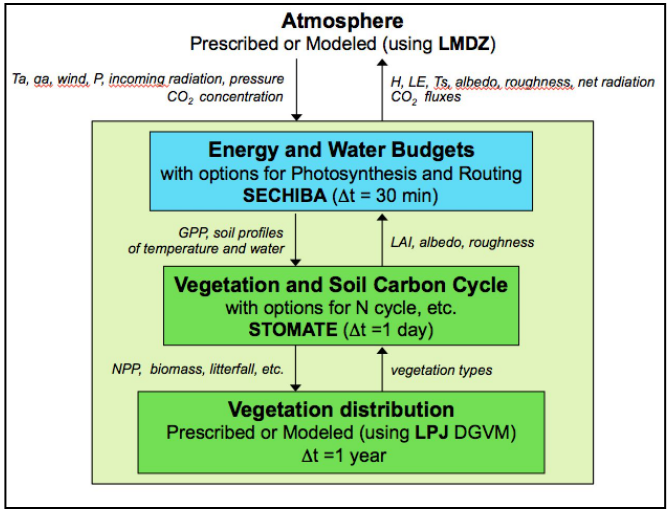
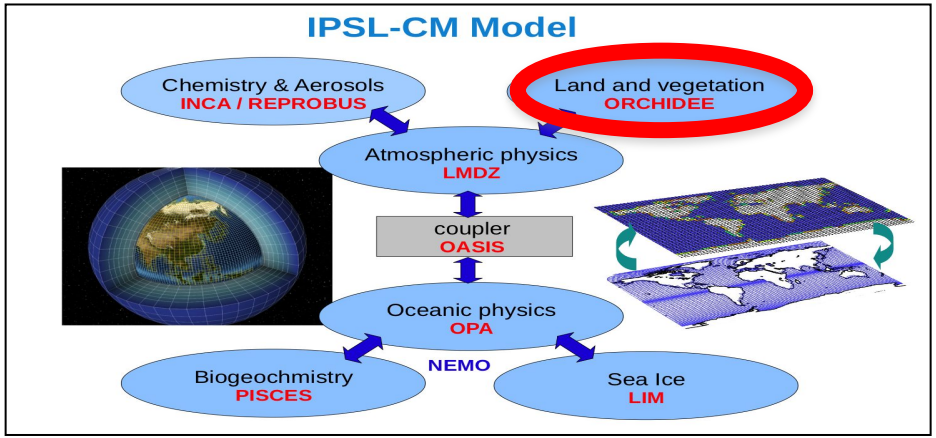
The ORCHIDEE project





The ORCHIDEE project

- COLLABORATIVE effort with many contributors !!

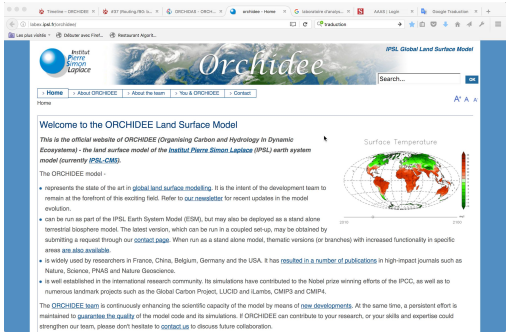
- Around 20 permanents and over 30 CDDs
  - Several laboratories but mainly from IPSL

- 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…

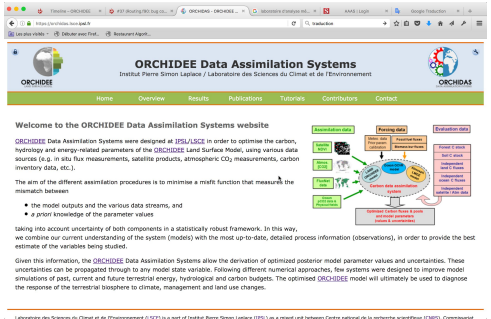
- Official web site :
  for external people



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

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

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



Specific documents

- https://docs.google.com/document/d/13R22r1fx0JoYKCojG1k3IM2C18RWuFNvxoYKdtacJEI/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

Project “Value, Vision, Mission” docuement

Model developments | Documentation | Source Code | Reference Simulations | Group Activities & Contact

Group Activities Page

- Contact & Mailing Lists
- Training courses
- ORCHIDEE Google document for: Ongoing-tasks / Governance / Papers / Projects (private access, you need to login)
- Use of publication with ORCHIDEE - Policy and ORCHIDEE recent papers: https://sharebox.lsce.ipsl.fr/index.php/s/AhJk0Bk6rdySXKL
- ORCHIDEE strategic plan: Definition of the value, vision, mission of the ORCHIDEE group defined during the ORCHIDEE day of March 17, 2023
- All meetings : Direct link to weekly meeting reports (private access, you need to login) and the last Orchidee retreat
- See also pages for past CMIP6 developments

⇒ To guide the overall ORCHIDEE group functioning !

Key words are :

Interdisciplinarity / Open science / Reciprocity / Scientific ethics /

Mutual trust and equity / Cooperative decision making / staying united

Single code / stable and well documented code / ...

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..

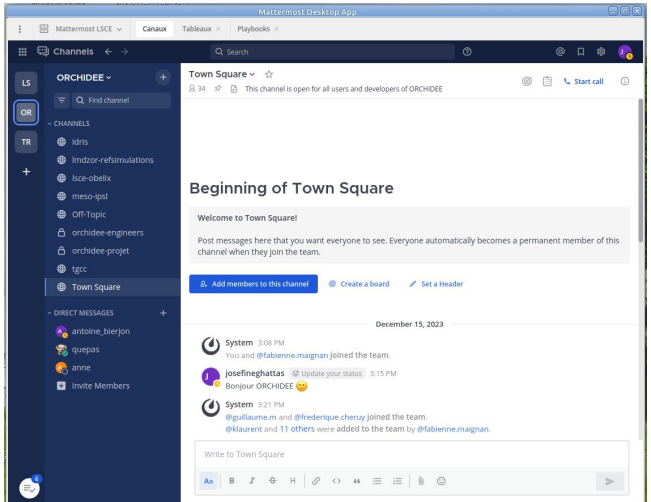
⇒ Find all lists under : https://listes.ipsl.fr/sympa/home
(you can subscribe directly on the web site)

New communication tool: “Mattermost”

Mattermost

- Newly started for ORCHIDEE, to be used for on-line communication, (similar to slack)

- Connexion https://mattermost.lsce.ipsl.fr/orchidee or via application(recommanded method)



You can:

- Discuss with others about ORCHIDEE
- Subscribe to existing channels
- Create new channels with specific topic and invite people

« 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
- New rules are coming up with the use of GPU (instead of CPU)
- NEEDED to get support from the group
- NEEDED if you want your code to be 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”

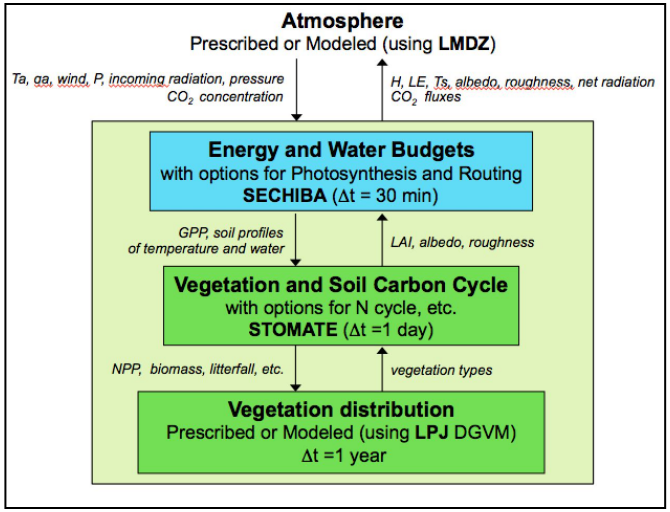
- TO BE USED SPARINGLY… (as little as you can)
- FIRST: Dig as much as you can into the code..
- SECOND: check the WIKI
- THIRD: ask your main advisor
- FOURTH: Ask your colleague/neighbour
- THEN: post a message to “orchidee-help@ipsl.jussieu.fr
- AS A RETURN, please:
  - Try to write a little summary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

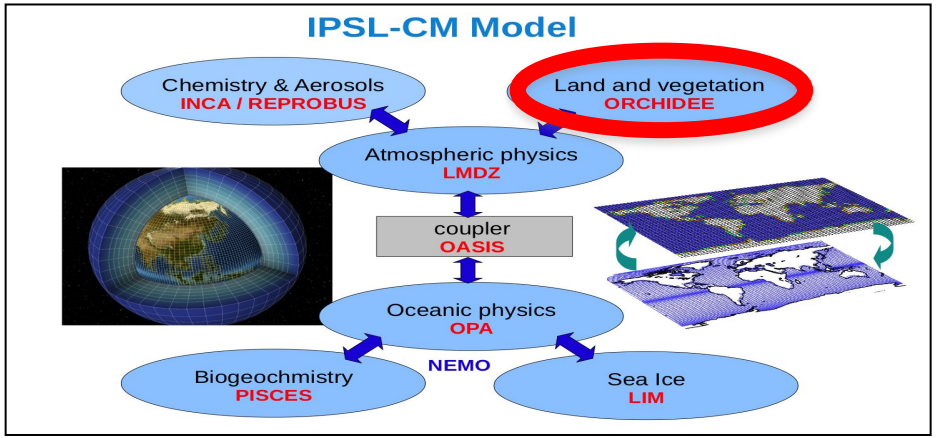
Fair Use policy

- 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

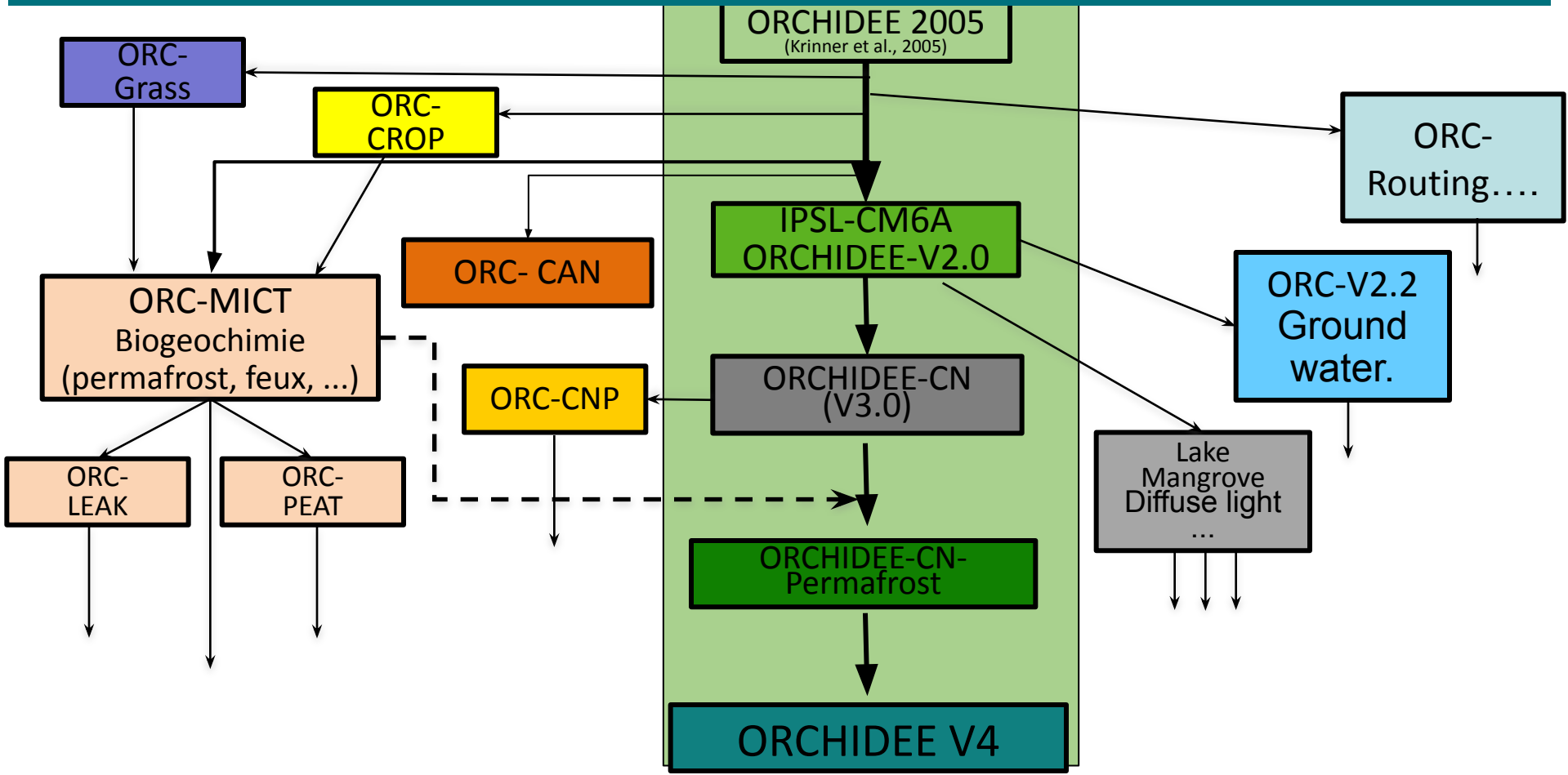
⇒ Access from the wiki:
https://forge.ipsl.jussieu.fr/orchidee/wiki/GroupActivities/UseOfORCHIDEEpolicy

Le modèle ORCHIDEE:
récent & futur développements





ORCHIDEE branches



ORCHIDEE developments (for CMIP6)

Implemented: V2

Recent: V3

Merging

New Aerodynamic resistance

Nitrogen – carbon Coupled cycles

Optimized albedo (using MODIS)

Permafrost carbon

Land cover based on ESA-CCI

Forest management & forest structure

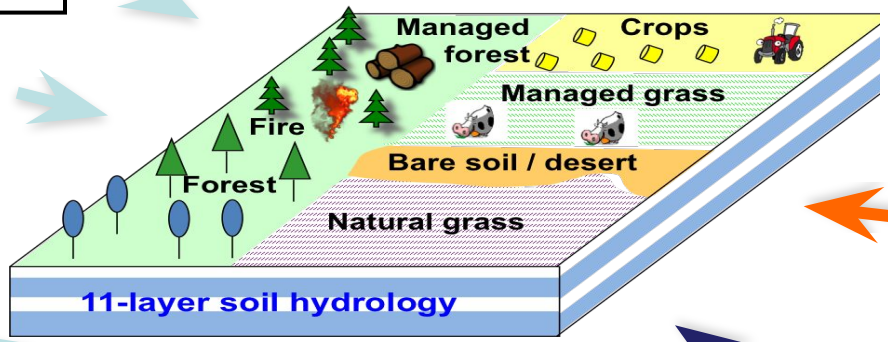
New 3 layers snow model

SPITFIRE and Land use gross transitions

11-layer soil hydrology With soil freezing

Improved Carbon cycle description

CH4 emissions (wetland and permafrost)



Other Mature/Ongoing developments

Biophysical

Lake model (FLAKE)

Irrigation

Termokarst lake

DOC – DIC transport by river

New boreal PFTs (Mosses, lichens, shrubs)

Biogeochemical

Nitrogen – Phosphorus - Carbon coupled cycles

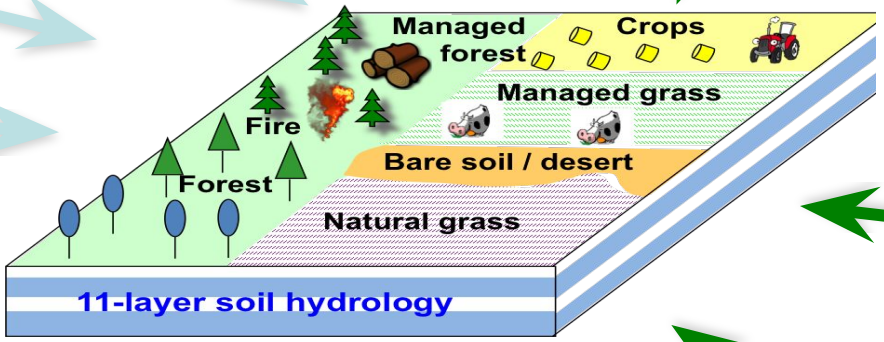
Crop model (wheat, corn, rice,…)

Grassland management

Peatland model (CH4)

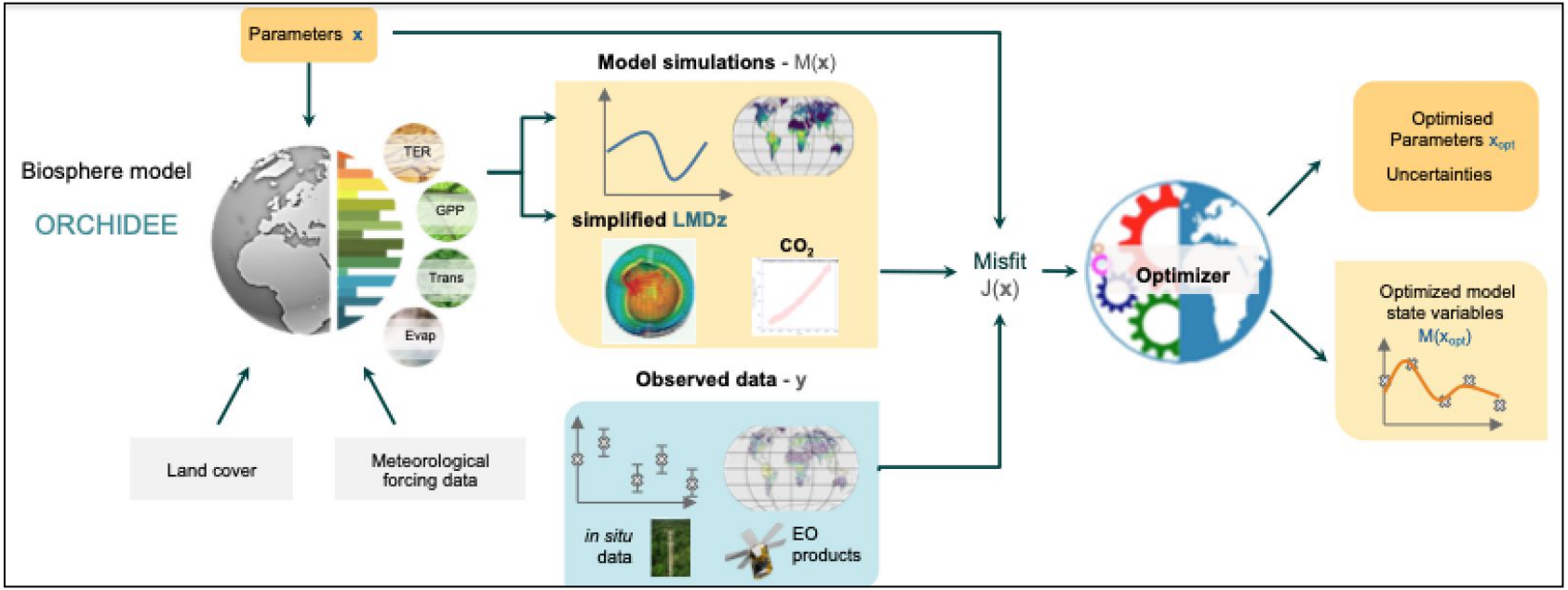
Herbivory (large herbivore)

Plant Traits



Parameter calibration is crucial !

(Data Assimilation)



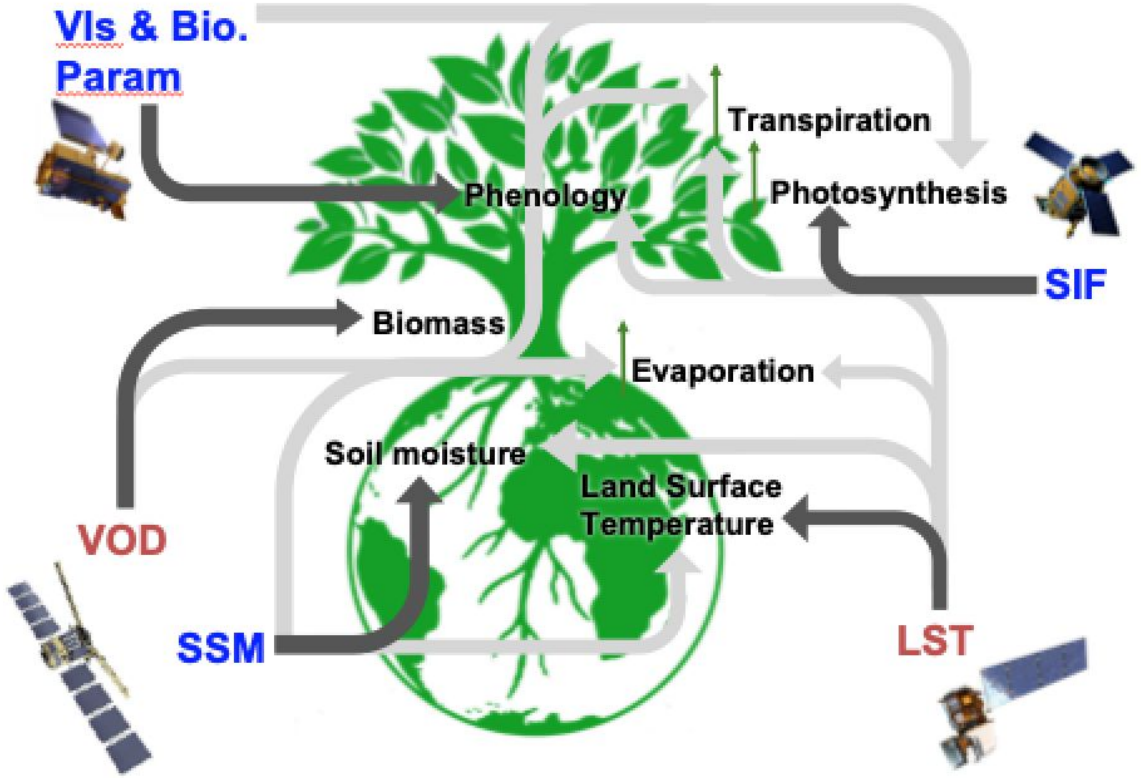
Parameter calibration is crucial !

(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/

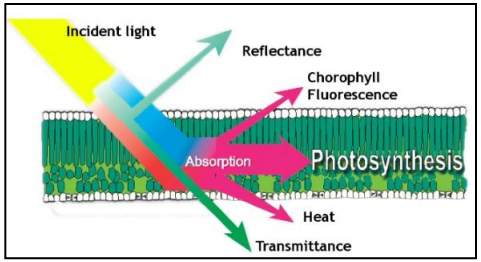
Satellite data assimilation

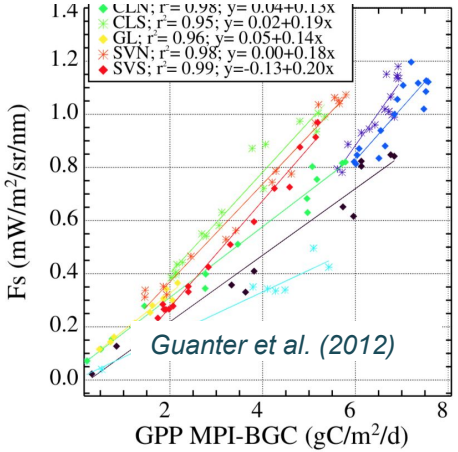


Realised / On-going

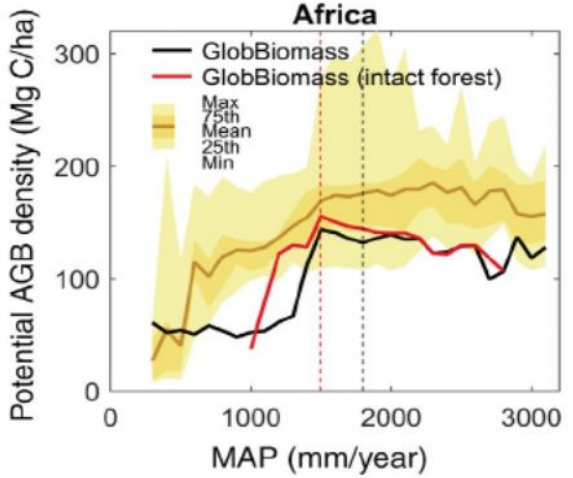
New data are coming with associated challenges !

Solar Induced fluorescence (SIF)





Satellite biomass data

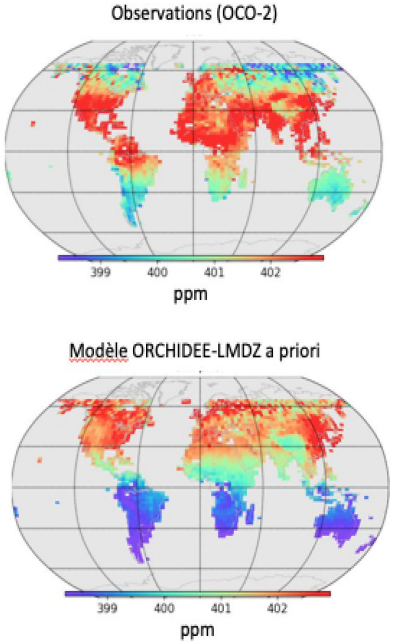


GlobBiomass (Obs)

DGVMs (Trendy)

Yang et al., GCP

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 / particule filter / …
- Computationally intensive !
- Not adapted for global calibrations !
- Nor for the spin up !

Emulator – based approaches

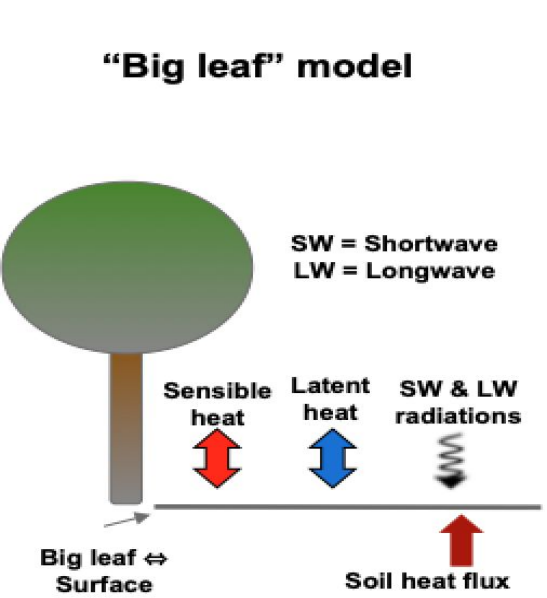
- Emerging techniques
- On-going use of the so-called « History Matching » approach
- Based on Gaussian Emulator of the full model !

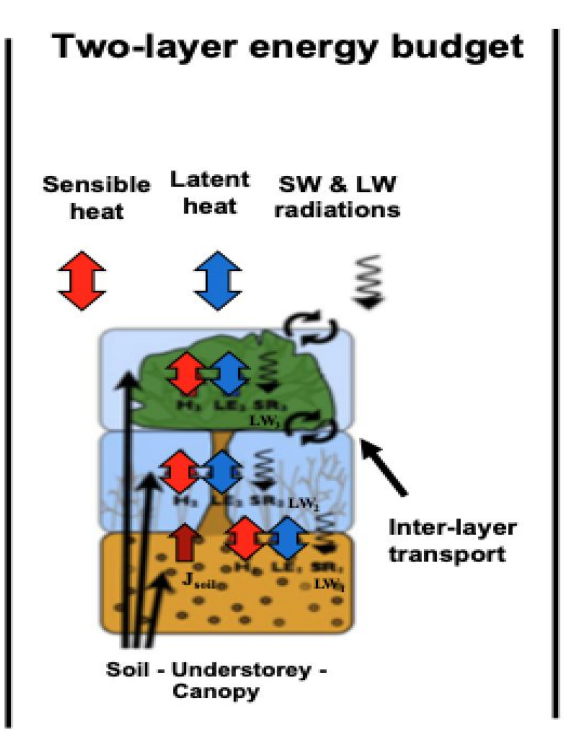
Energy and water budget recent / new developments

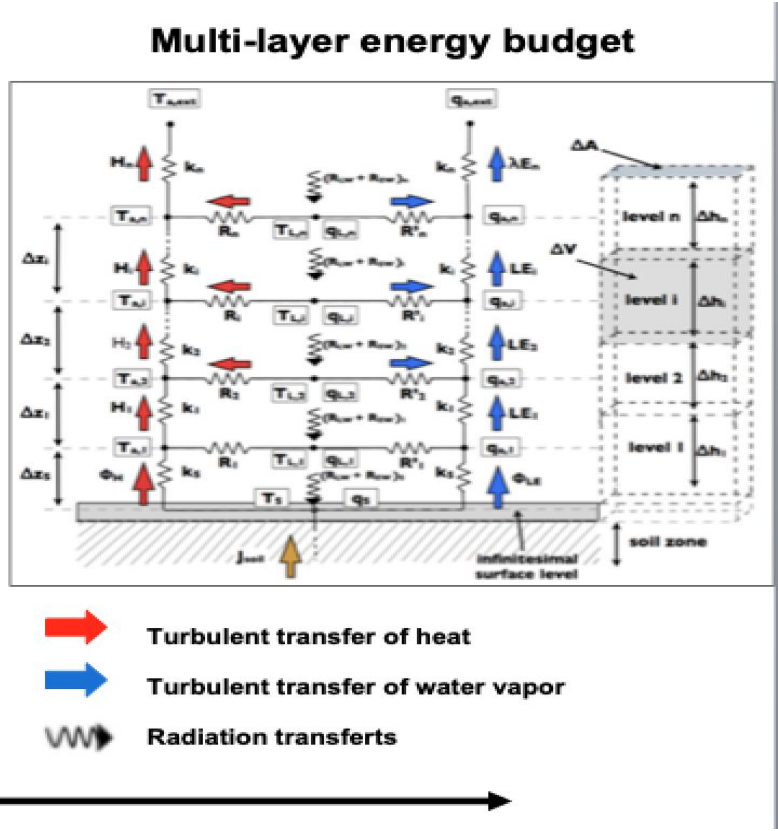
“Big leaf” model

Two-layer energy budget

Multi-layer energy budget



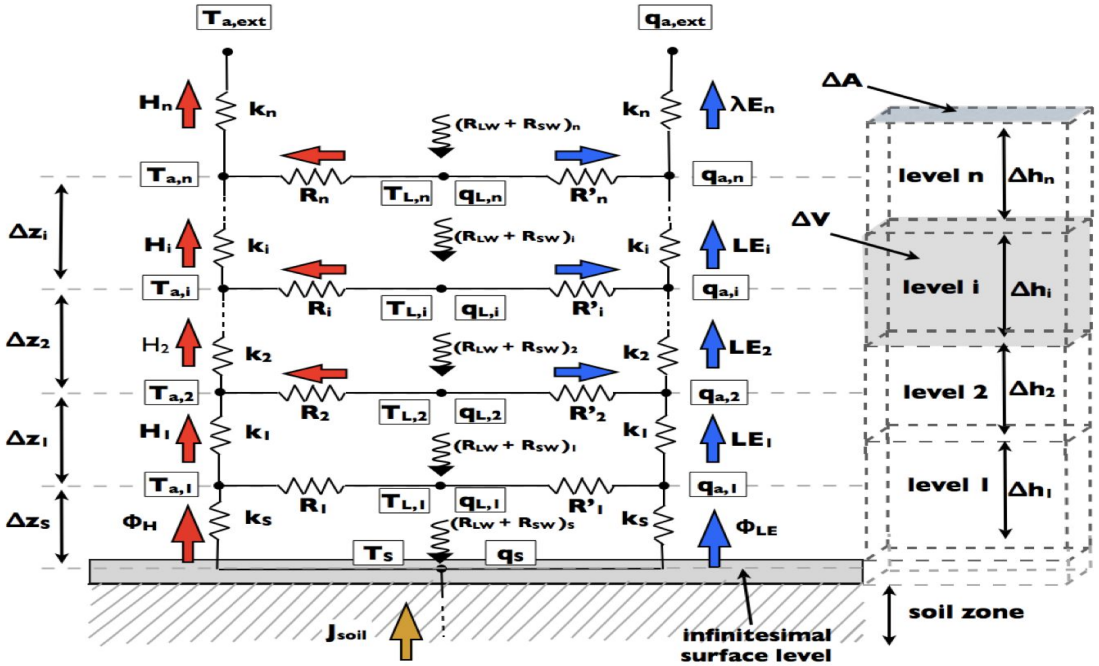




Complexity

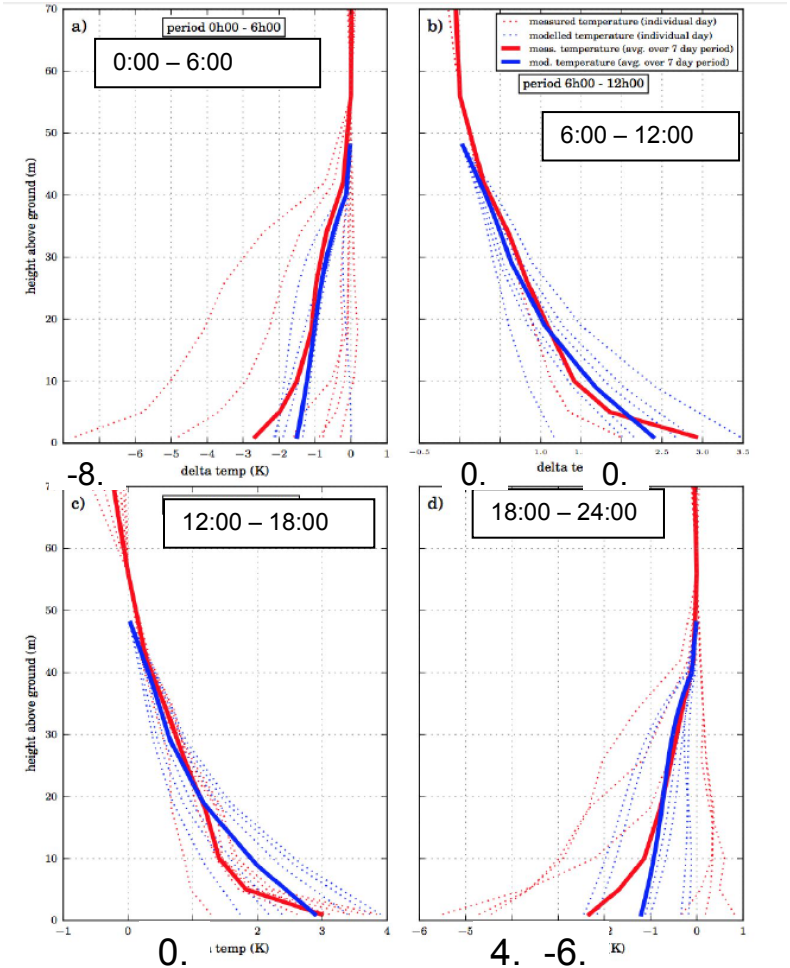
Vertical multi-layers scheme..

- 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



Daily temperature

Temperature profile at Tumbarumba site

Observations

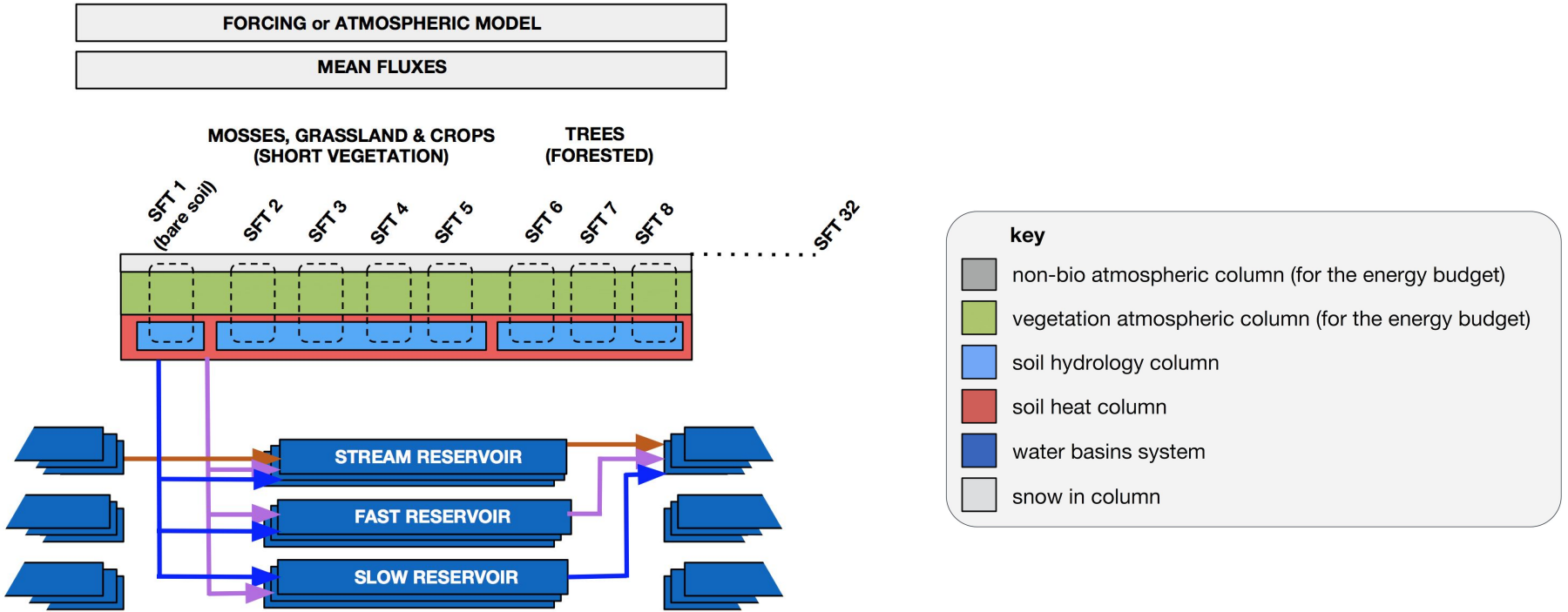
Model

Ryder et al., 2015

Current scheme !

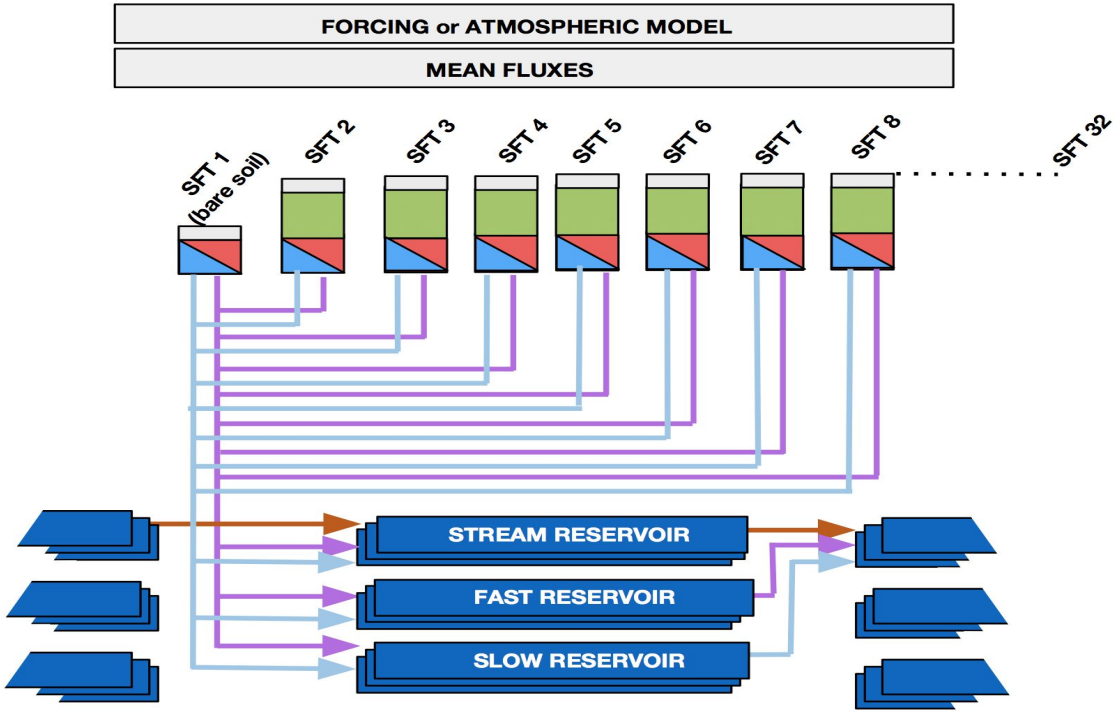
N_energy = 1 ; N_hydro = 3 (bare soil, short veg, trees)

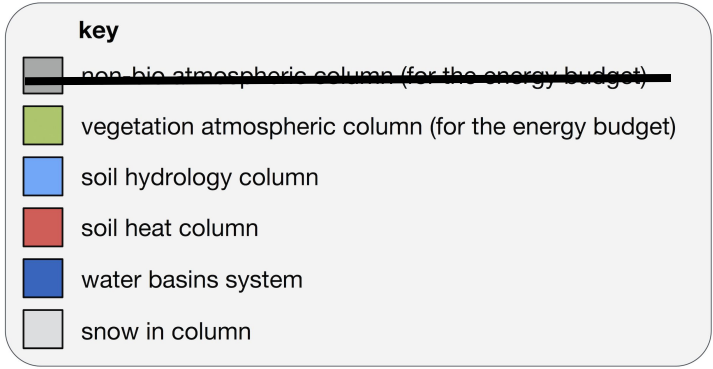
1 atmospheric column (mixing fluxes at first level) ; 1 routing scheme !



New multi-tiling approach : maximum split

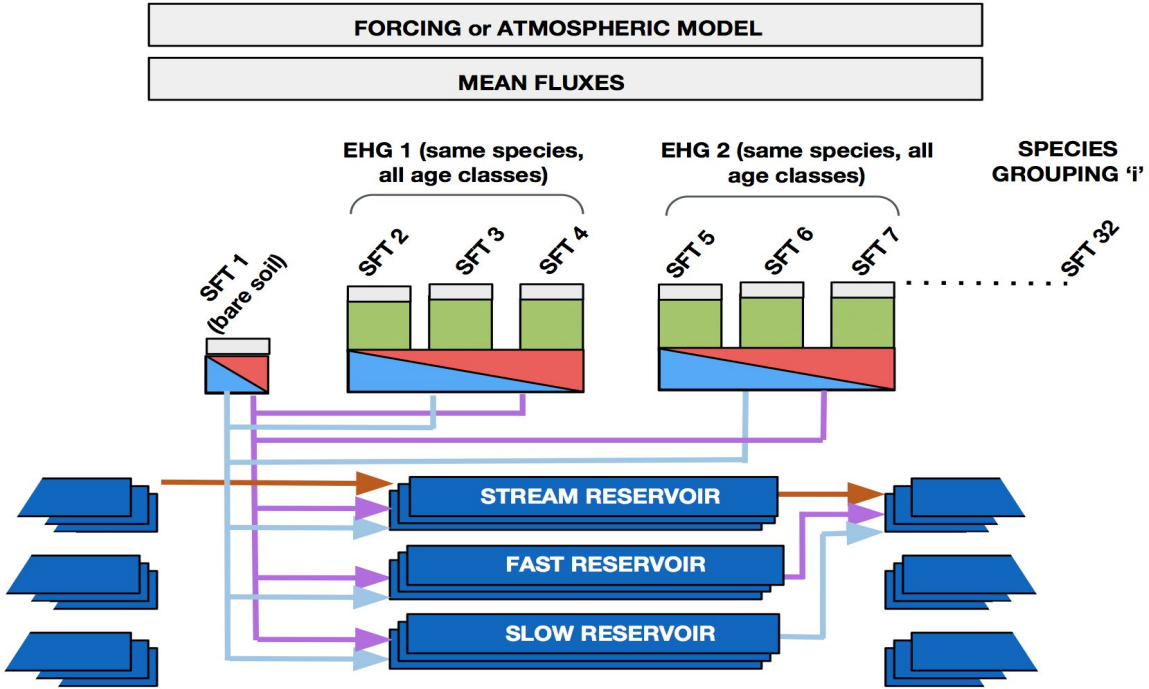
- Nhydro = Nener for each grid box ; But different across grid cells !
  (keep 2 params to reproduce current config with Nhydro = 3 / Nener =1)

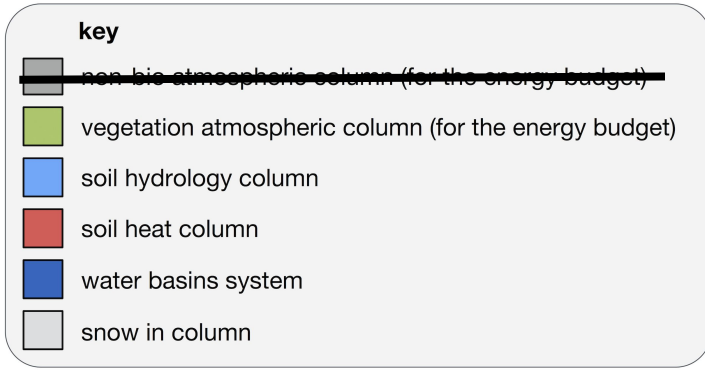




New multi-tiling approach : « intermediate » split

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



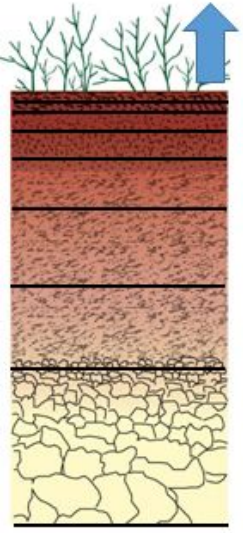


Hydraulic architecture to better capture drought impacts

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

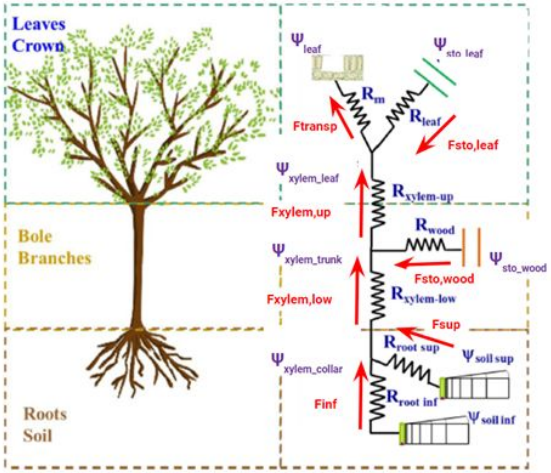
Previous version

- Soil moisture impact on Transpiration / gs
- SIMPLE linear equation !



New version

$$g_{c\,O_2} = g_0 + \frac{aA}{c_i - c_{i*}} f_{\Psi_{leaf}}$$



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

Julien Alleon, in prep

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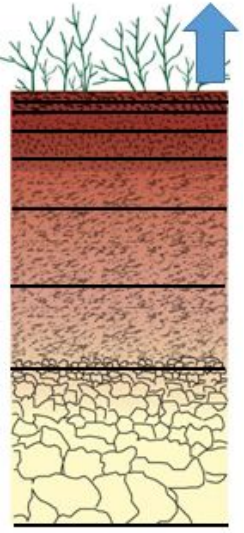

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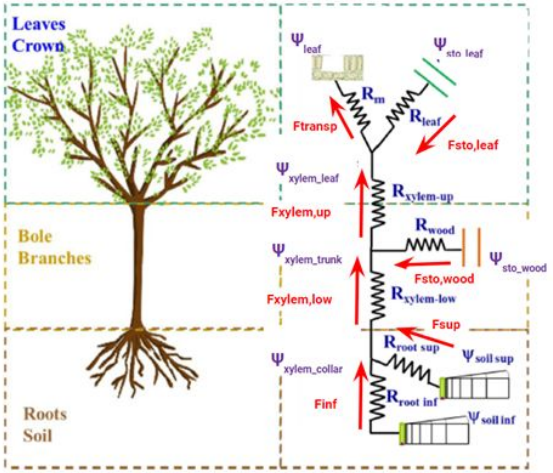

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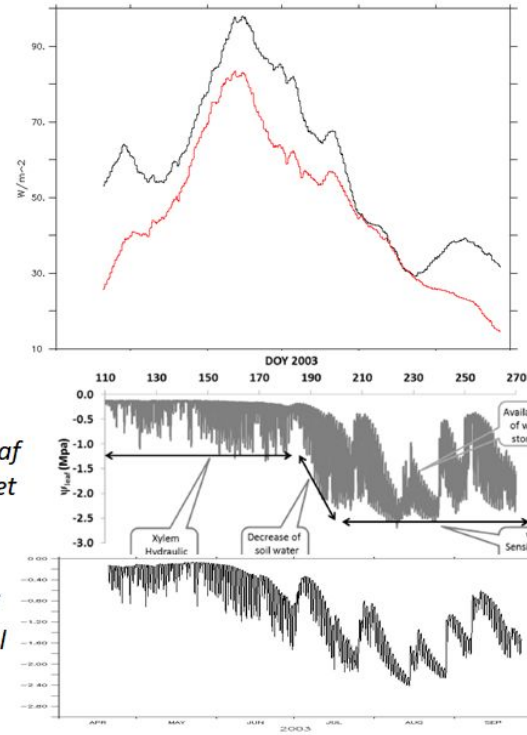
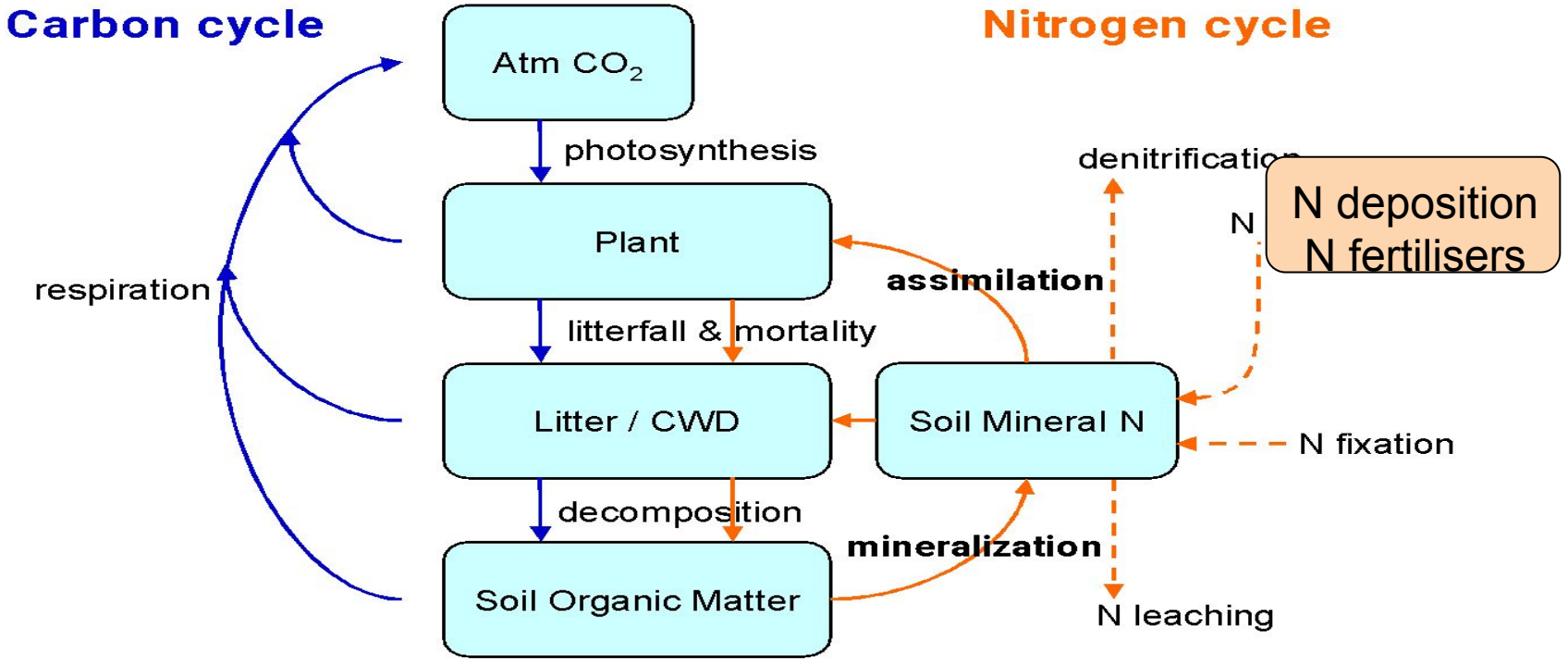


Julien Alleon, in prep

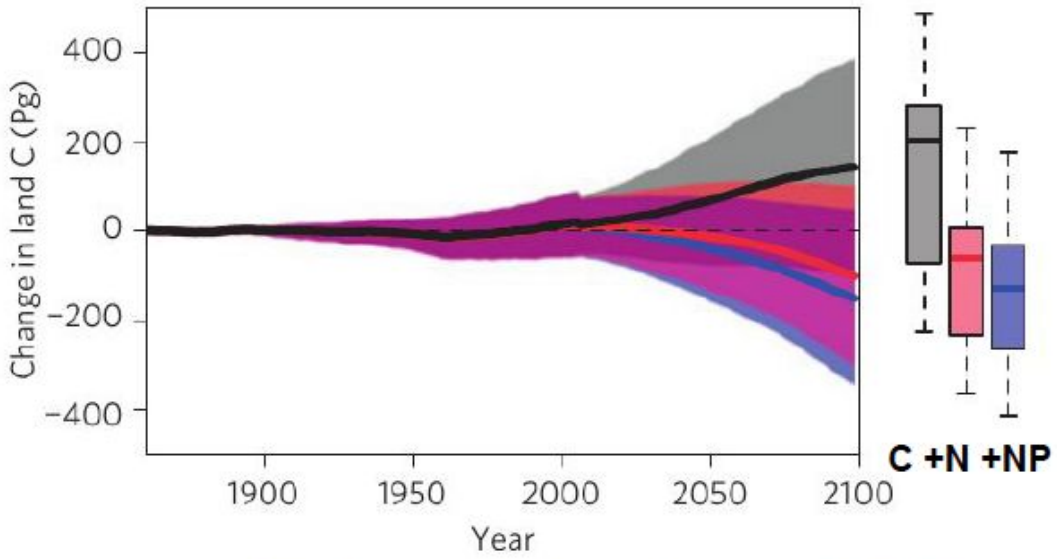
Nutrients cycles
recent / new developments

C & N land interactions



From Thornton et al., 2009

Adding the Phosphorus cycle

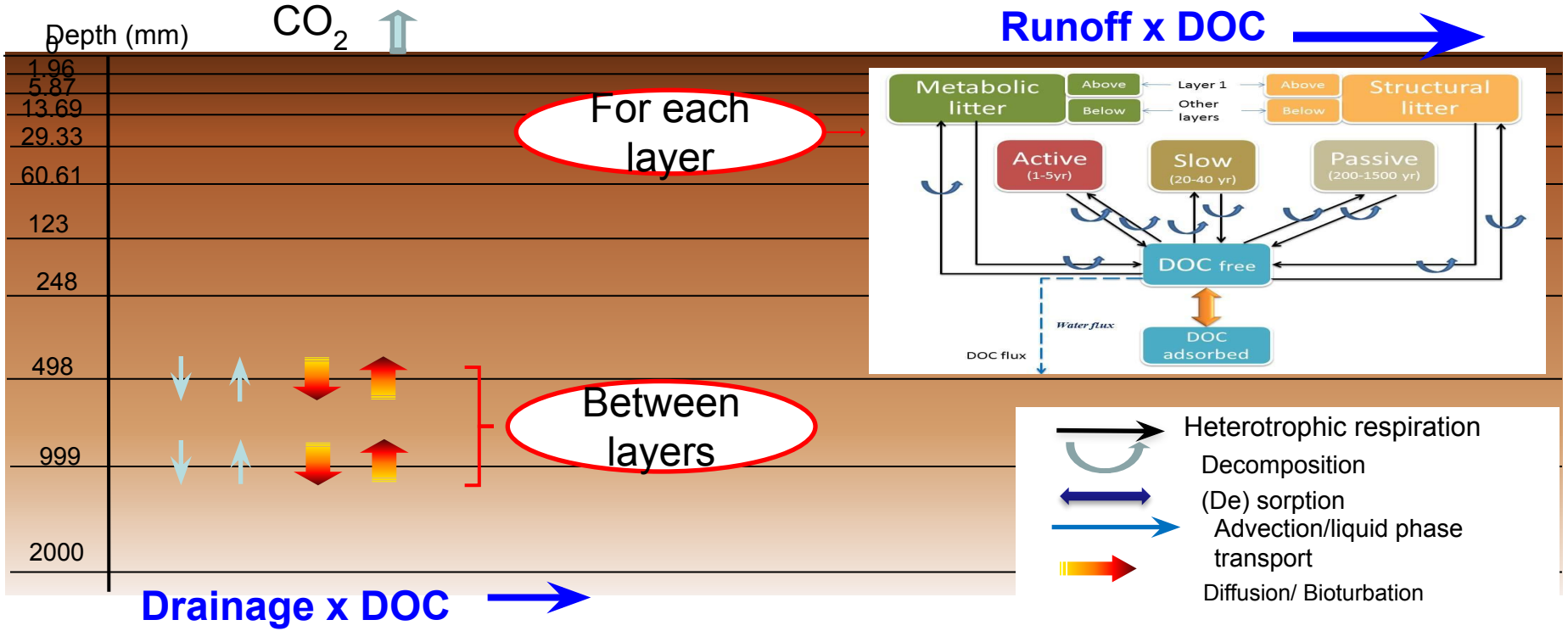


Wieder et al., Nat. Geosc., 2015

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

A new soil carbon model..

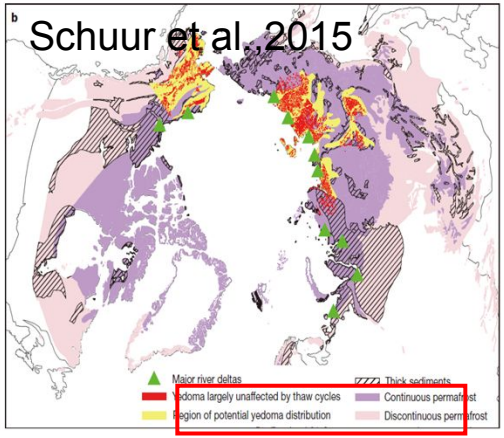
- Discretized soil carbon (11 layers) + new pools introduced (DOC)
- New decomposition scheme (priming): $\frac{\partial SOC}{\partial t} = I - k_{SOC} \times SOC \times (1 - e^{-c \times FOC}) \times \theta \times \tau$



Permafrost : Modeling Yedoma organic carbon formation

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

Dan Zhu et al.

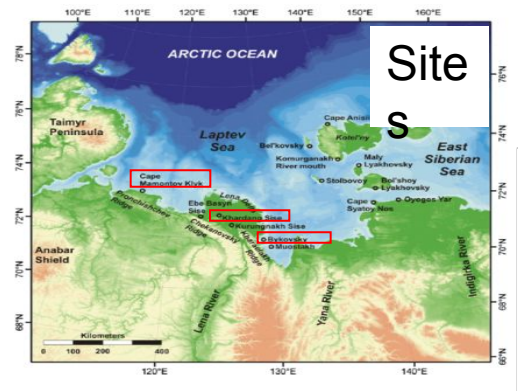


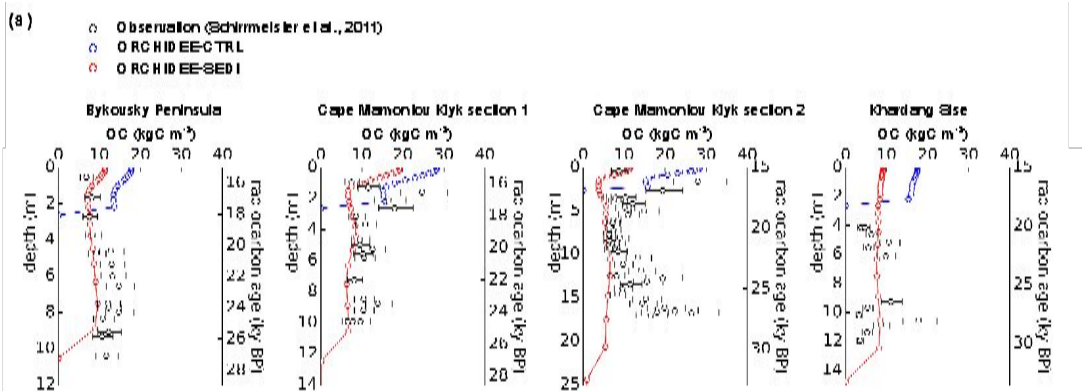
Area: ~1.3 million km^2

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

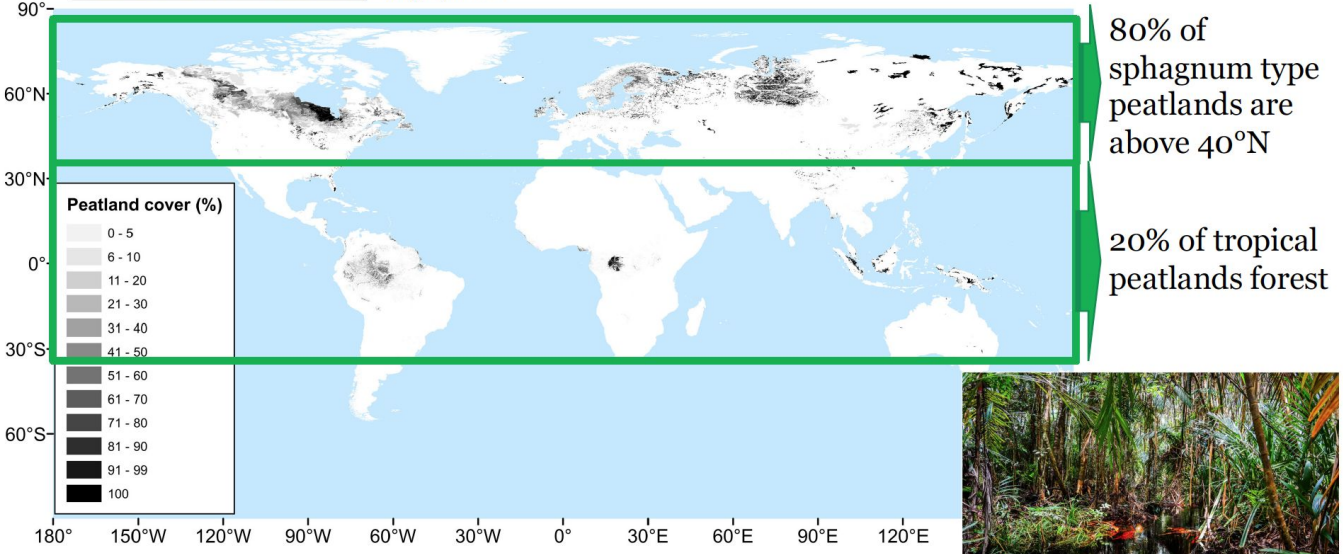




Peatland and CH4 modelling in ORCHIDEE

TYPES OF PEATLANDS

Laguette peatlands, Sologne, France



80% of sphagnum type peatlands are above 40°N

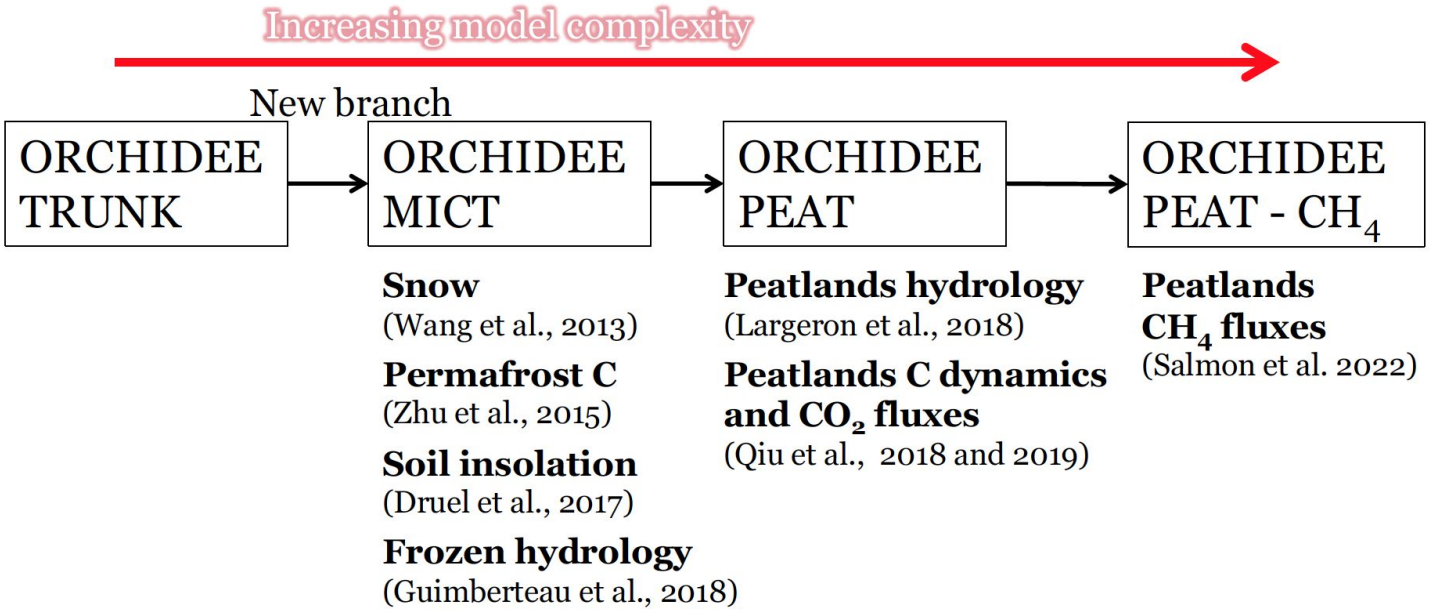
20% of tropical peatlands forest

PEATMAP (Xu et al., 2018)

Peat swamp forest in Zamrud National Park, Indonesia

Peatland and CH4 modelling in ORCHIDEE

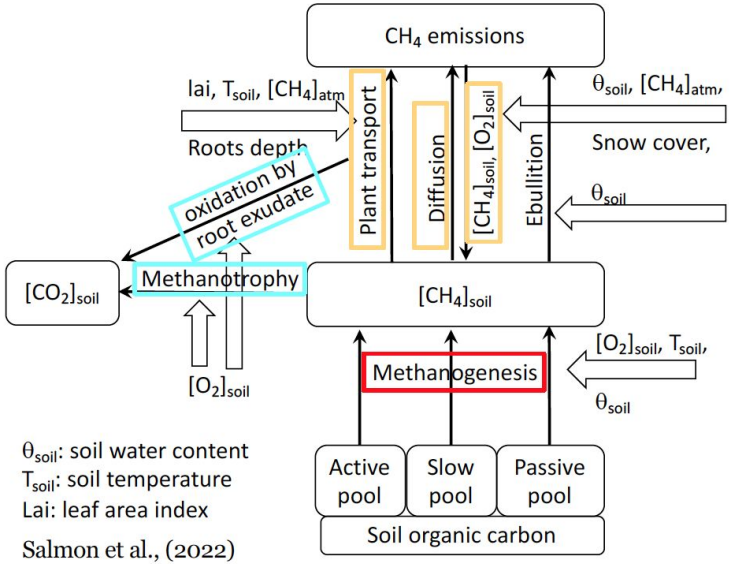
HIGH LATITUDE PROCESSES IN ORCHIDEE



Peatland and CH4 modelling in ORCHIDEE

METHANE EMISSIONS MODEL FOR PEATLANDS

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



θ_{soil}: soil water content
T_{soil}: soil temperature
Lai: leaf area index

Salmon et al., (2022)

7 parameters to calibrate

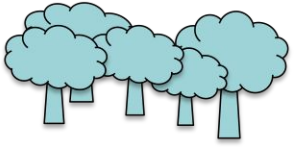
Global simulation of CH_4 emissions

⇒ Contact Elodie Salmon

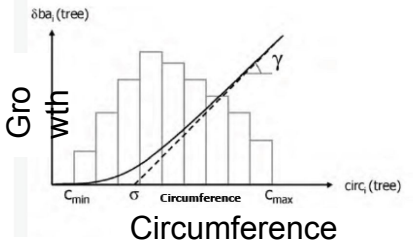
Land Management
recent / new developments

Forest management and stand description

Include diameter & age classes



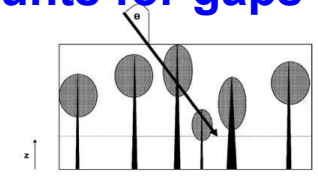
Allocation : "big get bigger"



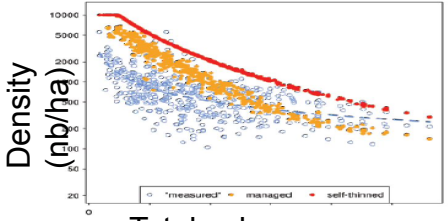
ORCHIDEE - Trunk

(Naudts et al., 2015)

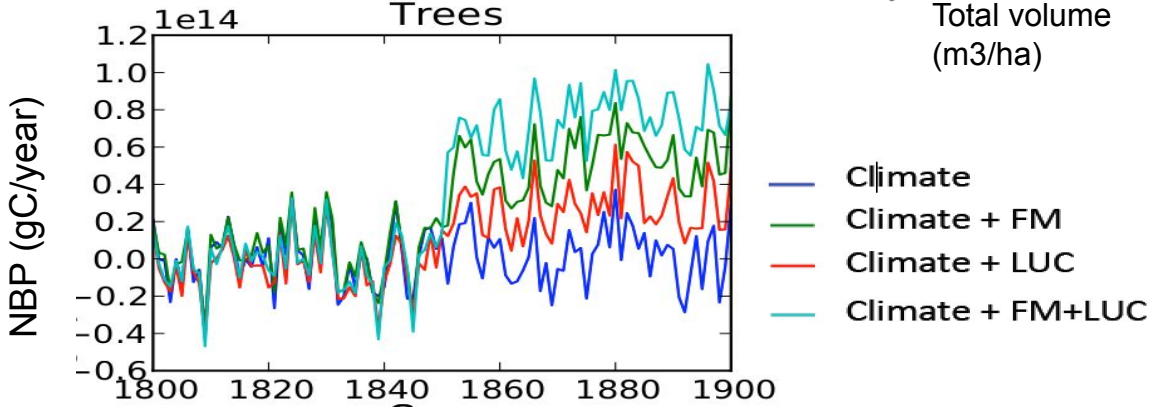
Accounts for gaps (PGAP)



Mortality from self-thinning



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



Gross land use change

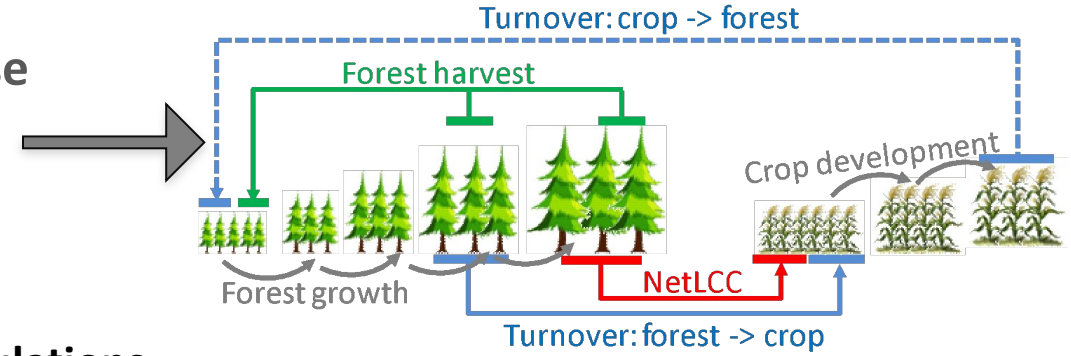

Deforestation


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).

Chao Yue et al.

Cultivated ecosystems : major crops

Phenology

Growth stage

LAI dynamics

Allocation

Competitions for C

Root vs. shoot

Vegetative vs. reproductive

Ċ Ċ

Managements

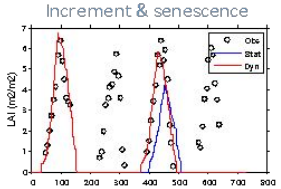
Residue

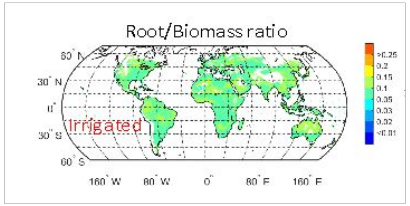
Fertilization

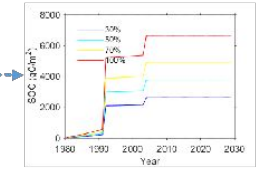
Irrigation

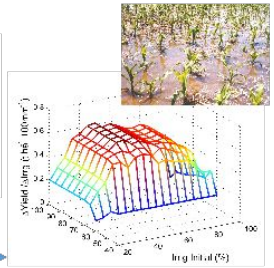
Rotation

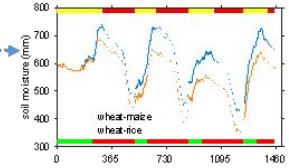
Ċ Ċ







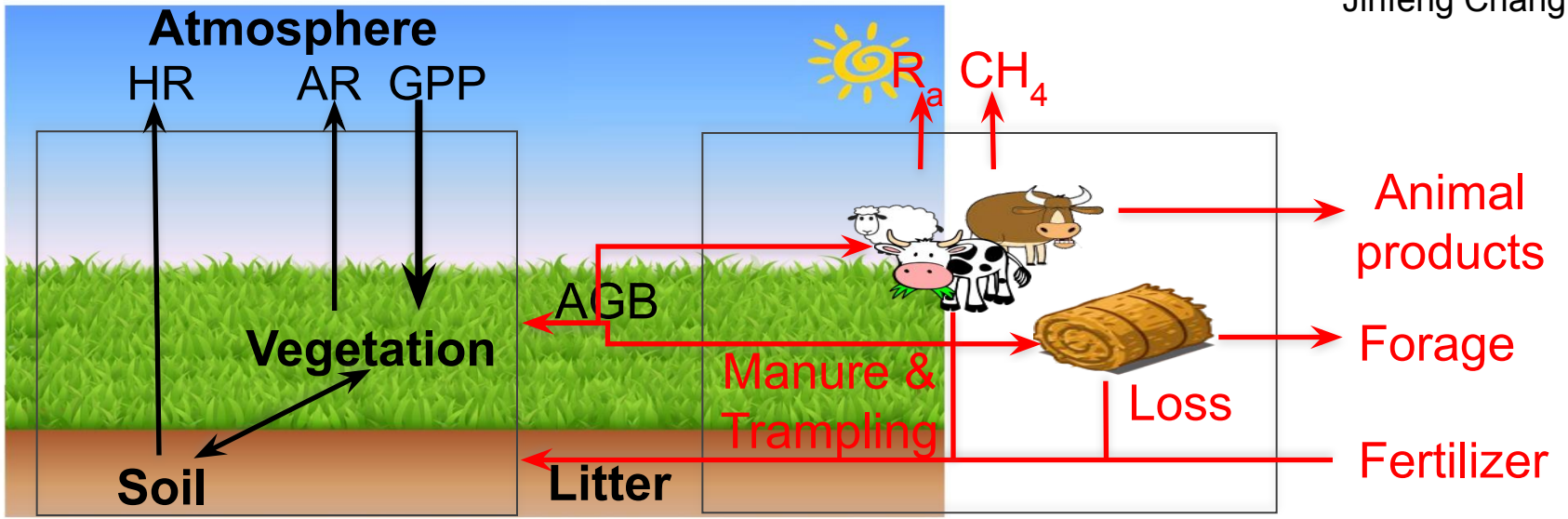




Xuhui Wang et al.

Grassland: from intensive pasture to rangeland

Jinfeng Chang et al.

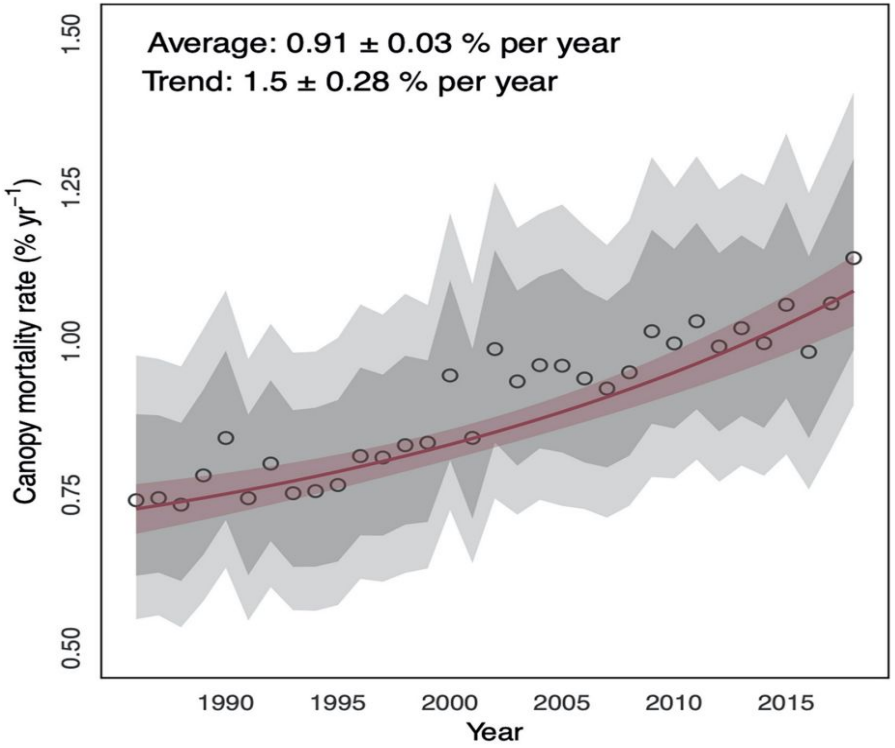


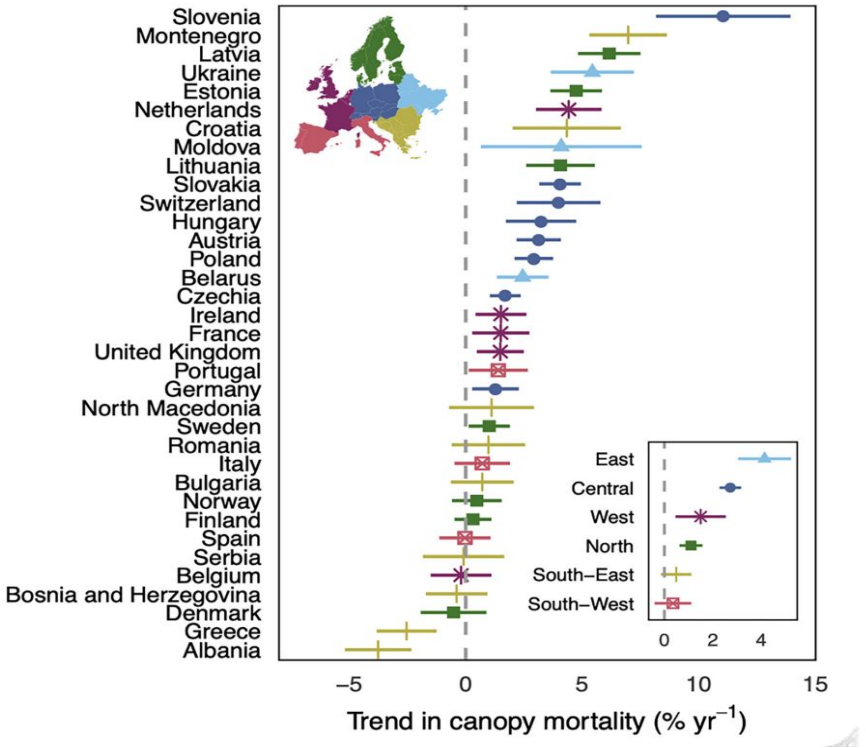
Applications:

- 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 !
(on-going developments)

Increasing trend in EU forest canopy mortality





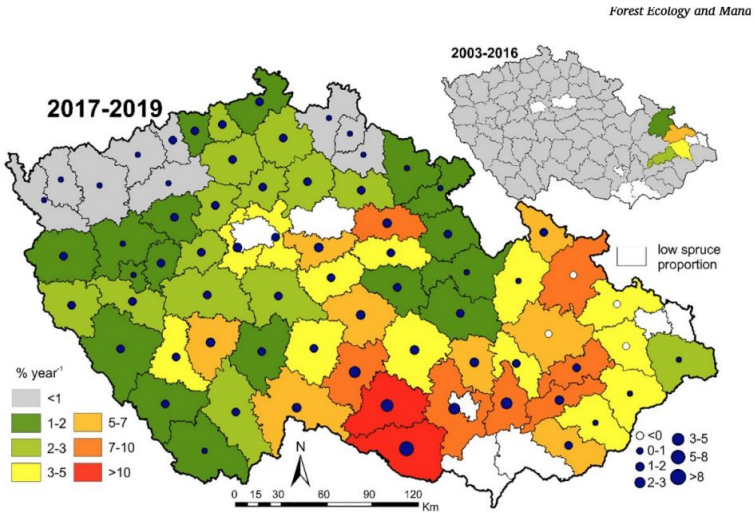
Senf et al. 2021, One Earth

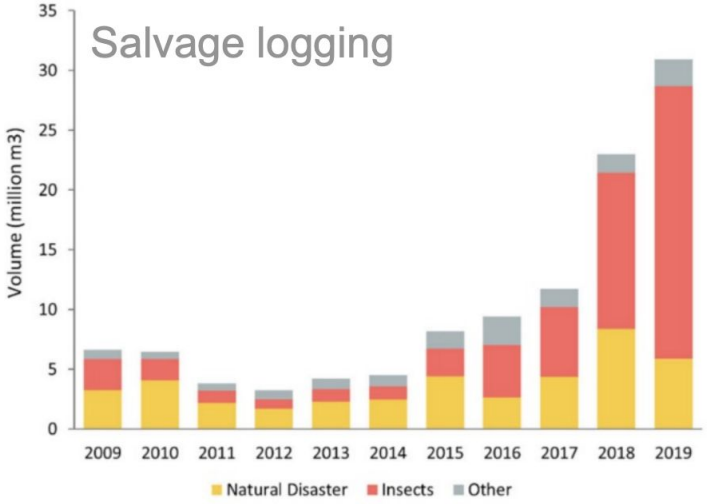
Increasing trend in EU forest canopy mortality

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



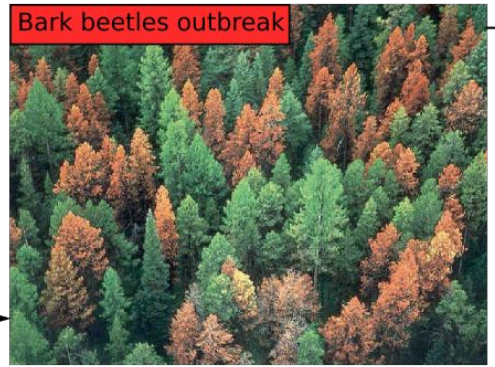


Natural Disaster **Insects** **Other**

Mortality cascade is key to model ecosystem stability

An example of mortality cascade we would like to implement.

Tree mortality



Tree mortality

Tree mortality

+ tree host

+ dead wood

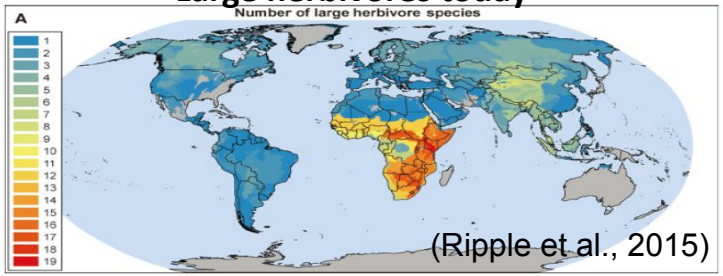
Abrupt mortality events need to be linked together in order to model mortality cascade

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

Various developments...

Representing wild large herbivores

Large herbivores today

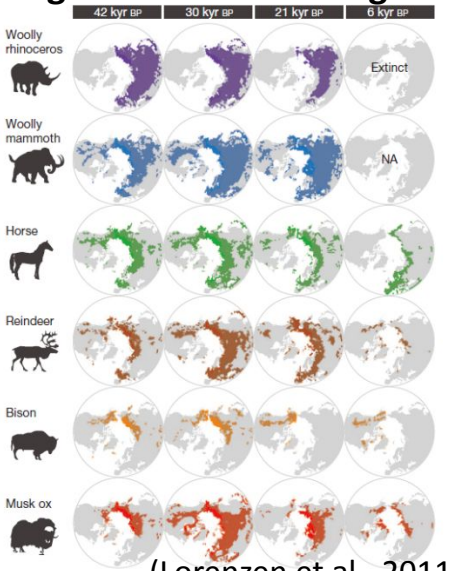


(Ripple et al., 2015)

Herbivore biomass in the Arctic during 40~15 kyr BP: **~9000** kg/km^2
⇒ comparable to today's African savannah

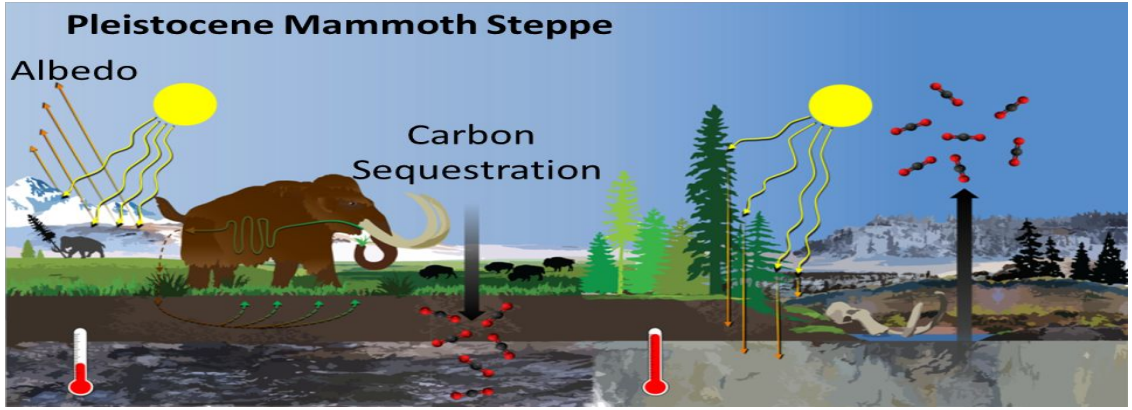
Bones preserved in yedoma deposits (Zimov et al., 2012)

Large herbivores during late-Pleistocene



(Lorenzen et al., 2011)

"keystone herbivore" hypothesis
(Owen-Smith, 1987; Zimov et al., 1995)



The terrestrial biosphere and atmospheric chemistry

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

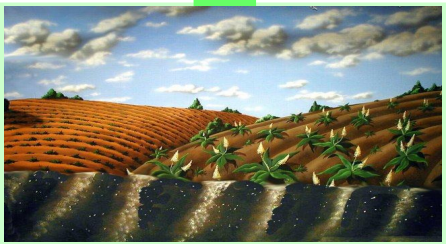
Nitrogen oxides
10% of global emissions

O_3

NOx

Isop.

OH



Vegetation

Wetlands

Soils - Cultures

Chemistry-vegetation retroactions

Atmospheric chemical composition

CO_2

Pollution: O_3, NOx, SO_2 and particles

Deposition

Deposition

Deposition

⇒ Growth, Distribution, Functioning

Vegetation

Wetlands

Soils - Cultures