



Evaluating surface-subsurface lateral flow interaction and solute concentration in a river channel using the diffusive wave inverse problem

Roger Moussa¹, Samer Majdalani², Jean-Baptiste Charlier^{3,4}, and Martin Le Mesnil^{1,3,4}

¹LISAH, Univ. Montpellier, INRAE, IRD, SupAgro, Montpellier, France.

²Univ. Montpellier, Polytech Montpellier/HSM, France.

³BRGM, Univ. Montpellier, Montpellier, France.

⁴G-eau, INRAE, CIRAD, IRD, AgroParisTech, Supagro, BRGM, Montpellier, France.

Lateral flow $L(t)$ representing surface-subsurface flow exchange is a major process during flood events, which can be either gains (positive) or losses (negative) to the channel. The inverse problem consists of evaluating $L(t)$ knowing the inflow $I(t)$ and the outflow $O(t)$ on a channel. However $L(t)$ and the corresponding solute concentration are very difficult to measure on real channels, and we are always not sure to which extent the evaluated $L(t)$ is close to the real one. This paper aims at evaluating $L(t)$ and the corresponding solute concentration in a channel using the analytical solution of the inverse problem of the Hayami diffusive wave equation (DWE) with $L(t)$ uniformly distributed along the channel, used in the MHYDAS model (Moussa et al., 2002). Applications are shown on an experimental channel (4 m) and on six natural river channels (5 to 20 km). First, we conceived and built a novel 4 m experimental channel (Majdalani et al., 2019) where $I(t)$, $O(t)$ and $L(t)$ and are highly controlled at 1 second time step and we realize 62 experimental hydrograph scenarios corresponding to different shapes of $I(t)$ and $L(t)$. We validate the hypotheses of both the DWE Hayami model and the corresponding inverse model (with very high criteria functions values for a large majority of scenarios) which reflects the ability of the DWE inverse model to reproduce complex lateral flow hydrograph and solute concentration dynamics (Moussa and Majdalani, 2018). Second, we apply the methodology on two French karst rivers in order to evaluate surface-subsurface flows during flood events (Le Mesnil et al., 2022): three river reaches in the Loue catchment in a temperate/mountainous climate, and three river reaches in the Cèze catchment in a Mediterranean climate. Results show that flood process seasonality is mainly related to karst aquifer saturation rate, while intra-site variability is linked to karst area extension and river morphology. Results are encouraging to extend this approach to a variety of sites, notably those affected by significant surface water-groundwater interaction and groundwater flooding. Such approach, by providing discretized information on flood processes, could help refining lumped hydrological models, or facilitate the use of semi-distributed ones. The coupled experimental-modelling approach proposed herein opens promising perspectives regarding the evaluation of lateral flow on real channels.

References

Le Mesnil M., Charlier J.-B., Moussa R., Caballero Y., 2022. Investigating flood processes in karst catchments by combining concentration-discharge relationship analysis and lateral flow simulation. *Journal of Hydrology* 605 (2022) 127358, 14 pp. <https://doi.org/10.1016/j.jhydrol.2021.127358>

Majdalani S., Moussa R., Chazarin J.-P., 2020. A novel platform to evaluate the dampening of water and solute transport in an experimental channel under unsteady flow conditions. *Hydrological Processes*, 34, 956-971. Article ID: hyp13624. DOI: 10.1002/hyp.13624

Moussa R., Majdalani S., 2019. Evaluating lateral flow in an experimental channel using the diffusive wave inverse problem. *Advances in Water Resources*, vol 127, 120-133. <https://doi.org/10.1016/j.advwatres.2019.03.009>

Moussa R., Voltz M., Andrieux P., 2002. Effects of the spatial organization of agricultural management on the hydrological behaviour of a farmed catchment during flood events. *Hydrological Processes* 16 : 393-412 (DOI: 10.1002/hyp.333).