Activity Report 2017

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

LEMON is located in Montpellier.

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Other Research Topics and Application Domains:

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1. Personnel

Research Scientist

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

Faculty Members

Gwladys Toulemonde [Univ Montpellier, Associate Professor, from Sep 2017]
Vincent Guinot [Univ Montpellier, Professor, HDR]
Fabien Marche [Univ Montpellier, Associate Professor, until Aug 2017, HDR]
Carole Delenne [Univ Montpellier, Associate Professor, HDR]

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Visiting Scientist

Joao Guilherme Caldas Steinstraesser [Univ Pierre et Marie Curie, from May 2017 until Jun 2017]

External Collaborator

Benjamin Commandre [Univ Montpellier]

2. Overall Objectives

2.1. Context

Coastal areas are more and more threatened by the sea level rise caused by global warming, and yet 60% of the world population lives in a 100km wide coastal strip (80% within 30km in French Brittany). This is why coastlines are concerned with many issues, of various types: economical, ecological, social, political, etc. To address these crucial issues, LEMON will be 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, collaborations with **several local academic research partners** will be considered. To mention but a few examples, we are in close contact with UMR Geosciences (morphodynamics), UMR G-Eau (hydraulics and data assimilation), UMR MARBEC (lagoon environment), UMR MISTEA (pollution and remediation of water resources).
- LEMON members are **involved in projects** funded by the current labex NUMEV and **actively participate to new initiatives** concerned with *sea and coast* modelling, both through the recently awarded MUSE project in Montpellier and in external (national, European, international) calls.
- from the **transfert & 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 very much concerned with the applications targeted by our team.

LEMON is a new common project-team between IMAG, Inria and HSM, whose faculty members have never been associated to former Inria groups. All fellows share a strong background in mathematical modelling, together with a taste for applications in littoral environment. As reflected in the expected contributions below, the research conducted by LEMON will be interdisciplinary, 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.
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.

3. Research Program

3.1. Inland flow processes

3.1.1. Shallow water models with porosity

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 [35]. 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 [53]. While the research on porosity-based shallow water models has accelerated over the past decade [48], [64], [68], [46], [45], [53], [78], [79], [74], [47], a number of research issues remain pending.

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 [64] [5], 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 [5]. Secondly, the flux and source term models fail to reproduce the alignment with the main street axes in a number of situations [4]. Another path for improvement concerns the upscaling of obstacle-induced drag terms in the presence of complex geometries. Recent upscaling research results (to be submitted for publication within the next few weeks) 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).

People

Carole DELENNE , Vincent GUINOT , Antoine ROUSSEAU

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 [53]. It has led to the development of the Dual Integral Porosity model [6]. 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 for year research program is set up for the validation, development and parametrization of shallow water models with porosity.

3.1.2. Forcing

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 scenarios requires a realistic modelling of the transitions between normal and extreme periods. [57] 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, [75] 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 [22], [55], that are not adapted to generate extreme rainfall events. Recent advances in spatio-temporal extremes modelling based on generalized Pareto processes [39], [71] and semi-parametric simulation techniques [28] are very promising and could form the base for relevant developments in our framework.

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 will be 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 3.3.1. The second step, that 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.

People

Carole DELENNE , Vincent GUINOT , Gwladys TOULEMONDE

External collaborations
The Cerise (2016-2018) project, led by Gwladys TOULEMONDE , is funded by INSU via 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) and Julie Carreau (IRD, HSM) will be involved in the second one.

3.1.3. Inland hydrobiological systems

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 [40], 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 [41], [23] and to the improvement of ODE models in order to account for space-heterogeneity of bioremediation processes in water resources [21].

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 3.1.1) 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.

People

Antoine ROUSSEAU , Vincent GUINOT , Joseph Kahn, PhD student (march 2018)

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).

3.1.4. Parametrization

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 essential to 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 [42], for example: to characterize the flood dynamics of great rivers [58], to monitor temporary ponds [69], but also to calibrate hydrodynamics models and assess roughness parameters [66], [49], [77].

Upscaled models developed in LEMON 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.

Four year research objectives

This research line consists in deriving methods and algorithms for the determination of upscaled model parameters from various types and sources of geodata: aerial photographs, urban databases, remote sensing SAR or optical data, etc. In developed countries, it is intended to extract information on the porosities and their principal directions from urban or 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 the raster format. Moreover, data is made increasingly available over the world thanks to crowdsourcing (e.g. OpenStreetMap). However, in order to achieve a correct parametrization of a porosity model, identifying areas with homogeneous porosity properties is necessary. Algorithms identifying the shape and extension of such areas are still to be developed.

In developing countries, such level of detail in vector format may not be available. 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 major 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 PhD thesis [37], [62]. 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.

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 heterogeneous data: topographic sampling points and located contour lines the levels of which are unknown or uncertain.

People
Carole DELENNE , Vincent GUINOT , Antoine ROUSSEAU

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 [36] and will continue in the coming years.

3.2. Marine and coastal systems

3.2.1. Multi-scale ocean modelling

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 [63], [56] 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 [54]. They embed dispersive terms that allow for shoaling and other bathymetry effects. Since the pioneering works of Green and Naghdi (see [43]), 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.

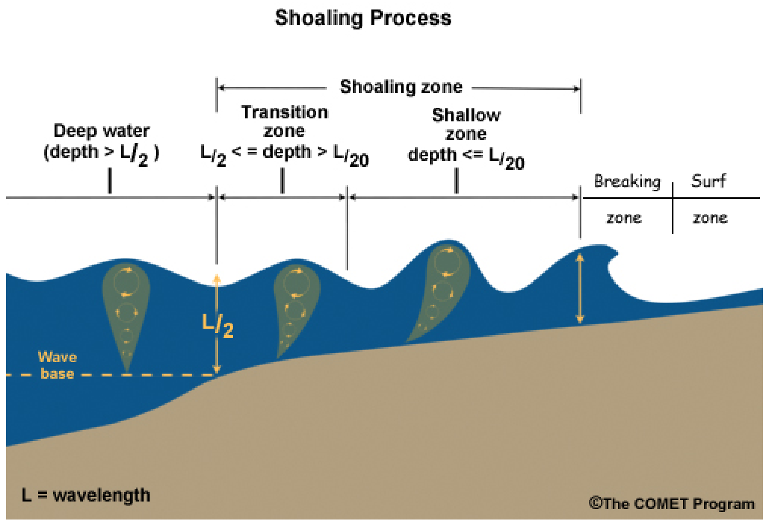

Figure 1. Deep sea, shoaling, breaking and surf zones.

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 Blayo and Rousseau on shallow water modelling (see [1] and [24]).

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.

People
Antoine ROUSSEAU , Joao Caldas

External collaborations

- **Eric Blayo** is the former scientific leader of team MOISE in Grenoble, where Antoine ROUSSEAU was first recruited. Blayo and 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 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.

3.2.2. Data-model interactions

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. [28] proposed such an approach. They first produced and studied a 52-year hindcast using the WW3 wave model [26], [29], [27], [72]. Then stemming from parts of the original work of [25], [44], [39], [28] 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 scenarios to be simulated.

Four year research objectives
A first objective is to establish the link between the simulation approach proposed by [28] and the Pareto Processes [39]. This will allow the work of [28] to be generalized, thus opening up the possibility o 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.

People
Antoine ROUSSEAU , Gwladys TOULEMONDE , Fátima Palacios Rodríguez

External collaborations

- The collaboration with Romain Chailan (TwinSolutions, Montpellier) and Frédéric Bouchette (Geo-sciences, 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 whith her co-advisors will considered a generalization of the proposed simulation method by [28].

3.3. Methodological developments

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

3.3.1. Stochastic models for extreme events

State of the Art
Max-stable random fields [67], [65], [52], [32], [59] 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 [34]. 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 appears as a generalization of the univariate formalism of the high thresholds exceeding a threshold based on the GPD, have been proposed [39], [71]. 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 [33], [70]. This has motivated the development of more flexible dependence models such as max-mixtures of max-stable and asymptotically independent processes [76], [20] for maxima data, and Gaussian scale mixture processes [60], [51] 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 [73] . 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 [30], [31], [50]) and remain difficult to interpret.

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.

People
Gwladys TOULEMONDE , Fátima Palacios Rodríguez

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).

3.3.2. Integrating heterogeneous data

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.

Four year research objectives
The assumption is made that even hardly accessible information often exists. This stems from the increasing availability of remote-sensing data, to the crowdsourcing 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. 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.

One possible application concerns the combination of on-field elevation measurements and level lines extracted from remote sensing data in the aim of retrieving the general topography of the domain (see section 3.1.4).

Another application studied in the Cart'Eaux project, is the production of regular and complete mapping of urban sewer systems. Contrary to drinkable water networks, the knowledge of sewer pipe location is not straightforward, even in developed countries. 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 [61]. Since manhole covers positions are expected to be known with low accuracy (positional uncertainty, detection errors), a stochastic algorithm will be 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 data mining is used to extract characteristics from data posted on the Web or available through governmental or specific databases. Using an appropriate keyword list, the web is scanned for text documents. 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.

People
Carole DELENNE , Vincent GUINOT , Gwladys TOULEMONDE , Benjamin Commandré

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). These collaborations will continue with the submission of new projects.
- 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).

3.3.3. Numerical methods for porosity models

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 [6]. This source term is not active in all situations but takes effect only when positive waves are involved [46] [4]. 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. Nor 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 [53], [64]. 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 [38] has addressed the issue for the single porosity equations, similar work remains to be done for integral- and multiple porosity-based models.

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.

People
Vincent GUINOT , Antoine ROUSSEAU

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)
- M.E. Vazquez-Cendon, Univ. Santiago da Compostela (Spain)
- A. Ferrari, R. Vacondio, S. Dazzi, P. Mignosa, Univ. Parma (Italy)
- O. Delestre, Univ. Nice-Sophia Antipolis (France)
- F. Benkhaldoun, Univ. Paris 13 (France)

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4. Application Domains

4.1. Inland flow processes

4.1.1. Shallow water models with porosity

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 [35]. 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 [53]. While the research on porosity-based shallow water models has accelerated over the past decade [48], [64], [68], [46], [45], [53], [78], [79], [74], [47], a number of research issues remain pending.

4.1.2. Forcing

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 scenarios requires a realistic modelling of the transitions between normal and extreme periods. [57] 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, [75] 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 [22], [55], that are not adapted to generate extreme rainfall events. Recent advances in spatio-temporal extremes modelling based on generalized Pareto processes [39], [71] and semi-parametric simulation techniques [28] are very promising and could form the base for relevant developments in our framework.

4.1.3. Inland hydrobiological systems

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 [40], 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 [41], [23] and to the improvement of ODE models in order to account for space-heterogeneity of bioremediation processes in water resources [21].

4.1.4. Parametrization

Numerical modelling requires data acquisition, both for model validation and for parameter assessment. Model benchmarking against laboratory experiments is an essential step and is essential to 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 [42], for example: to characterize the flood dynamics of great rivers [58], to monitor temporary ponds [69], but also to calibrate hydrodynamics models and assess roughness parameters [66], [49], [77].

Upscaled models developed in LEMON 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.

4.2. Marine and coastal systems

4.2.1. Multi-scale ocean modelling

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 [63], [56] 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 above). This is why Boussinesq-type models are prefered: see [54]. They embed dispersive terms that allow for shoaling and other bathymetry effects. Since the pioneering works of Green and Naghdi (see [43]), 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 Blayo and Rousseau on shallow water modelling (see [1] and [24]).

4.2.2. Data-model interactions

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. [28] proposed such an approach. They first produced and studied a 52-year hindcast using the WW3 wave model [26], [29], [27], [72]. Then stemming from parts of the original work of [25], [44], [39], [28] 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 scenarios to be simulated.

5. New Software and Platforms

5.1. Action Dépollution

FUNCTIONAL DESCRIPTION: Action Dépollution is a serious game made for learning how to purify fast and well a water reservoir, such as lakes. In the scope of the international initiative Mathematics of Planet Earth, this game shows an application of mathematics related to environmental education and sustainable development. The player can act as a researcher, that compares different strategies and looks for the best solution.

- Participants: Alain Rapaport, Alexis Pacholik and Antoine Rousseau
- Contact: Antoine Rousseau
- URL: https://depollution.inria.fr/

5.2. 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

5.3. 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. New Results

6.1. Boundary conditions and Schwarz waveform relaxation method for linear viscous Shallow Water equations in hydrodynamics

In [1] we propose in the present work an extension of the Schwarz waveform relaxation method to the case of viscous shallow water system with advection term. We first show the difficulties that arise when approximating the Dirichlet to Neumann operators if we consider an asymptotic analysis based on large Reynolds number regime and a small domain aspect ratio. Therefore we focus on the design of a Schwarz algorithm with Robin like boundary conditions. We prove the well-posedness and the convergence of the algorithm.

6.2. Modeling and control of in-situ decontamination of large water resources

In [3] we address the problem of the optimal control of in situ decontamination of water resources. We review several modeling, simulation and optimization techniques for this problem and their results. We show the benefit of combining tools from finite dimensional optimal control theory and numerical simulations of hydrodynamics equations, for providing simple and efficient feedback strategies.

6.3. On nontraditional quasi-geostrophic equations

In [7] we work on nontraditional models where the so-called traditional approximation on the Coriolis force is removed. In the derivation of the quasi-geostrophic equations, we carefully consider terms in δ/ε, where δ (aspect ratio) and ε (Rossby number) are both small numbers. We provide here some rigorous crossed-asymptotics with regards to these parameters, prove some mathematical results and compare QHQG and QG models.

6.4. Source term closures in shallow water models with porosity

In [4] the validity of flux and source term formulae used in shallow water models with porosity for urban flood simulations is assessed by solving the two-dimensional shallow water equations over computational domains representing periodic building layouts. The models under assessment are the Single Porosity (SP), the Integral Porosity (IP) and the Dual Integral Porosity (DIP) models. 9 different geometries are considered. 18 two-dimensional initial value problems and 6 two-dimensional boundary value problems are defined. This results in a set of 96 fine grid simulations. Analysing the simulation results leads to the following conclusions: (i) the DIP flux and source term models outperform those of the SP and IP models when the Riemann problem is aligned with the main street directions, (ii) all models give erroneous flux closures when is the Riemann problem is not aligned with one of the main street directions or when the main street directions are not orthogonal, (iii) the solution of the Riemann problem is self-similar in space-time when the street directions are orthogonal and the Riemann problem is aligned with one of them, (iv) a momentum balance confirms the existence of the transient momentum dissipation model presented in the DIP model, (v) none of the source term models presented so far in the literature allows all flow configurations to be accounted for(vi) future laboratory experiments aiming at the validation of flux and source term closures should focus on the high-resolution, two-dimensional monitoring of both water depth and flow velocity fields.

6.5. Consistency and bicharacteristic analysis of integral porosity shallow water models

The Integral Porosity and Dual Integral Porosity two-dimensional shallow water models have been proposed recently as upscaled models for urban floods. Very little is known so far about their consistency and wave propagation properties. Simple numerical experiments show that both models are unusually sensitive to the computational grid. In the present paper, a two-dimensional consistency and characteristic analysis is carried out for these two models. In [5] the following results are obtained: (i) the models are almost insensitive to grid design when the porosity is isotropic, (ii) anisotropic porosity fields induce an artificial polarization of the mass/momentum fluxes along preferential directions when triangular meshes are used and (iii) extra first-order derivatives appear in the governing equations when regular, quadrangular cells are used. The hyperbolic system is thus mesh-dependent, and with it the wave propagation properties of the model solutions. Criteria are derived to make the solution less mesh-dependent, but it is not certain that these criteria can be satisfied at all computational points when real-world situations are dealt with.

6.6. Dual integral porosity shallow water model for urban flood modelling

With CPU times 2 to 3 orders of magnitude smaller than classical shallow water-based models , the shallow water equations with porosity are a promising tool for large-scale modelling of urban floods. In [6], a new model formulation called the Dual Integral Porosity (DIP) model is presented and examined analytically and computationally with a series of benchmark tests. The DIP model is established from an integral mass and momentum balance whereby both porosity and flow variables are defined separately for control volumes and boundaries, and a closure scheme is introduced to link control volume-and boundary-based flow variables. Previously developed Integral Porosity (IP) models were limited to a single set of flow variables. A new transient momentum dissipation model is also introduced to account for the effects of sub-grid scale wave action on porosity model solutions, effects which are validated by fine-grid solutions of the classical shallow-water equations and shown to be important for achieving self-similarity in dam-break solutions. One-dimensional numerical test cases show that the proposed DIP model outperforms the IP model, with signicantly improved wave propagation speeds, water depths and discharge calculations. A two-dimensional field scale test case shows that the DIP model performs better than the IP model in mapping the floods extent and is slightly better in reproducing the anisotropy of the flow field when momentum dissipation parameters are calibrated.

6.7. DG method for dispersive Green-Naghdi equations

Concerning the development of the WaveBox code, we have introduced in [2] the first available numerical code allowing to solve some fully nonlinear and weakly dispersive asymptotic shallow water models on unstructured meshes. More precisely, we introduce a discontinuous Finite Element formulation (discontinuous-Galerkin) on simplicial unstructured meshes for the study of free surface flows based on the fully nonlinear and weakly dispersive Green-Naghdi equations. Working with a new class of asymptotically equivalent equations, which have a simplified analytical structure, we consider a decoupling strategy: we approximate the solutions of the classical shallow water equations sup- plemented with a source term globally accounting for the non-hydrostatic effects and we show that this source term can be computed through the resolution of scalar elliptic second-order sub-problems, with a use of a L-DG method. The assets of the proposed discrete formulation are: (i) the handling of arbitrary unstructured simplicial meshes, (ii) an arbitrary order of approximation in space, (iii) the exact preservation of the motionless steady states, (iv) the preservation of the water height positivity, (v) a simple way to enhance any numerical code based on the nonlinear shallow water equations. To improve the efficiency of the resolution of the elliptic part of the formulation, we also investigate the use of very recent skeleton Hybrid-High-Order (HHO) methods. These methods allow to dramatically reduce the number of degrees of freedom (DOF), using only the DOF located on the mesh skeleton. To initiate the development of such methods for nonlinear and un-stationnary problems, a new discrete formulation was developed for the advective Cahn-Hilliard equations in [17]. Such an approach will be extended to more complex asymptotic shallow water models in a near future.

7. Partnerships and Cooperations

7.1. 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.

7.2. National Initiatives

7.2.1. ANR

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

7.2.2. LEFE-INSU

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.

7.3. International Initiatives

7.3.1. Inria International Labs

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

7.3.2. Inria Associate Teams Not Involved in an Inria International Labs

7.3.2.1. 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.

7.3.3. Inria International Partners

7.3.3.1. 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 and Fabien MARCHE are involved in the research line *advanced modeling for marine energy*.

7.3.3.2. Informal International Partners

Vincent GUINOT collaborates with B.F. Sanders (Irvine University, Californie, USA)

Carole DELENNE and Vincent GUINOT collaborates with S. Soares-Frazao (Unité de Génie Civil, Université catholique de Louvain, Belgium)

7.3.4. Participation in Other International Programs

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

7.4. International Research Visitors

7.4.1. Visits of International Scientists

Andres Sepulveda (Univ Concepcion, Chile) visited the team in the framework of the CROCO summer school organized in Toulouse by the AIRSEA project-team.

José Galaz (PUC Santiago, Chile) visited Montpellier for one week.

7.4.1.1. Internships

Joao CALDAS (Ecole des Ponts, Ecole Polytechnique de Sao Paulo) was intern at Inria Chile / MERIC, advised by A. Rousseau.

8. Dissemination

8.1. Promoting Scientific Activities

8.1.1. Scientific Events Organisation

8.1.1.1. Member of the Organizing Committees

Carole DELENNE was member of the local organisation committee of the "Powders and Grains" congress that hold in Montpellier (Corum) in July 2017

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

8.1.2. Journal

8.1.2.1. Member of the Editorial Boards

Antoine ROUSSEAU is member of DCDS-S editorial board

8.1.2.2. Reviewer - Reviewing Activities

Carole DELENNE is reviewer Journal of Hydraulic Research, Water (2 manuscripts/year)

Vincent GUINOT is reviewer for Journal of Hydrology, Advances in Water Resources, Mathematical Problems in Engineering (3 manuscripts/year)

Antoine ROUSSEAU is reviewer for Journal of Hydrology (2 manuscripts/year)

8.1.3. Invited Talks

Antoine ROUSSEAU gave an invited talk to the Sino-French Conference on Computational and Applied Mathematics

8.1.4. 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).

8.1.5. 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

8.1.6. Research Administration

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

Vincent GUINOT is member of the HSM steering board,

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

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

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

Gwladys TOULEMONDE is elected to IMAG laboratory board

8.2. Teaching - Supervision - Juries

8.2.1. Teaching

License : C. Delenne, Méthodes mathématiques pour l'ingénieur, 10.5H CM, 22.5hTD, L3, Polytech Montpellier

License : C. Delenne, Hydraulique à surface libre, 15h CM, 15hTD, L3 (apprentissage), Polytech Montpellier

License : C. Delenne, Hydraulique, 28hTD, L1, IUT Génie Civil, Nîmes

License : C. Delenne, Algorithme et programmation 3h CM, 21hTD 15h projet, Polytech Montpellier, Université de Montpellier.

License : C. Delenne, Projets Eau et Génie Civil, 24hTP, Polytech Montpellier (apprentissage), Université de Montpellier.

License : V. Guinot, Mécanique des fluides, 72h ETD, L3, Polytech Montpellier, Université de Montpellier.

License : V. Guinot, Hydraulique à surface libre, 60h ETD, L3, Polytech Montpellier, Université de Montpellier.

License : F. Marche, Biomaths, 72h TD., L1, Université Montpellier

License : G. Toulemonde, Harmonisation Maths, 18h TD, L3, Polytech Montpellier, Université de Montpellier.

License : G. Toulemonde, Tutorat Maths, 5h TD, L3, Polytech Montpellier, Université de Montpellier.

License : G. Toulemonde, Modélisation et statistique, 18h CM, L3, Polytech Montpellier, Université de Montpellier.

License : G. Toulemonde, Modélisation statistique et analyse de données, 30h CM-TD, M1, Polytech Montpellier, Université de Montpellier.

Master : G. Toulemonde, Econométrie, 12h CM, 16h TD, M2, Polytech Montpellier, Université de Montpellier.

Master : G. Toulemonde, Econométrie avancée, 3h CM, 3h TD, M2, Faculté de Sciences Economiques, Université de Montpellier.

Master : C. Delenne, Hydraulique, 30hTP, M1, Polytech Montpellier, Université de Montpellier.

Master : C. Delenne, Spécialité hydraulique, 18h TD, Polytech Montpellier, Université de Montpellier.

Master : C. Delenne, Tutorat de stages et projets, apprentis, 100hETD, Polytech Montpellier, Université de Montpellier.

Master : V. Guinot, Méthodes Mathématiques pour l'Ingénieur, 18h ETD, M1, Polytech Montpellier, Université de Montpellier.

Master : V. Guinot, Hydraulique des Réseaux, 30h ETD, M1, Polytech Montpellier, Université de Montpellier.

Master : V. Guinot, Mécanique des Fluides, Master SPAE, 36h ETD, M1, UMontpellier

Master : V. Guinot, Transitoires hydrauliques, 54 h ETD, M1, Polytech Montpellier, Université de Montpellier.

Master : V. Guinot, tutorat de stages ingénieur, 15h ETD, M1, Polytech Montpellier, Université de Montpellier.

Master : V. Guinot, Modélisation hydraulique à surface libre 2D, 6h ETD, M2, Polytech Montpellier, Université de Montpellier.

Master : V. Guinot, Projet Industriel de Fin d'Etudes (PIFE), 30h ETD, M2, Polytech Montpellier, Université de Montpellier.

Master : V. Guinot, Tutorat de Stage de fin d'études ingénieur, 18h ETD, M2, Polytech Montpellier, Université de Montpellier.

Master : F. Marche, Analyse numérique des EDP, 24H CM, 12H TD, 15H TP., M1, Université Montpellier

Master : F. Marche, Calcul scientifique avancé, 26H CM, M2R, Université Montpellier

8.2.2. Supervision

Gwladys TOULEMONDE is responsible of the students recruitment in the IG department Polytech Montpellier.

Gwladys TOULEMONDE co-supervises a PhD thesis in an established collaboration with Sanofi and is ponctually implicated in 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)

8.2.3. Juries

Antoine ROUSSEAU was appointed external member of a recruitment campaign at IRSTEA (research engineer)

Antoine ROUSSEAU was appointed internal member of a recruitment campaign at Inria (HR jurist)

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

Carole DELENNE was appointed internal member of a recruitment campaign for a lecturer at University of Montpellier (LMGC/IUT Nîmes).

8.3. Popularization

Antoine ROUSSEAU gave several conferences for highschool students and their teachers, on the topics of mathematical modeling for environmental sciences:

Fête de la Science, Oct. 2017, Genopolys Montpellier (2 days)

Maths au lycée, Apr. 2017, Lycée de Castelnaudary (1 day)

Antoine ROUSSEAU is member of the national Inria network for scientific outreach *Médiation scientifique*

Antoine ROUSSEAU is member of the editorial board of Interstices

Antoine ROUSSEAU is member of the scientific board of Fondaton Blaise Pascal

Antoine ROUSSEAU co-authored the Calendrier Mathématique 2017

9. Bibliography

Publications of the year

Articles in International Peer-Reviewed Journals

[1] E. Blayo, A. Rousseau, M. Tayachi Pigeonnat. *Boundary conditions and Schwarz waveform relaxation method for linear viscous Shallow Water equations in hydrodynamics*, in "SMAI Journal of Computational Mathematics", 2017, vol. 3, pp. 117-137 [*DOI :* 10.5802/smai-jcm.22], https://hal.inria.fr/hal-01467335

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