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Bridging the gap between local scale hydraulic modeling and regional scale hydrological modeling

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According to the required objectives, surface routing methodologies can be classified into hydrodynamic methodologies and hydrological routing methodologies.

At the regional scale, hydrological routing models that are based on simplified hydrological techniques (ex. Muskingum, Muskingum-Cunge) are the main tools for routing discharge along river networks. These models offer the advantages of simplicity, however, they have limited capacity to simulate local scale processes such as river stages that are important in numerous water resources applications such as floodplain management, flood control operations, overtopping frequency and stream-aquifer interactions.

At the local scale, the principle tools are hydrodynamic routing methodologies (ex. Navier–Stokes 3D, Saint-Venant). Such models are capable of simulating complex hydrodynamic events at local scale such as inundations and overtopping frequency.

To date, hydrodynamic models are not widely used at the regional scale because they require high resolution morphological data that are not always available at regional scale, in addition to insufficient computational power and numerical difficulties when applied at regional scale.

The main objective of this study is to bridge the gap between the capacities of the two routing methodologies in order to provide a realistic simulation of river stage and discharge at the regional scale and eventually improve the simulation of stream-aquifer interactions.

The general framework is the distributed hydrological model Eau-Dyssée, which couples existing specialized models to address water resources in regional basins. The regional river routing scheme in EauDyssée is based on the equations of Muskingum that only simulates discharge along river networks.

The study focuses on the Oise basin (a 17 000 km2 sub-basin of the Seine River basin, in Northern France), for the period 1990-1995.
We used the hydrodynamic model HEC-RAS to achieve a hydrodynamic simulation of a 188-km reach, where 420 surveyed cross sections are available. This model is used to interpolate rating curves (river stage vs. discharge) with a mean resolution of 200 m. The latter are then projected onto the river grid cells of the regional hydrological model EauDyssée (1-km resolution), where they allow for fluctuating river stage, as a function of the discharge routed at the regional scale by EauDyssée. The altitude of the river surface defining its hydraulic head, these fluctuations influence the exchanges between the river and aquifer cells, which depend on the related vertical hydraulic gradient (Darcy's law).

This work outlines the efficiency of the approach to better simulate river stages and stream-aquifer interactions at regional scale with low computing cost. Furthermore, this framework coupling strategy have several perspectives: for example simulating the hydrodynamic behavior of alluvial wetlands, modeling more accurately the impact of climate change on hydrosystems, especially concerning pollutants removal or release by biogeochemical processes, or better assessing the risk of inundations at the regional scale.

Keywords: Hydrology, Hydrodynamics, Hydrogeology, Upscaling, Regional scale, Local scale, Stream-aquifer interactions