IN PARTNERSHIP WITH:
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Université Pierre et Marie Curie (Paris 6)

Activity Report 2017

Project-Team ANGE

Numerical Analysis, Geophysics and Ecology

IN COLLABORATION WITH: Laboratoire Jacques-Louis Lions (LJLL)

RESEARCH CENTER
Paris

THEME
Earth, Environmental and Energy Sciences

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Project-Team ANGE

Creation of the Team: 2012 November 01, updated into Project-Team: 2014 January 01

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1. Personnel

Research Scientists

Jacques Sainte-Marie [Team leader, CEREMA, Senior Researcher, HDR]
Vivien Mallet [Inria, Researcher, from Mar 2017]
Martin Parisot [Inria, Researcher]
Yohan Penel [CEREMA, Researcher]
Julien Salomon [Inria, Senior Researcher, from Oct 2017, HDR]

Faculty Members

Edwige Godlewski [Univ Pierre et Marie Curie, Professor, HDR]
Cindy Guichard [Univ Pierre et Marie Curie, Associate Professor]
Boris Haspot [Univ Dauphine Paris, Associate Professor, HDR]
Anne Mangeney [IPGP, Professor, HDR]

Julien Salomon [Univ Dauphine Paris, Associate Professor, until Sep 2017, HDR]

Post-Doctoral Fellows

Bilal Al Taki [Inria, from Sep 2017]
Pierre-Olivier Lamare [Inria]

PhD Students

Frédéric Allaire [Inria, from Nov 2017]
Léa Boittin [Inria]
Do Minh Hieu [Univ. Paris 13]
Virgile Dubos [Univ Pierre et Marie Curie, from Oct 2017]
Ngoc Bao Tran Le [IRSN]
Antoine Lesieur [Inria, from Oct 2017]
Hugo Martin [IPGP]
Ethem Nayir [Univ Pierre et Marie Curie, until Sep 2017]
Sebastian Reyes-Riffo [Univ. Paris Dauphine]
Jean Thorey [EDF, from Mar 2017 until Apr 2017]
Raphaël Ventura [Inria, from Mar 2017]
Fabien Wahl [Univ Pierre et Marie Curie]

Technical staff

Marius Guerard [Inria, from Mar 2017 until Aug 2017]
Janelle Hammond [Inria, from Nov 2017]
Fabien Souillé [Inria]
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Interns

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M Hamed Bouchiba [Inria, from Apr 2017 until Jul 2017]
Ani Miraçi [Inria, from Apr 2017 until Sep 2017]

Administrative Assistant

Maryse Desnous [Inria]

Visiting Scientist

Marie-Odile Bristeau [Retired]

External Collaborators

Nina Aguillon [UPMC, from Jan 2017]
Nora Aïssiouene [UPMC, from Feb 2017]
Emmanuel Audusse [Univ Paris-Nord]
Bernard Di Martino [Univ Corse, HDR]
Nicole Goutal [EDF, HDR]

Other

Jim Pioche [SciWorks Technologies, from Sep 2017]

2. Overall Objectives

2.1. Presentation

Among all aspects of geosciences, we mainly focus on gravity driven flows arising in many situations such as

- hazardous flows (flooding, rogue waves, landslides...),
- sustainable energies (hydrodynamics-biology coupling, biofuel production, marine energies...),
- risk management and land-use planning (morphodynamic evolutions, early warning systems...)

There exists a strong demand from scientists and engineers in fluid mechanics for models and numerical tools able to simulate not only the water depth and the velocity field but also the distribution and evolution of external quantities such as pollutants or biological species and the interaction between flows and structures (seashores, erosion processes...). The key point of the researches carried out within ANGE is to answer this demand by the development of efficient, robust and validated models and numerical tools.

2.2. Scientific challenges

Due to the variety of applications with a wide range of spatial scales, reduced-size models like the shallow water equations are generally required. From the modelling point of view, the main issue is to describe the behaviour of the flow with a reduced-size model taking into account several physical processes such as non-hydrostatic terms, biological species evolution, topography and structure interactions within the flow. The mathematical analysis of the resulting model do not enter the field of hyperbolic equations anymore and new strategies have to be proposed. Also, efficient numerical resolutions of reduced-size models requires particular attention due to the different time scales of the processes and in order to recover physical properties such as positivity, conservativity, entropy dissipation and equilibria.

The models can remain subject to uncertainties that originate from incomplete description of the physical processes and from uncertain parameters. Further development of the models may rely on the assimilation of observational data and the uncertainty quantification of the resulting analyses or forecasts.

3. Research Program

3.1. Overview

The research activities carried out within the ANGE team strongly couple the development of methodological tools with applications to real–life problems and the transfer of numerical codes. The main purpose is to obtain new models adapted to the physical phenomena at stake, identify the main properties that reflect the physical meaning of the models (uniqueness, conservativity, entropy dissipation, ...), propose effective numerical methods to approximate their solution in complex configurations (multi-dimensional, unstructured meshes, well-balanced, ...) and to assess the results with data in the purpose of potentially correcting the models.

The difficulties arising in gravity driven flow studies are threefold.

- Models and equations encountered in fluid mechanics (typically the free surface Navier-Stokes equations) are complex to analyze and solve.
- The underlying phenomena often take place over large domains with very heterogeneous length scales (size of the domain, mean depth, wave length, ...) and distinct time scales, *e.g.* coastal erosion, propagation of a tsunami, ...
- These problems are multi-physics with strong couplings and nonlinearities.

3.2. Modelling and analysis

Hazardous flows are complex physical phenomena that can hardly be represented by shallow water type systems of partial differential equations (PDEs). In this domain, the research program is devoted to the derivation and analysis of reduced complexity models compared to the Navier-Stokes equations, but relaxing the shallow water assumptions. The main purpose is then to obtain models well-adapted to the physical phenomena at stake.

Even if the resulting models do not strictly belong to the family of hyperbolic systems, they exhibit hyperbolic features: the analysis and discretisation techniques we intend to develop have connections with those used for hyperbolic conservation laws. It is worth noticing that the need for robust and efficient numerical procedures is reinforced by the smallness of dissipative effects in geophysical models which therefore generate singular solutions and instabilities.

On the one hand, the derivation of the Saint-Venant system from the Navier-Stokes equations is based on two approximations (the so-called shallow water assumptions), namely

- the horisontal fluid velocity is well approximated by its mean value along the vertical direction,
- the pressure is hydrostatic or equivalently the vertical acceleration of the fluid can be neglected compared to the gravitational effects.

As a consequence the objective is to get rid of these two assumptions, one after the other, in order to obtain models accurately approximating the incompressible Euler or Navier-Stokes equations.

On the other hand, many applications require the coupling with non-hydrodynamic equations, as in the case of micro-algae production or erosion processes. These new equations comprise non-hyperbolic features and a special analysis is needed.

3.2.1. Multilayer approach

As for the first shallow water assumption, *multi-layer* systems were proposed to describe the flow as a superposition of Saint-Venant type systems [34], [36], [37]. Even if this approach has provided interesting results, layers are considered separate and non-miscible fluids, which implies strong limitations. That is why we proposed a slightly different approach [1], [2] based on a Galerkin type decomposition along the vertical axis of all variables and leading, both for the model and its discretisation, to more accurate results.

A kinetic representation of our multilayer model allows to derive robust numerical schemes endowed with crucial properties such as: consistency, conservativity, positivity, preservation of equilibria, ... It is one of the major achievements of the team but it needs to be analyzed and extended in several directions namely:

- The convergence of the multilayer system towards the hydrostatic Euler system as the number of layers goes to infinity is a critical point. It is not fully satisfactory to have only formal estimates of the convergence and sharp estimates would provide an optimal number of layers.
- The introduction of several source terms due for instance to the Coriolis force or extra terms from changes of coordinates seems necessary. Their inclusion should lead to substantial modifications of the numerical scheme.
- Its hyperbolicity has not yet been proven and conversely the possible loss of hyperbolicity cannot be characterised. Similarly, the hyperbolic feature is essential in the propagation and generation of waves.

3.2.2. Non-hydrostatic models

The hydrostatic assumption consists in neglecting the vertical acceleration of the fluid. It is considered valid for a large class of geophysical flows but is restrictive in various situations where the dispersive effects (like wave propagation) cannot be neglected. For instance, when a wave reaches the coast, bathymetry variations give a vertical acceleration to the fluid that strongly modifies the wave characteristics and especially its height.

Processing an asymptotic expansion (w.r.t. the aspect ratio for shallow water flows) into the Navier-Stokes equations, we obtain at the leading order the Saint-Venant system. Going one step further leads to a vertically averaged version of the Euler/Navier-Stokes equations involving some non-hydrostatic terms. This model has several advantages:

- it admits an energy balance law (that is not the case for most dispersive models available in the literature),
- it reduces to the Saint-Venant system when the non-hydrostatic pressure term vanishes,
- it consists in a set of conservation laws with source terms,
- it does not contain high order derivatives.

3.2.3. Multi-physics modelling

The coupling of hydrodynamic equations with other equations in order to model interactions between complex systems represents an important part of the team research. More precisely, three multi-physics systems are investigated. More details about the industrial impact of these studies are presented in the following section.

- To estimate the risk for infrastructures in coastal zones or close to a river, the resolution of the shallow water equations with moving bathymetry is necessary. The first step consisted in the study of an additional equation largely used in engineering science: The Exner equation. The analysis enabled to exhibit drawbacks of the coupled model such as the lack of energy conservation or the strong variations of the solution from small perturbations. A new formulation is proposed to avoid these drawbacks. The new model consists in a coupling between conservation laws and an elliptic equation, like the Euler/Poisson system, suggesting to use well-known strategies for the analysis and the numerical resolution. In addition, the new formulation is derived from classical complex rheology models and allowed physical phenomena like threshold laws.
- Interaction between flows and floating structures is the challenge at the scale of the shallow water equations. This study requires a better understanding of the energy exchanges between the flow and the structure. The mathematical model of floating structures is very hard to solve numerically due to the non-penetration condition at the interface between the flow and the structure. It leads to infinite potential wave speeds that could not be solved with classical free surface numerical schemes. A relaxation model was derived to overcome this difficulty. It represents the interaction with the floating structure with a free surface model-type.
- If the interactions between hydrodynamics and biology phenomena are known through laboratory experiments, it is more difficult to predict the evolution, especially for the biological quantities, in a real and heterogeneous system. The objective is to model and reproduce the hydrodynamics modifications due to forcing term variations (in time and space). We are typically interested in phenomena such as eutrophication, development of harmful bacteria (cyanobacteria) and upwelling phenomena.

3.2.4. Data assimilation and inverse modelling

In environmental applications, the most accurate numerical models remain subject to uncertainties that originate from their parameters and shortcomings in their physical formulations. It is often desirable to quantify the resulting uncertainties in a model forecast. The propagation of the uncertainties may require the generation of ensembles of simulations that ideally sample from the probability density function of the forecast variables. Classical approaches rely on multiple models and on Monte Carlo simulations. The applied perturbations need to be calibrated for the ensemble of simulations to properly sample the uncertainties. Calibrations involve ensemble scores that compare the consistency between the ensemble simulations and the observational data. The computational requirements are so high that designing fast surrogate models or metamodels is often required.

In order to reduce the uncertainties, the fixed or mobile observations of various origins and accuracies can be merged with the simulation results. The uncertainties in the observations and their representativeness also need to be quantified in the process. The assimilation strategy can be formulated in terms of state estimation or parameter estimation (also called inverse modelling). Different algorithms are employed for static and dynamic models, for analyses and forecasts. A challenging question lies in the optimization of the observational network for the assimilation to be the most efficient at a given observational cost.

3.3. Numerical analysis

3.3.1. Non-hydrostatic scheme

The main challenge in the study of the non-hydrostatic model is to design a robust and efficient numerical scheme endowed with properties such as: positivity, wet/dry interfaces treatment, consistency. It must be noticed that even if the non-hydrostatic model looks like an extension of the Saint-Venant system, most of the known techniques used in the hydrostatic case are not efficient as we recover strong difficulties encountered in incompressible fluid mechanics due to the extra pressure term. These difficulties are reinforced by the absence of viscous/dissipative terms.

3.3.2. Space decomposition and adaptive scheme

In the quest for a better balance between accuracy and efficiency, a strategy consists in the adaptation of models. Indeed, the systems of partial differential equations we consider result from a hierarchy of simplifying assumptions. However, some of these hypotheses may turn out to be irrelevant locally. The adaptation of models thus consists in determining areas where a simplified model (*e.g.* shallow water type) is valid and where it is not. In the latter case, we may go back to the "parent" model (*e.g.* Euler) in the corresponding area. This implies to know how to handle the coupling between the aforementioned models from both theoretical and numerical points of view. In particular, the numerical treatment of transmission conditions is a key point. It requires the estimation of characteristic values (Riemann invariant) which have to be determined according to the regime (torrential or fluvial).

3.3.3. Asymptotic-Preserving scheme for source terms

Hydrodynamic models comprise advection and sources terms. The conservation of the balance between source terms, typically viscosity and friction, has a significant impact since the overall flow is generally a perturbation around an equilibrium. The design of numerical schemes able to preserve such balances is a challenge from both theoretical and industrial points of view. The concept of Asymptotic-Preserving (AP) methods is of great interest in order to overcome these issues.

Another difficulty occurs when a term, typically related to the pressure, becomes very large compared to the order of magnitude of the velocity. At this regime, namely the so-called *low Froude* (shallow water) or *low Mach* (Euler) regimes, the difference between the speed of the gravity waves and the physical velocity makes classical numerical schemes inefficient: firstly because of the error of truncation which is inversely proportional to the small parameters, secondly because of the time step governed by the largest speed of the gravity wave. AP methods made a breakthrough in the numerical resolution of asymptotic perturbations of partial-differential equations concerning the first point. The second one can be fixed using partially implicit scheme.

3.3.4. Multi-physics models

Coupling problems also arise within the fluid when it contains pollutants, density variations or biological species. For most situations, the interactions are small enough to use a splitting strategy and the classical numerical scheme for each sub-model, whether it be hydrodynamic or non-hydrodynamic.

The sediment transport raises interesting issues from a numerical aspect. This is an example of coupling between the flow and another phenomenon, namely the deformation of the bottom of the basin that can be carried out either by bed load where the sediment has its own velocity or suspended load in which the particles are mostly driven by the flow. This phenomenon involves different time scales and nonlinear retroactions; hence the need for accurate mechanical models and very robust numerical methods. In collaboration with industrial partners (EDF–LNHE), the team already works on the improvement of numerical methods for existing (mostly empirical) models but our aim is also to propose new (quite) simple models that contain important features and satisfy some basic mechanical requirements. The extension of our 3D models to the transport of weighted particles can also be here of great interest.

3.3.5. Optimisation

Numerical simulations are a very useful tool for the design of new processes, for instance in renewable energy or water decontamination. The optimisation of the process according to a well-defined objective such as the production of energy or the evaluation of a pollutant concentration is the logical upcoming challenge in order to propose competitive solutions in industrial context. First of all, the set of parameters that have a significant impact on the result and on which we can act in practice is identified. Then the optimal parameters can be obtained using the numerical codes produced by the team to estimate the performance for a given set of parameters with an additional loop such as gradient descent or Monte Carlo method. The optimisation is used in practice to determine the best profile for turbine pales, the best location for water turbine implantation, in particular for a farm.

4. Application Domains

4.1. Overview

Sustainable development and environment preservation have a growing importance and scientists have to address difficult issues such as: management of water resources, renewable energy production, bio/geochemistry of oceans, resilience of society w.r.t. hazardous flows, urban pollutions, ...

As mentioned above, the main issue is to propose models of reduced complexity, suitable for scientific computing and endowed with stability properties (continuous and/or discrete). In addition, models and their numerical approximations have to be confronted with experimental data, as analytical solutions are hardly accessible for these problems/models. A. Mangeney (IPGP) and N. Goutal (EDF) may provide useful data.

4.2. Geophysical flows

Reduced models like the shallow water equations are particularly well-adapted to the modelling of geophysical flows since there are characterized by large time or/and space scales. For long time simulations, the preservation of equilibria is essential as global solutions are a perturbation around them. The analysis and the numerical preservation of non-trivial equilibria, more precisely when the velocity does not vanish, are still a challenge. In the fields of oceanography and meteorology, the numerical preservation of the so-called geostrophic state, which is the balance between the gravity field and the Coriolis force, can significantly improve the forecasts. In addition, data assimilation is required to improve the simulations and correct the dissipative effect of the numerical scheme.

The sediment transport modelling is of major interest in terms of applications, in particular to estimate the sustainability of facilities with silt or scour, such as canals and bridges. Dredging or filling-up operations are expensive and generally not efficient in the long term. The objective is to determine a configuration almost stable for the facilities. In addition, it is also important to determine the impact of major events like emptying dam which is aimed at evacuating the sediments in the dam reservoir and requires a large discharge. However, the downstream impact should be measured in terms of turbidity, river morphology and flood.

4.3. Hydrological disasters

It is a violent, sudden and destructive flow. Between 1996 and 2005, nearly 80% of natural disasters in the world have meteorological or hydrological origines. The main interest of their study is to predict the areas in which they may occur most probably and to prevent damages by means of suitable amenities. In France, floods are the most recurring natural disasters and produce the worst damages. For example, it can be a cause or a consequence of a dam break. The large surface they cover and the long period they can last require the use of reduced models like the shallow water equations. In urban areas, the flow can be largely impacted by the debris, in particular cars, and this requires fluid/structure interactions be well understood. Moreover, underground flows, in particular in sewers, can accelerate and amplify the flow. To take them into account, the model and the numerical resolution should be able to treat the transition between free surface and underground flows.

Tsunamis are another hydrological disaster largely studied. Even if the propagation of the wave is globally well described by the shallow water model in oceans, it is no longer the case close to the epicenter and in the coastal zone where the bathymetry leads to vertical accretions and produces substantial dispersive effects. The non-hydrostatic terms have to be considered and an efficient numerical resolution should be induced.

While viscous effects can often be neglected in water flows, they have to be taken into account in situations such as avalanches, debris flows, pyroclastic flows, erosion processes, ...*i.e.* when the fluid rheology becomes more complex. Gravity driven granular flows consist of solid particles commonly mixed with an interstitial lighter fluid (liquid or gas) that may interact with the grains and decrease the intensity of their contacts, thus reducing energy dissipation and favoring propagation. Examples include subaerial or subaqueous rock avalanches (e.g. landslides).

4.4. Biodiversity and culture

Nowadays, simulations of the hydrodynamic regime of a river, a lake or an estuary, are not restricted to the determination of the water depth and the fluid velocity. They have to predict the distribution and evolution of external quantities such as pollutants, biological species or sediment concentration.

The potential of micro-algae as a source of biofuel and as a technological solution for CO2 fixation is the subject of intense academic and industrial research. Large-scale production of micro-algae has potential for biofuel applications owing to the high productivity that can be attained in high-rate raceway ponds. One of the key challenges in the production of micro-algae is to maximize algae growth with respect to the exogenous energy that must be used (paddlewheel, pumps, ...). There is a large number of parameters that need to be optimized (characteristics of the biological species, raceway shape, stirring provided by the paddlewheel). Consequently our strategy is to develop efficient models and numerical tools to reproduce the flow induced by the paddlewheel and the evolution of the biological species within this flow. Here, mathematical models can greatly help us reduce experimental costs. Owing to the high heterogeneity of raceways due to gradients of temperature, light intensity and nutrient availability through water height, we cannot use depth-averaged models. We adopt instead more accurate multilayer models that have recently been proposed. However, it is clear that many complex physical phenomena have to be added to our model, such as the effect of sunlight on water temperature and density, evaporation and external forcing.

Many problems previously mentioned also arise in larger scale systems like lakes. Hydrodynamics of lakes is mainly governed by geophysical forcing terms: wind, temperature variations, ...

4.5. Sustainable energy

One of the booming lines of business is the field of renewable and decarbonated energies. In particular in the marine realm, several processes have been proposed in order to produce electricity thanks to the recovering of wave, tidal and current energies. We may mention water-turbines, buoys turning variations of the water height into electricity or turbines motioned by currents. Although these processes produce an amount of energy which is less substantial than in thermal or nuclear power plants, they have smaller dimensions and can be set up more easily.

The fluid energy has kinetic and potential parts. The buoys use the potential energy whereas the water-turbines are activated by currents. To become economically relevant, these systems need to be optimized in order to improve their productivity. While for the construction of a harbour, the goal is to minimize swell, in our framework we intend to maximize the wave energy.

This is a complex and original issue which requires a fine model of energy exchanges and efficient numerical tools. In a second step, the optimisation of parameters that can be changed in real-life, such as bottom bathymetry and buoy shape, must be studied. Eventually, physical experiments will be necessary for the validation.

4.6. Urban environment

The urban environment is essentially studied for air and noise pollutions. Air pollution levels and noise pollution levels vary a lot from one street to next. The simulations are therefore carried out at street resolution and take into account the city geometry. The associated numerical models are subject to large uncertainties. Their input parameters, e.g. pollution emissions from road traffic, are also uncertain. Quantifying the simulation uncertainties is challenging because of the high computational costs of the numerical models. An appealing approach in this context is the use of metamodels, from which ensembles of simulations can be generated for uncertainty quantification.

The simulation uncertainties can be reduced by the assimilation of fixed and mobile sensors. High-quality fixed monitoring sensors are deployed in cities, and an increasing number of mobile sensors are added to the observational networks. Even smartphones can be used as noise sensors and dramatically increase the spatial coverage of the observations. The processing and assimilation of the observations raises many questions regarding the quality of the measurements and the design of the network of sensors.

4.7. SmartCity

There is a growing interest for environmental problems at city scale, where a large part of the population is concentrated and where major pollutions can occur. Numerical simulation is well established to study the urban environment, *e.g.* for road traffic modelling. As part of the smartcity movement, an increasing number of sensors collect measurements, at traditional fixed observation stations, but also on mobile devices, like smartphones. They must properly be taken into account given their number but also their potential low quality.

Pratical applications include air pollution and noise pollution. These directly relate to road traffic. Data assimilation and uncertainty propagation are key topics in these applications.

5. Highlights of the Year

5.1. Highlights of the Year

5.1.1. Human resources

A major event in the year was the merging with CLIME which induces the incorporation of several new researchers (1 Researcher, 1 engineer, 2 PhD). CLIME research is naturally complementary to ANGE works insofar as it provides high level tools to improve modelling and numerical results.

Another fact is J. Salomon's arrival as a Senior Researcher.

5.1.2. Scientific activities

There has been major achievements within the team in the framework of dispersive models. An increased research activity is carried out with spanish collaborators (Univ. Sevilla, Córdoba and Málaga) supported by several project call fundings. This lead to a main publication [30]. In the aftermath of N. Aïssiouene's PhD thesis, a new PhD has been hired to go further in the design of robust and efficient numerical algorithms.

As detailed in Section 10.1.1.1, members of the team were involved in the organisation of a substantial number of scientific events, either in the framework of national initiatives (mainly funded by CNRS) or due to the expertise in the field. Members are is particularly involved in the mathematical community.

5.1.3. Awards

L. Boittin and F. Wahl were granted a SIAM Student Travel Award to attend SIAM GS 2017. F. Wahl also received a Young Researcher Scholarship to attend the 2017 SMAI conference.

6. New Software and Platforms

6.1. Freshkiss

FREe Surface Hydrodynamics using KInetic SchemeS
KEYWORDS: Finite volume methods - Hydrostatic Navier-Stokes equations - Free surface flows

FUNCTIONAL DESCRIPTION: Freshkiss3D is a numerical code solving the 3D hydrostatic and incompressible Navier-Stokes equations with variable density.

- Participants: Fabien Souille, Emmanuel Audusse, Jacques Sainte Marie and Marie-Odile Bristeau
- Partners: UPMC - CEREMA
- Contact: Jacques Sainte Marie

6.2. TSUNAMATHS

KEYWORDS: Modeling - Tsunamis
FUNCTIONAL DESCRIPTION: Tsunamaths is an educational platform aiming at simulating historical tsunamis. Real data and mathematical explanations are provided to enable people to better understand the overall process of tsunamis.

- Participants: Emmanuel Audusse, Jacques Sainte Marie and Raouf Hamouda
- Contact: Jacques Sainte Marie
- URL: http://tsunamath.paris.inria.fr/

6.3. Verdandi

KEYWORDS: HPC - Model - Software Components - Partial differential equation
FUNCTIONAL DESCRIPTION: Verdandi is a free and open-source (LGPL) library for data assimilation. It includes various such methods for coupling one or several numerical models and observational data. Mainly targeted at large systems arising from the discretization of partial differential equations, the library is devised as generic, which allows for applications in a wide range of problems (biology and medicine, environment, image processing, etc.). Verdandi also includes tools to ease the application of data assimilation, in particular in the management of observations or for a priori uncertainty quantification. Implemented in C++, the library may be used with models implemented in Fortran, C, C++ or Python.

- Participants: Dominique Chapelle, Gautier Bureau, Nicolas Claude, Philippe Moireau and Vivien Mallet
- Contact: Vivien Mallet
- URL: http://verdandi.gforge.inria.fr/

6.4. Polyphemus

KEYWORD: Simulation
FUNCTIONAL DESCRIPTION: Polyphemus is a modeling system for air quality. As such, it is designed to yield up-to-date simulations in a reliable framework: data assimilation, ensemble forecast and daily forecasts. Its completeness makes it suitable for use in many applications: photochemistry, aerosols, radionuclides, etc. It is able to handle simulations from local to continental scales, with several physical models. It is divided into three main parts:

- libraries that gather data processing tools (SeldonData), physical parameterizations (AtmoData) and post-processing abilities (AtmoPy),
- programs for physical pre-processing and chemistry-transport models (Polair3D, Castor, two Gaussian models, a Lagrangian model),
- model drivers and observation modules for model coupling, ensemble forecasting and data assimilation.
- Participants: Sylvain Doré and Vivien Mallet
- Contact: Vivien Mallet
- URL: http://cerea.enpc.fr/polyphemus/

6.5. Urban noise analysis

KEYWORD: Environment perception

FUNCTIONAL DESCRIPTION: This software processes mobile observations collected by the application Ambiciti (previously known as SoundCity). It can merge simulated noise maps with the mobile observations.

- Authors: Raphaël Ventura, Vivien Mallet and Guillaume Cherel
- Contact: Vivien Mallet

7. New Results

7.1. Modelling of complex flows

7.1.1. Modelling and simulation of sediment transport

Participants: Emmanuel Audusse, Léa Boittin, Martin Parisot, Jacques Sainte-Marie.

Following previous works, a numerical scheme for the sediment layer is proposed and assessed. The influence of the viscosity on the behaviour of the sediment layer is studied. A numerical strategy for the resolution of the coupled model (water layer and sediment layer) is implemented. The behaviour of the coupled system is numerically assessed. Academic test cases are performed.

7.1.2. Modelling of photosynthesis through microalgae cultivation

Participants: Marie-Odile Bristeau, Jacques Sainte-Marie.

In collaboration with O. Bernard.

In the present multidisciplinary downscaling study, we reconstruct single cell trajectories in an open raceway and experimentally reproduce the according high frequency light pattern to observe its effect on the growth of Dunaliella salina. We show that the frequency of such a realistic signal plays a decisive role on the dynamics of photosynthesis, which reveal an unexpected photosynthetic response compared to that recorded under the on/off signals usually used in the literature. This study highlights the need for experiments with more realistic light stimuli in order to better understand microalgal growth at high cell density. We also propose an experimental protocol with simple piecewise constant, yet more realistic, light fluctuations.

7.1.3. Buoyancy modelling

Participants: Edwige Godlewski, Martin Parisot, Jacques Sainte-Marie, Fabien Wahl.

Firstly, the work of the previous year was completed and lead to the submission of an article [38]. More precisely the fixed point algorithm is rewritten using a new unknown. This allows to increase the numerical robustness and accuracy of the scheme. The proposed resolution is assessed on several stationary and non-stationary test cases with analytical solutions.

In the continuity of this work, the modelling of fluid-structure interaction resolution is added in the previous work in order to simulate floating structures for marine energy devices. In a first step only the vertical movement is studied, with no major scientific lock. In a second time the horizontal movement of the structure is considered and required a deeper analysis to ensure the entropy-stability at the discrete level.

7.1.4. A Free Interface Model for Static/Flowing Dynamics in Thin-Layer Flows of Granular Materials with Yield: Simple Shear Simulations and Comparison with Experiments

Participant: Anne Mangeney.

In collaboration with C. Lusso, F. Bouchut, A. Ern.

Flows of dense granular materials comprise regions where the material is flowing, and regions where it is static. In [15], we introduce two numerical methods to deal with the particular formulation of this model with a free interface. They are used to evaluate the respective role of yield and viscosity for the case of a constant source term, which corresponds to simple shear viscoplastic flows. Both the analytical solution of the inviscid model and the numerical solution of the viscous model (with a constant viscosity or the variable viscosity of the $\mu(I)$-rheology) are compared with experimental data.

7.1.5. Metamodelling of a road traffic assignment model

Participant: Vivien Mallet.

In collaboration with R. Chen, V. Aguiléra, F. Cohn, D. Poulet, F. Brocheton.

We proposed a metamodelling approach to design a close approximation to the traffic model, but with a very low computational cost. It consists in a dimensionality reduction of the model outputs by principal component analysis and a statistical emulation relying on regression and interpolation between training samples. A case study was carried out for the agglomeration of Clermont-Ferrand (France). Compared with traffic flow measurements, the performance of the metamodel is similar to that of the complete model during a one-month period, but the computational time decreases from 2 days on 110 cores to less than 1 minute on one core.

7.2. Assessments of models by means of experimental data and assimilation

7.2.1. Evaluation and calibration of mobile phones for noise monitoring application

Participants: Vivien Mallet, Raphaël Ventura.

In collaboration with V. Issarny, P-G. Raverdy, F. Rebhi.

The Ambiciti application was developed so as to acquire a larger control over the acquisition process by mobile phone sensors. Pink and narrowband noises were used to evaluate the phones' accuracy at levels ranging from background noise to 90 dB(A) inside the lab. Conclusions of this evaluation lead to the proposition of a calibration strategy that has been embedded in Ambiciti and applied to more than 50 devices during public events. In the perspective of citizens-driven noise sensing, in situ experiments were carried out, while additional tests helped to produce recommendations regarding the sensing context (grip, orientation, moving speed, mitigation, frictions, wind).

7.2.2. Assimilation of noise pollution data

Participants: Vivien Mallet, Raphaël Ventura.

In collaboration with P. Aumond, A. Can, V. Issarny.

We studied the generation of hourly noise maps in urban area at street resolution, based on temporally averaged simulation maps and mobile phone audio recordings. A data assimilation method produces an analysis noise map which is the so-called best linear unbiased estimator. We illustrated the method with a neighborhood-wide experiment.

Another work, lead by IFSTTAR, was dedicated to the spatial interpolation of point measurements collected at high density in Paris with a sound level meter. Compelling results were obtained with universal Kriging and a linear trend based on the distance to certain types of roads.

7.2.3. Granular and particle-laden flows: from laboratory experiments to field observations

Participant: Anne Mangeney.

In collaboration with R. Delannay, A. Valance, O. Roche and P. Richard.

A review article was written to provide an overview of dry granular flows and particle fluid mixtures, including experimental and numerical modelling at the laboratory scale, large scale hydrodynamics approaches and field observations. We also emphasize that the up-scaling from laboratory experiments to large scale geophysical flows still raises some theoretical physical challenges.

7.2.4. Continuum viscoplastic simulation of a granular column collapse on large slopes: $\mu(I)$ rheology and lateral wall effects

Participant: Anne Mangeney.

In collaboration with N. Martin, I. Ionescu, F. Bouchut and M. Farin.

We simulate here dry granular flows resulting from the collapse of granular columns on an inclined channel and compare precisely the results with laboratory experiments. The 2-D model is based on the so-called $\mu(I)$ rheology that induces a Drucker-Prager yield stress and a variable viscosity. We show that the use of a variable or a constant viscosity does not change significantly the results provided that these viscosities are of the same order. Finally, we observed that small-scale instabilities develop when refining the mesh.

7.3. Analysis of models in Fluid Mechanics

7.3.1. Analysis of the Riemann problem for a shallow water model with two velocities

Participants: Emmanuel Audusse, Edwige Godlewski, Martin Parisot.

In collaboration with N. Aguillon.

The question addressed in [24] is the hyperbolicity of a shallow water model with two velocities. The model is written in a nonconservative form and the analysis of its eigenstructure shows the possibility that two eigenvalues coincide. A definition of the nonconservative product is given which enables us to analyse the resonance and coalescence of waves. Eventually, we prove the well-posedness of the two dimensional Riemann problem with initial condition constant by half-plane.

7.3.2. Different formulations of an elliptic problem issued from geophysics

Participants: Cindy Guichard, Ani Miraçi, Yohan Penel, Jacques Sainte-Marie.

A simplified problem coming from [33] involving pressure and velocity unknowns is studied. Some weak formulations (conform or mixed) are derived and their well-posedness is analysed. These weak formulations are then discretised in a finite element framework with suitable discrete spaces.

7.4. Numerical methods for fluid flows

7.4.1. Kinetic entropy for the layer-averaged hydrostatic Navier-Stokes equations

Participants: Emmanuel Audusse, Marie-Odile Bristeau, Jacques Sainte-Marie.

In [26], the authors are interested in the numerical approximation of the hydrostatic free surface incompressible Navier-Stokes equations. By using a layer-averaged version of the equations, previous results obtained for shallow water system are extended. A vertically implicit / horizontally explicit finite volume kinetic scheme is designed that ensures the positivity of the approximated water depth, the well-balancing and a fully discrete energy inequality.

7.4.2. Numerical approximation of the 3d hydrostatic Navier-Stokes system with free surface

Participants: Marie-Odile Bristeau, Anne Mangeney, Jacques Sainte-Marie, Fabien Souillé.

In collaboration with S. Allgeyer, M. Vallée, R. Hamouda, D. Froger.

A stable and robust strategy is proposed to approximate incompressible hydrostatic Euler and Navier-Stokes systems with free surface. The idea is to use a Galerkin type approximation of the velocity field with piecewise constant basis functions in order to obtain an accurate description of the vertical profile of the horizontal velocity. We show that the model admits a kinetic interpretation, and we use this result to formulate a robust finite volume scheme for its numerical approximation.

7.4.3. Well balanced schemes for rotation dominated flows

Participants: Emmanuel Audusse, Do Minh Hieu, Yohan Penel.

In collaboration with P. Omnes.

In [27], we study the property of colocated Godunov type finite volume schemes applied to the linear wave equation with Coriolis source term. The purpose is to explain the bad behaviour of the classical scheme and to modify it in order to avoid accuracy issues around the geostophic equilibrium. We use tools from two communities: well-balanced schemes for the shallow water equation with topography and asymptotic preserving schemes for the low Mach model. CFL conditions that ensure the stability of fully discrete schemes are established. The extension to the nonlinear case is under study.

7.4.4. A two-dimensional method for a dispersive shallow water model

Participants: Nora Aïssiouene, Marie-Odile Bristeau, Anne Mangeney, Jacques Sainte-Marie.

In collaboration with C. Pares.

In [29], [6], we propose a numerical method for a two-dimensional dispersive shallow water system with topography [3]. A first approach in one dimension, based on a prediction-correction method initially introduced by Chorin-Temam has been presented in [33]. The prediction part leads to solving a shallow water system for which we use finite volume methods while the correction part leads to solving a mixed problem in velocity and pressure. From the variational formulation of the mixed problem proposed in [35], the idea is to apply a finite element method with compatible spaces to the two-dimensional problem on unstructured grids.

7.4.5. Entropy-satisfying scheme for a hierarchy of dispersive reduced models of free surface flow

Participant: Martin Parisot.

Article [32] is devoted to the numerical resolution in multidimensional framework of a hierarchy of reduced models of the free surface Euler equations. An entropy-satisfying scheme is proposed for the monolayer dispersive models [40] and [3]. To illustrate the accuracy and the robustness of the strategy, several numerical experiments are performed. In particular, the strategy is able to deal with dry areas without particular treatment. A work in progress focuses on the adaptation of the entropy-satisfying scheme to the layerwise models proposed in [30].

7.4.6. A lateral coupling between river channel and flood plain with implicit resolution of shallow water equations

Participant: Martin Parisot.

In collaboration with S. Barthélémy, N. Goutal, M.H. Le, S. Ricci.

Multi-dimensional coupling in river hydrodynamics offers a convenient solution to properly model complex flow while limiting the computational cost and taking the advantage of most pre-existing models. The project aims to adapt the lateral interface coupling proposed in [39] to the implicit version and assess it with real data from the Garonne River.

7.4.7. The discontinuous Galerkin gradient discretisation

Participant: Cindy Guichard.

In collaboration with R. Eymard.

The Symmetric Interior Penalty Galerkin (SIPG) method, based on Discontinuous Galerkin approximations, is shown to be included in the Gradient Discretisation Method (GDM) framework. Therefore, it can take benefit from the general properties of the GDM, since we prove that it meets the main mathematical gradient discretisation properties on any kind of polytopal mesh. We illustrate this inheritance property on the case of the p-Laplace problem [13].

7.4.8. Gradient-based optimization of a rotating algal biofilm process

Participants: Pierre-Olivier Lamare, Jacques Sainte-Marie.

In collaboration with N. Aguillon, O. Bernard.

Here we focus on the optimal control of an innovative process where the microalgae are fixed on a support. They are thus successively exposed to light and dark conditions. The resulting growth can be represented by a dynamical system describing the denaturation of key proteins due to an excess of light. A PDE model of the Rotating Algal Biofilm is then proposed, representing local microalgal growth submitted to the time varying light. An adjoint-based gradient method is proposed to identify the optimal (constant) process folding and the (time varying) velocity of the biofilm.

7.4.9. Method of reflections

Participant: Julien Salomon.

In collaboration with G. Legendre, P. Laurent, G. Ciaramella, M. Gander, L. Halpern.

In [17], the authors carefully trace the historical development of the methods of reflections, give several precise mathematical formulations and an equivalence result with the alternating Schwarz method for two particles.

In [31], a general abstract formulation is proposed in a given Hilbert setting and the procedure is interpreted in terms of subspace corrections. The unconditional convergence of the sequential form is proven and a modification of the parallel one is proposed to make it unconditionally converging.

7.5. Modelling of environmental impacts and natural hazards

7.5.1. Numerical simulation of the 30–45 ka debris avalanche flow of Montagne Pelée volcano, Martinique: from volcano flank collapse to submarine emplacement

Participant: Anne Mangeney.

In collaboration with M. Brunet, L. Moretti, A. Le Friant, E.D. Fernandez Nieto, F. Bouchut.

We simulate here the emplacement of the debris avalanche generated by the last flank collapse event of Montagne Pelée volcano (30–45 ka), Martinique, Lesser Antilles. Our objective is to assess the maximum distance (i.e., runout) that can be reached by this type of debris avalanche as a function of the volume involved. This result provides new constraints on the emplacement processes of debris avalanches associated with these collapses which can drastically change the related hazard assessment such as the generated tsunami, in a region known for its seismic and volcanic risks.

7.5.2. Global sensitivity analysis and uncertainty quantification of on-road traffic emissions

Participant: Vivien Mallet.

In collaboration with R. Chen, V. Aguiléra, F. Cohn, D. Poulet, F. Brocheton.

Road traffic emissions of air pollutants depend on both traffic flow and vehicle emission factors. Global sensitivity analyses, especially the computation of Sobol' indices, were carried out for the traffic model and the air pollutant emissions. In the process, the traffic model was replaced by a metamodel, or surrogate model, in order to reduce the high computational burden. The results identified the most important input parameters. Furthermore, the uncertainties in traffic flow and pollutant emissions were quantified by propagating into the model the uncertainties in the input parameters.

7.5.3. Uncertainty quantification in atmospheric dispersion of radionuclides

Participants: Ngoc Bao Tran Le, Vivien Mallet.

In collaboration with I. Korsakissok, R. Périllat, A. Mathieu, D. Didier.

In collaboration with IRSN, we investigated the uncertainties of the atmospheric-dispersion forecasts that are used during an accidental release of radionuclides like the Fukushima disaster. In order to quantify the uncertainties, Monte Carlo simulations and calibrations were carried out and coupled with ensemble meteorological forecasts from the European Centre for Medium-Range Weather Forecasts.

7.5.4. Simulation of air and noise pollution at high resolution and large scale

Participant: Vivien Mallet.

In collaboration with C. Pesin, P. Béal.

We developed fast surrogates for urban pollution models that they can be applied at global scale while preserving the street resolution, the main physical constraints and the performance against observational data. The surrogate models are based on the original models, machine learning algorithms and observational data.

7.6. Software developments

7.6.1. Improvements in the FRESHKISS3D code

Participants: Marie-Odile Bristeau, Jacques Sainte-Marie, Fabien Souillé.

Several tasks have been achieved in the FRESHKISS3D software:

- Reworked unittests and basic continuous integration
- Optimized IO functions
- Added compatibility with new mesh format
- Added generic run script that only takes yaml data as input
- Added validation cases and new example scripts
- Added paraview integrated post-processing scripts
- Reworked API and online documentation with sphinx
- Simplified dependencies and upgraded python to 3.6
- Worked on new numerical schemes:
  - Added implicit scheme for vertical exchanges terms
  - Reworked vertical viscosity scheme
  - Added new fluxes computations
  - Fixed vrious bugs (second order, viscosity, water state law)
  - Added vertical settling scheme on tracer (suspension models)
- Added 3D interpolator
- Added lagrangian particle tracking with reflexions on boundaries
- C++ Non-hydrostatic code (Nora) converted in cython (80%)
- Developement of a « Vilaine » package designed for SAUR/IAV/ANGE project

7.6.2. Numerical simulation of Free Surface Navier Stokes equations with Telemac 3D

Participants: Emmanuel Audusse, Nicole Goutal.

In collaboration with P. Quemar, A. Decoene, O. Lafitte, A. Leroy, C.T. Phan.

This work takes place in a joint project with EDF-LNHE (Laboratoire national d'hydraulique et d'environnement). The aim of the project is to understand the limitation of the actual numerical solution of the free surface Navier Stokes equations with software TELEMAC 3D and to propose new ways to handle important points as the advective part, the divergence free constraint, the coupling between velocity and hydrostatic pressure or the boundary conditions. A study of the mild-slope equation is also performed in order to obtain comparison solutions.

8. Bilateral Contracts and Grants with Industry

8.1. Bilateral Contracts with Industry

A contract has been made (120.000 euros) with SAUR, IAV (Institut d'Aménagement de la Vilaine) and Agence de l'eau Loire-Bretagne in collaboration with SciWorks Technologies. It deals with the modelling and the simulation of chlorides entry in the Vilaine reservoir.

The ANR project Hyflo-Eflu relies on a collaboration with the company "HydroTube Energie". It comprises the recruitment of a young engineer (J. Ledoux) and regular meetings with industrial (Bordeaux) and academic partners (Nantes).

The ANR project ESTIMAIR includes the SME NUMTECH for a commercial deployment of the project results.

The EIT Digital project Env&You involves the SME NUMTECH and the startup Ambiciti, whose products rely on the results of this European project.

8.2. Bilateral Grants with Industry

P. Quémar's PhD thesis is funded by EDF (CIFRE). His PhD is entitled "3D numerical simulations of environmental hydrolics: application to Telemac".

J. Thorey's PhD thesis was funded by EDF R&D (CIFRE). The title of PhD thesis was: "Ensemble forecasting using sequential aggregation for photovoltaic power applications".

9. Partnerships and Cooperations

9.1. National Initiatives

9.1.1. ANR SEDIFLO (2015-2019)

Participants: Emmanuel Audusse, Martin Parisot.

Program: ANR Défi 1 "Gestion sobre des ressources et adaptation au changement climatique" (JCJC)

Project acronym: SEDIFLO

Project title: Modelling and simulation of solid transport in rivers

Coordinator: Sébastien Boyaval (LHSV/ENPC)

Based on recent theoretical and experimental results, this project is aimed at modelling transport of sediments within rivers. It will rely on innovations from the point of view of rheology as well as advanced mathematical tools (asymptotic model reduction, PDE discretisation).

9.1.2. ANR Hyflo-Eflu (2016-2020)

Participants: Jérémy Ledoux, Martin Parisot, Jacques Sainte-Marie, Julien Salomon.

ANR project call: Energies marines renouvelables

Project acronym: Hyflo-Eflu

Project title: Hydroliennes flottantes et énergie fluviale

Coordinator: Julien Salomon

The project is a collaboration between the Inria-team ANGE, specialist of free surface flow and optimisation, and the industrial developers of the turbine, HYDROTUBE ENERGIE. The objective of the project HyFlo-EFlu is to deliver a numerical software able to simulate the dynamic of a floating water turbine in real context. For the academic partner, the main challenge is in the simulation of the floating structure at the scale of the river, and the modelling of the vertical and horisontal axis turbine. For the industrial partner, the objective is the validation of the stability of the structure and the performance in term of energy production.

9.1.3. ANR MIMOSA (2014–2017)

Participants: Marie-Odile Bristeau, Anne Mangeney, Bernard Di Martino, Jacques Sainte-Marie.

Program: ANR Défi 1 “Gestion sobre des ressources et adaptation au changement climatique”

Project acronym: MIMOSA

Project title: MIcroseism modelling and Seismic Applications

Coordinator: Eleonore Stutzmann (IPGP)

Seismic noise is recorded by broadband seismometers in the absence of earthquakes. It is generated by the atmosphere-ocean system with different mechanisms in the different frequency bands. Even though some mechanisms have been known for decades, an integrated understanding of the noise in the broadband period band 1-300sec is still missing. Using novel theoretical, numerical and signal processing methods, this project will provide a unified understanding of the noise sources and quantitative models for broadband noise. Conversely, we will be able to interpret seismic noise in terms of ocean wave properties. This first analysis step will lead to the identification and characterisation of source events, which we will use to improve noise tomography, and seismic monitoring.

9.1.4. ANR CHARMS (2016-2020)

Participant: Cindy Guichard.

ANR project call: Transformations et inter-conversions énergétiques

Project acronym: CHARMS

Project title: Modèles de réservoirs quantitatifs pour les systèmes hydrothermaux complexes

Coordinator: Simon Lopez (BRGM)

Funding: 73k euros for LJLL (in 767k euros for the whole project)

CHARMS ANR project is focused on the mathematical methods and software tools dedicated to the simulation of the physical models issued from geothermal engineering. The final objective is the achievement of a highly parallel code, validated on realistic cases.

9.1.5. CNRS Moset (2016-2017)

Participants: Emmanuel Audusse, Martin Parisot.

CNRS project call: INSU Tellus

Project acronym: Moset

Project title: Modélisation des suspensions concentrées naturelles

Coordinator: Emmanuel Audusse

In collaboration with G. Antoine (EDF), S. Boyaval (LHSV), C. Le Bouteiller (Irstea), M. Jodeau (EDF).

Gathering mathematicians (numerical analysis) and geophysicists, this project focuses on the quantitative prediction of solid transport. This issue raises several questions about rheology when the sediment concentration is high enough. It is crucial for modelling the dynamics of suspension. The collaboration aims at assessing models by means of experimental data and at providing preliminary numerical results to evaluate the order of magnitude of constraints.

9.1.6. CNRS Simulations of free-surface flows (2017)

Participants: Cindy Guichard, Martin Parisot, Yohan Penel, Jacques Sainte-Marie.

CNRS project call: PEPS JC

Project title: modélisation avancée et simulation d'écoulements à surface libre

Coordinator: Yohan Penel

Funding: 2.5k euros

In collaboration with E. Fernaández-Nieto.

Free-surface flows are extensively studied in the literature by means of simplified models (like the Shallow Water equations) due to the theoretical and numerical issues related to the Euler system. Intermediate models have then been derived to improve the accuracy and the physical relevance (e.g. taking into account hydrodynamic pressure or multilayer approaches). This collaboration aims at designing a hierarchy of multilayer models with a non-hydrostatic pressure as a discretisation along the vertical axis of the Euler equations. The hierarchy relies on the degree of approximation of the variables discretised with a Discontinuous Galerkin method for the vertical direction. These innovative models will imply a theoretical study and the development of numerical tools in dimensions 1 and 2 before the modelling of other physical phenomena (viscosity effects, ...).

9.1.7. CNRS Mocha (2017-2018)

Participant: Martin Parisot.

CNRS project call: LEFE

Project acronym: MOCHA

Project title: Multi-dimensiOnal Coupling in Hydraulics and data Assimilation

Coordinator: Martin Parisot

Funding: 14k euros

In collaboration with S. Barthélémy, N. Goutal, S. Ricci, M. Hoang Le.

Multi-dimensionnal coupling in river hydrodynamics offers a conveninent solution to properly model complex flow while limiting the computational cost and making the most of pre-exsiting models. The project aims to adapt the lateral interface coupling proposed in [39] to the implicit version and test it on real data for the Garonne River.

9.1.8. Inria Project Lab "Algae in Silico" (2015-2018)

Participants: Marie-Odile Bristeau, Yohan Penel, Jacques Sainte-Marie, Fabien Souillé.

In the aftermath of the ADT In@lgae (2013–2015), we developed a simulation tool for microalgae culture. An Inria Project Lab "Algae in Silico" has started in collaboration with Inria teams BIOCORE and DYLISS. It concerns microalgae culture for biofuel production and the aim is to provide an integrated platform for numerical simulation "from genes to industrial processes".

9.1.9. Inria Project Lab "CityLab" (2015-2018)

Participants: Vivien Mallet, Raphaël Ventura.

CityLab@Inria studies ICT solutions toward smart cities that promote both social and environmental sustainability.

9.1.10. GdR EGRIN (2013–2017)

Participants: Emmanuel Audusse, Bernard Di Martino, Nicole Goutal, Cindy Guichard, Anne Mangeney, Martin Parisot, Jacques Sainte-Marie.

EGRIN stands for Gravity-driven flows and natural hazards. J. Sainte-Marie is the head of the scientific committee of this CNRS research group and A. Mangeney is a member of the committee. Other members of the team involved in the project are local correspondents. The scientific goals of this project are the modelling, analysis and simulation of complex fluids by means of reduced-complexity models in the framework of geophysical flows.

9.1.11. ANR ESTIMAIR (2013-2017)

Participant: Vivien Mallet.

ANR project call: Modèles numériques

Project acronym: ESTIMAIR

Project title: Estimation d'incertitudes en simulation de la qualité de l'air à l'échelle urbaine

Coordinator: Vivien Mallet

Funding: 415k euros

The project aims to propagate uncertainties in a complete air quality modelling chain at urban scale, from road traffic assignment to air pollutant dispersion.

9.1.12. ANR FireCaster (2017-2020)

Participants: Frédéric Allaire, Vivien Mallet.

ANR project call: DS0104

Project acronym: FireCaster

Project title: Plateforme de prévision incendie et de réponse d'urgence

Coordinator: Jean-Baptiste Filippi (Univ. Corse)

Funding: 442k euros

The goal of the FireCaster project is to prototype a fire decision support system at the national scale to estimate upcoming fire risk (H+24 to H+48) and in case of crisis, to predict fire front position and local pollution (H+1 to H+12).

9.1.13. ANR CENSE (2017-2020)

Participants: Antoine Lesieur, Vivien Mallet.

ANR project call: DS0601

Project acronym: CENSE

Project title: Caractérisation des environnements sonores urbains : vers une approche globale associant données libres, mesures et modélisations

Coordinator: Judicaël Picaut (IFSTTAR)

Funding: 856k euros

The CENSE project aims at proposing a new methodology for the production of more realistic noise maps, based on an assimilation of simulated and measured data through a dense network of low-cost sensors.

9.1.14. ANR RAVEX (2017-2020)

Participant: Anne Mangeney.

ANR project call: DS0106

Project acronym: RAVEX

Project title: Développement d'une approche intégrée pour la réduction des Risques Associés au Volcanisme EXplosif, de la recherche sur l'aléa aux outils de gestion de crise : le cas de la Martinique

Coordinator: Olivier Roche (IRD)

Funding: 619k euros

9.1.15. ANR CARIB (2014-2017)

Participant: Anne Mangeney.

ANR project call: Simi6

Project acronym: CARIB

Project title: Fréquence et processus de mise en place des avalanches de débris tsunamigènes de l'arc des Petites Antilles : apport des forages de l'Expédition IODP 340 et impact en termes de risque

Coordinator: Anne Le Friant (IPGP)

Funding: 274k euros

9.1.16. ANR CINE-PARA (2015-2019)

Participant: Julien Salomon.

ANR project call: DS0708

Project acronym: CINE-PARA

Project title: Méthodes de parallélisation pour cinétiques complexes

Coordinator: Yvon Maday (LJLL)

9.2. European Initiatives

9.2.1. FP7 & H2020 Projects

9.2.1.1. ERC Consolidator Grant (2013-2018)

Participants: Anne Mangeney, Hugo Martin.

The project SLIDEQUAKES is about detection and understanding of landslides by observing and modelling gravitational flows and generated earthquakes and is funded by the European Research Council (2 million euros). More precisely, it deals with the mathematical, numerical and experimental modelling of gravitational flows and generated seismic waves coupled with field measurements to better understand and predict these natural hazards and their link with volcanic, seismic and climatic activities.

9.2.1.2. EoCoE (2015-2018)

Title: Energy oriented Centre of Excellence for computer applications

Program: H2020

Duration: October 2015 - October 2018

Coordinator: Édouard Audit (CEA)

Partners: CEA (Commissariat à l'Énergie Atomique et aux Énergies Alternatives, France), Forschungszentrum Julich (Germany), Max Planck Gesellschaft (Germany), ENEA (Agenzia Nazionale Per le Nuove Tecnologie, l'energia E Lo Sviluppo Economico Sostenibile, Italy), CERFACS (European Centre for Research and Advanced Training in Scientific Computing, France), Instytut Chemii Bioorganicznej Polskiej Akademii Nauk (Poland), Universita Degli Studi di Trento (Italy), Fraunhofer Gesellschaft (Germany), University of Bath (United Kingdom), CYL (The Cyprus Institute, Cyprus), CNR (National Research Council of Italy), Université Libre de Bruxelles (Belgium), BSC (Centro Nacional de Supercomputacion, Spain)

Inria contact: Michel Kern (Serena team)

Participants: Vivien Mallet

Abstract: The aim of the projevt is to establish an Energy Oriented Centre of Excellence for computing applications (EoCoE). EoCoE (pronounce “Echo”) will use the prodigious potential offered by the ever-growing computing infrastructure to foster and accelerate the European transition to a reliable and low carbon energy supply. To achieve this goal, we believe that the present revolution in hardware technology calls for a similar paradigm change in the way application codes are designed. EoCoE will assist the energy transition via targeted support to four renewable energy pillars: Meteo, Materials, Water and Fusion, each with a heavy reliance on numerical modelling. These four pillars will be anchored within a strong transversal multidisciplinary basis providing high-end expertise in applied mathematics and HPC. EoCoE is structured around a central Franco-German hub coordinating a pan-European network, gathering a total of 8 countries and 23 teams. Its partners are strongly engaged in both the HPC and energy fields; a prerequisite for the long-term sustainability of EoCoE and also ensuring that it is deeply integrated in the overall European strategy for HPC. The primary goal of EoCoE is to create a new, long lasting and sustainable community around computational energy science. At the same time, EoCoE is committed to deliver high-impact results within the first three years. It will resolve current bottlenecks in application codes, leading to new modelling capabilities and scientific advances among the four user communities; it will develop cutting-edge mathematical and numerical methods, and tools to foster the usage of Exascale computing. Dedicated services for laboratories and industries will be established to leverage this expertise and to foster an ecosystem around HPC for energy. EoCoE will give birth to new collaborations and working methods and will encourage widely spread best practices.

9.2.1.3. Env&You (2017)

Title: Env&You

Program: EIT Digital

Duration: January 2016 - December 2016

Coordinator: Inria (MiMove)

Partners: NUMTECH, Ambiciti, ForumVirium, TheCivicEngine

Inria contact: Valérie Issarny (Mimove project-team)

Participants: Vivien Mallet, Raphaël Ventura

Env&You aims at delivering the whole picture of urban pollution, from the individual exposure to neighborhood-by-neighborhood and day-to-day variation, to citisens and governments, informing their decisions for healthy urban living.

9.2.2. Collaborations with Major European Organisations

9.2.2.1. CNRS PICS NHML (2017-2019)

Program: CNRS PICS (projet international de collaboration scientifique)

Project acronym: NHML

Project title: non-hydrostatic multilayer models

Duration: 01/17-12/19

Coordinator: Yohan Penel (CEREMA)

Other partners: IMUS (Sevilla, Spain)

Participants: Martin Parisot (Inria), Jacques Sainte-Marie (CEREMA), Enrique Fernández-Nieto (Sevilla), Tomas Morales de Luna (Cordoba)

Funding: 12k euros

Abstract: This collaboration aims at designing a hierarchy of multilayer models with a non-hydrostatic pressure as a discretisation along the vertical axis of the Euler equations. The hierarchy relies on the degree of approximation of the variables discretised with a Discontinuous Galerkin method for the vertical direction. These innovative models will imply a theoretical study and the development of numerical tools in dimensions 1 and 2 before the modelling of other physical phenomena (viscosity effects, ...).

9.3. International Initiatives

9.3.1. Inria International Partners

9.3.1.1. Informal International Partners

Two collaborations with foreign colleagues are to be mentioned:

- A collaboration with spanish researchers has been initiated in 2016 to derive accurate models and effecient algorithms for free surface flows including non-hydrostatic effects.
- A joint work with R. LeVeque (Univ. Seattle) and M. Berger (New York Univ.) consists in modelling the impact of asteroids on the generation of tsunamis.

9.3.2. Participation in Other International Programs

9.3.2.1. PROCORE Hong-Kong (2016-2017)

Program: Hubert Curien PROCORE

Project title: time-parallelisation methods for control

Duration: 01/16-12/17

Coordinator: Felix Kwok (Univ. Hong-Kong)

Other partners: HKBU (Hong-Kong)

Funding: 5k euros

9.4. International Research Visitors

9.4.1. Visits to International Teams

9.4.1.1. Research Stays Abroad

- Y. Penel spent one month and a half (Mar.-Apr.) at the university of Sevilla (Spain) to collaborate with E. Fernández-Nieto.
- M. Parisot spent a week to Sevilla in April.

We also mention that M. Parisot spent four separate weeks at the university of Toulouse (CERFACS).

10. Dissemination

10.1. Promoting Scientific Activities

10.1.1. Scientific Events Organisation

10.1.1.1. Member of the Organising Committees

Y. Penel and J. Sainte-Marie organised (with E. Fernández-Nieto) the workshop “An overview on free-surface flows” that took place at Inria on November 13th-14th and that gathered 35 researchers (from France, US, Italy, Spain).

B. Di Martino, J. Sainte-Marie and A. Mangeney organised the 5th EGRIN summer school that took place at Cargèse from May, 29th to June, 2nd and that gathered 40 researchers.

E. Audusse was a member of the organising committee of the 8th edition of the conference “Finite-Volume for Complex Applications” (June, 12th to 16th, Lille).

M. Parisot organises the monthly ANGE seminar. The program for 2017 comprises: H. Martin (Jan), J. Sainte-Marie (Feb), V. Desveaux (Mar), V. Mallet (Apr), B. Al Taki (Sep), C. Cancès (Oct), R. Ventura (Nov), V. Duchêne (Dec).

J. Salomon co-organises the LJLL-Inria meetings (twice a month). L. Boittin co-organises the Junior Seminar at Inria–Paris.

E. Audusse, C. Guichard and Y. Penel organised the welcome session for newly recruited researchers in mathematics on behalf of national research institutions (CNRS, Inria, SFdS, SMAI, SMF) on January, 23rd.

We finally mention that M. Parisot and J. Salomon will organise a workshop entitled “Scientific computing and optimisation processes for renewable energies” at Inria on January 2018.

10.1.2. Journal

10.1.2.1. Reviewer - Reviewing Activities

Member	Journal
E. Audusse	M2AN, Water
C. Guichard	Springer Proc. Math., CRAS Mathematiques, Journal of Scientific Computing, Computers and Mathematics with Applications, Journal of Computational Physics, Numerical Methods for Partial Differential Equations
V. Mallet	JAMES, Atmospheric Environment
A. Mangeney	JGR, GRL, GJI
M. Parisot	ESAIM:ProcS, Springer Proc. Math., M2AN
Y. Penel	Springer Proc. Math., Journal of Computational Physics
J. Sainte-Marie	M2AN, Applied Mathematical Modelling, IJNMF, ANR, Journal of Scientific Computing
J. Salomon	CRAS, SIAM SISC, JMPA

10.1.3. Invited Talks

Conference	Location	Month	Members involved
Earth Sciences	Durham (UK)	January	A. Mangeney
DD24	Svalbard (Norway)	February	J. Salomon
Workshop on reduced order methods for wind and marine current power	Nice	February	J. Salomon
Entreprises pour l'environnement	Paris	March	V. Mallet
Clifford lectures	New-Orleans (USA)	April	J. Sainte-Marie
EGRIN (5th summer school)	Cargèse	June	E. Audusse, L. Boittin, A. Mangeney, M. Parisot, Y. Penel
SMAI 2017	Ronce-les-Bains	June	F. Wahl
Forecasting and risk management for renewable energy	Paris	June	V. Mallet
EGU Meeting "Environmental Seismology"	Ohlstadt (Germany)	June	A. Mangeney
InterNoise	Hong-Kong	August	V. Mallet
SIAM GS 2017	Erlangen (Germany)	September	E. Audusse, L. Boittin, F. Wahl
ENUMATH	Voss (Norway)	September	J. Salomon
Euromech colloquium 588	Toulouse	October	L. Boittin
Workshop EDP-Normandie	Caen	October	F. Wahl
Workshop on numerical schemes for low Mach number flows	Toulouse	November	Y. Penel
UMEMA	Torino (Italy)	November	V. Mallet
Numerical Methods for Shallow Water Equations and Related Models	Shenzhen (China)	November	J. Sainte-Marie
NumWave	Montpellier	December	E. Audusse, M. Parisot

Seminars	Date	Member
Clermont-Ferrand (Blaise Pascal)	January	B. Di Martino
Bordeaux (MathOcean)	February	E. Audusse, M. Parisot
Marne-la-Vallée (ENPC)	February	V. Mallet
Orléans (BRGM)	April	A. Mangeney
Tokyo (Earthquake Research Institute)	October	A. Mangeney
Saclay (CEA-LSCE)	October	V. Mallet

10.1.4. Leadership within the Scientific Community

Organisation	People	Duty
AMIES	E. Godlewski	Member of board
ANR	V. Mallet	Expert
CEREMADE lab council	J. Salomon	Member
CFEM	E. Godlewski	Director
EGRIN	E. Audusse	Correspondent (Paris 13)
	B. Di Martino	Correspondent (Corse)
	N. Goutal	Correspondent (EDF)
	C. Guichard	Correspondent (UPMC)
	B. Haspot	Correspondent (CEREMADE)
	A. Mangeney	Member of board
	M. Parisot	Correspondent (ANGE)
	J. Sainte-Marie	Scientific head
HCERES	A. Mangeney	Expert
LJLL	E. Godlewski	Deputy director
SMAI	Y. Penel	Member of board

A. Mangeney was a member of the hiring panel for a full professor position at Univ. Grenoble Alpes.

We also mention that V. Mallet and M. Parisot are members of the Inria committee of doctoral monitoring and that J. Salomon is in the committee for the next location of the centre Inria Paris (rue Barrault).

10.2. Teaching - Supervision - Juries

10.2.1. Teaching

PhD degree - J. Salomon, Variational inequalities, 6 hours (lectures), Mines ParisTech

Master's degree (M2) - E. Godlewski and J. Sainte-Marie, Hyperbolic models for complex flows and energy applications, 25 hours (lectures), Univ. Pierre et Marie Curie Paris 6

Master's degree (M2) - C. Guichard, Numerical methods for nonstationary PDEs, 6 hours (programming classes), Univ. Pierre et Marie Curie Paris 6

Master's degree (M2) - A. Mangeney and J. Sainte-Marie, Numerical methods in geosciences, 60 hours (lectures and programming classes), Univ. Paris Diderot Paris 7, IPGP

Master's degree (M2) - B. Di Martino, Mathematical modelling, 21 hours (lectures, example and programming classes), Univ. Corse

Master's degree (M2) - J. Salomon, Numerical methods for PDEs, 45 hours (lectures), Univ. Paris Dauphine

Master's degree (M2)- Y. Penel, Deterministic models in life sciences, 30h (lectures, example and programming classes), Univ. Paris Descartes

Master's degree (M2) - V. Mallet, Modelling of air quality, 4.5h (lectures), ENPC

Master's degree (M2) - V. Mallet, Simulation of atmospheric dispersion, 3h (programming classes), ENPC

Master's degree (M2) - V. Mallet, Data assimilation in geophysics, 7h (programming classes), ENPC

Engineering school (2nd year) - E. Audusse, ODEs: analysis and numerical simulation, 30 hours (lectures and example classes), Univ. Paris 13

Engineering school (2nd year) - E. Audusse, Finite difference method for PDEs, 21 hours (lectures), Univ. Paris 13

Master's degree (M1) - C. Guichard, Basis of numerical methods, 63 hours (programming classes), Univ. Pierre et Marie Curie Paris 6

Master's degree (M1) - A. Mangeney and J. Sainte-Marie, Modelling of gravity flows, 80 hours (lectures), Univ. Paris Diderot Paris 7, IPGP

Master's degree (M1) - B. Di Martino, Finite element methods, 18 hours (lectures and example classes), Univ. Corse

Master's degree (M1) - B. Di Martino, Risk modelling, 33 hours (lectures and example classes), Univ. Corse

Master's degree (M1) - J. Salomon, Numerical methods for PDEs, 85 hours (lectures and example classes), Univ. Paris Dauphine

Engineering school (1st year) - E. Audusse, Introduction to scientifi computing, 30 hours (lectures and example classes), Univ. Paris 13

Bachelor's degree (L3) - L. Boittin and C. Guichard, Numerical methods for ODEs, 101.5 hours (example and programming classes), Univ. Pierre et Marie Curie Paris 6

Bachelor's degree (L3) - C. Guichard, Python, 21 hours (programming classes), Univ. Pierre et Marie Curie Paris 6

Bachelor's degree (L3) - B. Di Martino, Linear numerical analysis, 54 hours (lectures and example classes), Univ. Corse

Bachelor's degree (L2) - B. Di Martino, Analysis, 54 hours (lectures and example classes), Univ. Corse

Bachelor's degree (L2) - Y. Penel and F. Wahl, Integration in 2 and 3 dimensions, 31 hours (lectures and example classes), Univ. Pierre et Marie Curie Paris 6

Bachelor's degree (L2) - C. Guichard, Some numerical approximations, 17 hours (lectures and programming classes), Univ. Pierre et Marie Curie Paris 6

Bachelor's degree (L1-L2) - B. Al Taki, Analysis and algebra, 12 hours (example classes), Univ. Pierre et Marie Curie Paris 6

Bachelor's degree (L1-L2) - Y. Penel, Linear algebra, ODEs, elementary probabilities, 20 hours (example classes), Univ. Pierre et Marie Curie Paris 6 (Roscoff)

Bachelor's degree (L1) - B. Di Martino, Mathematics, 18 hours (lectures and example classes), Univ. Corse

Bachelor's degree (L1) - F. Wahl, Sequences and integrals, linear algrebra, 54 hours (example classes), Univ. Pierre et Marie Curie Paris 6

Bachelor's degree (L1) - L. Boittin, Calculus, 38 hours (example classes), Univ. Pierre et Marie Curie Paris 6

Bachelor's degree (L1) - L. Boittin, Linear algebra, 18 hours (example classes), Univ. Pierre et Marie Curie Paris 6

Some members are responsible of educational pathways:

E. Audusse is the deputy director of the "Applied Mathematics and Scientific Computing" program of the SupGalilee engineering school.

E. Godlewski is the head of the "Mathematics for Industry" M.Sc. program of Univ. Pierre et Marie Curie Paris 6.

C. Guichard is the associated head of the "Mathematics and Programming" B. program of Univ. Pierre et Marie Curie Paris 6.

10.2.2. Supervision

PostDoc in progress -Bilal Al Taki, *Well-posedness multilayers Saint-Venant equation*, Inria, supervised by J. Sainte-Marie, B. Haspot and B. Di Martino, from 2017

PostDoc in progress - Guillaume Chérel, *Data assimilation for urban pollution*, Inria, supervised by V. Mallet, from 2016

PostDoc in progress - Virginie Durand, *Analysis of rockfalls and generated seismic signals at La Réunion*, Institut de Physique du Globe (Univ. Paris 7), supervised by A. Mangeney, from 2014

PostDoc in progress - Jannelle Hamond, *Uncertainty quantification applied to air quality simulation at urban scale*, Inria, supervised by V. Mallet, from 2017

PostDoc in progress - El Hadji Kone, *Numerical modelling of two-phase flows*, Institut de Physique du Globe (Univ. Paris 7), supervised by A. Mangeney (in collaboration with G. Narbona-Reina and E. Fernández-Nieto), from 2014

PostDoc in progress - Pierre-Olivier Lamarre, *Optimisation of the hydrodynamic regime in a raceway and lagrangian trajectories of algae*, Inria, supervised by J. Sainte-Marie (in collaboration with O. Bernard, BIOCORE), from 2016

PostDoc in progress - Sylvain Viroulet, *Numerical modelling of granular flows and generated forces on the topography*, Institut de Physique du Globe (Univ. Paris 7), supervised by A. Mangeney, from 2016

PhD - Do Minh Hieu, *Analyse mathématique et schémas volumes finis pour la simulation des écoulements quasi-géostrophiques à bas nombre de Froude*, Univ. Paris 13, supervised by E. Audusse and Y. Penel (in collaboration with S. Dellacherie and P. Omnes), defended on Dec. 17

PhD - Jean Thorey, *Prévision d'ensemble par agrégation séquentielle appliquée à la prévision de production d'énergie photovoltaïque*, Inria grant, supervised by V. Mallet (in collaboration with I. Herlin), defended on Sept. 17

PhD in progress - Frédéric Allaire, *Quantification du risque incendie par méta-modélisation de la propagation de feux de forêt*, Inria grant, supervised by V. Mallet and J. Sainte-Marie, from 2017

PhD in progress - Vincent Bachelet, *Granular flows and generated acoustic waves: a laboratory investigation*, Institut de Physique du Globe (Univ. Paris 7), supervised by A. Mangeney (in collaboration with J. De Rosny and R. Toussaint), from 2015

PhD in progress - Léa Boittin, *Modelling, analysis and efficient numerical resolution for erosion processes*, Univ. Pierre et Marie Curie Paris 6 (Inria grant), supervised by E. Audusse, M. Parisot and J. Sainte-Marie, from Jan. 16

PhD in progress - Pauline Bonnet, *Vers un catalogue des vêlages d'icebergs en région polaire par une approche couplée sismologie et modélisation mécanique*, Institut de Physique du Globe (Univ. Paris 7) & ENSAM-ParisTech, supervised by A. Mangeney (in collaboration with O. Castelnau and V. Yastrebof), from 2017

PhD in progress - Ruiwei Chen, *Uncertainty quantification in the simulation of traffic emissions*, ENPC, supervised by V. Mallet (in collaboration with V. Aguiléra, K. Sartelet), from 2014

PhD in progress - Virgile Dubos, *Numerical methods for the elliptic/parabolic parts of non-hydrostatic fluid models*, Univ. Pierre et Marie Curie Paris 6, supervised by C. Guichard, Y. Penel and J. Sainte-Marie, from 2017

PhD in progress - Nadia Jbili, *Contrôle optimal pour la résonance magnétique nucléaire*, Univ. Paris Dauphine, supervised by J. Salomon, from 2017

PhD in progress - Julian Kühnert, *Simulation of high frequency seismic waves*, Institut de Physique du Globe (Univ. Paris 7), supervised by A. Mangeney, from 2016

PhD in progress - Antoine Lesieur, *Estimation d'état et modélisation inverse appliquées à la pollution sonore en milieu urbain*, Inria grant, supervised by V. Mallet and J. Sainte-Marie, from 2017

PhD in progress - Hugo Martin, *Simulation of the coupling between seismic waves and granular flows*, Institut de Physique du Globe (Univ. Paris 7), supervised by A. Mangeney (in collaboration with Y. Maday), from 2016

PhD in progress - Ethem Nayir, *Approximation multi-vitesse des équations de Navier-Stokes hydrostatiques: Analyse mathématique et simulations numériques*, Univ. Pierre et Marie Curie Paris 6, supervised by E. Audusse, Y. Penel and J. Sainte-Marie, from 2014

PhD in progress - Nourelhouda Omrane, *Mathematical analysis and control of free-surface flows in variable domains*, Univ. Corse, supervised by B. Di Martino, from 2016

PhD in progress - Marc Peruzzetto, *Hazard assessment related to gravitational flows: from modelling to risk analysis*, Institut de Physique du Globe (Univ. Paris 7) & BRGM, supervised by A. Mangeney (in collaboration with G. Grandjean), from 2017

PhD in progress - Pierrick Quémar, *3D numerical simulations of environmental hydrolics: application to Telemac*, Univ. Paris 13, supervised by E. Audusse and N. Goutal (in collaboration with A. Decoene, O. Lafitte, A. Leroy and C. Tuân Phan), from 2016

PhD in progress - Sebastian Reyes-Riffo, *Mathematical methods for recovering marine energies*, Univ. Paris Dauphine, supervised by J. Salomon, from 2016

PhD in progress - Raphaël Ventura, *Estimation de la pollution sonore en milieu urbain par assimilation d'observations mobiles*, Inria grant, supervised by V. Mallet (in collaboration with I. Herlin), from 2014

PhD in progress - Fabien Wahl, *Modelling and analysis of interactions between free surface flows and floating objects*, Univ. Pierre et Marie Curie Paris 6, supervised by C. Guichard, E. Godlewski, M. Parisot and J. Sainte-Marie, from 2015

M2 internship - M Hamed Bouchiba, *Obtention du modèle Saint-Venant et stabilité des solutions faibles d'un système Navier-Stokes compressible*, Univ. Pierre et Marie Curie Paris 6, supervised by B. Di Martino and B. Haspot, Summer 2017

M2 internship - Anthony Guimpier, *Analyse d'instabilités gravitaires sur Mars*, IPGP, supervised by A. Mangeney (in collaboration with S. Conway, N. Mangold), Summer 2017

M2 internship - Ani Miraçi, *Formulation et étude numérique de la partie elliptique d'un problème couplé issu de la géophysique*, Univ. Pierre et Marie Curie Paris 6, supervised by C. Guichard, Y. Penel and J. Sainte-Marie, Summer 2017

M2 internship - Pablo Poulain, *Granular flows simulation and application to volcanic flank collapse*, IPGP, supervised by A. Mangeney (in collaboration with A. Le Friand, G. Boudon), Summer 2017

M2 internship - Laurie Supperamaniyen, *Dynamique éruptive du Piton de La Fournaise à partir d'enregistrements sismiques continus sur quelques éruptions*, IPGP, supervised by A. Mangeney (in collaboration with S. Vergniolle), Summer 2017

L3 internship - Jeanne Trinquier, *Tsunamath : module pédagogique présentant les travaux de modélisation et de simulation des tsunamis*, supervised by E. Audusse and J. Sainte-Marie, Summer 2017

10.2.3. Juries

Jan., PhD - J. Sainte-Marie: Amélie Simon (E. Centrale Lyon, *Modélisation des phénomènes de films liquides dans les turbines à vapeur*)

Feb., PhD - Y. Penel: Arthur Talpaert (École Polytechnique, *Simulation numérique directe de bulles sur maillage adaptatif avec algorithmes distribués*)

Mar., PhD - J. Sainte-Marie (referee): Nabil El Mocayd (Cerfacs – Univ. Toulouse, *La décomposition en polynôme du chaos pour l'amélioration de l'assimilation de données ensembliste en hydraulique fluviale*)

Mar., PhD - A. Mangeney (referee): Perrine Freydier (Univ. Grenoble Alpes – IRSTEA, *Dynamique interne au front d'écoulements à surface libre. Application aux laves torrentielles*)

May, PhD - J. Salomon: Francesc Fàbregas Flavià (École Centrale Nantes, *A Numerical Tool for the Frequency Domain Simulation of Large Clusters of Wave Energy Converters*)

May, PhD - V. Mallet: Chi Vuong NGuyen (École CEntrale Lyon, *Assimilation de données et couplage d'échelles pour la simulation de la dispersion atmosphérique en milieu urbain*)

Sept., PhD - V. Mallet: Jean Thorey (Univ. Pierre et Marie Curie, *Prévision d'ensemble par agrégation séquentielle appliquée à la prévision de production d'énergie photovoltaïque*)

Nov., PhD - J. Sainte-Marie (president): Charles Demay (Univ. Grenoble Alpes, *Modélisation et simulation des écoulements transitoires diphasiques eau-air dans les circuits hydrauliques*)

Nov., PhD - A. Mangeney (president): Thao Trinh (Univ. Rennes 1, *Mécanisme d'érosion et de déposition de l'écoulement granulaire sur un fond meuble*)

Dec., PhD - A. Mangeney (president): Julien Brondex (Univ. Grenoble Alpes – IGA, *Influence de l'endommagement et du frottement basal sur la dynamique de la ligne d'échouage*)

Dec., PhD - A. Mangeney: Alexis Bougouin (Institut National Polytechnique de Toulouse, *Étude expérimentale de l'effondrement d'une colonne fluide-grains*)

Dec., PhD - C. Guichard: Riad Sanchez (IFPEN – Univ. Paris-Saclay, *Techniques de bases réduites pour les écoulements diphasiques en milieux poreux*)

Dec., PhD - J. Sainte-Marie (referee): Athmane Bakhta (Univ. Paris-Est, *Modèles mathématiques et simulation numérique de dispositifs photovoltaïques*)

Dec., PhD - B. Di Martino: Réjane Fieschi (Univ. Corse, *Résolution d'équations d'ondes en dimension quelconque*)

Dec., PhD - E. Audusse and Y. Penel: Do Minh Hieu (Univ. Paris 13, *Analyse mathématique de schémas volume finis pour la simulation des écoulements quasi-géostrophiques à bas nombre de Froude*)

10.3. Popularisation

April - V. Mallet participated to the workshop Smart Cities organised by *Le Monde* in Lyon

May - L. Boittin and R. Ventura ran a stand on the occasion of the "salon de la culture et des jeux mathématiques" on behalf of AMIES

June - V. Mallet and R. Ventura helped the organising committee of the "noise walk" in Helsinki (as well as the November edition)

June-July - J. Trinquier's internship was dedicated to the development of an educational tool based on Tsunamath which incorporates modelling and simulation (supervision by E. Audusse and J. Sainte-Marie)

October - E. Audusse got involved in a TPE for students in 1^{re} S

November - R. Ventura provided an association in Paris with noise reports

November - Y. Penel ran a stand during the ONISEP exhibition

December - L. Boittin, Y. Penel and F. Wahl helped the organisation at the "Math. Employment" show

11. Bibliography

Major publications by the team in recent years

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[2] E. AUDUSSE, M.-O. BRISTEAU, B. PERTHAME, J. SAINTE-MARIE. *A multilayer Saint-Venant system with mass exchanges for Shallow Water flows. Derivation and numerical validation*, in "ESAIM Math. Model. Numer. Anal.", 2011, vol. 45, pp. 169-200, http://dx.doi.org/10.1051/m2an/2010036

[3] M.-O. BRISTEAU, A. MANGENEY, J. SAINTE-MARIE, N. SEGUIN. *An energy-consistent depth-averaged Euler system: derivation and properties*, in "Discrete and Continuous Dynamical Systems - Series B", 2015, vol. 20, n^{o} 4, 28 p.

[4] J. SAINTE-MARIE. *Vertically averaged models for the free surface Euler system. Derivation and kinetic interpretation*, in "Math. Models Methods Appl. Sci. (M3AS)", 2011, vol. 21, n^{o} 3, pp. 459-490, http://dx.doi.org/10.1142/S0218202511005118

Publications of the year

Articles in International Peer-Reviewed Journals

[5] N. AGUILLON, F. LAGOUTIÈRE, N. SEGUIN. *Convergence of finite volumes schemes for the coupling between the inviscid Burgers equation and a particle*, in "Mathematics of Computation", 2017, vol. 86, pp. 157-196, https://arxiv.org/abs/1412.0376 , https://hal.inria.fr/hal-01077311

[6] N. AISSIOUENE, M.-O. BRISTEAU, E. GODLEWSKI, A. MANGENEY, C. PARÉS, J. SAINTE-MARIE. *Application of a combined finite element -finite volume method to a 2D non-hydrostatic shallow water problem*, in "Springer Proceedings in Mathematics & Statistics", 2017, https://hal.archives-ouvertes.fr/hal-01664481

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[8] C. CANCÈS, C. GUICHARD. *Numerical analysis of a robust free energy diminishing Finite Volume scheme for parabolic equations with gradient structure*, in "Foundations of Computational Mathematics", 2017, vol. 17, n^{o} 6, pp. 1525-1584, https://arxiv.org/abs/1503.05649 , https://hal.archives-ouvertes.fr/hal-01119735

[9] R. CHEN, V. AGUILERA, V. MALLET, F. COHN, D. POULET, F. BROCHETON. *A sensitivity study of road transportation emissions at metropolitan scale*, in "Journal of Earth Sciences and Geotechnical Engineering", 2017, vol. 7, n^{o} 1, https://hal.inria.fr/hal-01676006

[10] R. DELANNAY, A. VALANCE, A. MANGENEY, O. ROCHE, P. RICHARD. *Granular and particle-laden flows: from laboratory experiments to field observations*, in "Journal of Physics D: Applied Physics", 2017, vol. 50, n^{o} 5, 40 p. [*DOI :* 10.1088/1361-6463/50/5/053001], https://hal-univ-rennes1.archives-ouvertes.fr/hal-01481019

[11] B. DI MARTINO, B. HASPOT, Y. PENEL. *Global stability of weak solutions for a multilayer Saint-Venant model with interactions between the layers*, in "Nonlinear Analysis: Hybrid Systems", November 2017, vol. 163, pp. 177 - 200 [*DOI :* 10.1016/J.NA.2017.07.010], https://hal.archives-ouvertes.fr/hal-01407886

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[13] R. EYMARD, C. GUICHARD. *Discontinuous Galerkin gradient discretisations for the approximation of second-order differential operators in divergence form*, in "Computational and Applied Mathematics", December 2017 [*DOI :* 10.1007/S40314-017-0558-2], https://hal.archives-ouvertes.fr/hal-01535147

[14] M. LACHOWICZ, H. LESZCZYŃSKI, M. PARISOT. *Blow-up and global existence for a kinetic equation of swarm formation*, in "Mathematical Models and Methods in Applied Sciences", June 2017, vol. 27, n^{o} 6, 22 p. [*DOI :* 10.1142/S0218202517400115], https://hal.inria.fr/hal-01370006

[15] C. LUSSO, F. BOUCHUT, A. ERN, A. MANGENEY. *A free interface model for static/flowing dynamics in thin-layer flows of granular materials with yield: simple shear simulations and comparison with experiments*, in "Applied Sciences", April 2017, vol. 7, n^{o} 4, 386 p. [*DOI :* 10.3390/APP7040386], https://hal-upec-upem.archives-ouvertes.fr/hal-00992309

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[18] J. THOREY, V. MALLET, P. BAUDIN. *Online learning with the Continuous Ranked Probability Score for ensemble forecasting*, in "Quarterly Journal of the Royal Meteorological Society", January 2017, vol. 143, n^{o} 702, pp. 521 - 529 [*DOI :* 10.1002/QJ.2940], https://hal.inria.fr/hal-01676007

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International Conferences with Proceedings

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