



Biogeochemical cycles and data assimilation

Philippe Peylin, Frédéric Chevallier, Philippe Ciais, and the team « Inversion-assimilation-teledetection » at LSCE

- **The ORCHIDEE land surface model**
- **Data assimilation schemes developed at LSCE**
- **Toward a global Carbon Cycle Data Assimilation System (CCDAS)**



ORCHIDEE

The Global Land Surface Model

ORCHIDEE

(ORganizing Carbon and Hydrology In Dynamic Ecosystems Environment)

A generic tool:

- To study coupled carbon & water & Nitrogen cycles
- To be used coupled to an AGCM or forced by external climate forcing
- High level of complexity : application from local to global scales
- High level of modularity to easy modules exchange

LSCE: N. Viovy, N. De Noblet, P. Ciais, P. Friedlingstein, P. Peylin, F. Maignan, J. Lathierre, N. Viuchard, S. Luysaert, S. Zaehle....

LMD: J. Polcher, K. Laval, F. Hourdin,...

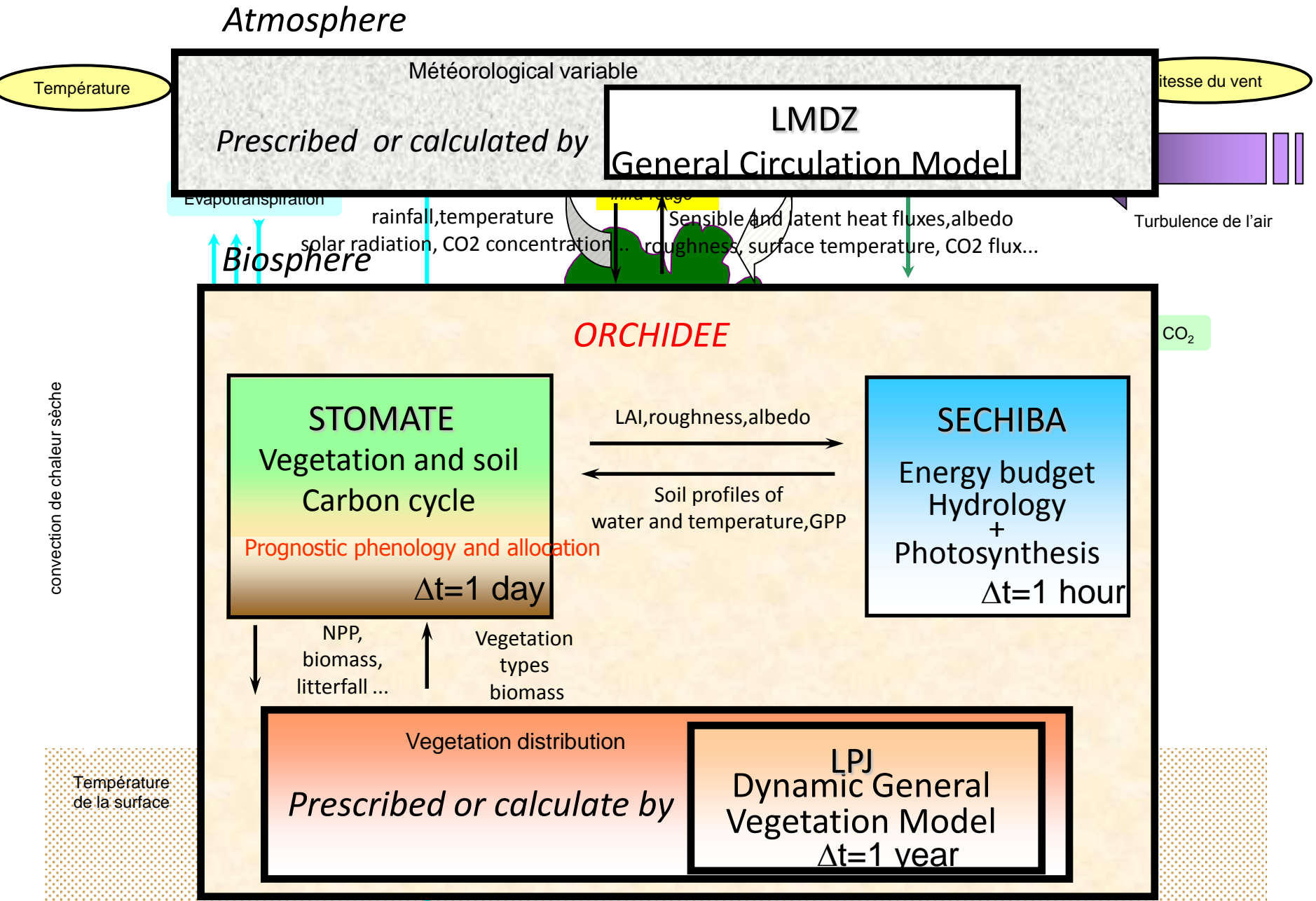
LGGE: G. Krinner

Sisyphe: A. Ducharne

U. Pekin: S. Piao

→ **Build a Community Land Surface Model...**

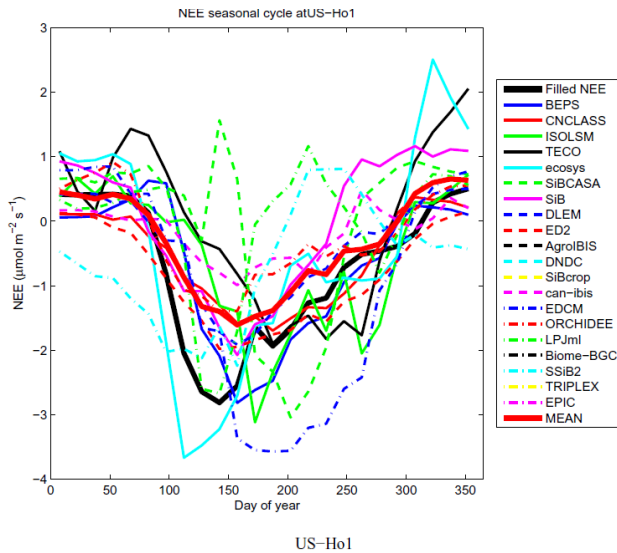
Major processes simulated by ORCHIDEE



Evaluation: NACP inter-comparison

Application : Change in N. Hemis. spring LAI

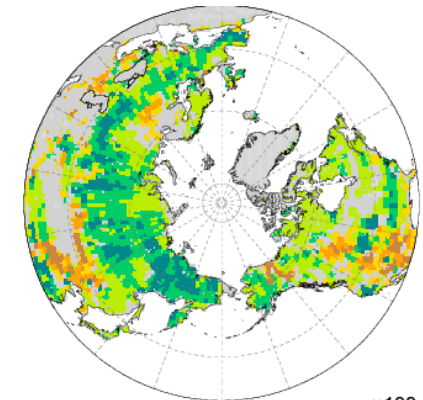
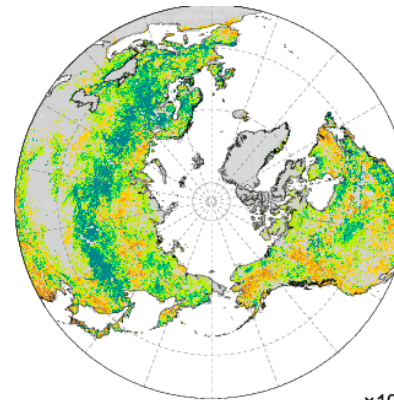
NEE: US- Howland site



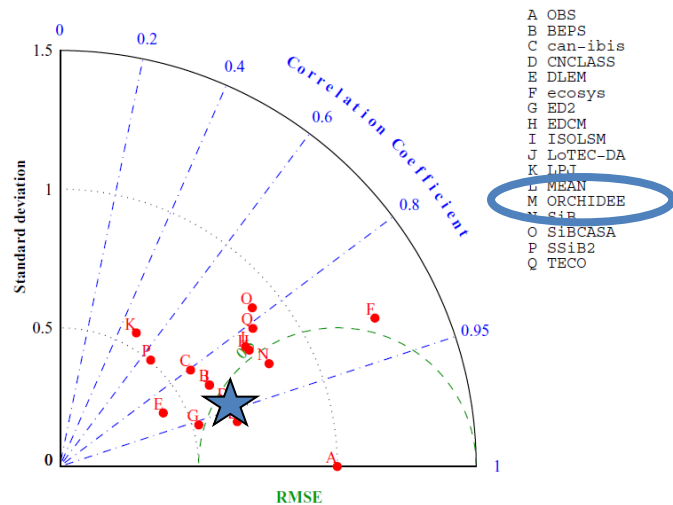
LAI trend (1982-2002)

NOAA data

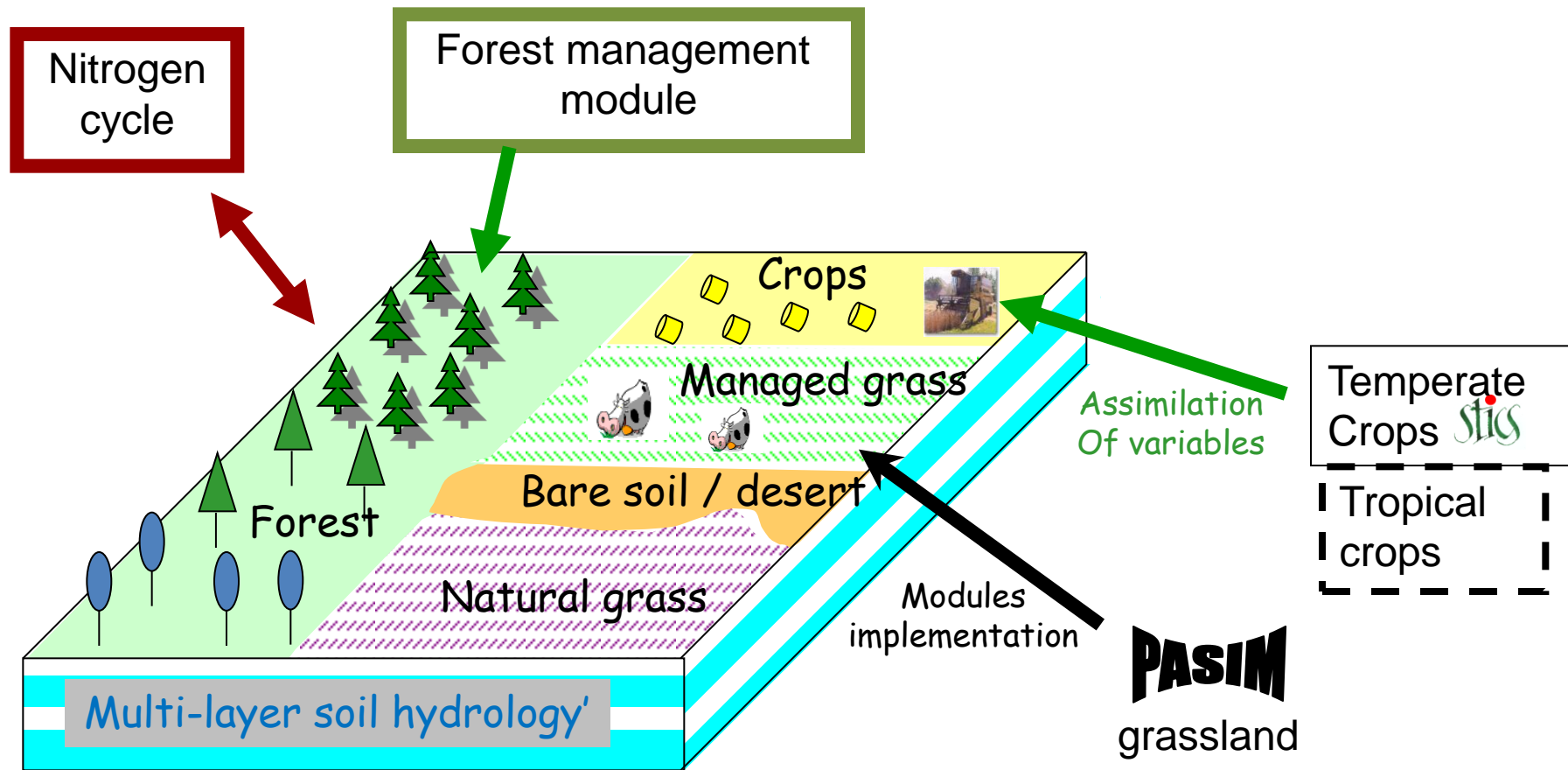
ORCHIDEE offline



➔ Attribution of greening effect
Temperature effect dominate



Recent improvements of ORCHIDEE



Ongoing developments:

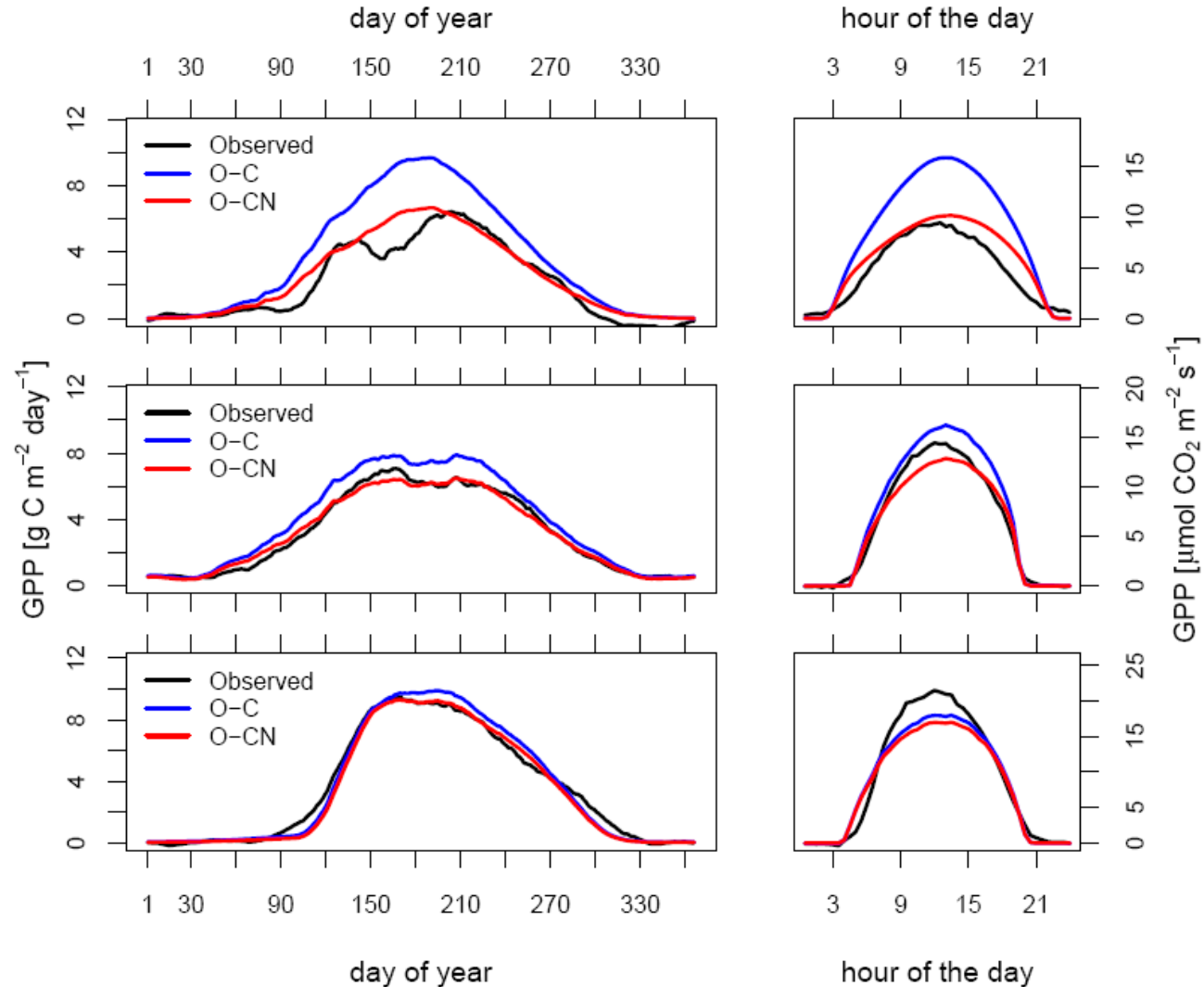
- Adjoint model of ORCHIDEE
- **Tropical-crop module : PKU**
- Improved Physic

Nitrogen Cycle: impact on CO₂ fluxes (European temperate & boreal forests)

Flakaliden
(Bor. needle leaved evergreen)

Weidenbrunnen
(Temp. needle leaved evergreen)

Sorø
(Temp. broadleaved deciduous)



Information system on Green House Gases at LSCE using Atmospheric data



Model – Data fusion systems to :

☐ Detect

- detect changes and their tendencies
- regional vulnerable sinks

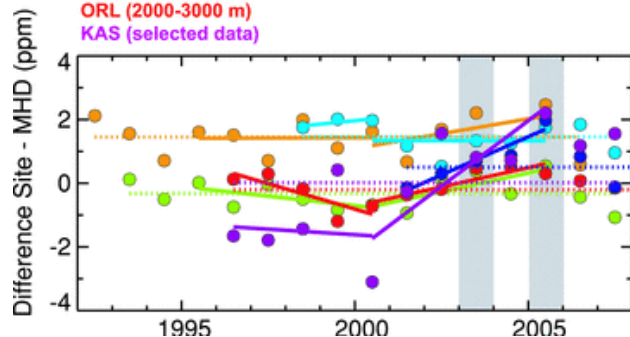
☐ Monitor

- the natural land & ocean carbon sinks

☐ Verify

- Confirm / Infirm declared emission reductions

PRS (selected data)
SCH (selected data)
PAL (selected data)
PUY (all data)
ORL (2000-3000 m)
KAS (selected data)



Ramonet et coll., 2010



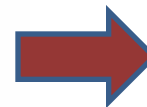
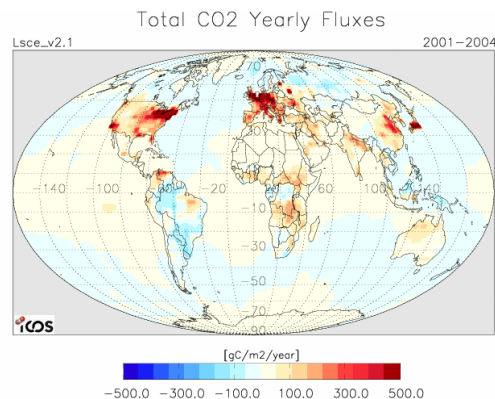
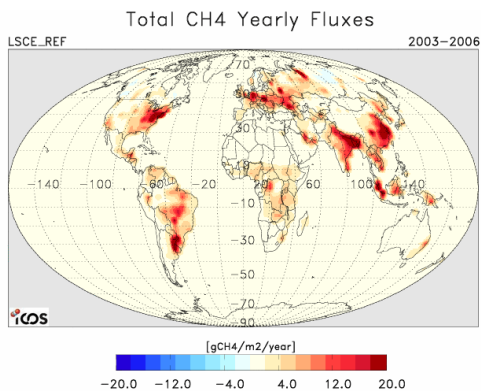
Deutsche Bank

Global Inversion system at LSCE

- **Variational approach** to retrieve information at « high » resolution
 - Weekly CO₂ fluxes at 3.75x2.5 deg²
- **Ensemble approach** to retrieve information at « low » resolution
 - Uncertainties for typical CO₂ flux quantities

$$p(\mathbf{x}|\mathbf{y}) = \frac{p(\mathbf{x}) \cdot p(\mathbf{y}|\mathbf{x})}{p(\mathbf{y})} \quad (\text{Baye's theorem})$$

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



CarboScope - "Greenhouse gases at earth surface" - Mozilla Firefox

http://www.carboscope.eu

Welcome To CarboScope

General Overview

- Home
- What is an Inversion?
- The Carbon Cycle
- The Methane Cycle

View CO₂ Fluxes

- Flux Maps
- Flux Time Series
- Flux Numerical Table

View CH₄ Fluxes

- Flux Maps
- Flux Time Series
- Flux Numerical Table

View DGVM CO₂ Fluxes

- Flux Maps

Resources

- CO₂ Contributors
- CH₄ Contributors
- Glossary

Information and Help

- Terms of Use
- Release History
- Contact Us
- FAQ

CO₂ Fluxes from atmospheric inversions

Flux Maps

Total CO₂ Yearly Fluxes 2003

Flux Maps

Total CH₄ Yearly Fluxes 2003

[gC/m²/year]

-500.0 -300.0 -100.0 100.0 300.0 500.0

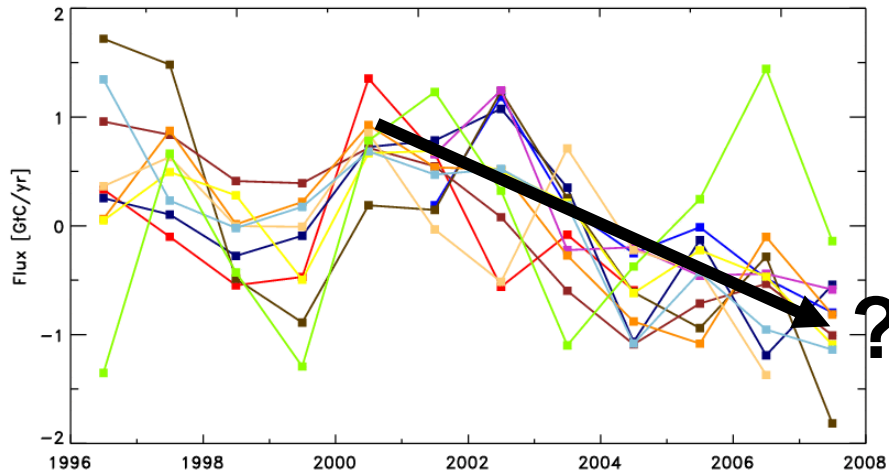
[gCH₄/m²/year]

-20.0 -12.0 -4.0 4.0 12.0 20.0

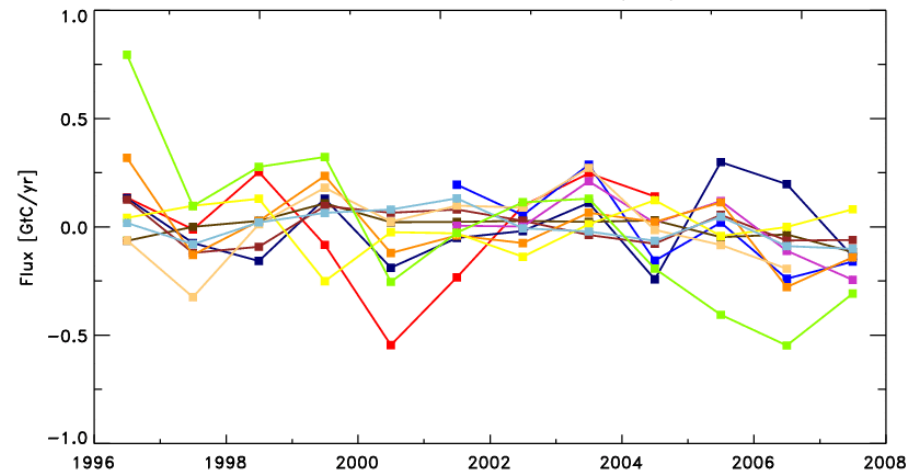
Terminé

IAV (several atmospheric inversions)

N. America



N. Atlantic



LSCE_an_v2.1

JENA_s96_v3.2

CTracker_EU

LSCE_var_v1.

C13_MATCH

CTracker_US

TRCOM_me

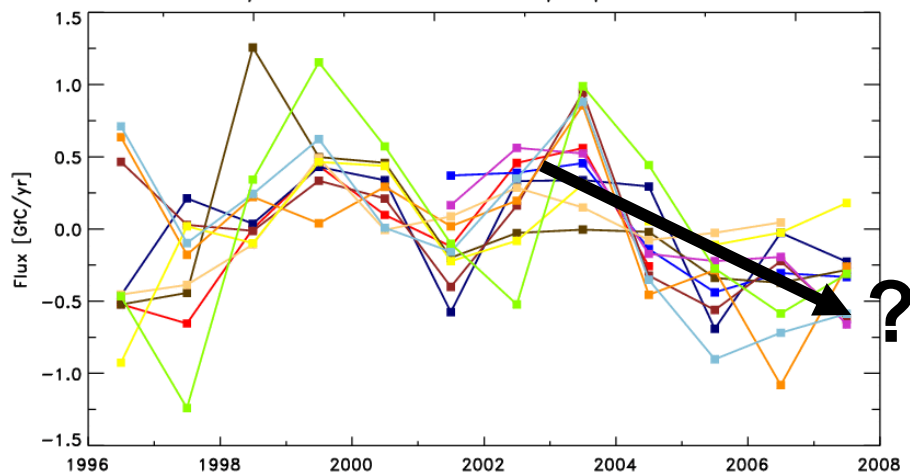
RIGC_patra

JMA_2010

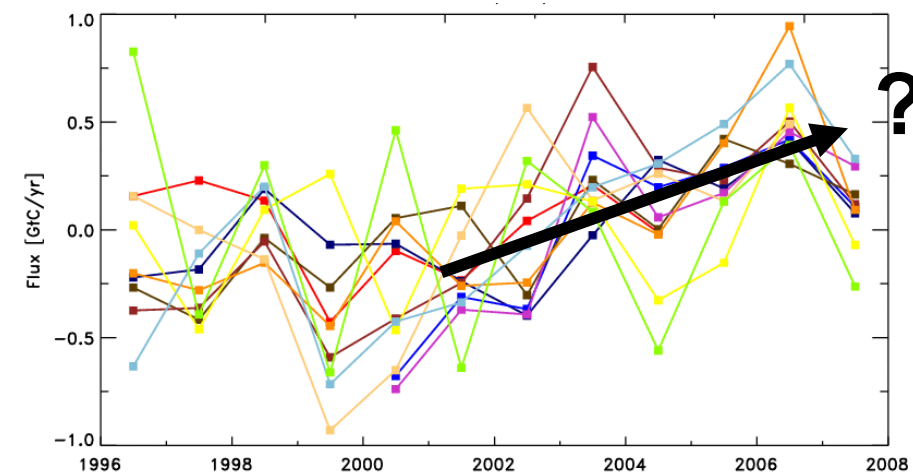
C13_CCAM

NCAM_Niwa

Europe



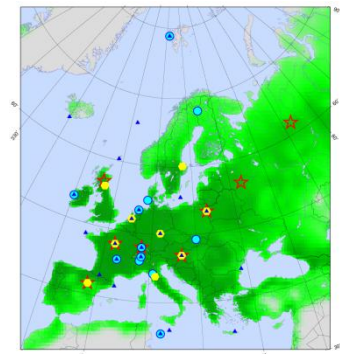
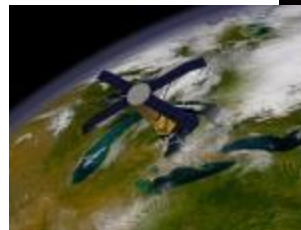
N. Asia



Valorisation of new/futur satellite observations

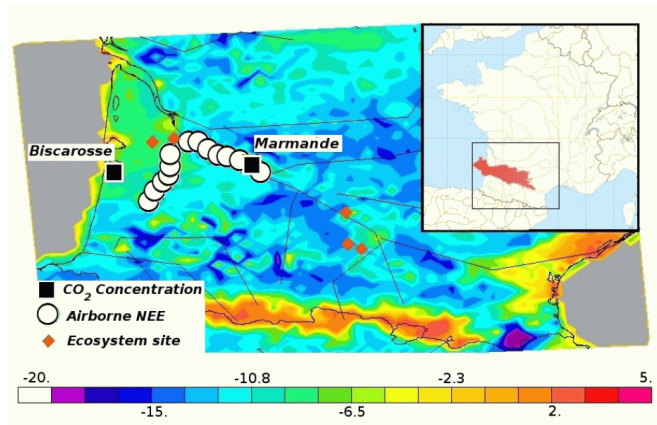
(Atmospheric & land data)

- Strong links with most ongoing « observation projects »
 - ICOS network
 - NIES (GOSAT)
 - NASA (OCO-2)
 - CNES (MERLIN, MicroCarb, IASI-NG)
 - ESA (CarbonSat, A-SCOPE, BIOMASS)

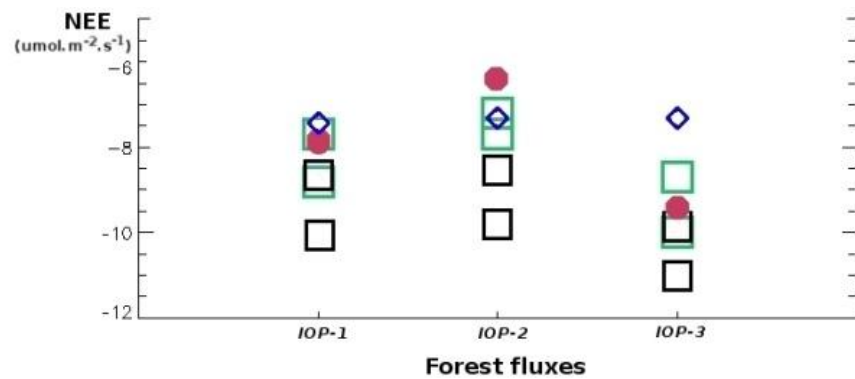
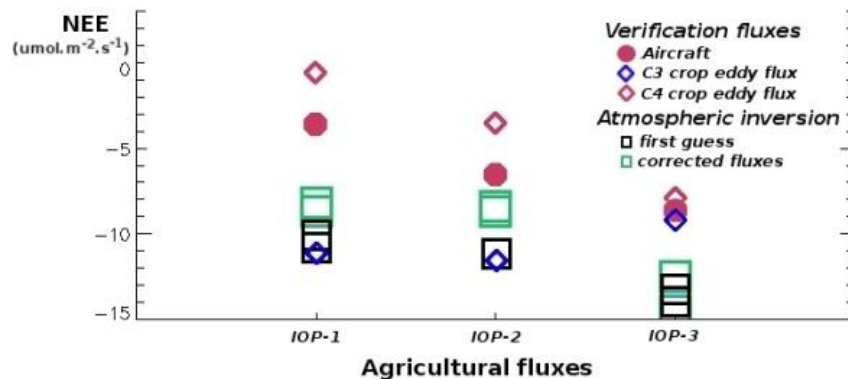


Example of small scale monitoring: « South west France » at 8km resolution

- Experience over the « Landes » forest in France using meso-scale models: MesoNH-LPDM

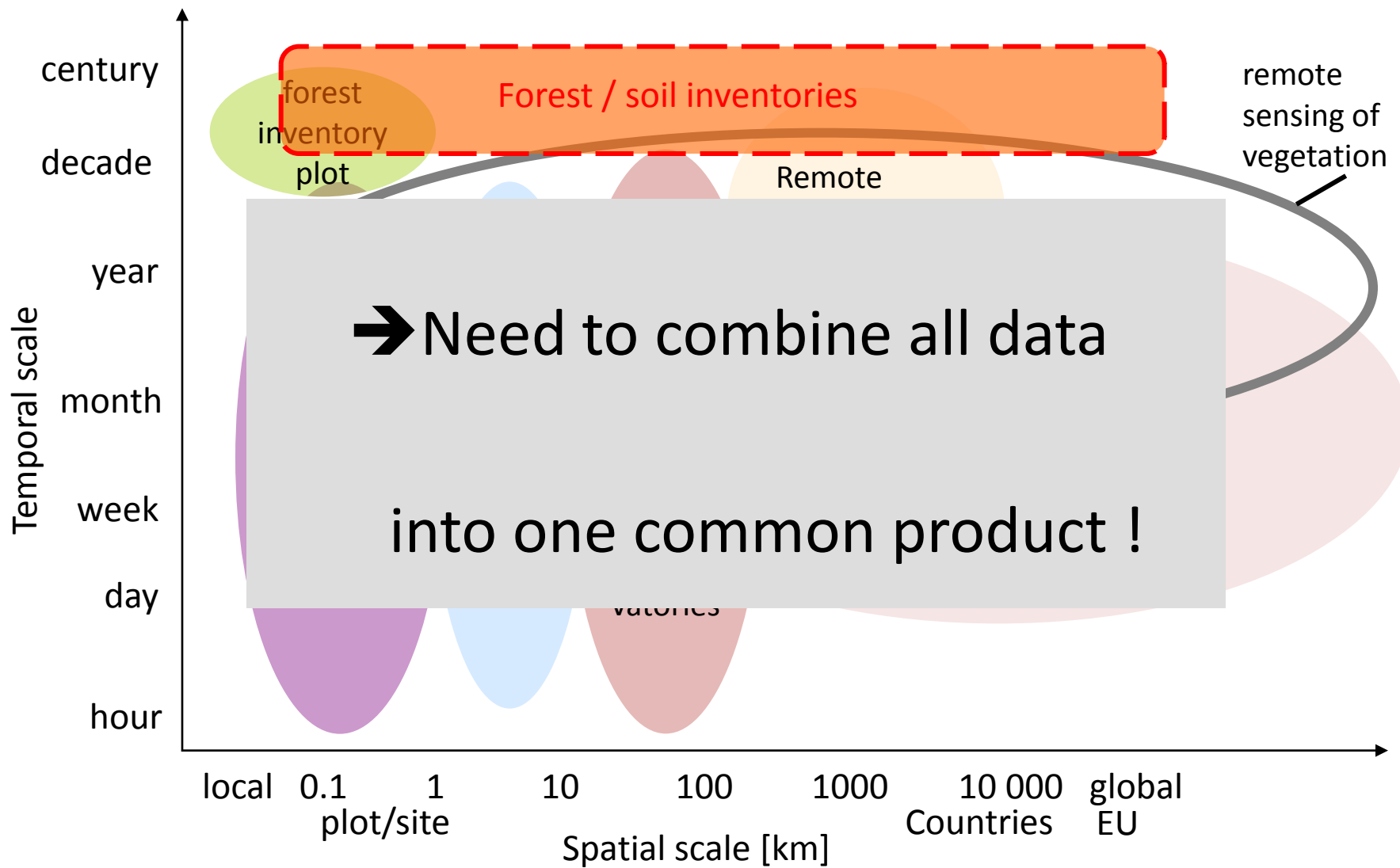


→ Coherence between inverse fluxes (8km) and flux measurements (1km), *Lauvaux et al. (2009)*

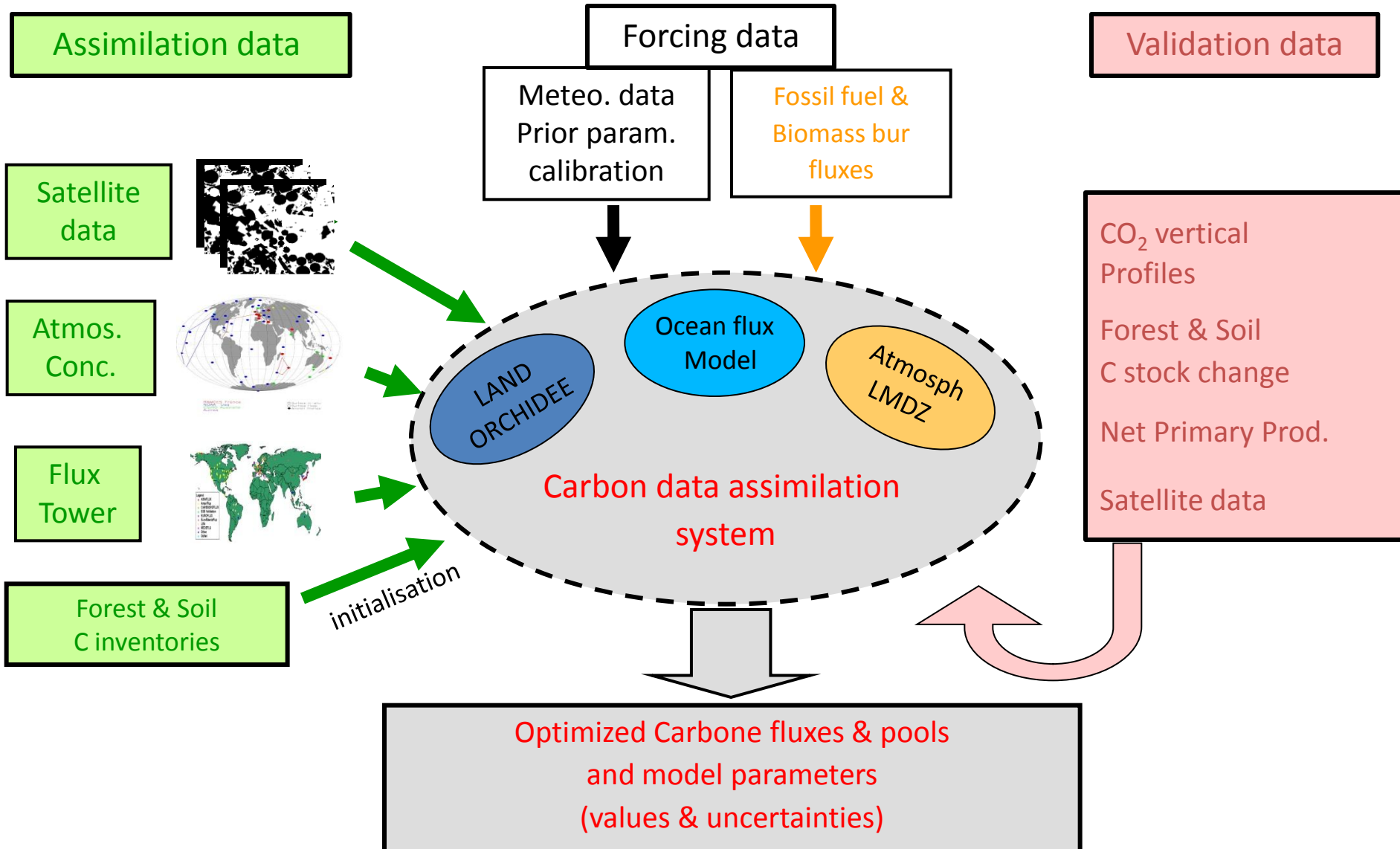


Next challenge :

**How to best use
the overall data diversity
together
with process-based models ?**



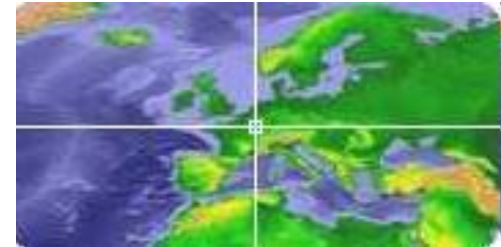
Carbon Cycle Data Assimilation System at LSCE



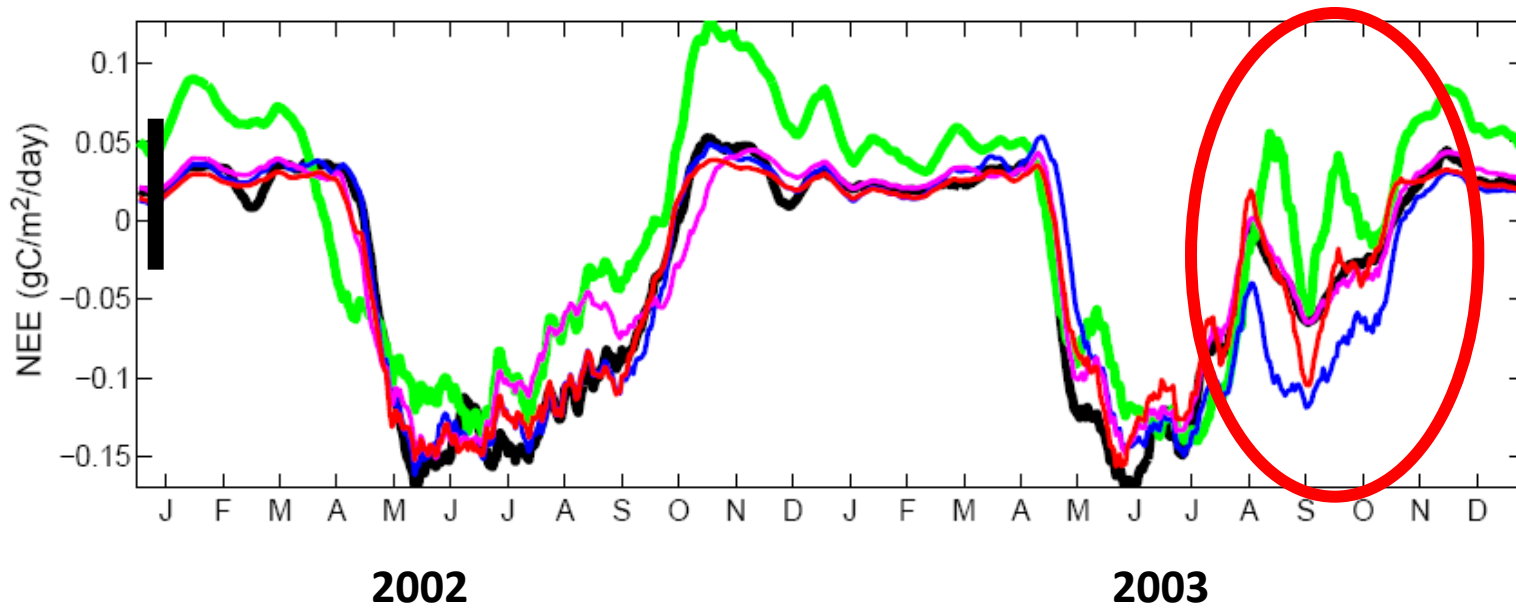
Assimilation of FluxNet data

Question: ability of the model to represent year to year flux variations ?

- **Ex: Beech forest : Hesse site (France)**
- **Assimilation of daily NEE / Latent Heat**
- **25 parameters**
- **period : 2001 – 2004**
 - **optimisation for each year separately**
 - **optimisation for the whole period**



Hesse site : Model – data fit (2 yrs)



RMSE
(x100)

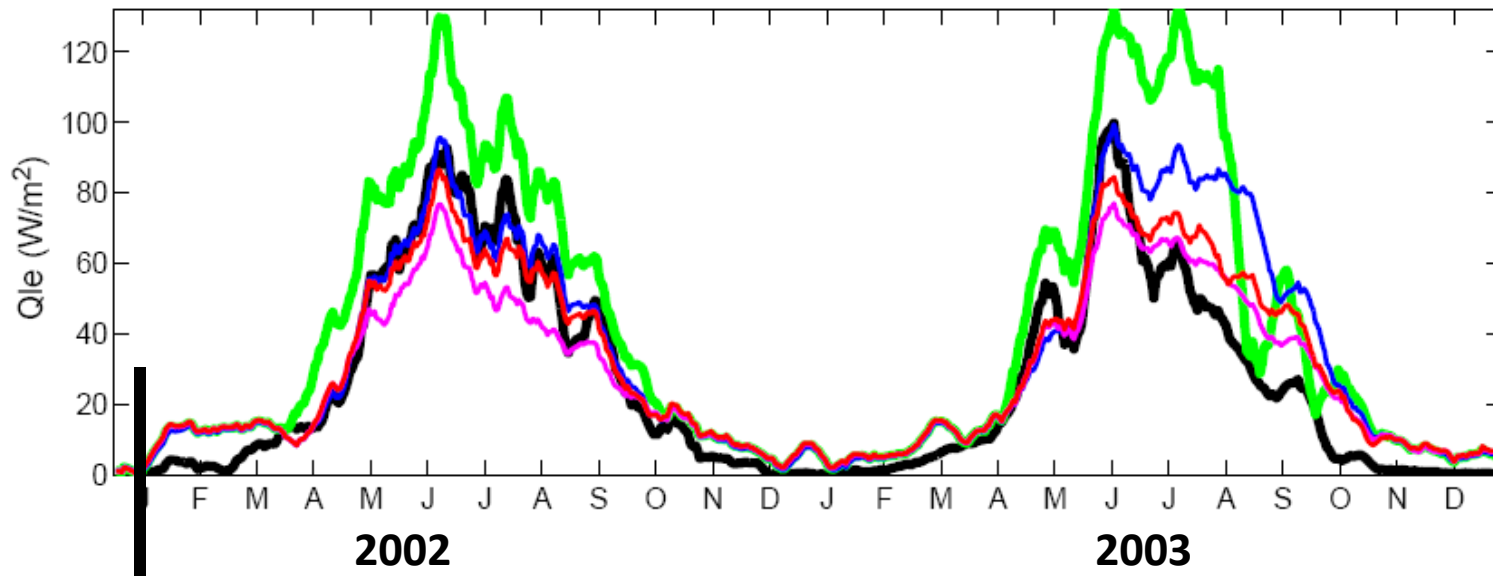
Data

Prior: 41

2002: 22

2003: 19

All yrs: 13



RMSE

Data

Prior: 21

2002: 13

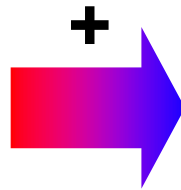
2003: 10

All yrs: 9

Forest management: Changes in the simulation of carbon stocks and fluxes

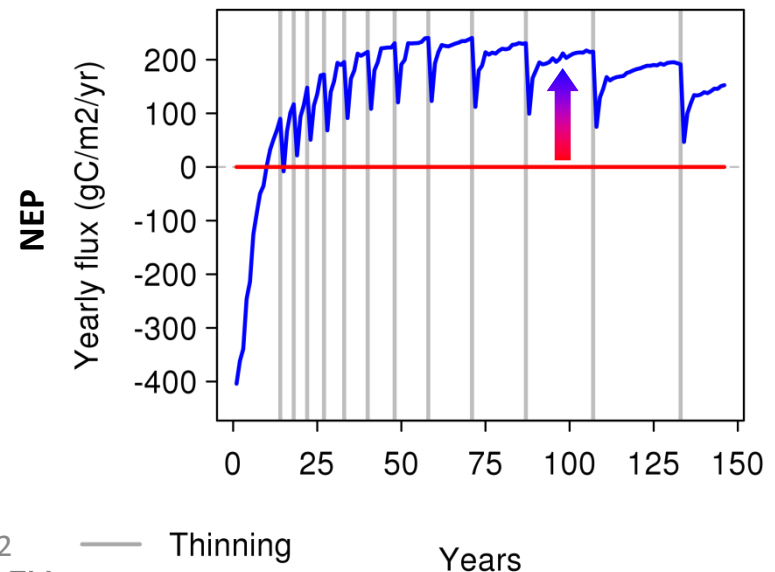
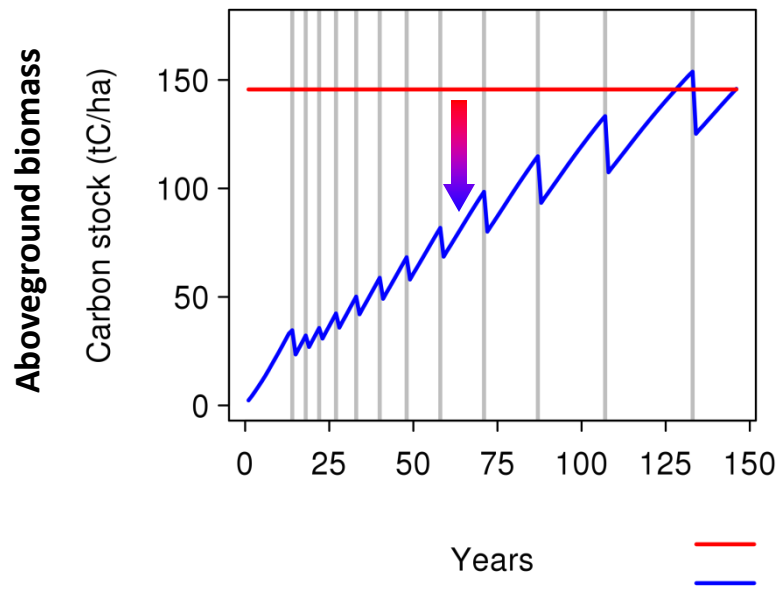
ORCHIDEE standard

- Photosynthesis
- Allocation
- Constant mortality
- Decomposition
- Phenology

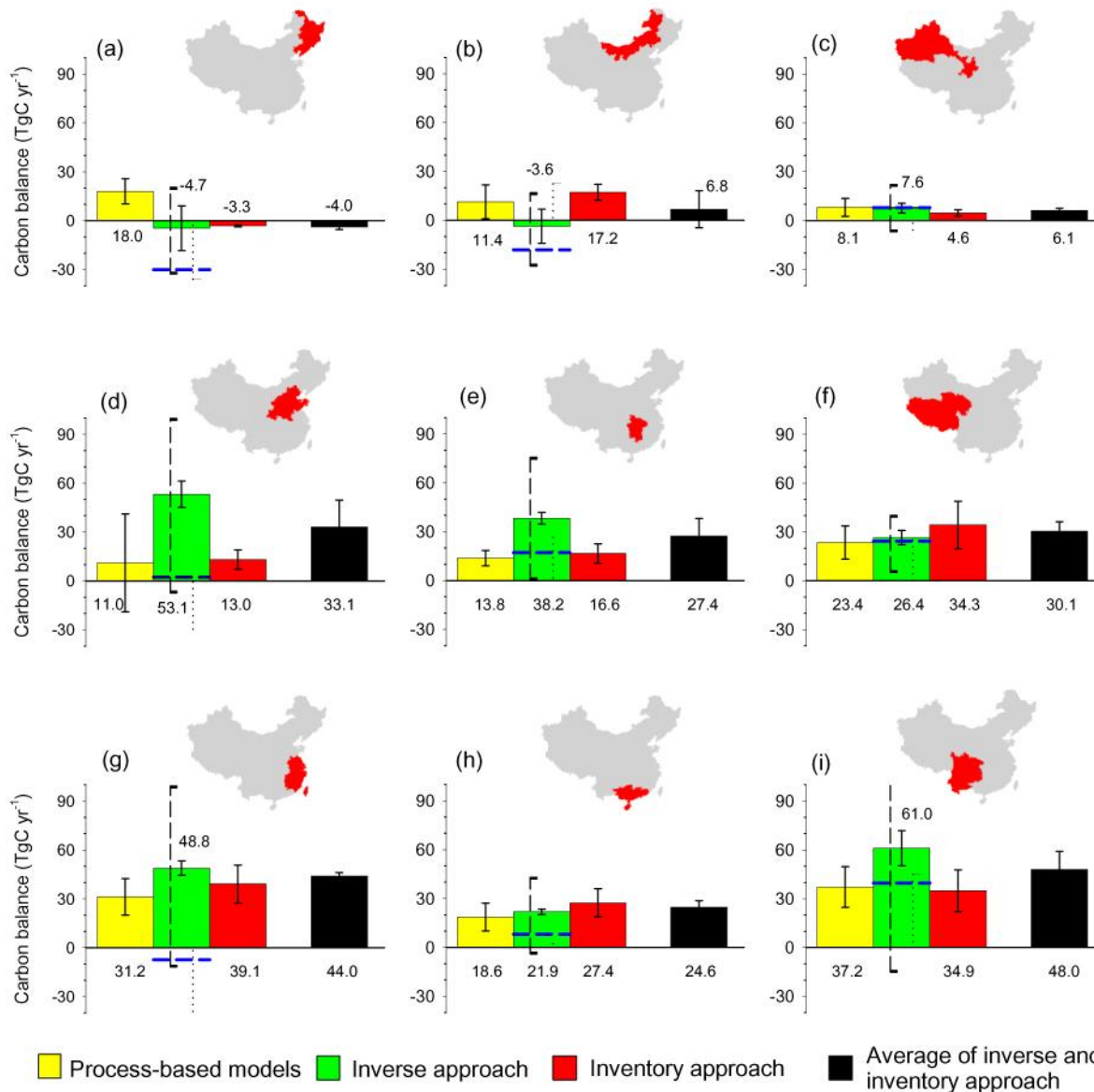


ORCHIDEE-Forest Management

- Age / size dependency of photosynthesis and allocation
- Explicit mortality: self-thinning or management
- Slow decomposition of woody debris



Spatial distribution of the C balance in China



→ Coherence between Biosphere models (ORCHIDEE) and atmospheric inversion estimates