RESEARCH CENTRE

Inria Branch at the University of Montpellier

IN PARTNERSHIP WITH:

Université de Montpellier, CNRS

2024

ACTIVITY REPORT

Project-Team

LEMON

Littoral Environment: M0dels and Numerics

IN COLLABORATION WITH: HydroSciences Montpellier (HSM), Institut Montpelliérain Alexander Grothendieck (IMAG)

DOMAIN

Digital Health, Biology and Earth

THEME

Earth, Environmental and Energy Sciences

Inria

Contents

Project-Team LEMON

Creation of the Project-Team: 2019 January 01

Keywords

Computer sciences and digital sciences

A3.1.4. – Uncertain data

A3.1.10. – Heterogeneous data

A3.4.1. – Supervised learning

A3.4.2. – Unsupervised learning

A6.1.1. – Continuous Modeling (PDE, ODE)

A6.1.2. – Stochastic Modeling

A6.1.4. – Multiscale modeling

A6.1.5. – Multiphysics modeling

A6.2.1. – Numerical analysis of PDE and ODE

A6.2.2. – Numerical probability

A6.2.3. – Probabilistic methods

A6.2.4. – Statistical methods

A6.3.3. – Data processing

A6.3.4. – Model reduction

A6.3.5. – Uncertainty Quantification

A6.5.2. – Fluid mechanics

A6.5.3. – Transport

A6.5.4. – Waves

A9.6. – Decision support

Other research topics and application domains

B3.1. – Sustainable development

B3.2. – Climate and meteorology

B3.3.2. – Water: sea & ocean, lake & river

B3.3.3. – Nearshore

B3.4.1. – Natural risks

B3.4.3. – Pollution

B3.6. – Ecology

B3.6.1. – Biodiversity

B4.3.2. – Hydro-energy

B6.5. – Information systems

B8.3. – Urbanism and urban planning

B8.4. – Security and personal assistance

B8.4.1. – Crisis management

B9.11. – Risk management

B9.11.1. – Environmental risks

1 Team members, visitors, external collaborators

Research Scientist

- Antoine Rousseau [Team leader, INRIA, Senior Researcher, HDR]

Faculty Members

- Konstantin Brenner [UNIV COTE D'AZUR, Associate Professor, until Feb 2024]
- Carole Delenne [UNIV MONTPELLIER, Associate Professor, until Aug 2024, HDR]
- Pascal Finaud Guyot [UNIV MONTPELLIER, Associate Professor, HDR]
- Vincent Guinot [UNIV MONTPELLIER, Professor, HDR]
- Nicolas Meyer [UNIV MONTPELLIER, Associate Professor]
- Gwladys Toulemonde [UNIV MONTPELLIER, Professor, HDR]

Post-Doctoral Fellow

- Katia Ait Ameur [INRIA, Post-Doctoral Fellow]

PhD Students

- Mitra Aelami [UNIV MONTPELLIER, from Oct 2024]
- Anne Bernard [UNIV MONTPELLIER, from Oct 2024]
- Fadil Boodoo [UNIV MONTPELLIER]
- Alexis Boulin [UNIV COTE D'AZUR, until Sep 2024]
- Alexandre Capel [UNIV MONTPELLIER, from Oct 2024]
- Omar Et Targuy [UNIV ARTOIS]
- Jose Daniel Galaz Mora [INRIA, until Jun 2024]
- Chloe Serre Combe [UNIV MONTPELLIER]
- Samuel Valiquette [CIRAD]

Technical Staff

- Lilas Bugeau [INRIA, Engineer, from Sep 2024]
- Jose Daniel Galaz Mora [Inria, from Sep 2024 until Nov 2024, Outreach mission for Tsunamilab at Cité des Sciences]

Interns and Apprentices

- Flavien Baudu [INRIA, Intern, from Mar 2024 until Aug 2024]
- Lucas Fourny [INRIA, Intern, from Apr 2024 until Sep 2024]
- Leonardo Russo [INRIA, Intern, from Mar 2024 until Jul 2024]

Administrative Assistant

- Cathy Desseaux [INRIA]

External Collaborator

- Carole Delenne [UNIV AIX-MARSEILLE, from Sep 2024, HDR]

2 Overall objectives

Coastal areas are increasingly threatened by global warming-induced sea level rise. At the same time, 60% of the world population lives in a 100 km wide coastal strip (80% within 30 km from the shore in French Brittany). This is why coastlines are concerned with many issues of various types: economical, ecological, social, political, etc. Coastal areas are natural interfaces between various media (*e.g.* wind/sea/sand/land). The physical processes acting on these media have very different time scales, hence the need to build complex systems coupling nonlinear partial differential equations and random processes to describe them. To address these crucial issues, **LEMON is an interdisciplinary team working on the design, analysis and application of deterministic and stochastic models for inland and marine littoral processes, with an emphasis on both standalone models and hybrid systems.**

The spot of Montpellier offers large opportunities:

Important academic research community Additionally to IMAG[1] and HSM[2], we interact with several local academic research partners. To mention but a few examples, we collaborate with UMR MISTEA (pollution and remediation of water resources) and UMR LISAH (hydrology in agricultural areas). Regular contacts are also maintained with UMR Geosciences (morphodynamics), UMR G-Eau (hydraulics, data assimilation and flood economy), UMR MARBEC (lagoon environment).

MIPS pole The LEMON members are involved in projects funded by the current MIPS pole at University of Montpellier and actively participate in new initiatives pertaining to *sea and coast* modeling, both in Montpellier and through external (national, European, international) calls.

Industrial and economic community From the transfer & innovation viewpoint, the team members already interact with several local partners such as Cereg Ingénierie, IRT Saint-Exupéry, Tour du Valat, Predict Services, Artelia, Montpellier Métropole and Berger-Levrault.

The general scope of the LEMON project-team is to develop mathematical and computational methods for the modeling of hydraulic and hydrodynamic processes. The mathematical tools used are deterministic (PDEs, ODEs) and/or probabilistic (extreme value theory). Applications range from regional oceanography to coastal management, including risk assessment for natural hazards on the coastline (submersion and urban floods, tsunamis, pollution).

LEMON is a common research team between HSM (UM, CNRS, IRD), IMAG (UM, CNRS) and Inria, whose faculty members have never been associated to Inria groups in the past. All fellows share a strong background in mathematical modeling, together with a taste for applications to the littoral environment. As reflected in the team contributions, the research conducted by LEMON is interdisciplinary [3], thanks to the team members expertise (deterministic and stochastic modeling, computational and experimental aspects) and to regular collaborations with scientists from other domains. We believe this is both an originality and a strength for LEMON .

3 Research program

Foreword

Interdisciplinarity is a characteristic and a strength for LEMON. We want to build on this mix by developing two main research axes - physics-driven and data-driven models - applied to free-surface hydraulic

[1] Institut Montpelliérain Alexander Grothendieck - UMR5149

[2] HydroSciences Montpellier - UMR 5569 - Note that HSM number changed from 5569 to 5151 in January 2021

[3] HSM UMR is a research unit affiliated to the National Institute for Sciences of the Universe (INSU) of CNRS, while the IMAG UMR is affiliated to the National Institute for Mathematical Sciences and their Interactions (INSMI).

processes and their coupling. These two axes will intersect through the hybridization of models and all this work will serve the development of the SW2D-LEMON software so that it remains both an operational easy to use software and a scientific reference of international standard.

3.1 Physics-driven models

3.1.1 Upscaled urban flood modeling

Participants: Lilas Bugeau, Carole Delenne, Pascal Finaud-Guyot, Vincent Guinot, Antoine Rousseau.

Collaboration: Brett Sanders *(UCI, USA)*, Sandra Soarez Frazao *(UCL, Belgium)*.

Concerning the physics-driven modeling axis, we will continue to work with porosity models, and more generally with upscaling mechanisms for free surface hydraulics. We know since [21] that each upscaled model is biased, which also eventually distorts downscaling operations. We wish to better identify these biases and take them into account in order to improve both the large-scale simulations (development of new models), and the small-scale ones (downscaling using compensation techniques between large-scale models).
The collaboration with University California Irvine (UCI) started in 2014 with research on the representation of urban anisotropic features in integral porosity models [24]. It has led to the development of the Dual Integral Porosity model [22]. Ongoing research focuses on improved representations of urban anisotropy in urban flood modeling.
Université Catholique de Louvain (UCL) is one of the few places with experimental facilities allowing for the systematic, detailed validation of porosity models. The collaboration with UCL started in 2005 and is still active.

3.1.2 Large time steps methods for hydraulic processes

Participants: Pascal Finaud-Guyot, Vincent Guinot, Antoine Rousseau.

Collaboration: Philippe Helluy *(Univ. Strasbourg & Inria TONUS)*.

In line with fast changes in the whole society, our scientific community is more and more sensitive to the environmental footprint of research. We already claim that porosity models can be valued for their sobriety, thanks to coarse space meshes and low computational cost simulations. We also wish to develop a time discretization strategy that will continue to lighten our algorithms. A first theoretical work has been carried out for 1D models, we wish to generalize it to 2D models and implement it into operational models.
Discussions have started with team TONUS in Strasbourg, as "CFL (Courant–Friedrichs–Lewy condition)-less" methods are also used by the team for kinetic-relaxation approximation [23].

3.1.3 Street-buildings interactions during flood events

Participants: Pascal Finaud-Guyot, Cécile Choley.

The improvement of realistic flood scenarios also requires the addition of specific processes: we will continue the modeling of interaction with buildings (work initiated by Cécile Choley's PhD thesis) and develop the transport of log jams in an urban flow, using the functionalities allowed by the concept of porosity to better take into account the feedback of log jams on the flow (crowding process).

3.1.4 Coupling coastal ocean and urban flood models

Participants: Antoine Rousseau, Jose Daniel Galaz Mora.

Collaboration: Maria Kazolea *(Inria, team CARDAMOM)*.

Finally, we wish to continue to couple the numerical models developed by the team with other processes: relying on collaborations external to LEMON (as is currently the case with the SURF project of Inria for the Green-Naghdi / shallow water coupling) or recruiting new permanent members, we will use the team's strengths in free-surface hydraulics and in model coupling to explore new fields of application.

3.2 Data-driven models

Participants: Carole Delenne, Pascal Finaud-Guyot, Vincent Guinot, Nicolas Meyer, Antoine Rousseau, Gwladys Toulemonde, Katia Ait Ameur, Mitra Aelami, Anne Bernard, Fadil Boodoo, Alexis Boulin, Omar Et Targuy, Jose Daniel Galaz Mora, Chloe Serre Combe, Samuel Valiquette.

One of the originality of LEMON is that we can count on a data-driven component that we wish to develop further. Data are indeed essential throughout the whole modeling/forecast process: providing source terms, bathymetric information, initial and boundary conditions; allowing model hybridization (using data assimilation or artificial intelligence methods); processing model outputs for risk measurements and decision making.

3.2.1 Data fusion and parameter estimation

Participants: Carole Delenne.

Macroscopic models such as those developed by the team have advantages in terms of computational cost, but also in terms of time saved in the processing of the mesh which does not need to describe complex geometries. However, these models require new parameters that reflect the statistical properties of the domain geometry or the topography/bathymetry of the modeled area. The directional and connectivity properties of the environment have to be estimated from geographical data. In the continuity of Vita Ayoub's thesis [20], LEMON will work on the development of methods for the automatic estimation of these parameters from cartographic or Earth observation data. The objective will be to set up a methodology for continuous acquisition and automatic fusion of new information in order to improve the mapping of the study area as often as the hydrodynamic models require it.

3.2.2 Space-time variability of rainfalls

Participants: Anne Bernard, Nicolas Meyer, Gwladys Toulemonde, Chloe Serre Combe.

Collaboration: Thomas Opitz *(INRAe, Avignon)*, Philippe Naveau *(LSCE, CNRS, Gif-sur-Yvette)*.

Understanding the spatial and temporal variability of rainfalls that can generate flash floods is a major challenge. This knowledge is essential to build stochastic methods for simulating scenarios integrating realistic spatiotemporal extreme rainfall fields. This modeling must be done keeping in mind the importance of the physical interpretation of data simulated with such models. We aim to develop, propose, study and implement models adapted to the presence of extreme values taking into account the associated complex dependencies. One difficulty lies in modeling the transitions (in time and space) between no rain, regular rainfall and extreme rainfall. Reproducing spatial or temporal non-stationarity in the intensities as well as in the dependency structure is also a challenge we wish to address.

3.2.3 Multivariate dependence

Participants: Nicolas Meyer, Gwladys Toulemonde, Alexis Boulin, Samuel Valiquette.

Collaboration: Elena Di Bernardino *(LJAD, UniCA)*, Thomas Laloé *(LJAD, UniCA)*, Eric Marchand *(Université de Sherbrooke)*, Frédéric Mortier *(Cirad, Montpellier)*, Jean Peyhardi *(IMAG, Université de Montpellier)*.

In the medium term, we want to develop appropriate risk measures that can then be used to assess the potential impacts of extreme rainfall events. Multivariate risk measures should be considered, as flood risk indicators are usually derived by combining different hydraulic variables. We would be interested in the estimation of risk sets, the idea being in the simplest framework to identify all the combinations of water height/velocity values which would lead to a risk higher than a fixed level. More generally, the question of modeling dependence in statistics, and in particular when we consider extremes, is one to which we want to contribute, as is the consideration of compound events.

3.2.4 Clustering and sparsity models for rainfall

Participants: Nicolas Meyer, Gwladys Toulemonde, Alexis Boulin.

Collaboration: Elena Di Bernardino *(LJAD, UniCA)*, Thomas Laloé *(LJAD, UniCA)*.

Finally, our aim is to model forcing terms (rainfall, wind, etc.) for a large number of stations and with a small time scale. In addition, many covariates will be included in the models to better explain the phenomena. This means that we will deal with high dimensional data and with potentially many parameters. This is a limitation in terms of computation time and from a statistical point of view. We will therefore continue to propose methods to reduce the dimension: grouping stations for which the rainfall

has a similar behavior (clustering) and highlighting a few significant parameters that are sufficient to explain the model (sparsity).

3.3 Hybrid modeling

Participants: Carole Delenne, Pascal Finaud-Guyot, Vincent Guinot, Nicolas Meyer, Antoine Rousseau, Gwladys Toulemonde, Katia Ait Ameur, Mitra Aelami, Anne Bernard, Fadil Boodoo, Cécile Choley, Omar Et Targuy, Jose Daniel Galaz Mora, Chloe Serre Combe.

At the interface between these two main axes, we would like to continue working with hybrid models, in particular thanks to artificial intelligence techniques. Our team is interested in the techniques of physically informed neural networks (PINNs) in fluid mechanics and participates in several working groups on this subject. Keeping in mind that we are not experts on this topic and that the competition is intense, we will explore, notably in Fadil Boodoo's PhD, the use of AI methods for the simulation of rainfall-flood systems (together with rainfall-discharge and discharge-flood intermediate steps). We would also like to explore the transfer of knowledge from configurations for which the data are numerous and of high quality (digital terrain model accurately known, good quality instrumentation) to more rudimentary computational domains.

To specify and carry out this work program, we hope that LEMON will be able to count on an Inria recruitment in the next 2 or 3 years (several candidates have already expressed interest in the 2023 competition). We will also benefit from data from the Water in the City observatory, structured around the HSM laboratory and led by members of LEMON. The SW2D-LEMON software will of course be at the core of transfers operated by the team: we will continue to devote time of our permanent staff to its development, while willing to integrate this tool into a larger Inria platform in which engineering time (possibly shared with other teams) could be made available in order to enable us to focus on our primary research missions.

4 Application domains

4.1 Overview

The protection of coastal areas around the world has become an important issue of concern, including within the scientific community. The coastline is defined as the physical separation between the sea or ocean on the one hand and the inland on the other, but these two worlds are in fact intertwined, which contributes to the difficulty of their modeling, both from a physical and statistical point of view.

4.2 Coastal oceanography

Wave propagation models in the nearshore zone have evolved significantly over the last 15 years, with contributions that increasingly take into account effects related to variations of bathymetry, hence the non-hydrostatic nature of the flow. These models, very specific to the coastal zone, must be able to be coupled (together and with external models) so as to allow wave propagation numerical models to be integrated into numerical forecasting platforms, both in oceanography and in flood risk management.

4.3 Urban floods

Due to climate change and rising sea levels, more and more cities are facing the risk of flooding. Whether they are in coastal areas or near rivers, these cities, which are inherently highly artificial and therefore poorly resistant to rising water levels, require different types of numerical models for flood risk: accurate (and potentially costly) models for land use planning, but also fast models, which can be run in real time, for crisis management.

4.4 Hasard and risk assessment

Modeling and risk assessment are at the heart of environmental science. Whether the events considered are of natural or anthropogenic origin, their economic, ecological or human impacts are too important to be neglected. By definition, the more extreme an event is, the lower its frequency of occurrence and therefore the less data available to characterize it. Hence the importance of using statistical tools dedicated to the modeling of extreme events, in order to provide risk management tools that are as safe and effective as possible.

5 Social and environmental responsibility

5.1 Footprint of research activities

As for all Inria teams, the many calculations we perform (on our personal computers or on dedicated clusters) do have an environmental cost. This cost is linked both to the resources needed to manufacture the machines we use, and to the energy consumed to run them.

LEMON members are aware of the climate emergency and are participating in actions on this subject. For example, Pascal Finaud-Guyot is involved in the "sustainable development and social responsibility" working group at Polytech Montpellier and in "energy footprint reduction" working group at HSM with Carole Delenne. Several members of the team also participate to the local group of Inria Montpellier Antenna dedicated to sustainable development and social responsibility.

Several LEMON members are committed to limit their professional air travel to 10.000km per year.

5.2 Impact of research results

Our research activities have an indirect impact in terms of environmental responsibility:

- the research carried out by the team contributes to the seek of numerical frugality in numerical hydraulic modeling;
- in addition, given the climate change already underway, the team's work in environmental risk assessment and management contributes to better anticipation of natural hasards which, unfortunately, will continue to occur in the coming decades.

6 New software, platforms, open data

6.1 New software

6.1.1 SW2D-Lemon

Name: Shallow Water 2D - Lemon C++ software

Keywords: Numerical simulations, Shallow water equations, Upscaling, Finite volume methods

Scientific Description: SW2D-LEMON (SW2D for Shallow Water 2D) is developed by the LEMON research team in Montpellier. SW2D-LEMON is a multi-model software focusing on shallow water-based models. It includes an unprecedented collection of upscaled (porosity) models used for shallow water equations and transport- reaction processes. Porosity models are obtained by averaging the two-dimensional shallow water equations over large areas containing both a water and a solid phase. The size of a computational cell can be increased by a factor 10 to 50 compared to a 2D shallow water model, with CPU times reduced by 2 to 3 orders of magnitude. Applications include urban flood simulations as well as flows over complex topography. Besides the standard shallow water equations (the default model), several porosity models are included in the platform: (i) Single Porosity, (ii) Dual Integral Porosity, and (iii) Depth-dependent Porosity model. Various flow processes (friction, head losses, wind, momentum diffusion, precipitation/infiltration) can be

included in a modular way by activating specific execution flags. Several examples are included to illustrate the potential of SW2D.

Functional Description: Urban floods are usually simulated using two-dimensional shallow water models. A correct representation of the urban geometry and hydraulics would require that the average computational cell size be between 0.1 m and 1 m. The meshing and computation costs make the simulation of entire districts/conurbations impracticable in the current state of computer technology. An alternative approach consists in upscaling the shallow water equations using averaging techniques. This leads to introducing storage and conveyance porosities, as well as additional source terms, in the mass and momentum balance equations. Various versions of porosity-based shallow water models have been proposed in the literature. The Shallow Water 2 Dimensions (SW2D) computational code embeds various finite volume discretizations of these models. It uses fully unstructured meshes with arbitrary numbers of edges. The key features of the models and numerical techniques embedded in SW2D are : - specific momentum/energy dissipation models that are active only under transient conditions. Such models, that are not present in classical shallow water models, stem from the upscaling of the shallow water equations and prove essential in modeling the features of fast urban flow transients accurately - modified HLLC solvers for an improved discretization of the momentum source terms stemming from porosity gradients - higher-order reconstruction techniques that allow for faster and more stable calculations in the presence of wetting/drying fronts.

Release Contributions: - binary file for educational purposes (including documentation) first release - remove dependency with former package geo through mc.inria.fr ## version 0.8.1 - 04/02/2021 - now using dtk-forge (packages should be more homogeneous) (!220) - fixed frequency refresh for simulation (!246) - fixed using the control bar before finish breaking the results (!249) - fixed spurious call to close (!247) - added help menu (!238) - forbid loading settings during simulation (!244) ## version 0.8.0a - 28/01/2021 - logging now appears in the GUI sw2dModeler (!212) - you can extract values at chosen time using a dedicated text file (!217) - added various scripts and examples (!230 !229) - output file name changed (!224)

News of the Year: - recruitment of Lilas Bugeau (code developer) - large CFL method - soil infiltration source terms - code refactoring & loop optimization - write post-processing tools (max velocity, wetting time) - selafin output - write more tests - write user and developer doc

URL: https://sw2d.inria.fr/

Publications: hal-03882644, hal-01884110, hal-01878242, hal-01582224, hal-01541070, hal-01465071, hal-01118743, hal-02269526, hal-02269564, hal-03224056, hal-03224050, hal-02903282

Contact: Antoine Rousseau

Participants: Lilas Bugeau, Vincent Guinot, Antoine Rousseau, Carole Delenne, Pascal Finaud Guyot

Partners: Université de Montpellier, CNRS, IRD

6.1.2 tsunamilab

Name: TsunamiLab

Keywords: Tsunamis, GPGPU, Dissemination, Web

Functional Description: TsunamiLab is an interactive tsunami simulation and visualization platform that teaches and raises awareness about tsunamis through interactive experiences. It allows science communicators, teachers, students and science enthusiasts to create virtual tsunamis or recreate historical tsunamis, and study their features in various digital and augmented reality formats.

TsunamiLab-Pool: Using cameras and projectors, the "pool" format allows children and adults to interact with their own hands, gathered around the circular screen. This allows the instructor to teach and engage several children simultaneously, in a way that is entertaining for all.

Web Platform: The platform's website allows anyone to simulate historical tsunamis, observe how they propagated in the ocean, and test what would have happened if they had been of greater or lesser magnitude.

Hologram: Through a prism, a holographic image makes it possible to observe the impact in different parts of the world at the same time.

Large Touch Screen: Support for large touch screens allows teachers to observe and explain phenomena in an engaging way in front of a group of students.

News of the Year: - new device to detect finger movement - Tsunamilab workshop at Fête de la Science 2024 (Cité des Sciences, Paris)

URL: https://jgalazm.github.io/TsunamiLabTN/

Publications: hal-02112763, hal-03514473, hal-04912272

Contact: Jose Daniel Galaz Mora

Participants: Jose Daniel Galaz Mora, Antoine Rousseau

Partners: Cigiden, Inria Chile

7 New results

7.1 Physics-driven models

7.1.1 Porosity models for upscaled urban flood modeling

Participants: Pascal Finaud-Guyot, Antoine Rousseau.

Collaboration: Cristián Escauriaza *(PUC Santiago, Chile)*, Sebastián Nash *(PUC Santiago, Chile)*.

When modeling large-scale urban floods, the use of porosity non-linear shallow water equations emerges as an interesting sub-grid approach for reducing computation time while preserving the structure of the solution. In such models, fine-scale topographic information is represented at a coarser scale through porosity parameters, enabling a speed-up in computations at the expense of losing accuracy while computing hydrodynamic variables. In [4], we use the Single Porosity model (SP) in Cartesian coordinates to simulate flows in both an idealized and a real-world urban area, while gradually increasing the spatial resolution. During such partial coarsening, in which we move from fine-scale to macro-scale, the porosity distribution changes within the urban zone from a highly heterogeneous field to a more uniform one. At an intermediate meso-scale, where the cell size is of the order of the street width and the reduction in computation time is still significant, the main preferential flow paths within the urban area can be captured by means of the porosity gradient. At such a scale, good agreement with refined classical model solutions is found for flow depth, flood extension, and hazard index, both in magnitude and spatial distribution. Numerical results highlight the importance of porosity models for quickly assessing flow properties during an event and improving real-txme decision-making through reliable information. This work was also presented in [19].

7.1.2 Coupling

Coupling dispersive and non-dispersive shallow water models

Participants: Antoine Rousseau, José Galaz.

Collaboration: Maria Kazolea *(Inria CARDAMOM)*.

In [8], we derive transmission operators for coupling linear Green-Naghdi equations (LGNE) with linear shallow water equations (LSWE) - the heterogeneous case - or for coupling LGNE with LGNE - the homogeneous case. We derive them from a domain decomposition method (Neumann-Dirichlet) of the linear Euler equations by applying the same vertical-averaging process and truncation of the asymptotic expansion of the velocity field used in the derivation of the equations. We find that the new asymptotic transmision conditions also correspond to Neumann and Dirichlet operators. In the homogeneous case, the method has the same convergence condition as the parent domain decomposition method but leads to a solution that is different from the monodomain solution due to a term of order one. In the heterogeneous case, the Neumann-Dirichlet operators translate into a simple interpolation across the interface, with an extra term of order 2 in space. We show numerically that, in this case, the method introduces oscillations whose amplitude grows as the mesh is refined, thus leading to an unstable scheme. This work was also presented in [18] and in José Galaz's PhD thesis [14].

7.1.3 Numerical methods for hyperbolic systems of equations

Multi-step variant of the parareal algorithm: convergence analysis and numerics

Participants: Katia Ait Ameur.

Collaboration: Yvon Maday *(LJLL, Paris)*.

In [1], we consider the problem of accelerating the numerical simulation of time dependent problems involving a multi-step time scheme by the parareal algorithm. The parareal method is based on combining predictions made by a coarse and cheap propagator, with corrections computed with two propagators: the coarse one and a precise and expensive propagator used in a parallel way over the time windows. A multi-step time scheme can potentially bring higher approximation orders than plain one-step methods but the initialization of each time window needs to be appropriately chosen. Our main contribution is the design and analysis of an algorithm adapted to this type of discretization without being too much intrusive in the coarse or fine propagators. At convergence, the parareal algorithm provides a solution that coincides with the solution of the fine solver. In the classical version of parareal, the local initial condition of each time window is corrected at every iteration.

Large CFL explicit scheme for hyperbolic systems

Participants: Vincent Guinot, Antoine Rousseau.

In [3], a large CFL algorithm is presented for the explicit, finite volume solution of hyperbolic systems of conservation laws. The Riemann problems used in the flux computation are determined using averaging kernels that extend over several computational cells. The usual Courant-Friedrichs-Lewy stability constraint is replaced with a constraint involving the kernel support size. This makes the method unconditionally stable with respect to the size of the computational cells, allowing the computational mesh to be refined locally to an arbitrary degree without altering solution stability. The practical implementation of the method is detailed for the shallow water equations with topographical source term. Computational examples report applications of the method to the linear advection, Burgers and shallow water equations. In the case of sharp bottom discontinuities, the need for improved, well-balanced discretizations of the geometric source term is acknowledged.

7.2 Data-driven models

Multivariate peaks-over-threshold with latent variable representations of generalized Pareto vectors

Participants: Gwladys Toulemonde.

Collaboration: Carlo Gaetan *(Venice)*, Thomas Opitz *(Inrae Avignon)*, Jean-Noël Bacro *(IMAG, Montpellier)*.

A flexible multivariate threshold exceedances modeling is defined based on component-wise ratios between any two independent random vectors with exponential and Gamma marginal distributions. This construction allows flexibility in terms of extremal bivariate dependence. More precisely, asymptotic dependence and independence are possible, as well as hybrid situations. Two useful parametric model classes will be presented. One of the two, based on Gamma convolution models, will be illustrated through a simulation study. Good performance is shown for likelihood-based estimation of summaries of bivariate extremal dependence for several scenarii. This work has been presented in an invited seminar in UCL and is published in [2].

7.2.1 Heterogeneous data

Data collection and representation for urban water networks

Participants: Carole Delenne, Omar Et-Targuy.

Collaboration: Salem Benferhat *(CRIL Lens)*, Ahlame Begdouri *(Université Sidi Mohamed Ben Abdellah)*, Thanh-Nghi Do *(Can Tho University)*, Truong-Thanh Ma *(Can Tho University)*.

Wastewater network management is a critical aspect of ensuring public health and environmental sustainability. In classical models such as shapefile, different databases are used to store various types of geometric data, including points, lines, and polygons. For instance, the components of wastewater networks are stored in such different databases, which yield difficulties in accurately depicting the connectivity among the wastewater network components that are physically interconnected in reality. To address this issue, [6] discusses the limitations of the separate databases approach for representing wastewater networks in Shapefile and proposes a novel graph-based approach. In this approach, each component of the network (such as manholes, structures, pumps, etc.) is represented as a node in the novel graph, while the pipes represent the connections between them. By adopting the proposed

representation, the real interconnected nature of the wastewater network can be effectively captured and visualized. The validation of this approach, using five real datasets, confirms its ability to connect the various components of the wastewater network via a graph-based representation. Other ongoing works on other types of wastewater network data (such as analogue maps [7] or inspection videos [11]) uses this representation in graphs with the final aim of data fusion.

Combining SAR imagery and topography for the automatic retrieval of floodwater depth maps

Participants: Carole Delenne.

Collaboration: Vita Ayoub *(Luxembourg Institute of Science and Technology)*, Renaud Hostache *(Espace DEV, IRD Montpellier)*, Marco Chini *(Luxembourg Institute of Science and Technology)*, Ramona Maria-Pelich *(Luxembourg Institute of Science and Technology)*, Patrick Matgen *(Luxembourg Institute of Science and Technology)*.

In [9] we propose and evaluate an innovative method for automatically retrieving floodwater depth maps by combining SAR-derived flood extent maps and topography data. The proposed algorithm can integrate as topography data either Digital Elevation Models (DEMs) or the Height Above Nearest Drainage (HAND) derived from these DEMs. The algorithm is applied using SAR (Synthetic Aperture Radar) images, DEMs and HAND maps of various spatial resolutions. We use as a test case the flood event that hit River Severn in the UK in July 2007. The maps obtained using our algorithms are evaluated using the results of shallow-water model simulations and aerial photographs. The results show that high level of accuracies (Root Mean Squared Deviations of Water Depth equal 0.52 cm) can be obtained if DEMs and SAR images of high resolution are used.

7.3 Hybrid models

7.3.1 Data assimilation

Adjoint-based sensitivity analysis and assimilation of multi-source data for the inference of spatio-temporal parameters in a 2D urban flood hydraulic model

Participants: Carole Delenne.

Collaboration: Léo Pujol *(Hydrosciences Montpellier, IRD)*, Pierre-André Garambois *(RECOVER, INRAe)*, Jean-Louis Perrin *(Hydrosciences Montpellier, IRD)*.

In [5] we present a novel approach for the calibration of distributed parameters in a 2D urban flood hydraulic model. It focuses on the challenging issue of inferring distributed friction parameters from multi-source heterogeneous spatio-temporal observations of their hydraulic signatures in the context of an urban flash flood in a complex street network. A variational data assimilation algorithm is used to infer high-dimensional multi-variate parameters (spatialized friction and inflow discharge time series) using multi-source observations. This method relies on a differentiable 2D shallow water hydraulic model which enables to generate high-resolution sensitivity maps of local gradients and Derivative-based Global Sensitivity Measures (DGSM), enabling to guide adequate definition of parameter spatialization for the data assimilation process. Assimilated data include real local limnigraphic measurements and high-water marks collected after a major flood event, as well as modeled flow velocity used in twin experiments setups. This study is the first to leverage high-water marks with a variational method for the calibration of distributed parameters in an urban flood model.

8 Bilateral contracts and grants with industry

8.1 Bilateral grants with industry

AMIES grant with CEREG

Participants: Antoine Rousseau, Pascal Finaud Guyot, Vincent Guinot, Lilas Bugeau.

In 2024 we obtained a MAHéO grant from AMIES for a collaboration with CEREG on hydraulic modeling with SW2D-LEMON. Lias Bugeau has been hired by our team in this framework.

9 Partnerships and cooperations

9.1 International initiatives

9.1.1 Associate Teams in the framework of an Inria International Lab or in the framework of an Inria International Program

FLOTTE

Participants: Antoine Rousseau, Pascal Finaud Guyot.

Collaboration: Sebastian Nash *(PUC Santiago, Chile)*, Cristian Escauriaza *(PUC Santiago, Chile)*.

Title: FLOod and TransporT Equations

Duration: 2023 ->

Coordinator: Cristián Escauriaza (cescauri@ing.puc.cl)

Partners:

- Pontificia Universidad Católica de Chile Santiago (Chili)

Inria contact: Antoine Rousseau

Summary: The overall objective of the research program is to develop a numerical tool able to represent, in urban area, flood and transport (sediment, debris and vehicle) propagation as the potential feedback from transport to the flow. Several directions are identified: - Shallow water and transport models coupling - Upscaling of transport model - Sensitivity analysis

9.1.2 Participation in other International Programs

Abidjan: eaux et ville en mutation.

Participants: Carole Delenne.

Collaboration: Jean-Louis Perrin *(IRD, Montpellier)*.

Carole Delenne is a member of the project "Abidjan: eaux et ville en mutation" funded by the UNESCO Center on water ICIREWARD, led by Jean-Louis Perrin (HSM) in collaboration with Université Nangui Abrogoua. Abidjan, the economic capital of Côte d'Ivoire, is set to see its population double by 2050. Faced with the far-reaching changes observed over the last 10 years, this project aims to gain a better understanding of their impact on the urban water cycle, with major issues relating to flooding, domestic effluent management, resource pollution and the city's drinking water supply.

Multiscale flood simulations using artificial neural networks

Participants: Antoine Rousseau, Vincent Guinot, Gwladys Toulemonde, Katia Ait-Ameur.

Collaboration: Luis Martí *(Inria Chile)*.

In this collaboration with Inria Chile, we work to explore neural network-based methods for down-scaling urban flood simulations. These methods are based both on classical shallow water models and on the porosity models produced by LEMON.

9.2 International research visitors

9.2.1 Visits of international scientists

Visits from PUC Santiago, Chile.

Cristian Escauriaza

Status: Researcher

Institution of origin: PUC Santiago

Country: Chile

Dates: September 2024 (1 week)

Context of the visit: LEMON workshop

Mobility program/type of mobility: EA FLOTTE

Sebastian Nash

Status: PhD Candidate

Institution of origin: PUC Santiago

Country: Chile

Dates: September 2024 (1 week)

Context of the visit: LEMON workshop

Mobility program/type of mobility: EA FLOTTE

9.3 European initiatives:

9.3.1 Horizon Europe

Participants: Carole Delenne, Omar Et Targuy, Fadil Boodoo, Mitra Aelami, Flavien Baudu.

Collaboration: Salem Benferhat *(CRIL, Univ. Artois)*, Nanée Chahinian *(IRD, Montpellier)*, Umberto Straccia *(CNR Pisa)*, Ahlame Begdouri *(USMBA, Morocco)*, Tommy Meyer *(University of Cape Town)*, Nghi Do *(Can Tho University)*.

Carole Delenne is a member of the STARWARS European project steering committee: STormwAteR and WastewAteR networkS heterogeneous data AI-driven management (MSCA Staff Exchange program, Grant Number 101086252). Omar Et Targuy, Fadil Boodoo, Mitra Aelami and Flavien Baudu have and will benefit from secondments in Vietnam, Italie, Morocco and South Africa until end of 2026.

Public and private stakeholders of the wastewater and stormwater sectors are increasingly faced with large quantities and multiple sources of information/data of different nature: databases of factual data, geographical data, various types of images, digital and analogue maps, intervention reports, incomplete and imprecise data (on locations and the geometric features of networks), evolving and conflicting data (from different eras and sources), etc. The main objective of this multidisciplinary project is to provide novel proposals for the management of heterogeneous data with an application to stormwater and wastewater networks. The STARWARS project aims to bring together researchers from the AI and Water Sciences communities in order to enhance the emergence of new practical solutions for representing, managing, modeling, merging, completing, reasoning, explaining and query answering over data of different forms pertaining to stormwater and wastewater networks.

9.3.2 ChistERA

Participants: Carole Delenne.

Collaboration: Salem Benferhat *(CRIL/Univ. Artois)*, Nanée Chahinian *(IRD Montpellier)*, Zoltan Kato *(University of Szeged, Hungary)*, Inés Couso *(University of Oviedo, Spain)*.

9.4 National initiatives

9.4.1 ANR MUFFINS

Participants: Antoine Rousseau, Pascal Finaud-Guyot, Gwladys Toulemonde.

Pascal Finaud Guyot, Antoine Rousseau and Gwladys Toulemonde are members of ANR MUFFINS (MUltiscale Flood Forecasting with INnovating Solutions) led by Pierre-André Garambois (INRAE) including the following partners: IMT, Univ Eiffel, Cerema IMFT, CCR, Météo/SPCME, SCHAPI. The objective of the MUFFINS project is to develop new accurate and computationally efficient flood forecasting approaches, enabling the transfer of information between models (meteo-hydrology-hydraulic-damage) and scales (from local runoff generation over areas lesser than 1 km^2 to flood propagation on catchments of thousands of km^2), and taking advantage of innovative data (in situ, remote observation, opportunistic)

to reduce forecasts uncertainties.

9.4.2 ANR CROQUIS

Participants: Carole Delenne.

Carole Delenne is a member (and co-leader of several tasks and a WP) of ANR CROQUIS (Collecting, Representing, cOmpleting, merging and Querying heterogeneous and UncertaIn waStewater and stormwater network data) led by Salem Benferhat (CRIL) and funded in 2022. In this project, we refer to data of different nature such as geographical databases, various types of images, digital/analogue maps, intervention reports, etc. Heterogeneity also refers to the imperfection of the available information where data may be unreliable, imprecise, incomplete, dynamic and conflicting. One of the objectives of CROQUIS is to answer the need for establishing a methodological framework to collect, complete, centralize, update and archive data. Approaches based on Machine Learning (ML) techniques enhanced with basic additional knowledge will be developed along with knowledge-driven query answering and reasoning mechanisms to infer new data needed for hydraulic modeling. In particular, we aim to develop an enhanced query answering tool that should be easily integrated into existing information systems in order to fully exploit available resources and to better exploit meta information such as uncertainty.

9.4.3 ANR SWIFT

Participants: Carole Delenne.

Carole Delenne is a member (and co-leader of several tasks and a WP) of ANR SWIFT (Shallow Water modeling and satellite Imagery combination for improving Flood predicTion) project. The SWIFT project aims to develop innovative methods for combining big data, derived from satellite Earth observation, and hydrodynamic simulations to improve flood inundation modeling at local to regional scales. The project focuses on urban and peri-urban areas and relies on the advanced exploitation of SAR, optical and topography data to characterize complex inundation flows. The project focuses on urban and peri-urban areas and relies on the advanced exploitation of SAR, optical and topography data to characterize complex inundation flows. Flavien Baudu's PhD at IRD, co-supervised by Carole Delenne with Renaud Hostache is funded by ANR SWIFT. A postdoc at Aix Marseille University, supervised by Carole Delenne will also be funded by this project.

9.4.4 ANR GAMBAS

Participants: Gwladys Toulemonde.

Gwladys Toulemonde is member of the ANR project GAMBAS (Generating Advances in Modeling Biodiversity And ecosystem Services) led by Frédéric Mortier (CIRAD) and involving 6 partners (CIRAD, INRAE, LECA at Grenoble, IMAG at Montpellier, the Museum d'histoire naturelle and the LMO at Paris-Saclay) for a total of 569k€. GAMBAS gathers a collective composed of quantitative ecologists and mathematicians with aspirations in ecology in order to expand Joint Species Distribution Models (JSDMs). The PhD grant of Samuel Valiquette is fully funded by this project.

9.4.5 ANR McLaren

Participants: Gwladys Toulemonde.

Gwladys Toulemonde is involved in the ANR project McLaren (Machine Learning and Risk Evaluation). The University of Côte d'Azur, the University of Montpellier, INRAE, Inria and the CNRS are involved in this project. The overall objective of the project is to bring significant innovations in these two areas of statistical learning and risk assessment. The PhD grant of Alexis Boulin is fully funded by this project.

9.4.6 ANR EXSTA

Participants: Nicolas Meyer.

Nicolas Meyer is member of the ANR project EXSTA (EXtremes, STatistical learning and Applications), led by Anne Sabourin, Université de Paris, 2024-2028. This project aims at developing machine learning techniques to study extreme values.

9.5 Regional initiatives

9.5.1 Eau-PiUM

Participants: Mitra Aelami, Anne Bernard, Carole Delenne, Gwladys Toulemonde, Vincent Guinot, Nicolas Meyer.

Collaboration: Renaud Hostache *(IRD, Montpellier)*.

This is a project from the IDIL graduate program of the University of Montpellier, funding two doctoral contracts (ED GAIA and ED I2S) between 2024 and 2027.

Flooding is the leading natural hazard in France, with particularly severe impacts particularly severe in urban and coastal areas. To improve our understanding and prediction of these extreme events, we are proposing several important extensions to the SW2D (Shallow water 2D) flow model, developed by the Inria-LEMON team in Montpellier. Firstly, we propose a high spatial and temporal resolution stochastic simulator for extreme precipitation forcing in urban and coastal environments (PhD 1, Mitra Aelami, *Urban flood risk modeling with neural networks and the impact of extreme spatio-temporal rainfall events*, doctoral school GAIA). This precipitation is a forcing term for the flow models studied in the second thesis. Indeed, the second axis of the project will consist in applying a hydraulic model for the simulation of urban flooding, which will serve as a learning base for an artificial intelligence model enabling the rapid estimation of flooded areas (PhD 2, Anne Bernard, *Stochastic rainfall generators and impact studies on flood risk in Montpellier*, doctoral school I2S). Secondly, we will develop spatialized sensitivity analysis methods to study how extreme values in the model's spatialized bivariate outputs (water heights and velocities) depend on the spatial patterns of extreme forcing. This impact study will be carried out at the intersection of the two thesis topics. The project aims to develop new generic methodological tools, as well as scenarios and maps of flood risk in the Montpellier region, taking into account the potential effects of climate change.

10 Dissemination

10.1 Promoting scientific activities

Carole Delenne participated to the week: "Math C pour L" organized in February by the SMF (société Mathématique de France), SMAI and SFdS for female undergraduate students.

Gwladys Toulemonde co-organized for the SFdS (Société Française de Statistique) the national program "Math C pour L" and more specifically the stage at CIRM in February 2024.

10.1.1 Scientific events: organisation

Member of the organizing committees

- Carole Delenne co-organized ExCH-2024 Journées sur l'explicabilité et la gestion d'informations géographiques et spatiales. Arras, June 17-18, 2024.
- Gwladys Toulemonde co-organized the « 24ème Forum des jeunes mathématiciennes et mathématiciens » which is an initiative of «Femmes et Mathématiques», in November, 2024 at Montpellier (France).

Member of the conference program committees

- Gwladys Toulemonde partipated to the scientific program committee of the 15th International Meeting on Statistical Climatology (IMSC) in Toulouse from June 24 to June 28, 2024.
- Gwladys Toulemonde co-organized a conference in Statistic during the "Rencontre Montpellier-Sherbrooke" in June 2024, Sherbrooke, Canada.

10.1.2 Journal

Member of the editorial boards

- Antoine Rousseau is associate editor of Discrete and Continuous Dynamical Systems - Series S.

Reviewer - reviewing activities

- Carole Delenne is a reviewer for several Journals such as Journal of Hydraulic Research, Water, Computers Environment and Urban Systems (1 to 3 manuscripts/year).
- Vincent Guinot is a reviewer for Journal of Hydrology, Advances in Water Resources, Mathematical Problems in Engineering (3 manuscripts/year).
- Nicolas Meyer is a reviewer for several journals, such as Extremes, Annals of Statistics, Bernoulli (1 to 3 manuscripts per year).
- Antoine Rousseau is a reviewer for Journal of Hydrology and Environmental Modelling and Assessment (2 manuscripts/year), DCDS-S (1 manuscript/year) and Computer Methods in Applied Mechanics and Engineering (1 manuscript/year).
- Pascal Finaud Guyot is a reviewer for Journal of Hydroinformatics, Advances in Water Resources, Environmental Modelling and Software, Journal of Hydrology (2 manuscripts/year).
- Gwladys Toulemonde is a reviewer for statistical journals (like Annals of applied statistics, Computational statistics and data analysis, Dependence modelling, Extremes, Journal of applied Statistics, Journal of Statistical Theory and Practice, Statistics and Computing) and also Esaim or Water Ressources research (1 to 3 manuscripts/year).

10.1.3 Invited talks

- Antoine Rousseau was invited to give a lecture in Graphdeco's workshop "Workshop on machine learning, geometry and fluid simulation", December 2024.
- Gwladys Toulemonde was invited in the session "Extreme value theory for environmental applications" at CMStatistics, London, December 2024.

10.1.4 Leadership within the scientific community

- Vincent Guinot is head of the "Eau dans la Ville" cross-disciplinary research group at HSM (20 staff members) and of the Urban Observatory of HSM.

10.1.5 Scientific expertise

- Vincent Guinot is a member of the board for scientific strategy at HSM.
- Antoine Rousseau is a member of the Inria Center at Université Côte d'Azur scientific board (Bureau du Comité des Projets).
- Gwladys Toulemonde was a hceres expert for the research evaluation of a UMR in 2024.
- Gwladys Toulemonde was an external reviewer for the Icelandic Research Fund, expert panel on Engineering and technical sciences in 2024.
- Gwladys Toulemonde was an expert for UGA (Univertsité Grenoble Alpes) for Initiatives de Recherche à Grenoble Alpes (IRGA), 2024.

10.1.6 Research administration

- Carole Delenne is elected member of the Ecole Doctorale GAIA board.
- Antoine Rousseau is head of the LEMON team at Inria Branch at Université de Montpellier (6 staff members).
- Antoine Rousseau is a member of the Inria Center at Université Côte d'Azur steering board (Comité des Projets).
- Antoine Rousseau is deputy director of the Inria branch at the University of Montpellier.
- Gwladys Toulemonde is elected member of the French Statistical Society board (Société Française de Statistique, SFdS) until July, 2024.
- Gwladys Toulemonde is elected member of Environment group of the French Statistical Society board (Société Française de Statistique, SFdS).
- Gwladys Toulemonde is elected member of the liaison commitee of the MAS Group (Modélisation Aléatoire et Statistique), SMAI (Société de Mathématiques Appliquées et Industrielles) until August, 2024..

10.2 Teaching - Supervision - Juries

10.2.1 Academic involvement / responsibilities

5 UM-affiliated members of LEMON are Academics, for a total teaching load of approximately 1000 hrs/year. Moreover, these members undertook significant administrative duties (approx. 1000 hrs) in 2023:

- Carole Delenne is Program coordinator of the last year of "Eau et Génie Civil - EGC" (Water and Civil Engineering) and the penultimate year of "Sciences et technologies de l'eau" (water science and technology) of the engineering program at Polytech Montpellier.

- Pascal Finaud Guyot is Program coordinator (Year 2) and Sustainable Development coordinator for the EGC engineering program at Polytech Montpellier.
- Nicolas Meyer is head of Master 1 Statistics and Data Science at Université Montpellier.
- Gwladys Toulemonde is Admissions office coordinator at Polytech Montpellier (500+ students/ year).

10.2.2 Supervision

PhD defended this year

- Samuel Valiquette, (co-directed by Eric Marchand, Frédéric Mortier and Gwladys Toulemonde), Sur les données de comptage dans le cadre des valeurs extrêmes et la modélisation multivariée, July 2024, Université de Sherbrooke (Canada) and Université de Montpellier, [15].
- Jose Daniel Galaz Mora, Coupling methods of phase-resolving coastal wave models, June 2024, Université de Montpellier, [14].
- Alexis Boulin (co-directed by Thomas Laloé, Elena di Bernardino and Gwladys Toulemonde), Variable clustering of multivariate time series according to the dependence of their extremes, September 2024, Université Côte d'Azur (UniCA), [13].

PhD in progress

- Mitra Aelami, "Study of the risk of urban flooding using neural networks and the impact of extreme spatio-temporal rainfall events", since October 2024, supervised by Carole Delenne, Gwladys Toulemonde and Renaud Hostache.
- Flavien Baudu, "Assimilation de données d'observation de la Terre dans des modèles hydrauliques à surface libre pour améliorer la prévision des inondations à large échelle", since December 2024, supervised by Renaud Hostache and Carole Delenne.
- Anne Bernard, "Stochastic rainfall generators and impact studies on flood risk in Montpellier", since October 2024, supervised by Nicolas Meyer and Gwladys Toulemonde.
- Fadil Boodoo, "Hydrodynamic model and artificial intelligence for a flood forecasting system", since January 2021, supervised by Carole Delenne and Renaud Hostache (Université de Montpellier).
- Alexandre Capel, "Modèles graphiques pour les extrêmes", since October 2024, supervised by Nicolas Meyer and Gwladys Toulemonde with Marine Demangeot (Univ Montpellier Paul Valery).
- Chloe Serre Combe, Stochastic generators of extreme precipitation and risk assessment of urban flooding at high spatiotemporal resolution, since October 2022, supervised by Gwladys Toulemonde, Nicolas Meyer, and Thomas Opitz (Inrae Avignon)
- Omar Et Targuy, practical fusion and heterogeneous conditioning of uncertain data, since October 2022, supervised by Salem Benferhat, Ahlame Begdouri and Carole Delenne.

10.2.3 Juries

- Antoine Rousseau was member of the Inria Junior Researcher (CRCN/ISFP) committee in Grenoble
- Gwladys Toulemonde participated to two "comités de sélections" in 2024, in Nantes for a professor in statistic and in Grenoble for a MCF in statistic.
- Ph.D. defense chair: Antoine Rousseau served as Jury chair for the Ph.D. thesis of Nicolas Rosset (Université Côte d'Azur) on "Fast simulation of wind-obstacle interactions Applications to desertscape modeling and car design".

- Ph.D. defense chair: Gwladys Toulemonde served as Jury chair for the Ph.D. thesis of Nicolas Lafon (Université Paris Saclay) on "Statistical learning for geosciences:methods for extreme generation and data assimilation".
- Ph.D. defense referee: Gwladys Toulemonde was referee for the Ph.D of Abubakar Haruna (Université Grenoble Alpes) on "Amélioration de l'estimation des risques de précipitations".
- Ph.D. defense member: Gwladys Toulemonde was jury member for the Ph.D. thesis of Paula Gonzalez "Méthodes de quantification des probabilités de records climatiques".
- Ph.D. defense member: Carole Delenne was jury member for the Ph.D. thesis of Chuanyin Jiang (Université de Montpellier) on "Mécanismes de dissolution et karstification naissante dans les carbonates fracturés: aperçu de la modélisation thermo-hydro-mécanique-chimique (THMC)"

10.3 Popularization

10.3.1 Specific official responsibilities in science outreach structures

- Gwladys Toulemonde has been appointed ambassador for Inria as part of the Fête de la Science 2024, on the theme “an ocean of knowledge.”
- Antoine Rousseau is co-editor of the national blog binaire, published by Le Monde.

10.3.2 Participation in Live events

- Antoine Rousseau and José Galaz participated to the Fête de la Science 2024 in Paris, Cité des Sciences, with the Tsunamilab platform, see [10].
- Carole Delenne participated several times in the reception of secondary school students in the framework of Digi'Filles (ISDM, Univ Montpellier): children's version of the “fresque du climat”, water cycle.
- Gwladys Toulemonde is involved in the board of the CFEM (commission française pour l'enseignement des mathématiques) since October, 2019, representing the SFdS.
- Gwladys Toulemonde participated to the Salon Culture et Jeux Mathématiques in Paris, Place saint Sulpice, May 2024.
- Pascal Finaud-Guyot, Nicolas Meyer and Gwladys Toulemonde organized sessions of the “Fresque du climat” for the Master 1 students in Statistics and Data Science and for Polytech students, respectively.
- Carole Delenne is part of OpenING and WidenING projects of the "Fondation Polytech", which aims to provide a series of educational 'seeds': these are a mixture of lectures and exercises on a particular concept, which students can complete independently (with guidance if required) in one or two hours.
- Carole Delenne and Gwladys Toulemonde are part of Math'Start Project, that aims to provide a Moodle-based library of mathematical exercises to remedy, restore and consolidate numeracy skills at L1 level in mathematics. These deliverables will complement the resources already available in the form of educational 'seeds' of the OpenING project.

11 Scientific production

11.1 Publications of the year

International journals

[1] K. Ait-Ameur and Y. Maday. 'Multi-step variant of the parareal algorithm: convergence analysis and numerics'. In: *ESAIM: Mathematical Modelling and Numerical Analysis* 58.2 (Mar. 2024), pp. 673–694. DOI: 10.1051/m2an/2024014. URL: https://hal.science/hal-04549056 (cit. on p. 12).

[2] J.-N. Bacro, C. Gaetan, T. Opitz and G. Toulemonde. 'Multivariate peaks-over-threshold with latent variable representations of generalized Pareto vectors'. In: *Extremes* (20th Dec. 2024). DOI: 10.1007/s10687-024-00503-2. URL: https://inria.hal.science/hal-03965533 (cit. on p. 13).

[3] V. Guinot and A. Rousseau. 'Large Courant–Friedrichs–Lewy explicit scheme for one-dimensional hyperbolic conservation laws'. In: *International Journal for Numerical Methods in Fluids* 96.11 (4th July 2024), pp. 1760–1794. DOI: 10.1002/fld.5322. URL: https://inria.hal.science/hal-03882644 (cit. on p. 13).

[4] S. Nash, C. Escauriaza, P. Finaud-Guyot, W. Jahn and A. Rousseau. 'Single Porosity Model: Exploring the Spatial Resolution Limits in Complex Urban Patterns'. In: *Journal of Hydrology* 637 (Mar. 2024), p. 131239. DOI: 10.1016/j.jhydrol.2024.131239. URL: https://inria.hal.science/hal-04224771 (cit. on p. 11).

[5] L. Pujol, P.-A. Garambois, C. Delenne and J.-L. Perrin. 'Adjoint-based sensitivity analysis and assimilation of multi-source data for the inference of spatio-temporal parameters in a 2D urban flood hydraulic model'. In: *Journal of Hydrology* 643 (2024), p. 131885. DOI: 10.1016/j.jhydrol.2024.131885. URL: https://hal.science/hal-04643149 (cit. on p. 14).

[6] O. Et-Targuy, C. Delenne, S. Benferhat, A. Begdouri, T.-N. Do and T.-T. Ma. 'From GIS to Graphical Representation for Maintaining Connectivity of Wastewater Network Elements'. In: *SN Computer Science* 5.7 (2nd Sept. 2024), p. 851. DOI: 10.1007/s42979-024-03174-9. URL: https://hal.science/hal-04684574 (cit. on p. 13).

International peer-reviewed conferences

[7] I. El Miqdadi, F. Abouzid, S. Benferhat, N. Chahinian and C. Delenne. 'A Graph-Based Representation of Wastewater Maps'. In: IEEE BigData 2024 - 2024 IEEE International Conference on Big Data. Washington DC, United States, 17th Dec. 2024. URL: https://hal.science/hal-04844749 (cit. on p. 14).

[8] J. Galaz, M. Kazolea and A. Rousseau. 'Coupling Dispersive Shallow Water Models by Deriving Asymptotic Interface Operators'. In: *Domain Decomposition Methods in Science and Engineering XXVII*. 27th International Conference on Domain Decomposition Methods in Science and Engineering - DD27. Vol. 149. Lecture Notes in Computational Science and Engineering. Prague, Czech Republic: Springer Nature Switzerland, 23rd Jan. 2024, pp. 181–188. DOI: 10.1007/978-3-031-50769-4_21. URL: https://inria.hal.science/hal-03851031 (cit. on p. 12).

[9] R. Hostache, V. Ayoub, M. Chini, R. Maria-Pelich, P. Matgen and C. Delenne. 'Combining SAR imagery and topography for the automatic retrieval of floodwater depth maps'. In: *IEEE Xplore*. IGARSS 2024 - 2024 IEEE International Geoscience and Remote Sensing Symposium. IGARSS 2024 - 2024 IEEE International Geoscience and Remote Sensing Symposium : proceedings. Athènes, Greece, 8th July 2024. URL: https://hal.science/hal-04827007 (cit. on p. 14).

[10] A. Rousseau and J. D. Galaz Mora. 'Atelier Tsunamilab à la Cité des Sciences'. In: Fête de la Sciences 2024. Paris Cité des sciences, France, 4th Oct. 2024. URL: https://inria.hal.science/hal-04912272 (cit. on p. 23).

[11] M.-T. Tran-Nguyen, S. Benferhat, N. Chahinian, C. Delenne and T.-N. Do. 'Building a Wastewater Network Graph from Inspection Videos'. In: *Communications in Computer and Information Science*. ISDS 2024 - 2nd International Conference on Intelligent Systems and Data Science. Vol. CCIS-2190. Intelligent Systems and Data Science : 2nd International Conference, ISDS 20. Nha Trang city, Vietnam: Springer Nature Singapore, 8th Nov. 2024, pp. 188–202. DOI: 10.1007/978-981-97-9613-7_14. URL: https://hal.science/hal-04783710 (cit. on p. 14).

Conferences without proceedings

[12] N. Skifa, F. Boodoo, C. Delenne, R. Hostache and M. Abily. 'Impact of training dataset size and its hydrometeorological typology on LSTM performance for rainfall-runoff modeling: a case study of the Severn river'. In: *Advances in Hydroinformatics—SimHydro 2023 Volume 2*. SimHydro conference 2023. Vol. 2. Chatou, France: Springer, 18th Sept. 2024, pp. 107–128. DOI: 10.1007/978-981-97-4076-5. URL: https://hal.science/hal-04375806.

Doctoral dissertations and habilitation theses

[13] A. Boulin. 'Variable clustering of multivariate time series according to the dependence of their extremes'. Université Côte d'Azur, 30th Sept. 2024. URL: https://theses.hal.science/tel-04767333 (cit. on p. 22).

[14] J. Galaz. 'Coupling methods of phase-resolving coastal wave models'. Université de montpellier, 26th June 2024. URL: https://inria.hal.science/tel-04689721 (cit. on pp. 12, 22).

[15] S. Valiquette. 'On counting data within the framework of extreme values and multivariate modeling'. Université de Montpellier; Université de Sherbrooke. Département de mathématiques, 3rd July 2024. URL: https://theses.hal.science/tel-04811942 (cit. on p. 22).

Reports & preprints

[16] K. Ait-Ameur, M. Essadki, M. Massot and T. Pichard. *Limitation strategies for high-order discontinuous Galerkin schemes applied to an Eulerian model of polydisperse sprays*. 5th Jan. 2024. URL: https://hal.science/hal-04374640.

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