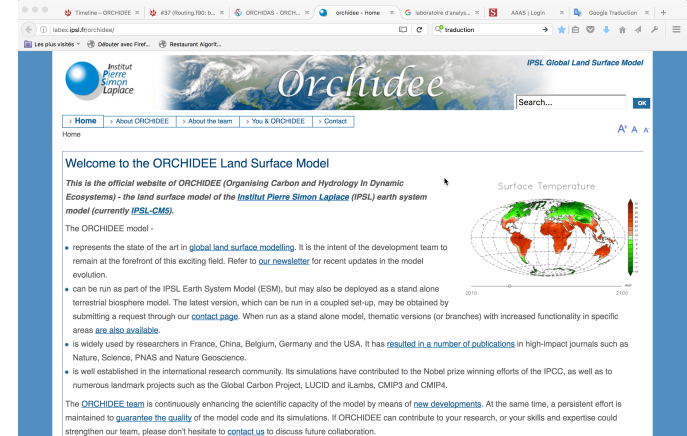


The ORCHIDEE project

- COLLABORATIVE effort with many contributors !!
- More than 15 permanents and over 30 CDDs
 - Several laboratories but mainly from IPSL
- YOU will include new processes or change some of them
 - ➔ It should benefit to the ORC project
- Never forget:
 - ➔ The current ORC model that will allow your research results from a huge team work !

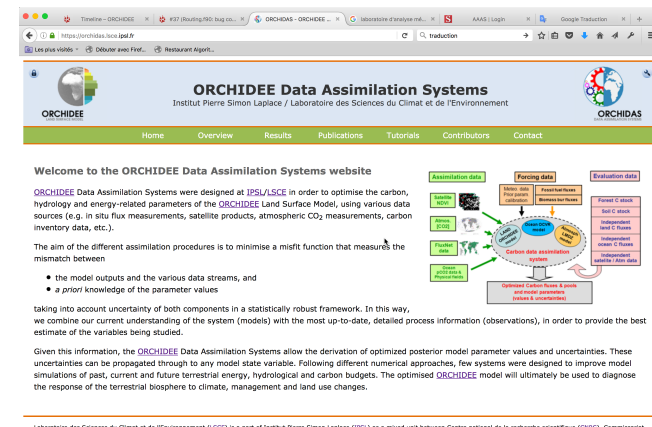
Several web sites...

- Official web site :
for external people



- Wiki web site: contains all what you need
<https://forge.ipsl.jussieu.fr/orchidee/wiki>

- Web site for Data Assimilation
<https://orchidas.lsce.ipsl.fr/>



- Web site for ref simulation visualisation
<https://orchidas.lsce.ipsl.fr/mapper/>

Specific documents

➤ <https://docs.google.com/document/d/13R22r1fx0JoYKCojG1k3IM2C18RWuFNvxoYKdtacJEl/edit?usp=sharing>

Contain some information on:

- ✧ Governance
- ✧ Project and articles
- ✧ List of all people working with ORCHIDEE (with their activity)
=> Everyone to update

➤ <https://sharebox.lsce.ipsl.fr/index.php/s/AhJk0Bk6rdySXKL>
« SHOULD » contain recently submitted ORC articles

Several mailing lists

➤ ORCHIDEE-DEV:

All users and developpers.

Main list to exchange information

➤ ORCHIDEE-PROJECT:

Restricted mainly to permanent people plus few CDDs « main developpers »..

➤ ORCHIDEE-HELP

To use with parsimony..

➔ Find all lists under : <https://listes.ipsl.fr/sympa/home>
(you can subscribe directly on the web site)

« Animation »

- ORC – DEV meeting every 2 months on specific scientific and technical topics
- Irregular « annual retreat »
next one not decided yet !!
- Project meeting every Friday morning (restricted):
 - ➔ Summary accessible to everyone
(need to be log on to see the summary)

<https://forge.ipsl.jussieu.fr/orchidee/wiki/GroupActivities/Meetings/Weekly>

Coding guidelines..

- A document that summarizes the MAJOR RULES that you NEED TO FOLLOW when developing new code
 - NEEDED to get support from the group
 - NEEDED if you want your code to be further used and included in the main ORC version
 - You are welcome to suggest new coding rules...
- ➔ **Access coding guidelines under :**
<https://forge.ipsl.jussieu.fr/orchidee/wiki/Documentation>
- ➔ **Make use of SVN to develop your own branch**

Use of the “Help”

- TO BE USED SPARINGLY... (as little as you can)
- FIRST: Dig as much as you can into the code..
- SECOND: check the WIKI
- THIRD: ask your main advisor
- FOURTH: Ask your colleague/neighbour
- THEN: post a message to “orchidee-help@ipsi.jussieu.fr
- AS A RETURN, please:
 - Try to write a little summary of the answer to your question on the WIKI (if relevant)
 - Use the “How to ?” section

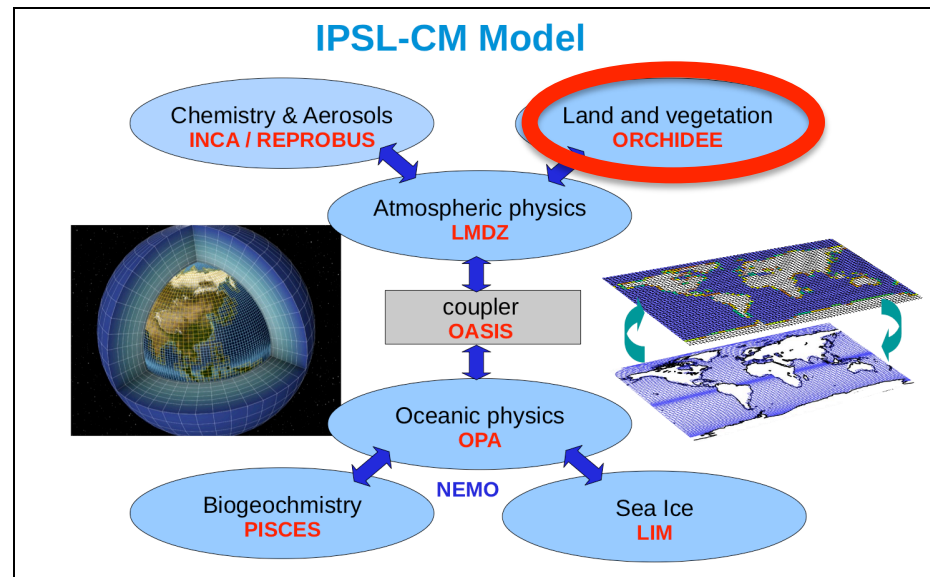
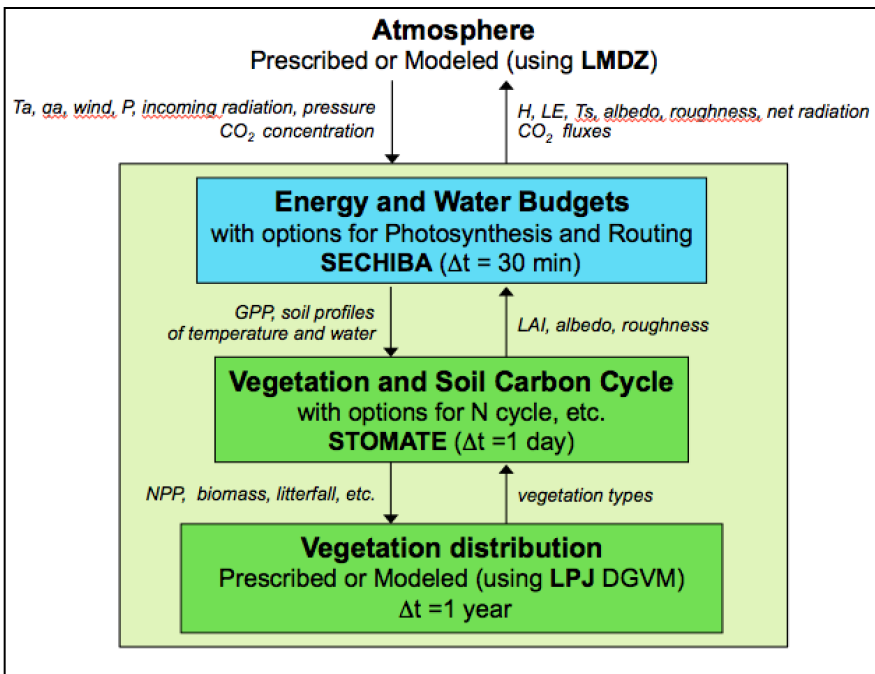
Fair Use policy

- To ensure “reward” to developers of new physical modules and people maintaining the code (including drivers)
- New developments are not “free” to use : fair use should include/propose co-authorship to the developers
- Reward the “difficult” and less visible technical maintenance and improvement of the code
- Try to prevent “competition” within the ORC group

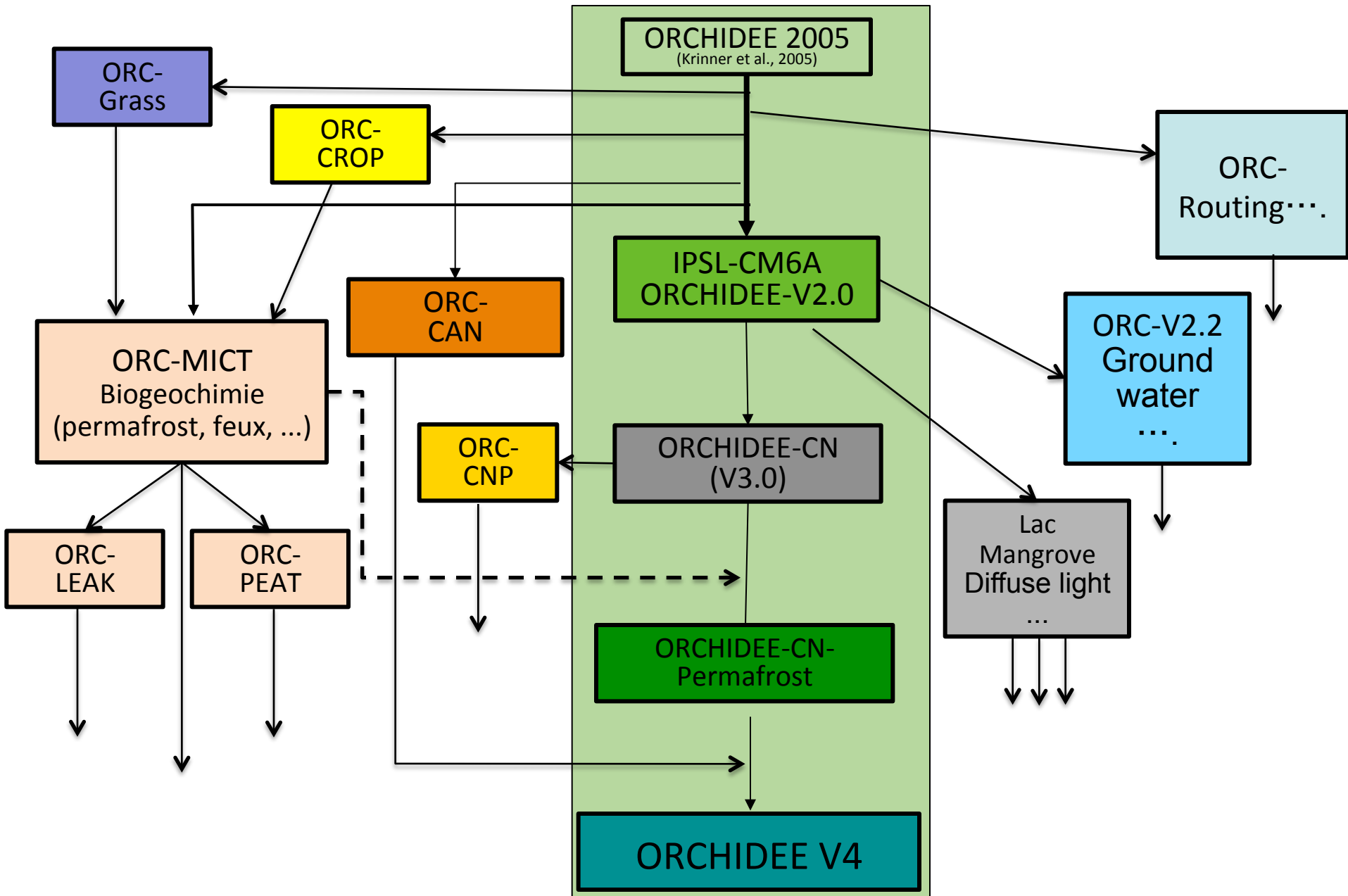
→ Access from the wiki:

<https://forge.ipsl.jussieu.fr/orchidee/wiki/GroupActivities/UseOfORCHIDEEpolicy>

Le modèle ORCHIDEE: récent & futur développements



ORCHIDEE branches

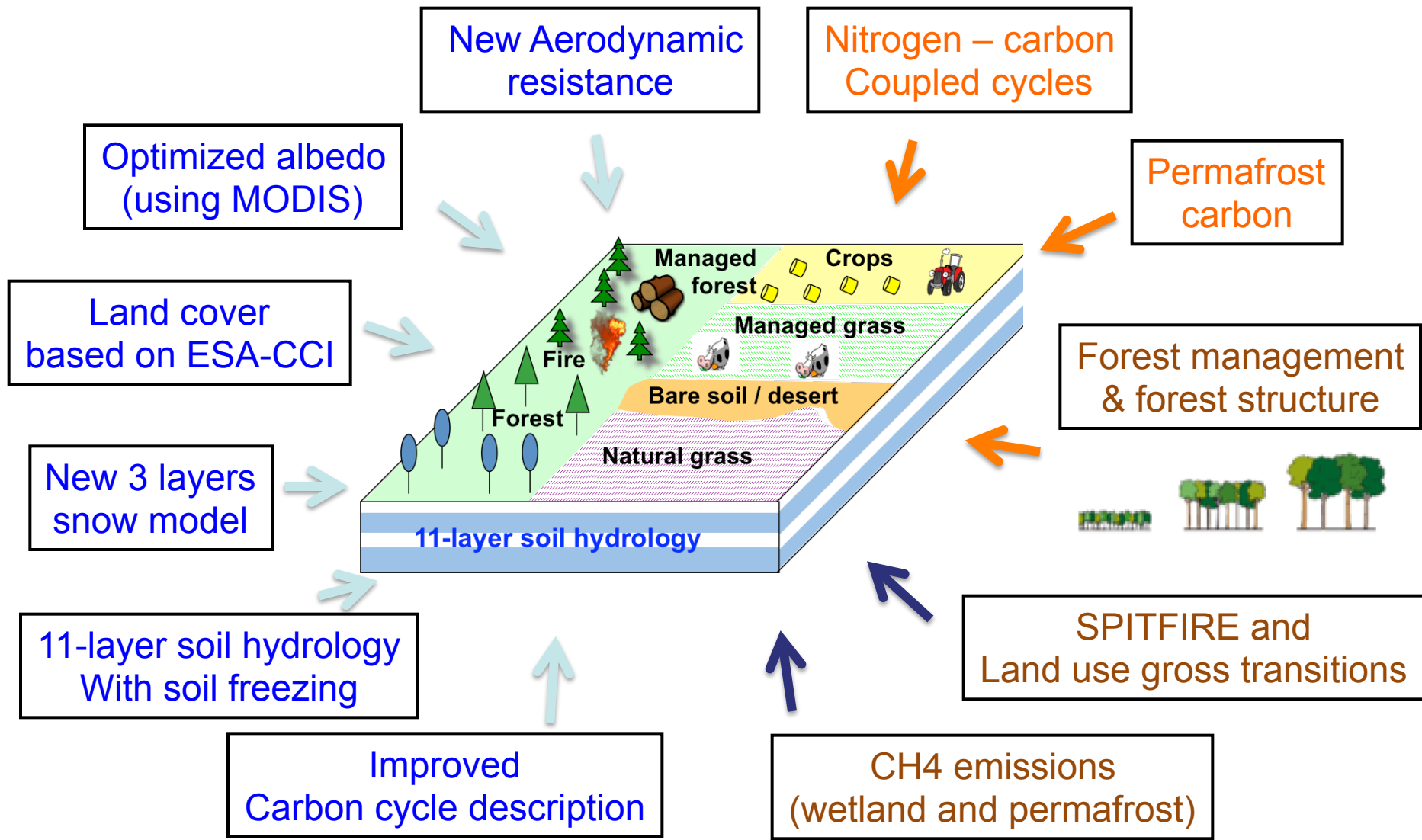


ORCHIDEE recent developments (for CMIP6)

Implemented: V1

Recent: V1.5

Merging



Other Mature/Ongoing developments

Biophysical

Biogeochemical

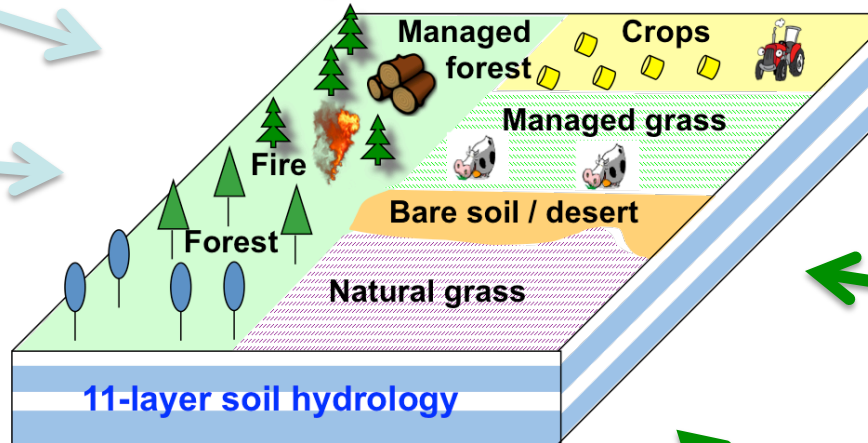
Lake model (FLAKE)

Nitrogen – Phosphorus
- Carbon coupled cycles

Irrigation

Termokarst lake

DOC – DIC
transport
by river



Crop model
(wheat, corn,
rice,...)

Grassland
management

Peatland model
(CH₄)

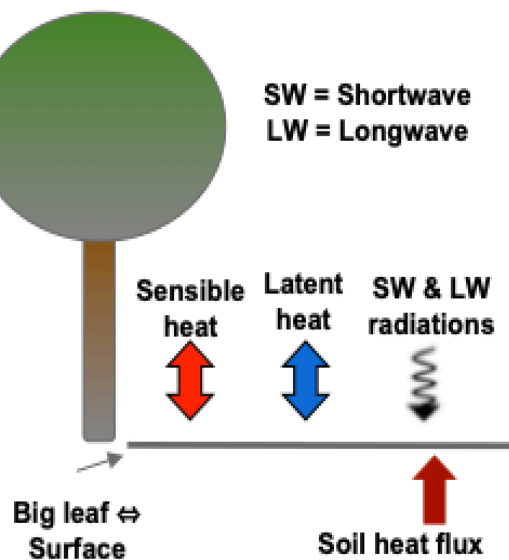
Herbivory
(large herbivore)

New boreal PFTs
(Mosses, lichens, shrubs)

Plant Traits

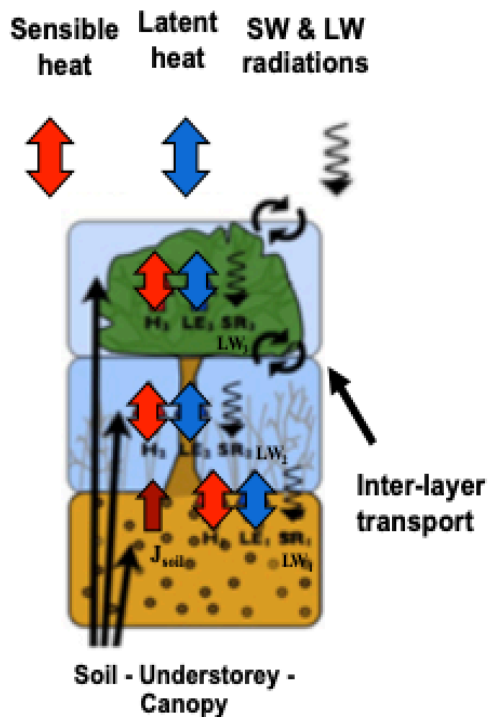
Energy and water budget

"Big leaf" model



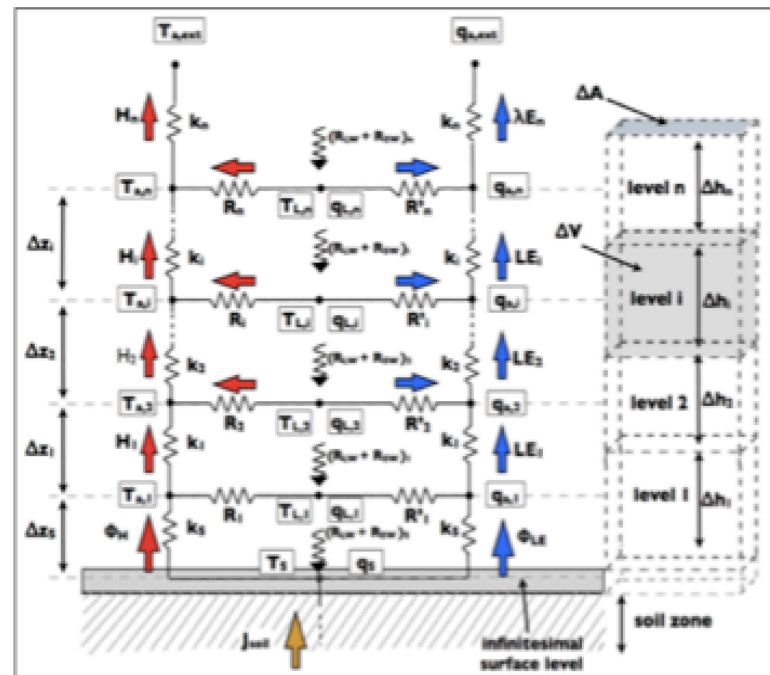
Two-layer energy budget

Two-layer energy budget



Multi-layer energy budget

Multi-layer energy budget



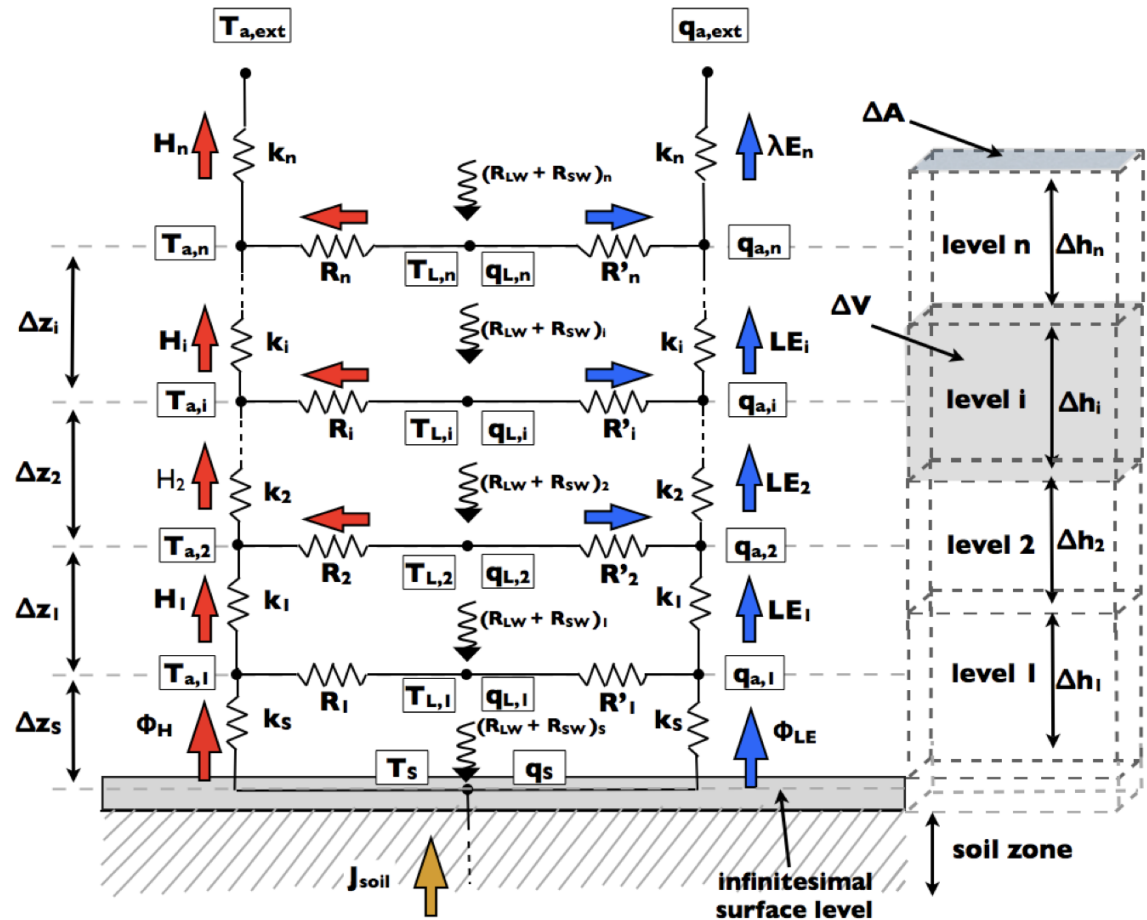
- ➔ Turbulent transfer of heat
- ➔ Turbulent transfer of water vapor
- ⤿ Radiation transfers

Complexity



Vertical multi-layers scheme..

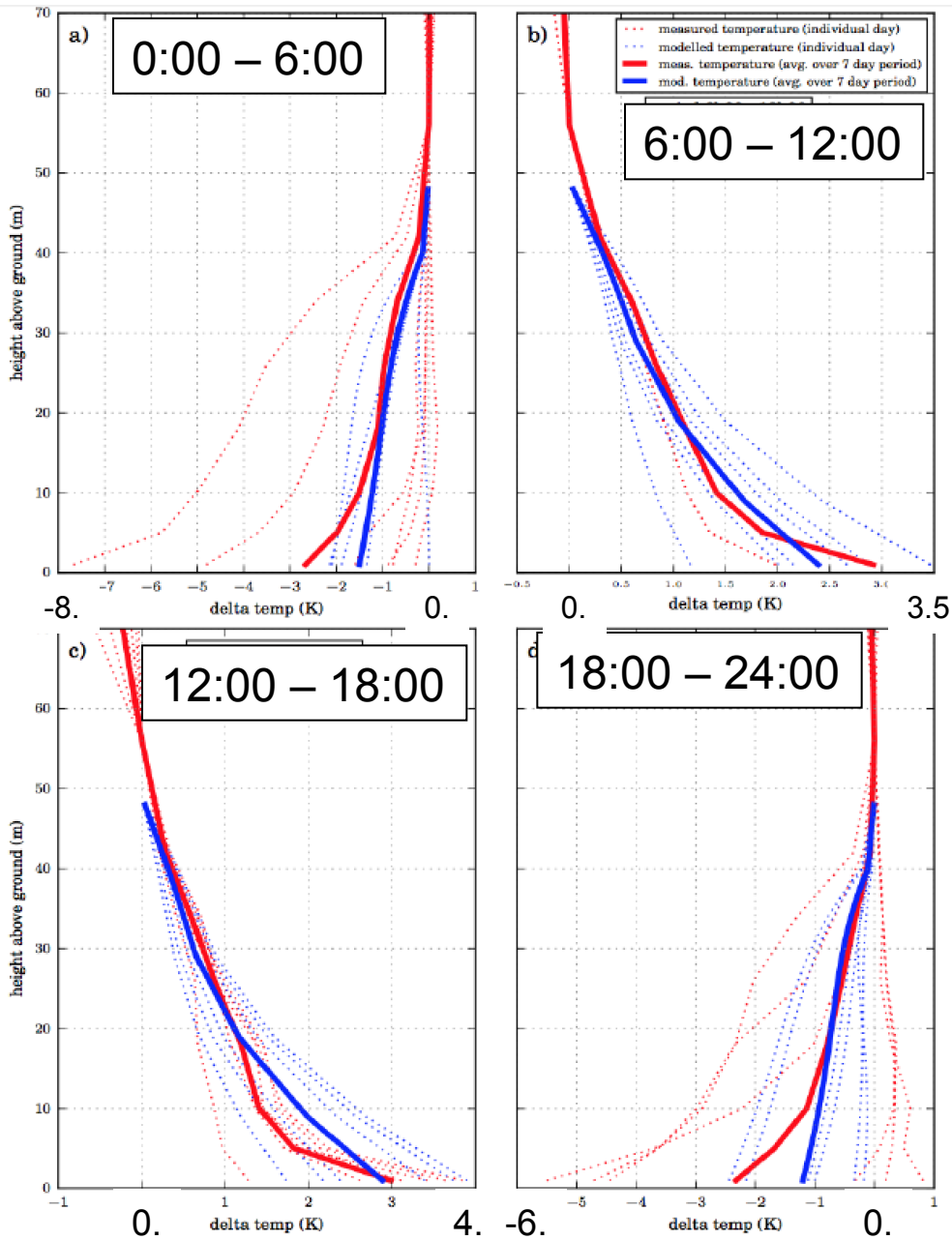
- Free number of layers
- E / W / C exchange at each level
- Turbulence mixing within air canopy
- Light penetration following Pgap model



Implementation constraints :

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

Temperature profile at Tumberumba site



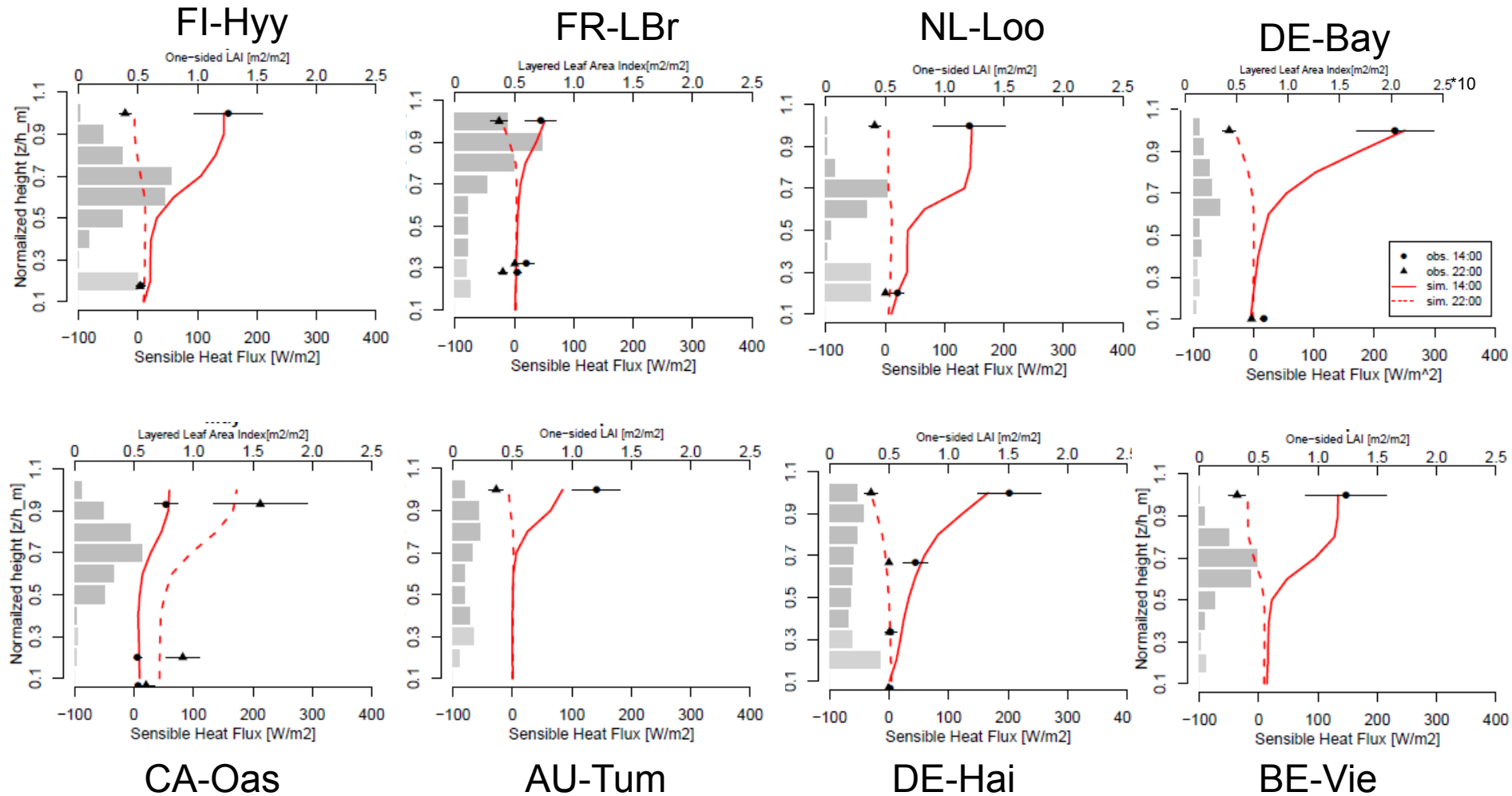
Observations

Model

Daily temperature

Sensible heat flux with multi-layers scheme

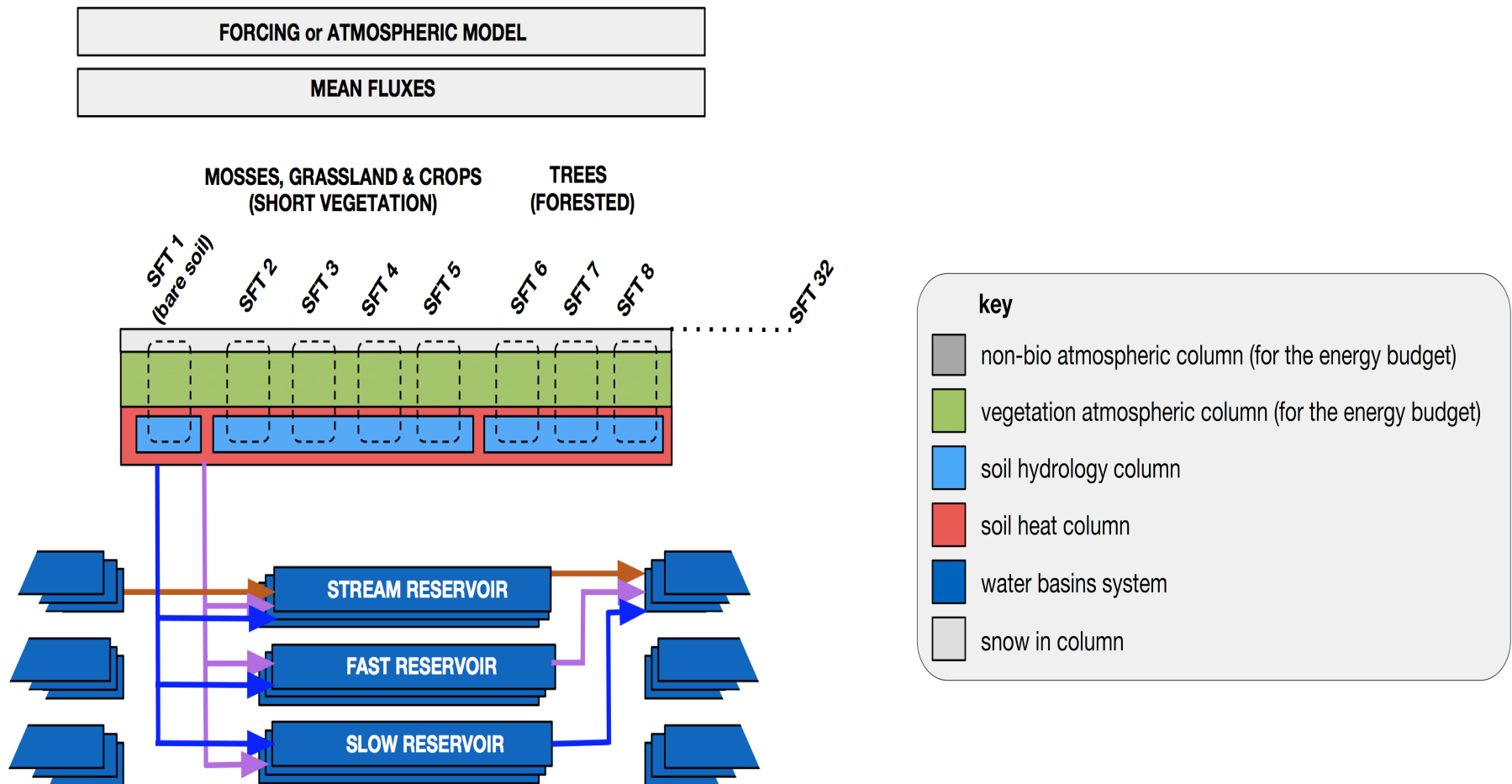
▲ ● Obs - - - 22:00 ——— 14:00



Current scheme !

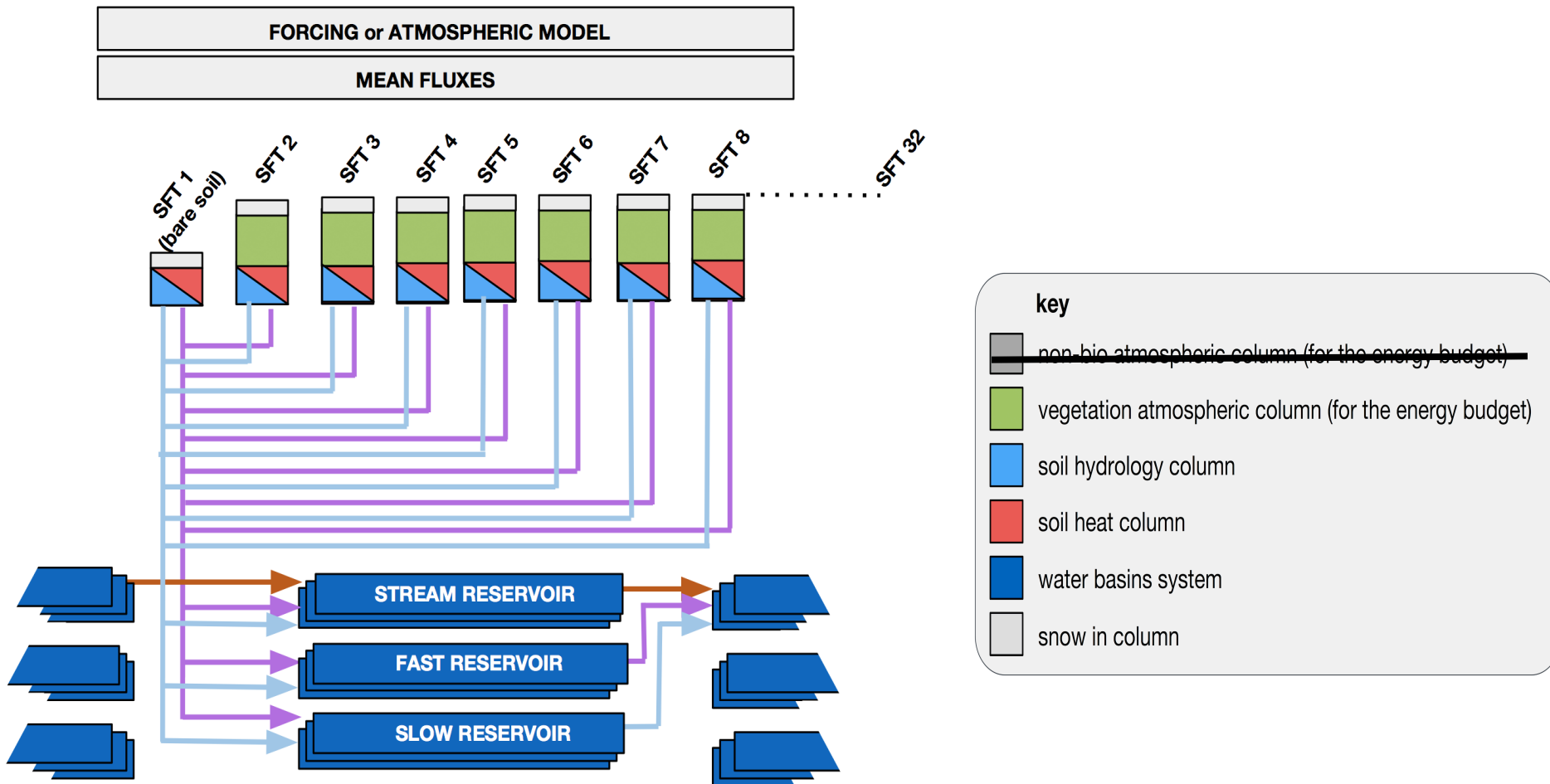
$N_{\text{energy}} = 1$; $N_{\text{hydro}} = 3$ (bare soil, short veg, trees)

1 atmospheric column (mixing fluxes at first level) ; 1 routing scheme !



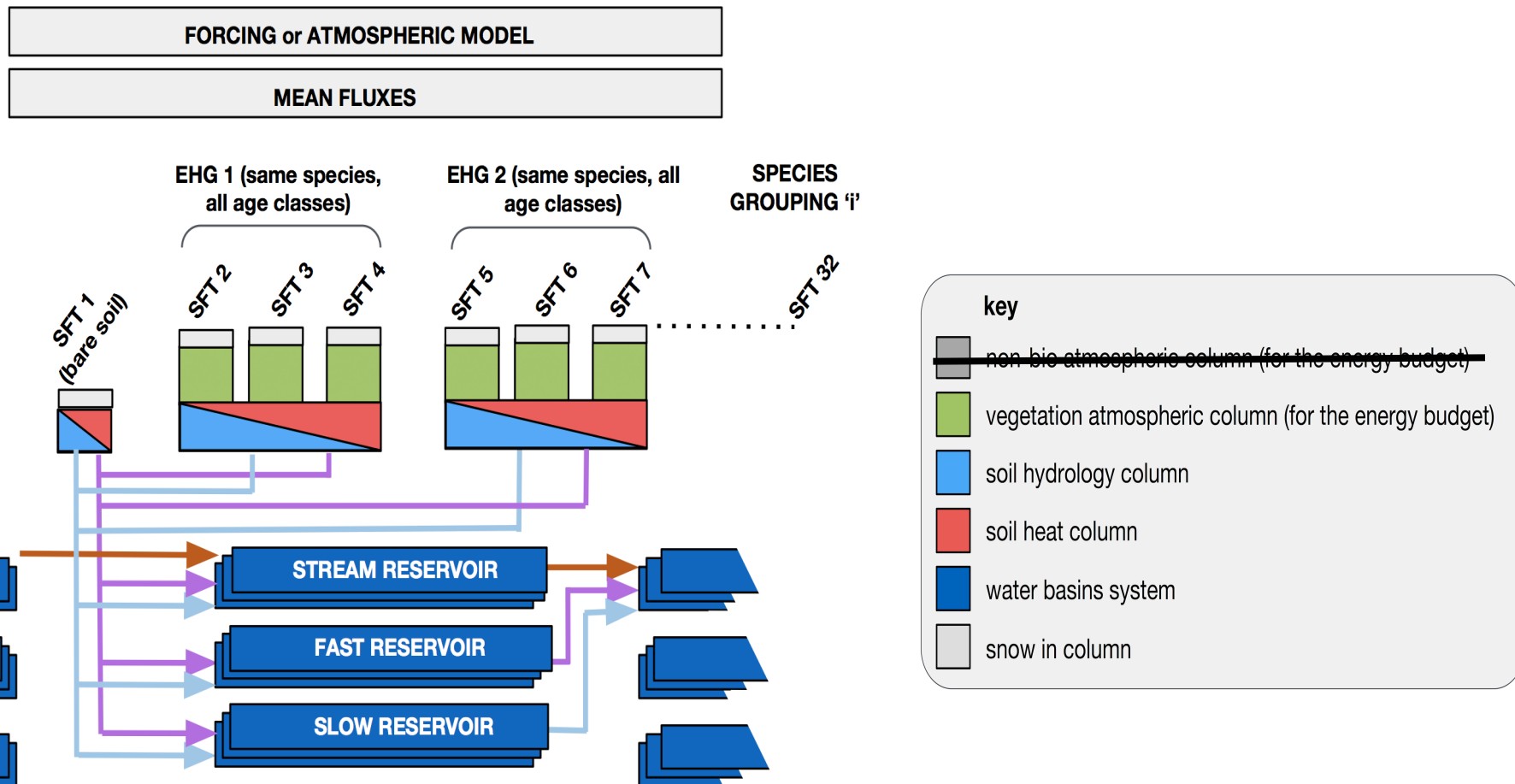
New multi-tiling approach : maximum split

- $N_{hydro} = N_{ener}$ for each grid box ; But different across grid cells !
(keep 2 params to reproduce current config with $N_{hydro} = 3 / N_{ener} = 1$)



New multi-tiling approach : « intermediate » split

- Define a set of intermediate grouping with different options
- Variable grouping per grid cell



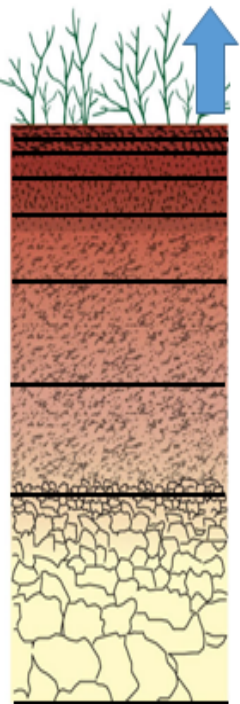
Hydraulic architecture to better capture drought impacts

→ Integration of a complete Hydraulic architecture based on water potential Tuzet et al. (2017)

Previous version

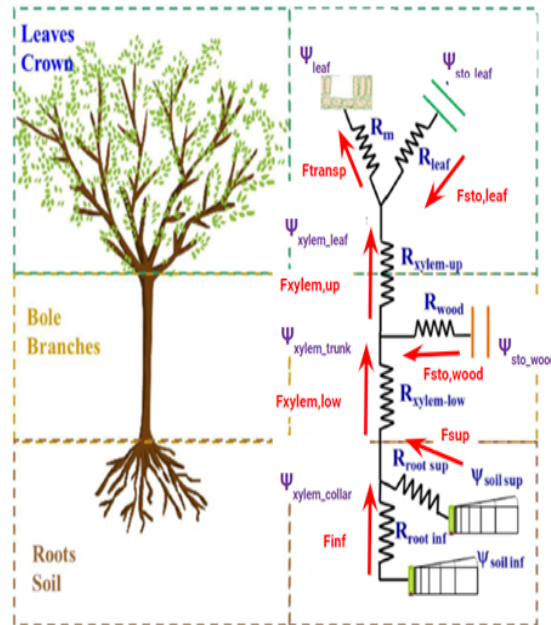
Soil moisture impact on Transpiration / gs

→ SIMPLE linear equation !



New version

$$g_{CO_2} = g_0 + \frac{aA}{c_i - c_{i^*}} f_{\psi_{leaf}}$$



$$\frac{\partial \theta}{\partial t} = \frac{1}{r} \frac{\partial}{\partial r} (r D(\theta) \frac{\partial \theta}{\partial r})$$

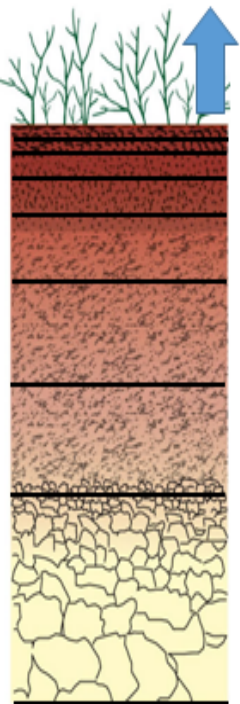
Hydraulic architecture to better capture drought impacts

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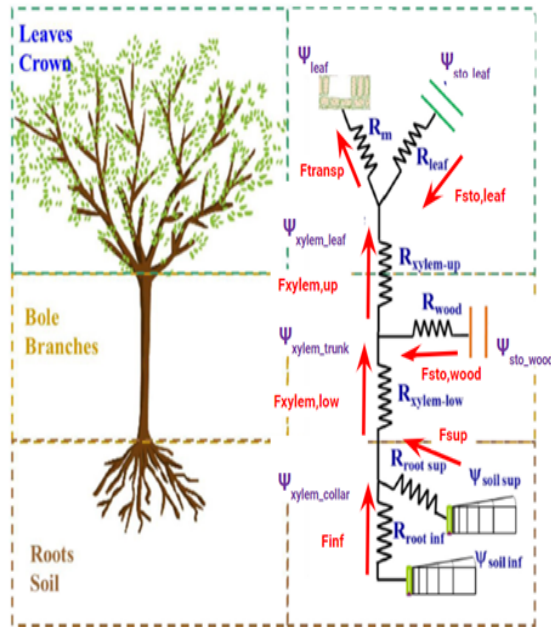
Soil moisture impact on Transpiration / g_s

→ SIMPLE linear equation !

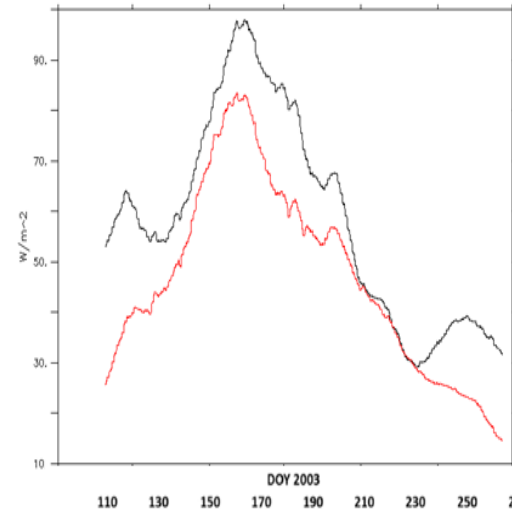


New version

$$g_{CO_2} = g_0 + \frac{aA}{c_i - c_{i^*}} f_{\psi_{leaf}}$$



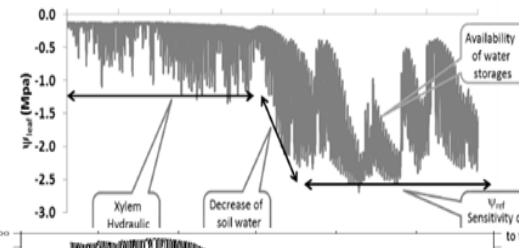
$$\frac{\partial \theta}{\partial t} = \frac{1}{r} \frac{\partial}{\partial r} (rD(\theta) \frac{\partial \theta}{\partial r})$$



Hesse, Summer 2003 (with adjustments)

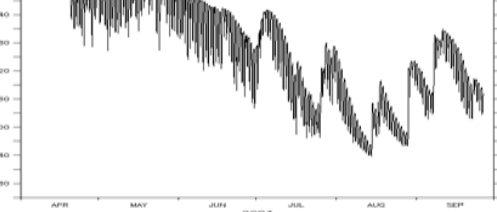
— LE Model
— LE Obs

ψ_{leaf}
Tuzet



Tuzet et al. (2017)

ψ_{leaf}
Model



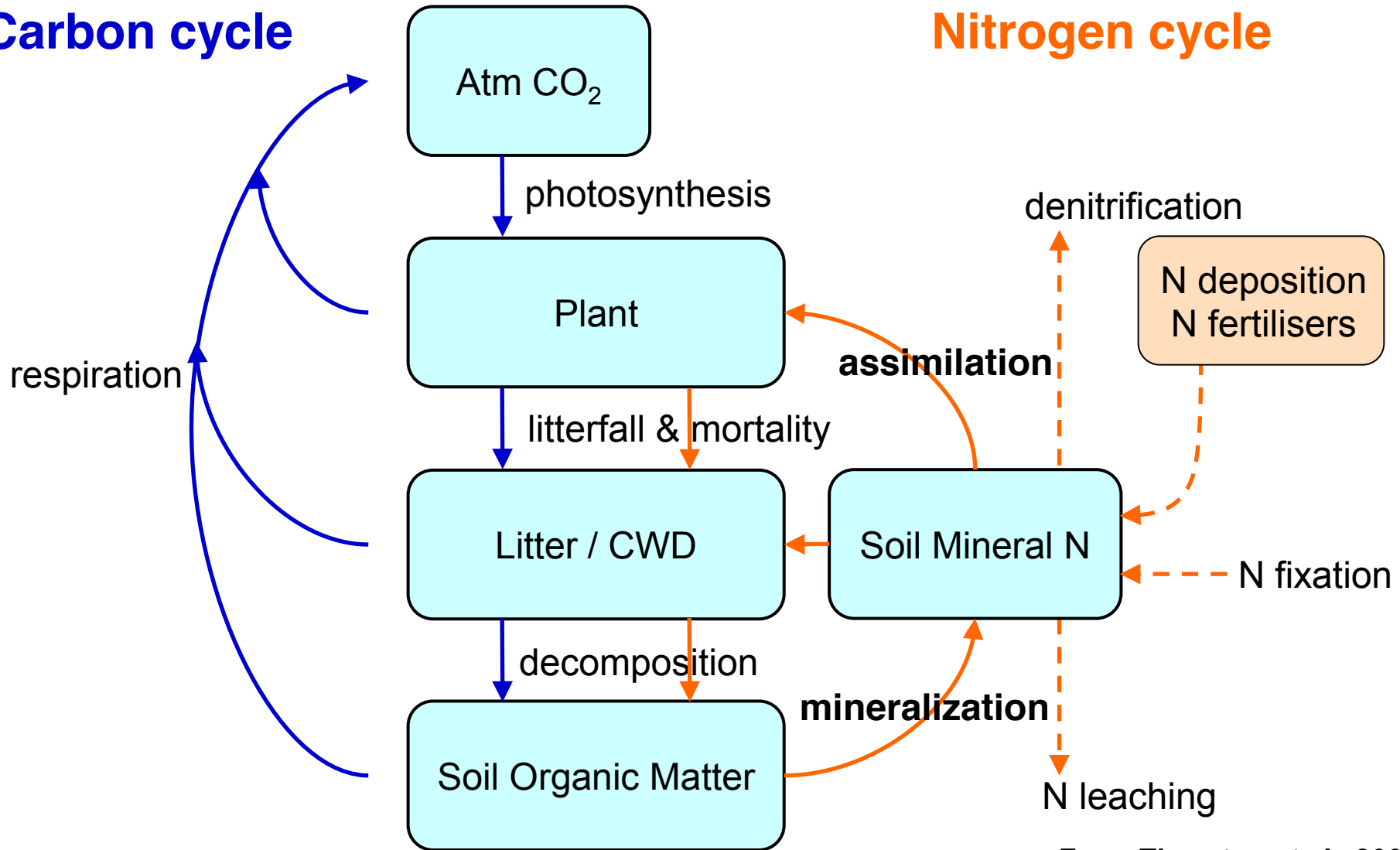
Julien Alleon, in prep

Nutrients cycles !

C & N land interactions

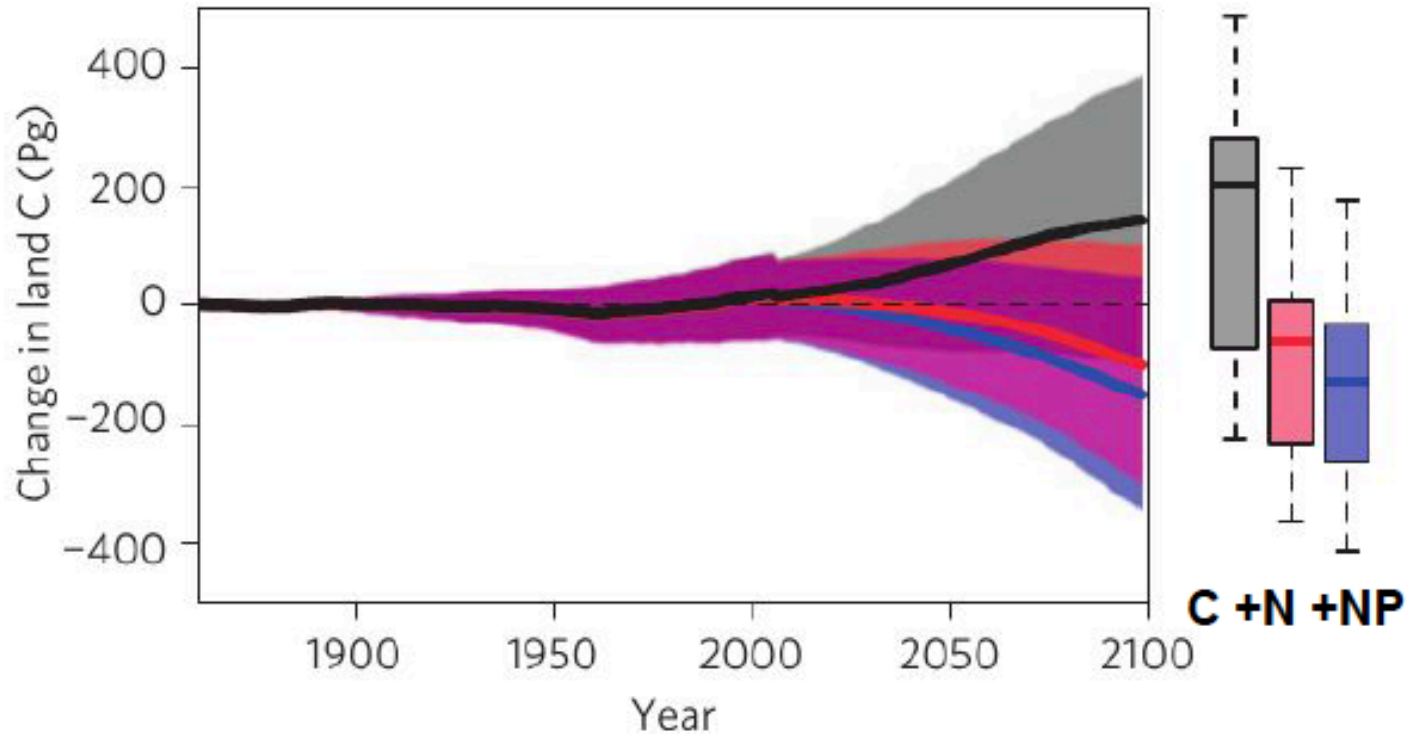
Carbon cycle

Nitrogen cycle



From Thornton et al., 2009

Adding the Phosphorus cycle

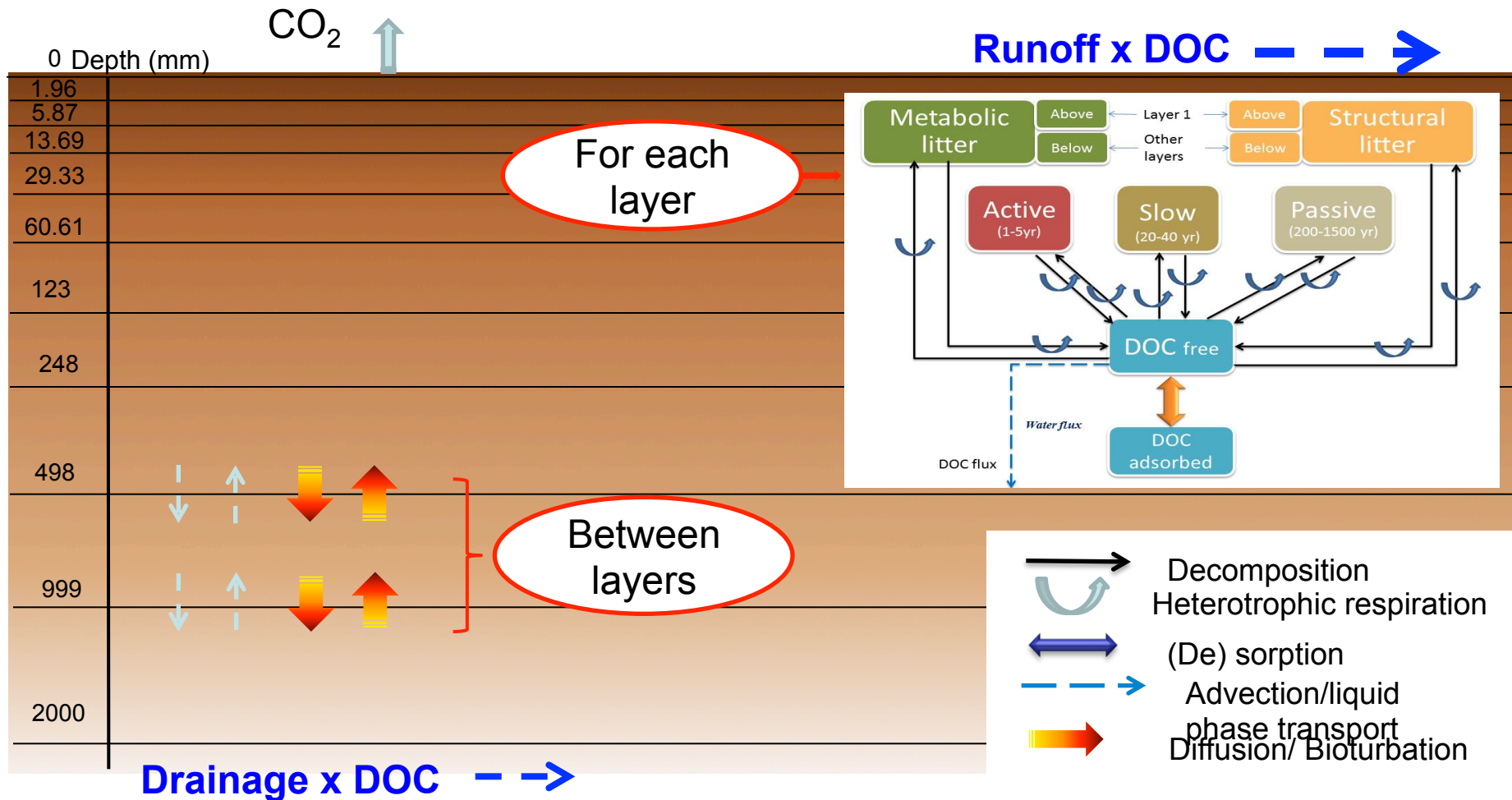


Wieder et al., Nat. Geosc., 2015

➔ Work done with ORCHIDEE-CNP version : Goll et al. 2017

A new soil carbon model..

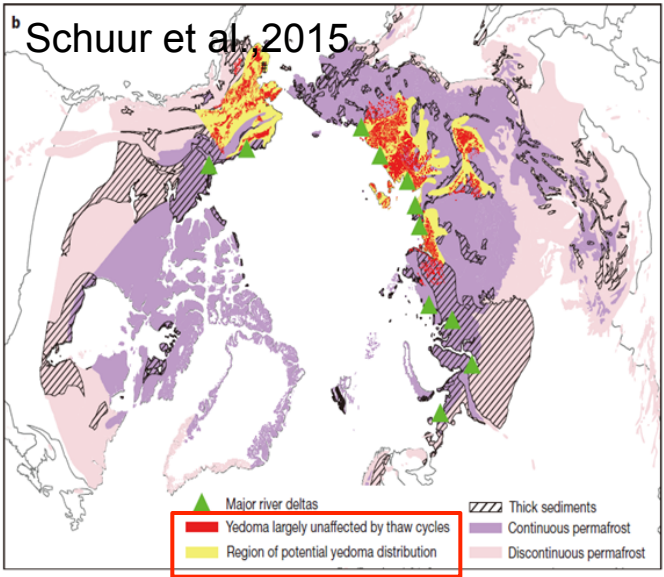
- Discretized soil carbon (11 layers) + new pools introduced (DOC)
- New decomposition scheme (priming): $\frac{\partial SOC}{\partial t} = I - k_{SOC} \times SOC \times (1 - e^{-c \times FOC}) \times \theta \times \tau$



Permafrost : Modeling Yedoma organic carbon formation

Yedoma: organic-rich, ice-rich, thick deposits in permafrost region

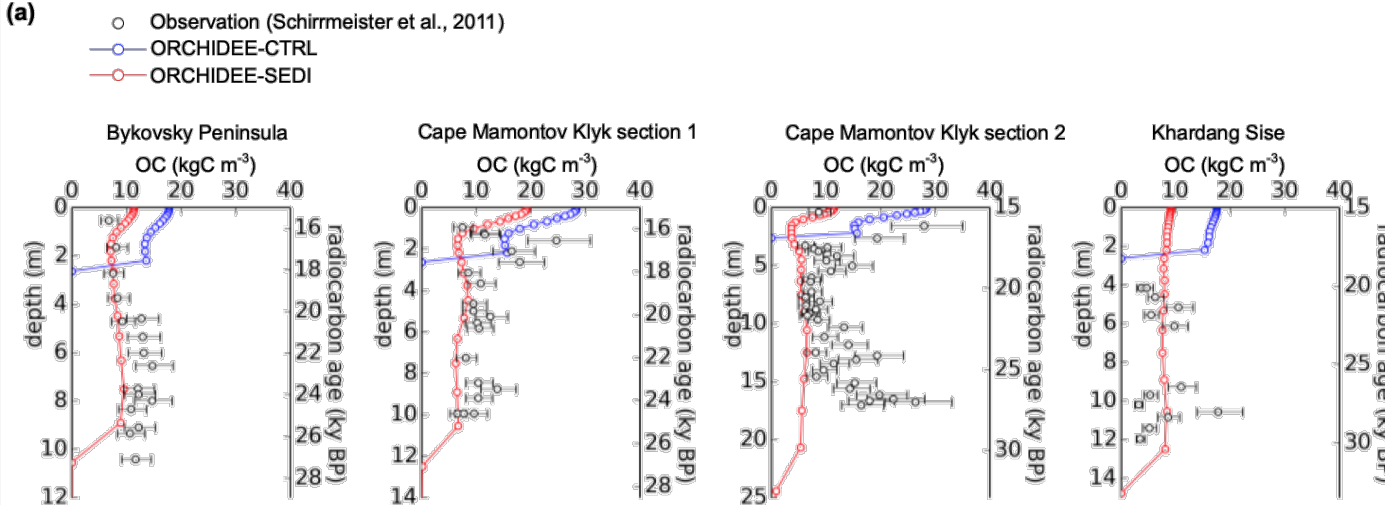
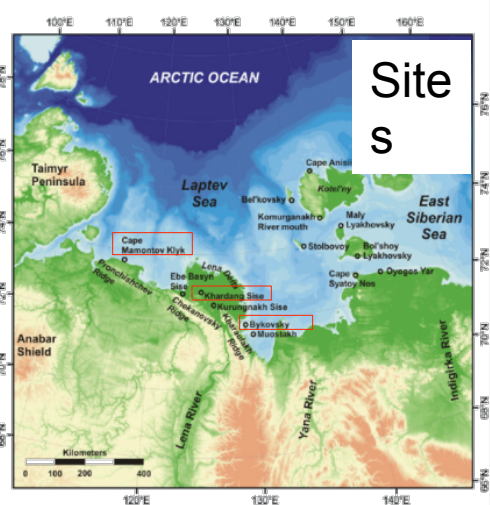
Dan Zhu et al.



Area: ~1.3 million km²
C stock: 300-550 PgC

- **Large ice content: 50-80 vol%**
- **Ancient carbon: accumulated during last ice age (~60-15 kyr)**
- **Depth 5-50m, C contents ~2%**
- **Formation condition: sedimentation**

The new model can reproduce vertical profiles of Yedoma organic carbon

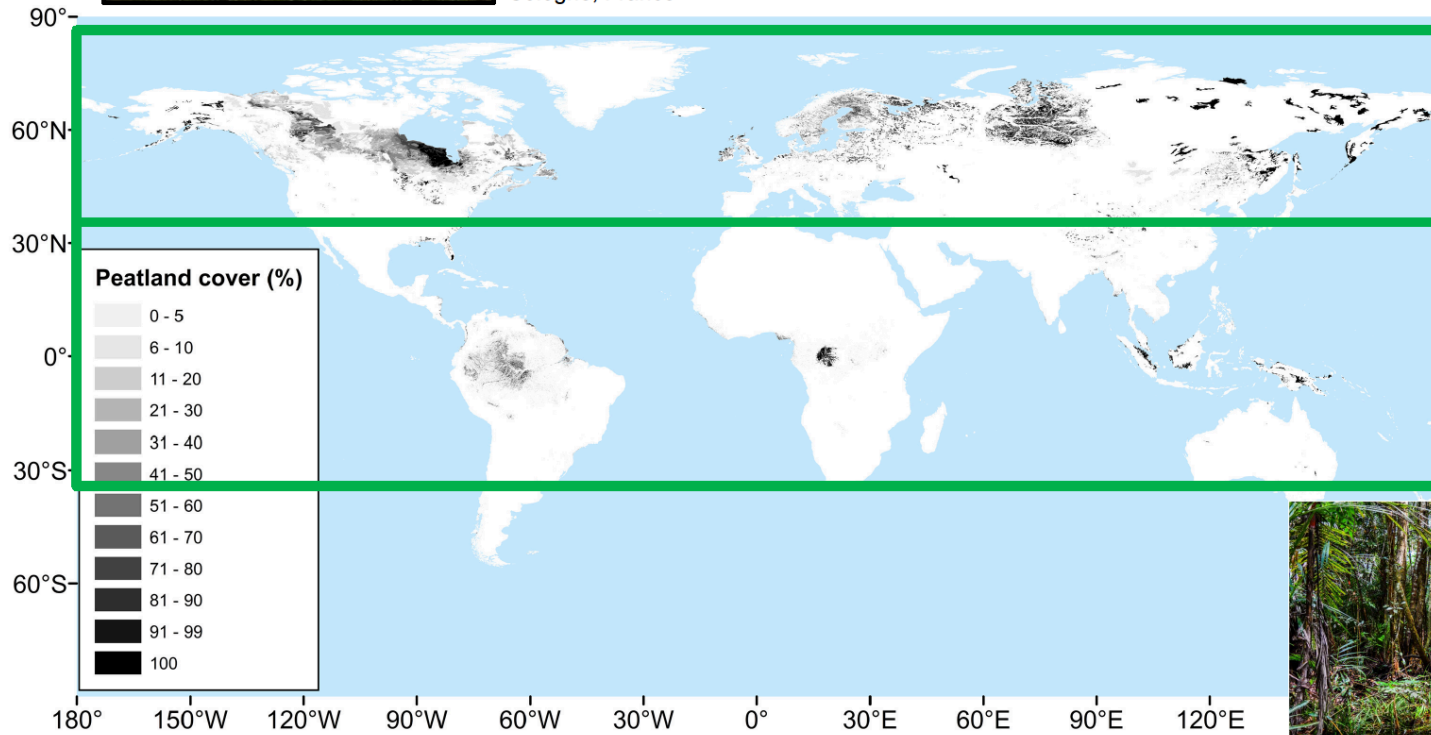


Peatland and CH4 modelling in ORCHIDEE



Laguette peatlands,
Sologne, France

TYPES OF PEATLANDS



80% of sphagnum type peatlands are above 40°N

20% of tropical peatlands forest

PEATMAP (Xu et al., 2018)

Peat swamp forest in Zamrud National Park, Indonesia



HIGH LATITUDE PROCESSES IN ORCHIDEE

Increasing model complexity



New branch

ORCHIDEE
TRUNK

ORCHIDEE
MICT

ORCHIDEE
PEAT

ORCHIDEE
PEAT - CH₄

Snow
(Wang et al., 2013)

Permafrost C
(Zhu et al., 2015)

Soil insolation
(Druel et al., 2017)

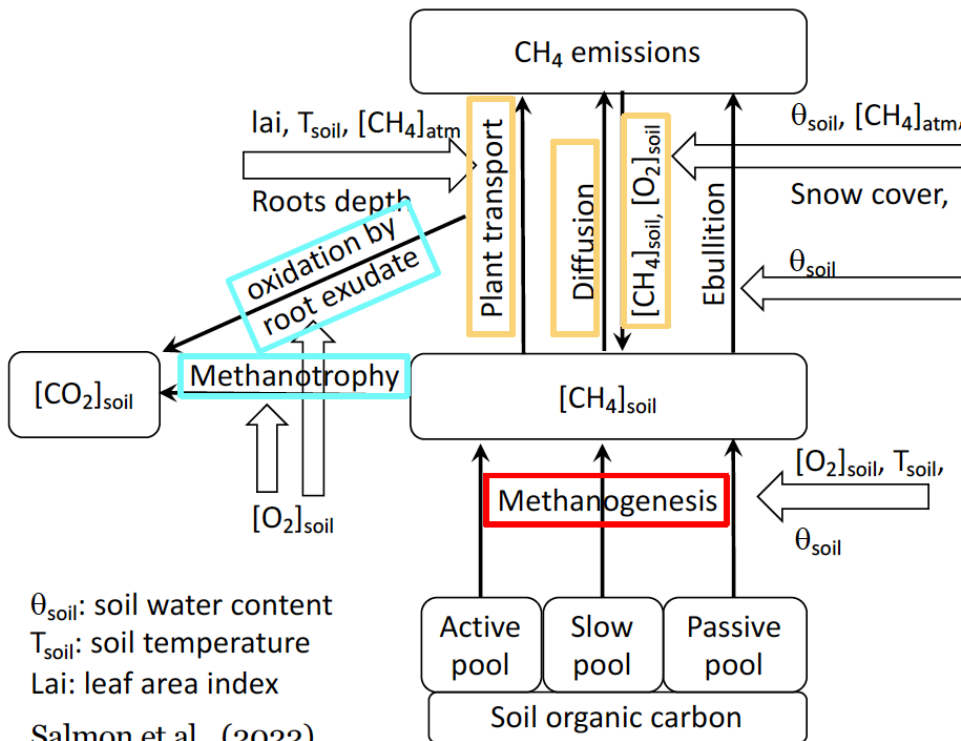
Frozen hydrology
(Guimberteau et al., 2018)

Peatlands hydrology
(Largeron et al., 2018)
**Peatlands C dynamics
and CO₂ fluxes**
(Qiu et al., 2018 and 2019)

**Peatlands
CH₄ fluxes**
(Salmon et al. 2022)

METHANE EMISSIONS MODEL FOR PEATLANDS

$$\frac{\partial [CH_4](z, t)}{\partial t} = \underbrace{f_{MG_a} + f_{MG_s} + f_{MG_p}}_{\text{CH}_4 \text{ stock}} - \underbrace{f_{Diff}}_{\text{CH}_4 \text{ transport}} - \underbrace{f_{Ebu}}_{\text{CH}_4 \text{ transport}} - \underbrace{f_{PMT}}_{\text{CH}_4 \text{ transport}} - \underbrace{f_{MT}}_{\text{CH}_4 \text{ loss}}$$



7 parameters to calibrate



Global simulation of CH₄ emissions

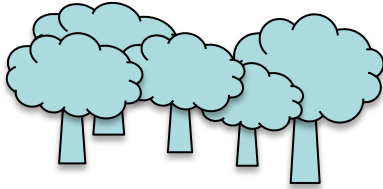
θ_{soil}: soil water content
 T_{soil}: soil temperature
 lai: leaf area index
 Salmon et al., (2022)

➔ Contact Elodie Salmon

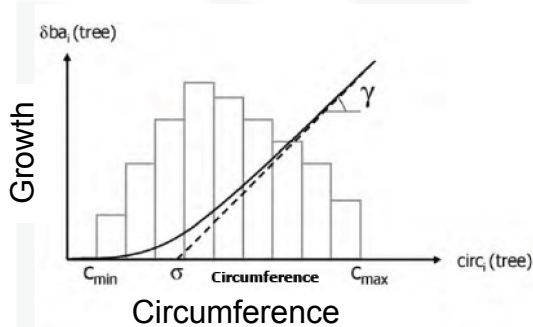
Land Management !

Forest management and stand description

Include diameter & age classes

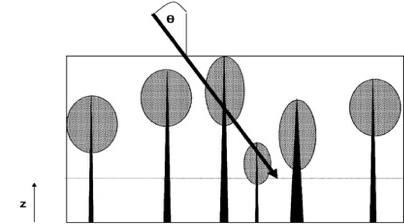


Allocation : “big get bigger”

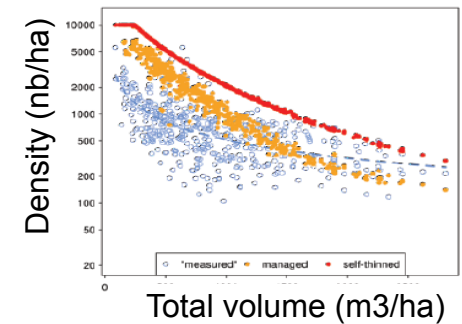


(Naudts et al., 2015)

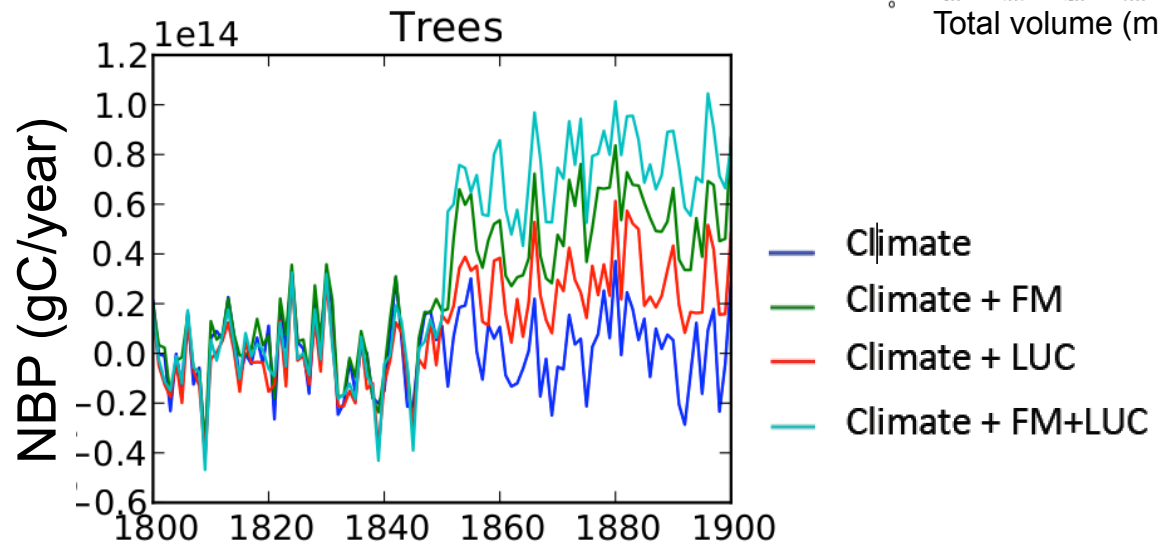
Accounts for gaps (PGAP)



Mortality from self-thinning



➔ Impact of climate,
Forest management,
Land Use Change
on European NBP



Gross land use change



Deforestation



Shifting cultivation

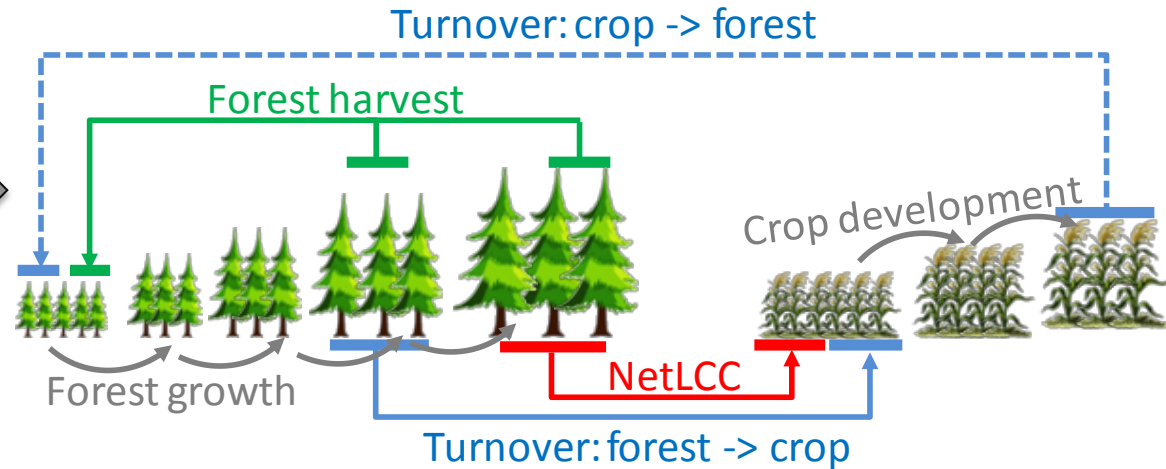
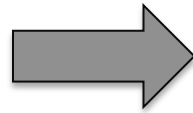


Shifting cultivation



Wood harvest

Gross land use change with age cohorts

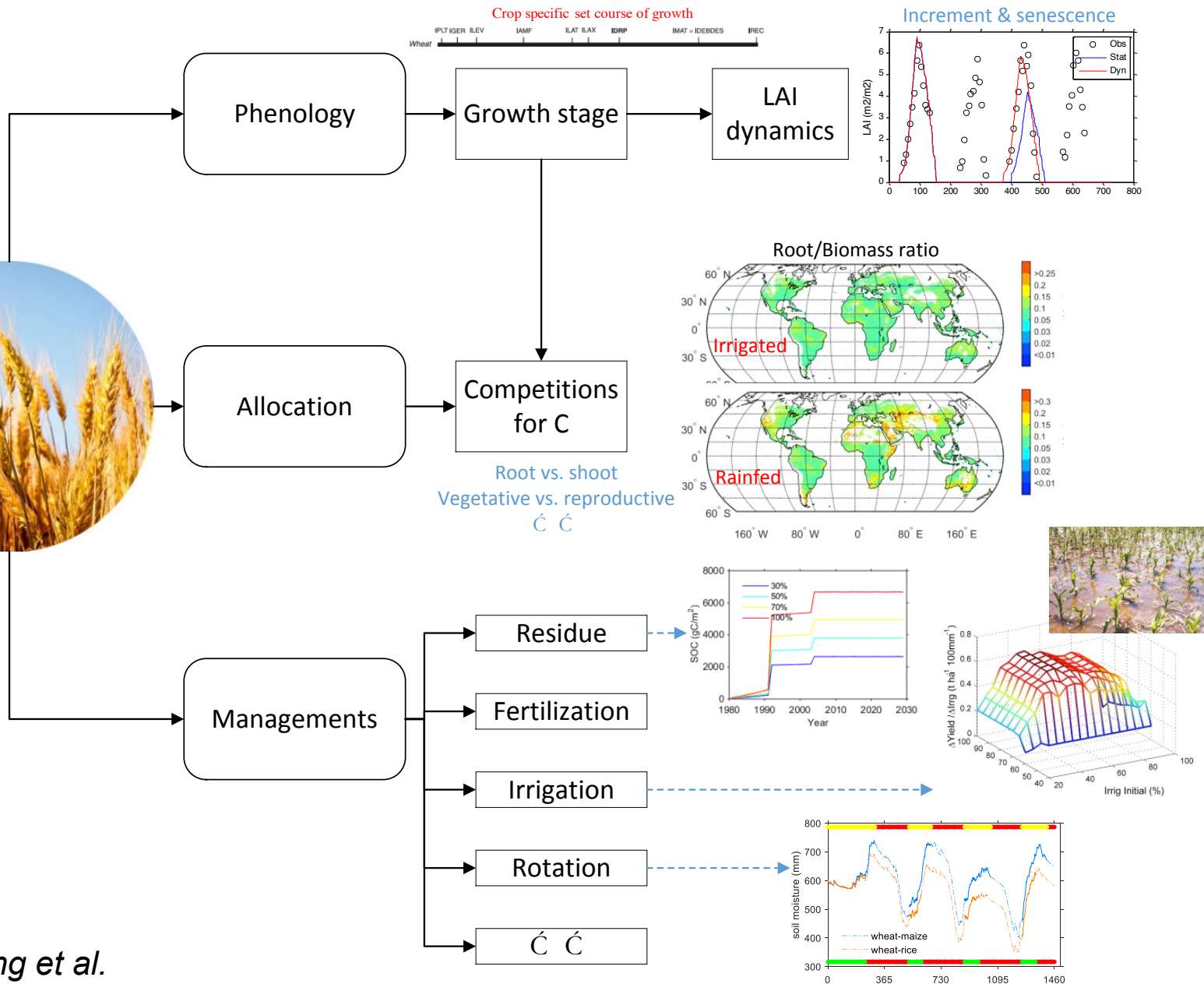


Factorial simulations

Simulations	Net LCC	Turnover	Harvest
S0 (S'0)			
S1 (S'1)	✓		
S2 (S'2)	✓	✓	
S3 (S'3)	✓	✓	✓

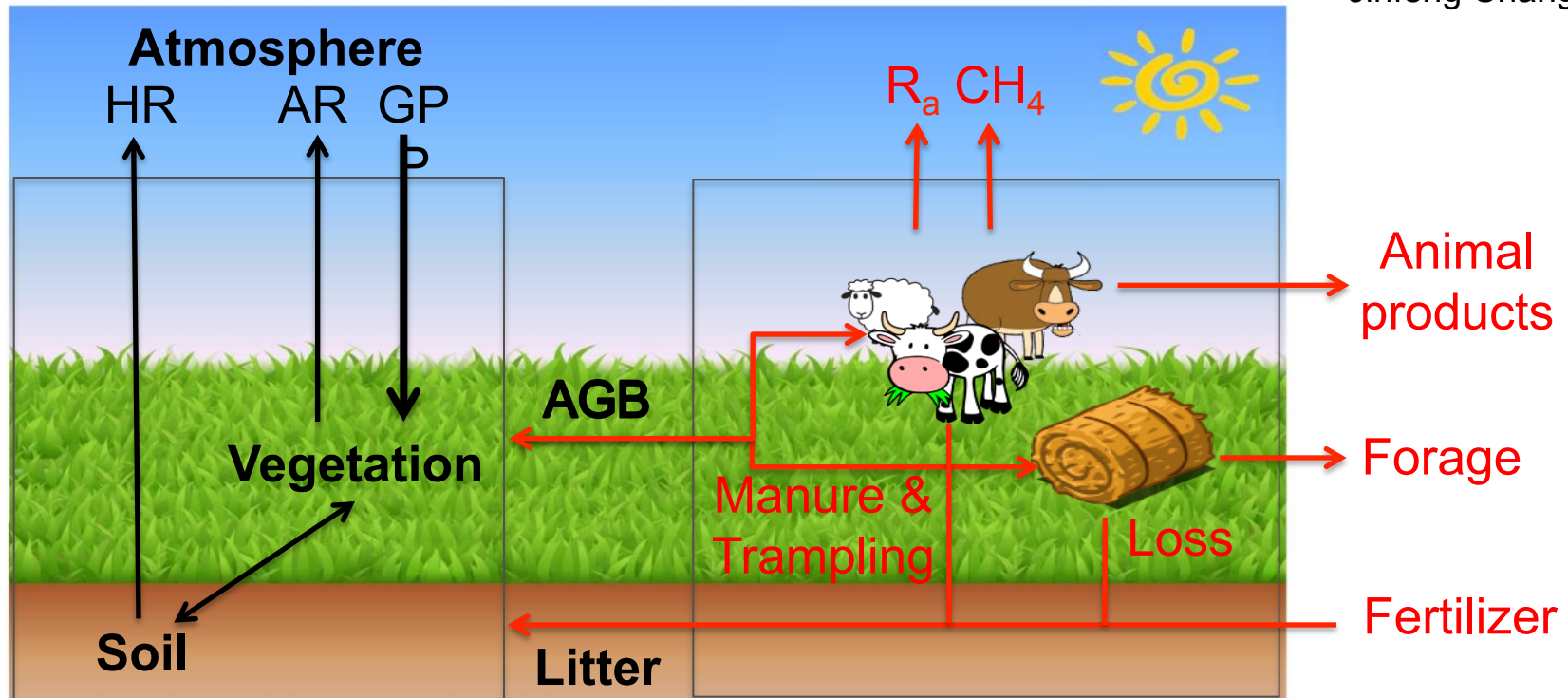
→ allow to quantify the contributions of different land use change processes (net change, land turnover or shifting cultivation and wood harvest).

Cultivated ecosystems : major crops



Grassland: from intensive pasture to rangeland

Jinfeng Chang et al.



ORCHIDEE

Management module from PaSim

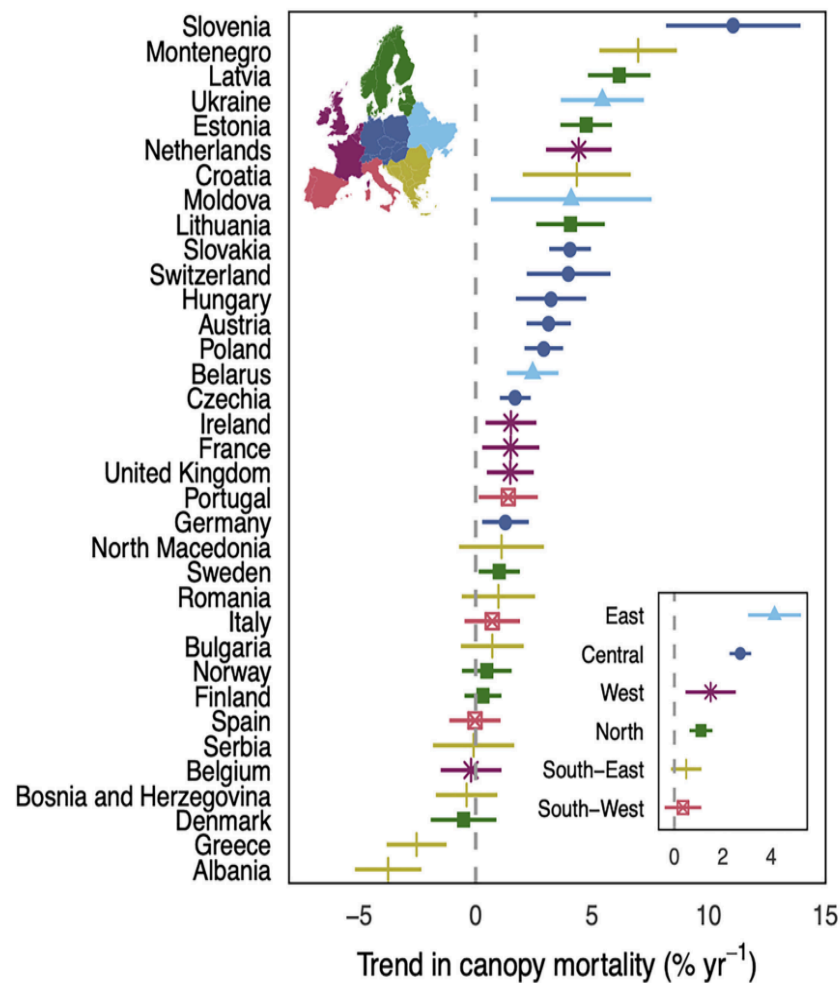
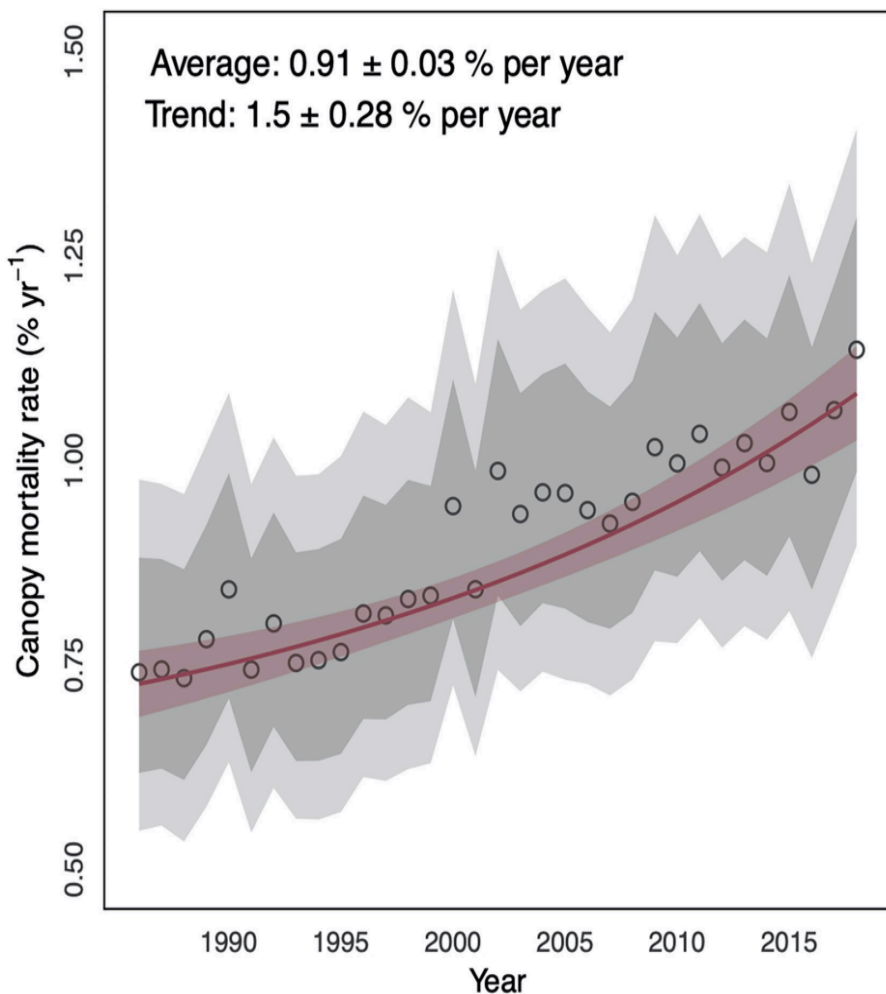
(Graux et al., 2012 ; Vuichard et al., 2007)

Applications:

- Grassland management optimization/adaptation (simulating potential productivity)
- Reconstruction of historical management intensity
- Long-term carbon and GHG balance of grassland ecosystem and livestock farm.
- Milk production simulation and projection.

Biotic effects in ORCHIDEE !

Increasing trend in EU forest canopy mortality



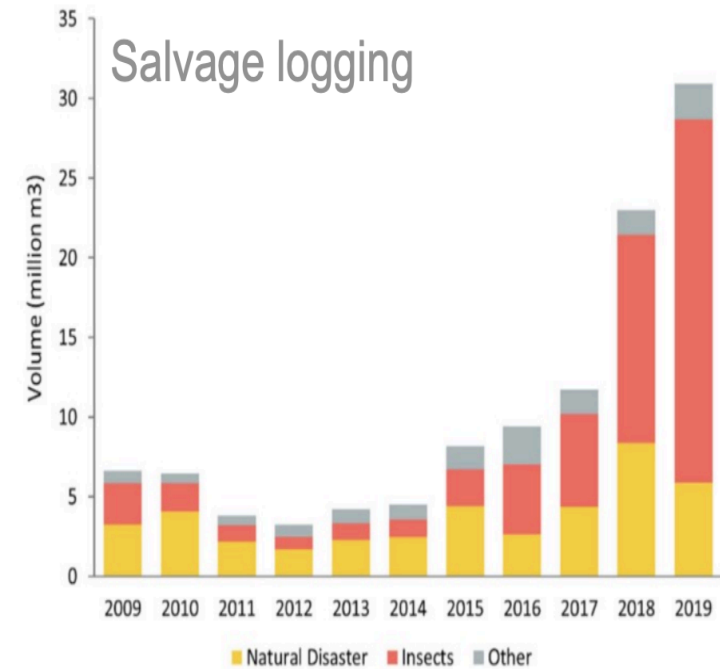
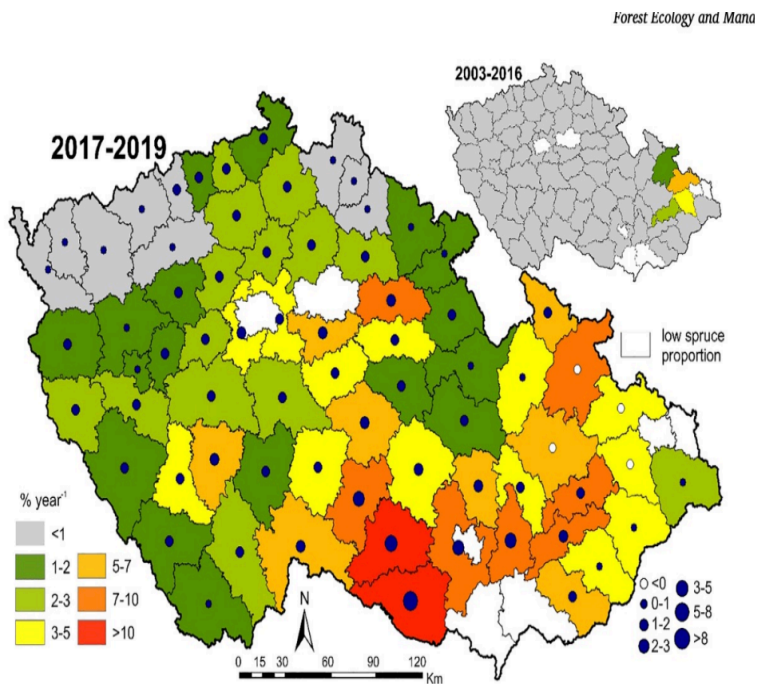
Increasing trend in EU forest canopy mortality

Devastating outbreak of bark beetles in the Czech Republic: Drivers, impacts, and management implications

T. Hlásny^{a,*}, S. Zimová^a, K. Merganičová^a, P. Štěpánek^b, R. Modlinger^a, M. Turčáni^a

^a Czech University of Life Sciences in Prague, Faculty of Forestry and Wood Sciences, Czech Republic

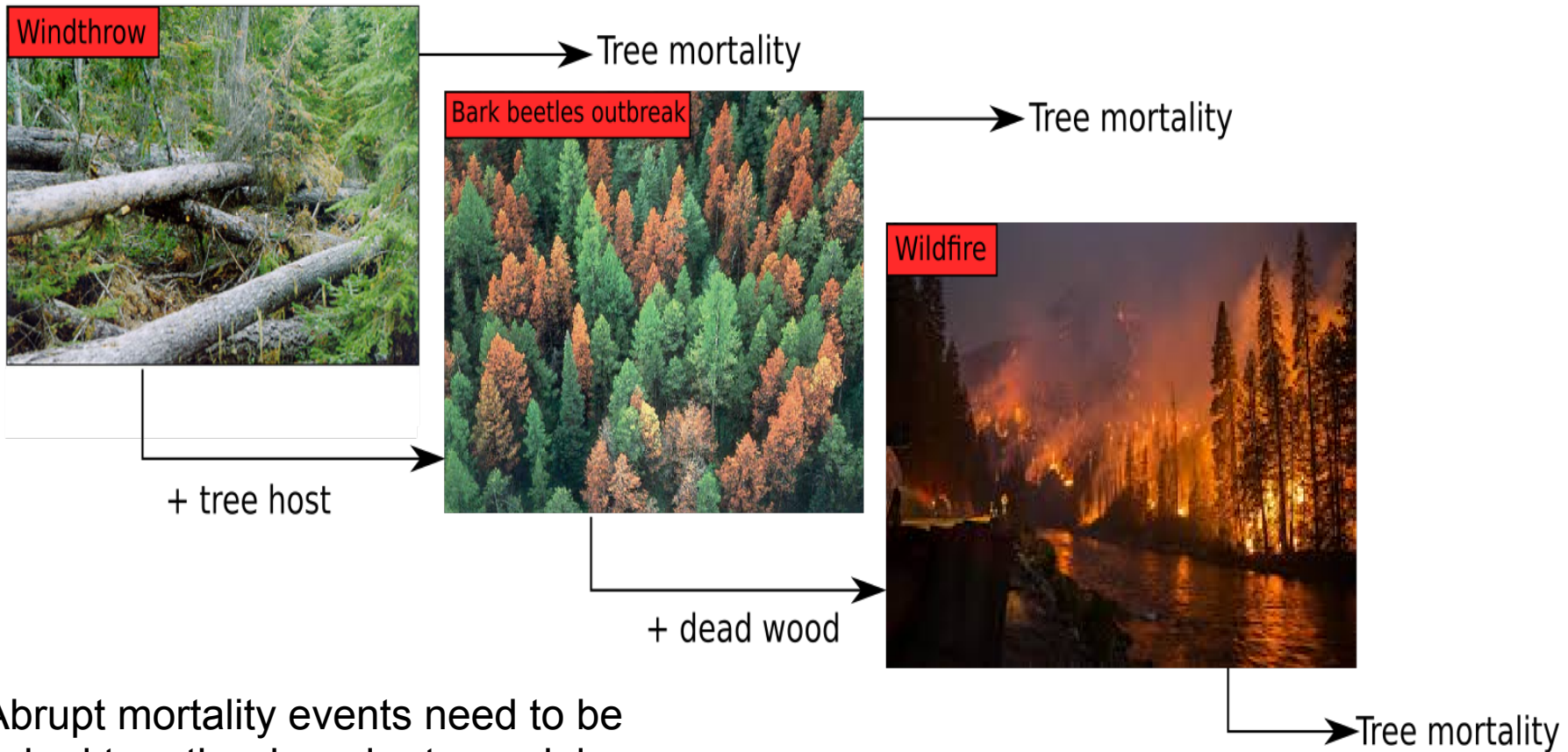
^b Global Change Research Institute, Czech Academy of Sciences, Czech Republic



Natural Disaster **Insects** Other

Mortality cascade is key to model ecosystem stability

An example of mortality cascade we would like to implement.

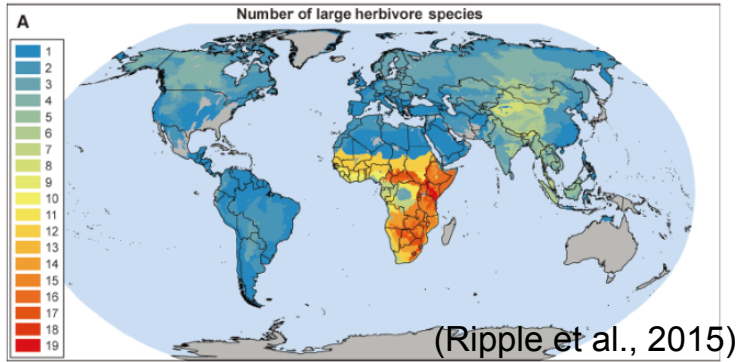


Abrupt mortality events need to be linked together in order to model mortality cascade

Various developments...

Representing wild large herbivores

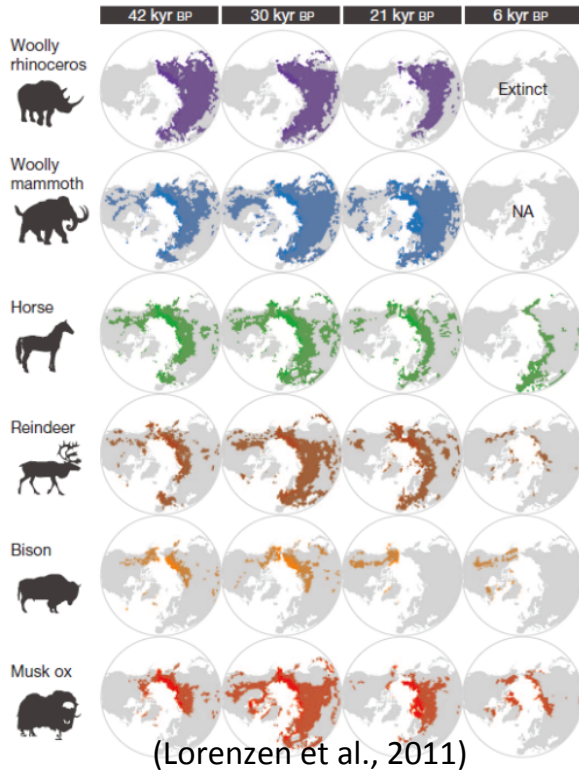
Large herbivores today



Bones preserved in yedoma deposits (Zimov et al., 2012)

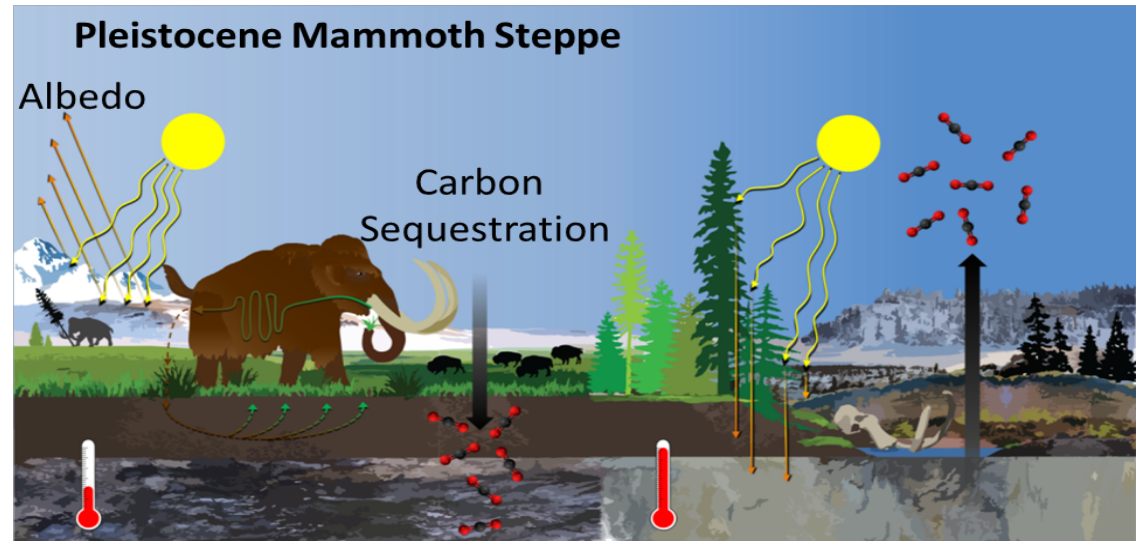
Herbivore biomass in the Arctic during 40~15 kyr BP:
 ~9000 kg/km²
 → comparable to today's African savannah

Large herbivores during late-Pleistocene

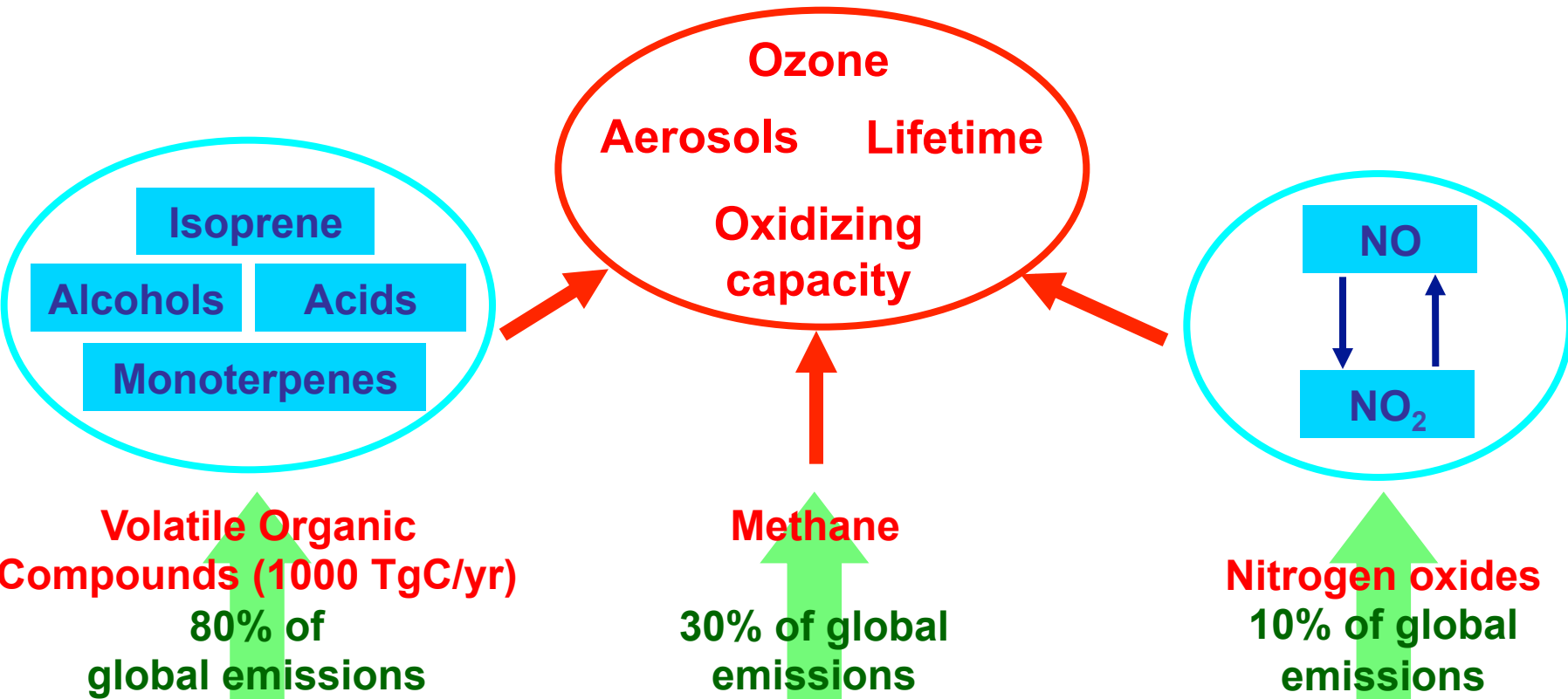


“keystone herbivore” hypothesis

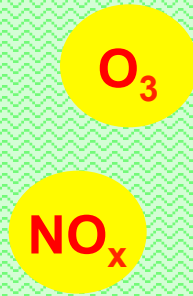
(Owen-Smith, 1987; Zimov et al., 1995)



The terrestrial biosphere and atmospheric chemistry



Vegetation



Wetlands



Soils - Cultures

Chemistry-vegetation retroactions

Atmospheric chemical composition

CO₂

Pollution: O₃, NO_x, SO₂ and particles

Deposition



Deposition



Deposition



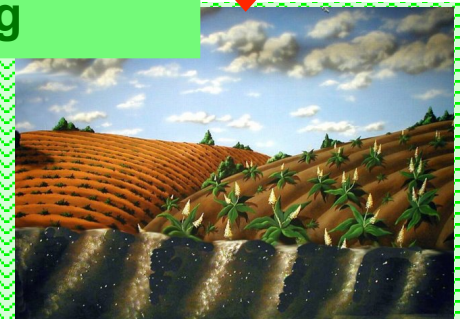
→ Growth, Distribution, Functioning



Vegetation

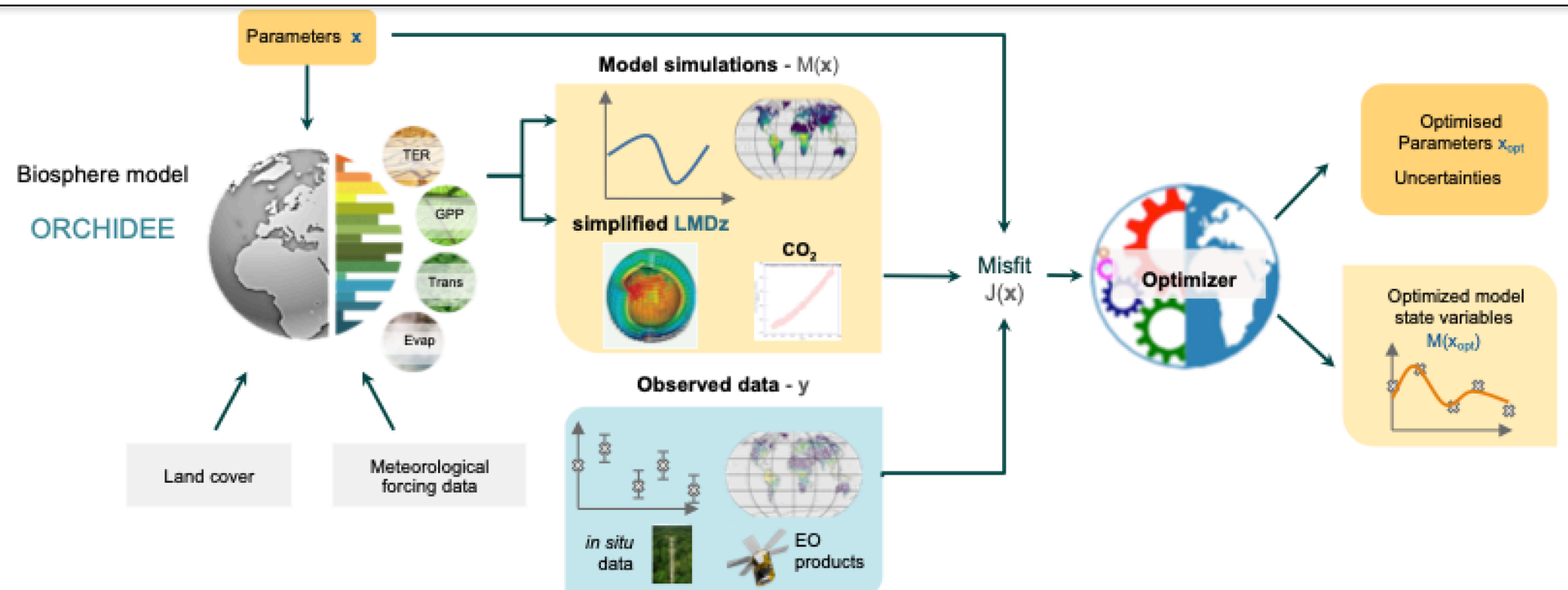


Wetlands



Soils - Cultures

Parameter calibration is crucial ! (Data Assimilation)



Parameter calibration is crucial !

(Data Assimilation work with ORCHIDEE)

- More than 12 years of experience with ORCHIDEE
 - Initially around the Carbon Cycle
 - Now on all aspects (W / Energy / ..)
- A dedicated website: <https://orchidas.lsce.ipsl.fr/>



The banner features the ORCHIDEE logo on the left, which includes a globe and the text 'ORCHIDEE LAND SURFACE MODEL'. In the center, the text reads 'ORCHIDEE Data Assimilation Systems' followed by 'Institut Pierre Simon Laplace / Laboratoire des Sciences du Climat et de l'Environnement'. On the right is the ORCHIDAS logo, featuring a globe with gears and the text 'ORCHIDAS DATA ASSIMILATION SYSTEMS'. A navigation bar at the bottom contains the following links: Overview, Results, Publications, Tutorials, People, and Contact.

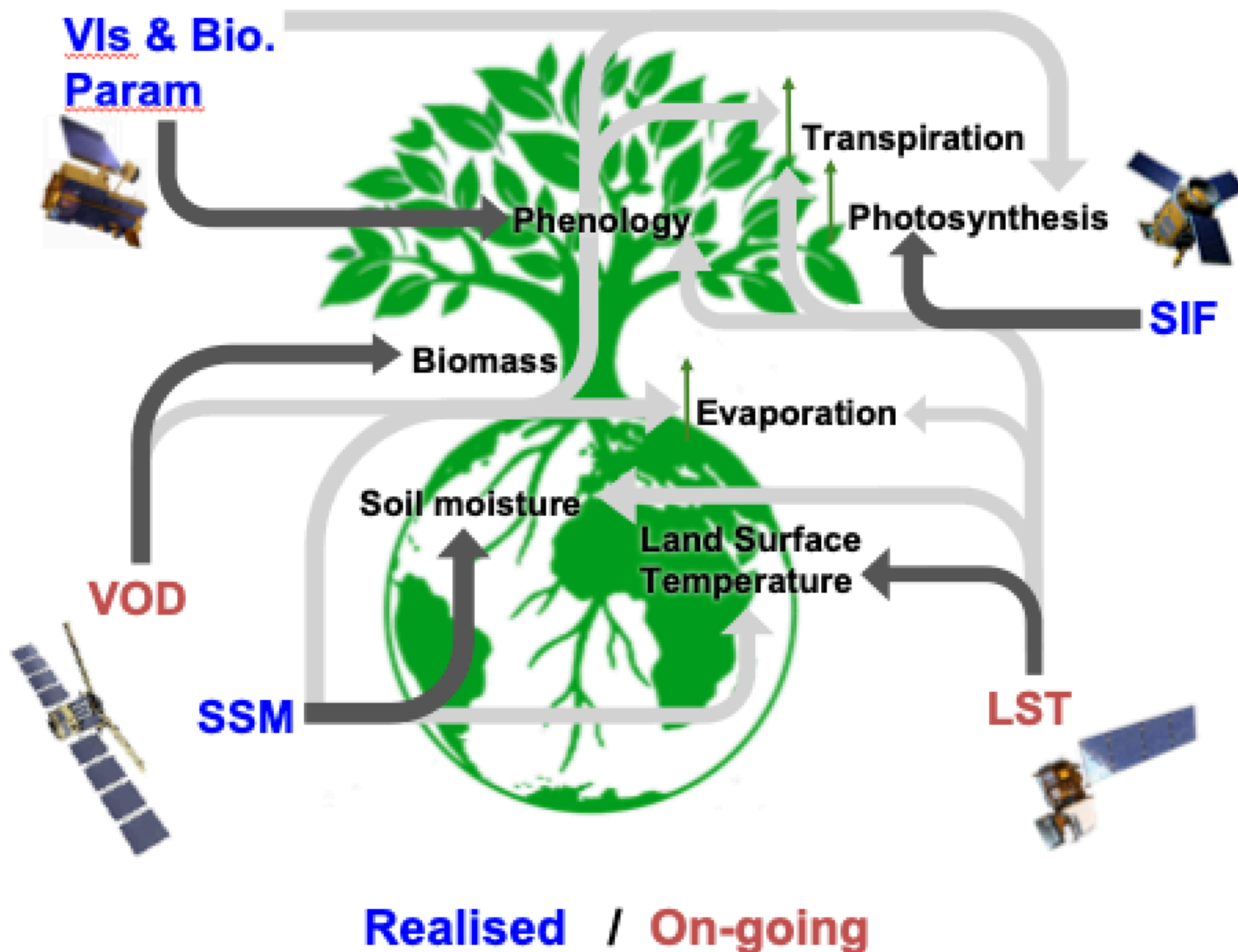
ORCHIDEE
LAND SURFACE MODEL

ORCHIDEE Data Assimilation Systems
Institut Pierre Simon Laplace / Laboratoire des Sciences du Climat et de l'Environnement

ORCHIDAS
DATA ASSIMILATION SYSTEMS

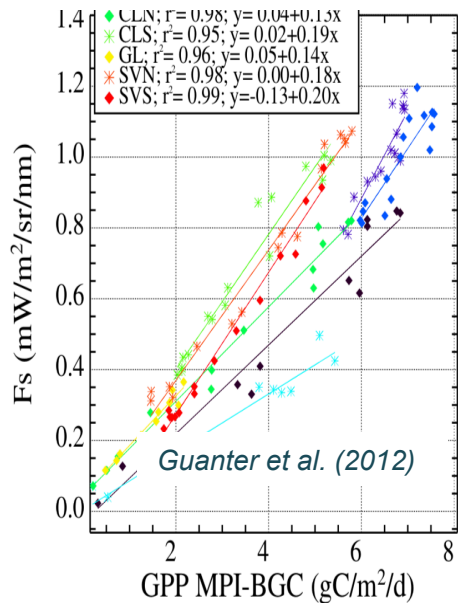
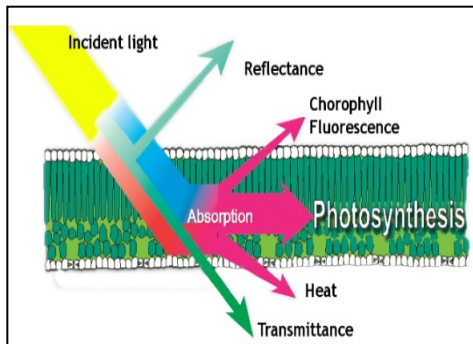
Overview Results Publications Tutorials People Contact

Satellite data assimilation

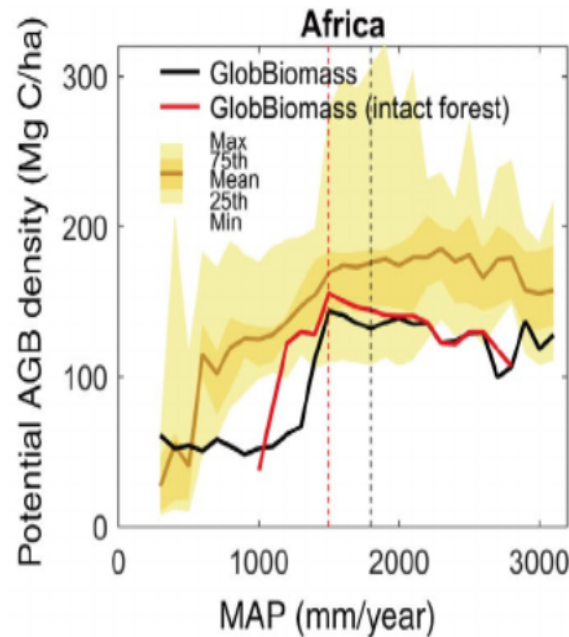


New data are coming with associated challenges !

Solar Induced fluorescence (SIF)



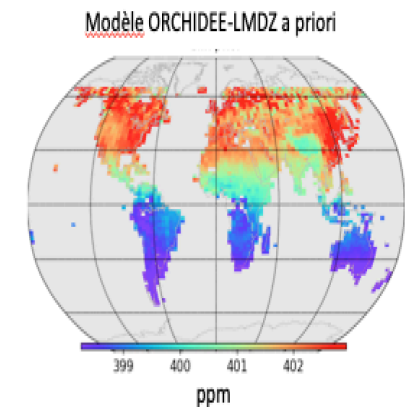
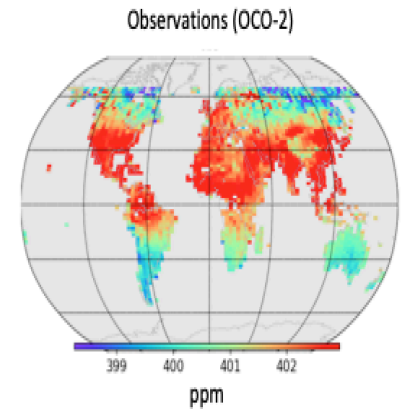
Satellite biomass data



GlobBiomass (Obs)
 DGVMs (Trendy)

Yang et al., GCP (2019)

Satellite XCO2 data



On-Going work

In parallel new developments in DA methods around ORCHIDEE

Gradient based methods

- On-going effort to calculate **the TL model and Adjoint** of any ORCHIDEE version
- Very difficult !
Based on Automatic differentiation tools (TAF)
- Proxy approach with finite differences

Monte Carlo methods

- Using **Genetic Algorithm** / particle filter / ...
- **Computationally intensive !**
- Not adapted for global calibrations !
- Nor for the spin up !

Emulator – based approaches

- Emerging techniques
- On-going use of the so-called « **History Matching** » approach
- Based on **Gaussian Emulator** of the full model !