Estimating energy fluxes within the stream-aquifer interface of the Avenelles basin

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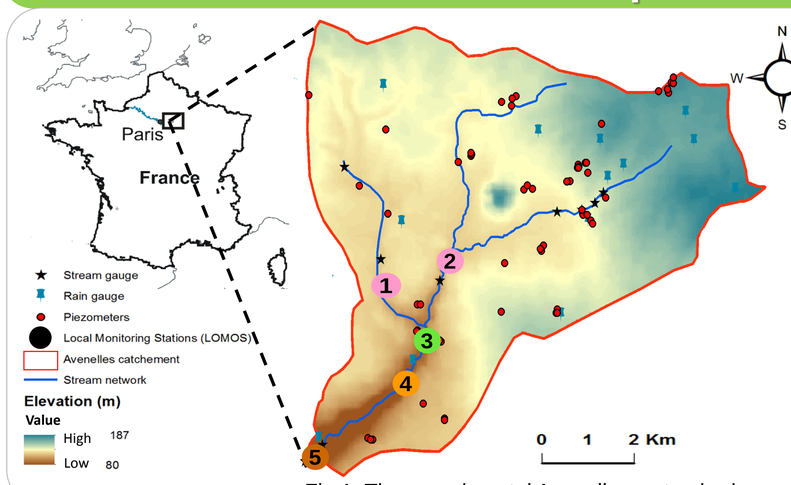
Motivations and objectives

- Understanding of the water temperature evolution to follow the water flow, the water quality, the ecosystem state evolution and to predict future modifications induced by climate change.
- Study of the temporal and spatial evolution of the energy budget within the stream-aquifer interface along the stream network of the Avenelles watershed

Avenelles Basin: Experimental Basin

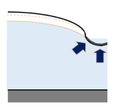


- Area of 46 km²
- 70 km east from Paris
- Agricultural Watershed
- 6 km of the stream network representing different types of connectivity with the underlying aquifers
- 5 Local monitoring stations LOMOS

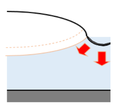
Fig.1: The experimental Avenelles watershed

Field interpretation

- Exfiltration : $h_{aquifer} - h_{river} > 0$



- Infiltration : $h_{aquifer} - h_{river} < 0$



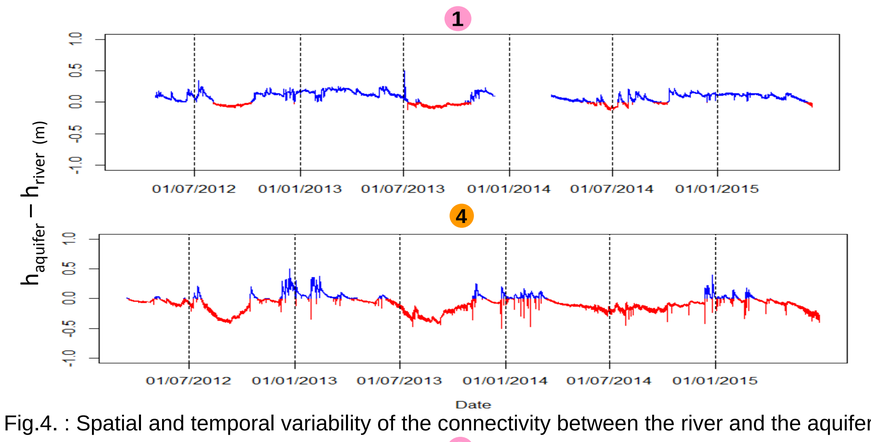
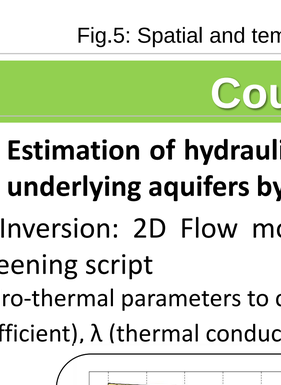


Fig.4. : Spatial and temporal variability of the connectivity between the river and the aquifer



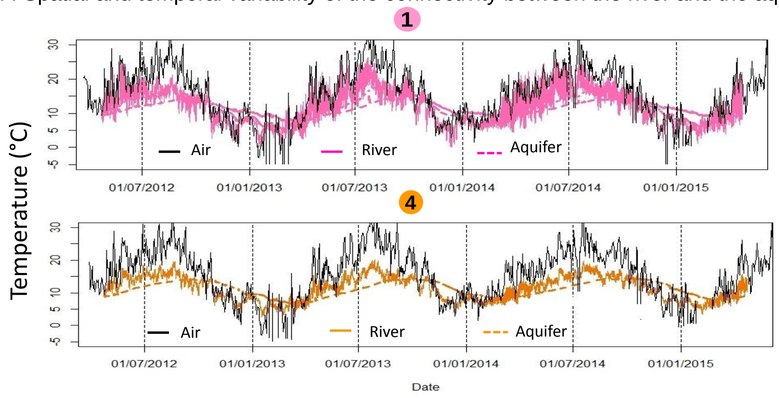


Fig.5: Spatial and temporal variability of the temperature from the upstream (1) to the downstream (4)

Coupled hydrothermal modelling

Estimation of hydraulic and thermal parameters of the Hyporheic zone (HZ) and the underlying aquifers by inversion

- Inversion: 2D Flow model and heat transport METIS (Goblet, 2011) + parameters screening script

Hydro-thermal parameters to calibrate θ (k, ω, λ, Cρ) : k (hydraulic conductivity), ω (specific storage coefficient), λ (thermal conductivity), Cρ (Volumetric heat capacity)

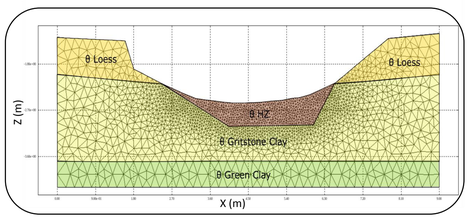


Fig.6: 2D hydro-thermal model mesh (LOMOS 3)

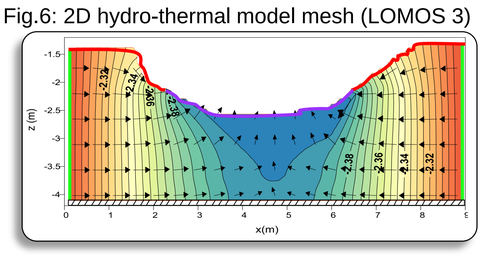


Fig.7: 2D hydro-thermal model with applied boundary conditions (River and aquifer water level and temperature time series)

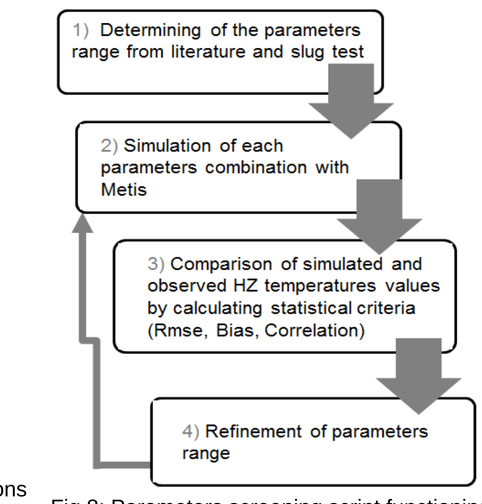
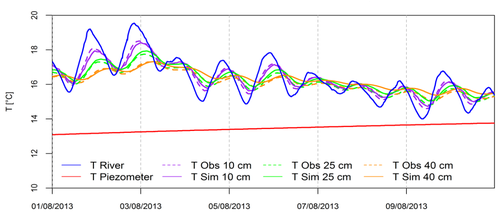


Fig.8: Parameters screening script functioning

Calibration of local models: Results of the LOMOS 3

- Calibration (infiltration case)



- Validation (exfiltration case)

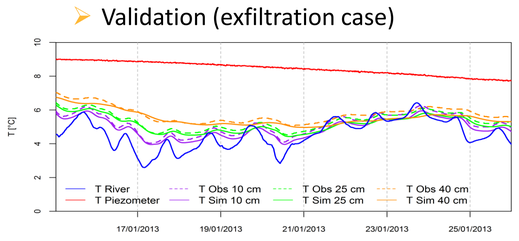


Fig.9: Comparison between HZ simulated temperatures (continuous lines) and HZ observed temperatures (dashed lines)

Conclusions

- New understanding of the stream-aquifer interface functioning shifting from pure hydrological characterizing toward a more subtle view that accounts for thermal processes.
- High spatio-temporal variability of water and heat exchanges dynamics within the stream-aquifer interface at the five LOMOS.
- The Hyporheic zone hydrodynamic and thermal properties play a crucial role on controlling heat exchanges by modulating the atmospheric factors influence on the conductive flux and the impact of regional fluxes on the advective flux.
- Quantification of local heat fluxes : heat fluxes by conduction reveal diel (low frequency) and seasonal (high frequency) variabilities correlated with atmospheric drivers and modulated by the porous media thermal properties while the heat fluxes by advection indicate a correlation with the intensity of hydrological events.

Geological sections and Field investigations

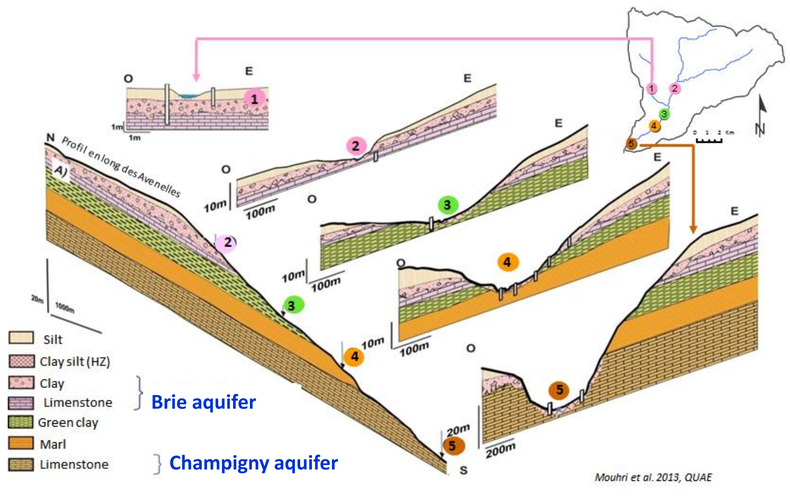
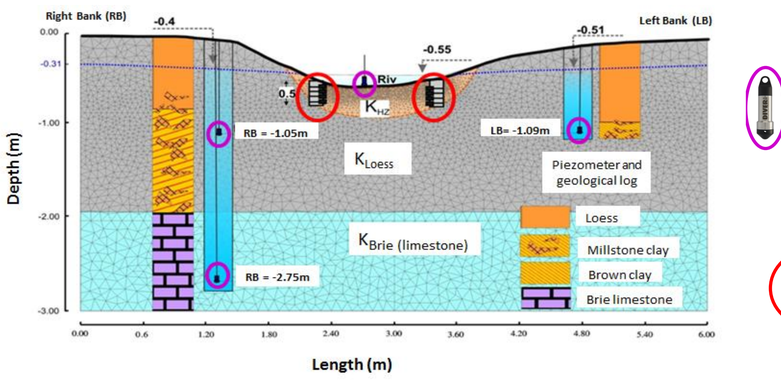


Fig.2: Geological sections evolution along the Avenelles stream network

- The upstream sections (1 and 2) are connected with the Brie aquifer unit. The intermediate stream sections (3 and 4) are in contact with an aquitard unit (green clays and gypsum and marls respectively). The downstream section (5) is connected with the Champigny aquifer unit.



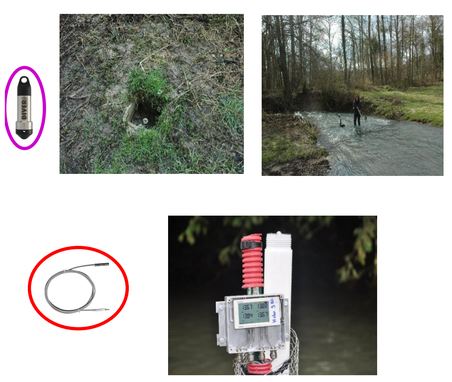


Fig.3: A local monitoring station (LOMOS) of stream-aquifer exchanges

Numerical results

Quantification of water and heat stream-aquifer exchanges over the 3 years timeseries

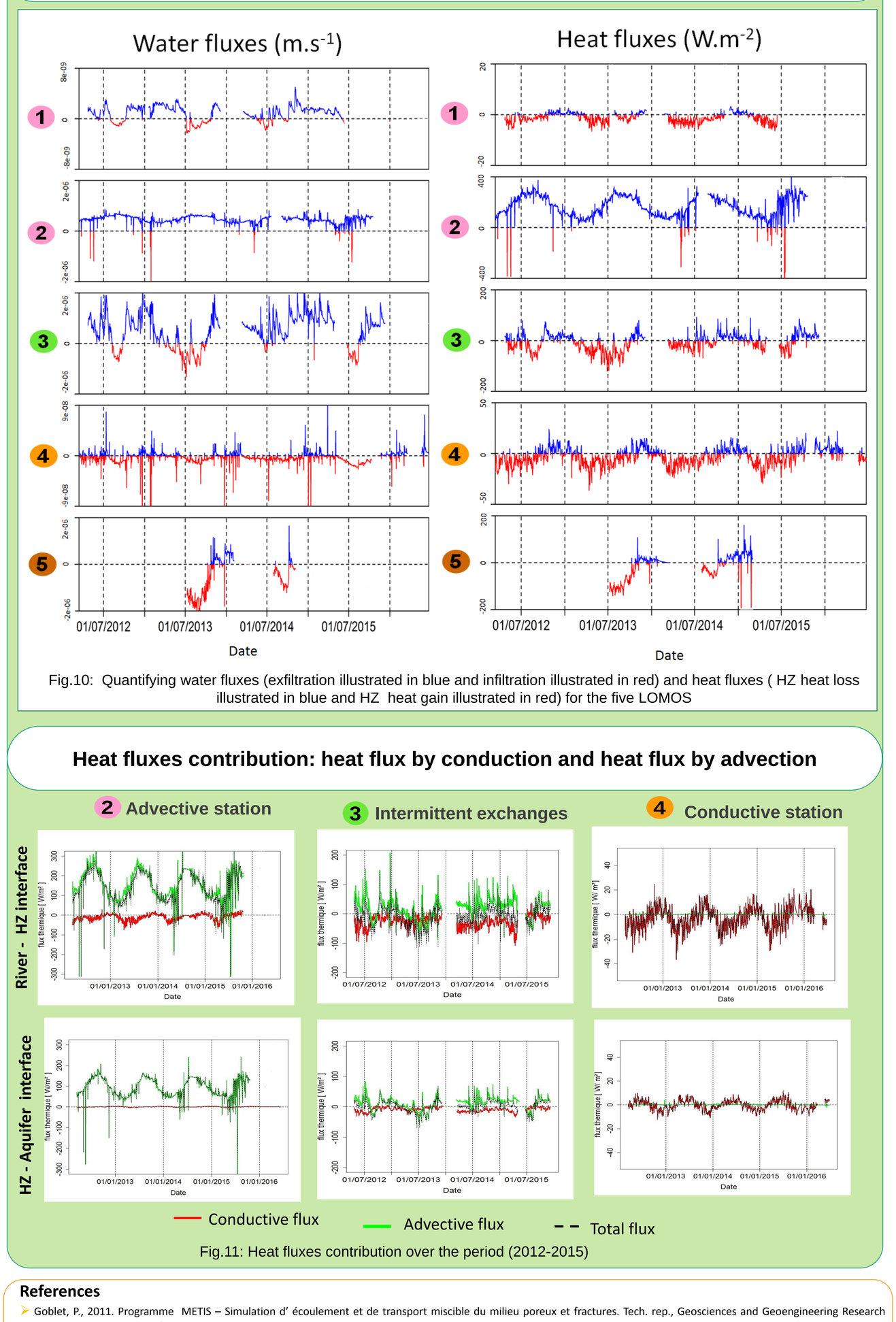


Fig.10: Quantifying water fluxes (exfiltration illustrated in blue and infiltration illustrated in red) and heat fluxes (HZ heat loss illustrated in blue and HZ heat gain illustrated in red) for the five LOMOS

Heat fluxes contribution: heat flux by conduction and heat flux by advection

Fig.11: Heat fluxes contribution over the period (2012-2015)

References

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