Research engineer in hydrology and flood forecasting
18 months

Université Gustave Eiffel – campus de Nantes (44), France
Département Géotechnique, Risques naturels et Sciences de la Terre
Laboratoire Eau Environnement (GERS-LEE)

Position objectives

This position is a contribution to the ANR MUFFINS research project - MUltiscale Flood Forecasting with Innovative Solutions (https://anr.fr/Projet-ANR-21-CE04-0021), which deals with flash flood forecasting. The main aim of the project is to develop integrated and continuous forecasting chains, offering the ability to anticipate flows, inundated areas and impacts, and capable of covering and transferring information between different scales of phenomena (from local surface water runoff up to the overflooding of gauged or ungauged rivers), while taking advantage of innovative data (in situ or remote sensing, measurements or proxies, ...). Particularly, this objective requires the development of distributed hydrological models and fine-resolution hydraulic models, as well as their integration and connection within flood forecasting chains.

The position is part of work package 3 of the project, aiming to discuss the methods developed and their operational benefits with an end-user's group, which includes operational flood forecasting centers (SPCs), local authorities, etc.. The main objective of this WP is to illustrate and evaluate the methods based on the reforecast of recent flood events which affected the study areas selected in the project (Huveaune, Argens and Gapeau watersheds).

The aim of the work will be to produce the reforecasts of past events necessary for exchanges with the end-user group, based on the flood forecasting approaches developed in the MUFFINS project. This will involve applying different modelling chains, and reproducing the course of the studied events, particularly the successive runs of forecasts and the times at which they could have been launched and made available in a real-world situation. This work will require the handling of different modelling tools developed by the project partners.

Planned activities

The case studies and events to be studied will be refined at the beginning of the contract, based on exchanges with the project's end-user's group. The case studies will probably include the Huveaune and Gapeau basins, and the objective will be to replay several flood events in each of these basins. The reforecasts will have to illustrate the ability to anticipate floods and their impacts, at the scale of the whole catchments, and to integrate in the forecast phenomena occurring at different scales, from local surface water runoff up to the overflooding of main rivers as well as small ungauged streams.

The modelling chains to be applied will be based on the approaches already applied and tested as part of the MUFFINS project's PhDs and research contributions. Particularly, the first modelling chain to be applied will combine :

- Short-range ensemble rainfall forecasts (+3h to +6h), provided with regular updates (15 min to 1h, see Godet et al., 2023). These products are provided by the Centre National de Recherche Météorologique (CNRM). They are not all yet operational, so their time of release in real-life situations will have to be estimated.

- The SMASH hydrological model developed at INRAE (https://smash.recover.inrae.fr/index.html), in a version including parameters regionalization (Jay-Allemand et al., 2020; Colleoni et al., 2022; Huynh et al., 2023). The model will be applied with a 1-kilometer resolution and a time step of 15min, using a pre-existing regional calibration or through a specific calibration specific for the studied basins. It will be forced with the above-mentioned rainfall ensemble forecasts to obtain hydrological ensembles of forecasts.
- A pre-existing library of flood scenarios (Nicolle et al., 2021, 2023; Nicolle & Payrastre, 2023), produced with the Floodos 2D model (Davy et al., 2017; Hocini et al., 2021), and which currently includes 8 flood scenarios for return periods ranging from 2 to 1000 years. This library will be extended if necessary to extend or improve flood scenarios for instance based on unsteady hydraulic models.
- A simple representation of impacts, which can be obtained through the simple counting of the stakes present in the inundated areas, or through models enabling the valorisation of water heights (e.g. for instance the Roadino method for the estimations of risks of road cuts, see Osman, 2021).

This first modelling chain is the simplest that will be considered. It will enable to easily cover all the watersheds concerned by the case studies. The chaining of models will follow the principles proposed in Juliette Godet's PhD (in progress), particularly for the connection between the SMASH model forecasts and inundation scenarios (Godet, Gaume, et al., 2023).

The evaluations of forecasts will focus on the capacity to correctly anticipate flow discharges, inundations, water heights and damages observed. These evaluations will build on recent works achieved at Université Gustave Eiffel, in the fields of evaluating discharge forecasts (M. Charpentier-Noyer et al., 2023; Godet, Payrastre, et al., 2023), flooded areas and water heights (Hocini et al., 2021; Hocini, 2022), or impacts (Le Bihan et al., 2017; Maryse Charpentier-Noyer, 2022). The assessment of impacts will be adapted according to the data available for each of the studied events.

In a second phase, variants and/or improvements to the initial forecasting chain will be proposed and tested, depending on the objectives defined by the end-user's group, and the specific features of each case study. The objectives may be, for example, to improve the anticipation, and/or to better describe the inundations at specific scales (local runoff in urban areas, river overflow in complex confluence sectors). These variants or improvements may include:

- alternative rainfall forecast products, enabling a better representation of uncertainties and/or larger forecast ranges (up to 24 hours).
- improving the description of inundations in complex hydraulic sectors such as confluences, or in impacts hotspots requiring a better accuracy. This could be achieved by increasing the number of inundation scenarios integrated into the chain, or by running 2D unsteady hydraulic models (Telemac 2D, DassFlow2D), or even machine learning models as surrogates (M. Allabou's PhD) to directly retrieve the inundation patterns from flow forecasts.
- improving the description of inundations in upstream areas exposed to surface water flooding. This could be achieved by using flood scenarios derived from 2D unsteady models directly run with rainfall forcing (Cartino 2D approach based on Telemac 2D, Pons et al., 2021). Where appropriate, this approach could be based on the methodological aspects defined in Akshay Kowlesser's PhD (in progress), in terms of the number of scenarios and the way they are integrated into the forecasting chain (recognition based on a sequence of forecast rainfall).

Skills required

Very good computing and programming skills, particularly R and Python languages (also if possible C++, Fortran)

Experience in geographic information systems (GIS)

Experience or knowledge in rainfall-runoff hydrological modelling and hydraulic modelling.

Good relational skills and capacity of working in a team (multiple interactions with project contributors and end-users group)

Thoroughness and adaptability

Writing skills

Good level in English, and French (if possible)

Education and experience

Initial master degree in applied mathematics, computer science, hydrology or hydraulics. A PhD degree or an equivalent professional experience (1 to 4 years) would be appreciated.

Work conditions

The position is opened at Université Gustave Eiffel in the Laboratoire Eau Environement (LEE), which is part of the GERS Department (geosciences). The LEE laboratory is located in Bouguenais, nearby Nantes (44), France.

The lab currently employs 39 people, and its activities are focused on three main research topics: urban water management and adaptation to global change; environmental assessment of urban soils and recycled materials; hydrographic networks, flash floods and inundation risks.

Working time is 38.5 hours a week, with flexible working hours (badge system). A restaurant and sports facilities are available on the campus.

Teleworking is possible for up to two days a week, and can be launched after an initial start period of two months. Rights for annual leave include 25 days of vacation and 20 additional days of RTT (10 free days and 10 days fixed by the university).

Some visits of a few days may be required to the MUFFINS partner laboratories (Inrae Aix en Provence, Cerema Aix en Provence, IMT Toulouse) for training on the different modelling tools to be applied.

Applications, date of start and duration

Applications should be sent by the 9th of February 2024 at the latest, to the contacts below (CV + motivation letter). The start is expected in spring or summer 2024, for a period of 18 months.

Contacts

Olivier Payrastre, Université Gustave Eiffel, GERS-LEE (olivier.payrastre@univ-eiffel.fr) – coordinator of WP3 in the MUFFINS project

Pierre Nicolle, Université Gustave Eiffel, GERS-LEE (pierre.nicolle@univ-eiffel.fr)

Pierre André Garambois, INRAE Recover (pierre.andre.garambois@inrae.fr) – main coordinator of MUFFINS project

Pierre Javelle, INRAE Recover (pierre.javelle@inrae.fr)

References

Scientific publications and defended PhDs :

Charpentier-Noyer, M., Peredo, D., Fleury, A., Marchal, H., Bouttier, F., Gaume, E., et al. (2023). A methodological framework for the evaluation of short-range flash-flood hydrometeorological forecasts at the event scale. *Natural Hazards and Earth System Sciences*, *23*(6), 2001–2029. https://doi.org/10.5194/nhess-23-2001-2023

Charpentier-Noyer, Maryse. (2022). *Évaluation de prévisions hydrométéorologiques d'ensemble des crues soudaines à partir de données sur les impacts* (Thèse de Doctorat). Nantes Université, Université Gustave Eiffel. Retrieved from https://www.theses.fr/s234690

Colleoni, F., Garambois, P.-A., Javelle, P., Jay-Allemand, M., & Arnaud, P. (2022). *Adjoint-based spatially distributed calibration of a grid GR-based parsimonious hydrological model over 312 French catchments with SMASH platform* (preprint). Catchment hydrology/Modelling approaches. https://doi.org/10.5194/egusphere-2022-506

Davy, P., Croissant, T., & Lague, D. (2017). A precipiton method to calculate river hydrodynamics, with applications to flood prediction, landscape evolution models, and braiding instabilities. *J. Geophys. Res. Earth Surf.*, *122*(8), 1491–1512. https://doi.org/10.1002/2016JF004156

Godet, J., Payrastre, O., Javelle, P., & Bouttier, F. (2023). Assessing the ability of a new seamless short-range ensemble rainfall product to anticipate flash floods in the French Mediterranean area. *Natural Hazards and Earth System Sciences*, *23*(11), 3355–3377. https://doi.org/10.5194/nhess-23-3355-2023

Godet, J., Gaume, E., Javelle, P., Nicolle, P., & Payrastre, O. (2023). *Technical note: Comparing three different methods for allocating river points to coarse-resolution hydrological modelling grid cells* (preprint). Global hydrology/Modelling approaches. https://doi.org/10.5194/hess-2023-165

Hocini, N. (2022). *Evaluation de méthodes automatisées de cartographie des zones inondables adaptées à la prévision des crues soudaines.* (Thèse de Doctorat). Nantes Université, Université Gustave Eiffel. Retrieved from https://www.theses.fr/2022NANU4015

Hocini, N., Payrastre, O., Bourgin, F., Gaume, E., Davy, P., Lague, D., et al. (2021). Performance of automated methods for flash flood inundation mapping : a comparison of a digital terrain model (DTM) filling and two hydrodynamic methods. *Hydrology and Earth System Sciences*, *25*(6), 2979–2995. https://doi.org/10.5194/hess-25-2979-2021

Huynh, N. N. T., Garambois, P.-A., Colleoni, F., & Javelle, P. (2023). Signatures-and-sensitivity-based multi-criteria variational calibration for distributed hydrological modeling applied to Mediterranean floods (Version 2). https://doi.org/10.48550/ARXIV.2305.19307

Jay-Allemand, M., Javelle, P., Gejadze, I., Arnaud, P., Malaterre, P.-O., Fine, J.-A., & Organde, D. (2020). On the potential of variational calibration for a fully distributed hydrological model: application on a Mediterranean catchment. *Hydrology and Earth System Sciences*, *24*(11), 5519–5538. https://doi.org/10.5194/hess-24-5519-2020

Le Bihan, G., Payrastre, O., Gaume, E., Moncoulon, D., & Pons, F. (2017). The challenge of forecasting impacts of flash floods: test of a simplified hydraulic approach and validation based on insurance claim data. *HYDROLOGY AND EARTH SYSTEM SCIENCES*, *21*(11), 5911–5928. https://doi.org/10.5194/hess-21-5911-2017

Nicolle, P., & Payrastre, O. (2023). *Evaluation d'un catalogue d'inondation mono-fréquence couvrant l'arc méditerranéen (rapport d'étape).* (Convention DGPR-Université Gustave Eiffel 2022 n°2201357657 du 26/07/2022 - Action 8.1) (p. 15). Université Gustave Eiffel. Retrieved from https://hal.science/hal-04159336

Nicolle, P., Payrastre, O., & Hocini, N. (2021). *Production d'un catalogue d'emprises inondées mono-fréquence sur les petits cours d'eau de l'arc méditerranéen (rapport d'étape)* (Convention DGPR-Université Gustave Eiffel 2020 n°2201239477 du 8 Juin 2020 - Action 8.1) (p. 14). Université Gsutave Eiffel. Retrieved from https://hal.science/hal-03327095

Nicolle, P., Payrastre, O., & Hocini, N. (2023). *Méthode de prétraitement des MNT pour l'amélioration des calculs automatisés de zones inondables* (Convention DGPR-Université Gustave Eiffel 2022 n°2201357657 du 26/07/2022 - Action 8.2) (p. 17). Université Gustave Eiffel. Retrieved from https://hal.science/hal-04159337

Osman, J. (2021). *Simulation of Road Network Cuts by Flooding during the October 2018 Flood in the Aude River Watershed.* (master internship report) (p. 28 p.). Grenoble INP - ENSE3 & Université Grenoble Alpes.

Pons, F., Alquier, M., Paya, E., Moulin, C., Panier, N., & Chollet, A.-E. (2021). Premiers tests de la méthode Cartino2D sur le territoire de Toulon Provence Méditerranée. *LHB*, *107*(1), 1–13. https://doi.org/10.1080/00186368.2021.1912968

Ongoing PhDs within the MUFFINS project:

M. Allabou (2022-), Réductions de modèle d'hydrodynamique pour simuler en temps réel la dynamique de plaines d'inondations, thèse de Doctorat, Université de Toulouse

Juliette Godet (2022-), Evaluation d'une chaine de prévision immédiate des impacts des crues soudaines à l'échelle de l'arc méditerranéen francais, thèse de Doctorat, Université Gustave Eiffel

Truyen Huynh (2022-), Vers une meilleure anticipation des crues méditerranéennes sur les bassins versants non jaugés - modélisations hydrologiques hybrides régionalisées, thèse de Doctorat, Aix-Marseille Université.

Akshay Kowlesser (2023-), Développement d'un cadre de prévision du ruissellement urbain et des crues éclair basé sur les impacts, en France et en Inde, thèse de Doctorat, Université Gustave Eiffel