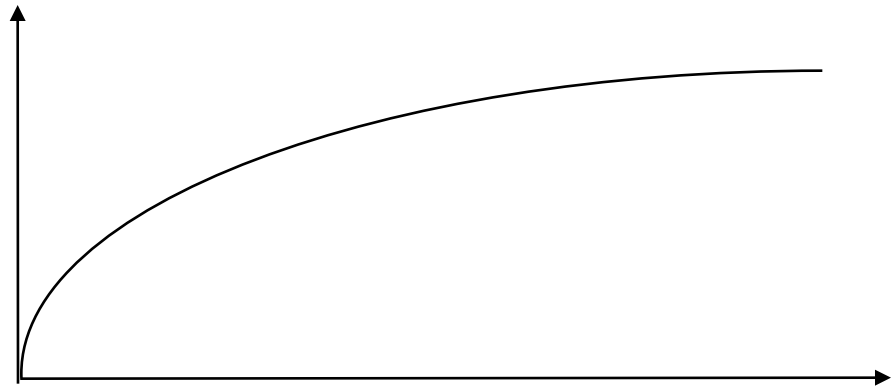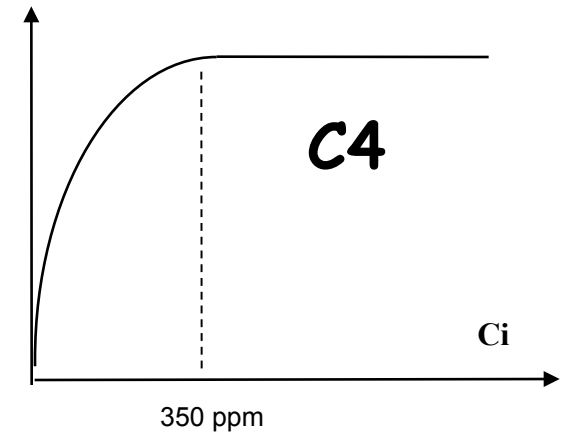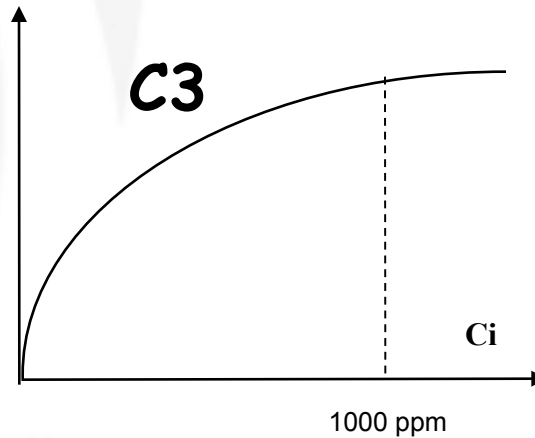
# From the leaf to the canopy

- PS and Gs are calculated at each LAI level:

- Beer-Lambert decrease of light in the canopy

- Exponential decrease of Vmax (but limited to 30%) to mimic nitrogen decrease

- The others parameters (e.g $CO_2$, rel hum..) are held constants.
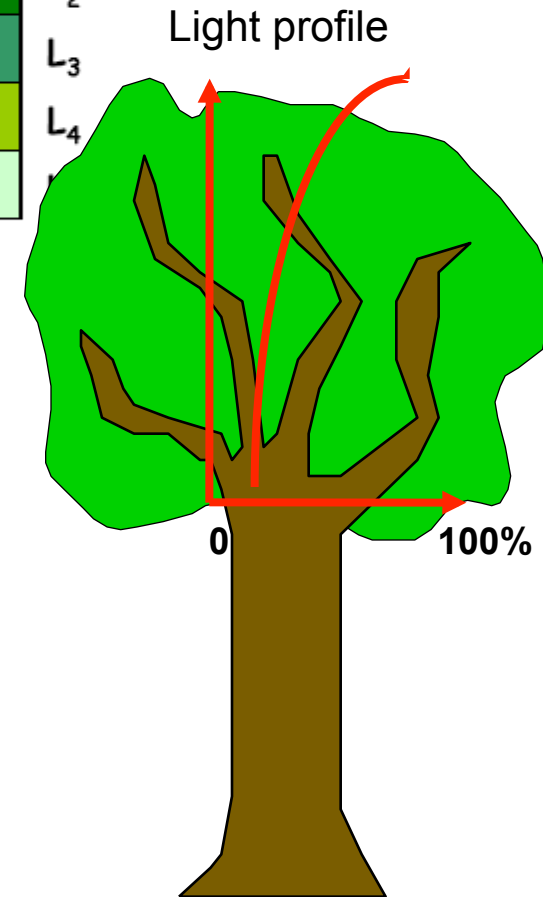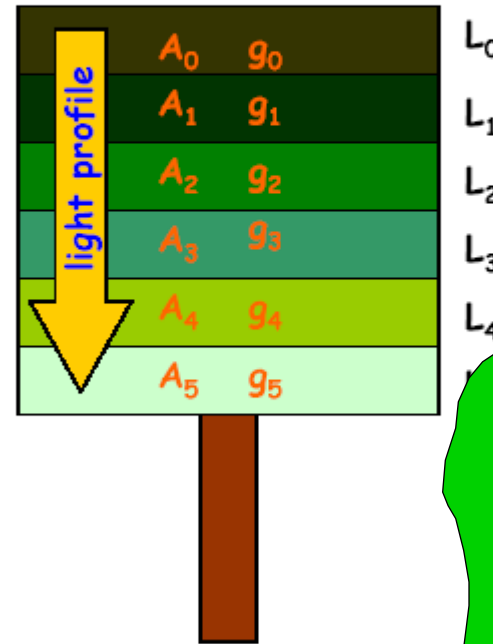
# Interface

- ## Meteorological data
  - ### from monthly to half-hourly time-step

Precipitation

Radiation

Temperature

Wind Speed

Air Humidity

$CO_2$ Concentration

Model

Met data
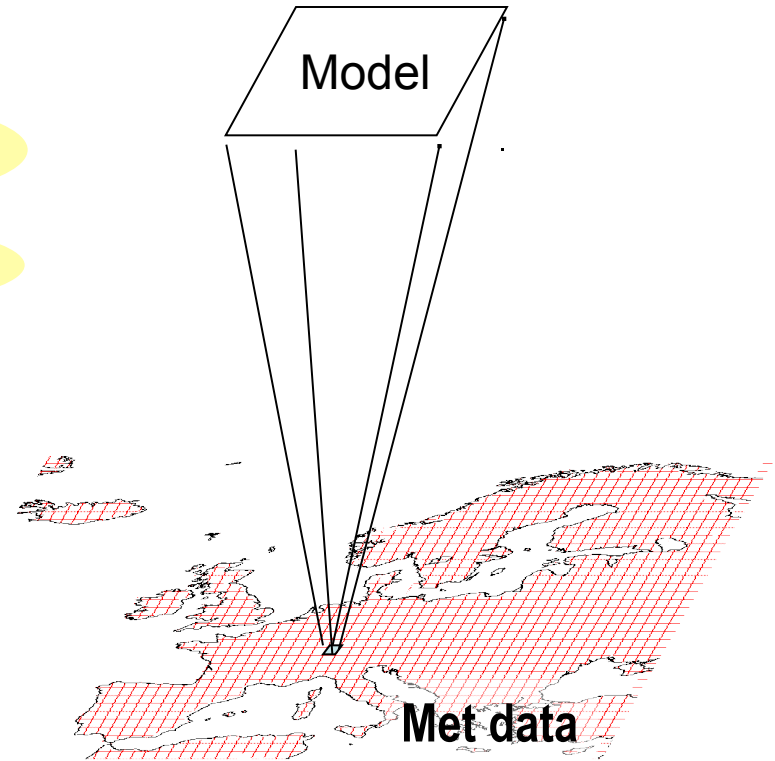
# Interface (2)

- Soil data
    - Soil color
    - Texture

- Optionnal (=f$^n$ of the config)
    - LAI map (SECHIBA seule)
    - Vegetation map (ORCHIDEE without the dynamic component)

# Vegetation map
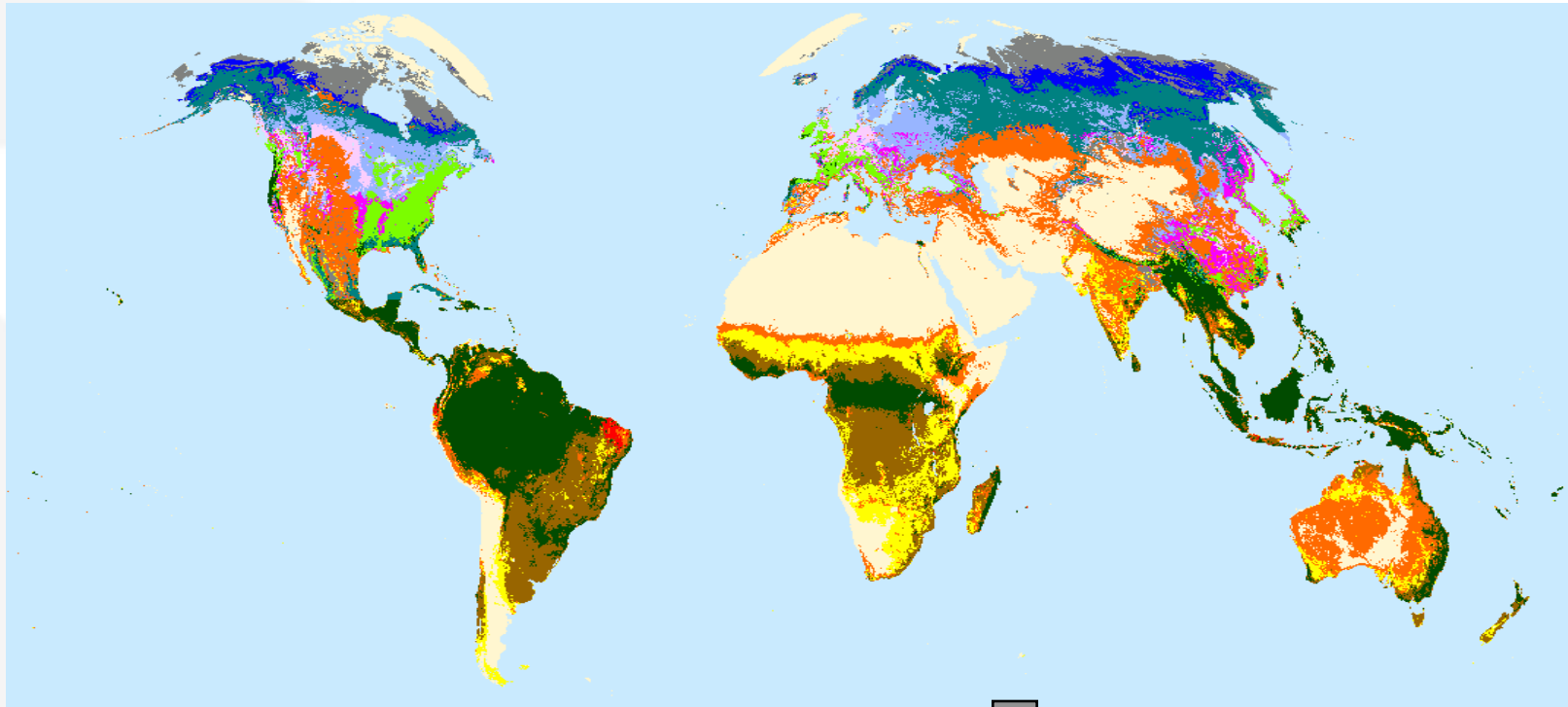


Evergreen Needleleaf Forests (Taïga)

Evergreen Broadleaf Forests

Deciduous Needleleaf Forest/Woodland

Deciduous Broadleaf Forests

Mixed Forests

Closed Shrublands

Open Shrublands (Tundra)

Woody Savannas

Savannas

Grasslands

Croplands

Cropland/natural vegetation Mosaics

Bare Soil/ Ice

# Evaluation strategy

- System
  - Multi-processes
  - Multi-components

Evaluation set
=> To check that the model behaves well for good reasons

- Spatial scale
  - from local to global scales

- Temporal scale
  - Daily / seasonal / interannual cycles

# On-site evaluation

- ## The FLUXNET network
  - ### Approx. 250 sites
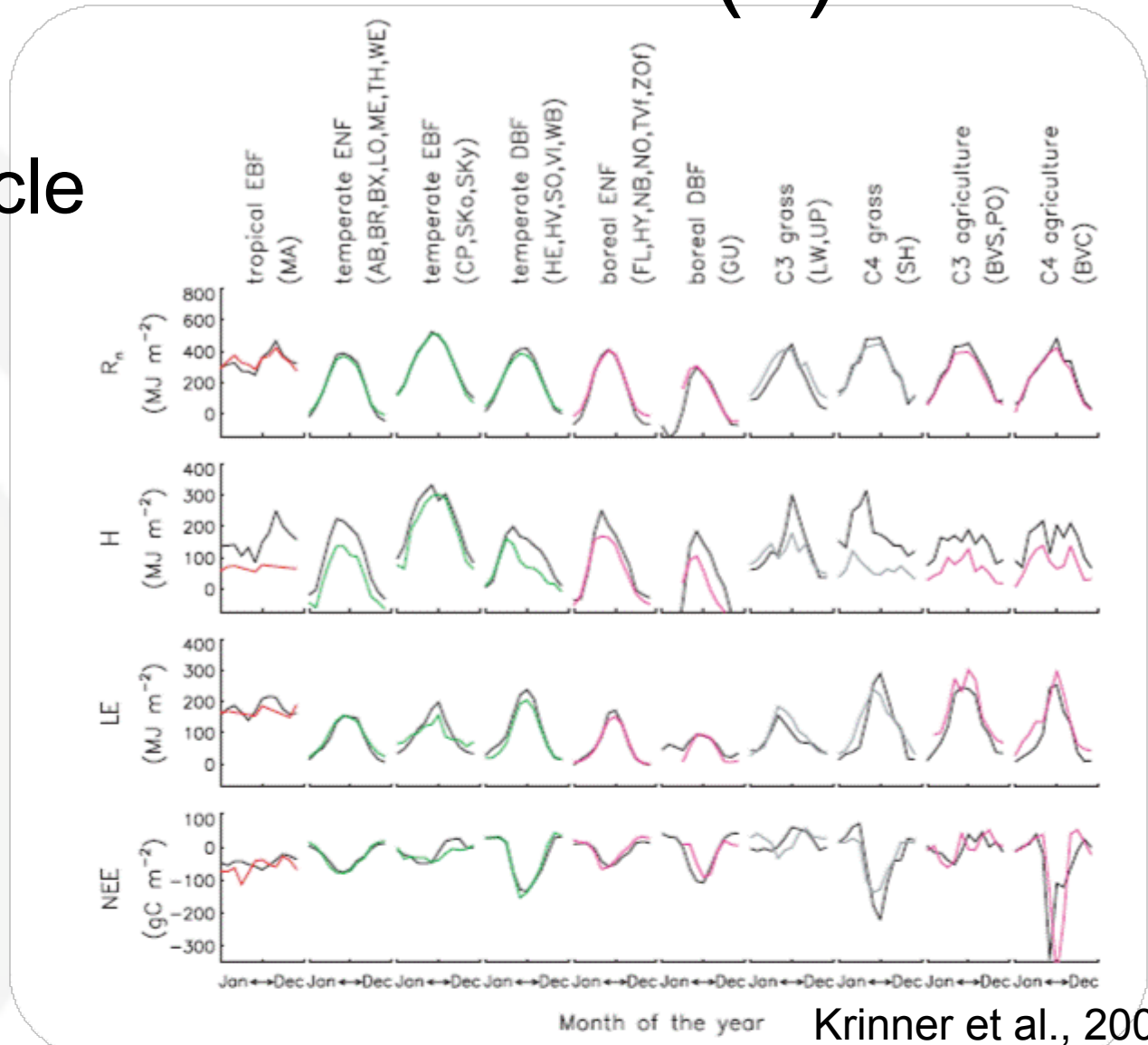  - ### Time-series from 1 to up to 10 years
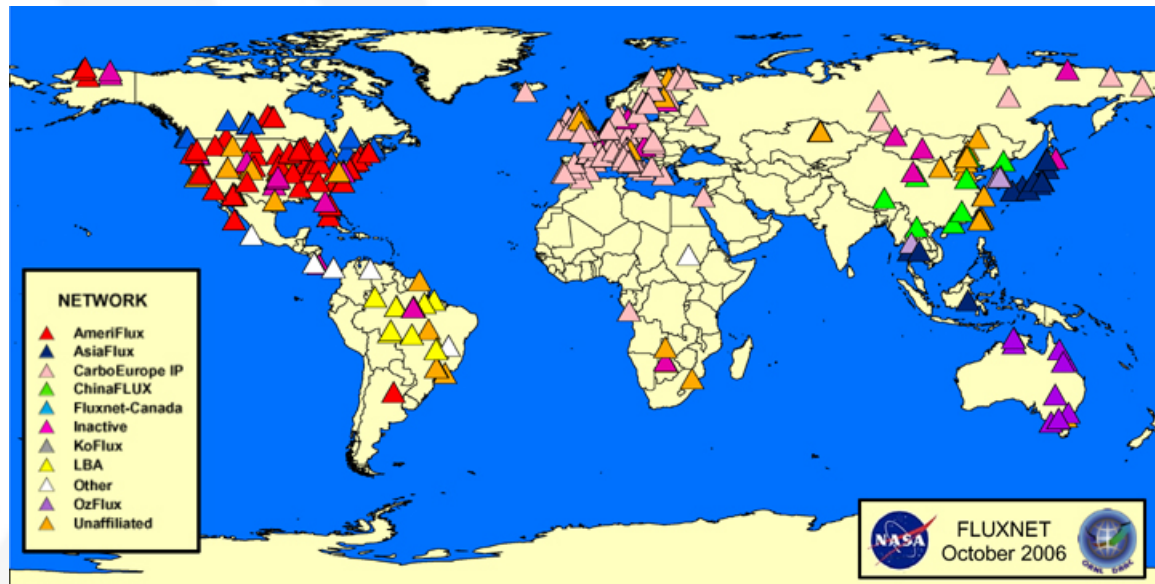
# On-site evaluation

Daily cycle
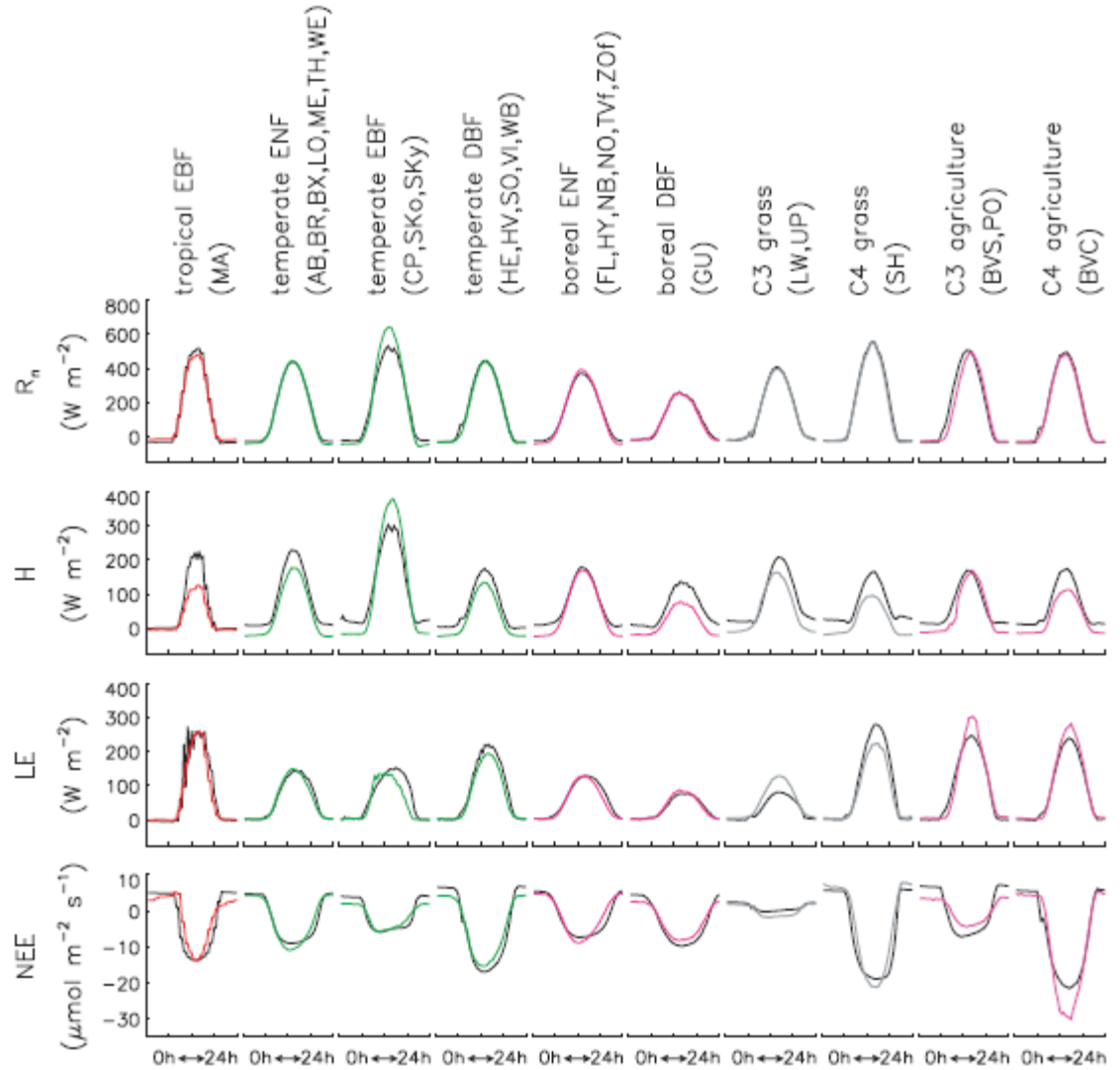


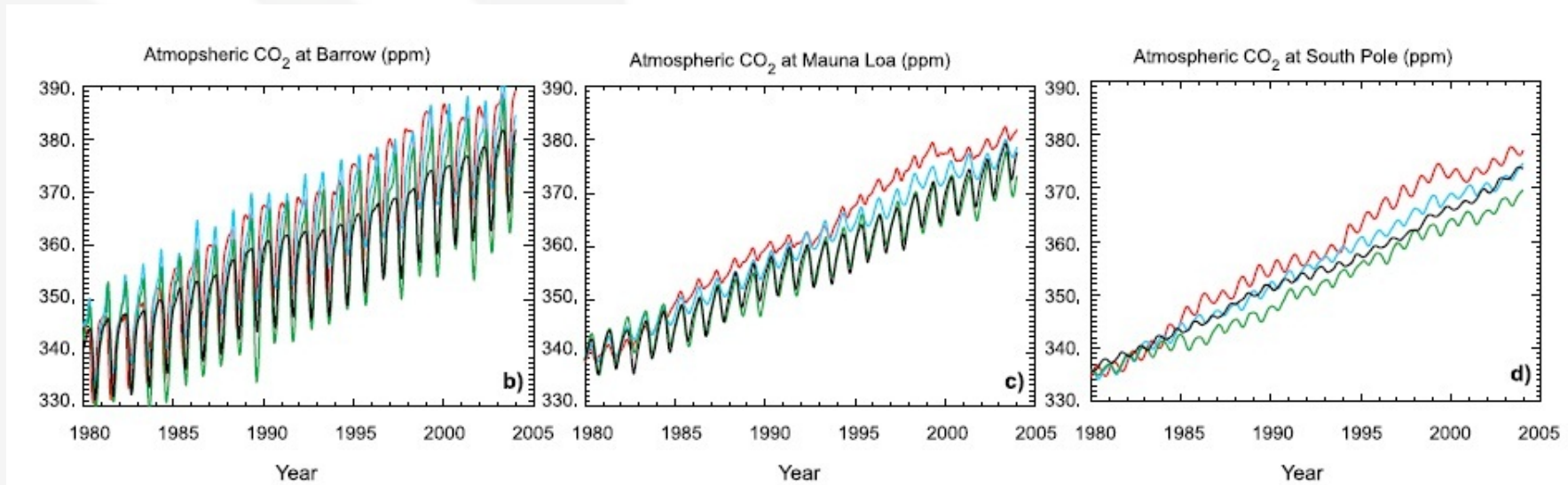Krinner et al., 2005

# On-site evaluation (2)

Seasonal cycle



Krinner et al., 2005

# [CO$_2$] evaluation at stations

- Global simulations
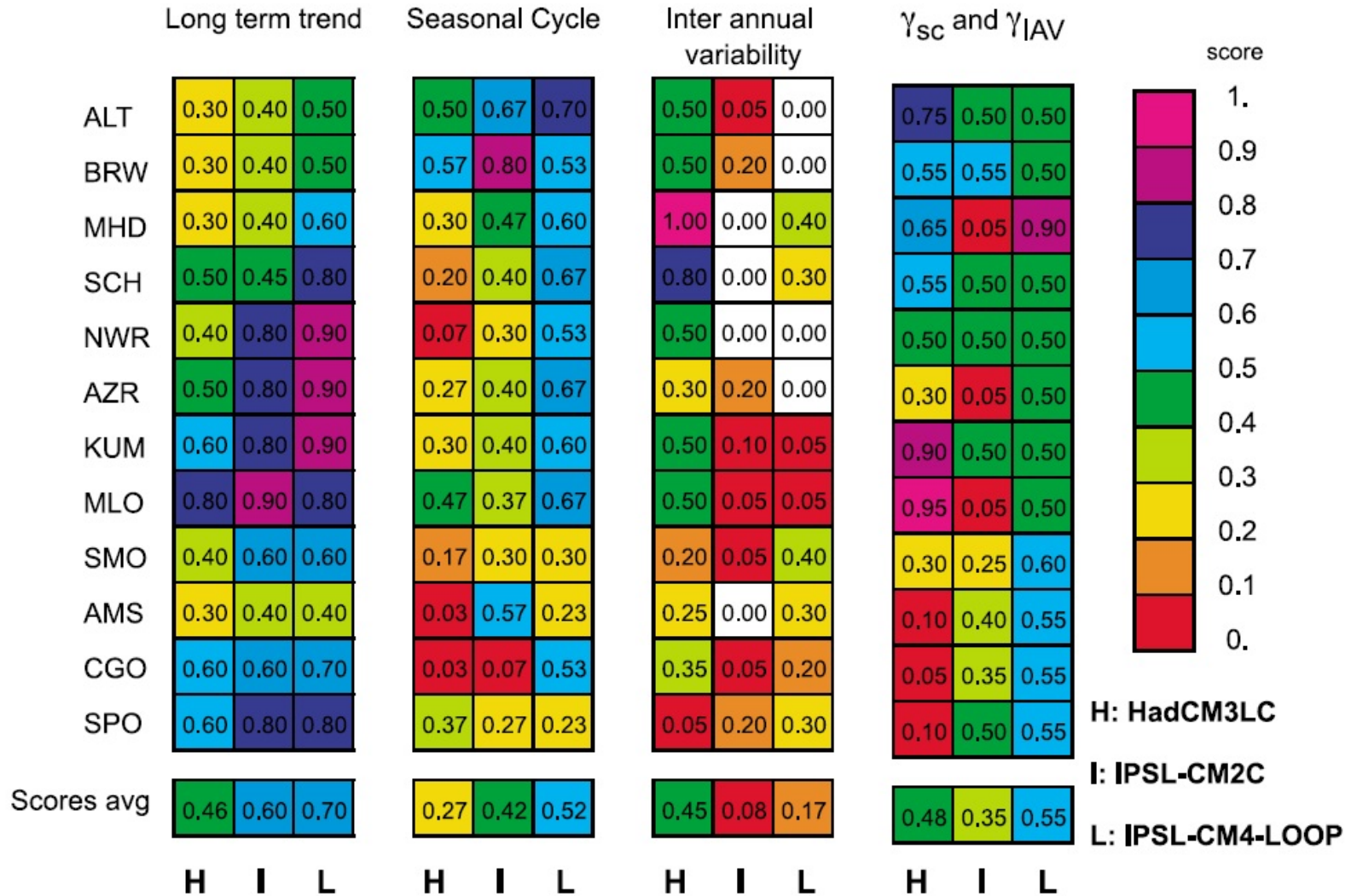  - Where Land / Ocean / Atmosphere are coupled



Atmospheric CO$_2$ at Barrow (ppm) — Atmospheric CO$_2$ at Mauna Loa (ppm) — Atmospheric CO$_2$ at South Pole (ppm)

HadCM3LC
IPSL-CM2-C
IPSL-CM4-LOOP
Observations

Cadule et al., 2010
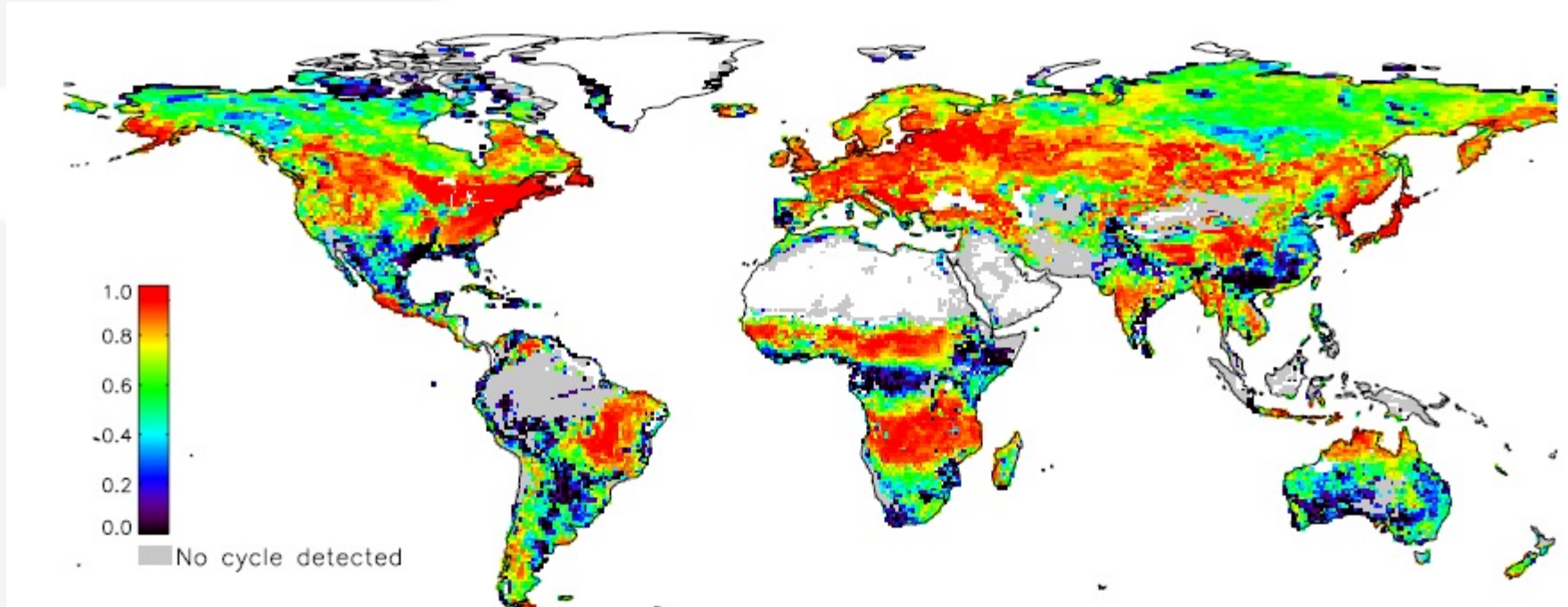
# [CO₂] evaluation at stations



Cadule et al., 2010

# Phenology evaluation

## Remote-sensed data



NDVI/FPAR Time-Series

NDVI/FPAR Mean Annual Cycle

[21.0S, 22.7E]

NDVI
FPAR new phenology

NDVI/FPAR Anomalies Time-Series

r=+0.59

r=+0.52
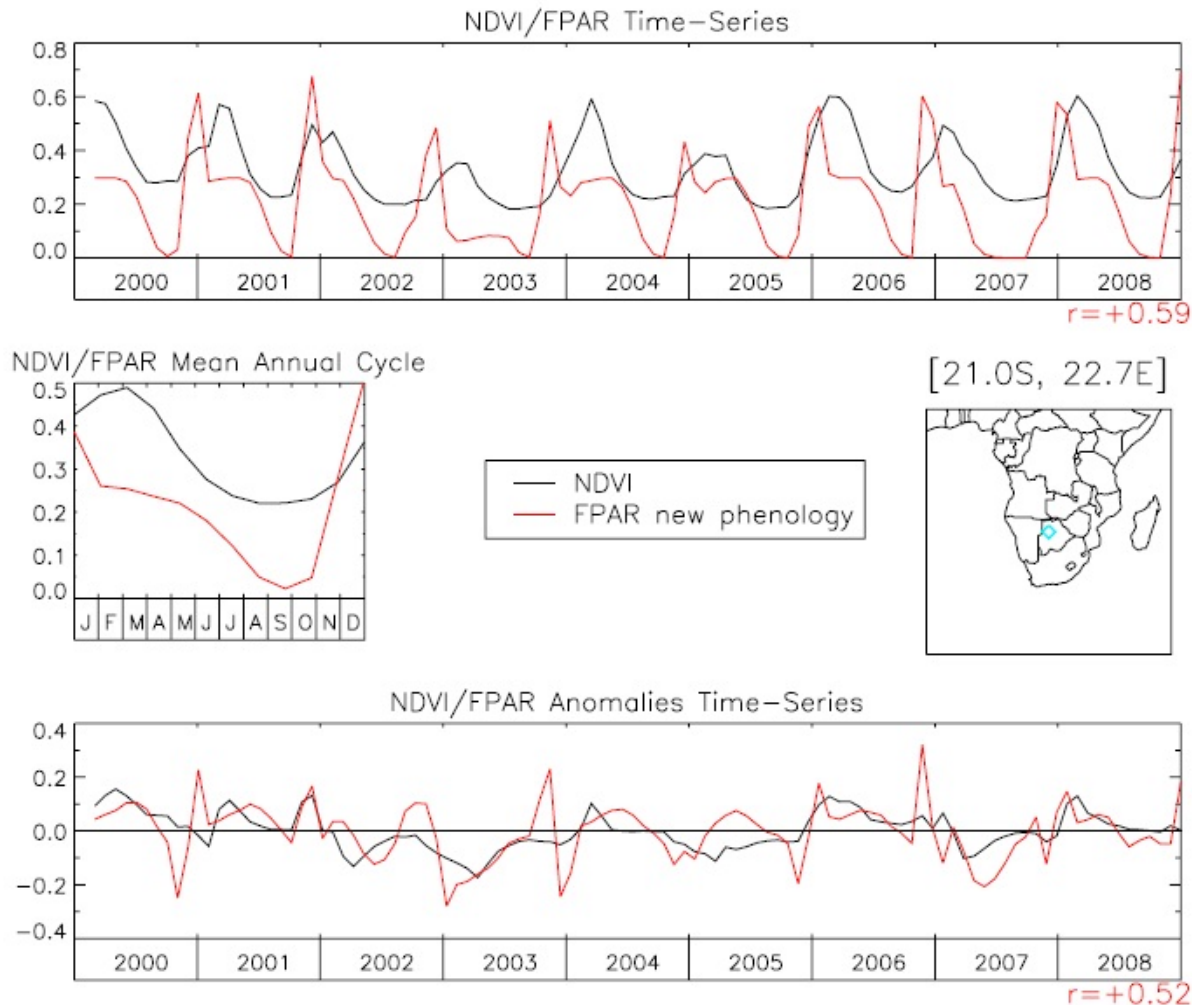
Maignan et al., en review

# Phenology evaluation (2)



Correlation map between monthly NDVIobs et FPARsim mensuels (2000-2008)
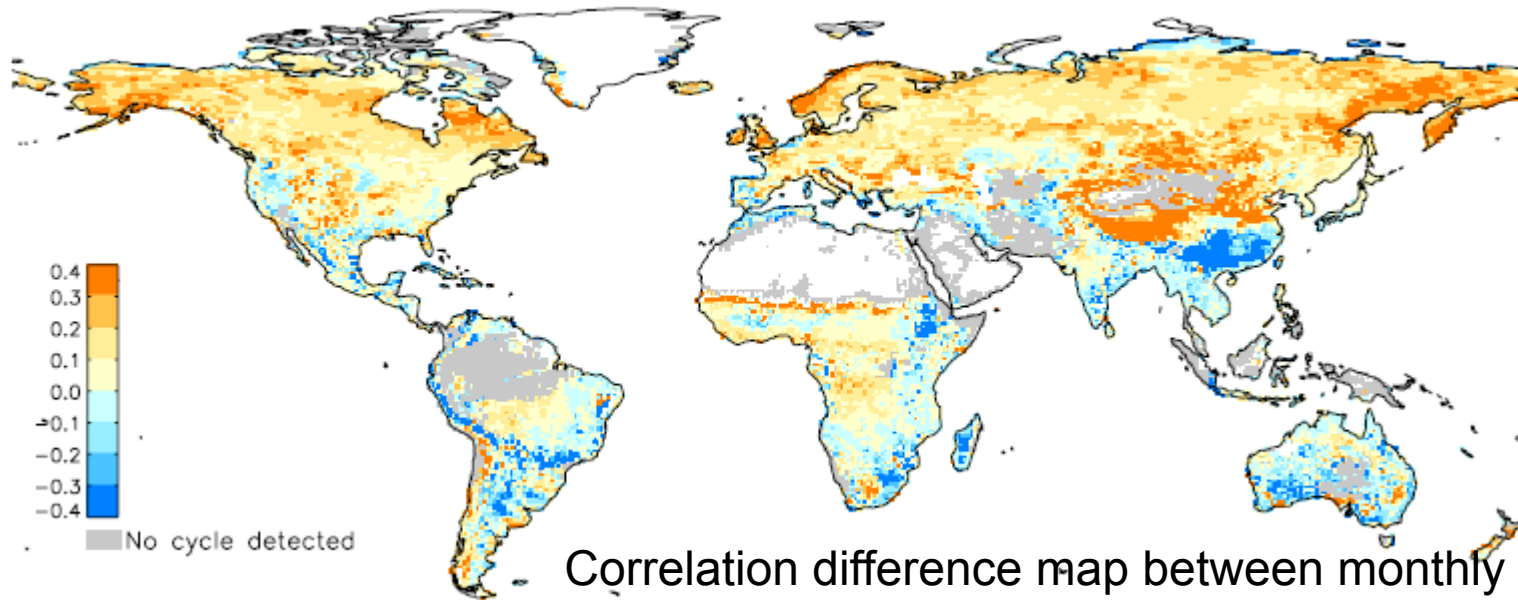
Maignan et al., 2011

# Phenology evaluation (3)
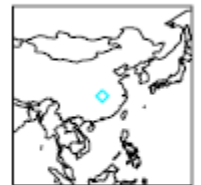


NDVI/FPAR correlations weighted normalized histogram

current phenology
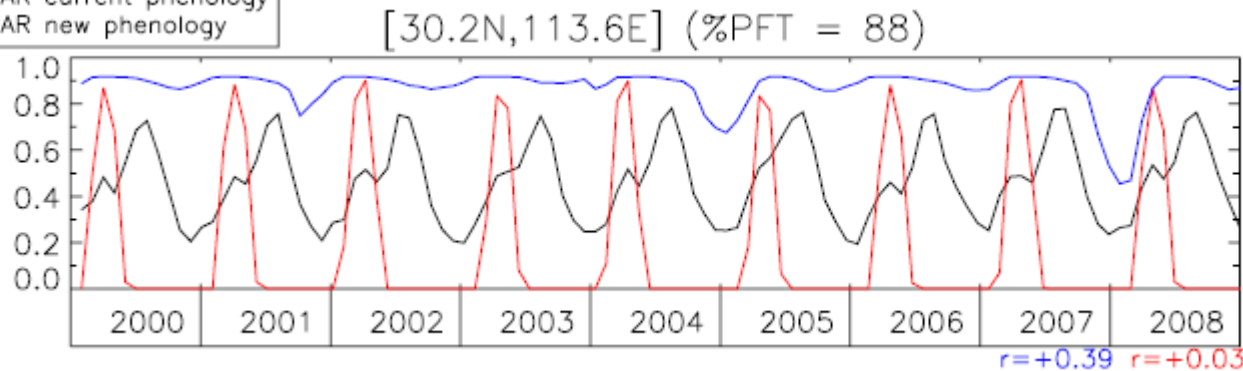new phenology
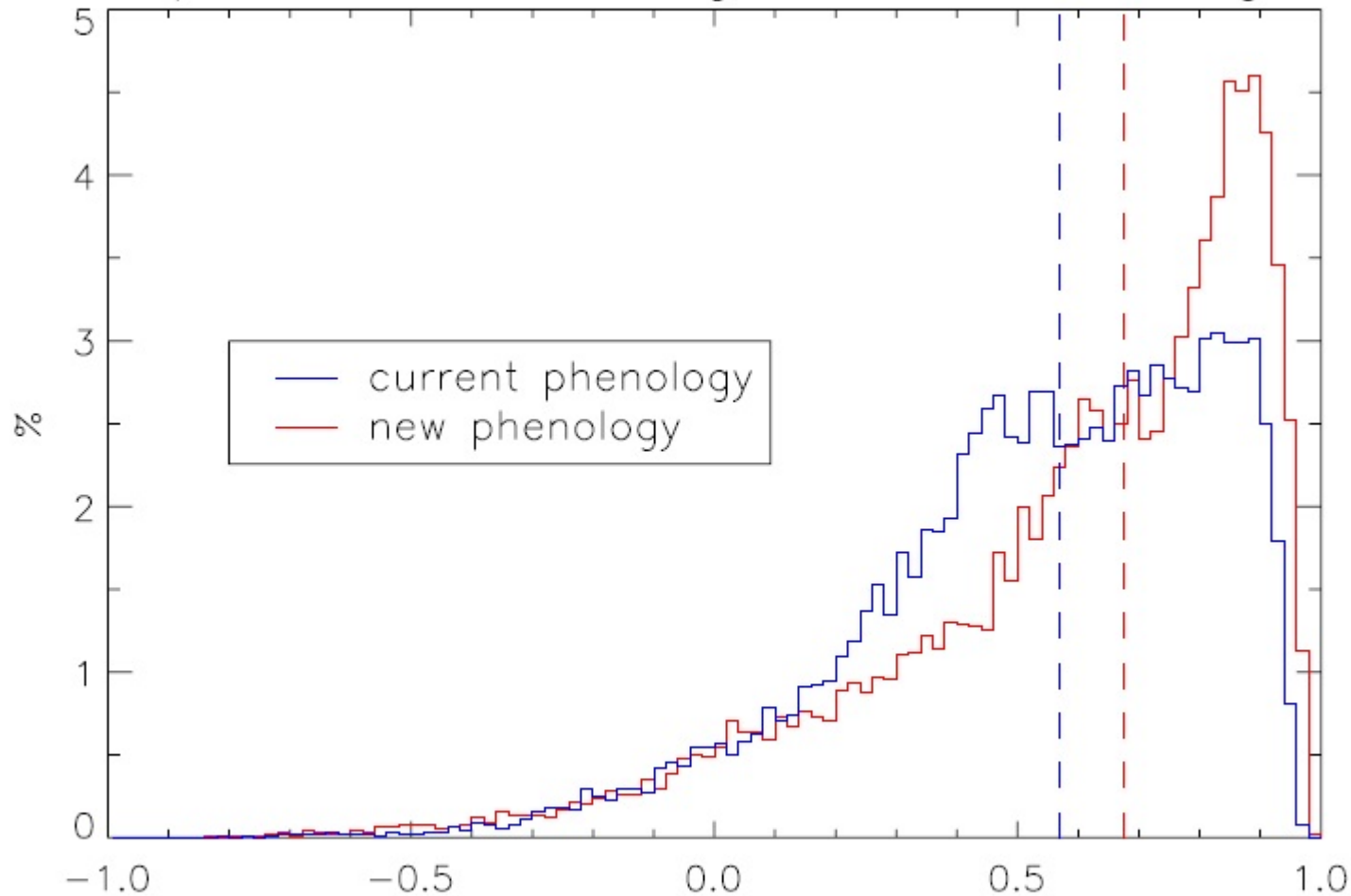
Maignan et al., 2011

# Phenology evaluation (4)



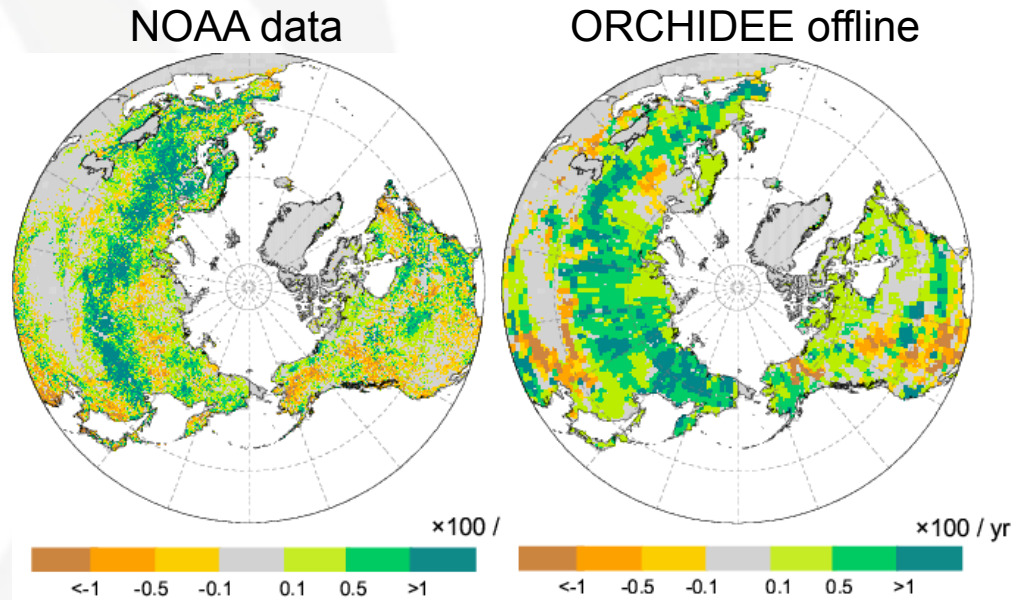Correlation difference map between monthly NDVIobs et FPARsim (2000-2008) for 2 versions

# Study on the greening of the North Hemisphere

- A) detection

LAI trend (1982-2002)

NOAA data ORCHIDEE offline



Piao et al., 2006

*Piao et al., GRL, 2006*

# Study on the greening of the North Hemisphere

- B) Attribution



(A) CO2 only

(B) Temperature only

(C) Precipitation only

(F) Dominant driving factors

×0.001 / yr

×0.001 / yr

×0.001 / yr

<8  -4  -1  1  4  >8

<8  -4  -1  1  4  >8

<8  -4  -1  1  4  >8

LAI increase due to temperature
LAI increase due to precipitation
LAI increase due to CO2
LAI decrease due to temperature
LAI decrease due to precipitation
LAI change due to other factors
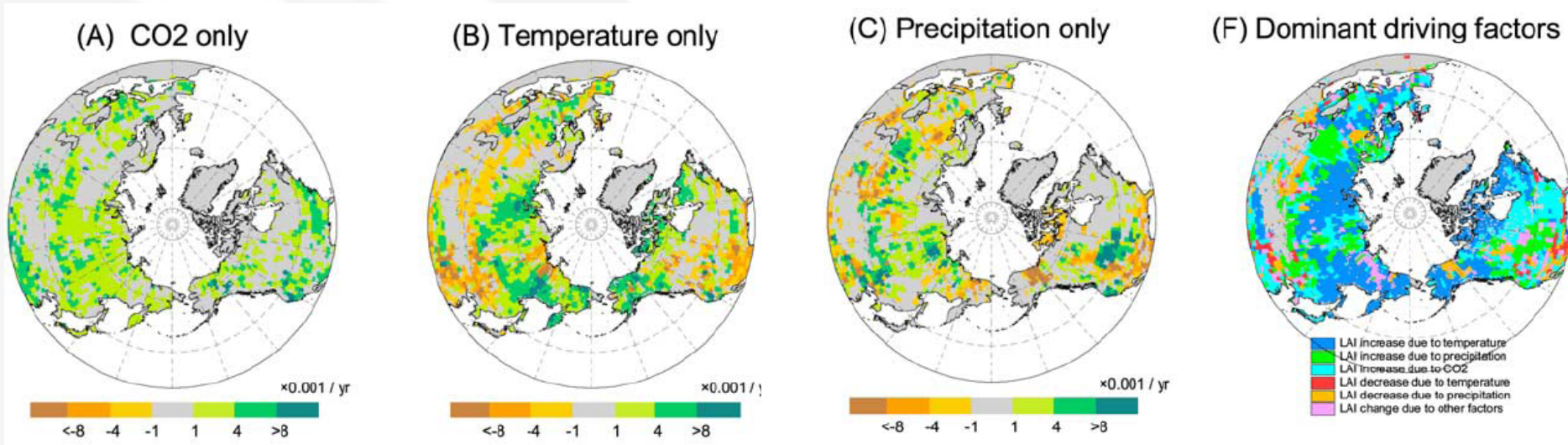
Piao et al., 2006

# Evaluating the 'Hydrological' component
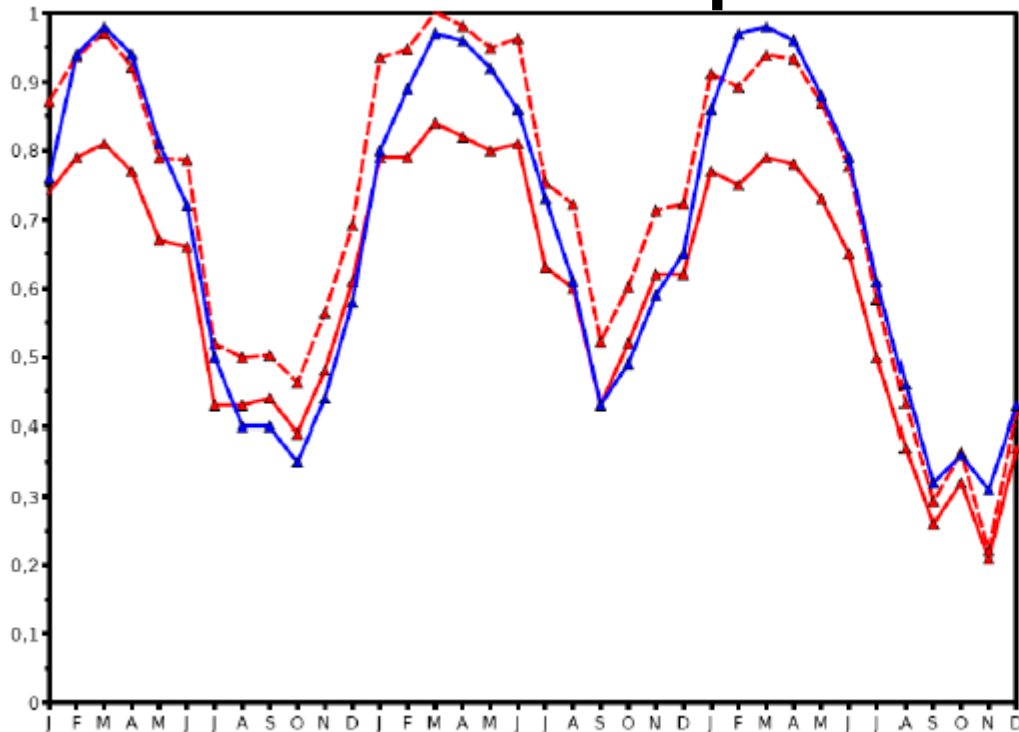


Variation of soil humidity index in Illinois (17 stations) over 3 years

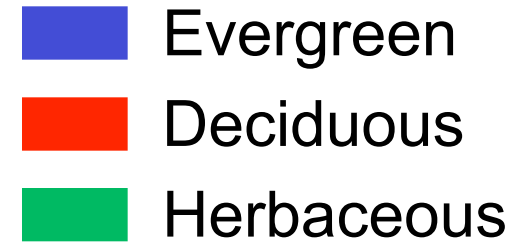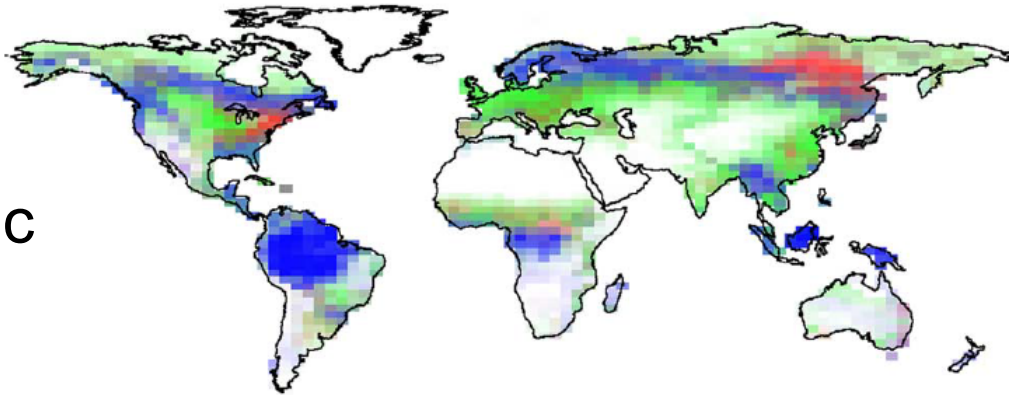*(M. Guimberteau, Thèse, 2010)*

# Evaluating the 'Hydrological' component
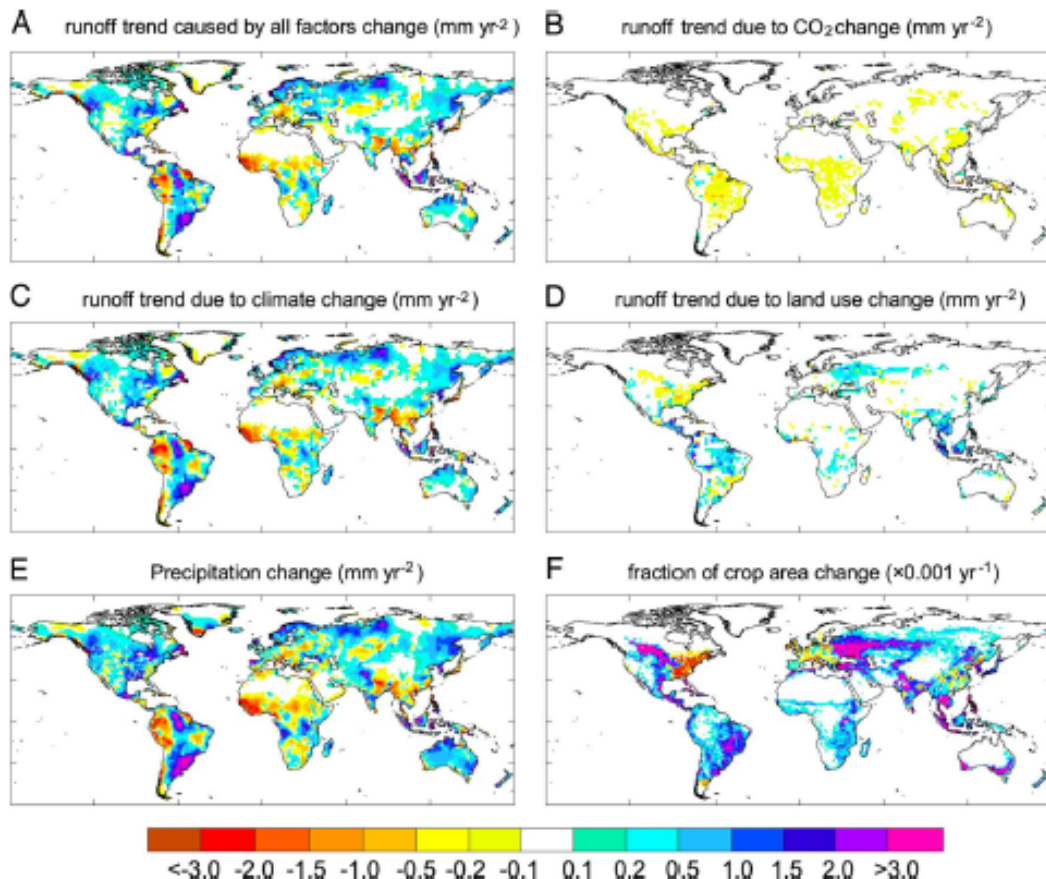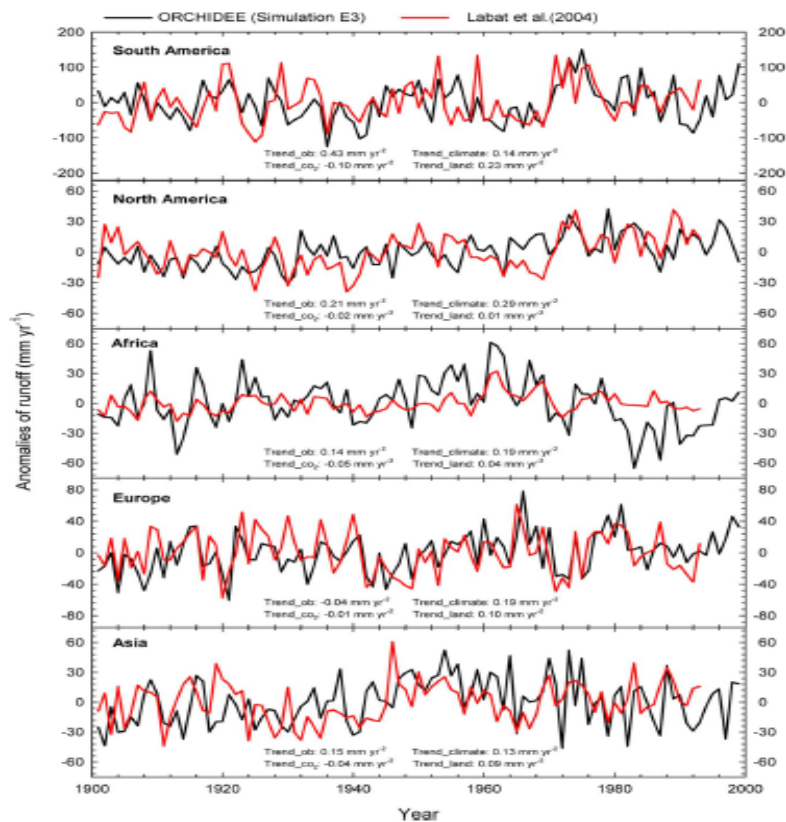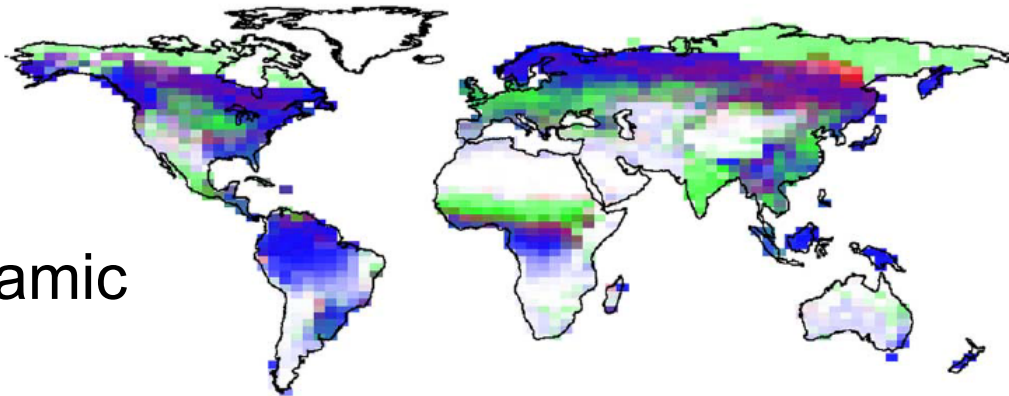


Piao et al., 2007

# Vegetation dynamic



Static

Dynamic

Evergreen
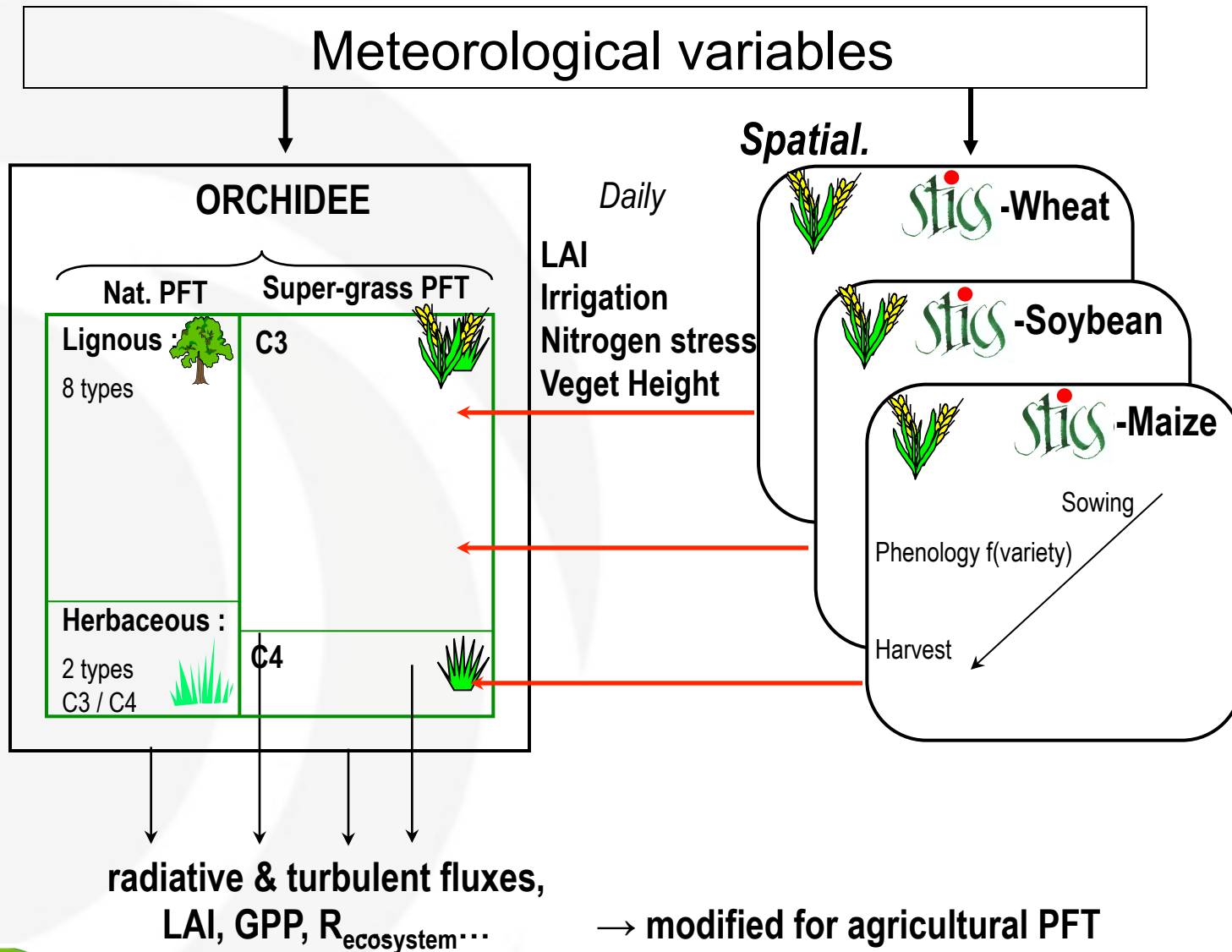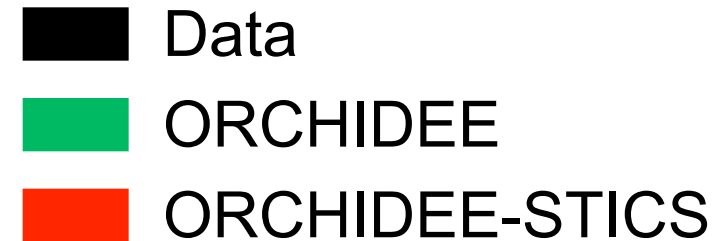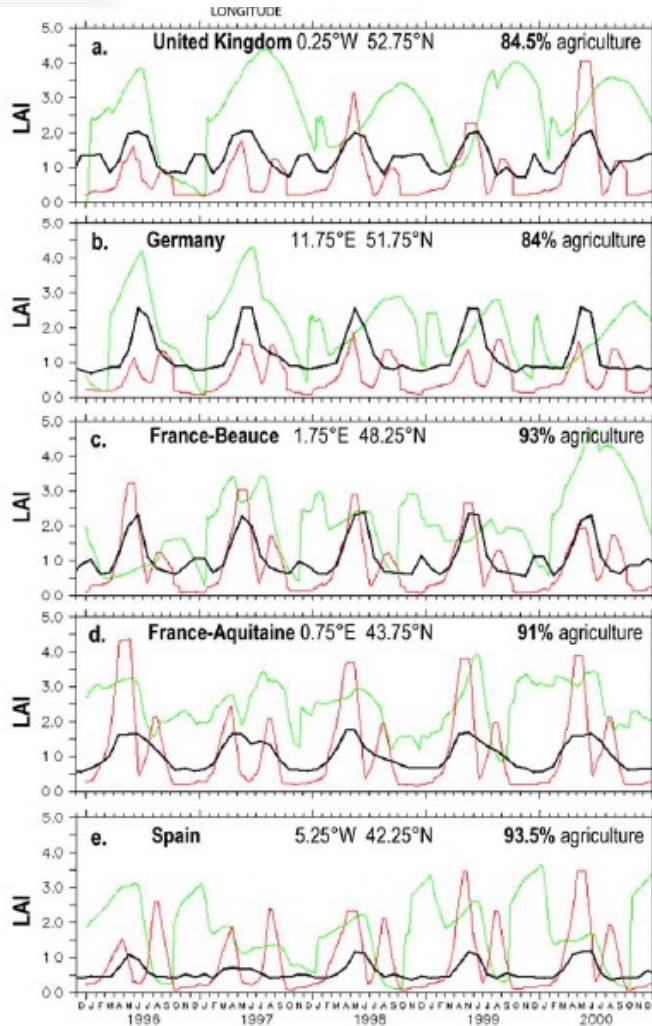Deciduous
Herbaceous

# Ongoing developments

- C-N interactions
- Forest & crop management
- Wetland emissions
- New multi-layers energy budget
- New radiative transfert scheme
- New vegetation types (based on trait concept)
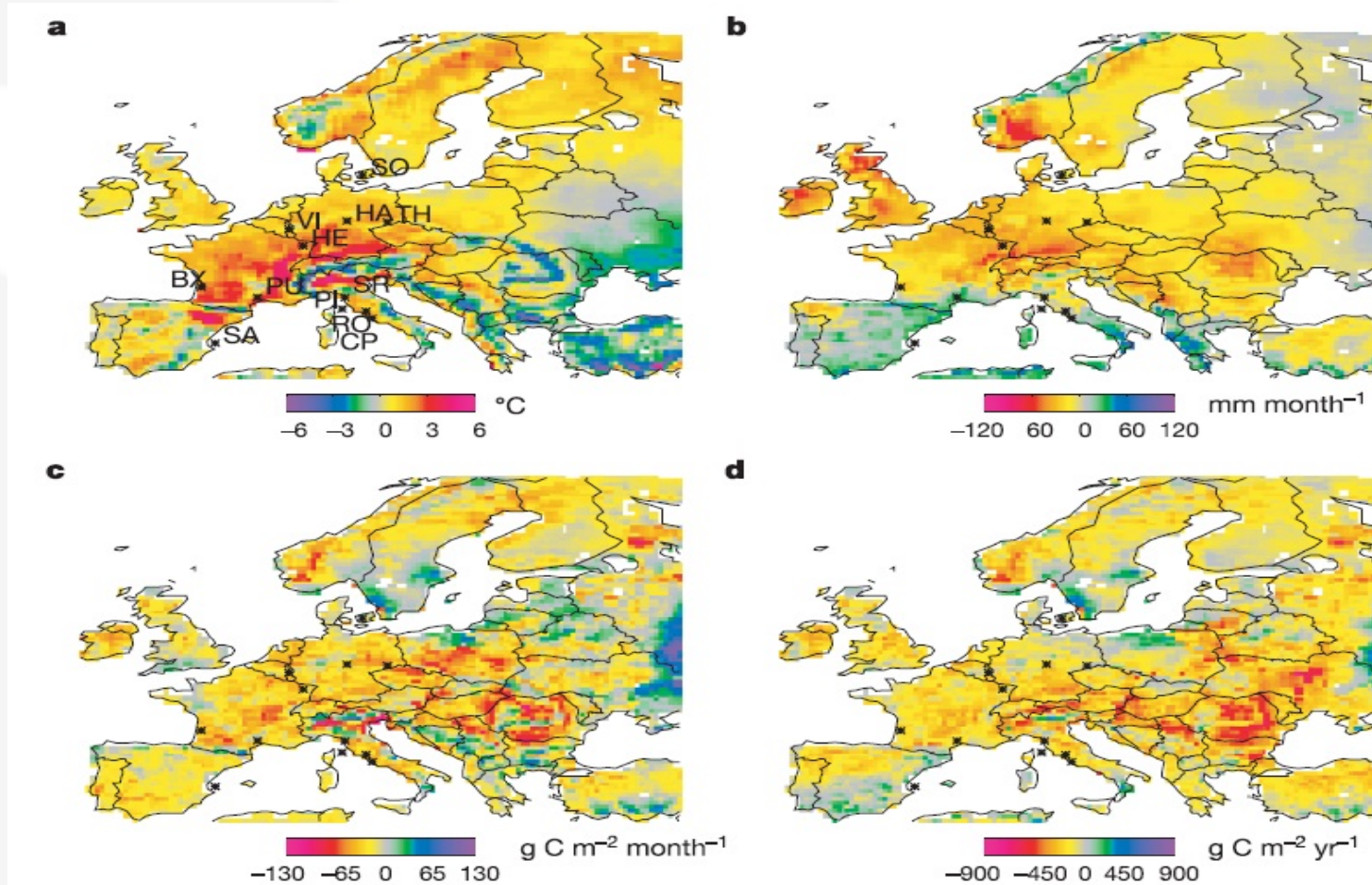
# ORCHIDEE-STICS coupling scheme

# O-S: Evaluation of LAI



Data
ORCHIDEE
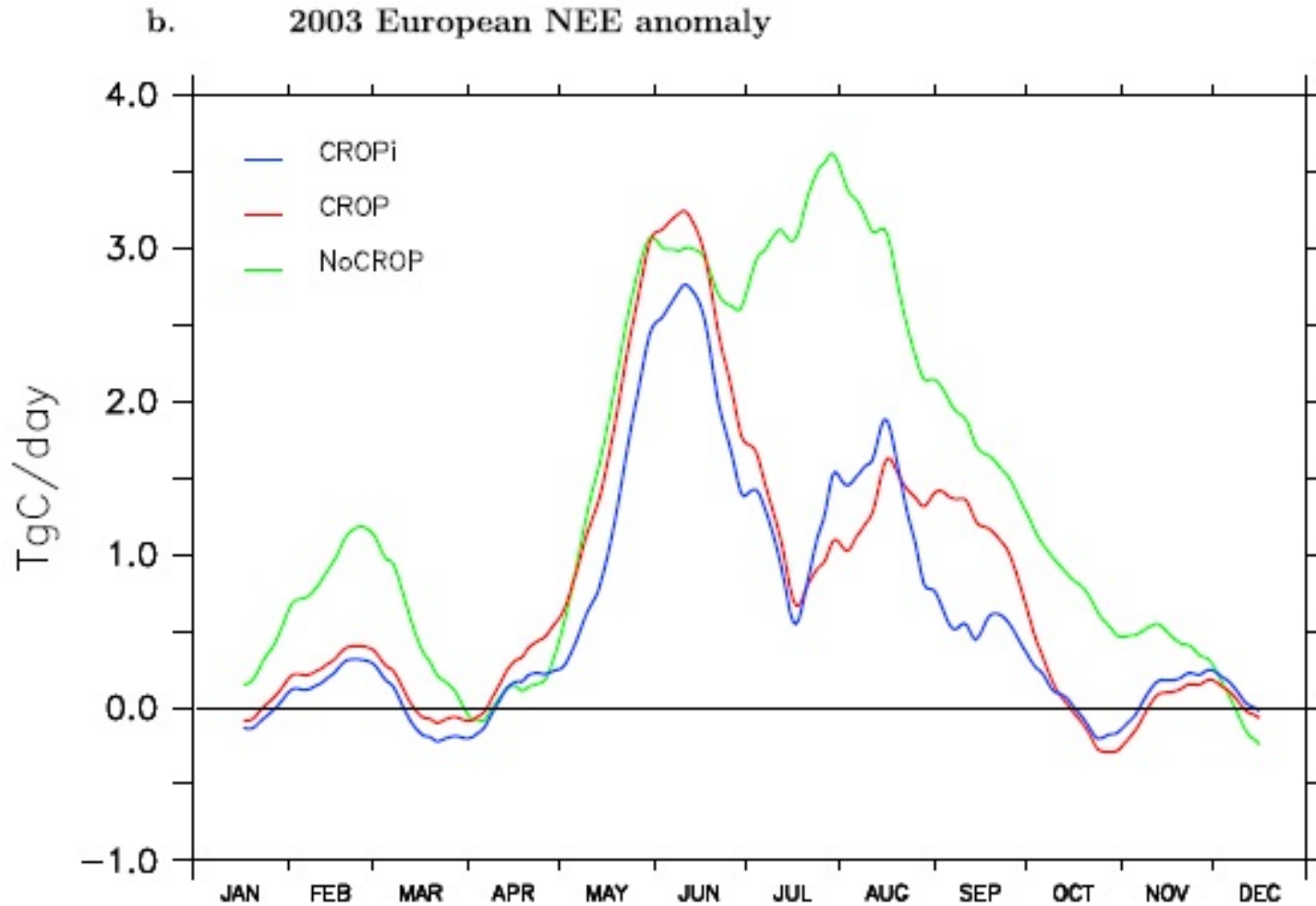ORCHIDEE-STICS

Smith et al., 2010

# O-S: Impact of the 2003 heatwave



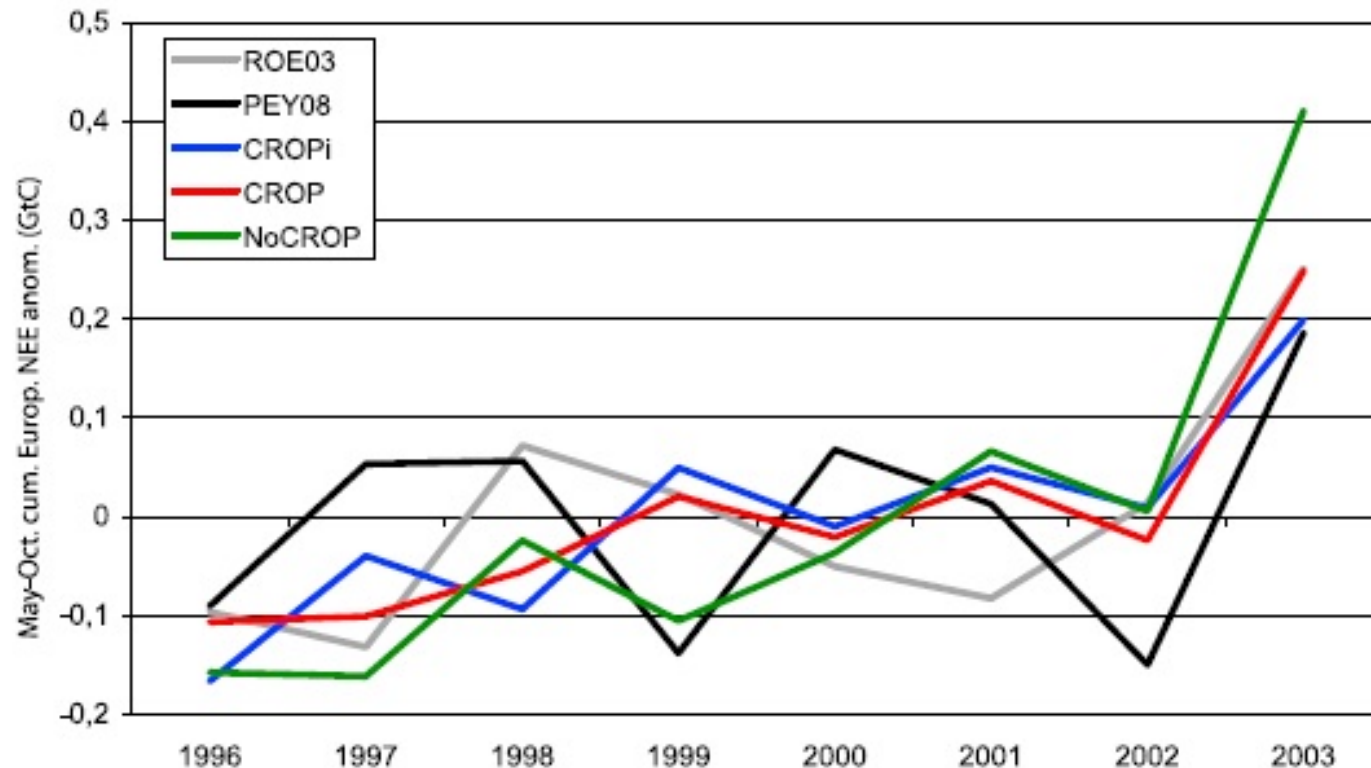Ciais et al., 2005

# O-S: Net C flux anomaly



Smith et al., 2010

# O-S: Comparison with a top-down approach
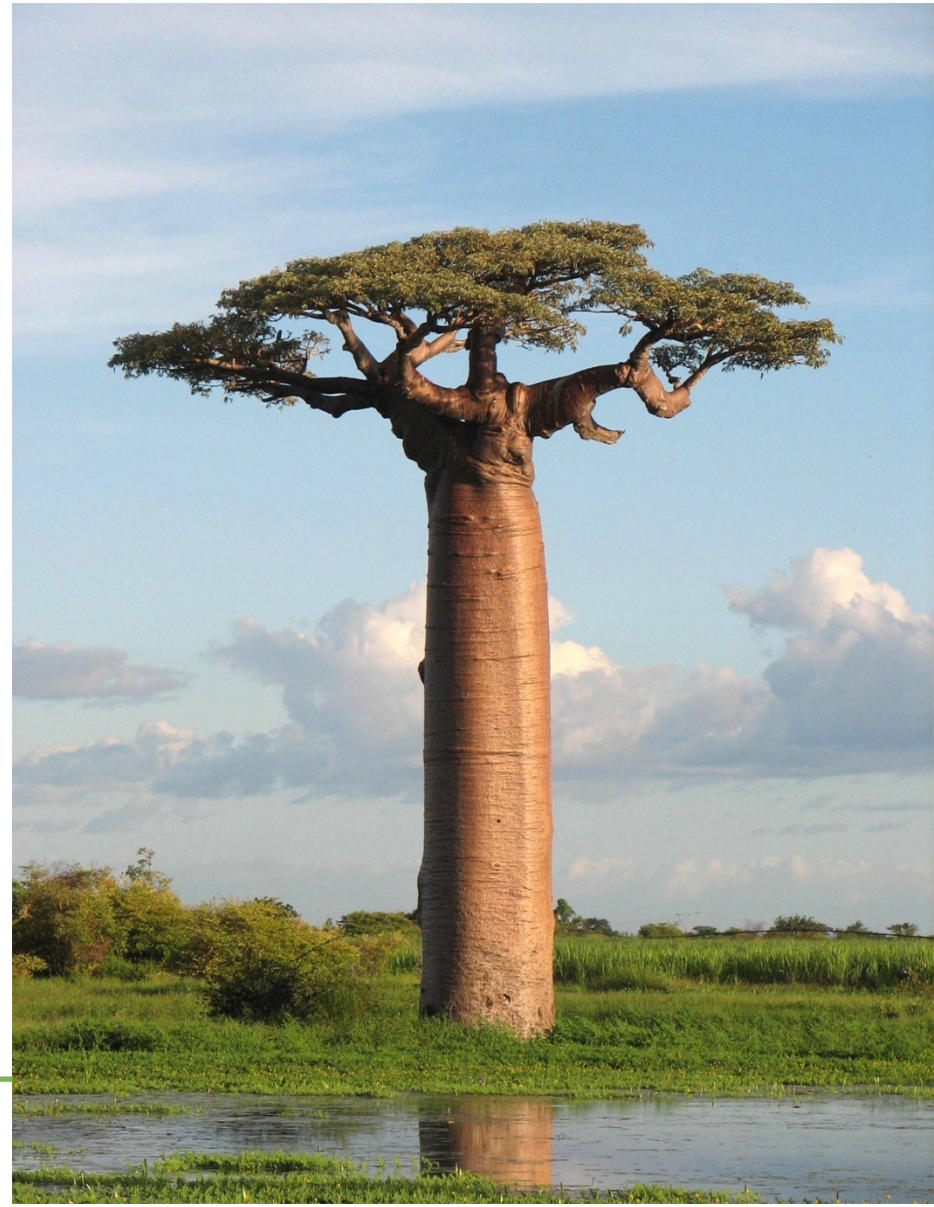


Smith et al., 2010

# Conclusion

- Evaluation
  - Well tested models
  - Lack of a systematic evaluation
- New developments to be included
  - By keeping the constraint that the model serves for several types of application
  - How to consider developments that induce low scores for good reasons

**ORCHIDEE yesterday...**

**ORCHIDEE tomorow...**

# More on ORCHIDEE

- 'Official' site
    - labex.ipsl.fr/orchidee/
- Wiki site:
    - forge.ipsl.jussieu.fr/orchidee/wiki
- Mailing lists
    - forge.ipsl.jussieu.fr/orchidee/wiki/Contact