AAP China Scholarship Council - CSC 2024

PROJET DE RECHERCHE DOCTORALE (PRD)

Titre du PRD : Hydro-sedimentary and biogeochemical functioning of aquatic systems: contribution of satellite imagery to the modelling the Seine River (France)

DIRECTION de THESE

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Unité de recherche : Code (ex. UMR xxx) et Intitulé : UMR 7619 METIS Milieux environnementaux, transferts et interactions dans les hydrosystèmes et les sols

Ecole doctorale de rattachement : ED398 - GRNE

Nombre de doctorants actuellement encadrés : 2

CO-DIRECTION de THESE (HDR) ou CO-ENCADREMENT (Non HDR) :

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Unité de recherche : Code (ex. UMR xxx) et Intitulé : UMR 7619 METIS Milieux environnementaux, transferts et interactions dans les hydrosystèmes et les sols

Ecole doctorale de rattachement Sorbonne Université : ED398 - GRNE ou autre :

Nombre de doctorants actuellement encadrés : 0

CO-TUTELLE INTERNATIONALE envisagée : ☐ OUI ☒ NON

DESCRIPTIF du PRD :

*Ce texte sera affiché en ligne à destination des candidates et candidats chinois : il ne doit pas excéder **2 pages** doit être rédigé en **ANGLAIS***

The quality of continental waters is affected by a wide range of natural (hydromorphological, climatic, etc.) and anthropogenic (point source, diffuse pollution) constraints that control the metabolism of aquatic ecosystems from the smallest streams to the largest river stretches. Among these constraints, hydrological conditions control the erosion of suspended solid and the associated fluxes of particulate pollutants reaching the drainage network. They also set the dilution conditions in the receiving water masses, where it can influence the impact of point sources releases, and also control the potential growth of micro-organisms (growth rate vs. dilution rate). In addition, flow velocities determine the residence time of water masses (and the associated biogeochemical reactivity), and control the dynamics of particulate elements in the water column (erosion, transport, deposition) and at the interface with the benthic sediment. The development of models that can jointly describe the hydro-sedimentary and biogeochemical functioning of aquatic ecosystems can help in quantifying the respective contribution of these controlling factors in both space (on the scale of a catchment area) and time (seasonal variations).

The thesis proposal will consider the ultra-anthropised area of the Seine river basin (76,000 km² including the Paris conurbation, France), where more than 30 years of research has been carried out as part of the PIREN-Seine program. The development of the pyNuts-Riverstrahler model was (Thieu et al. 2017) part of the PIREN-Seine program. This Lagrangian calculation combines a mechanistic representation of the hydrological and biogeochemical processes operating in the aquatic continuum (RIVE model: Billen et al., 1994; Wang et al. 2023). It calculates spatial and seasonal variations (with a temporal resolution of 10 days) of water discharge and quality for any hydrographic network, based on the RIVE biogeochemical model (where the processes are described with infra-hourly resolution). The genericity of this modelling approach enables its applications on a large variety of scales and across significant climatic and anthropogenic gradients (Desmit et al. 2018). All the codes developed in this research are community-based and openly accessible (https://gitlab.in2p3.fr/rive).

The first aim of the thesis will be to revisit (spatially and temporally) the methods for quantifying sediment transport towards aquatic compartments. Indeed, many studies assess gross erosion (Cerdan et al., 2010) and involve a spatial redistribution of eroded material as well as the calibration of a sedminent ratio (Delmas et al. 2009) to estimate net erosion to hydrosystems. More recently, the WaTEM/SEDEM model (Borrelli et al. 2018) was used to estimate multiannual average net erosive fluxes with a spatial resolution of 25 m, making it possible to estimate total inputs to the hydrographic network. While the improvement in spatial granularity is significant, temporal dynamics may be improved by the use of satellite imagery. In addition to quantifying suspended solids more effectively, these results will help to improve all the associated diffuse particulate inputs to the pyNuts-Riverstrahler model (in particular: total inorganic phosphorus PIT, particulate organic carbon POC, and amorphous silica ASi).

In its current configuration, the pyNuts-Riverstrahler model incorporates water flows and diffuse sources of total suspended solids (TSS) as boundary conditions modelling the quality of hydrographic networks. A second challenge of the thesis will concern the modelling of flow velocities and hydraulic dilution capacities along the entire length of the hydrographic network. The first step will be to improve the representation of water discharge, by coupling the biogeochemical model with the GR or CaWaQS hydrodynamic models, which enable distributed simulations of water discharge

based on climatic forcing. Also, the pyNuts-Riverstrahler modelling relies on several morphological parameters (slopes, width, Manning's coefficient) alongside water discharge to estimate water levels and flow velocities. The determination of these parameters is supported by accurate topographic layers and recent hydromorphological databases (CarHyCe, Gob et al. 2014), but could also be enhanced by new water-level data produced by the SWOT (Surface Water and Ocean Topography) missions. The research will help to identify the respective contribution of hydrological and biogeochemical controls on the functioning of the Seine River, and to characterize its sensitivity to climate change involving more intense floods and more severe low-water periods (Raimonet et al. 2018).

The third objective of the thesis will be to strengthen the aquatic modelling of sediment transport. In the pyNuts-Riverstrahler model, two flow components (sub-surface and subsurface) are required, and transport capacity is directly related to flow velocity using a conceptual formalism (Velikanov). Several approaches exist for determining sediment transport, and several configurations will be tested, from simple power models (Asselman 2000), empirical modelling based on shear stress (e.g. Meyer-Peter and Müller 1948) or conceptual reservoir modelling (Lidén 1999). Remote sensing processing chain based on inland water colour analysis (Pole Theia, https://www.theia-land.fr) will be used in tandem with in-situ measurements of turbidity and TSS concentrations, to validate the models simulations. By improving the representation of TSS concentrations in rivers, this third research topic will also improve the simulation of dissolved elements (e.g. orthophosphate PO4) adsorbed onto particles. Induced impact on lighting conditions (extinction coefficients integrated over the depth of the water column) and primary production modelled by the RIVE model will also benefit indirectly from this research.

Ludovic Oudin and Vincent Thieu will jointly supervise the PhD work, which will be carried out at UMR 7619 METIS, Sorbonne University (Paris, France), within the GRNE doctoral school. Ludovic Oudin will offer his expertise in hydrological and hydraulic modelling and Vincent Thieu will provide his expertise in biogeochemical modelling and remote sensing.

References

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