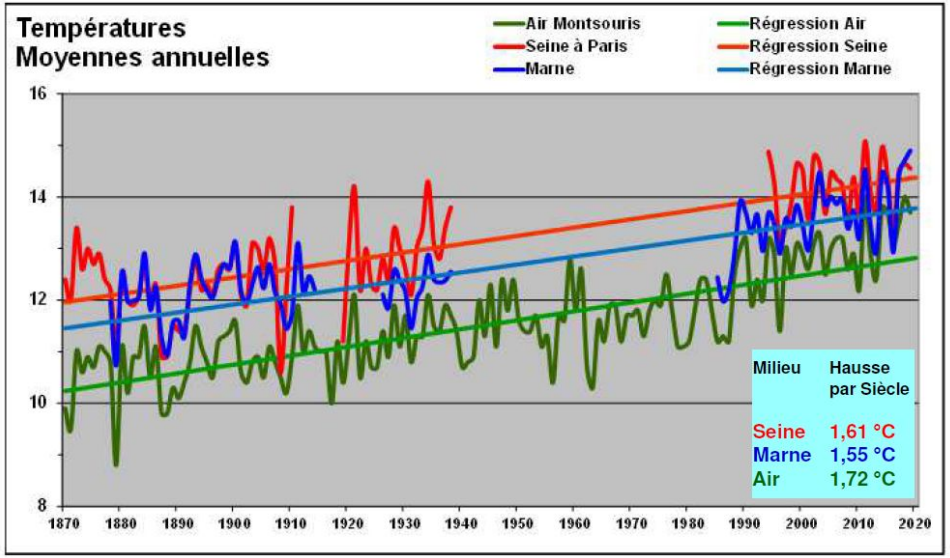
Modeling of the energy and water fluxes in the Seine hydrosystem

Couplage ORCHIDEE-CaWaQS à l'échelle du bassin de la Seine

Deniz Kilic[1], Agnés Rivière[1], Nicolas Flipo[1], Agnés Ducharne[2], Philippe Peylin[3]

- [1]Geosciences Department, MINES ParisTech, PSL University, Fontainebleau, France (deniz.kilic@mines-paristech.fr)
- [2]METIS (Milieux Environnementaux, Transferts et Interactions dans les Hydrosystèmes et les Sols), Institut Pierre Simon Laplace (IPSL), Sorbonne Université, CNRS, EPHE, Paris, France
- [3]Laboratoire des Sciences du Climat et de l'Environnement, LSCE/IPSL, CEA-CNRS-UVSQ, Université Paris-Saclay, F-91191, Gif-sur-Yvette, France

Introduction

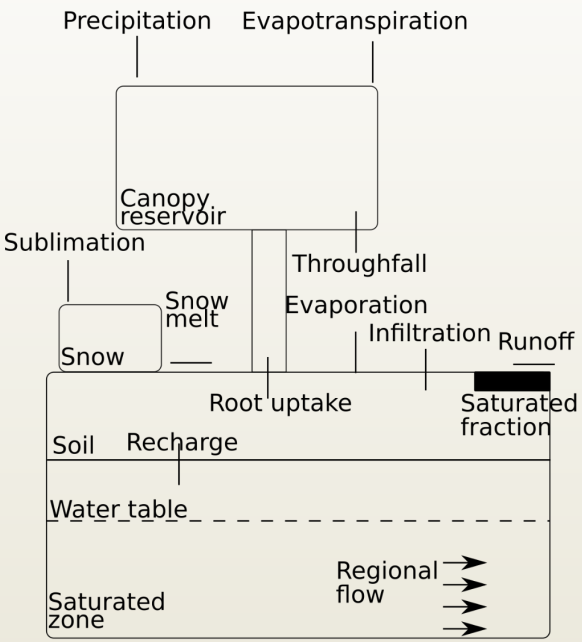


Source: River temperature evolution over time, William Thomas (DRIEE, 2019)

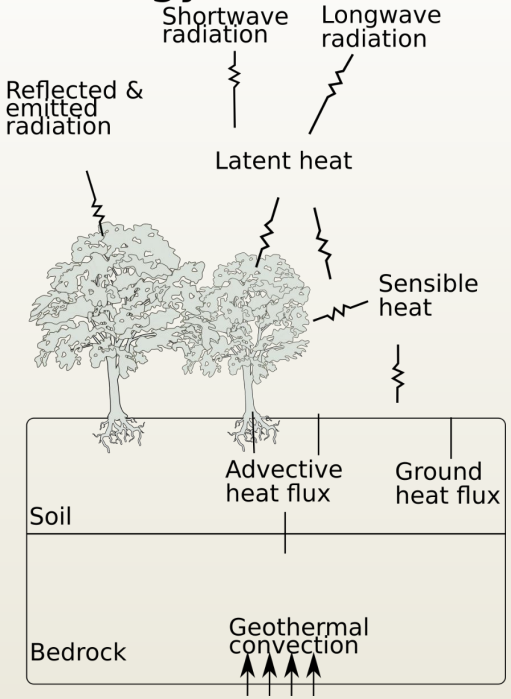
- How the climate change impacts the energy fluxes inside the Seine hydrosystem?
- What is the role of groundwater in a potential dampening effect of air temperature increase on river temperatures?
- How will the groundwater temperature evolve under the impact of climate change?

Introduction

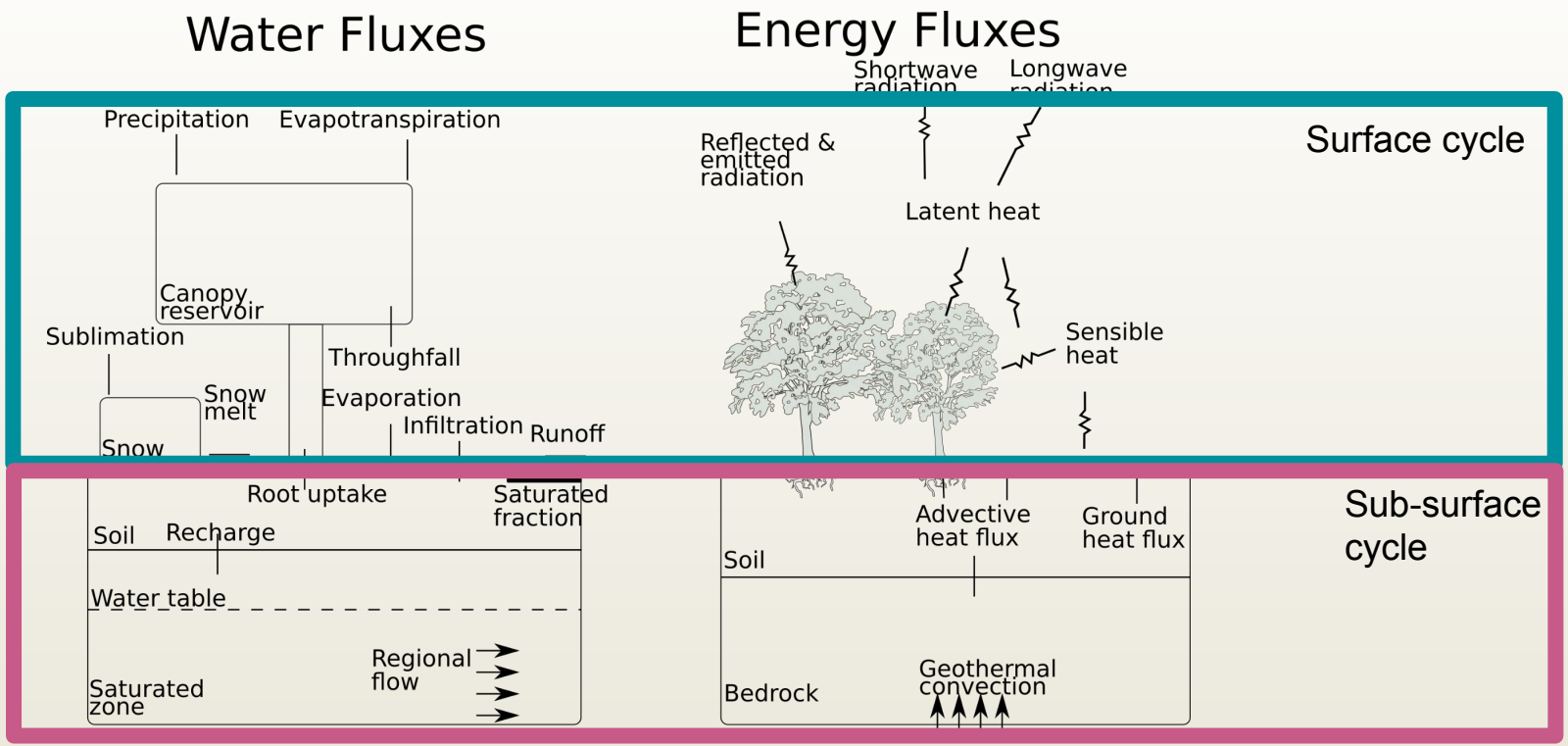
Water Fluxes



Energy Fluxes

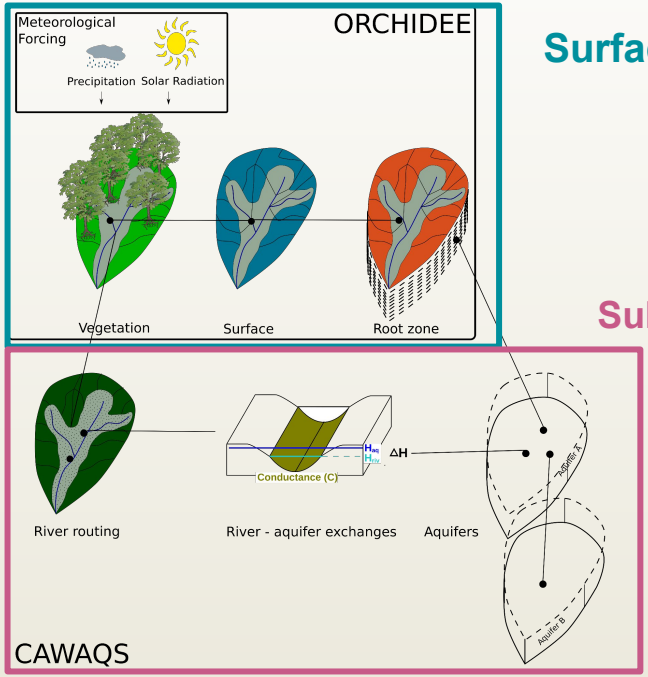


Introduction



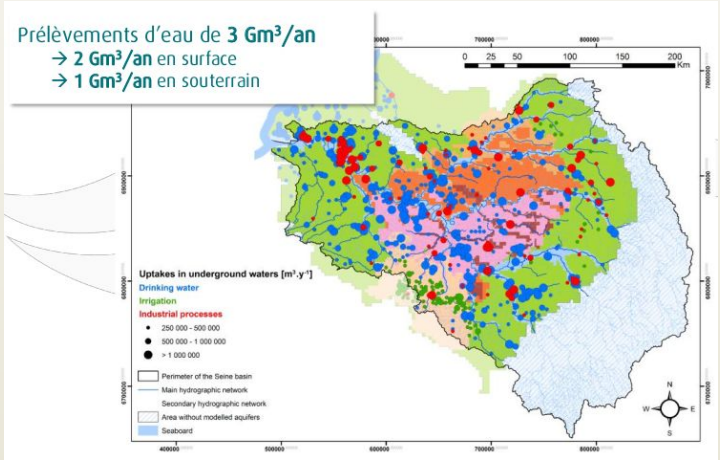
Coupling of ORCHIDEE-CaWaQS

- **Advantages:**
  - Explicit representation of **surface water cycle**
  - Estimation of net **surface energy balance**
  - Inclusion of the **vegetation processes**
  - Ability to represent **the river and GW fluxes**
  - Explicit **water withdrawal from each aquifer**
  - Ability to extend the model into carbon cycle studies



Surface cycle

Sub-surface cycle



CAWAQS: Simulating the sub-surface regional water cycle

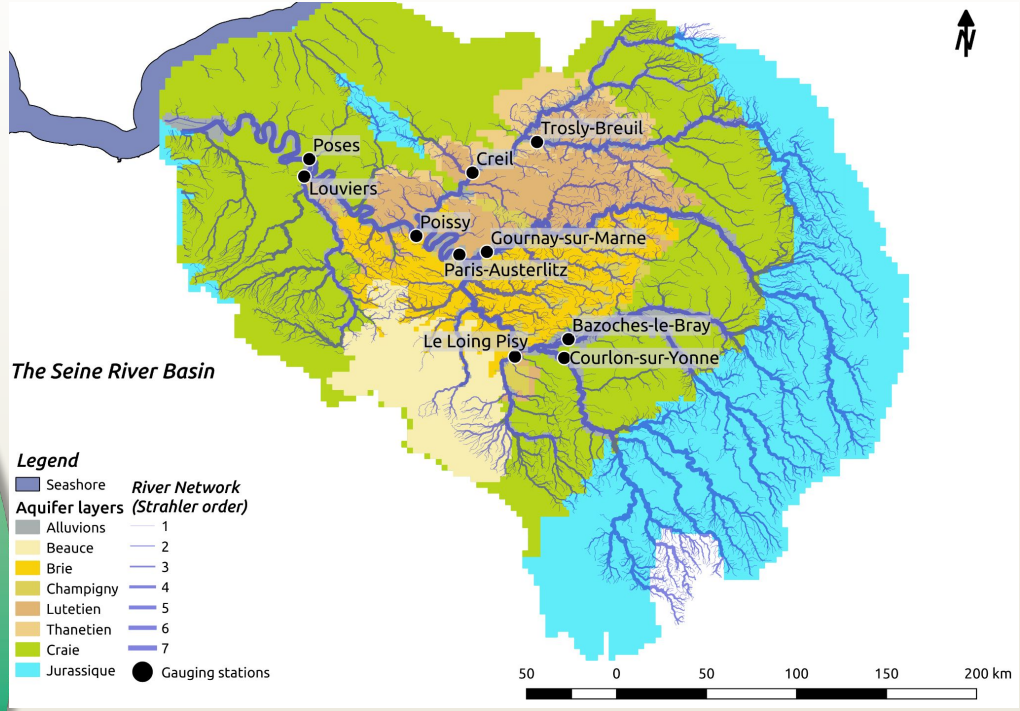
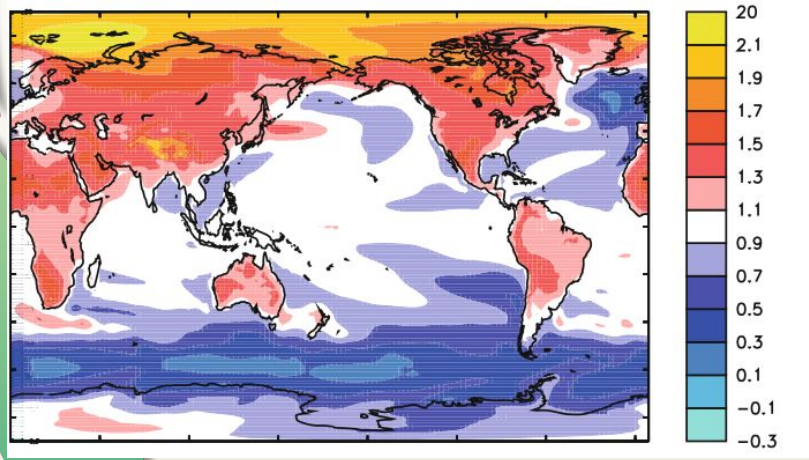


Figure: The Seine basin hydrogeological layers and the river network

- The CaWaQS Seine application (Flipo et al., 2020) simulates the hydrosystem water cycle for the period **1970-2018** at **daily** time steps
- The effective rainfall is estimated as **230 mm/y**
- Infiltration is estimated as **152 mm/y**
- The contribution of groundwater to river flow ranges between **10-60%**
- Impact of the groundwater temperature on river temperatures could be significant in the **head catchments**

ORCHIDEE: Simulating the surface regional water cycle



Normalized temperature change according to CMIP5 global simulations by ORCHIDEE (Dufresne et al, 2013)

A Soil-Vegetation-Atmosphere-Transfer model developed by Institut Pierre-Simon Laplace (Krinner et al., 2005; tag2.2)

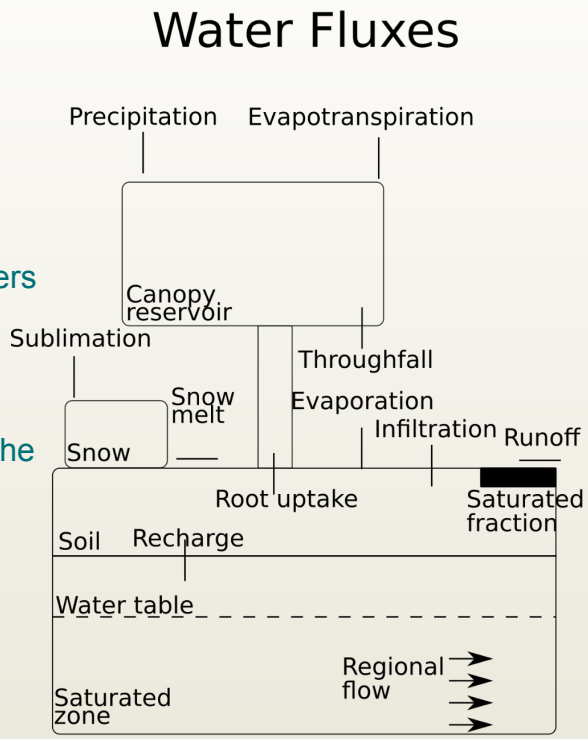
- **Simulates terrestrial hydrology**
- **Global - Regional applications** (2500 km² minimum)
- **Vegetation life** dynamics
- Solves 1-D water flow and heat transport for the top 2m of the soil (unsaturated and saturated part)
- **Energy balance between soil, vegetation and atmosphere**

Hydrological coupling of ORCHIDEE & CaWaQS

Steps taken to couple ORCHIDEE with CaWaQS

1. Regionalization of the model to simulate the surface water cycle
   - SAFRAN reanalysis data as meteorological forcing (64km^2, hourly)
   - High resolution albedo, vegetation and soil distribution maps
   - Regional parameters of soil hydraulics and vegetation parameters

2. Process improvement:
   - **Urban areas** are dealt by reducing the infiltration rates, where the available water discharges as runoff at each time step
   - Estimation of **wilting point-field capacity** with explicit Van Genuchten-Mualem relationship



ORCHIDEE Setup: Vegetation map

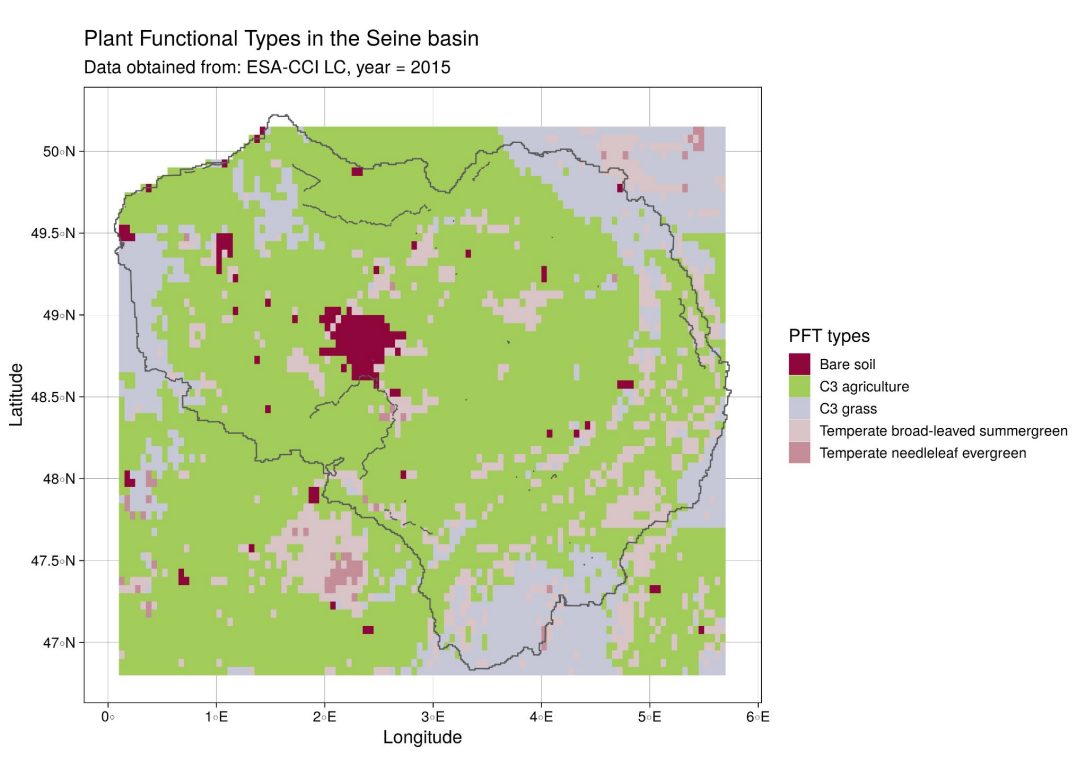
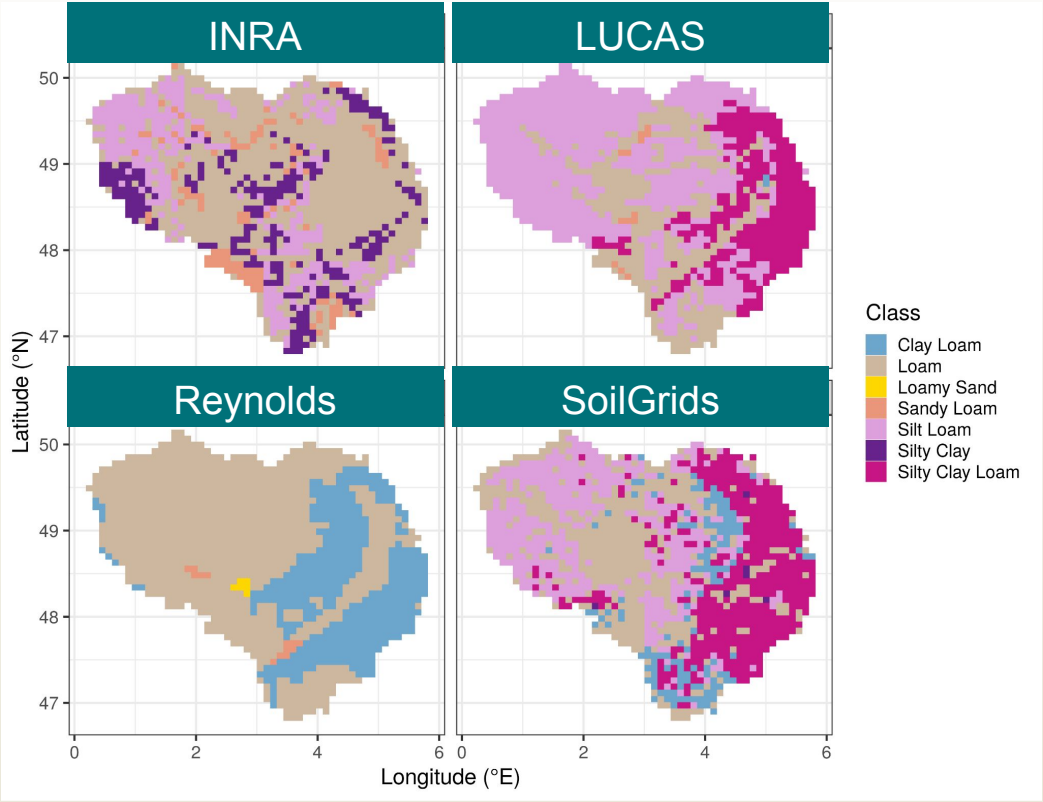


Figure: Dominant vegetation distribution in the Seine basin (ESA-CCI, 2015)

- **15 distinct vegetation types** represent the vegetation classes in ORCHIDEE
- **68 parameters** are associated with each vegetation type
- These parameters represent important processes:
  - Photosyntesis,
  - Respiration,
  - Stomatal conduction
  - Phenology
  - Mortality
  - Senescence

ORCHIDEE Setup: Various soil maps

- **Calibrate the distribution of the soil classes**
  - **12 soil classes** are defined by USDA soil classification (Carsel & Parrish, 1988)
  - Each soil class corresponds to **13 parameters** to represent the infiltration in the **unsaturated area**, the **soil water storage** and the **thermal fluxes**.
  - **4 Surface soil distribution maps** have been tested



Dominant soil distribution in the Seine basin (ESA-CCI, 2015)

Calibration of ORCHIDEE

Calibration period: Aug-2000 - Jul-2018

A total of 32 parameters are calibrated:

- Vegetation parameters (LAImin,max, Stomatal conductance etc.)
- Soil parameters (Hydraulic conductivity, porosity etc.)
- Albedo & aerodynamic resistance related parameters (Surface albedo, surface roughness)

Number of simulation performed: 28

- Post processing to remove GW pumping based on the data from AESN

Objective function:

- Minimize bias on discharge (4 models)
- Comparison with satellite products ETref, LAI to obtain the best

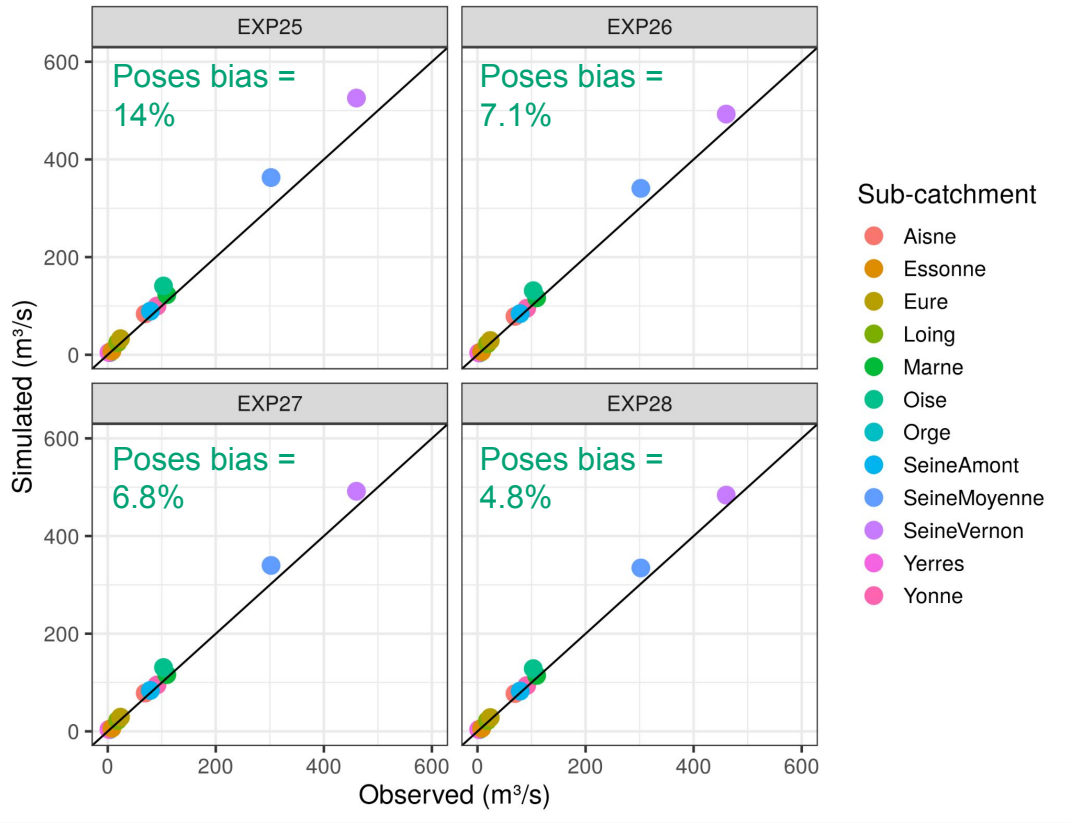
Source of calibrated variables

Variable	Description	Spatial resolution	Period	Uncertainty	Source
Q (daily)	Streamflow	Point	2000-2018		Eau France
ETref (daily)	Actual evapotranspiration	25 km	2003-2018	-0.41 - 0.65 mm/d mean absolute difference	GLEAM v3.3*
LAI (mean)	Reference LAI	25 km	1981-2015	RMSE = 0.676	GIMMS v3**

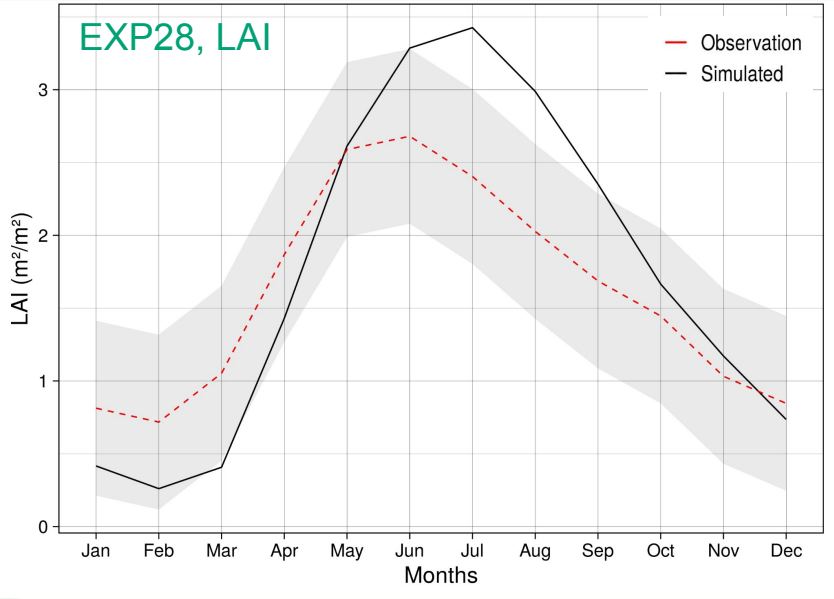
Sources: *Martens et al 2017, GMD; **Mao et al. 2019.

Results: Surface model calibration

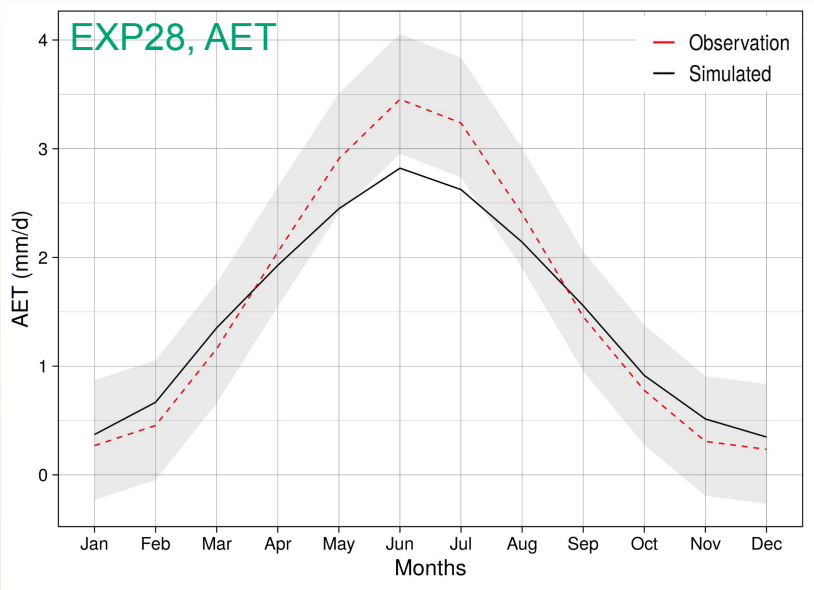
Mean annual total runoff by ORCHIDEE vs discharge observations



Results: LAI and AET monthly variations



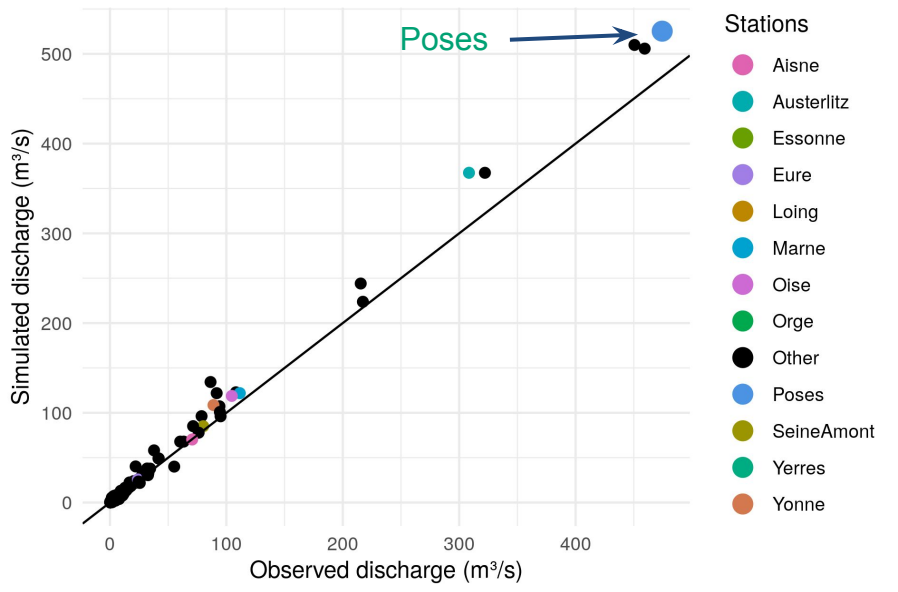
Monthly variation of Simulated LAI vs REF



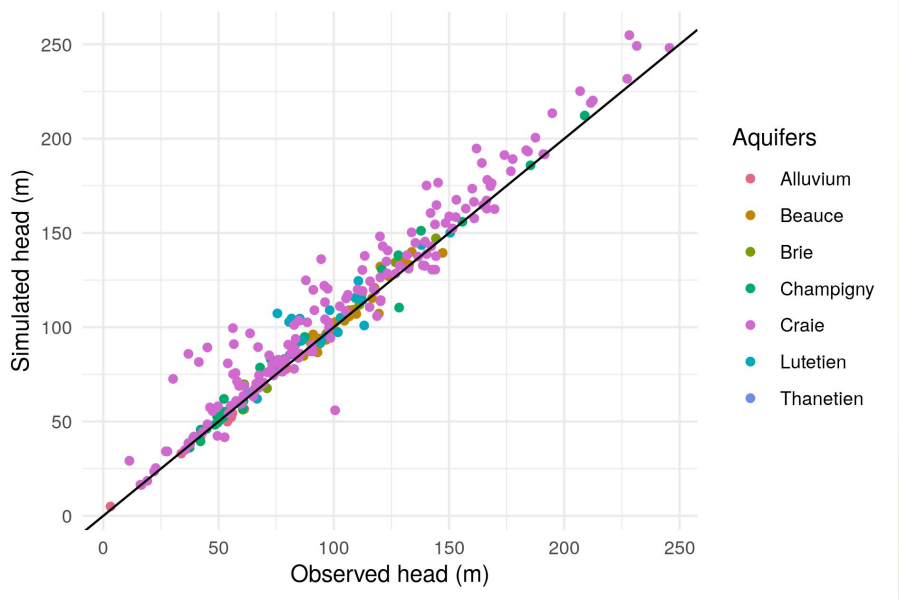
Monthly variation of Simulated AET vs REF

Results: ORCHIDEE-CaWaQs simulations

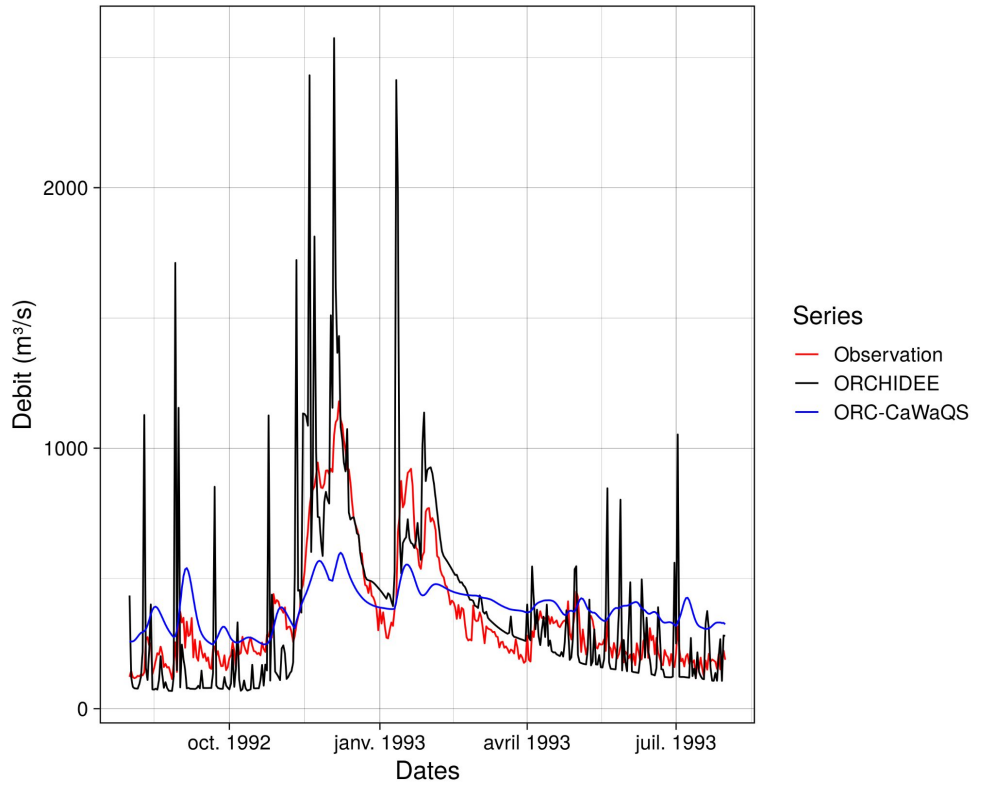
Mean annual discharge (2000-2018)



Mean piezometric levels (2000-2018)



Results: ORCHIDEE-CaWaQs simulations



Observed and simulated discharge at Poses station

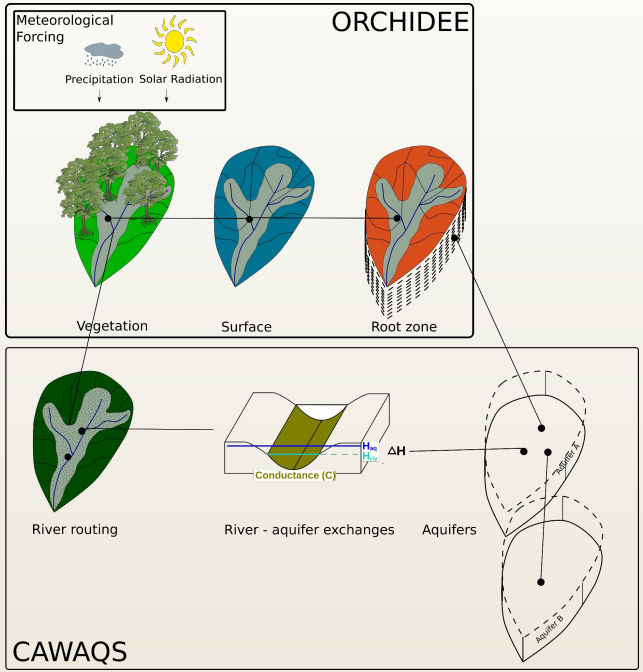
- Magnitude of the discharge is well captured
- The discharge evolution of the coupled model is representative yet.
- The partition of effective rainfall into runoff and recharge by the ORCHIDEE-CAWAQS coupling requires further refinement

Conclusions and perspectives

- **ORCHIDEE and CaWaQS are coupled at the scale of the Seine basin**
  - Actual evapotranspiration is simulated properly by the ORCHIDEE application
  - The calibration needs to be refined for the soil properties (Runoff vs recharge)

- The second part of the study will be the coupling of the simulated soil temperatures with the CaWaQS heat transport module

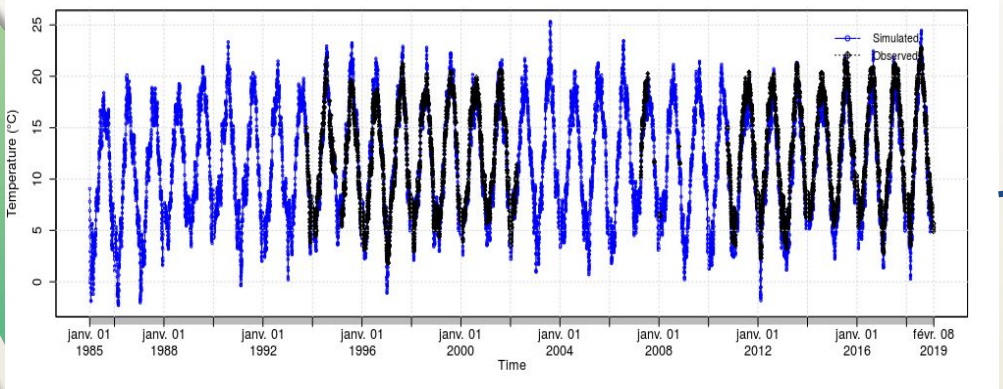
- **What is needed to achieve the heat coupling?**
  - Heat transfer at the stream-aquifer interface



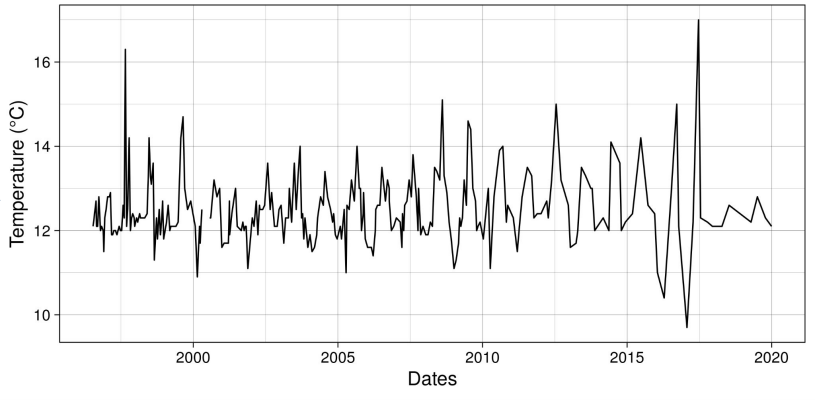
Conclusions and perspectives

- **Quantification of the impact of the climate change on the GW temperature will be simulated**

Soil temperature estimates by ORCHIDEE vs observations at Boissy - 2m depth



Observed aquifer temperature at Montreuil, source: ADES



- **The heat transport will be used to improve the calibration of the water cycle at the hydrosystem level**

Merci beaucoup pour votre attention!

The Seine River,
Samois-sur-Seine, 2020

Contact: deniz.kilic@mines-paristech.fr

References

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