PostDoc position

Implementing tracers in hydrogeological models to improve predictive skills : application to territorial planning and water sharing issues

Summary

Climate change, combined with increasing water consumption and landscape change, is increasing the pressure on groundwater and soil resources. The role of numerical hydrological models is becoming paramount to explore possible futures and to better decide and act in the face of uncertainty. Models have the pivotal role to represent the complexity of the natural and anthropized environment to answer place-specific questions. However, two main issues limit the predictive capabilities of hydrological models (Wada et al., 2013) : (1) the need to study the behavior of the hydrological system under never-before-seen climatic conditions (Milly et al. 2009), so that current management tools are now based on compromised hypotheses and (2) the need to address the scale challenges (Blöschl and Sivapalan, 1995) and to represent physically the system in its complexity, including surface-groundwater interactions (Abhervé et al., 2023), as well as the cumulative effects of local water management infrastructures (de Graaf, 2019, Xie et al., 2020, Guillaumot et al., 2023).

In this challenge to improve model predictive capabilities, we hypothesize that the incorporation of distributed observations representing a range of water flow paths into physical models will provide critical information to better represent how water is stored and released in hydrological systems, i.e. the non-linear storage-discharge relationships. This modeling experiment will be proposed on the Guidel Observatory (Figure 1)

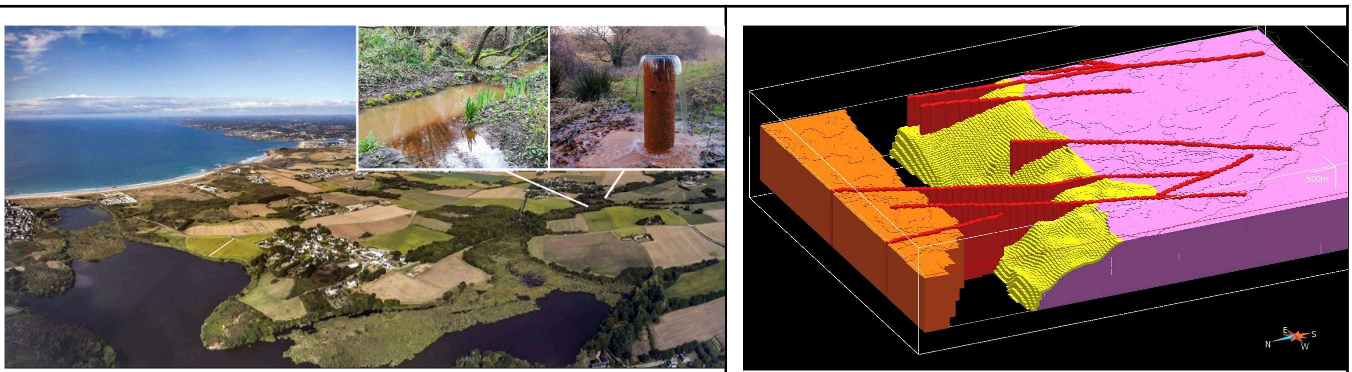

Figure 1 : (left) Photo of the classified groundwater-dependent ecosystem on the Brittany coast. (right) illustration of Guidel geological model based on geological and geophysical data, to be implemented in coupled surface-subsurface hydrogeological model

Key Words

Heterogeneity, Groundwater, Water flow paths, Tracers, Modflow,

Project Description

Model descriptive capabilities are often judged on classical observation, whether integrative (river discharge) and/or point information (water content, well data), leading to a set of equiprobable models with diverging behavior under future conditions (e.g. Xie et al., 2020). Improving predictive skills requires to better inform the model, with two main targets : (1) represent subsurface heterogeneities and its impact on water flow paths and (2) represent spatially distributed boundary conditions. New data are required, as well as tools to evaluate their specific information content.

New opportunities arise from spatially distributed information, such as high resolution remote sensing, informing on surface condition evolution (Li et al., 2018), yet, with limited information on deep processes. On the contrary, tracers can inform on a range of groundwater processes (Holmes et al., 2023), such as flow pattern, flow partitioning, water age, … In both cases, two general questions remain :(1) what is the relevant framework to implement such information in high resolution hydrological models, and (2) what is their actual information content with respect to more classical observations.

In this work, we hypothesize that tracers bring original data to better inform on water flow path in the subsurface, and therefore support the representation of water flowpaths in heterogeneous hydrogeological systems and improve the representation of storage-discharge relationships. We propose a numerical experiment in which the production and transfer of different kinds of tracers (isotopes, radon) are implemented in a modflow module.

The recruited person will strengthen the team working on Hydromodpy[1] python package to facilitate the deployment of unconfined aquifer catchment-scale hydrogeological models.

Context

The proposition is anchored both on a European project with shared scientific questions and a highly instrumented and documented observatory.

The post-doc is set within the European project BLUE TRANSITION[2] “How to make my region climate resilient”, which brings together 24 partners from 6 countries in the “North Sea”, gathering researchers, managers, territorial stakeholders around 16 pilot sites in a common context of increasing pressures in coastal areas. The diversity of the actors involved and the regulatory frameworks is a favorable and very inspiring context for the student. Locally, the project translates into very concrete questions linked to the onset of a pumping station in an aquifer (to meet the growing water needs), located upstream of a classified ecosystem. This increase in pressure in a context of reduced precipitation requires a move away from emergency management towards planning.

The project is set on the Ploemeur-Guidel observatory[3], which is part of the OZCAR research infrastructure (https://www.ozcar-ri.org), which is a highly instrumented and monitored catchment on the Brittany Coast in a fractured crystalline geological context and oceanic climate. The observatory is set on a natural deep groundwater resurgence and documents how groundwater contributes to the water cycle and shapes ecosystems. It is built on 2 sub-sites, one highly anthropized, the other in natural state. In Ploemeur, groundwater has been pumped since 1991, supplying more than 1 million m3 of clean drinking water annual at a sustainable rate. Such high productivity is explained by the specific fractured network in granite and micaschists, draining deep geological layers (~400 m). Guidel site is in a similar, but natural context. Deep iron-rich groundwater is upflowing, creating surface and deep groundwater-dependent ecosystems, and feeding a classified coastal wetland. Both sites have very dense equipment to study rapid to long-term surface-depth exchanges.

Supervision

Camille Bouchez *camille.bouchez@univ-rennes.fr ,*

Laurent Longuevergne *laurent.longuevergne@univ-rennes.fr*

Maria Klepikova *maria.klepikova@univ-rennes.fr*

Pre-Requisite

PhD in environmental / geosciences with interest in hydrological modeling.

Skills in hydrological numerical modeling (modflow / flopy)

Framework

Monthly Salary : Gross from 3000€ to 4000€ / month depending on experience, plus social security

[1] https://app.readthedocs.org/projects/hydromod/
[2] https://www.interregnorthsea.eu/blue-transition
[3] https://hplus.ore.fr/ploemeur and https://deims.org/731f3ced-148d-4eb5-aa46-870fa22be713

Publications :

Abhervé, R., Roques, C., Gauvain, A., Longuevergne, L., Louaisil, S., Aquilina, L., & de Dreuzy, J. R. (2023). Calibration of groundwater seepage against the spatial distribution of the stream network to assess catchment-scale hydraulic properties. *Hydrology and Earth System Sciences*, *27*(17), 3221-3239.

Blöschl, G., & Sivapalan, M. (1995). Scale issues in hydrological modelling: a review. *Hydrological processes*, *9*(3-4), 251-290.

de Graaf, I. E., Gleeson, T., Van Beek, L. P. H., Sutanudjaja, E. H., & Bierkens, M. F. (2019). Environmental flow limits to global groundwater pumping. *Nature*, *574*(7776), 90-94.

Guillaumot, L., Longuevergne, L., Marçais, J., Lavenant, N., & Bour, O. (2022). Frequency domain water table fluctuations reveal impacts of intense rainfall and vadose zone thickness on groundwater recharge. *Hydrology and Earth System Sciences*, *26*(22), 5697-5720.

Guillaumot, L., Smilovic, M., Burek, P., De Bruijn, J., Greve, P., Kahil, T., & Wada, Y. (2022). Coupling a large-scale hydrological model (CWatM v1. 1) with a high-resolution groundwater flow model (MODFLOW 6) to assess the impact of irrigation at regional scale. Geoscientific Model Development, 15(18), 7099-7120.

Holmes, T. L., Stadnyk, T. A., Asadzadeh, M., & Gibson, J. J. (2023). Guidance on large scale hydrologic model calibration with isotope tracers. *Journal of Hydrology*, *621*, 129604.

Larochelle, S., Chanard, K., Fleitout, L., Fortin, J., Gualandi, A., Longuevergne, L., ... & Avouac, J. P. (2022). Understanding the geodetic signature of large aquifer systems: Example of the Ozark Plateaus in Central United States. *Journal of Geophysical Research: Solid Earth*, *127*(3), e2021JB023097.

Li, Y., Grimaldi, S., Pauwels, V. R., & Walker, J. P. (2018). Hydrologic model calibration using remotely sensed soil moisture and discharge measurements: The impact on predictions at gauged and ungauged locations. *Journal of hydrology*, *557*, 897-909.

Milly, P. C., Betancourt, J., Falkenmark, M., Hirsch, R. M., Kundzewicz, Z. W., Lettenmaier, D. P., & Stouffer, R. J. (2008). Stationarity is dead: Whither water management?. *Science*, *319*(5863), 573-574.

Osorio-Leon, I., Bouchez, C., Chatton, E., Lavenant, N., Longuevergne, L., & Le Borgne, T. (2023). Hydrological and geological controls for the depth distribution of dissolved oxygen and iron in silicate catchments. *Water Resources Research*, *59*(8), e2023WR034986.

Xie, H., Longuevergne, L., Ringler, C., & Scanlon, B. R. (2020). Integrating groundwater irrigation into hydrological simulation of India: Case of improving model representation of anthropogenic water use impact using GRACE. *Journal of Hydrology: Regional Studies*, *29*, 100681.

Wada, Y., Wisser, D., Eisner, S., Flörke, M., Gerten, D., Haddeland, I., ... & Schewe, J. (2013). Multimodel projections and uncertainties of irrigation water demand under climate change. *Geophysical research letters*, *40*(17), 4626-4632.