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Project-Team LEMON

Littoral Environment: M0dels and Numerics

RESEARCH CENTER
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THEME
Earth, Environmental and Energy Sciences

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1. Team, Visitors, External Collaborators

Research Scientists

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Gwladys Toulemonde [Univ de Montpellier, Researcher]

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Cecile Choley [Engees, PhD Student, from Nov 2019]
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2. Overall Objectives

2.1. Context

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 coupled and hybrid systems.**
The spot of Montpellier offers large opportunities:

- additionally to IMAG [1] and HSM [2], we collaborate with **several local academic research partners**. To mention but a few examples, we are in close contact in Montpellier with UMR MISTEA (pollution and remediation of water resources), UMR Geosciences (morphodynamics), UMR G-Eau (hydraulics and data assimilation), UMR MARBEC (lagoon environment), UMR LISAH (hydrology in agricultural areas).
- The LEMON members are **involved in projects** funded by the current NUMEV Labex and **actively participate in new initiatives** pertaining to *sea and coast* modelling, both through the recently awarded MUSE project in Montpellier and through external (national, European, international) calls.
- From the **transfer & innovation viewpoint**, the team members already interact with several local partners such as Cereg Ingénierie, Tour du Valat, Predict Services and Berger-Levrault.
- **Regional urban development and land use policies** are natural application fields for the developments undertaken in LEMON.

The general scope of the LEMON project-team is to develop mathematical and computational methods for the modelling of coastal 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).

[1] Institut Montpelliérain Alexander Grothendieck - UMR5149
[2] HydroSciences Montpellier - UMR 5569

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

3. Research Program

3.1. Foreword

The team has three main scientific objectives. The first is to develop new models and advanced mathematical methods for inland flow processes. The second is to investigate the derivation and use of coupled models for marine and coastal processes (mainly hydrodynamics, but not only). The third is to develop theoretical methods to be used in the mathematical models serving the first two objectives. As mentioned above, the targeted applications cover PDE models and related extreme events using a hierarchy of models of increasing complexity. LEMON members also contribute to research projects that are not in the core of the team topics and that correspond to external collaborations: they are mentioned in the fourth section below.
In every section, people involved in the project are listed in alphabetical order, except for the first one (underlined) which corresponds to the leading scientist on the corresponding objective.

3.2. Inland flow processes

3.2.1. Shallow water models with porosity

3.2.1.1. State of the Art

Simulating urban floods and free surface flows in wetlands requires considerable computational power. Two-dimensional shallow water models are needed. Capturing the relevant hydraulic detail often requires computational cell sizes smaller than one meter. For instance, meshing a complete urban area with a sufficient accuracy would require 10^6 to 10^8 cells, and simulating one second often requires several CPU seconds. This makes the use of such model for crisis management impossible. Similar issues arise when modelling wetlands and coastal lagoons, where large areas are often connected by an overwhelming number of narrow channels, obstructed by vegetation and a strongly variable bathymetry. Describing such channels with the level of detail required in a 2D model is impracticable. A new generation of models overcoming this issue has emerged over the last 20 years: porosity-based shallow water models. They are obtained by averaging the two-dimensional shallow water equations over large areas containing both water and a solid phase [29]. 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 [48]. While the research on porosity-based shallow water models has accelerated over the past decade [43], [59], [62], [39], [38], [48], [73], [74], [68], [69], a number of research issues remain pending.

3.2.1.2. Four year research objectives

The research objectives are (i) to improve the upscaling of the flux and source term models to be embedded in porosity shallow water models, (ii) to validate these models against laboratory and in situ measurements. Improving the upscaled flux and source term models for urban applications requires that description of anisotropy in porosity models be improved to account for the preferential flows induced by building and street alignment. The description of the porosity embedded in the most widespread porosity approach, the so-called Integral Porosity model [59], [41], has been shown to provide an incomplete description of the connectivity properties of the urban medium. Firstly, the governing equations are strongly mesh-dependent because of

[3]HSM is a research unit (UMR) 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 Interactions (INSMI).

consistency issues [41]. Secondly, the flux and source term models fail to reproduce the alignment with the main street axes in a number of situations [40]. Another path for improvement concerns the upscaling of obstacle-induced drag terms in the presence of complex geometries. Recent upscaling research results obtained by the LEMON team in collaboration with Tour du Valat suggest that the effects of microtopography on the flow cannot be upscaled using "classical" equation-of-state approaches, as done in most hydraulic models. A totally different approach must be proposed. The next four years will be devoted to the development and validation of improved flux and source term closures in the presence of strongly anisotropic urban geometries and in the presence of strongly variable topography. Validation will involve not only the comparison of porosity model outputs with refined flow simulation results, but also the validation against experimental data sets. No experimental data set allowing for a sound validation of flux closures in porosity models can be found in the literature. Laboratory experiments will be developed specifically in view of the validation of porosity models. Such experiments will be set up and carried out in collaboration with the Université Catholique de Louvain (UCL), that has an excellent track record in experimental hydraulics and the development of flow monitoring and data acquisition equipment. These activities will take place in the framework of the PoroCity Associate International Laboratory (see next paragraph).

3.2.1.3. People

Vincent Guinot, Carole Delenne, Pascal Finaud-Guyot, Antoine Rousseau.

3.2.1.4. External collaborations

- Tour du Valat (O. Boutron): the partnership with TdV focuses on the development and application of depth-dependent porosity models to the simulation of coastal lagoons, where the bathymetry and geometry is too complex to be represented using refined flow models.
- University of California Irvine (B. Sanders): the collaboration with UCI started in 2014 with research on the representation of urban anisotropic features in integral porosity models [48]. It has led to the development of the Dual Integral Porosity model [42]. Ongoing research focuses on improved representations of urban anisotropy in urban floods modelling.
- Université Catholique de Louvain - UCL (S. Soares-Frazão): 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 will continue with the PoroCity Associate International Laboratory proposal. In this proposal, a four year research program is set up for the validation, development and parametrization of shallow water models with porosity.
- Luxembourg Institute of Technology (R. Hostache): the collaboration with LIST started in 2018 with the project CASCADE funded by the Fond National de la Recherche du Luxembourg, and the co-direction of Vita Ayoub. The depth-dependant porosity model is applied to simulate the flooding of the Severn river (UK).

3.2.2. Forcing

3.2.2.1. State of the Art

Reproducing optimally realistic spatio-temporal rainfall fields is of salient importance to the forcing of hydrodynamic models. This challenging task requires combining intense, usual and dry weather events. Far from being straightforward, this combination of extreme and non-extreme scenarii requires a realistic modelling of the transitions between normal and extreme periods. [52] have proposed in a univariate framework a statistical model that can serve as a generator and that takes into account low, moderate and intense precipitation. In the same vein, [70] developed a bivariate model. However, its extension to a spatial framework remains a challenge. Existing spatial precipitation stochastic generators are generally based on Gaussian spatial processes [15], [50], that are not adapted to generate extreme rainfall events. Recent advances in spatio-temporal extremes modelling based on generalized Pareto processes [32], [65] and semi-parametric simulation techniques [21] are very promising and could form the base for relevant developments in our framework.

3.2.2.2. Four year research objectives

The purpose is to develop stochastic methods for the simulation of realistic spatio-temporal processes integrating extreme events. Two steps are identified. The first one is about the simulation of extreme events and the second one concerns the combination of extreme and non extreme events in order to build complete, realistic precipitations time series. As far as the first step is concerned, a first task is to understand and to model the space-time structure of hydrological extremes such as those observed in the French Mediterranean basin, that is known for its intense rainfall events (Cevenol episodes), which have recently received increased attention. We will propose modelling approaches based on the exceedance, which allows the simulated fields to be interpreted as events. Parametric, semi-parametric and non-parametric approaches are currently under consideration. They would allow a number of scientific locks to be removed. Examples of such locks are e.g. accounting for the temporal dimension and for various dependence structures (asymptotic dependence or asymptotic independence possibly depending on the dimension and/or the distance considered). Methodological aspects are detailed in Section 3.4.1. The second step, which is not straightforward, consists in combining different spatio-temporal simulations in order to help to ultimately develop a stochastic precipitation generator capable of producing full precipitation fields, including dry and non-extreme wet periods.

3.2.2.3. People

Gwladys Toulemonde, Carole Delenne, Vincent Guinot.

3.2.2.4. External collaborations

The Cerise (2016-2018) and Fraise (2019-2021) projects (see 8.2), led by Gwladys Toulemonde, are funded by the action MANU (MAthematical and Numerical methods) of the CNRS LEFE program [4]. Among others, they aim to propose methods for simulating scenarii integrating spatio-temporal extremes fields with a possible asymptotic independence for impact studies in environmental sciences. Among the members of this project, Jean-Noel Bacro (IMAG, UM), Carlo Gaetan (DAIS, Italy) and Thomas Opitz (BioSP, MIA, INRA) are involved in the first step as identified in the research objectives of the present sub-section. Denis Allard (BioSP, MIA, INRA), Julie Carreau (IRD, HSM) and Philippe Naveau (CNRS, LSCE) will be involved in the second one.

3.2.3. Parametrization of shallow water models with porosity

3.2.3.1. State of the Art

Numerical modelling requires data acquisition, both for model validation and for parameter assessment. Model benchmarking against laboratory experiments is an essential step and is an integral part of the team's strategy. However, scale model experiments may have several drawbacks: (i) experiments are very expensive and extremely time-consuming, (ii) experiments cannot always be replicated, and measurement have precision and reliability limitations, (iii) dimensional similarity (in terms of geometry and flow characteristic variables such as Froude or Reynolds numbers) cannot always be preserved.

An ideal way to obtain data would be to carry out in situ measurements. But this would be too costly at the scale of studied systems, not to mention the fact that field may become impracticable during flood periods.

Geographical and remote sensing data are becoming widely available with high spatial and temporal resolutions. Several recent studies have shown that flood extends can be extracted from optical or radar images [35], for example: to characterize the flood dynamics of great rivers [53], to monitor temporary ponds [63], but also to calibrate hydrodynamics models and assess roughness parameters (e.g. [72].

Upscaled models developed in LEMON (see 3.2.1) embed new parameters that reflect the statistical properties of the medium geometry and the subgrid topography. New methods are thus to be developed to characterize such properties from remote sensing and geographical data.

3.2.3.2. Four year research objectives

This research line consists in deriving methods and algorithms for the determination of upscaled model parameters from geodata.

[4] Les Enveloppes Fluides et l'Environnement

For applications in urban areas, it is intended to extract information on the porosity parameters from National geographical survey databases largely available in developed countries. Such databases usually incorporate separate layers for roads, buildings, parking lots, yards, etc. Most of the information is stored in vector form, which can be expected to make the treatment of urban anisotropic properties easier than with a raster format. In developing countries, data is made increasingly available over the world thanks to crowdsourcing (e.g. OpenStreetMap) the required level of detail sometimes not available in vector format, especially in suburban areas, where lawns, parks and other vegetated areas, that may also contribute to flood propagation and storage, are not always mapped. In this context, the necessary information can be extracted from aerial and/or satellite images, that are widely available and the spatial resolution of which improves constantly, using supervised classification approaches.

For applications in great rivers the main objective is to develop an efficient framework for optimally integrating remote sensing derived flood information to compensate the lack of observation related to riverbed bathymetry and river discharge. The effective integration of such remote sensing-derived flood information into hydraulic models remains a critical issue. In partnership with R. Hostache (LIST), we will investigate new ways for making use of SEO data (i.e. flooded areas and water level estimates derived from SAR data collections) for retrieving uncertain model parameters and boundary conditions. The method will be developed and validated using synthetically generated data sets as well as real-event data retrieved from the European Space Agency's archives. Extensive testing will be carried out in a number of high magnitude events recorded over the Severn (United Kingdom) and Zambezi (Mozambique) floodplain areas.

In wetlands applications, connectivity between different ponds is highly dependent on the free surface elevation, thus conditioning the presence of a flow. Characterizing such connectivity requires that topographical variations be known with high accuracy. Despite the increased availability of direct topographic measurements from LiDARS on riverine systems, data collection remains costly when wide areas are involved. Data acquisition may also be difficult when poorly accessible areas are dealt with. If the amount of topographic points is limited, information on elevation contour lines can be easily extracted from the flood dynamics visible in simple SAR or optical images. A challenge is thus to use such data in order to estimate continuous topography on the floodplain combining topographic sampling points and located contour lines the levels of which are unknown or uncertain.

3.2.3.3. People

Carole Delenne, Vincent Guinot, Antoine Rousseau, Pascal Finaud-Guyot

3.2.3.4. External collaborations

- A first attempt for topography reconstruction in wetlands was done in collaboration with J.-S. Bailly (LISAH) in 2016 [30]. It is intended to reactivate this topic in the coming years.
- Porosity model calibration for application on great rivers will be done in the framework of CASCADE project in collaboration with R. Hostache (LIST).
- A collaboration started with the LISAH laboratory to investigate the feasibility of depth-dependent porosity laws reconstruction over cultivates areas. LISAH personel involved: D. Feurer, D. Raclot.

3.3. Marine and coastal systems

3.3.1. Multi-scale ocean modelling

The expertise of LEMON in this scientific domain is more in the introduction and analysis of new boundary conditions for ocean modelling systems, that can be tested on academical home-designed test cases. This is in the core of Antoine Rousseau's contributions over the past years. The real implementation, within operational ocean models, has to be done thanks to external collaborations which have already started with LEMON (see below).

3.3.1.1. State of the Art

In physical oceanography, all operational models - regardless of the scale they apply to - are derived from the complete equations of geophysical fluid dynamics. Depending on the considered process properties (nonlinearity, scale) and the available computational power, the original equations are adapted with some simplifying hypotheses. The reader can refer to [58], [51] for a hierarchical presentation of such models.
In the nearshore area, the hydrostatic approximation that is used is most large scales models (high sea) cannot be used without a massive loss of accuracy. In particular, shallow water models are inappropriate to describe the physical processes that occur in this zone (see Figure 1). This is why Boussinesq-type models are prefered: see [49]. They embed dispersive terms that allow for shoaling and other bathymetry effects. Since the pioneering works of Green and Naghdi (see [36]), numerous theoretical and numerical studies have been delivered by the "mathematical oceanography" community, more specifically in France (see the works of Lannes, Marche, Sainte-Marie, Bresch, etc.). The corresponding numerical models (BOSZ, WaveBox) must thus be integrated in any reasonable nearshore modelling platform.

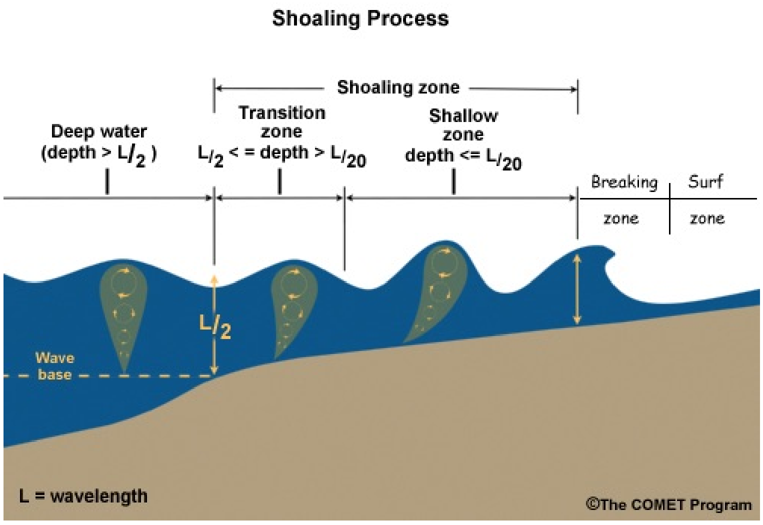

Figure 1. Deep sea, shoaling, and breaking zones.

However, these models cannot simply replace all previous models everywhere in the ocean: dispersive models are useless away from the shore and it is known that wave breaking cannot be simulated using Boussinesq-type equations. Hence the need to couple these models with others. Some work has been done in this direction with a multi-level nesting using software packages such as ROMS, but to the best of our knowledge, all the "boxes" rely on the same governing equations with different grid resolutions. A real coupling between different models is a more difficult task since different models may have different mathematical properties, as shown in the work by Eric Blayo and Antoine Rousseau on shallow water modelling (see [17]).

3.3.1.2. Four year research objectives

Starting from the knowledge acquired in the collaboration with Eric Blayo on model coupling using domain decomposition techniques, our ambition is to propose theoretical and numerical tools in order to incorporate nearshore ocean models into large complex systems including several space and time scales. Two complementary research directions are considered:

- **Dispersive *vs* non-dispersive shallow water models**. As depicted in Figure 1 above, Boussinesq-type models (embedding dispersive effects) should be used in the so-called shoaling zone. The coupling with classical deep-sea / shallow water models has to be done such that all the processes in Figure 1 are correctly modelled (by different equations), with a reduced numerical cost. As a first guess, we think that Schwarz-type methods (widely used by the DDM community) could be good candidates, in particular when the interface locations are well-known. Moving interfaces (depending on the flow, the bathymetry and naturally the wind and all external forcings) is a more challenging objective that will be tackled after the first step (known interface) is achieved.

- **spectral *vs* time-domain models**. In the context of mathematical modelling and numerical simulation for the marine energy, we want to build a coupled numerical model that would be able to simulate wave propagation in domains covering both off-shore regions, where spectral models are used, and nearshore regions, better described by nonlinear dispersive (Boussinesq-type) models.
  While spectral models work with a statistical and phase-averaged description of the waves, solving the evolution of its energy spectrum, Boussinesq-type models are phase-resolving and solves nonlinear dispersive shallow water equations for physical variables (surface elevation and velocity) in the time domain. Furthermore, the time and space scales are very different: they are much larger in the case of spectral models, which justifies their use for modelling off-shore propagation over large time frames. Moreover, important small scale phenomena in nearshore areas are better captured by Boussinesq models, in which the time step is limited by the CFL condition.
  From a mathematical and modelling point of view, this task mainly consists in working on the boundary conditions of each model, managing the simultaneous use of spectral and time series data, while studying transparent boundary conditions for the models and developing domain decomposition approaches to improve the exchange of information.

3.3.1.3. People

Antoine Rousseau, Joao Guilherme Caldas Steinstraesser

3.3.1.4. External collaborations

- **Eric Blayo** is the former scientific leader of team MOISE in Grenoble, where Antoine Rousseau was first recruited. Eric Blayo and Antoine Rousseau have co-advised 3 PhDs and continue to work together on coupling methods in hydrodynamics, especially in the framework of the COMODO ANR network.
- **Fabien Marche** (at IMAG, Montpellier, currently on leave in Bordeaux) is an expert in numerical modelling and analysis of Boussinesq-type models. He is the principal investigator of the WaveBox software project, to be embedded in the national scale Uhaina initiative.
- In the framework of its collaboration with **MERIC**, Antoine Rousseau and Joao Guilherme Caldas Steinstraesser collaborate with the consortium DiMe (ANR-FEM project), and more particularly with Jean-François Filipot ans Volker Roeber for the coupling of spectral and time-domain methods.

3.3.2. Data-model interactions

3.3.2.1. State of the Art

An alternative to direct observations is the chaining of numerical models, which for instance represent the physic from offshore to coastal areas. Typically, output data from atmospheric and ocean circulation models are used as forcings for a wave model, which in turn feeds a littoral model. In the case of extreme events, their numerical simulation from physical models is generally unreachable. This is due to a lack of knowledge on boundary conditions and on their physical reliability for such extreme quantities. Based on numerical simulated data, an alternative is to use statistical approaches. [21] proposed such an approach. They first produced and studied a 52-year hindcast using the WW3 wave model [19], [22], [20], [66]. Then stemming from parts of the original work of [18], [37], [32], [21] proposed a semi-parametric approach which aims to simulate extreme space-time waves processes to, in turn, force a littoral hazard model. Nevertheless their approach allows only a very small number of scenarii to be simulated.

3.3.2.2. Four year research objectives

A first objective is to establish the link between the simulation approach proposed by [21] and the Pareto Processes [32]. This will allow the work of [21] to be generalized, thus opening up the possibility of generating an infinity of extreme scenarii. While continuing to favor the semi- or non-parametric approaches made possible by the access to high spatial resolution calculations, we will try to capture the strength of potentially decreasing extremal dependence when moving towards higher values, which requires the development of models that allow for so-called asymptotic independence.

3.3.2.3. People

Gwladys Toulemonde, Fátima Palacios Rodríguez, Antoine Rousseau

3.3.2.4. External collaborations

- since late 2019, LEMON has started a collaboration with IRT Saint-Exupéry on the hybridization of models and large amounts of data for the modelling of urban floods
- The collaboration with Romain Chailan (IMAG, UM, CNRS) and Frédéric Bouchette (Geosciences, UM) started in 2012 during the PhD of Romain entitled Application of scientific computing and statistical analysis to address coastal hazards.
- During her post doctoral position, Fátima Palacios Rodríguez with her co-advisors will considered a generalization of the proposed simulation method by [21].

3.4. Methodological developments

In addition to the application-driven sections, the team also works on the following theoretical questions. They are clearly connected to the abovementioned scientific issues but do not correspond to a specific application or process.

3.4.1. Stochastic models for extreme events

3.4.1.1. State of the Art

Max-stable random fields [61], [60], [46], [26], [54] are the natural limit models for spatial maximum data and have spawned a very rich literature. An overview of typical approaches to modelling maxima is due to [28]. Physical interpretation of simulated data from such models can be discussed. An alternative to the max-stable framework are models for threshold exceedances. Processes called GPD processes, which appear as a generalization of the univariate formalism of the high thresholds exceeding a threshold based on the GPD, have been proposed [32], [65]. Strong advantages of these thresholding techniques are their capability to exploit more information from the data and explicitly model the original event data. However, the asymptotic dependence stability in these limiting processes for maximum and threshold exceedance tends to be overly restrictive when asymptotic dependence strength decreases at high levels and may ultimately vanish in the case of asymptotic independence. Such behaviours appear to be characteristic for many real-world data sets such as precipitation fields [27], [64]. This has motivated the development of more flexible dependence models such as max-mixtures of max-stable and asymptotically independent processes [71], [13] for maxima data, and Gaussian scale mixture processes [55], [45] for threshold exceedances. These models can accommodate asymptotic dependence, asymptotic independence and Gaussian dependence with a smooth transition. Extreme events also generally present a temporal dependence [67] . Developing flexible space-time models for extremes is crucial for characterizing the temporal persistence of extreme events spanning several time steps; such models are important for short-term prediction in applications such as the forecasting of wind power and for extreme event scenario generators providing inputs to impact models, for instance in hydrology and agriculture. Currently, only few models are available from the statistical literature (see for instance [24], [25], [44]) and remain difficult to interpret.

3.4.1.2. Four year research objectives

The objective is to extend state-of-the-art methodology with respect to three important aspects: 1) adapting well-studied spatial modelling techniques for extreme events based on asymptotically justified models for threshold exceedances to the space-time setup; 2) replacing restrictive parametric dependence modelling by semiparametric or nonparametric approaches; 3) proposing more flexible spatial models in terms of asymmetry or in terms of dependence. This means being able to capture the strength of potentially decreasing extremal dependence when moving towards higher values, which requires developing models that allow for so-called asymptotic independence.

3.4.1.3. People

Gwladys Toulemonde, Fátima Palacios Rodríguez

3.4.1.4. External collaborations

In a natural way, the Cerise and Fraise project members are the main collaborators for developing and studying new stochastic models for extremes.

- More specifically, research with Jean-Noel Bacro (IMAG, UM), Carlo Gaetan (DAIS, Italy) and Thomas Opitz (BioSP, MIA, INRA) focuses on relaxing dependence hypothesis.
- The asymmetry issue and generalization of some Copula-based models are studied with Julie Carreau (IRD, HydroSciences, UM).

3.4.2. Integrating heterogeneous data

3.4.2.1. State of the Art

Assuming that a given hydrodynamic models is deemed to perform satisfactorily, this is far from being sufficient for its practical application. Accurate information is required concerning the overall geometry of the area under study and model parametrization is a necessary step towards the operational use. When large areas are considered, data acquisition may turn out prohibitive in terms of cost and time, not to mention the fact that information is sometimes not accessible directly on the field. To give but one example, how can the roughness of an underground sewer pipe be measured? A strategy should be established to benefit from all the possible sources of information in order to gather data into a geographical database, along with confidence indexes.

The assumption is made that even hardly accessible information often exists. This stems from the increasing availability of remote-sensing data, to the crowd-sourcing of geographical databases, including the inexhaustible source of information provided by the Internet. However, information remains quite fragmented and stored in various formats: images, vector shapes, texts, etc.

This path of research begun with the Cart'Eaux project (2015-2018), that aims to produce regular and complete mapping of urban wastewater system. Contrary to drinkable water networks, the knowledge of sewer pipe location is not straightforward, even in developed countries. Over the past century, it was common practice for public service providers to install, operate and repair their networks separately [57]. Now local authorities are confronted with the task of combining data produced by different parts, having distinct formats, variable precision and granularity [23].

3.4.2.2. Four year research objectives

The overall objective of this research line is to develop methodologies to gather various types of data in the aim of producing an accurate mapping of the studied systems for hydrodynamics models.

Concerning wastewater networks, the methodology applied consists in inferring the shape of the network from a partial dataset of manhole covers that can be detected from aerial images [56]. Since manhole covers positions are expected to be known with low accuracy (positional uncertainty, detection errors), a stochastic algorithm is set up to provide a set of probable network geometries [4]. As more information is required for hydraulic modelling than the simple mapping of the network (slopes, diameters, materials, etc.), text mining techniques such as used in [47] are particularly interesting to extract characteristics from data posted on the Web or available through governmental or specific databases. Using an appropriate keyword list, thematic entities are identified and linked to the surrounding spatial and temporal entities in order to ease the burden of data collection. It is clear at this stage that obtaining numerical values on specific pipes will be challenging. Thus, when no information is found, decision rules will be used to assign acceptable numerical values to enable the final hydraulic modelling.

In any case, the confidence associated to each piece of data, be it directly measured or reached from a roundabout route, should be assessed and taken into account in the modelling process. This can be done by generating a set of probable inputs (geometry, boundary conditions, forcing, etc.) yielding simulation results along with the associated uncertainty.

Combining heterogeneous data for a better knowledge of studied systems raises the question of data fusion. What is the reality when contradictory information is collected from different sources? Dealing with spatial information, offset are quite frequent between different geographical data layers; pattern comparison approaches should be developed to judge whether two pieces of information represented by two elements close to each other are in reality identical, complementary, or contradictory.

3.4.2.3. People

Carole Delenne, Vincent Guinot, Antoine Rousseau, Gwladys Toulemonde

3.4.2.4. External collaborations

The Cart'Eaux project has been a lever to develop a collaboration with Berger-Levrault company and several multidisciplinary collaborations for image treatment (LIRMM), text analysis (LIRMM and TETIS) and network cartography (LISAH, IFSTTAR).

- The MeDo project lead by N. Chahinian (HSM) in collaboration with linguists of UMR Praxiling, uses data mining and text analysis approaches to retrieve information on wastewater networks from the Web. Carole Delenne has a slight implication in this project, as domain expert to guide the text annotations and for the uncertainties definition and representation in the mapping of the data collected.
- Concerning geographical data fusion for the wastewater network cartograhpy, the Phd thesis of Yassine Bel-Ghaddar has been funded by the French Association of Research and Technology (ANRT) in collaboration with Berger-Levrault company and in co-direction with A. Begdouri (LSIA Fès, Morocco).

3.4.3. Numerical methods for porosity models

3.4.3.1. State of the Art

Porosity-based shallow water models are governed by hyperbolic systems of conservation laws. The most widespread method used to solve such systems is the finite volume approach. The fluxes are computed by solving Riemann problems at the cell interfaces. This requires that the wave propagation properties stemming from the governing equations be known with sufficient accuracy. Most porosity models, however, are governed by non-standard hyperbolic systems.

Firstly, the most recently developed DIP models include a momentum source term involving the divergence of the momentum fluxes [42]. This source term is not active in all situations but takes effect only when positive waves are involved [39], [40]. The consequence is a discontinuous flux tensor and discontinuous wave propagation properties. The consequences of this on the existence and uniqueness of solutions to initial value problems (especially the Riemann problem) are not known, or are the consequences on the accuracy of the numerical methods used to solve this new type of equations.

Secondly, most applications of these models involve anisotropic porosity fields [48], [59]. Such anisotropy can be modelled using 2×2 porosity tensors, with principal directions that are not aligned with those of the Riemann problems in two dimensions of space. The solution of such Riemann problems has not been investigated yet. Moreover, the governing equations not being invariant by rotation, their solution on unstructured grids is not straightforward.

Thirdly, the Riemann-based, finite volume solution of the governing equations require that the Riemann problem be solved in the presence of a porosity discontinuity. While recent work [31] has addressed the issue for the single porosity equations, similar work remains to be done for integral- and multiple porosity-based models.

3.4.3.2. Four year research objectives

The four year research objectives are the following:

- investigate the properties of the analytical solutions of the Riemann problem for a continuous, anisotropic porosity field,
- extend the properties of such analytical solutions to discontinuous porosity fields,
- derive accurate and CPU-efficient approximate Riemann solvers for the solution of the conservation form of the porosity equations.

3.4.3.3. People

Vincent Guinot, Pascal Finaud-Guyot

3.4.3.4. External collaborations

Owing to the limited staff of the LEMON team, external collaborations will be sought with researchers in applied mathematics. Examples of researchers working in the field are

- Minh Le, Saint Venant laboratory, Chatou (France): numerical methods for shallow water flows, experience with the 2D, finite element/finte volume-based Telemac2D system.
- M.E. Vazquez-Cendon, Univ. Santiago da Compostela (Spain): finite volume methods for shallow water hydrodynamics and transport, developed Riemann solvers for the single porosity equations.
- A. Ferrari, R. Vacondio, S. Dazzi, P. Mignosa, Univ. Parma (Italy): applied mathematics, Riemann solvers for the single porosity equations.
- O. Delestre, Univ. Nice-Sophia Antipolis (France): development of numerical methods for shallow water flows (source term treatment, etc.)
- F. Benkhaldoun, Univ. Paris 13 (France): development of Riemann solvers for the porous shallow water equations.

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3.4.4. Inland hydrobiological systems

3.4.4.1. State of the Art

Water bodies such as lakes or coastal lagoons (possibly connected to the sea) located in high human activity areas are subject to various kinds of stress such as industrial pollution, high water demand or bacterial blooms caused by freshwater over-enrichment. For obvious environmental reasons, these water resources have to be protected, hence the need to better understand and possibly control such fragile ecosystems to eventually develop decision-making tools. From a modelling point of view, they share a common feature in that they all involve interacting biological and hydrological processes. According to [33], models may be classified into two main types: “minimal dynamic models” and “complex dynamic models”. These two model types do not have the same objectives. While the former are more heuristic and rather depict the likelihood of considered processes, the latter are usually derived from fundamental laws of biochemistry or fluid dynamics. Of course, the latter necessitate much more computational resources than the former. In addition, controlling such complex systems (usually governed by PDEs) is by far more difficult that controlling the simpler ODE-driven command systems.
LEMON has already contributed both to the reduction of PDE models for the simulation of water confinement in coastal lagoons [34], [16] and to the improvement of ODE models in order to account for space-heterogeneity of bioremediation processes in water resources [14].

3.4.4.2. Four year research objectives

In collaboration with colleagues from the ANR-ANSWER project and colleagues from INRA, our ambition is to improve existing models of lagoon/marine ecosystems by integrating both accurate and numerically affordable coupled hydrobiological systems. A major challenge is to find an optimal trade-off between the level of detail in the description of the ecosystem and the level of complexity in terms of number of parameters (in particular regarding the governing equations for inter-species reactions). The model(s) should be able to reproduce the inter-annual variability of the observed dynamics of the ecosystem in response to meteorological forcing. This will require the adaptation of hydrodynamics equations to such time scales (reduced/upscaled models such as porosity shallow water models (see Section 3.2.1) will have to be considered) together with the coupling with the ecological models. At short time scales (i.e. the weekly time scale), accurate (but possibly CPU-consuming) 3D hydrodynamic models processes (describing thermal stratification, mixing, current velocity, sediment resuspension, wind waves...) are needed. On the longer term, it is intended to develop reduced models accounting for spatial heterogeneity.

The team will focus on two main application projects in the coming years:

- the ANR ANSWER project (2017-2021, with INRA Montpellier and LEESU) focusing on the cyanobacteria dynamics in lagoons and lakes. A PhD student is co-advised by Antoine Rousseau in collaboration with Céline Casenave (INRA, Montpellier).
- the long term collaboration with Alain Rapaport (INRA Montpellier) will continue both on the bioremediation of water resources such as the Tunquen lagoon in Chile and with a new ongoing project on water reuse (converting wastewater into water that can be reused for other purposes such as irrigation of agricultural fields). Several projects are submitted to the ANR and local funding structures in Montpellier.

3.4.4.3. People

Céline Casenave (INRA Montpellier), Antoine Rousseau, Vincent Guinot, Joseph Luis Kahn Casapia.

3.4.4.4. External collaborations

- ANR ANSWER consortium: Céline Casenave (UMR MISTEA, INRA Montpellier), Brigitte Vinçon-Leite (UM LEESU, ENPC), Jean-François Humbert (UMR IEES, UPMC). ANSWER is a French-Chinese collaborative project that focuses on the modelling and simulation of eutrophic lake ecosystems to study the impact of anthropogenic environmental changes on the proliferation of cyanobacteria. Worldwide the current environmental situation is preoccupying: man-driven water needs increase, while the quality of the available resources is deteriorating due to pollution of various kinds and to hydric stress. In particular, the eutrophication of lentic ecosystems due to excessive inputs of nutrients (phosphorus and nitrogen) has become a major problem because it promotes cyanobacteria blooms, which disrupt the functioning and the uses of the ecosystems.
- A. Rousseau has a long lasting collaboration with Alain Rapaport (UMR MISTEA, INRA Montpellier) and Héctor Ramirez (CMM, Université du Chili).

4. Highlights of the Year

4.1. Highlights of the Year

- Antoine Rousseau and Cécile Choley have participated to the Climate Change Conference (COP25) in Madrid.
- Year 2019 has been a year with lots of changes for the team with 4 new members and 1 departure:
  - Since October 2019, Fátima Palacios Rodríguez is hired as associate professor at the *Departement Economía Financiera Actuarial y Estadística de Facultad de Ciencias Económicas y Empresariales de Universidad Complutense de Madrid*

– 4 new members joined the team in 2019: Pascal Finaud-Guyot (associate professor at the Montpellier University, Laboratory HydroSciences Montpellier) has a permanent member and Cécile Choley (PhD, funding: ANR Project DEUFI), Vita Ayoub (PhD, funding: Luxembourg National Research Fund) and Yassine Bel-Ghaddar (PhD, funding: Bourse CIFRE ANRT).

5. New Software and Platforms

5.1. SW2D

Shallow Water 2 Dimensions

KEYWORDS: Numerical simulations - Shallow water equations

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. Ituses 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 FUNCTIONAL DESCRIPTION: GUI, C++ translation

- Participant: Vincent Guinot
- Partner: Université de Montpellier
- Contact: Vincent Guinot

5.2. WindPoS-SDM-LAM

KEYWORDS: Numerical simulations - 3D - Fluid mechanics

FUNCTIONAL DESCRIPTION: Software platform for wind modeling.

- Authors: Antoine Rousseau, Cristian Paris Ibarra, Jacques Morice, Mireille Bossy and Sélim Kraria
- Contact: Mireille Bossy
- URL: https://windpos.inria.fr

5.3. SDM

Stochastic Downsaling Method

FUNCTIONAL DESCRIPTION: The computation of the wind at small scale and the estimation of its uncertainties is of particular importance for applications such as wind energy resource estimation. To this aim, starting in 2005, we have developed a new method based on the combination of an existing Numerical Weather Prediction model providing a coarse prediction, and a Lagrangian Stochastic Model for turbulent flows. This Stochastic Downscaling Method (SDM) requires a specific modeling of the turbulence closure, and involves various simulation techniques whose combination is totally original (such as Poisson solvers, optimal transportation mass algorithm, original Euler scheme for confined Langevin stochastic processes, and stochastic particle methods).

- Participants: Antoine Rousseau, Antoine Rousseau, Claire Chauvin, Frederic Bernardin and Mireille Bossy
- Contact: Mireille Bossy

5.4. OceaPoS-SDM

KEYWORDS: 3D - Turbulence - Oceanography - Numerical simulations - Stochastic models - Marine Energies

FUNCTIONAL DESCRIPTION: Simulation platform for ocean turbulence and interaction with hydroturbines

- Partner: MERIC
- Contact: Mireille Bossy

6. New Results

6.1. Inland flow processes

6.1.1. Shallow water models with porosity

We propose in [10] a discussion on the publication 'Dam break in rectangular channels with different upstream-downstream widths' (Valiani and Caleffi, 2019). The authors consider an augmented shallow water system for modelling the dam-break problem in a channel with discontinuous width and present its analytical solutions depending on the upstream-downstream water depth and channel's width ratios. In this discussion we contest the conservation of the hydraulic head through the width's discontinuity, which is stated by the authors, and we exemplify it by performing 2D Shallow water simulations reproducing some test cases presented in the paper.

6.1.2. Forcing

A book chapter entitled *Space-time simulations of extreme rainfall : why and how ?* involving among others two members of the team, Vincent Guinot and Gwladys Toulemonde has been written and accepted for publication [6]. The book whose title is *Mathematical Modeling of Random and Deterministic Phenomena* will be published by Wiley. This chapter aims to present practical interest of doing space-time simulations of extreme rainfall and to propose a state-of-art about that.

6.2. Marine and coastal systems

6.2.1. Numerical Modelling of Hydrokinetic Turbines

Recent studies have pointed out the potential of several coastal or river areas to provide significant energy resources in the near future. However, technological processes for extracting energy using Marine Current Energy Converters (MCEC) are not generically "field-ready" and still require significant research to be set up. The book chapter [8] comes within this framework: we develop the numerical model OceaPoS, useful to carry out a comprehensive description of turbulent flow patterns past MCEC and forward optimize the turbine arrays configurations and evaluate their environmental effects. The OceaPos model consists in describing the fluid as an ensemble of Lagrangian particles ruled by a Stochastic process. OceaPos follows the same methodology than SDM-WindPoS model for wind farm simulations and adapts the Lagrangian stochastic downscaling method (SDM) to the tidal and oceanic boundary layer. We also introduce a Lagrangian version of actuator discs to take account of one or several MCEC's devices and their effects on the flow dynamics. Several benchmarks are presented, and numerical predictions are compared to experimental results.

6.2.2. Multi-scale ocean modeling

In [3], we derive discrete transparent boundary conditions for a class of linearized Boussinesq equations. These conditions happen to be non-local in time and we test numerically their accuracy with a Crank-Nicolson time-discretization on a staggered grid. We use the derived transparent boundary conditions as interface conditions in a domain decomposition method, where they become local in time. We analyze numerically their efficiency thanks to comparisons made with other interface conditions.

In Cemracs 2019 in Marseille, Joao CALDAS was enrolled in the project "Model analysis for tsunami generation by landslides", with Louis EMERALD (PhD student, Université de Rennes), Emmanuel AUDUSSE (maître de conférences, Université Paris 13), Martin PARISOT (chargé de recherche, Inria Bordeaux, CARDAMOM team), Philippe HEINRICH (researcher, CEA) and Alexandre PARIS (PhD student, CEA). The project, funded by CEA, aims to study and compare different fluid mechanics models (Navier-Stokes, Boussinesq, Shallow Water equations) in the simulation of waves generated by landslides. The observed behaviour of the models is correlated to the amount of energy transferred from the sediments to the fluid, both in the wave generation zone (next to the landslide) and in the wave propagation zone (far away from it). An inverse problem is proposed for recovering the landslide from a given evolution of the free surface elevation. A publication will appear in the proceedings of CEMRACS 2019.

6.3. Stochastic models for extreme events

6.3.1. Hierarchical space-time modeling of exceedances

This novel approach is presented in this subsection but it is important to note that it also could has been presented in the subsection *Forcing* because the proposed method could be used as rainfall forcing and because it answers to some mentionned challenges.

The statistical modeling of space-time extremes in environmental applications is a valuable approach to understand complex dependencies in observed data and to generate realistic scenarios for impact models. Motivated by hourly rainfall data in Southern France presenting asymptotic independence, we propose in a joint work (J.N. Bacro, C. Gaetan, T. Opitz and G. Toulemonde) published in the Journal of the ASA [2] a novel hierarchical model for high threshold exceedances leading to asymptotic independence in space and time. Our approach is based on representing a generalized Pareto distribution as a Gamma mixture of an exponential distribution, enabling us to keep marginal distributions which are coherent with univariate extreme value theory. The key idea is to use a kernel convolution of a space-time Gamma random process based on influence zones defined as cylinders with an ellipsoidal basis to generate anisotropic spatio-temporal dependence in exceedances. Statistical inference is based on a composite likelihood for the observed censored excesses. The practical usefulness of our model is illustrated on the previously mentionned hourly precipitation data set from a region in Southern France. This work has also been presented by Gwladys Toulemonde in 2019 in two invited talks (EVA, Zagreb 2019; CMStatistics, ERCIM, London 2019), in one contributed international conference (ISI, Kuala Lumpur, 2019) and one seminar organized by the "Ecole Polytechnique" (Paris, 2019).

6.3.2. Extension of the XGumbel copula to the spatial framework

An extension of the XGumbel copula to the spatial framework has been developped. This work has been presented in the international conference Extreme Value Analysis (EVA 2019, Zagreb) and is currently under review [9]. The XGumbel copula combines two Gumbel copulas with weight parameters, termed extra-parameters, taking values in the unit hyper-cube. In a multisite study, the copula dimension being the number of sites, the XGumbel copula quickly becomes over-parametrized. In addition, interpolation to ungauged locations is not easily achieved. We propose a spatial model for maxima that combines a spatial regression for GEV marginals built with a vector generalized linear model and the spatialized XGumbel copula defined thanks to a spatial mapping for the extra-parameters. The mapping is designed shaped as a disk according to bivariate properties of the XGumbel copula. An Approximate Bayesian Computation (ABC) scheme that seeks to reproduce upper tail dependence coefficients for distance classes is used to infer the parameters. The extension of the XGumbel copula to the spatial framework has been used to study annual maxima of daily precipitation totals at 177 gauged stations over a 57 year period in the French Mediterranean.

7. Bilateral Contracts and Grants with Industry

7.1. IRT

In late 2019, we started a new collaboration with IRT Saint-Exupéry for the hybridization of numerical models and large amount of data for the modeling of urban floods.

7.2. Berger-Levrault

A research collaboration convention was signed with Berger-Levrault company (Montpellier) for three years, in the framework of Yassine Bel-Ghaddar thesis (CIFRE ANRT France/Maroc).

7.3. CEREG/GERIMU

The GERIMU project entered its second phase in 2019. The industrial version of the SW2D computational code was parallelized and tested by ASA Company (subcontractor). Integration of all software components into the final software product will take place during the first half of 2020.

8. Partnerships and Cooperations

8.1. Regional Initiatives

The MeDo project (lead by N. Chahinian) in which Carole Delenne participates is funded by Occitanie Region.

8.2. National Initiatives

Antoine Rousseau is member of the ANR project ANSWER (PI Céline Casenave), 2016-2020

Gwladys Toulemonde is head of a project (2019-2021) funded by INSU via the action MANU (MAthematical and NUmerical methods) of the LEFE program. This project, called Fraise, is focused on rainfall forcing by stochastic simulation for hydrological impact studies from dry periods to extreme events. The consortium involved in this project is larger than the Cerise one (14 researchers from 8 partners : AgroParisTech, CNRS, INRA, Inria, IRD, Université de Lyon 1, Université de Montpellier and the University of Venise in Italy).

Gwladys Toulemonde is member of the ANR project Gambas (PI Frédéric Mortier, Cirad), 2019-2023. The project GAMBAS focuses on joint species distribution models. These models can provide a better understanding and more accurate predictions of species distributions based on environmental variables while taking into account the effects of all other co-occurring species (e.g. competition).

Pascal Finaud-Guyot is member of the ANR project DEUFI (PI André Paquier, IRSTEA Lyon), 2019-2022

All the team is involved in the Inria ADT named SW2D-Lemon. This development project led to 2 coding sprints (of 2 weeks each) with the development team in Sophia. Thanks to this project, SW2D is now a C++ platform, with a dedicate GUI.

8.3. International Initiatives

Gwladys Toulemonde is member of the PHC Utique project (with Tunisia) AMANDE (PI Julie Carreau, IRD), 2019-2021. The project AMANDE focuses on stochastic and semi-parametric approaches combined to teledetection for the study of the water stress.

8.3.1. Inria International Labs

Inria Chile. Associate Team involved in the International Lab: NEMOLOCO

Title: NEw MOdeLing tOols for Coastal Oceanography

International Partner (Institution - Laboratory - Researcher): Pontificia Universidad Católica de Chile (Chile) - CIGIDEN - Rodrigo Cienfuegos

Start year: 2017

See also: https://team.inria.fr/lemon/en/

The NEMOLOCO project targets the improvement of models in the coastal zone. Expected contributions concern: 1) design and implementation of domain decomposition and coupling techniques for coastal modeling; 2) high resolution ocean simulation (including nesting) thanks to the software ROMS-CROCO, applied to biological tracers tracking.

8.3.2. Inria International Partners

8.3.2.1. Informal International Partners

A research collaboration agreement was signed with LSIA, Fès University, Morocco in the framework of Yassine Bel-Ghaddar PhD thesis.

8.4. International Research Visitors

8.4.1. Visits of International Scientists

Carlo Gaetan from the University of Venise in Italy has been invited thanks to the Fraise project one week in april, 2019.

9. Dissemination

9.1. Promoting Scientific Activities

9.1.1. Scientific Events: Selection

9.1.1.1. Member of the Conference Program Committees

Gwladys Toulemonde is member of the scientific committee of Spatial Statistics 2019 (Sitges, Spain)

9.1.2. Journal

9.1.2.1. Member of the Editorial Boards

Gwladys Toulemonde is guest editor of a special issue of the Journal Spatial Statistics entitled Space-time modeling of rare events and environmental risks. This special issue is related to the conference METMA 9 organized in 2018 in Montpellier by Gwladys Toulemonde and Liliane Bel.

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

9.1.2.2. Reviewer - Reviewing Activities

Carole Delenne is a reviewer for 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)

Antoine Rousseau is a reviewer for Journal of Hydrology and Environmental Modeling & Assessment (3 manuscripts/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 computational statistics and data analysis, Dependence modeling, Extremes, Journal of applied Statistics, Journal of Statistical Theory and Practice, Statistics and Computing, Water Ressources research (1 to 3 manuscripts/year)

9.1.3. Invited Talks

Gwladys Toulemonde was invited in a session of the Extreme Value Analysis (EVA) conference in July, 2019 (Zagreb, Croatia).

Gwladys Toulemonde was invited in a session of the ERCIM-CMStatistics conference in December, 2019 (London, UK).

Antoine Rousseau was invited at side event on AI and numerical modelling at COP25 (Madrid, Spain) in December 2019.

9.1.4. Leadership within the Scientific Community

Antoine Rousseau is the scientific coordinator of the the research line *advanced modeling for marine energy* at MERIC (Santiago, Chile).

9.1.5. Scientific Expertise

Gwladys Toulemonde is appointed by the Occitanie region to the scientific board in charge of innovation projects in the field of intelligent systems and digital data chain

Antoine Rousseau is member of the international scientific board of the Climat-AmSud program

9.1.6. Research Administration

Vincent Guinot is head of the ETH team at HSM (10 staff members),

Vincent Guinot is a member of the HSM steering board,

Carole Delenne is elected member of the HSM board (UMR 5569),

Antoine Rousseau is head of the LEMON team at Inria CRI-SAM (5 staff members),

Antoine Rousseau is a member of the Inria CRI-SAM steering board (*Comité des Projets*)

Antoine Rousseau is a member of the Inria CRI-SAM scientific board (*Bureau du Comité des Projets*)

Gwladys Toulemonde is elected member of the IMAG board (UMR 5149)

Gwladys Toulemonde is elected member of the MIPS Scientific Department (Mathematics, Computer Science, Physics and Systems), a component of the University of Montpellier

Gwladys Toulemonde is elected member of the French Statistical Society board (*Société Française de Statistique, SFdS*) and vice-president since july 2019

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*)

Gwladys Toulemonde was appointed in 2019 external member of a MCF recruitment at the university of Compiègne (MCF 4121, section CNU 26).

Gwladys Toulemonde was appointed in 2019 external member of a MCF recruitment at the university of Nice (MCF 4576, section CNU 26).

9.2. Teaching - Supervision - Juries

9.2.1. Teaching

Four LEMON permanent members (out of five) are university staff and have teaching duties. Most of their lectures are given at master level at Polytech Montpellier in the departments Informatics and Management (IG), Water Sciences and Technologies (STE) and Water and Civil Engineering (EGC) as well in other courses of University of Montpellier. The teaching load is summarized in Table 1.

Table 1. Teaching

Antoine Rousseau	Teaching M1 level: 0 to 30 hrs/year Student supervision: 50 hrs/year
Carole Delenne	Teaching L1-M2 level: 200-250 hrs/year hydraulics, applied mathematics, informatics Student tutorship and supervision: 50-100 hrs/year
Gwladys Toulemonde	50% CNRS delegation in 2019 Teaching L3/M1/M2 level: 128 hrs in 2019 mathematics, probability, statistics, data mining
Pascal Finaud-Guyot	Teaching L3/M1/M2 level: 200-250 hrs/year hydraulics, applied mathematics, informatics Student tutorship and supervision: 50-100 hrs/year
Vincent Guinot	Teaching L3/M1/M2 level: 290 hrs/year Student tutorship and supervision: 50-100 hrs/year

Gwladys Toulemonde is responsible for student recruitment at the IG department (Polytech Montpellier).

9.2.2. Supervision

PostDoc: Gwladys Toulemonde advises a post-doctoral fellow (F. Palacios-Rodriguez) from october 2017 to september 2019 on spatio-temporal extreme processes to assess flood hazards [11], [12] (NUMEV funding until Oct 2018)

PhD : Gwladys Toulemonde has co-supervised a PhD thesis defended in september 2019 in an established collaboration with Sanofi and is also involved in two other industrial collaborations (BALEA, Twin Solutions)

PhD in progress :

- Vita Ayoub, "Assimilation of satellite derived flood information for better parameterizing and controlling large scale hydraulic models over data scarse areas", november 2018, Carole Delenneand R. Hostache (LIST, Luxembourg).
- Yassine Bel-Ghaddar, "Data fusion for urban network mapping. Application to sanitation networks", may 2019, Carole Delenneand A. Begdouri (LSIA, Fès, Morocco).
- Joseph Luis Kahn Casapia, "Coupling hydro-ecological reduced models for the simulation of fresh water ecosystems", September 2018, Antoine Rousseau and C. Casenave (INRA, Montpellier).
- Joao Guilherme Caldas Steinstraesser, "Coupling large and small scale shallow water models with porosity in the presence of anisotropy", October 2019, Antoine Rousseau and Vincent Guinot.
- Cécile Choley, "Experimental an numerical study of the street-building exchange during urban floods", November 2019, Pascal Finaud-Guyot.

9.2.3. Juries

Gwladys Toulemonde has participated to the PhD thesis jury of Abdul-Fattah Abu-Awwad defended in June 2019 at the University of Lyon.

Carole Delenne was invited member of the PhD thesis jury of Gabrielle Rudi Chovelon, defended in May 2019 at SupAgro Montpellier.

9.3. Popularization

9.3.1. Internal or external Inria responsibilities

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 is involved in the board of Animath since october, 2019, representing the SFdS.

Gwladys Toulemonde is a member of the organizing committee of the Forum Emploi Math (FEM 2019, Paris).

Antoine Rousseau is member of the scientific board of Fondation Blaise Pascal

Antoine Rousseau is member of the *MakeSEnS* group at Inria, instructed by Inria's management to make proposals for the institute to tackle current environmental issues: see [7]

Antoine Rousseau is co-editor of the national blog binaire, published by Le Monde

9.3.2. Articles and contents

- *Pour une écologie numérique* (in french), blog post on binaire, Antoine Rousseau, 2019.
- *Ces océans qu'on modélise* (in french), blog post on binaire, Antoine Rousseau and coauthors, 2019.

9.3.3. Education

In 2019, Antoine Rousseau gave public lectures in the junior school of Aubais, France (30 kids, 10 years old): 2.5 days of introduction to coding.

9.3.4. Interventions

Antoine Rousseau gave a 2h lecture in Lycée Joffre (high school), Montpellier, France (60 students, 18-20 years old). The conference was linked to the 2019-2020 topic for the french engineering schools competition (TIPE): mathematical modelling for oceans. Antoine Rousseau also dedicated one full day to help young students to design their TIPE project.

10. Bibliography

Major publications by the team in recent years

[1] V. GUINOT, C. DELENNE, A. ROUSSEAU, O. BOUTRON. *Flux closures and source term models for shallow water models with depth-dependent integral porosity*, in "Advances in Water Resources", September 2018, vol. 122, pp. 1-26 [*DOI :* 10.1016/J.ADVWATRES.2018.09.014], https://hal.archives-ouvertes.fr/hal-01884110

Publications of the year

Articles in International Peer-Reviewed Journals

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