Impact of groundwater withdrawals on surface-subsurface exchanges at the Seine basin scale

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Human settlement on the Seine basin

- Urban areas
- Arable land
- Grassland
- Forest

Seine Bassin :

65 000 km2

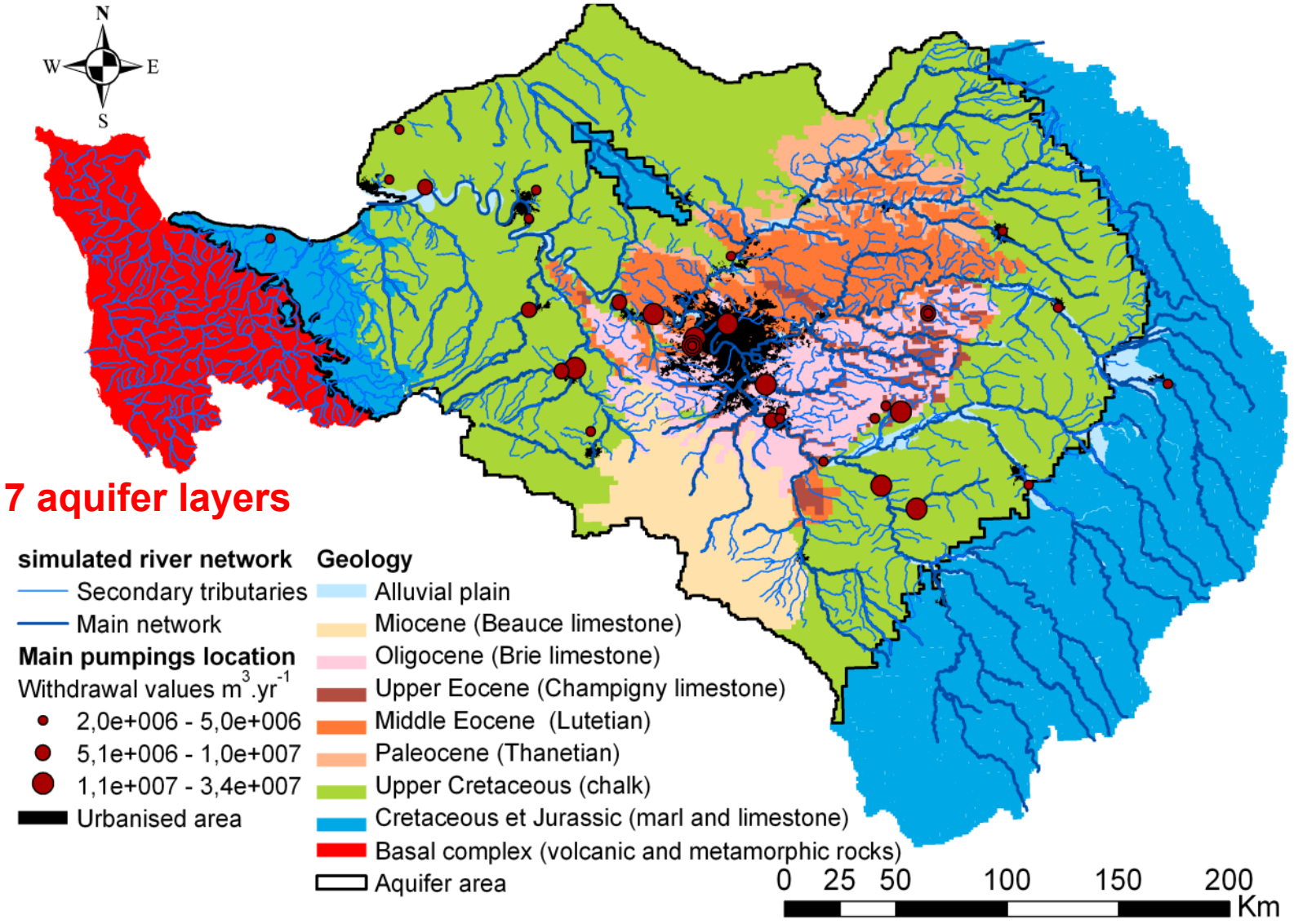
17 M inhabitants

Paris Megacity:

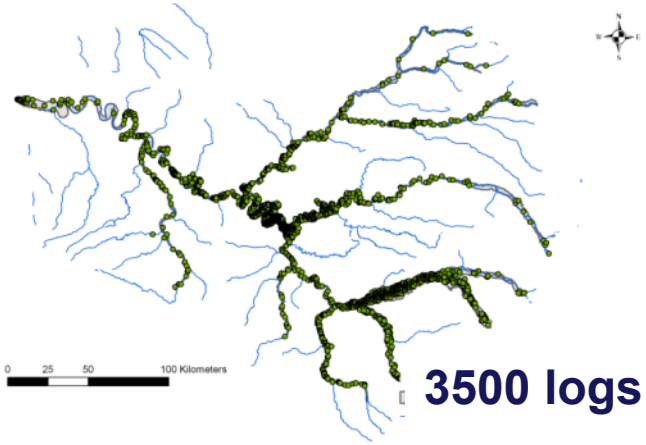
10 M inhabitants

100 km

Aquifer system

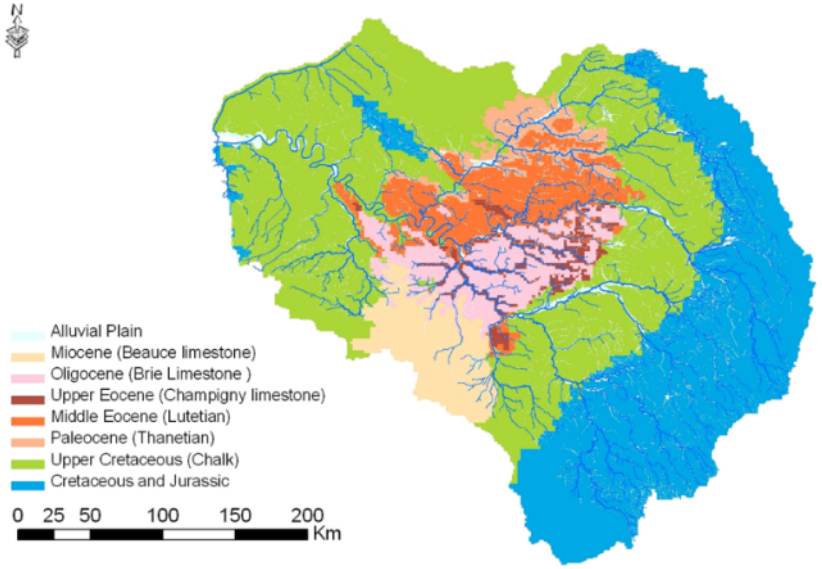


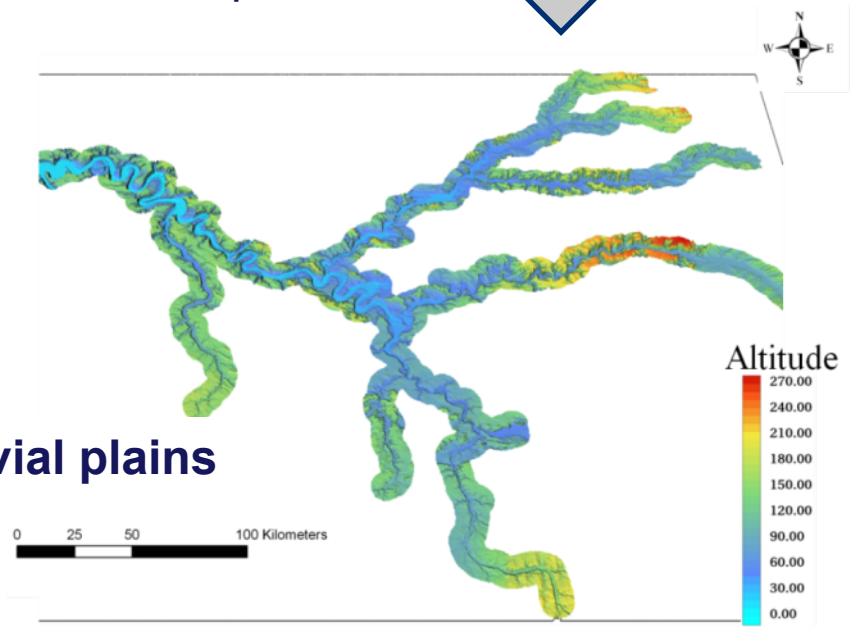
Aquifer system and alluvial plains



3500 logs

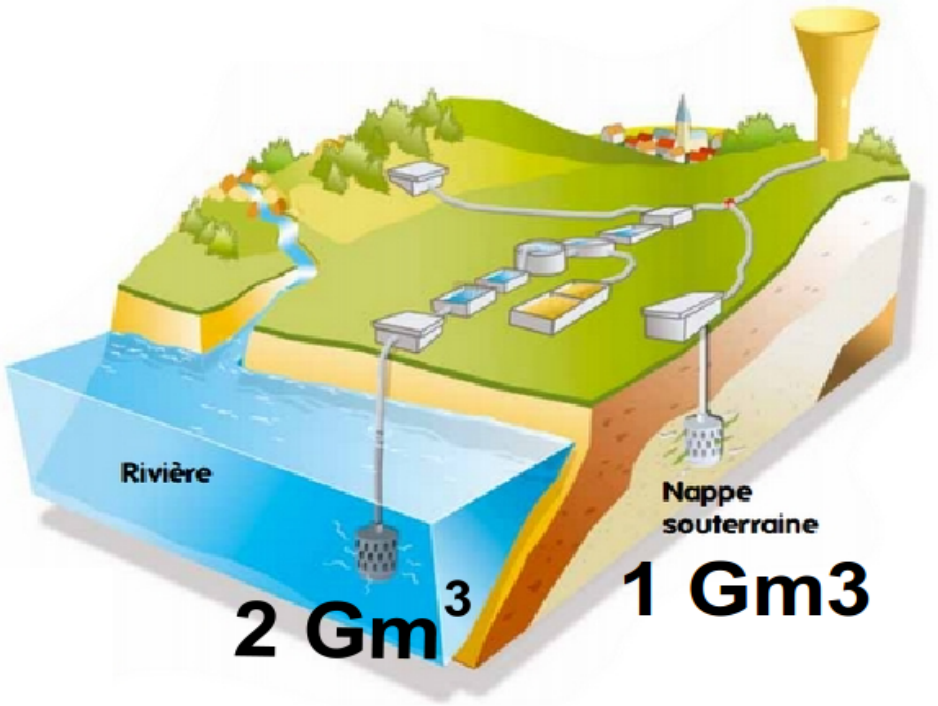
Geostatistics → interpolation



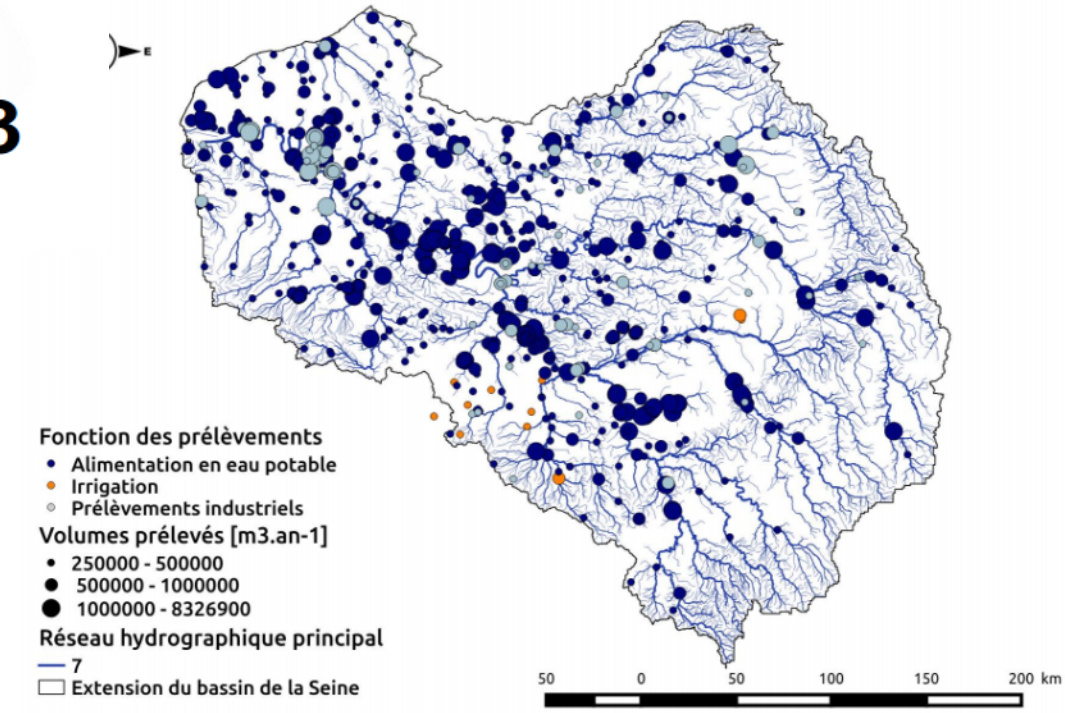


Geometry of 3500 km of alluvial plains

Water withdrawals

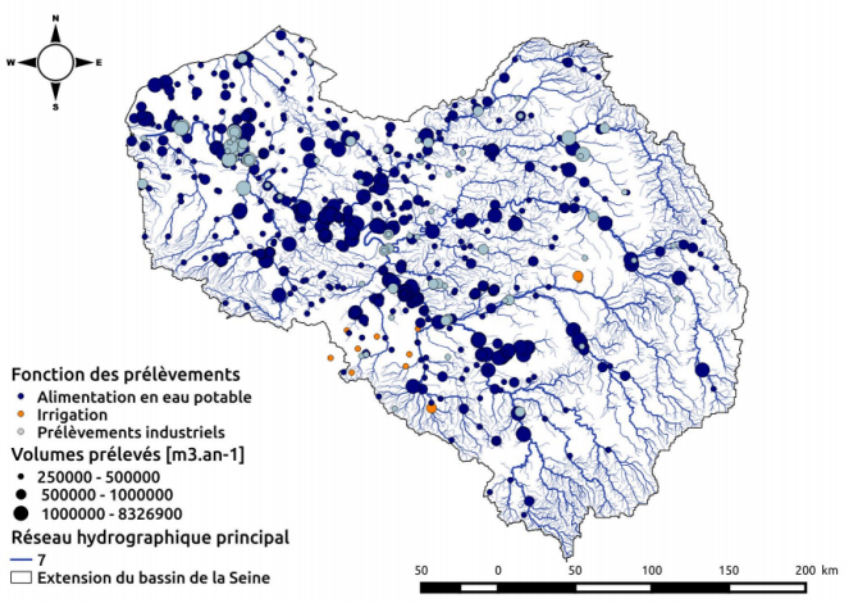


Annual reports to water authorities
Distributed in space since the 90's



3 $Gm^3.a^{-1}$ (AESN 2013)

Water withdrawals' implementation in the model



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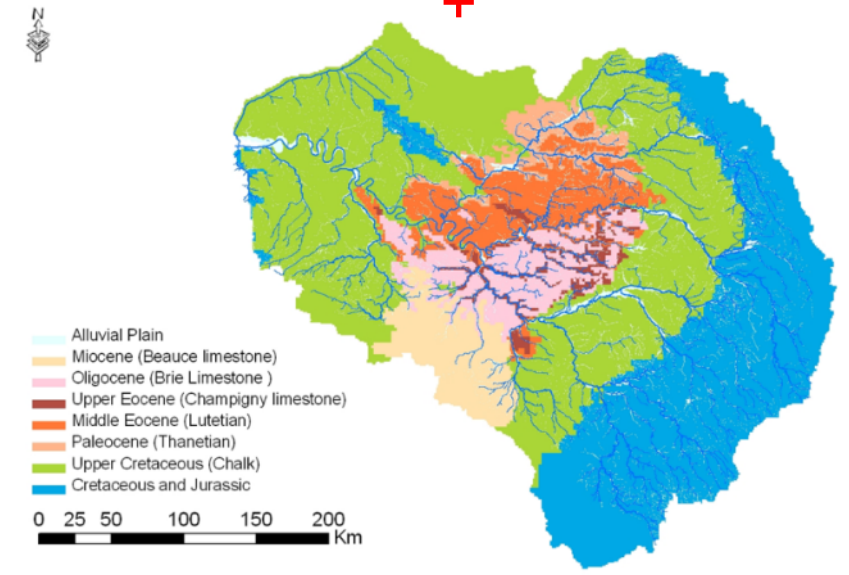


Upper aquifer unit

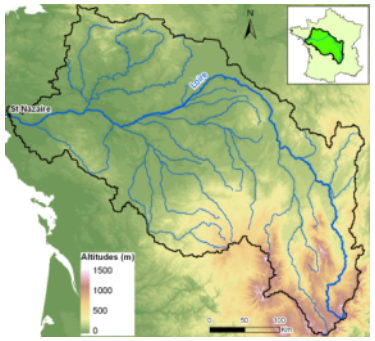
Lower aquifer unit

Associated to the lower aquifer unit

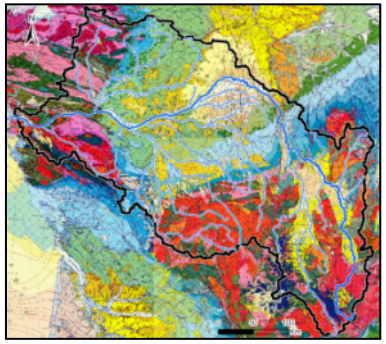
The reported annual water amount is distributed in time depending on the water usage

Data needed to model the system : exemple of the Loire basin

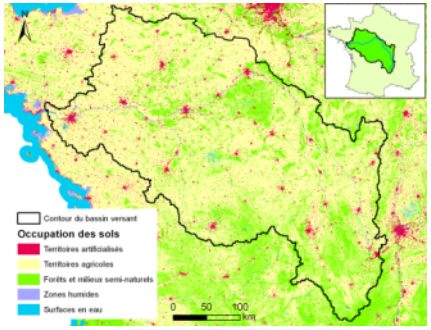
DEM & stream network



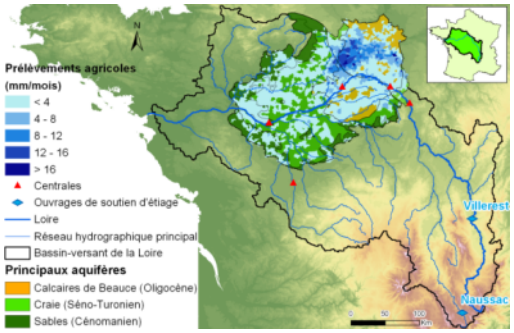
Geology



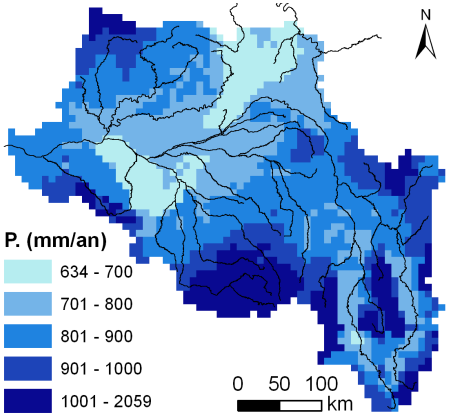
Land use



Withdrawals



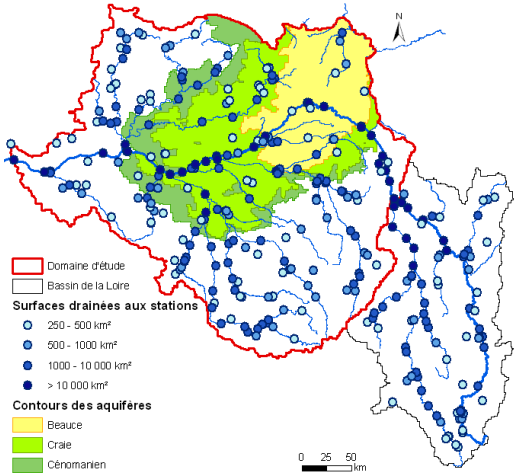
Météo : Precipitation, PET



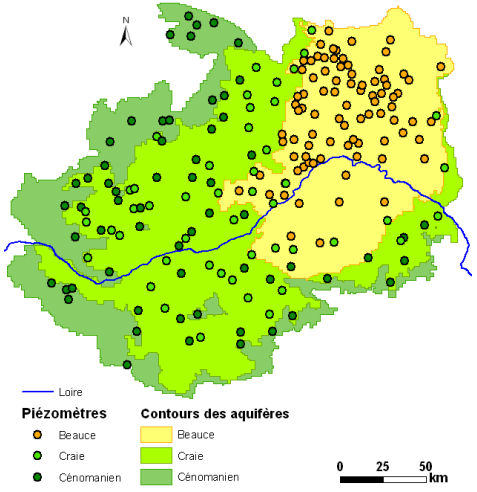
Simulations

Daily time step

Discharges



Piezometers



Flipo et al. 2012. WRR; Baratelli et al. 2016. JH

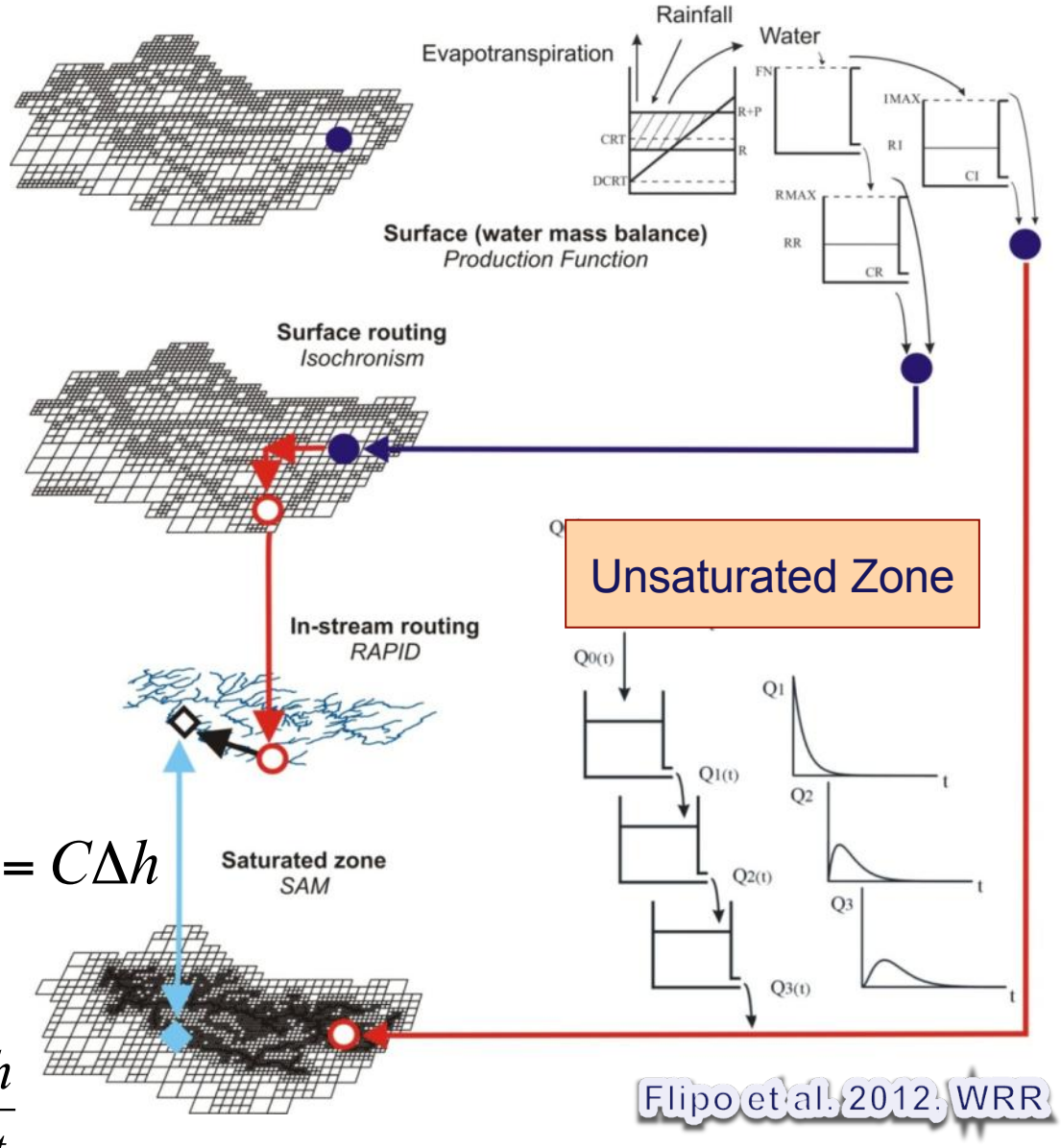
Coupled hydrological hydrogeological model

Surface Water Balance

Watershed Routing

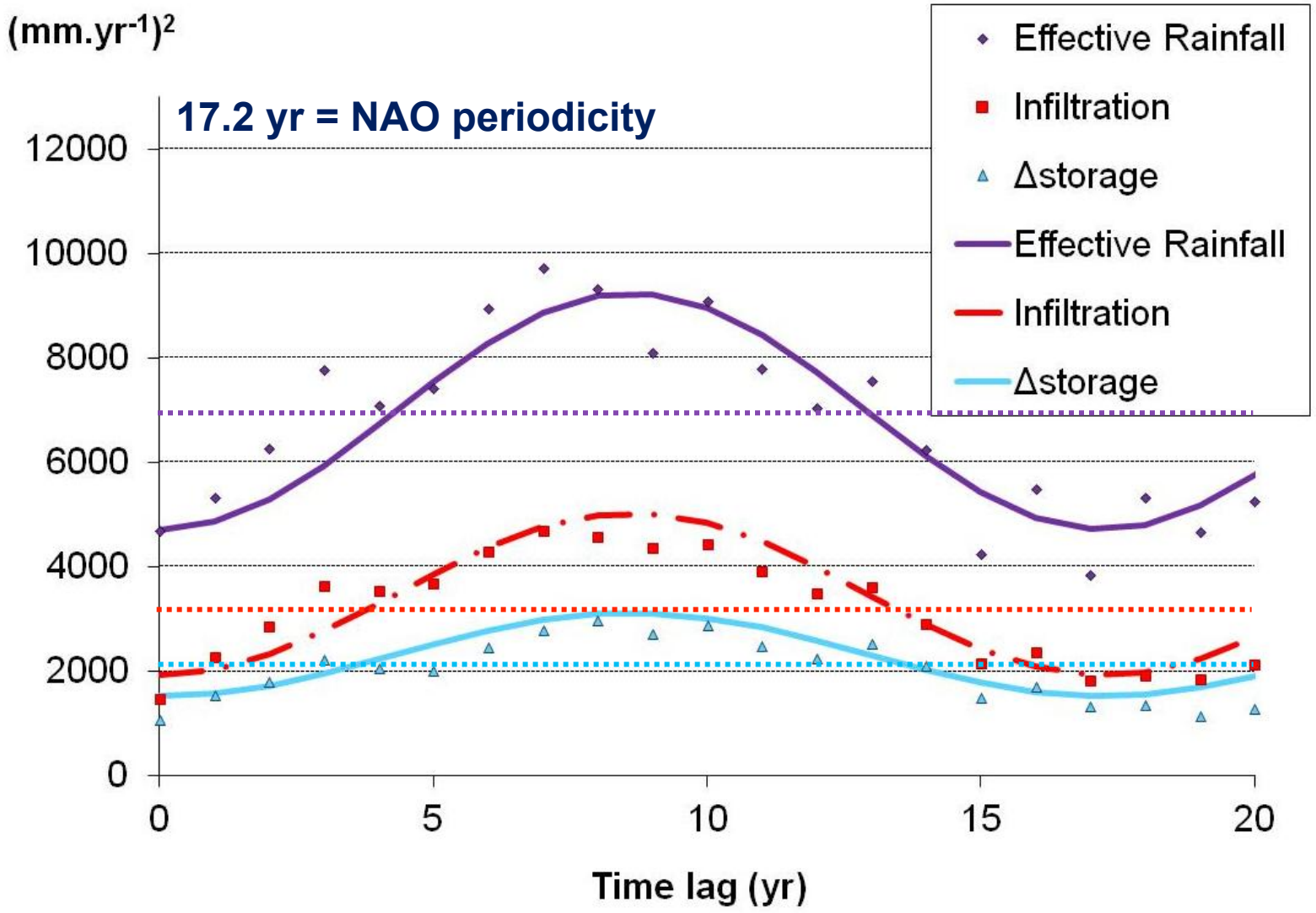
River Routing

Groundwater



$$div(\vec{T} \cdot \overrightarrow{grad}(h)) = Q + S\frac{\partial h}{\partial t}$$

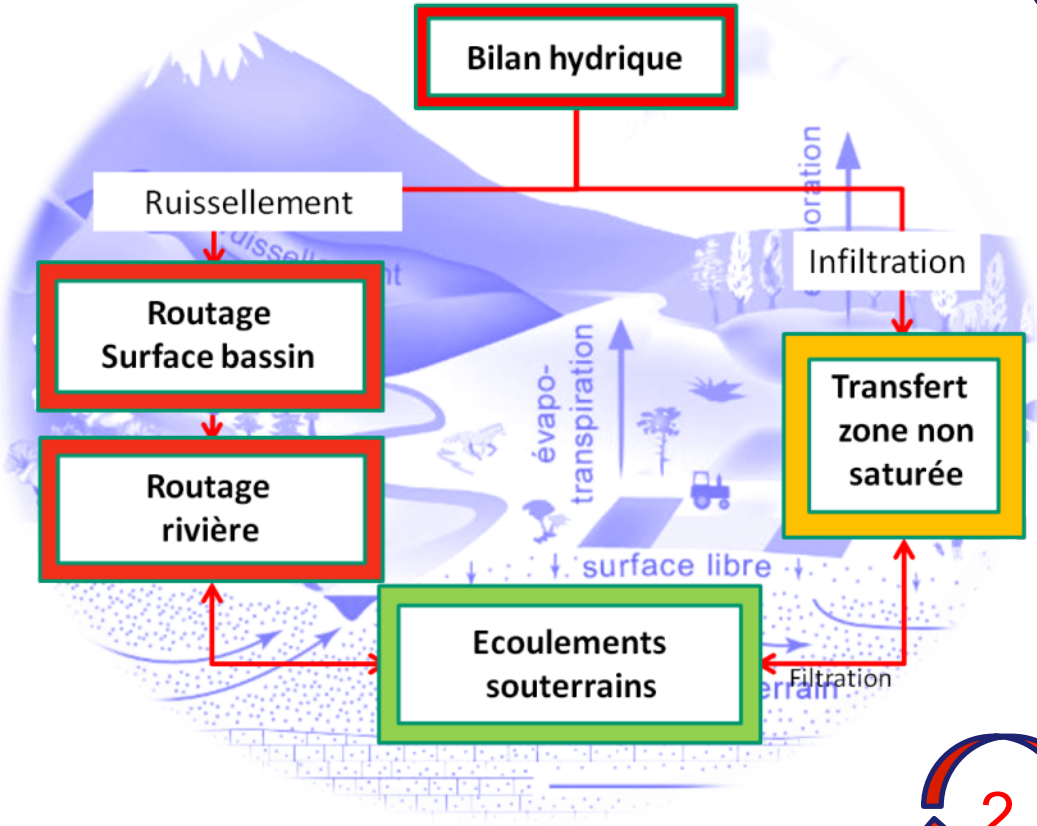
Stationarity of the water budget over a climatic period (NAO)



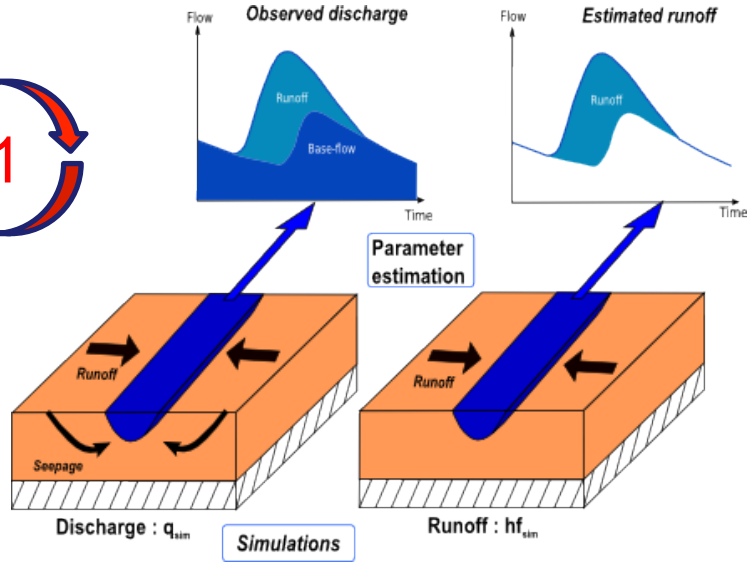
Flipo et al. 2012, WRR

2-step calibration method over a climatic period

Joint optimization on discharge and baseflow



1



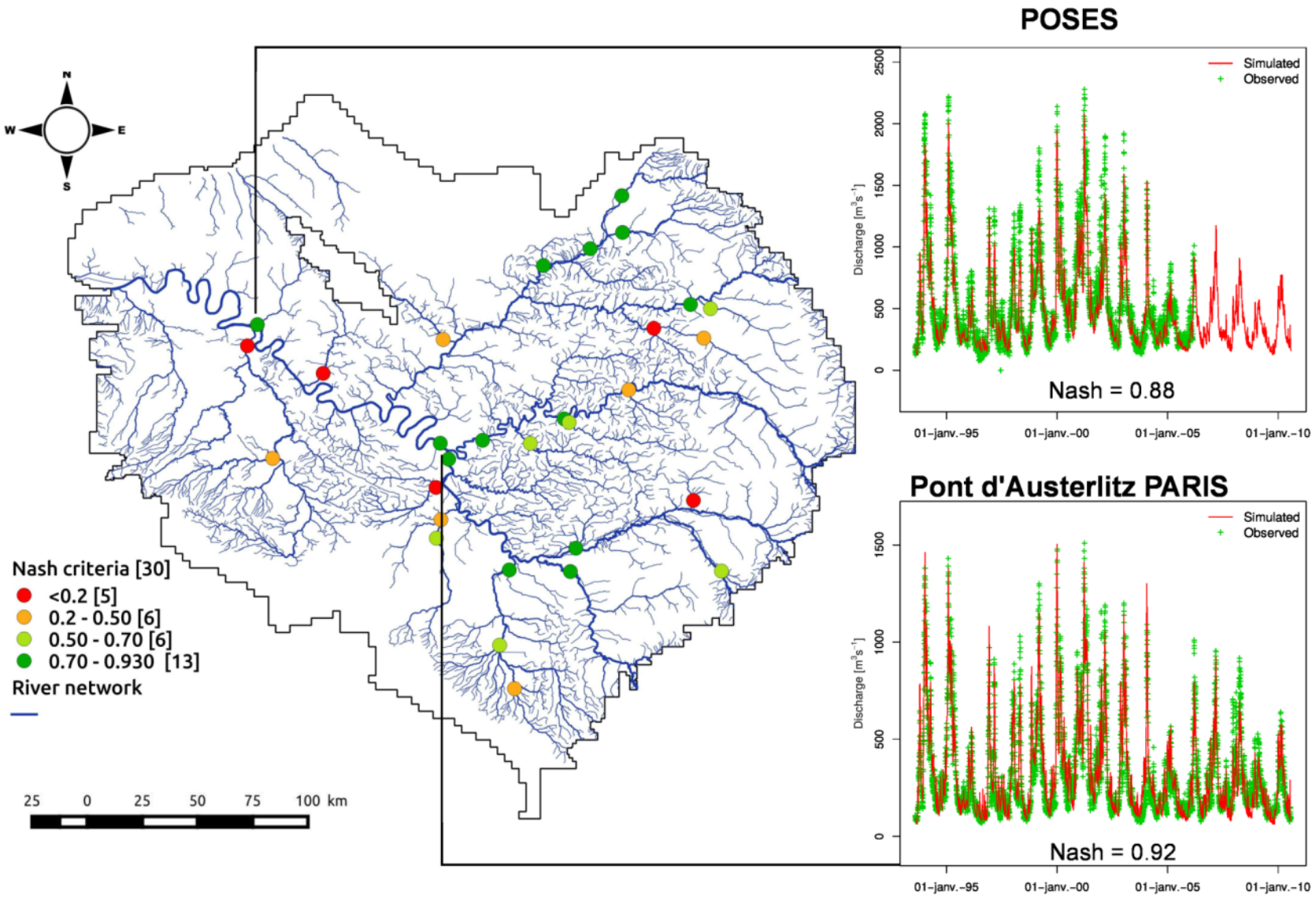
Labarthe 2016; Labarthe et al, In prep

2

Subsurface calibration by trial-error campaigns

Flipo et al. 2012, WRR; Labarthe et al, In prep

Performances : simulated discharge

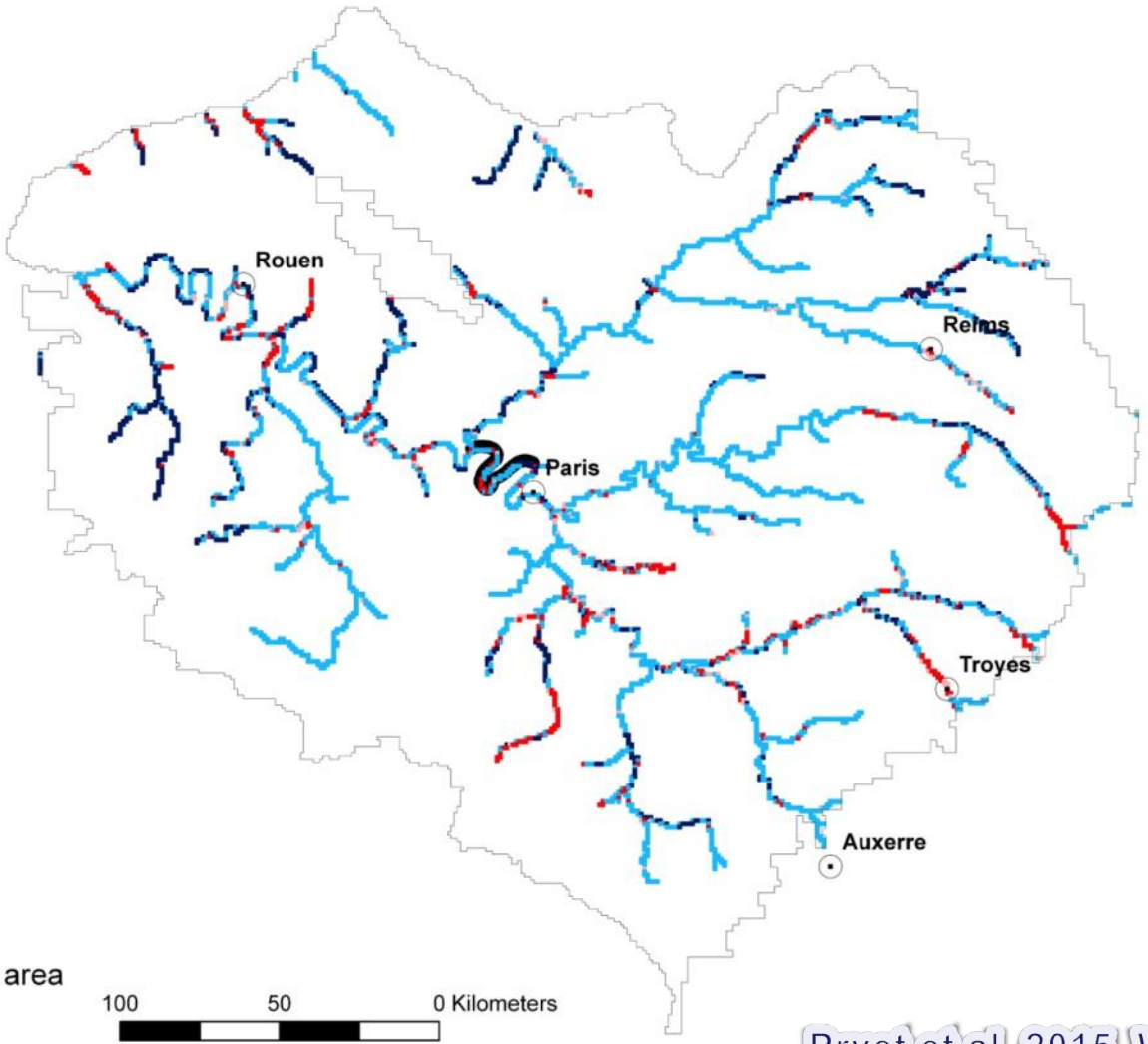


Labarthe et al, In prep

Stream-aquifer exchanges (1993-2010)

$$q_{aq->riv} = fK_h L(H_n - H_r)$$

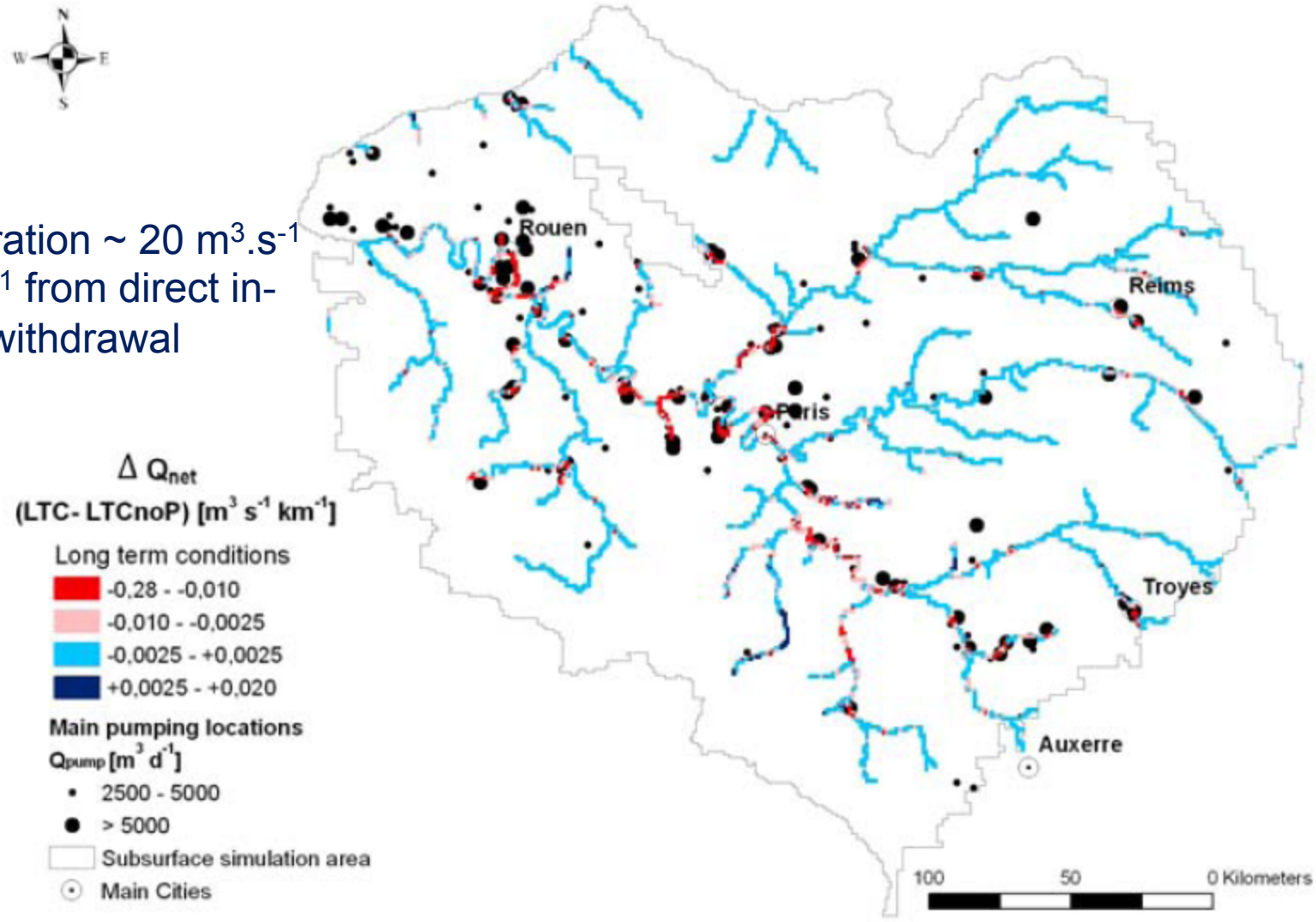
3250 km
82% draining
~60 $m^3.s^{-1}$



Pryet et al. 2015, WRM

Effect of pumping

Re-infiltration ~ 20 $m^3.s^{-1}$
~3 $m^3.s^{-1}$ from direct in-stream withdrawal



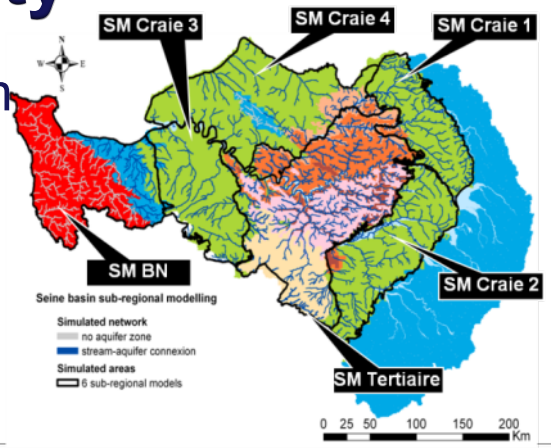
Pryet et al. 2015. WRM

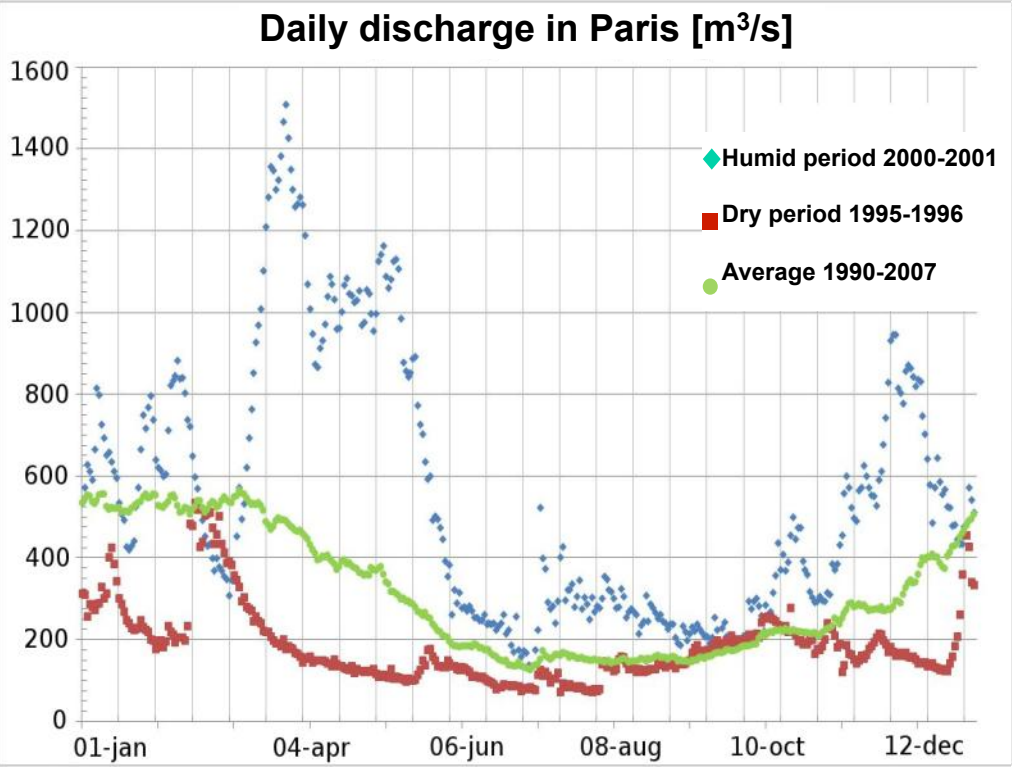
Spatio-temporal variability

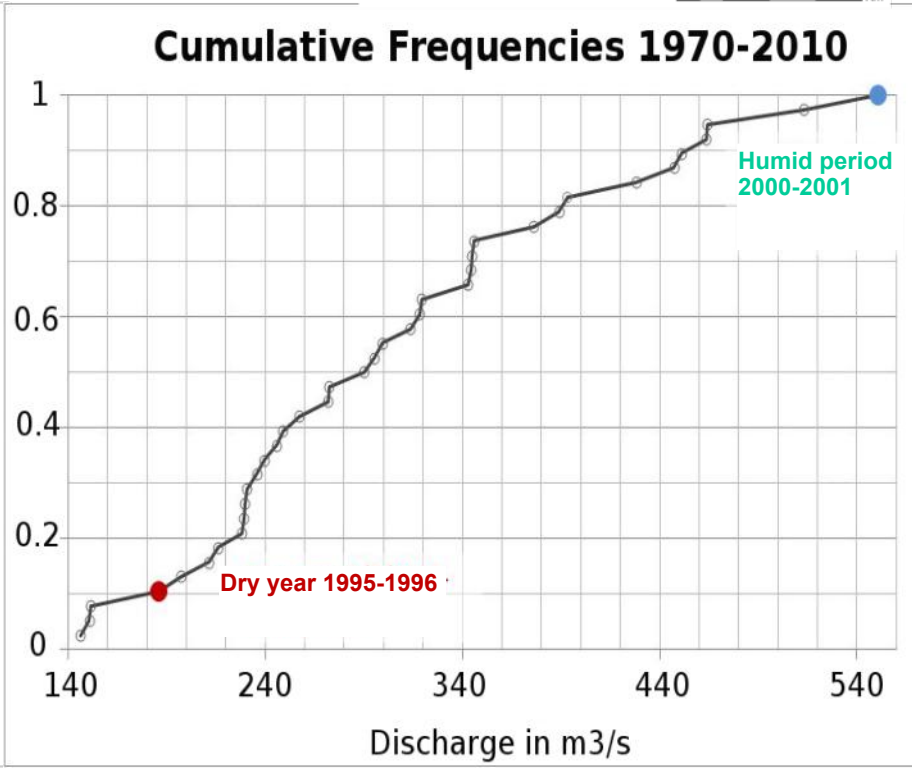
Simulation period 17 years (1993-2010) over 14000km of stream network

Focus on :

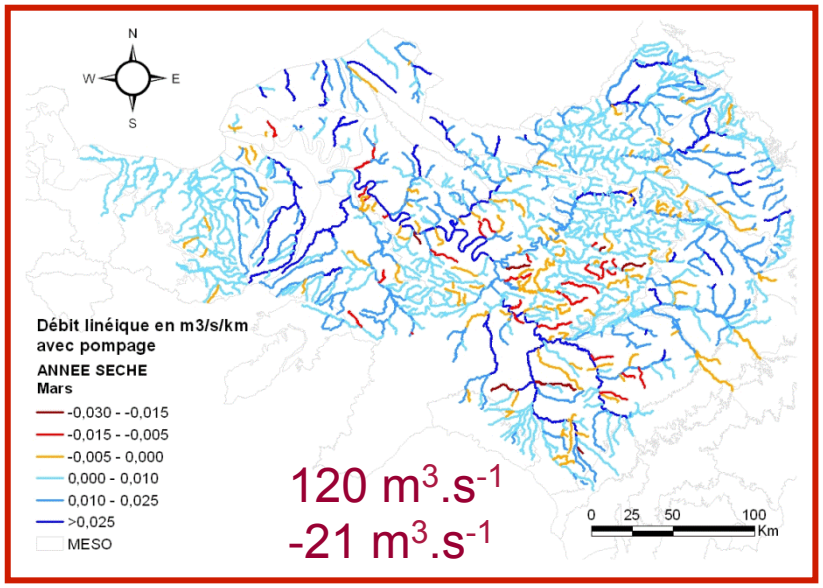
- 2 contrasted hydrological conditions (dry, wet)
- Average condition (over the simulated period)

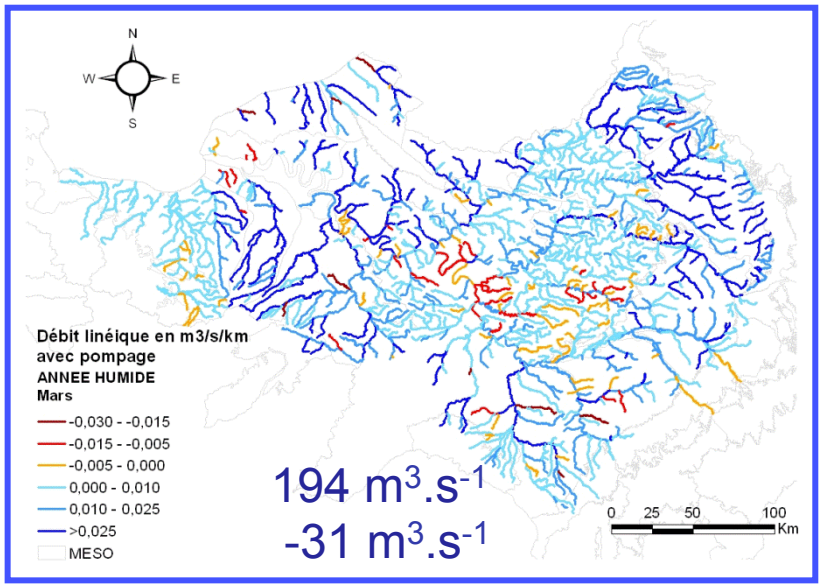




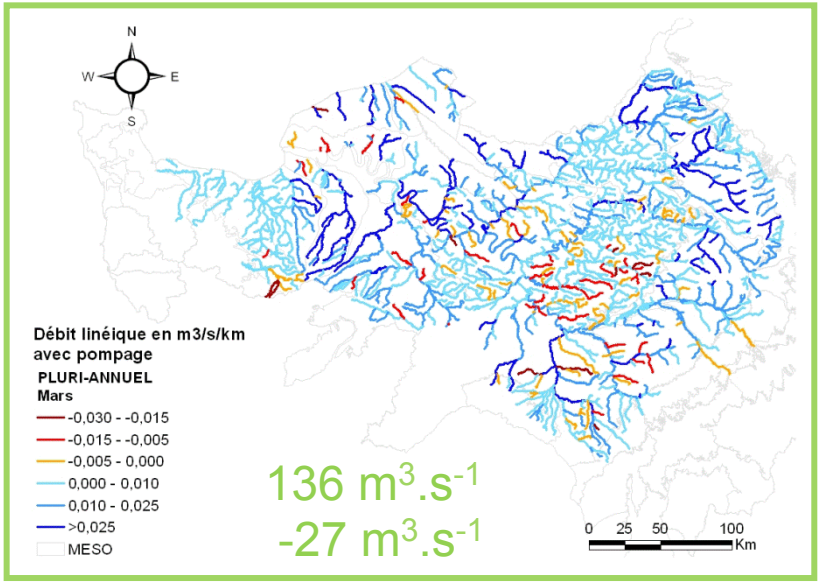


Spatio-temporal variability of the exchanges





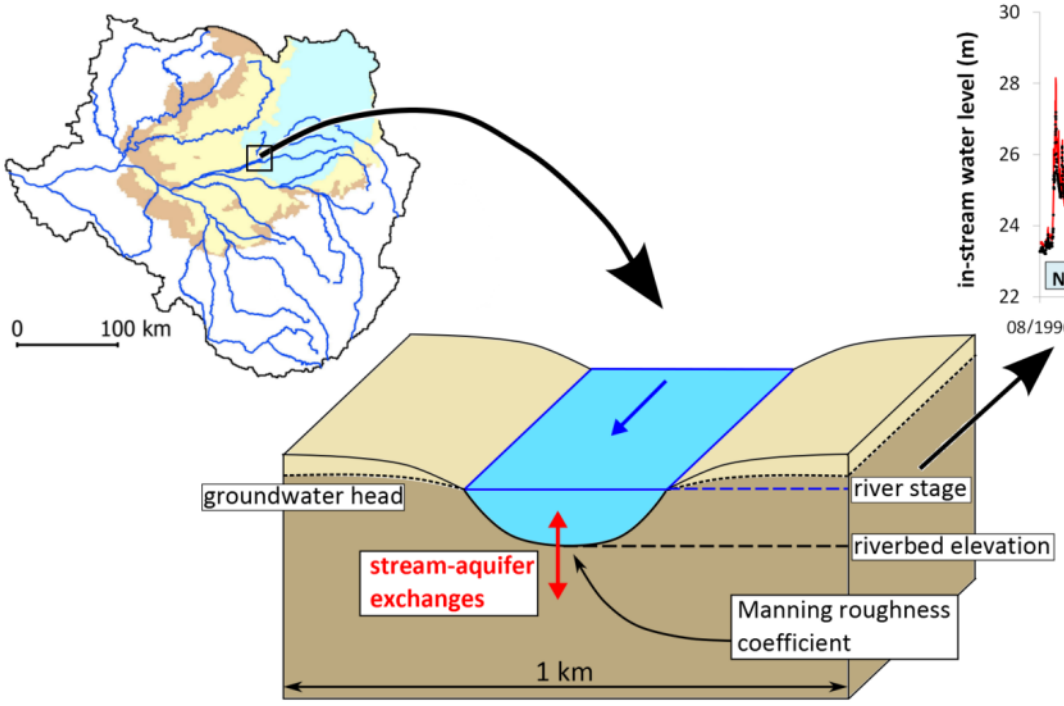
Period	Exfiltration [m³/s]	Infiltration [m³/s]	Net exchanges
Dry	-13.6	3.2	**-16.8**
Wet	-15.2	3.9	**-19.1**
Average	-14.8	3.7	**-18.5**

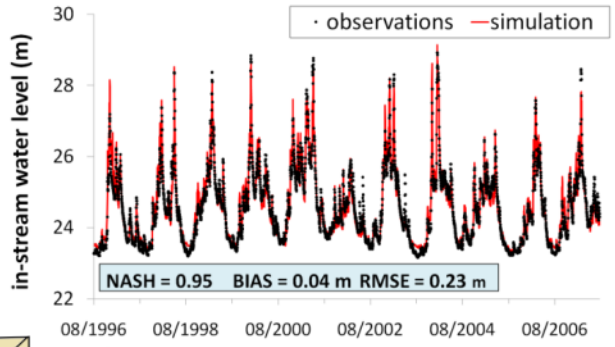


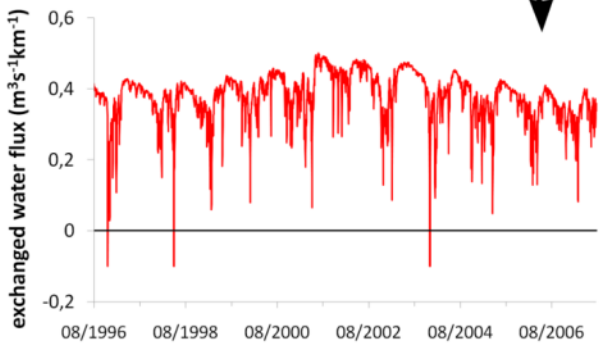
Flipo et al. 2013; Labarthe et al. 2014, IAEG

Priorities for stream-aquifer exchanges simulation at the regional scale

1. Water level fluctuations → physical processes
2. Estimate riverbed elevation
3. Estimate Manning roughness
4. Estimate the conductance coefficient



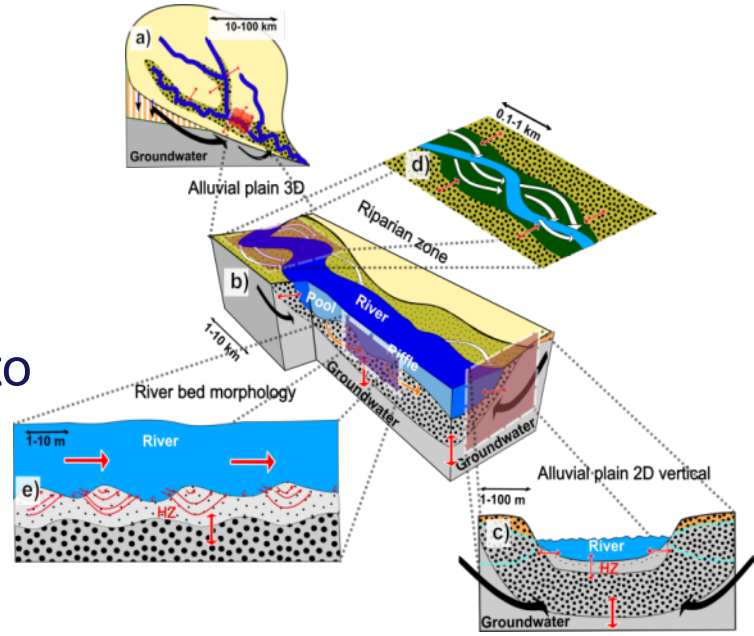




Baratelli et al. 2016, JH; Saleh et al. 2011, JH

Further challenges

- **Develop up and downscaling methodologies based on the nested stream-aquifer interfaces**
  - →structured around the river network to account for local complex hydro landscape



Flipo et al. 2014. HESS

- **Assimilate spaceborne water levels**
  - → SWOT mission

Biancamaria et al. 2015. SG

Thank you

Baratelli, F., Flipo, N., Moatar, F. (2016). Distributed quantification of stream-aquifer exchanges at the regional scale: sensitivity to in-stream water level fluctuations, riverbed elevation and Manning coefficient. Journal of Hydrology. In press. doi:10.1016/j.jhydrol.2016.09.041

Biancamaria, S., Lettenmaier, D.P., Pavelsky, T. (2015). The SWOT mission and its capabilities for land hydrology. Surv Geophys, doi:10.1007/s10712-015-9346-y

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Pryet, A., Labarthe, B., Saleh, F., Akopian, M., and Flipo, N. (2015) Reporting of stream-aquifer flow distribution at the regional scale with a distributed process-based model, Water Resour. Manage., 29, 139-159. doi: 10.1007/s11269-014-0832-7

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