Évaluation par modélisation inverse des apports latéraux en crues et des concentrations en solutés: Applications sur une plateforme expérimentale et sur des bassins naturels

(Modelling lateral flow and solute concentration in a river channel during flood events)

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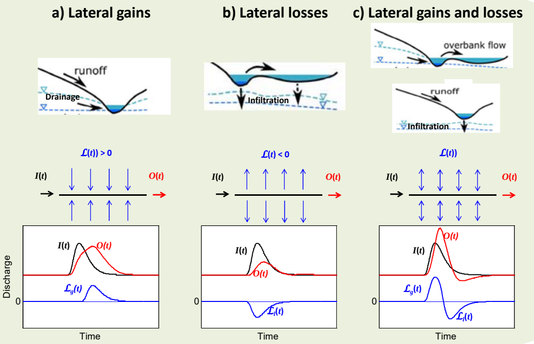
Introduction

Lateral flow $\mathcal{L}(t)$ is a major process during flood events, which can represent either a gain for the reach such as surface runoff from hillslopes or water table drainage, or a loss such as overbank flow during extreme floods or infiltration into the aquifer. Despite recent progress in measurements, lateral flow cannot be measured. This work aims at evaluating $\mathcal{L}(t)$ and the corresponding solute concentration in a channel using the Diffusive Wave Equation DWE :

$$\frac{\partial Q}{\partial t} + C(Q)\left[\frac{\partial Q}{\partial x} - q\right] - D(Q)\left[\frac{\partial^2 Q}{\partial x^2} - \frac{\partial q}{\partial x}\right] = 0$$

where $q(x, t)$ is the lateral flow per unit length supposed uniformly distributed along the channel, $C(Q)$ the celerity, and $D(Q)$ the diffusivity. Moussa (1996) developed an analytical solution of the inverse problem which enables to calculate $\mathcal{L}(t)$ knowing the inflow $I(t)$, the outflow $O(t)$, and the parameters C and D calibrated on events without lateral flow. Application are conducted on : i) an experimental platform, and ii) on natural basins.



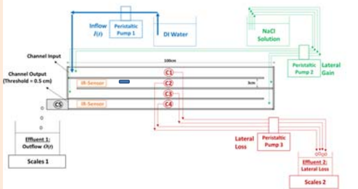
1. Experimental platform

(*Majdalani et al., 2020*)

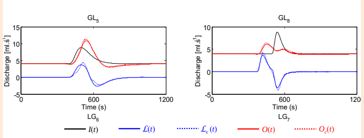
Application on an experimental channel or a scale model of the river, where the hydrographs and the electrical conductivity of the water of the inflows, outflows and lateral gains/losses are measured: the objective of these experiments is to have a large number of flood events in a controlled environment to: i) validate the inverse DWE model for water and solute; ii) model complex hydraulic relationships such as hysteresis stage-discharge and concentration-discharge hysteresis.

a) Experimental rectangular channel

(*Moussa and Majdalani, 2020*)



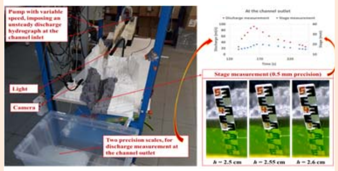
Dimensions 4 m x 3 cm x 4 cm; Conductivity meters C1 to C5.



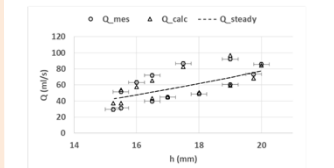
Examples of the validation of the inverse DWE model on 2 scenarios. Comparison between the observed lateral flow $\mathcal{L}$(t) and the calculated $\mathcal{L}$c(t).

b) 3D printed model of the Var river

(*Majdalani et al., 2023*)



Dimensions 180 cm x 3 cm x 4 cm; ruler for measuring the water level, and example of flow rate and water level measurements.

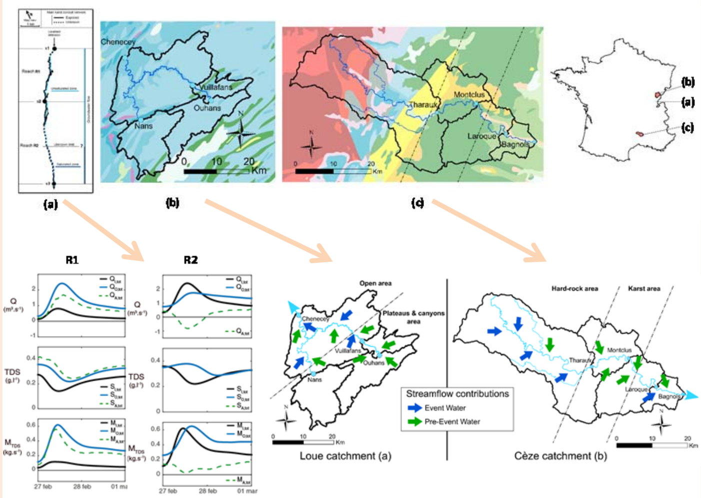


Example of hysteresis Depth (h) – Discharge (Q). Comparison between measured Q_mes and the calculated Q_cal from Jones formulae.

2. Application on karstic basins

(*Charlier et al., 2019*)

Application on natural karstic basins where hydrographs and concentrations of inflows and outflows only are available: the objective is to apply the methodology to sites where data on lateral flow are lacking, in order to establish a hydrological conceptual scheme of groundwater-river exchanges during floods: (a) Fourbanne (*Cholet et al., 2017*), (b) Loue, and (c) Cèze (*Le Mesnil et al., 2021, 2022*).



Application of the inverse DWE model to calculate $\mathcal{L}(t) = Q_{A\_tot}$ and the concentration.

Conceptual model of main flood processes.

Conclusion

- Development of the inverse DWE model in order to calculate lateral gains and losses as well as the concentrations.
- Realization of an experimental platform characterized by low space occupation, short experimental duration, high measurement precision, high quality experimental curves, low water and energy consumption, and the ability to test a wide variety of hydrograph scenarios.
- Applications on a rectangular channel and on a reduced model of the downstream part of the Var.
- The platform provides a large number of flood events in a controlled environment, essential for checking and validating hydraulic inverse DWE model and H-Q and C-Q hysteresis
- The applications on natural karstic basins enables to evaluate lateral flows of lateral and to propose a conceptual hydrological model during flood events.

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