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Spatio-temporal approach and modeling for the identification and quantification of water exchange between a river and its alluvial aquifer – application to the Rhône River

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In order to better understand the water exchange dynamics between large rivers and their alluvial aquifer three types of tools were used and compared: deterministic models, black box models and models of mutivariate spatial analysis. The complementarity between these methods is discussed on an area with high socio-economic stakes concerning the use of water resources, around Péage-de-Roussillon (France, Rhône River). The studied area has a length of 22 kilometers and a width comprised between 2 and 4 kilometers. The alluvial layer shows a high conductivity (10-2 to 10-4 m/s) and has a depth varying between 10 and 30 meters.

A 5.5 years period was considered with time steps of 4 hours between measurements of water level. The groundwater level was monitored in 20 stations while 5 river gauging stations were used. As the collected data show some gaps and errors, a signal analysis was performed to detect the errors and auto regressive linear models were used to rebuild the missing data.

Several tests using signal processing techniques were performed to characterise the aquifer behaviour. A principal component analysis was undertaken on the piezometric head data. It allowed defining the two main explanatory factors to the groundwater fluctuations: the variability of surface water level and of pumping rates. Spectral analyses were also carried out through the use of Fourier and Wavelet analysis. Mapping of different areas within the aquifer is based on the frequency filtering, on the delay, on the attenuation and on the correlation between the surface water levels and the piezometric heads. It was found that these parameters are not always correlated to one another. However the effect of river fluctuations on groundwater level decreases overall with the distance to the river.

Then a deterministic physically-based model of the aquifer was implemented: a surface water model was linked with a groundwater model. An accurate computation of the surface water level was found to be of prime importance in estimating the exchange fluxes between the reservoirs. Clogging at the surface water/groundwater interface also appears to play a significant role: some parts below the river channel were found likely to be unsaturated. The deterministic model then enables a physical interpretation of the areas mapped using the signal analyses techniques.

Results obtained during present investigation shows that the surface water level could be a relevant explanatory factor to the groundwater level. A better insight at the temporal and spatial variability of the exchange fluxes was gained through the use of different, but complementary, tools which allow reducing the global uncertainties in river/aquifer interactions.