ORCHIDEE sub-grid processes: Multi-tiling for Energy, Water and Carbon

Agenda

- The new “multi-tiling” versions of ORCHIDEE. Present and discuss principles of the approach, first results, questions on how to best implement multi-tiling in ORC (C. Ottlé)
- Multi-tiling within JULES model (J. Polcher)
- ORCHIDEE-MICT: How multi-tiling has been implemented in the crop version (Ph. Ciais)
- Multi-tiling for hydrology: new results about hillslope heterogeneities and perspectives for a comprehensive description of wetlands (A. Ducharne)
- Multi-tiling for the soil carbon cycle (B. Guenet / A.S. Lonsø)
- Multi-tiling implementation in ORCHIDEE: questions on how to best implement multi-tiling in ORC (A.S. Lonsø)

- Open discussions (Lead: Ph. Peylin)

Multi-Energy Budgets in ORCHIDEE
ORCHIDEE-DOFOCO
ORCHIDEE-MEB
ORCHIDEE-LAKE

J. Ryder, A.S. Lansø, V. Bastrikov, K. Petrus, A. Bernus,
C. Ottlé, P. Peylin, S. Luyssaert, J. Polcher

OUTLINE - Multi-Tiling in ORCHIDEE

- Motivations
- Multi-tiling frameworks
  - MEB and LAK results
- Questions for future developments:
  - Spatialization
  - Treatment of NOBIO surfaces
  - Implementation in ORCHIDEE CAN
    - ✓ Model structure
    - ✓ Array construction

Motivations: better representation of subgrid variability

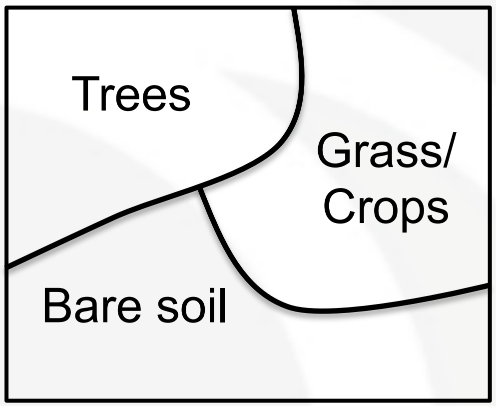
Land cover plays a key role on surface variables and fluxes

- Land cover determines the hydro/thermal/roughness properties
- Surface processes non linear (average ≠ integration)
- Continental surfaces highly heterogeneous
- Landscape heterogeneity and vegetation patterns are controlled by topography, slope, aspect, water availability, etc…
- Soil and vegetation strongly linked, spatial organisation is not random
- Snow/glaciers covered areas should benefit from separate EWBs
- Representation of water bodies, urban areas, etc.. requires specific processes and separate EWBs

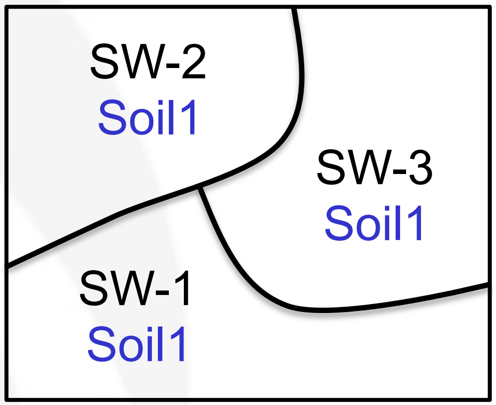
Landscape heterogeneity & organisation

ORCHIDEE 1 Energy and 3 water budgets per grid cell, 1 atmospheric column

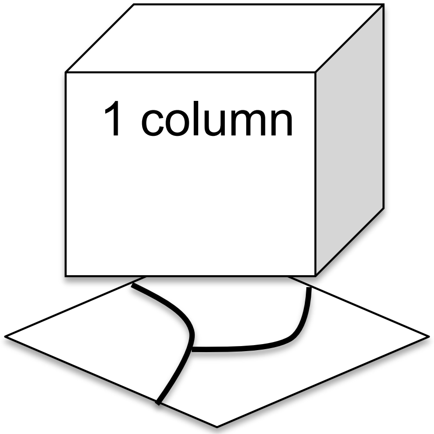
Surface Vegetation



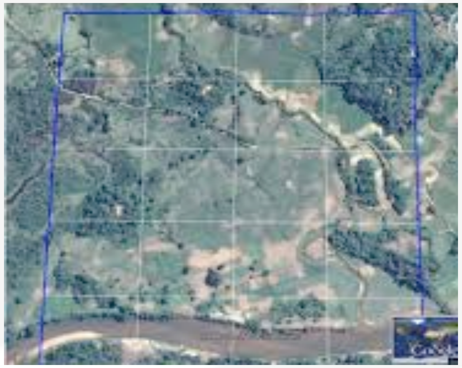
Ground Hydrology



Atmospheric coupling



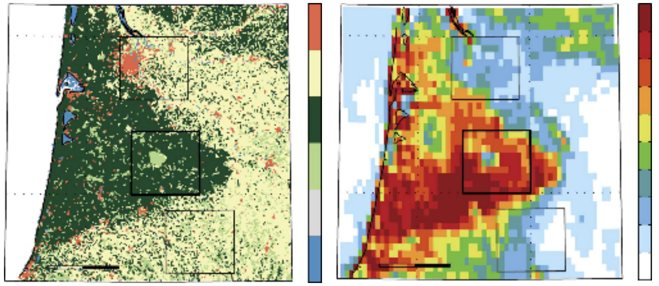
Reality



Satellite product ≈10 m

Soil properties
- Topography (dam to km)

Forest cover ➔ more cloud



Ex: Landes forest - France
(Teuling et al. 2017)

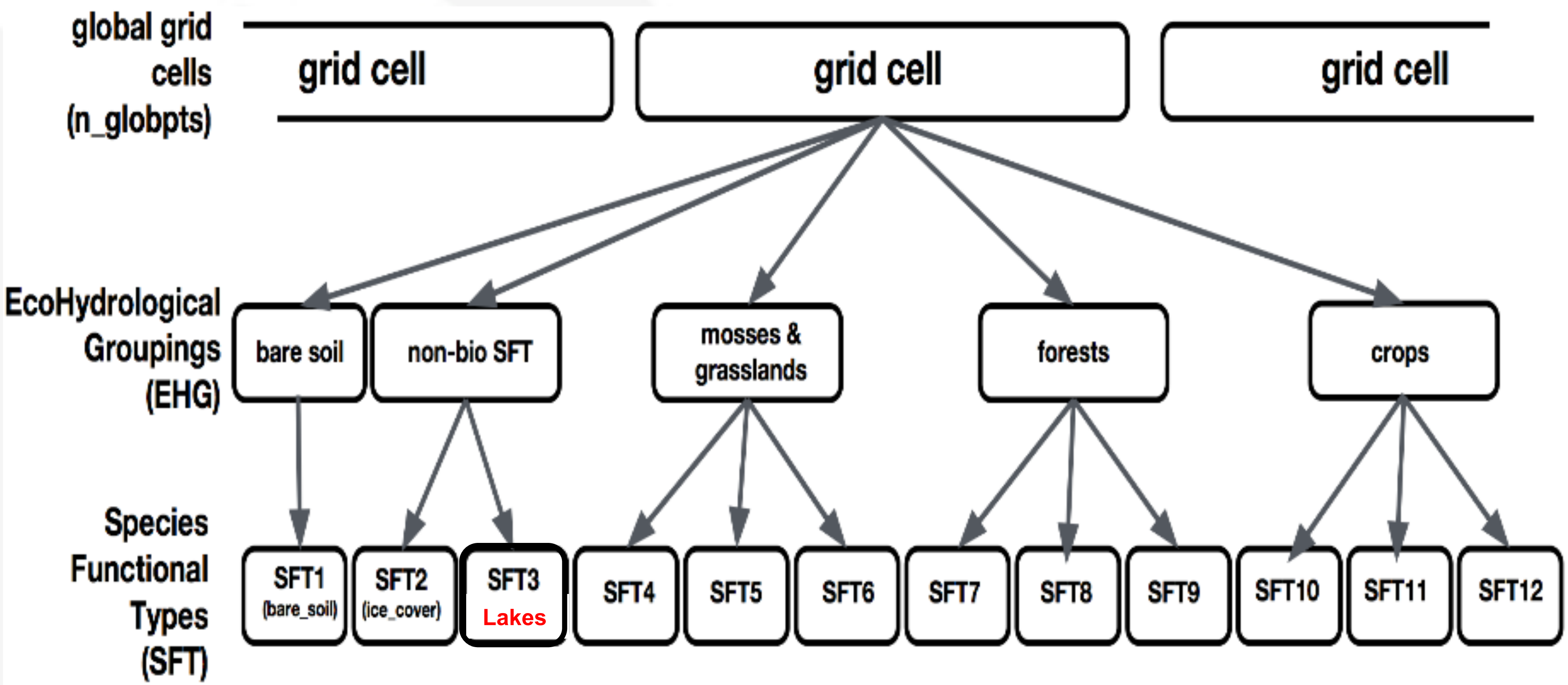
People involved:

- James Ryder (Oct-2015 - June 2016)
- Karine Pétrus (Oct 2016 - Aug 2018)
- Vladislav Bastikov (Nov 2018 -)
- Anne- Sofie Lonso (Jan 2019 -)
- Anthony Bernus (Oct 2018...)

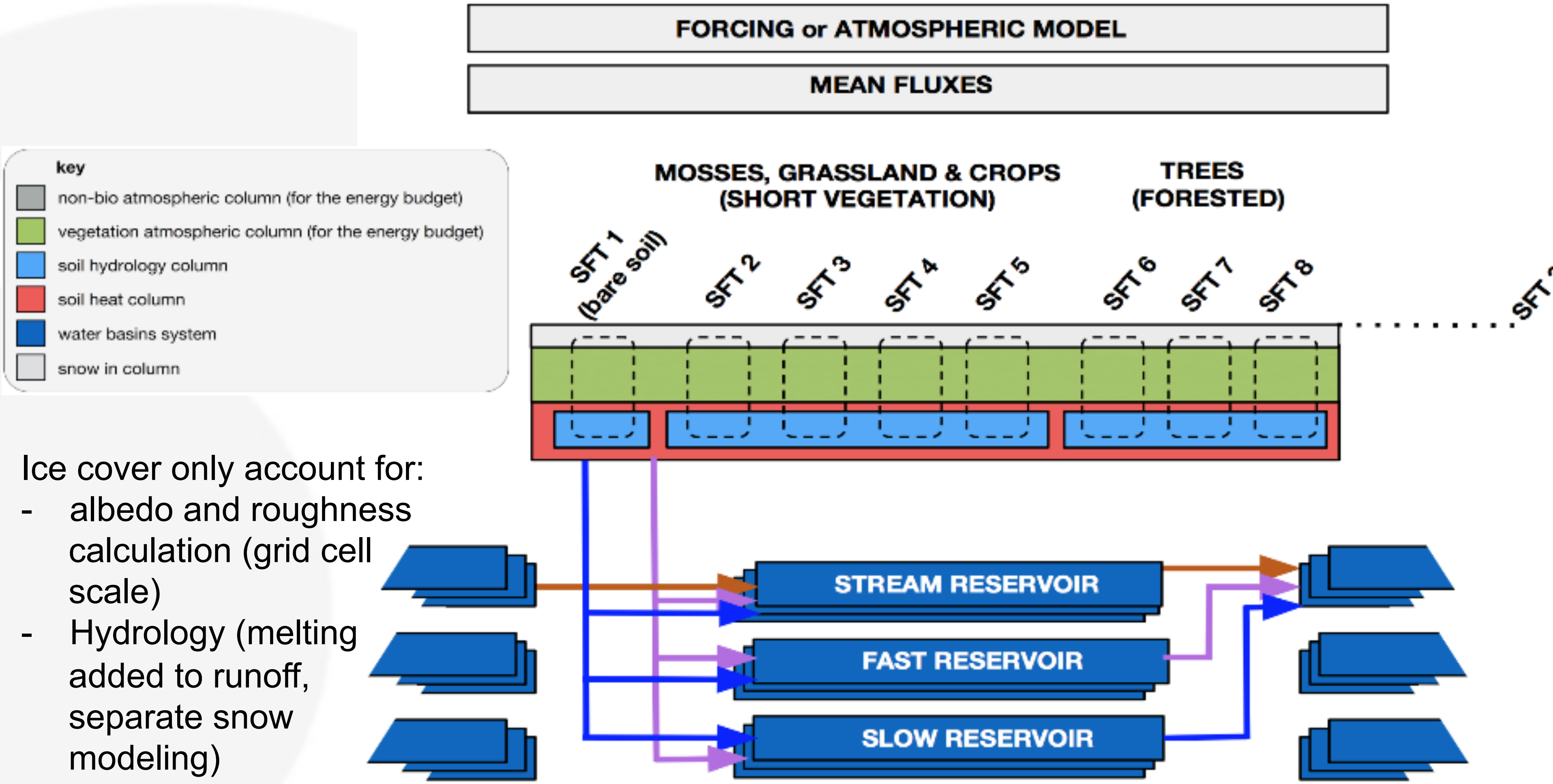
+ Catherine O., Philippe P., Jan P., Sebastiaan L., Fabienne M., Josefine G....

ORCHIDEE modeling approach

Representation of land cover heterogeneity: PFTs / SFTs



Current Trunk version (case A)

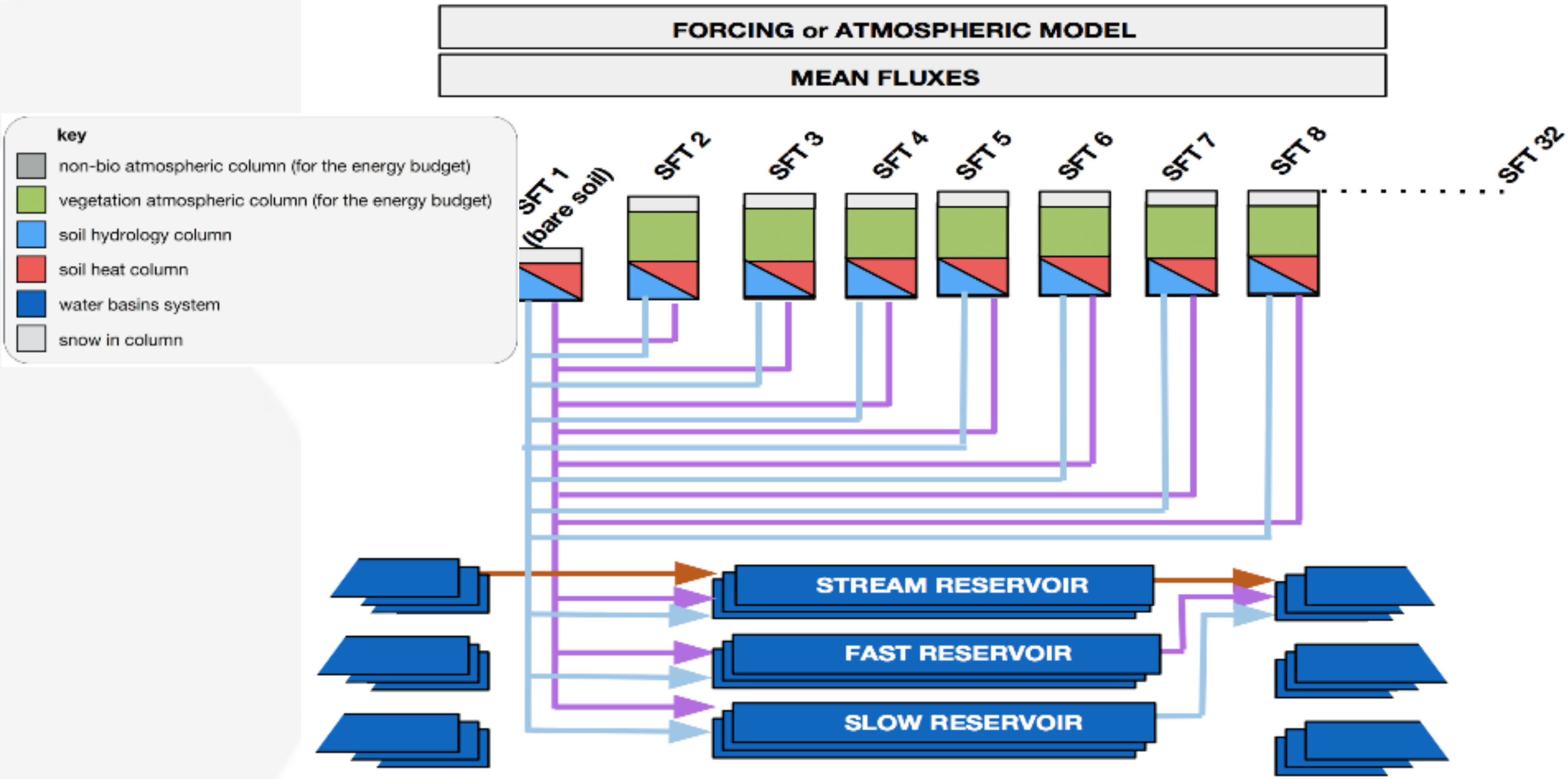


Ice cover only account for:

- albedo and roughness calculation (grid cell scale)
- Hydrology (melting added to runoff, separate snow modeling)

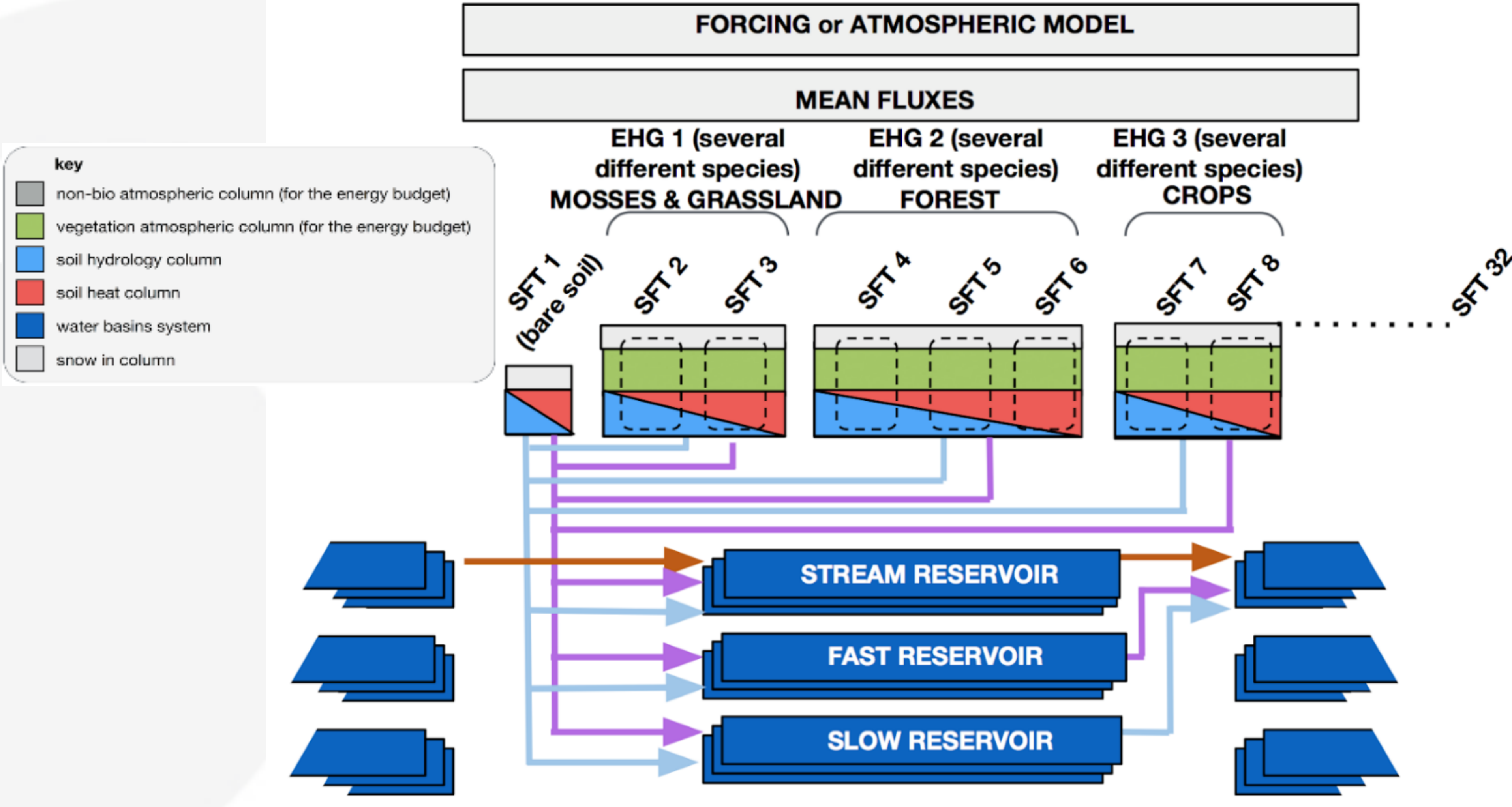
A single energy budget, snow budget and soil thermal scheme for all SFTs combined . Note that there are separate soil hydrology for bare soil, short vegetation and forested ecohydrological groupings

Multi-tile version (case B)



One energy budget per Surface Functional Type (SFT), one snow budget per SFT and one soil column (hydro and thermics) per SFT

Surface Functional Type grouping (case C)



One energy budget per Ecohydrological group (EHG), one snow budget per EHG and one soil column per EHG

Present status of the various branches

- ORCHIDEE-DOFOCO: running on 1 grid cell, not validated yet
- ORCHIDEE-MEB: based on Trunk version 4369, validated and running on 1 grid cell
- ORCHIDEE-LAK: based on Trunk version 4369 and MEB version 5169, including Flake lake model, validated and running on 1 grid cell

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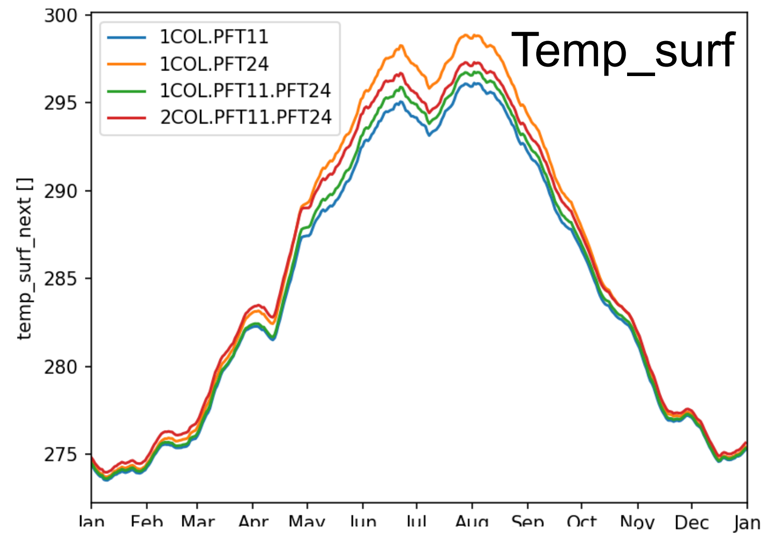
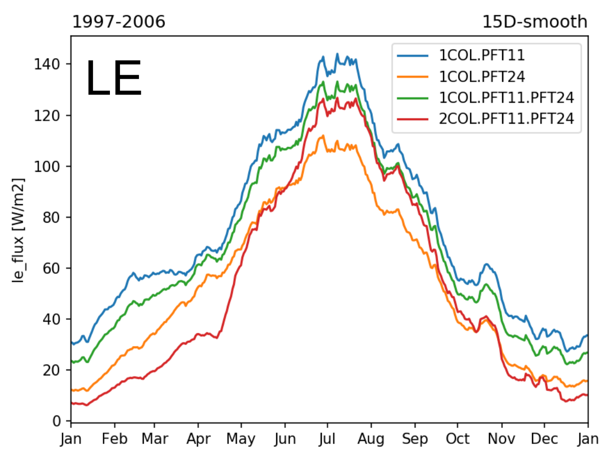
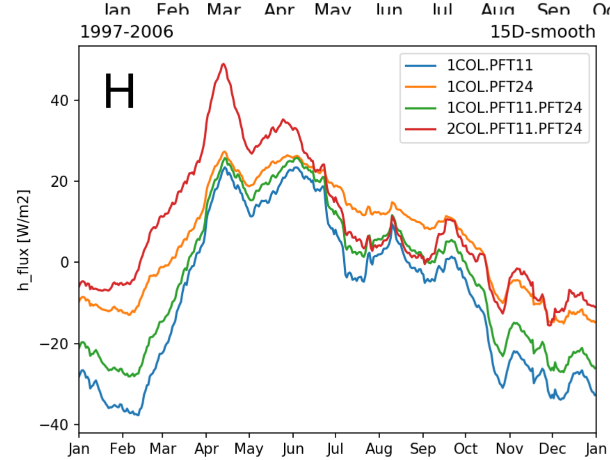
Multi-tiling energy budget

Single tile 100 % Beech Forest,
Single tile 100% grasslands,
Single tile, 50 % beech forest, 50 % graslands
Two-tile, 1 tile 100% beech + 1 tile 100% grassland.

- FLUXNET site FR-Hes(48.7 N, 7.1E)
- Atmospheric forcing : 1997-2006
- Spinup : 3 x 10Y
- Output frequency : half-hourly
- Post-processing : daily mean + 15-day moving average window





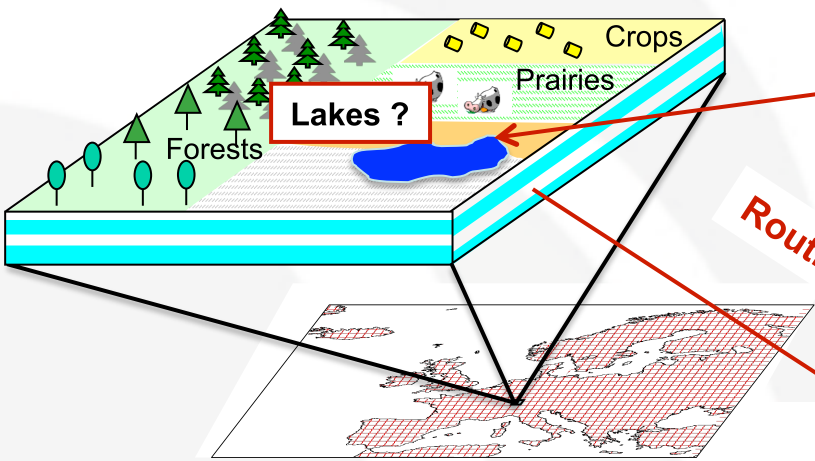


Preliminary results
Still some issues

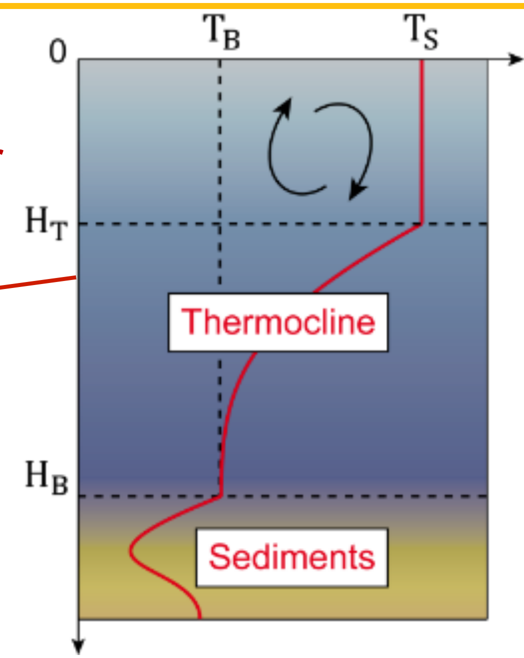
ORCHIDEE-LAK:

Flake 1D model (Mironov, 2010), implemented in ORCHIDEE-MEB

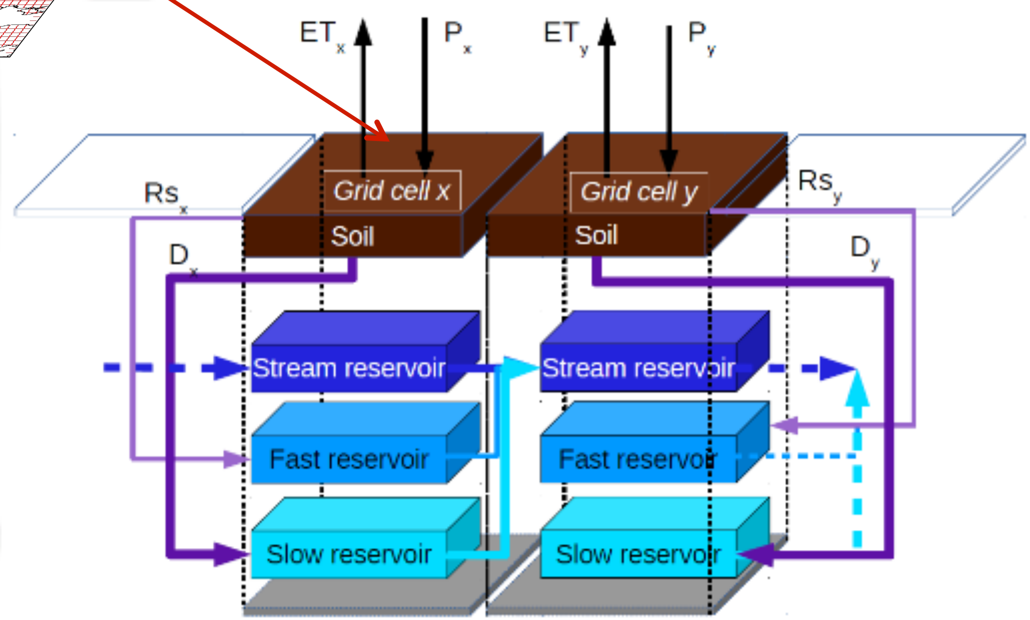
Surface energy budget, snow and freezing processes calculated by ORCHIDEE



Flake model approach for solving lake temperature profile

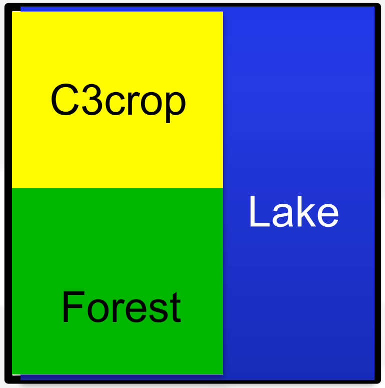


Routing module

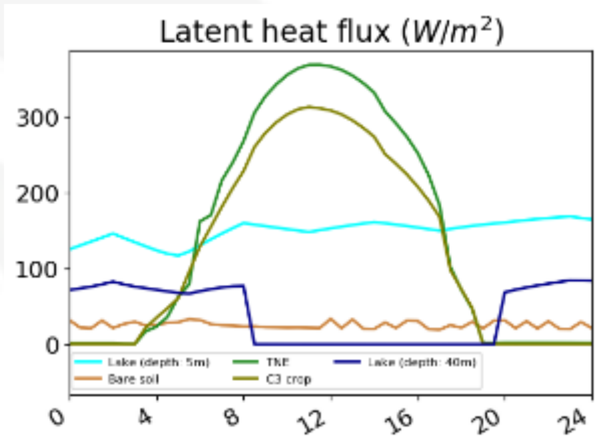


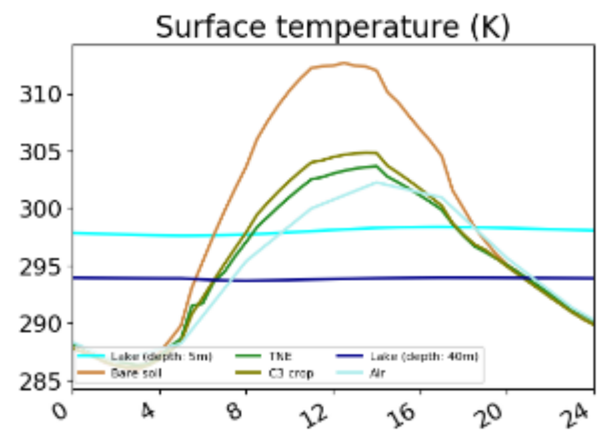
River routing module

ORCHIDEE-MEB and LAK simulations (grid cell)

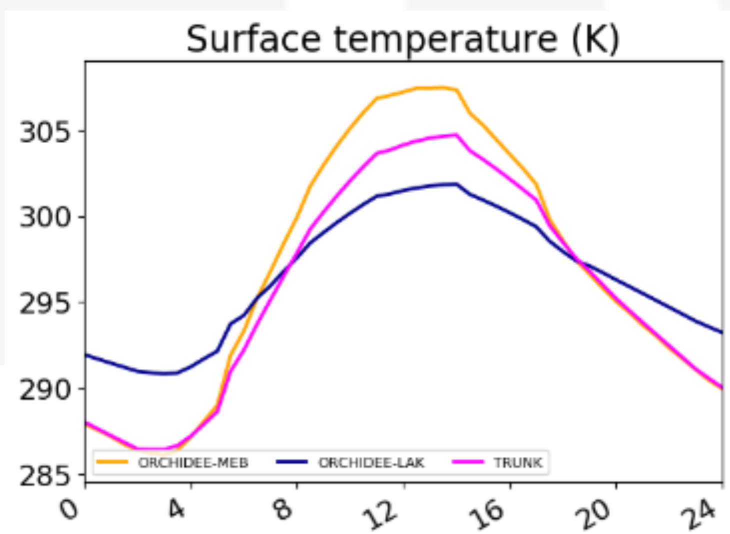


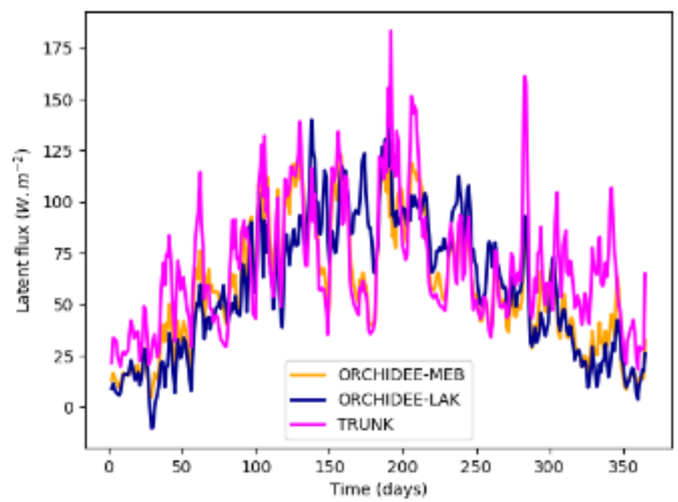
Comparison to ORCHIDEE Trunk: example of a pixel composed of 40% lake, 30% C3 crop, 30% Forest, Lakes represented as bare soil in the Trunk version.





Comparison at pixel scale to ORCHIDEE Trunk and ORCHIDEE MEB:





Perspectives

- How to move on ?
  - Present versions work only on 1 grid cell
  - To run global simulations, input/output procedures need to be developed
  - The NOBIO issue need to be solved: NOBIO presently concerned only glaciers and is embedded "badly" in the hydrol/snow and thermal routines
  - The computing time and the size of the output files have increased by a factor of 3 to 4
  - Operational LAK version needed urgently

Main questions ?

- Should we code MEB in ORCHIDEE-CAN differently?
- Which level of flexibility (between cases A / B / C)?
- Should we potentially have different grouping "cases A / B / C" for each pixel?
- Should we for each "group" have an additional split for the energy and water budgets: Snow-covered vs Snow-free budgets?
- What is the best method to code the multi-tiling energy budget ? (-> next slide)

How to code the multi-energy budget ?

1. Meta loop over all “groups” of or individual SFT, in “Sechiba” to call “Enerbil” for each of them
   - Need to store the “energy related” prognostic variables in specific arrays in “Sechiba”
   - Then load the data into common working arrays for “Enerbil”

   ➔ modular but “complex” array manipulations

2. Loop over all energy budgets within “Enerbil”
   Add a dimension (nenerbil) for most arrays in “Enerbil”

   ➔less modular but more straightforward

➔Strategy to be decided collectively...

The problem of sparse arrays !

- Typical arrays for carbon related variables
  XX (npts, npft_max, n_diameter_class, [n_species, …])
  n_diameter_class: only for tree PFTs
  n_species: Carbon, Nitrogen, isotopes, etc ..

➔ Sparse matrix as for each pts npft may be << npft_max
And for grass/crops n_diameter = 1

➔ Potential solution: group all dimensions into 1 index: “nall”
- ➔ Need to have specific functions to get the index of PTS, PFT, diameter, species, … from « nall » and vice versa
- ➔ Need to expend the arrays for saving on output files !
- ➔ Rem: working with “nall” can be also parallelised

Additional slides

Accounting for sub-grid heterogeneity ?

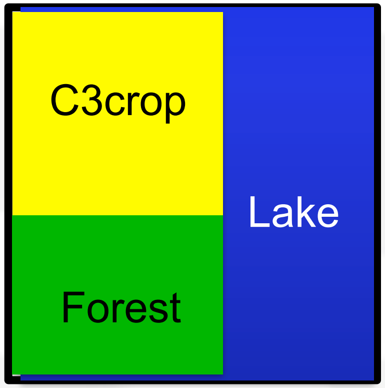
➔ Existing/upcoming new products of HR (10m) land cover open new possibilities !

➔ Plant types/species – topography – soil properties (water, nutrients) are not random within grid cells of 20 – 50 km !

➔ ESA HRlandCover project

- 10-15 m HR land cover over Amazonia, Sahel, Siberia
- How to use these maps to better characterize:
  - Tile organisation (with slope, elevation, …)
  - Level of Tree Clumping at landscape- and stand scale
  - Drag coefficients for atmospheric exchanges

ORCHIDEE-LAK simulations (local grid scale)



Comparison to ORCHIDEE Trunk: example of a pixel composed of 40% lake, 30% C3 crop, 30% Forest, Lakes represented as bare soil in the previous version.

Large impact of lake depth on surface temperature & fluxes

Significant contribution of lakes in ORCHIDEE