Activity Report 2018

Team LEMON

Littoral, Environnement : Méthodes et Outils Numériques

Inria teams are typically groups of researchers working on the definition of a common project, and objectives, with the goal to arrive at the creation of a project-team. Such project-teams may include other partners (universities or research institutions).

RESEARCH CENTER
Sophia Antipolis - Méditerranée

THEME
Earth, Environmental and Energy Sciences

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Team LEMON

Creation of the Team: 2014 January 01, updated into Project-Team: 2019 January 01

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Other Research Topics and Application Domains:

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1. Team, Visitors, External Collaborators

Research Scientist

Antoine Rousseau [Team leader, Inria, Researcher, HDR]

Faculty Members

Carole Delenne [Univ de Montpellier, Associate Professor, HDR]
Vincent Guinot [Univ de Montpellier, Professor, HDR]
Gwladys Toulemonde [Univ de Montpellier, Associate Professor]

Post-Doctoral Fellow

Fatima Palacios Rodriguez [Univ de Montpellier, from Feb 2018]

PhD Students

Joao Guilherme Caldas Steinstraesser [Inria, from Sep 2018]
Joseph Luis Kahn Casapia [Univ de Montpellier, from Sep 2018]

Intern

Gaspard Kemlin [Fundacion Inria Chile, until Jul 2018]

Administrative Assistant

Annie Aliaga [Inria]

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 and HSM, we collaborate with **several local academic research partners**. To mention but a few examples, we are in close contact 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).

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 [1], 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.

[1] 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).

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 [44]. 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 [67]. While the research on porosity-based shallow water models has accelerated over the past decade [61], [80], [84], [56], [55], [67], [96], [97], [91], [92], 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 [80], [58], 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 consistency issues [58]. Secondly, the flux and source term models fail to reproduce the alignment with the main street axes in a number of situations [57]. 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, 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 [67]. It has led to the development of the Dual Integral Porosity model [59]. 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.

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. [72] 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, [93] 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 [30], [69], that are not adapted to generate extreme rainfall events. Recent advances in spatio-temporal extremes modelling based on generalized Pareto processes [48], [87] and semi-parametric simulation techniques [36] 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) project, led by Gwladys Toulemonde, is funded by the action MANU (MAthematical and Numerical methods) of the LEFE program. It aims 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.

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 [51], for example: to characterize the flood dynamics of great rivers [73], to monitor temporary ponds [85], but also to calibrate hydrodynamics models and assess roughness parameters [82], [62], [95].

Upscaled models developed in LEMON (see 3.2.1) embed new parameters that reflect the statistical properties of the medium geometry. Two types of information are needed: the directional properties of the medium and its flow connectivity properties. New methods are thus to be developed to characterize such statistical properties from 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. In developed countries, it is intended to extract information on the porosity parameters and their principal directions from National geographical survey databases. 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). However, such level of detail in vector format is still not available in many countries. Moreover, vector data for the street network does not provide all the relevant information. In suburban areas, lawns, parks and other vegetated areas may also contribute to flood propagation and storage. In this context, it is intended to extract the necessary information from aerial and/or satellite images, that are widely available and the spatial resolution of which improves constantly. A research line will consist in deriving the information on street preferential orientation using textural analysis techniques. Such techniques have been used successfully in the field of agricultural pattern identification during Carole Delenne's PhD thesis [46], [77]. However, their application to the urban environment raises a number of issues. One of them is the strongly discontinuous character of the urban medium, that makes textural analysis difficult.

Moreover, in order to achieve a correct parametrization, identifying areas with homogeneous porosity properties is necessary. Algorithms identifying the shape and extension of such areas are still to be developed.

In wetlands applications, the flow connectivity is a function of the free surface elevation. 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

3.2.3.4. External collaborations

- The methodologies concerning geographical databases in vector form will be developed in strong collaboration with C. Dieulin at HSM in the framework of the PoroCity Associate International Laboratory cited above.
- Research on topography reconstruction in wetlands begun in collaboration with J.-S. Bailly (LISAH) in 2016 [45] and will continue in the coming years.

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 [79], [70] 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 [68]. They embed dispersive terms that allow for shoaling and other bathymetry effects. Since the pioneering works of Green and Naghdi (see [52]), 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.

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 [32]).

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.

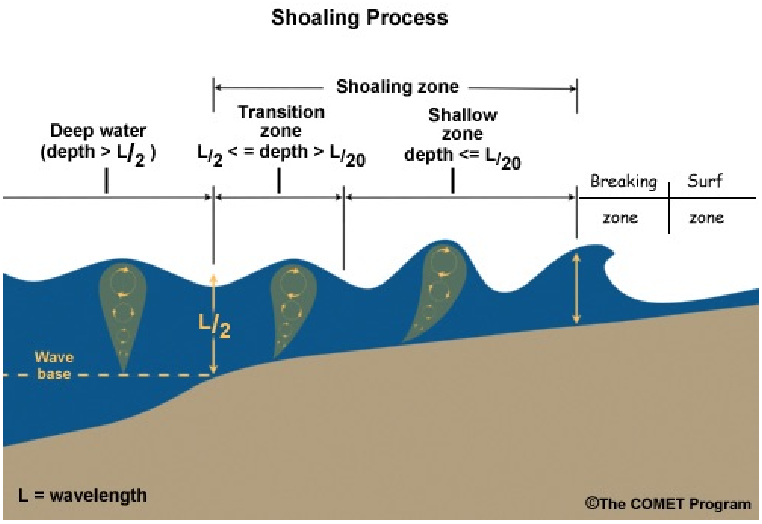

Figure 1. Deep sea, shoaling, and breaking zones.

- **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. [36] proposed such an approach. They first produced and studied a 52-year hindcast using the WW3 wave model [34], [37], [35], [88]. Then stemming from parts of the original work of [33], [53], [48], [36] 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 [36] and the Pareto Processes [48]. This will allow the work of [36] 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

- 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 [36].

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 [83], [81], [65], [41], [74] 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 [43]. 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 [48], [87]. 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 [42], [86]. This has motivated the development of more flexible dependence models such as max-mixtures of max-stable and asymptotically independent processes [94], [28] for maxima data, and Gaussian scale mixture processes [75], [64] 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 [89] . 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 [39], [40], [63]) 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 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 [78]. Now local authorities are confronted with the task of combining data produced by different parts, having distinct formats, variable precision and granularity [38].

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 [76]. 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. 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 [66] 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.

In collaboration with J.S. Bailly (LISAH), it is intended to extend the application field of the Cart'Eaux project to rainwater collection systems, involving free surface ditches. These are particularly present in peri-urban areas and are integral part of the green corridor by playing a crucial environmental role of pollution retention and ecological continuity. Multiple-point geostatistics methods [54] will be explored, especially the Direct Sampling approach [71], efficient to simulate spatial heterogeneities by combining continuous and categorized data. When a variable is observed at a given location, the method uses it as conditional information to guide the simulation of another variable of interest in the whole spatial field.

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).

- A new project lead by N. Chahinian (HSM) has recently been funded concerning data mining and text analysis, in collaboration with linguists of URM Praxiling. Carole Delenne will have a slight implication in this project.
- A phd thesis will be submitted to the French Association of Research and Technology (ANRT) in co-funding with Berger-Levrault company concerning data fusion.
- The problematic of inferring a connected network from scarce or uncertain data is common to several research topics in LEMON such as sewage or drainage systems, urban media and wetlands. A generic methodology will be developed in collaboration with J.-S. Bailly (LISAH).

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 [59]. This source term is not active in all situations but takes effect only when positive waves are involved [56], [57]. 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 [67], [80]. 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 [47] 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

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. External collaborations

3.4.4.1. Inland hydrobiological systems

3.4.4.1.1. 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 [49], 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 [50], [31] and to the improvement of ODE models in order to account for space-heterogeneity of bioremediation processes in water resources [29].

3.4.4.1.2. 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 will be 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.

3.4.4.1.3. People

Céline Casenave (INRA Montpellier), Antoine Rousseau, Vincent Guinot, Joseph Luis Kahn Casapia, PhD student (march 2018)

3.4.4.1.4. 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. Application Domains

4.1. Simulation of extreme events

The models and methods developed within this research line aim to support decision-making in the field of flood crisis management. This concerns various types of floods.

- rainfall-induced floods, stemming from intense rainfall events (see 3.2.3, 3.4.1, 3.4.2),
- fluvial floods
- fast rising flood waves induced by dam/dike break or tsunami waves (see 3.3.1, 3.2.2),
- coastal submersion (storm surges).

The aforementioned models and methods can be used at the three stages of the flood crisis.

- Before the crisis, models can be run offline to assess the vulnerability and resilience of alternative urbanization schemes, rescue actions and mitigation policies to various meteorological/coastal scenarios. This includes the simulation of extreme forcings (wind, wave and/or rainfall fields) from a limited set of available records, see subsection 3.3.2.
- During the crisis, either fast-running porosity models or pre-computed scenarios may be used to support real-time decision-making for rescue actions.
- After the crisis, data and experience collected at the crisis stage may be used to enrich the simulation database, better parametrize the models and methods.

4.2. Marine and coastal systems

LEMON will consider interactions between various processes (and the corresponding models) in coastal oceanography. Our guideline is the design and implementation of accurate numerical methods to simulate physical and/or ecological processes involving various time and space scales:

- modelling of waves in several regimes of the coastal area (shoaling, breaking, running, etc.) implies the implementation of numerical models involving various physical regimes (2D, 3D, hydrostatic, dispersive, etc.) which cannot be studied independently (in particular in the framework of marine energies). Each of the corresponding models has its own specificity, requirements and experts. Hence the difficulty to build a multiphysics (coupled) global ocean system at the coastal scale.
- for most coastal marine organisms, including algae, invertebrates and fish, dispersal, genetic connectivity and the replenishment of coastal populations depend on the character of the coastal ocean. Modelling this dispersal process and larval transport across the surfzone is at the foremost of marine conservation ecology and requires advanced ocean modelling (in addition to the specific biological processes).

LEMON has a strong expertise on mathematical modelling and coupling techniques (borrowed from domain decomposition models) that will be intensely used in these frameworks. As far as extreme events are concerned, we want to build a data generator which will allow the study of the effects of various scenarios on impact measures. To do so, we will first analyze data simulated from a physical system and detect extreme events. The latter will be used to generate and calibrate as many realistic extreme events as necessary.

5. Highlights of the Year

5.1. Highlights of the Year

- Undoubtedly the most important highlight is the "go" decision of Inria's Project Committee for the creation of the LEMON team. This decision was made at the end of 2018 and the team will officilly exist as "Equipe Projet" as of 2019.
- 3 new members joined the team in 2018: Fatima Palacios Rodrigouez (funding source: Inria) started a PostDoc as of November 2018. Joao Guilherme Caldas Steinstraesser (funding source: Inria) and Joseph Luis Kahn Casapia (funding sources: ANR/Inria) started their PhD in October and November this year.
- The publication of the depth-dependent porosity model [4] is the result of a three year, joint research effort carried out by the team. With Vincent Guinot , Carole Delenne and Antoine Rousseau from LEMON and Olivier Boutron from Tour du Valat as co-authors, this publication is emblematic of the team's activities in the field of porosity model development.

6. New Software and Platforms

6.1. 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.

- Participant: Vincent Guinot
- Contact: Vincent Guinot

6.2. 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

6.3. 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

6.4. 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

7. New Results

7.1. Inland flow processes

7.1.1. Shallow water models with porosity

7.1.1.1. DDP model.

A new porosity model was published in 2018. The Depth-Dependent Porosity (DDP) model [4] was developed to account for subgrid-scale topographical features in shallow water models. The purpose is to allow flows to be modelled using coarse grids in the presence of strongly contrasted topography (e.g. ditches, narrow channels, submerged obstacles). Applications range from the modelling of lagoon/wetland dynamics to the submersion of urban areas by dambreak or tsunami waves. The development is the result of a team work in cooperation with the Tour du Valat research institute (O. Boutron). The developments are incorporated in the SW2D code.

7.1.1.2. Porosity model validation.

The first experimental results validating the Dual Integral Porosity (DIP) model were presented at the RiverFlow 2018 International conference [9]. This work was carried out in collaboration with S. Soares-Frazão at Université Catholique de Louvain (UCL). Two stays of Carole Delenne and Vincent Guinot at UCL to participate in the experimental campaign in 2017 had been supported financially by the LEMON budget. A journal article presenting these experiments in detail has been submitted to the Journal of Hydraulic Research and is currently awaiting the final decision.

7.1.2. Forcing

Stochastic approaches can be used to generate forcing scenarios randomly. To this end, an accurate characterization of the spatio-temporal variability and rainfall intensity distribution must be obtained from available data. So we have deeply studied a gridded hourly rainfall dataset in a region in Mediterranean France and proposed a semiparametric method to simulate spatio-temporal scenarios for extreme events. Our work was presented in the following international conferences: METMA 2018 - 9th Workshop on Spatio-temporal modelling (June 2018, Montpellier) [11] and SWGEN 2018 - Stochastic Weather Generators Conference (October 2018, Boulder, United States)[10]. Moreover we have invited P. Naveau (CNRS, LSCE) during two weeks and we have begun a collaboration concerning the construction of a unique temporal model permitting to deal with both ordinary and extreme events.

7.1.3. Inland hydrological systems

The PhD of Joseph Luis Kahn Casapia (co-advised by Antoine Rousseau and Céline Casenave from INRA) has just started (Oct. 2018). The objective of the thesis is the modelling of cyanobacteria blooms in shallow water lakes such as TaiHu, in China. This work is done in the framework of the ANSWER research project funded by ANR, with a co-funding by labex NUMEV in Montpellier.
A publication presenting the KarstMod modelling platform was accepted in Environmental Modelling & Software [6]. KarstMod incorporates a number of developments by Vincent Guinot, including the Hysteretic [90] and the infinite characteristic time [60] transfer functions.
A family of multi-region transport models in heterogeneous porous media have been derived and validated experimentally [5]. The publication with Carole Delenne and Vincent Guinot as co-authors presents not only experimental results, but also a theoretical analysis of the transport and dispersion properties of a variety of models, depending on the structure of the flow field.

7.1.4. Parametrization

With an objective of assessing flood hazard at large scale, the CASACADE project has been funded by the Luxembourg National Research Fund and provides for a phD (started in November 2018 by Vita Ayoub) concerning assimilation of satellite derived flood information for better parameterizing and controlling large scale hydraulic models over data scarce areas. One of the model used will be the DDP model [4]. The effective integration of remote sensing-derived flood information into this model will be investigated in this project for retrieving uncertain model parameters and boundary conditions. The PhD is co-directed by Carole Delenneand Renaud HOSTACHE from the Luxembourg Institute of Sciences and Technologies (LIST).

7.2. Marine and coastal systems

7.2.1. Multi-scale ocean modelling

We proposed in [2] a Schwarz-based domain decomposition method for solving a dispersion equation consisting on the linearized KdV equation without the advective term, using simple interface operators based on the exact transparent boundary conditions for this equation. An optimization process is performed for obtaining the approximation that provides the method with the fastest convergence to the solution of the monodomain problem.
We also moved towards more complex equations and derived in [13], [12] 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 used the derived transparent boundary conditions as interface conditions in a domain decomposition method, where they become local in time. We analyzed numerically their efficiency thanks to comparisons made with other interface conditions. A paper [19] is submitted for publication in addition to the aforementioned talks.

7.2.2. Data-model interactions

To go further with what have been explained in subsection Forcings, there are clear advantages of thresholding techniques in stochastic approaches aiming to simulate extreme events. They permit to exploit information from more data (compared to the block-maxima approach) and to explicitely model the original event. Pareto processes have been mostly used in a parametric framework, thereby using assumptions on the choce of the underlying dependence structure that may be strong. We have proposed a semi-parametric approach ([10], [11]) and we have shown the links between this semi-parametric method and the Pareto processes. A key benefit of the proposed method is to allow the generation of an unlimited number of realizations of these extreme fields. This work will be submitted for publication during the first trimester of 2019.

7.3. Methodological developments

7.3.1. Stochastic models for extreme events

In extreme value theory, there is two main approaches. The first one is based on block maxima and involve max-stable models. Indeed the use of extreme value copula for extreme events is justified by the theory of multivariate extreme. The most accessible models are too simplistic when they are used in a high-dimensional framework. That is why we have proposed in a spatial context to combine two Gumbel copulas. By doing that, we reduce the complexity considering the weight parameter as a function depending on covariates. Moreover interpolation becomes straightforward and enable the interpretation of the parameters with distances between sites. Properties of the proposed model such as the possible extremal dependencies varying in space are studied and inference relies on ABC techniques. This work will be submitted for publication during the first quarter of 2019 (see also [14]).

The second approach is based on high threshold exceedances. We have proposed a novel hierarchical model for this kind of data 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 been presented in two invited talks in 2018 ([16], [17]) and is under revision in JASA [27].

7.3.2. Integrating heterogeneous data

In the framework of the Cart'Eaux project, a stochastic algorithm has been set up to provide a set of probable wastewater networks geometries, obtained from manhole covers positions and cost functions based on general guidelines for such networks construction. The methodology and results are presented in a publication submitted to Computers, Environment and Urban Systems Journal.

Meanwhile, the MeDo project led by N. CHAHINIAN in collaboration with linguists, aims at identifying thematic entities related to wastewater networks in automatically collected documents on the web. This project has been presented in [8].

A PhD thesis has just been funded by ANRT and Berger-Levrault company concerning the fusion of the heterogeneous and uncertain data collected. This PhD (Yassine BEL-GHADDAR) will starts at the beginning of 2019 and will be co-directed by Carole Delenne and Ahlame BEGDOURI from the LSIA laboratory of FST Fes (Maroc).

8. Bilateral Contracts and Grants with Industry

8.1. Bilateral Contracts with Industry

LEMON has been collaborating for a while with Olivier Boutron (La Tour du Valat) and we had a specific contract in 2018 to adapt our software SW2D to specificities of Camargue lakes and lagoons. This has lead to a common paper.

9. Partnerships and Cooperations

9.1. Regional Initiatives

Cart'Eaux project (European Regional Development Fund (ERDF)): in partnership with colleagues of LIRMM and HSM (Montpellier) and with Berger-Levrault company, Carole Delenne and Benjamin COMMANDRE are developing a methodology that will collect and merge multi-sources data in the aim of mapping urban drainage networks for hydraulic modeling purpose. This chain of treatment includes: i) detection of manhole covers from remote sensing data (aerial images, numerical elevation models...), 2) development of an algorithm to retrieve the network from the detected points and other information such as roads or topography, 3) data manning to extract useful characteristics for the hydraulic model, from various databases available or from documents automatically gathered from the web. A confidence index will be given to each characteristic assessed and a sensitivity analysis will enable the software to propose a hydraulic model together with an associated uncertainty.

The GeRIMU project (Gestion du Risque d'Inondation en Milieu Urbain) will be based on the SW2D computational code. The purpose is to optimize and implement the commercial version of the code into a complete software chain for the forecasting and scenario appraisal for rainfall-generated urban floods on the scale of the urban area. The test and application site is the entire urban area of Montpellier.

9.2. National Initiatives

Antoine Rousseau is member of the ANR project ANSWER (PI Céline Casenave), 2016-2019

Gwladys Toulemonde is head of a project (2016-2018) funded by INSU via the action MANU (MAthematical and NUmerical methods) of the LEFE program. This project, called Cerise, aims to propose methods for simulating scenarii integrating spatio-temporal extremes fields with eventual asymptotic independence for impact studies in environmental sciences. Fatima PALACIOS-RODRIGUEZ is also a member of this project.

9.3. International Initiatives

9.3.1. Inria International Labs

Antoine Rousseau collaborates with Inria Chile through the partnership with MERIC in Chile. Two visits every year.

9.3.1.1. Associated team 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: - design and implementation of domain decomposition and coupling techniques for coastal modeling - high resolution ocean simulation (including nesting) thanks to the software ROMS-CROCO, applied to biological tracers tracking.

9.3.2. Inria International Partners

9.3.2.1. Declared Inria International Partners

In 2015, the *Marine Energies Research International Center* (MERIC) was launched in Chile by CORFO. Antoine Rousseau is the scientific coordinator for Inria, and several members of LEMON, CARDAMOM and TOSCA research teams will be involved in this 8 years project driven by DCNS. Antoine Rousseau is involved in the research line *advanced modeling for marine energy*.

9.3.2.2. Informal International Partners

Vincent Guinot collaborates with B.F. Sanders (University of California Irvine, USA)

Carole Delenne and Vincent Guinot collaborate with S. Soares-Frazao (Unité de Génie Civil, Université catholique de Louvain, Belgium)

Gwladys Toulemonde collaborates with C. Gaetan (Università Ca' Foscari - Venezia)

9.3.3. Participation in Other International Programs

Antoine Rousseauwas member of a successfull application to the REDES (Conicyt, Chile) program with H. Ramirez (CMM, Santiago) and P. Gajardo (UTFSM, Valparaiso).

9.4. International Research Visitors

Rodrigo Cienfuegos (PUC Santiago, Chile) visited Paris for two weeks in June (collaboration around TsunamiLab).

10. Dissemination

10.1. Promoting Scientific Activities

10.1.1. Scientific Event Organisation

10.1.1.1. Member of Organizing Committee

Gwladys Toulemonde is chair of the organizing committee of the international conference METMA IX (June 2018, Montpellier).

10.1.2. Journal

10.1.2.1. Member of Editorial Board

Antoine Rousseau is member of DCDS-S editorial board

Gwladys Toulemonde is guest editor (with L. Bel, AgroParisTech) of the Special Issue entitled "Space-time modeling of rare events and environmental risks" which will be published in Spatial Statistics.

10.1.2.2. Reviewer - Reviewing Activities

Carole Delenne is a reviewer for Journal of Hydraulic Research, Water (2 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 (2 manuscripts/year)

10.1.3. 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).

10.1.4. Scientific Expertise

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

Carole Delenne was reviewer for the STIC-AmSud Program

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

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

10.1.5. 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,

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*)

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*)

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*)

10.2. Teaching - Supervision - Juries

10.2.1. Teaching

Three LEMON permanent members (out of four) 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. Carole Delenne is also teaching manager of the department EGC at Polytech. The teaching load is summarized in Table 1.

Table 1. Teaching

Antoine	Teaching M1 level: 0 to 30 hrs/year Student supervision: 50 hrs/year
Carole	Teaching L1-M2 level: 200-250 hrs/year hydraulics, applied mathematics, informatics Student tutorship and supervision: 50-100 hrs/year
Gwladys	Teaching L3/M1/M2 level: 200-250 hrs/year mathematics, probability, statistics, data mining Student tutorship and supervision: 50-100 hrs/year
Vincent	Teaching L3/M1/M2 level: 290 hrs/year Student tutorship and supervision: 50-100 hrs/year

10.2.2. Supervision

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

Gwladys Toulemonde co-supervises a PhD thesis in an established collaboration with Sanofi and is also involved in two other industrial collaborations (BALEA, Twin Solutions)

Gwladys Toulemonde advises a post-doctoral fellow since october 2017 on spatio-temporal extreme processes to assess flood hazards (NUMEV funding until Oct 2018)

10.2.3. Juries

Antoine Rousseau was appointed internal member of a recruitment campaign at Inria (CR2 at Inria CRI-SAM)

10.3. Popularization

Antoine Rousseau is member of the editorial board of Interstices and the Binaire Blog in Le Monde.

10.3.1. Internal or external Inria responsibilities

Antoine Rousseau is member of "Bureau du Comité des Équipes-Projet" in the research center of Sophia-Antipolis Méditerranée.

10.3.2. Interventions

Antoine Rousseau has given lectures in the following events:

- Fête de la Science (Genopolys Montpellier) and Semaine des maths (Collège Les Fontanilles, Castelnaudary)
- FUTUR·E·S in La Villette (Paris) for a demo of Tsunamilab
- another Tsunamilab demo for Region Occitanie (November 30th, Port Barcarrès)
- Centre d'Alembert (Orsay-Saclay)
- public schools of Aubais (Gard) and Castelnaudary (Aude)

10.3.3. Internal action

- Antoine Rousseau gave a talk in the Café des Sciences at Inria Rocquencourt, March 20th.

10.3.4. Creation of media or tools for science outreach

- Antoine Rousseau has contributed to the development of Tsunamilab in collaboration with Inria Chile
- Antoine Rousseau is a co-administrator of the association Le Calendrier Mathématique

11. 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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