Contribution of SWOT-like data to model lake/reservoirs in ORCHIDEE land surface model

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Objectives

Representation of **lakes/reservoirs** in the ORCHIDEE Land Surface Model, continental part of IPSL-LMDZ climate model

Use Remote Sensing data (especially altimetry) to **calibrate/control model parameters** via Data Assimilation methods

Framework of the **SPAWET project** funded by CNES (2016-2018), cf. poster 11.

Workplan

Development of a **lake modeling** in ORCHIDEE (in progress)

Development of **Data Assimilation tools** (just starting…)

Application/tests on **Seine river reservoirs,** study of **the assimilation of** SWOT-like observations based on the **simplified large scale simulator**

Outline

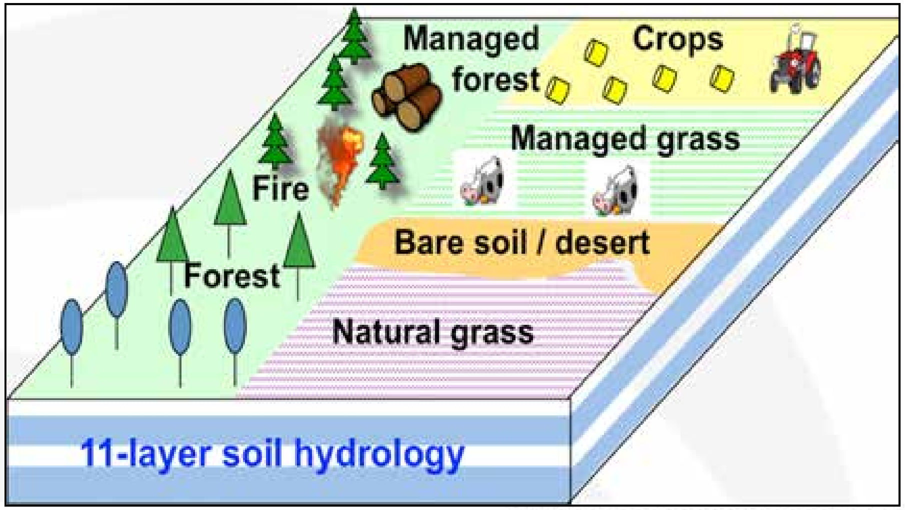
Model developments in ORCHIDEE

Study region

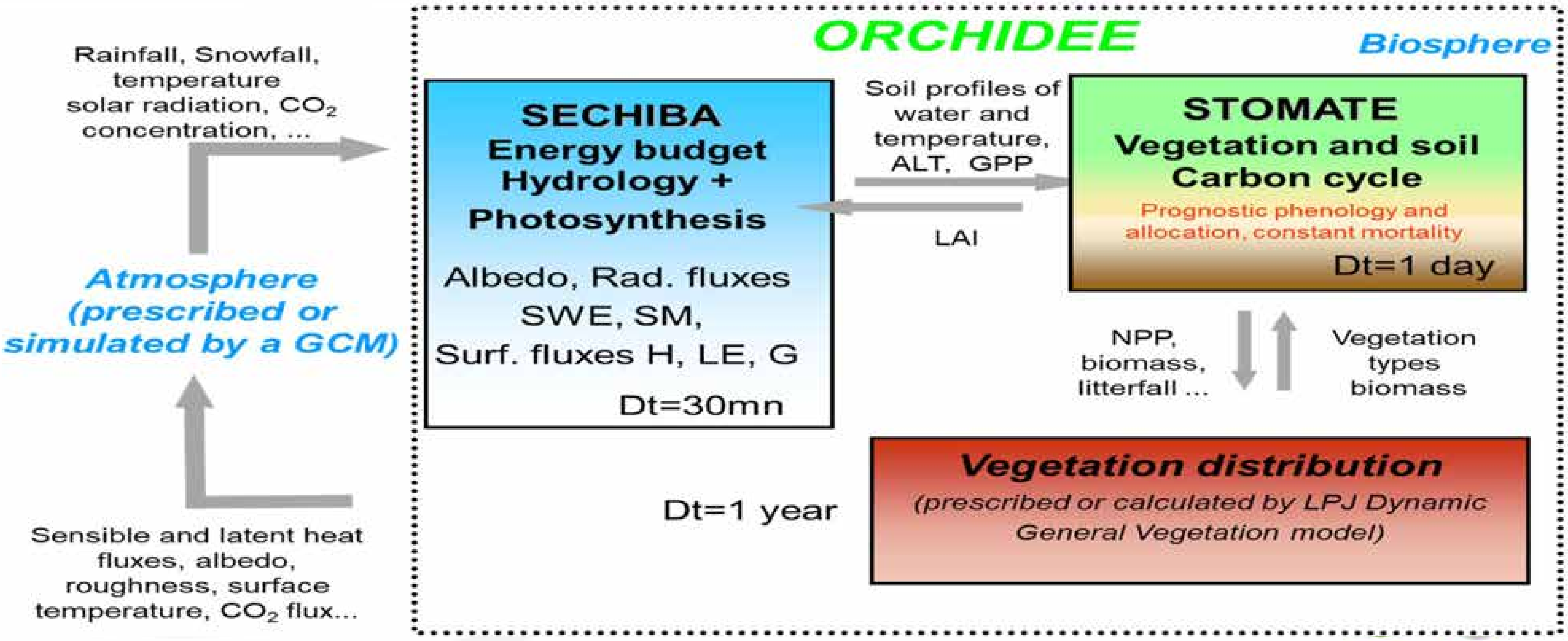
Lake surface water elevation errors

Preliminary experiments: model sensitivity to lake depth, impact on atmospheric fluxes

ORCHIDEE land surface model



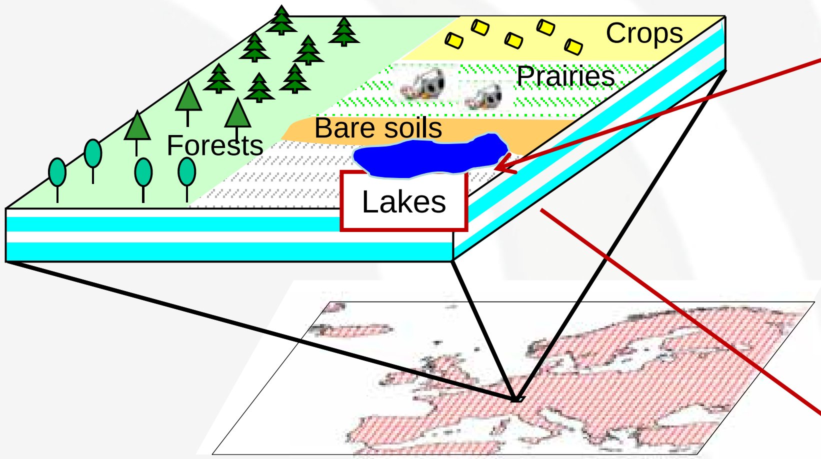
- Land surface component of the IPSL – Earth System Model
- Computes energy, water, carbon and nitrogen balances of terrestrial ecosystems



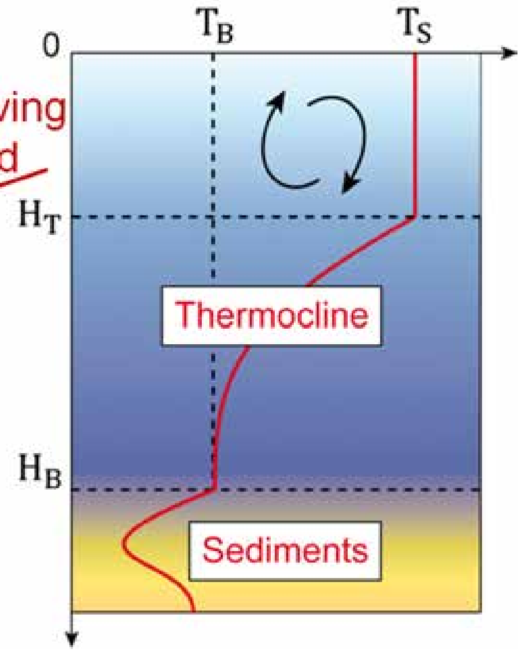
Lake energy budget modeling :

Based on Flake 1D model (Mironov, 2010) and ORCHIDEE-MEB version (Ryder et al. in prep.)

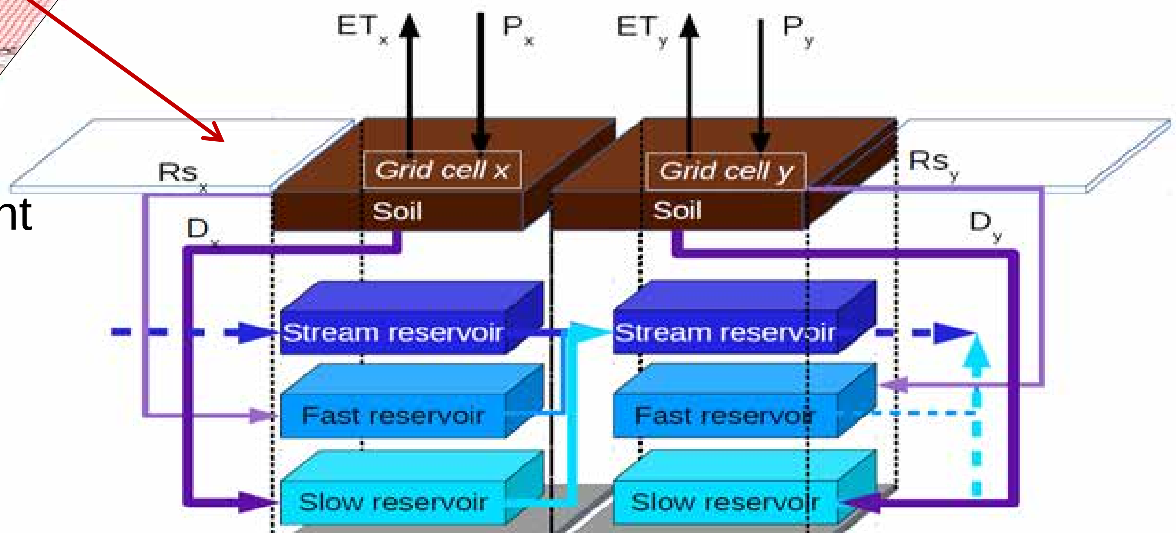
ORCHIDEE MEB version : separate water and energy budgets on each land cover class (Surface Functional Types)



Flake model approach for solving lake temperature profile and surface fluxes



River routing module



1st step: lake area fraction constant

2d step: Mass balance calculation and links to river routing, water table and subgrid runoff

Flake model: 4 layers considered for EB calculation

- The mixed layer where temperature is constant
- The thermocline where temperature vary with depth
- Two sediment layers (optional)

} described by self-similarity laws

- Water freezing/melting processes
- Snow model on ice cover

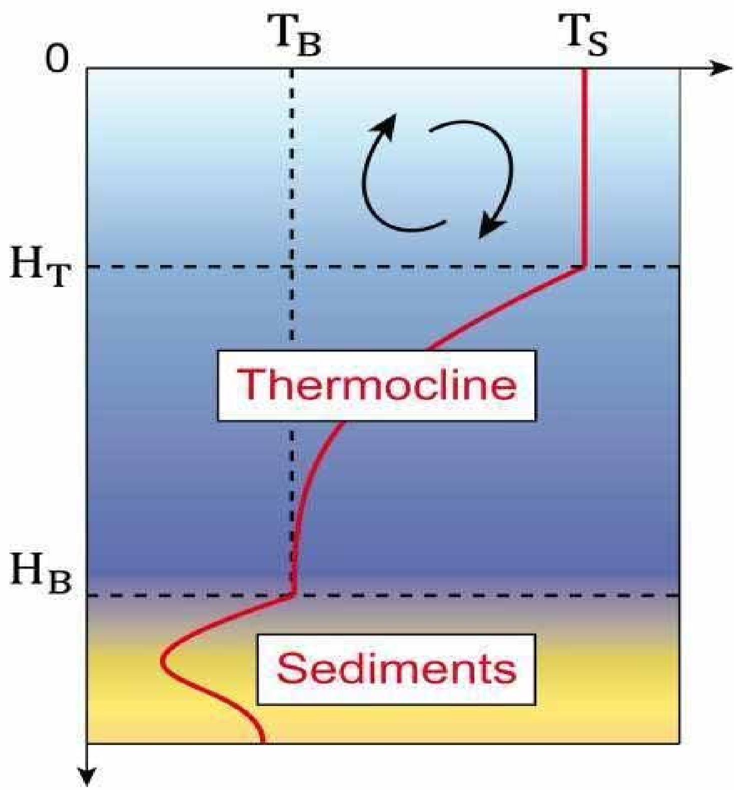
Surface and bulk energy budgets allows to estimate a mean lake temperature, the depth of the mixed layer, bottom (T_B) and surface (Ts) temperatures and surface fluxes

H_B = Lake depth

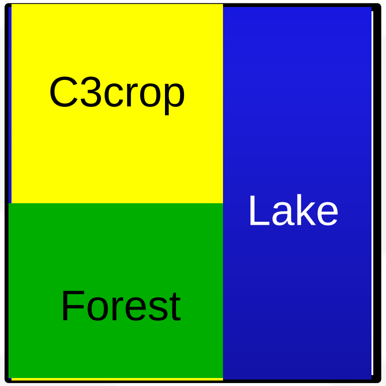
H_T= Mixed layer thickness

T_B = Bottom temperature

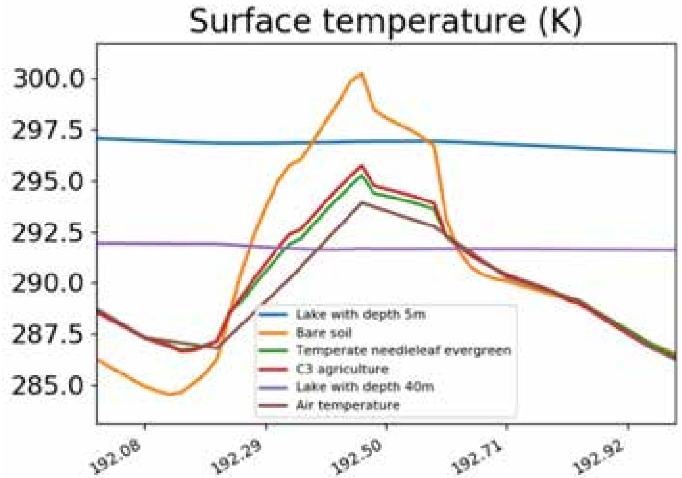
Ts = Surface temperature or mixed layer



ORCHIDEE-FLake simulations (local grid scale)



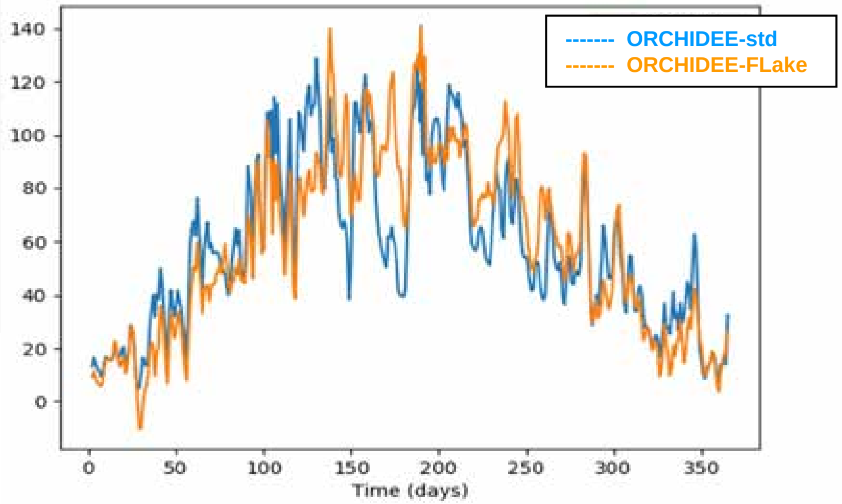
Comparison to ORCHIDEE standard: example of a pixel composed of 40% lake, 30% C3 crop, 30% Forest, Lakes represented as bare soil in the std version…



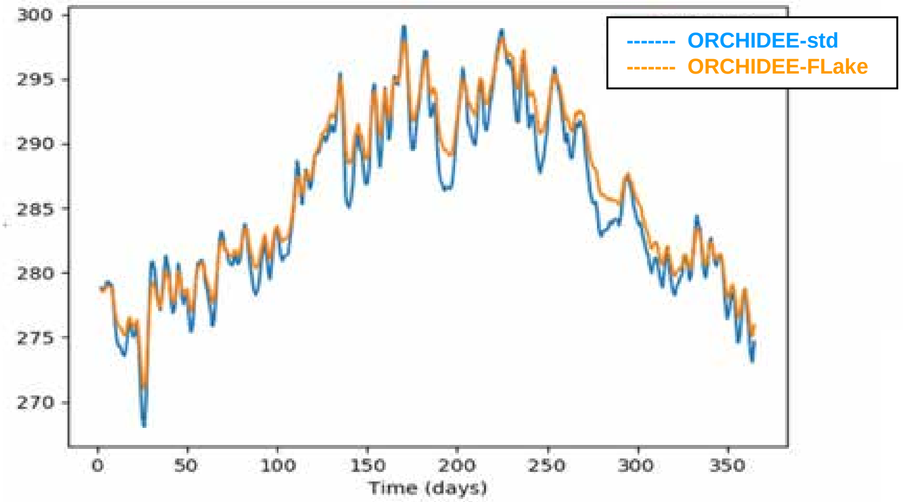
Large impact of lake depth on surface temperature & fluxes

Significant contribution of lakes in ORCHIDEE

Latent heat flux (W/m²)

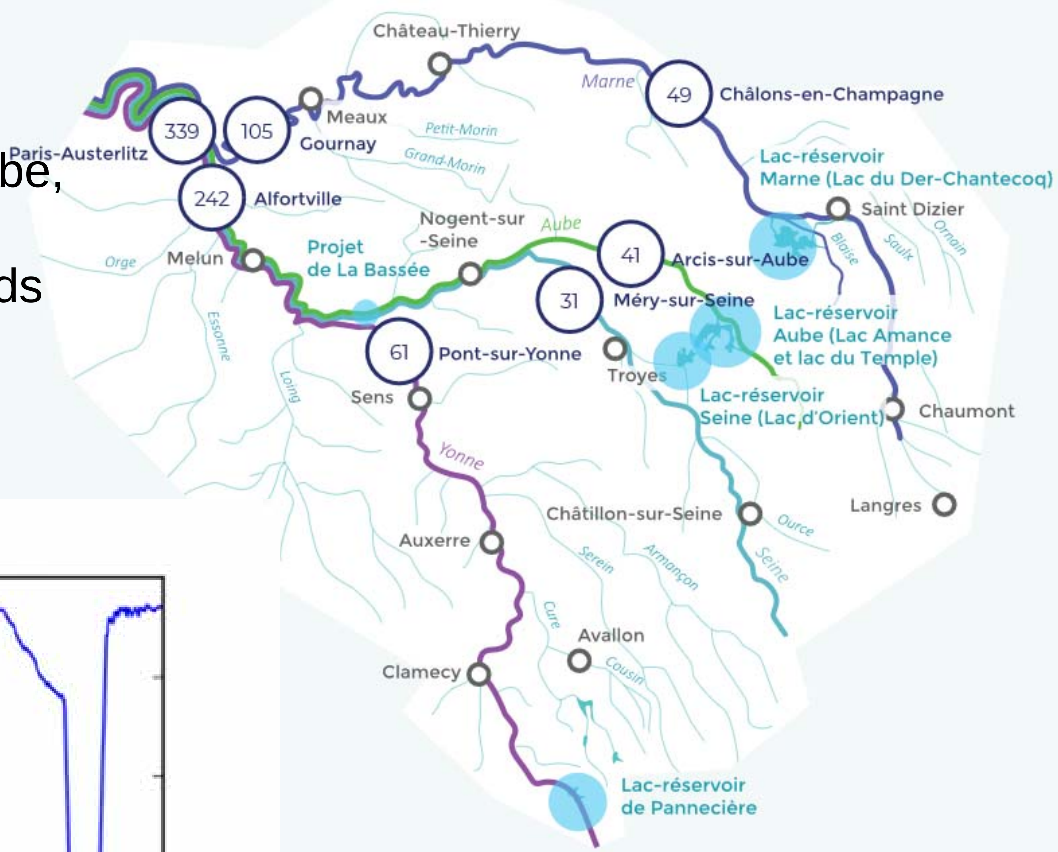


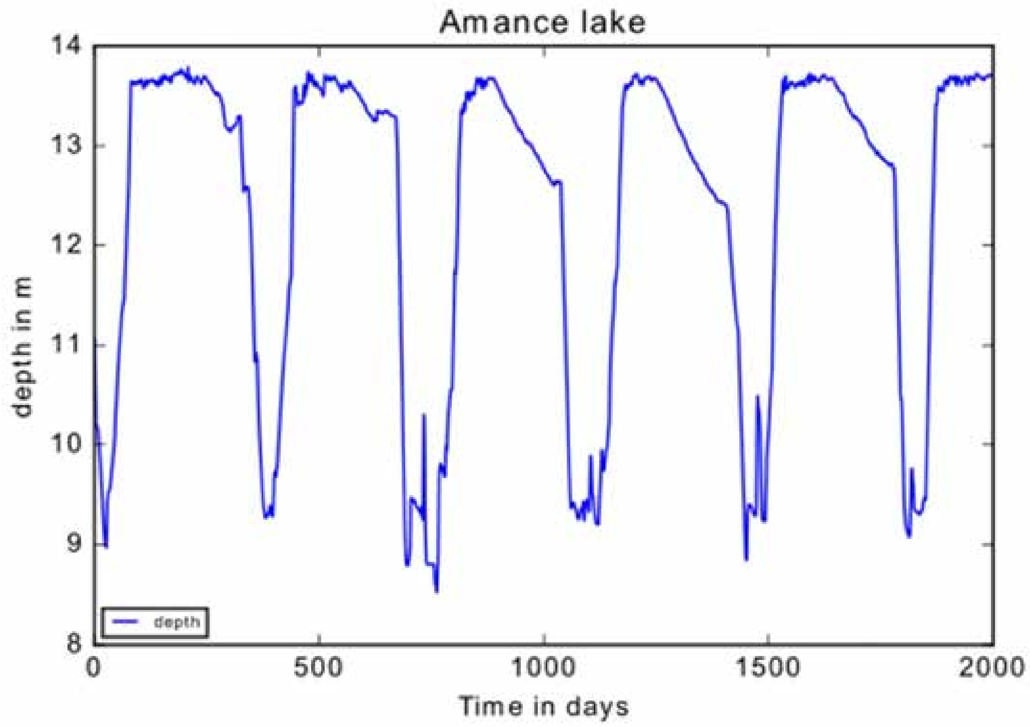
Surface temperature (K)



Lakes / reservoirs studied (Seine river)

Designed to control floods and protect Paris region:
- 5 large lakes on Seine and Marne, Aube, Yonne tributaries
- Filled in winter/spring to store the floods
- Water released in summer/fall to hold water levels and allow maximal water storage





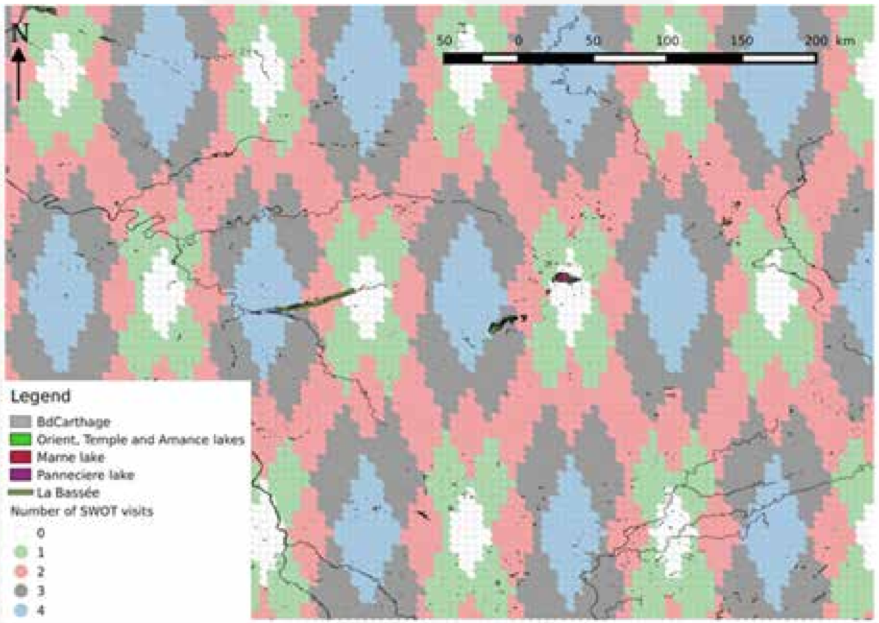
Lake	River	Surface Area (km2)	Depth range (m)
Der-Chantecoq	Marne	48	19
Orient	Seine	23	18
Temple	Aube	18	12
Amance	Aube	5	12
Pannecière	Yonne	5.2	48

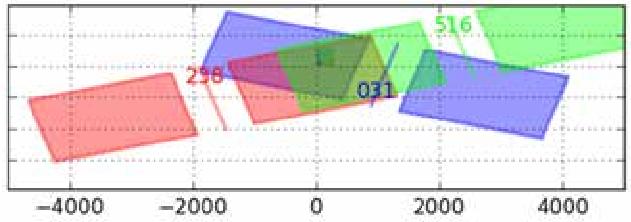
Generation of SWOT pseudo-observations

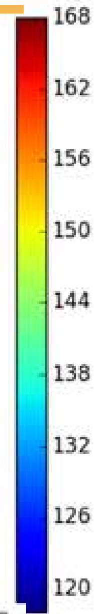
Use of the **large scale (LS) simulator**: compute **water elevation errors** given **lake geometry and instrumental noise** including geolocation error

Simulation over the Seine lakes/reservoirs:

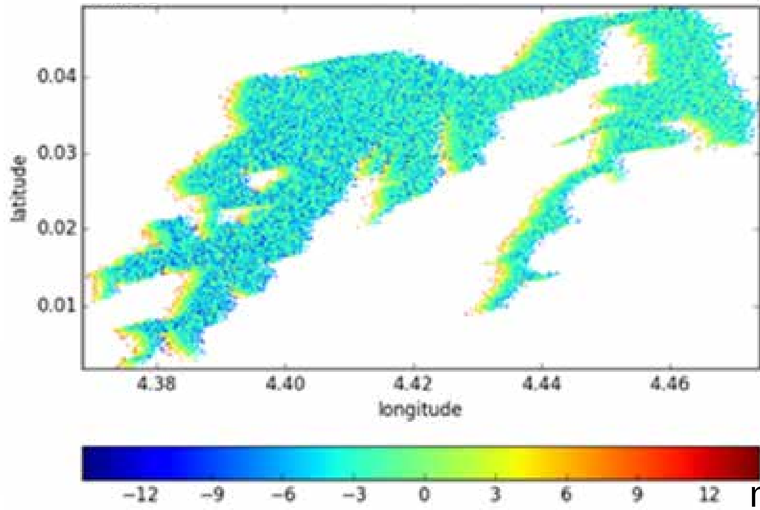
Orbit selection :







Simulated pixel cloud



Simulator parameters :

height perturbation = grey noise (bias = 5cm (constant in the swath), standard deviation (std) varying with viewing angle) : Multiplicative factor = $(50)^{-0.5}$; No temporal evolution of the error parameters

Generation of SWOT pseudo-observations

Large number of observations on the 4 Seine reservoirs (depending on the lake position in the swath, N vary between 10^4 (for the smallest) to 2.10^5

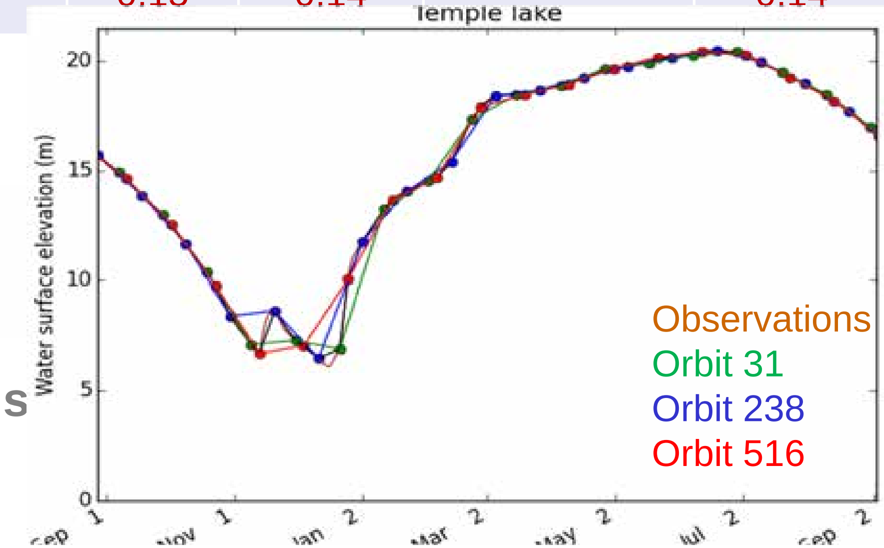
Results in terms of errors

Mean and Max values calculated on 6 years of observations equal to a few cms

Lakes	Orient	Temple	Panneciere	Amance
Area (km²)	23	18	5,2	5
Mean Error (cm) (Orbit 31) and Max(m)	4.38	5.51	5.05	5.00
	0.13	0,15	0,12	0,14
Mean Error (cm) (Orbit 238) and Max(m)	4.66	5.72	4.72	-
	0,12	0,14	0,12	-
Mean Error (cm) (Orbit 516) and Max(m)	4.35	4.45	-	4.95
	0.15	0.14	-	0.14

Generation of **SWOT-like observations** by adding the simulated errors to true measurements at SWOT sampling times.

Allow to study the **influence of temporal sampling on WSE and volume estimations**



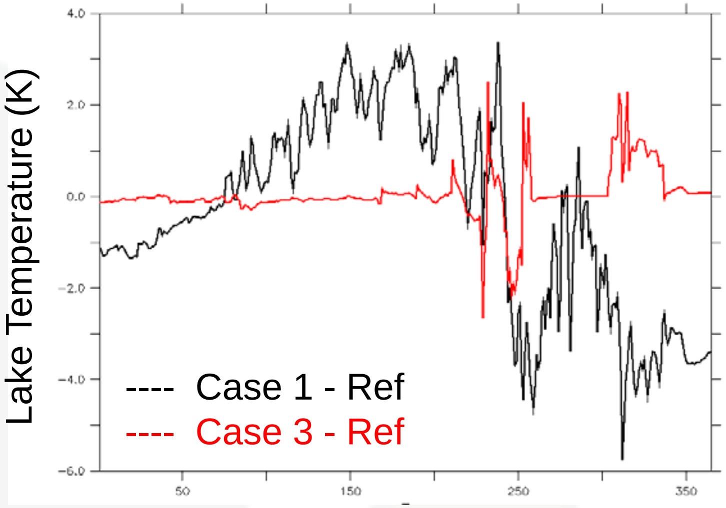
Data assimilation in ORCHIDEE-FLake

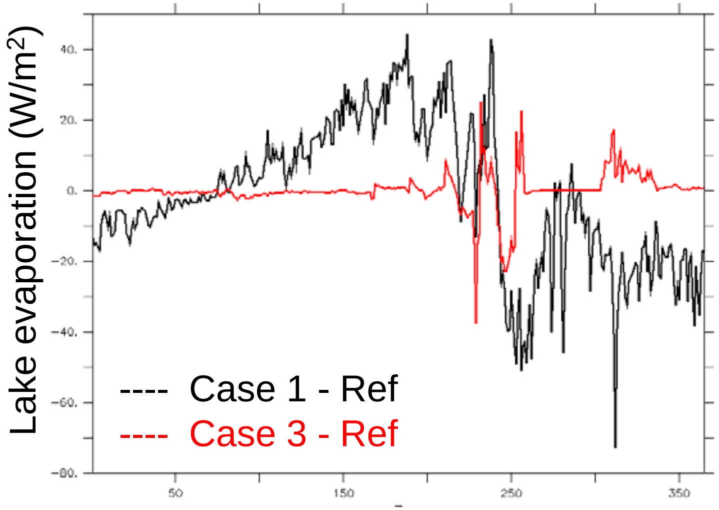
Direct forcing of depth observations (Pannecière Lake):

Case 1: Lake simulation with a **constant depth** of 40 m

Case 2: with **observed daily depths** (Ref.)

Case 3: using **SWOT depths** updated once/cycle





Errors **up to 6 K and 70 W/m^2** in daily mean between Case 2 and Case 1, **reduced to 4 K and 30 W/m^2** between Case 3 and Case 2.

Remaining errors during the periods of emptying/filling **where 21-day sampling not sufficient** to follow the rapid variations of water volumes.

Over one year, **error of lake evaporation reduced** from **+17 mm/m^2 to +3 mm/m^2**

Conclusions / Perspectives

ORCHIDEE-Flake model developed in **a multitile / MEB version**, shows **significant impact of lake depth** on surface temperature and fluxes

Validation in progress **with in-situ and satellite datasets** (lake temperature, evaporation and ice phenology)

SWOT error simulations: few centimeters for the Seine reservoirs, promising to control depth variable.

<u>On-going developments</u>:

- **mass budget equation** to predict lake volume and area evolution,
- application **of particle filter / smoother** to assimilate SWOT data and control lake depth/volume
- joint **assimilation of surface temperature and reflectances / albedo** to control **evaporation and turbidity parameters** as well.