INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET EN AUTOMATIQUE

Project-Team tosca

TO Simulate and CAlibrate stochastic models

Sophia Antipolis - Méditerranée, Nancy - Grand Est

Theme : Stochastic Methods and Models

Activity Report

2010

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1. Team

Research Scientists

Denis Talay [Team Leader, Research Director Inria (Sophia Antipolis – Méditerranée), HdR]
Mireille Bossy [Research Director Inria (Sophia Antipolis – Méditerranée), HdR]
Madalina Deaconu [Research Scientist Inria (Nancy – Grand Est), HdR]
Antoine Lejay [Research Scientist Inria (Nancy – Grand Est), HdR]
Etienne Tanré [Research Scientist Inria (Sophia Antipolis – Méditerranée)]
Nicolas Champagnat [Research Scientist Inria (Sophia Antipolis – Méditerranée)]

Faculty Members

Pierre-Emmanuel Jabin [Professor, on leave from Université de Nice – Sophia Antipolis until February 28 and since September 1, HdR]
Samuel Herrmann [Assistant Professor, École des Mines de Nancy, HdR]

External Collaborators

Pierre-Louis Lions [Professor, Collège de France, HdR]
Sylvain Maire [Assistant Professor, Université de Toulon et du Var, HdR]

PhD Students

Paul Charton [Nancy, from September]
Julien Claisse [Sophia Antipolis]
Viet-Dung Doan [Sophia Antipolis, project-team OASIS and TOSCA, until April 30]
Dalia Ibrahim [Sophia Antipolis]
Numa Lescot [Paris/Nancy, CIFRE]
Sebastian Niklitschek Soto [Sophia Antipolis, since October 1]
Nicolas Perrin [Sophia Antipolis]
Julian Tugaut [Nancy, till July]
Laurent Violeau [Sophia Antipolis, since October 15]

Administrative Assistants

Sophie Drouot [TR Inria (Nancy – Grand Est)]
Christine Faber [TR Inria (Sophia Antipolis – Méditerrannée)]

2. Overall Objectives

2.1. Overall Objectives

The Inria Research team TOSCA is located both at Inria Sophia-Antipolis – Méditerranée and Inria Nancy – Grand Est. The team develops and analyzes stochastic models and probabilistic numerical methods. The present fields of applications are in finance, fluid mechanics, molecular dynamics, chemical kinetics, neurosciences and population dynamics.

The problems where stochastic models arise are numerous, and the critical reasons for which stochastic models are used make analyzes and simulations difficult.

The TOSCA team thus aims to develop calibration and simulation methods for stochastic models in cases where **singularities** in the coefficients or **boundary conditions** make them hard to discretize and estimate. For this, we are willing to tackle theoretical and numerical questions which are motivated by real applications.

We are interested in developing **stochastic numerical methods** and **transverse methodologies** that cover several fields of applications, instead of having chosen a particular field of application (e.g., Biology, or Fluid Mechanics, or Chemistry). We justify this way to proceed as follows:

- From a couple of years now, we have attacked singular problems to answer questions coming from economists, meteorologists, biologists and engineers with whom we collaborate within industrial contracts or research programs such as ACI, ANR, GDR. To solve their problems which are so complex that stochastic processes are involved in the modelling, these colleagues need to combine expertise and knowledge in many fields: deterministic computing, computer science, vision, algorithm analysis, etc. We are incompetent in these fields, and therefore we could not pretend to fully treat any of these problems. A contrario, we are requested to bring our expertise in stochastic modelling and simulation to extremely various domains of applications.
- In spite of this diversity, whatever the application is, one has to simulate stochastic processes solutions to equations of the type

$$\begin{cases} X_t(\omega) &= X_0(\omega) + \left(\int_0^t \int_{\mathbb{R}^d} b(X_s, y) \mu_s(dy) ds \right)(\omega) \\ & \quad + \left(\int_0^t \int_{\mathbb{R}^d} \sigma(X_s, y) \mu_s(dy) dZ_s \right)(\omega), \\ \mu_s &= \text{Law of } X_s \text{ for all } s \geq 0, \end{cases} \tag{1}$$

  in order to compute statistics of the laws of functionals of these solutions. In addition, several fields often produce very similar "pathologies" of the model (1) or of the statistics to compute: for example, Pope's Lagrangian stochastic particles in Fluid Mechanics and models in Molecular Dynamics produce the same degeneracy in (1), namely, one has to substitute 'Conditional Law of components of X_s given the other ones' to 'Law of X_s'; as well, when studying chartist strategies in Finance and stochastic resonance in the electrical working of neurons, we encounter close questions on the density functions of the random passage times of processes (X_t) at given thresholds.
- Theory and numerical experiments show that each 'pathology' of the model (1) requires specific analysis and numerical methods. However, they require common abstract tools (Malliavin calculus, propagation of chaos theory, nonlinear PDE analysis, etc.) and common numerical methodologies (stochastic particle systems, Monte Carlo simulations, time discretization of stochastic differential equations, etc.). Thus each application takes benefit from the modelling and numerical knowledge developed for all the other ones.

The TOSCA team is currently studying models in relation with Geophysics, Neuro-sciences, Fluid Mechanics, Chemical Kinetics, Meteorology, Molecular Dynamics, Population Dynamics, Evolutionary Dynamics and Finance. We also construct and study stochastic particle systems for Fluid Mechanics, coagulation–fragmentation, stationary nonlinear PDEs, variance reduction techniques for Monte-Carlo computations and numerical methods combining deterministic and stochastic steps to solve nonlinear PDEs in Finance.

3. Scientific Foundations

3.1. Scientific Foundations

Most often physicists, economists, biologists, engineers need a stochastic model because they cannot describe the physical, economical, biological, etc., experiment under consideration with deterministic systems, either because of its complexity and/or its dimension or because precise measurements are impossible. Then they renounce to get the description of the state of the system at future times given its initial conditions and try instead to get a statistical description of the evolution of the system. For example, they desire to compute occurrence probabilities for critical events such as overstepping of given thresholds by financial losses or neuronal electrical potentials, or to compute the mean value of the time of occurrence of interesting events such as the fragmentation up to a very low size of a large proportion of a given population of particles. By nature such problems lead to complex modelling issues: one has to choose appropriate stochastic models, which require a thorough knowledge of their qualitative properties, and then one has to calibrate them, which requires specific statistical methods to face the lack of data or the inaccuracy of these data. In addition, having chosen a family of models and computed the desired statistics, one has to evaluate the sensitivity of the results to the unavoidable model specifications. The TOSCA team, in collaboration with specialists of the relevant fields, develops theoretical studies of stochastic models, calibration procedures, and sensitivity analysis methods.

In view of the complexity of the experiments, and thus of the stochastic models, one cannot expect to use closed form solutions of simple equations in order to compute the desired statistics. Often one even has no other representation than the probabilistic definition (e.g., this is the case when one is interested in the quantiles of the probability law of the possible losses of financial portfolios). Consequently the practitioners need Monte Carlo methods combined with simulations of stochastic models. As the models cannot be simulated exactly, they also need approximation methods which can be efficiently used on computers. The TOSCA team develops mathematical studies and numerical experiments in order to determine the global accuracy and the global efficiency of such algorithms.

The simulation of stochastic processes is not motivated by stochastic models only. The stochastic differential calculus allows one to represent solutions of certain deterministic partial differential equations in terms of probability distributions of functionals of appropriate stochastic processes. For example, elliptic and parabolic linear equations are related to classical stochastic differential equations, whereas nonlinear equations such as the Burgers and the Navier–Stokes equations are related to McKean stochastic differential equations describing the asymptotic behavior of stochastic particle systems. In view of such probabilistic representations one can get numerical approximations by using discretization methods of the stochastic differential systems under consideration. These methods may be more efficient than deterministic methods when the space dimension of the PDE is large or when the viscosity is small. The TOSCA team develops new probabilistic representations in order to propose probabilistic numerical methods for equations such as conservation law equations, kinetic equations, nonlinear Fokker–Planck equations.

4. Application Domains

4.1. Introduction

TOSCA is interested in developing stochastic models and probabilistic numerical methods. Our present motivations come from Finance, Neurosciences and Biology, Fluid Mechanics and Meteorology, Chemical Kinetics, Diffusions in random media, Transverse problems and Softwares and Numerical experiments.

4.2. Finance

For a long time now TOSCA has collaborated with researchers and practitioners in various financial institutions and insurance companies. We are particularly interested in calibration problems, risk analysis (especially model risk analysis), optimal portfolio management, Monte Carlo methods for option pricing and risk analysis, asset and liabilities management. We also work on the partial differential equations related to financial issues, for example the stochastic control Hamilton–Jacobi–Bellman equations. We study existence, uniqueness, qualitative properties and appropriate deterministic or probabilistic numerical methods. At the time being we pay a special attention to the financial consequences induced by modelling errors and calibration errors on hedging strategies and portfolio management strategies.

4.3. Neurosciences and Biology

The interest of TOSCA in biology is developing in three main directions: neurosciences, molecular dynamics and population dynamics. In neurosciences, stochastic methods are developed to analyze stochastic resonance effects and to solve inverse problems. For example, we are studying probabilistic interpretations and Monte Carlo methods for divergence form second-order differential operators with discontinuous coefficients, motivated by the 3D MEG inverse problem. Our research in molecular dynamics focus on the development of Monte Carlo methods for the Poisson-Boltzmann equation which also involves a divergence form operator, and of original algorithms to construct improved simulation techniques for protein folding or interactions. Finally, our interest in population dynamics comes from ecology, evolution and genetics. For example, we are studying the emergence of diversity through the phenomenon of evolutionary branching in adaptive dynamics. Some collaborations in biostatistics on cancer problems are also being initiated.

4.4. Fluid Mechanics and Meteorology

In Fluid Mechanics we develop probabilistic methods to solve vanishing vorticity problems and to study the behavior of complex flows at the boundary, and their interaction with the boundary. We elaborate and analyze stochastic particle algorithms. Our studies concern the convergence analysis of these methods on theoretical test cases and the design of original schemes for applicative cases. A first example concerns the micro-macro model of polymeric fluids (the FENE model). A second example concerns Pope's Lagrangian modelling of turbulent flows, motivated by the problem of modelling and computing characteristic properties of the local wind activity in areas where windmills are built. Our goal is to estimate local resources in energy which are subject to meteorological randomness by combining large scale wind models and small scale Monte Carlo techniques, and to simulate management strategies of wind resources.

4.5. Chemical Kinetics

The TOSCA team is studying coagulation and fragmentation models, that have numerous areas of applications (polymerization, aerosols, cement industry, copper industry, population dynamics...). Our current motivation comes from the industrial copper crushers in Chile. We aim to model and calibrate the process of fragmentation of brass particles of copper in industrial crushers, in order to improve their efficiency at a low cost.

4.6. Diffusions in random media

A *random medium* is a material with a lot of heterogeneity which can be described only statistically. Typical examples are fissured porous media with rocks of different types, turbulent fluids or unknown or deficient materials in which polymers evolve or waves propagate. These last few years, the TOSCA team has been in relation with the Geophysics community on problems related to underground diffusions, especially those which concern waste transport or oil extraction. We are extending our previous results on the simulation of diffusion processes generated by divergence form operators with discontinuous coefficients. Such an operator appears for example from the Darcy law for the behavior of a fluid in a porous media. We are also developing another class of Monte Carlo methods to simulate diffusion phenomena in discontinuous media.

4.7. Transverse problems

Several of the topics of interest of TOSCA do not only concern a single area of application. This is the case of particular methods for the long time simulations of nonlinear McKean-Vlasov PDEs, the problem of simulation of multivalued models, variance reduction techniques or stochastic partial differential equations. For example, multivalued processes have applications in random mechanics or neurosciences, and variance reduction techniques have applications in any situation where Monte Carlo methods are applicable.

4.8. Software, numerical experiments

TOSCA is interested in designing algorithms of resolution of specific equations in accordance with the needs of practitioners. We benefit from our strong experience on the programming of probabilistic algorithms on various architectures including intensive computation architectures. In particular, our activity will concern the development of grid computing techniques to solve large dimensional problems in Finance. We are also interested in intensively comparing various Monte Carlo methods on PDEs and in the development of open source libraries for our numerical methods in Fluid Mechanics, Meteorology, MEG or Chemical Kinetics.

5. New Results

5.1. Probabilistic numerical methods, stochastic modelling and applications

Participants: Mireille Bossy, Nicolas Champagnat, Julien Claisse, Madalina Deaconu, Samuel Herrmann, Pierre-Emmanuel Jabin, Antoine Lejay, Sylvain Maire, Sebastian Niklitschek Soto, Nicolas Perrin, Denis Talay, Etienne Tanré, Julian Tugaut.

5.1.1. Published works and preprints

- M. Bossy, in collaboration with F. Bernardin (CETE Clermont Ferrand), J.-F. Jabir (Univ. Chile), C. Chauvin and A. Rousseau (MOISE team, INRIA Grenoble – Rhône-Alpes), did major improvements to the SDM model described in Section 6.1.2 concerning its ability to take into account the forcing conditions at the boundary as well as periodic boundary conditions (see [16]). In addition, they also worked on some numerical tests that aim to validate the SDM model for a near wall flow.
- M. Bossy, N. Champagnat, S. Maire and D. Talay have studied the probabilistic intepretation of divergence form operators with piecewise constant coefficients in any dimension, and obtained various Monte Carlo approximation techniques of the linearized Poisson-Boltzmann PDE of Molecular Dynamics [17], http://hal.inria.fr/inria-00459411/en.
- N. Champagnat works with F. Campillo (MERE team, INRIA Sophia Antipolis – Méditerranée) on individual-based models of clonal plant communities. They proposed several ways to take into account the graph structure of the population [47], http://hal.inria.fr/inria-00526379/en, and are currently working on various large population scalings of these systems.
- N. Champagnat worked with C. Chipot (Univ. of Illinois) and E. Faou (IPSO team, IRISA, Rennes) on a probabilistic approach to ill-posed and high-dimensional least squares approximation problems, and its application in Chemistry to compute the charge distribution of a molecule [21], http://hal.inria.fr/inria-00345411/en.
- N. Champagnat works with A. Lambert (Univ. Paris 6) on splitting trees with Poissonian mutations. Assuming that each mutation is neutral and gives a new type in the population, they obtained explicit expressions for the expected number of types carried by a fixed number of individual living in the population at time t [49], http://hal.inria.fr/inria-00515481/en. They are currently working on the large time convergence of the sizes of the most frequent and oldest types in the population.
- N. Champagnat and P.-E. Jabin studied the phenomenon of evolutionary branching, by which mutations and selection drive a population to subdivide into several subpopulations with distinct types, using a PDE approach. They proved that, in the limit of small mutations, the evolution of the dominant types in the population is governed by the maxima of the solution of a Hamilton-Jacobi equation with constraints [48], http://hal.inria.fr/inria-00488979/en.
- N. Champagnat and P.-E. Jabin worked with G. Raoul (Univ. Cambridge) on the large time convergence of the solution of competitive Lotka-Volterra systems in any dimensions and chemostat systems with an arbitrary number of species and resources [23], http://hal.inria.fr/inria-00495991/en.

- M. Cissé (ENSAE-Sénégal), P. Patie (Univ. libre de Bruxelles) and E. Tanré have solved explicitly the optimal stopping problem with random discounting and an additive functional as cost of observations for a regular linear diffusion [50], http://hal.inria.fr/inria-00458901/en.
- A. Lejay and S. Maire have introduced a numerical scheme to compute solutions of diffusion equations in heterogeneous media based on a kinetic approximation combined with efficient random walks techniques. Stochastic PDEs and a hard problem in the nuclear waste context have been solved [35], http://hal.inria.fr/inria-00358003/en.
- A. Lejay worked on the global existence of solutions of rough differential equations with unbounded coefficients [51], http://hal.inria.fr/inria-00451193/en.
- C. De Luigi (Univ. Toulon) and S. Maire have developed an automatic algorithm to compute integrals and approximations of functions in medium dimensions. It has been tested on basket options pricing [25], http://hal.inria.fr/inria-00442778/en.
- C. De Luigi (Univ. Toulon), S. Maire and S. Dumont (Univ. Picardie) have developed a spectral method to compute the solution of the Poisson equation in a hypercube in dimension up to 8 [26], http://hal.inria.fr/inria-00442773/en.
- P.-E. Jabin and G. Raoul (Univ. Cambridge) have studied the large time behaviour of population dynamics models with competition between individuals [32].
- P.-E. Jabin, incollaboration with J. Calvo (Univ. Granada, Spain), have studied large time asymptotics in modified models of coagulating particles, which are better suited to biological models [20].
- P.-E. Jabin obtained with J. Barré (Univ. Nice – Sophia Antipolis) and M. Hauray (Univ. Aix-Marseille 1) some stability estimates for particle systems in finite time, uniform in the number of particles [15].
- P.-E. Jabin and J. Soler (Univ. Granda, Spain) have derived and analysed new models describing the fragmentation of small particles due to the deformation induced on them by a fluid. These models take the form of coupled Boltzmann & Navier–Stokes fragmentation models and are obtained under the simplifying assumption that the particles are constituted by spheres jointed by springs [33].
- P.-E. Jabin proved in [31] the well posedness of solutions to differential equations under fields that are “almost BV” (SBV in fact).

5.1.2. Other works in progress

- In collaboration with J.-F. Jabir and J. Fontbona (CMM and Universidad de Chile, Santiago de Chile), M. Bossy has studied theoretical problems on the Lagrangian stochastic modelling, in particular the link between the Lagrangian version of divergence free constraint (and the uniform density constraint), with an additional potential term, in the Lagrangian equation, having some similitude with the role of the Eulerian pressure term.
- N. Champagnat worked with P. Diaconis (Stanford Univ.) and L. Miclo (Univ. Toulouse 3) on the full spectral decomposition of the transition matrix of two-dimensional Markov chains $(X_n, Y_n)_{n\geq 0}$ in $\mathbb{Z}_+^2$, which are *neutral* in the sense that $(X_n + Y_n)_{n\geq 0}$ is a Markov process. Because of the specific form of the eigenvectors, they were also able to characterize all the Dirichlet eigenvectors in subdomains of $\mathbb{Z}_+^2$ of the form $\{(i,j) \in \mathbb{Z}_+^2 : i + j \geq d\}$ for all $d \geq 0$. As an application, they could determine the quasi-stationary and quasi-limiting distributions of such processes.
- J. Claisse has continued his Ph.D. under the supervision of N. Champagnat and D. Talay on stochastic control of population dynamics. He completed a finite-horizon optimal control problem and is currently working on an ergodic one. In addition, he is working on applications of optimal control theory in cancer therapy.
- A. Lejay worked with Soledad Torres (Universidad de Valparaíso, Chile) and Ernesto Mordecki (Uruguay) on the statistical estimation of the skewness parameter of the Skew Brownian motion. This work is part of the MathAmSud program described in Section 7.3.

- A. Lejay worked with Rolando Rebolledo (Universidad Pontificia Catolica, Chile) on the estimation of processes with discontinuous coefficients. This work is part of the MathAmSud program described in Section 7.3.
- S. Maire and E. Tanré have generalised the spectral methods for elliptic PDEs developed in [55], [56] to the case of pure Neumann boundary conditions. Some additional difficulties occur because the stochastic representation of the solutions is defined only up to an additive constant and as a limit involving local time approximations [54]. By taking into account these additional properties, they still obtained a spectral matrix which condition number is asymptotically one.
- S. Maire and C. Prissette (Univ. Toulon) are developing a genetic algorithm to solve sudoku puzzles. The algorithm is based on cross entropy techniques combined with efficient stop and restart tools.
- N. Perrin continued his PhD. on stochastic methods in molecular dynamics under the supervision of M. Bossy, N. Champagnat and D. Talay. He is studying a method due to P. Malliavin (French Academy of Science) based on the Fourier analysis of covariance matrices with delay in order to identify the fast and slow components of a molecular dynamics and to construct simplified projected dynamics. He is currently analysing the performance of this method on particular stochastic dynamics with well identified fast and slow components.
- D. Talay and E. Tanré, in collaboration with F. Delarue and S. Rubenthaler (Univ. Nice – Sophia Antipolis), have given a precise approximation of the interspike intervals for the LIF model, describing the activity of a single neuron. This work is part of the ANR MANDy project (see Section 6.1.1).
- D. Talay, in collaboration with M. Martinez (Univ. Paris-Est), discretized stochastic differential equations related to one-dimensional partial differential equations of parabolic type involving a divergence form operator with a discontinuous coefficient. They obtained accurate pointwise estimates for the derivatives of these solutions, from which they get convergence rate estimates in the weak sense of the stochastic discretization scheme. To obtain these estimates, they develop a stochastic approach of transmission parabolic problems.
- E. Tanré worked with R. Coffré (PUC, Chile), R. Fraiman (Univ. de San Andrés, Argentina and Univ. de la República, Uruguay), R. Rebolledo (PUC, Chile) on modelling and estimating the conformal energy and the conductivity in ion channels. An important part of the activity of a single neuron can be measured by the voltage accross its membrane. A part of the voltage variation is due to the motion of ions through ions channels. In this work, they model and study the gating dynamics of ions channels. They assume that the gating takes continuous values, i.e. that the gate can be in any intermediate state between the opened state and the closed state. A relation between the voltage, the current and the gating is given by the conductivity function. They also compare thsi model with experimental data. This work is part of the MathAmSud program described in Section 7.3.
- Dr. Angela Ganz, from the Pontificia Universidad Católica de Chile, spent two weeks in TOSCA in Sophia Antipolis this summer to work on the wind power modelling. This work is part of the MathAmSud program described in Section 7.3.
- A. Lejay spent two weeks in Santiago and Valaparaíso to work with R. Rebolledo and S. Torres on the estimation problem of skew brownian motion and diffusion processes with discontinuous coefficients. This work is part of the MathAmSud program described in Section 7.3.
- S. Herrmann worked with J. Tugaut on self-stabilizing diffusions, that is diffusions attracted by their own law, wandering in a double-well landscape. They focus their attention on existence of several invariant measures, exit time problems, large deviations.

5.2. Financial Mathematics

Participants: Mireille Bossy, Nicolas Champagnat, Dalia Ibrahim, Numa Lescot, Denis Talay, Etienne Tanré, Laurent Violeau.

5.2.1. Published works and preprints

- M. Cissé (ENSAE-Sénégal), P. Patie (univ. libre de Bruxelles) and E. Tanré have solved explicitly the optimal stopping problem with random discounting and an additive functional as cost of observations for a regular linear diffusion. See [50], http://hal.inria.fr/inria-00458901/en/.

5.2.2. Other works in progress

- In collaboration with N. Maïzi (CMA – Mines Paristech) and O. Pourtallier (COPRIN team, INRIA Sophia Antipolis – Méditerranée), M. Bossy, and L. Violeau studied the indifference pricing for carbon emission allowances, as a short term model value of carbon (see Section 6.1.2). The indifference pricing methodology describes the way an industrial agent on the emission allowances market chooses his production strategy. An utility function represents the preferences of the producer and its risk aversion. The outputs of its production have stochastic prices on the market, so that the optimal production strategy arises as the solution of a stochastic control problem.

  In that case, the resulting stochastic control problem is degenerate, but its well-posedness could be proved: the value function is the unique solution of a Hamilton-Jacobi-Bellman equation. The numerical resolution of the HJB equation has been implemented by L. Violeau using an implicit monotone finite difference method, which was proven to be consistent, stable and converging. The code produced allows the participants to conveniently analyze *indifference prices* and their sensitivities to different parameters.
- N. Champagnat and E. Tanré continued their work with S. Maroso (Univ. Montpellier 2) on super-replication of up-and-out barrier options under Gamma constraints, and on the numerical study of the quadratic risk minimization problem for the hedging of barrier options when a minimal delay is imposed between two successive portfolio reallocations. This year, they could significantly improve to computational cost of the numerical resolution of the corresponding Hamilton-Jacobi-Bellman problem. This work is currently being written.
- **Mathematical modelling for technical analysis techniques** Since November 2010, D. Ibrahim has been working on her Ph.D. thesis on Mathematical modeling of technical analysis in finance, under supervision of D. Talay and E. Tanré. The aim of her work is to study the performances of a technical analysis tool designed to detect changes in the volatility term : The Bollinger Bands. First, she has studied the performances of this indicator in a modified Black-Scholes model such that the rate of volatility changes at an unknown random time τ, independent of the Brownian motion governing the prices. She showed that this indicator has the capacity to detect the increasing changes in the volatility. Secondly, she exhibited a mathematical optimal strategy by modifying usual techniques in both the dual and the classical PDE approaches in stochastic control theory, in order to circumvent the discontinuity of the filtration generated by the price process.

  This work is part of the contract with FINRISK (see Section 7.3).
- Madalina Deaconu visited the team of Roger Temam at Indiana University in order to start collaborations on the probabilistic approach of uncertainties for the primitive equations.

6. Contracts and Grants with Industry

6.1. Contracts with Industry

6.1.1. ANR projects

- N. Champagnat is member of the ANR MANEGE (Modèles Aléatoires eN Écologie, Génétique et Évolution, started in 2009 under the direction of S. Méléard, Ecole Polytechnique) whose aim is to provide methodological and conceptual advances in the study of stochastic processes modeling ecology, population genetics and evolution of life. Our work is sustained by regular exchanges with biologists from several teams in France. In addition, the three working groups that operate in each of the three poles of the MANEGE project (Paris, Palaiseau, Marseille) unite all local probabilistic interests in our issues. http://www.cmap.polytechnique.fr/~anr-manege/index_en.html

- N. Champagnat is member of the ANR MODECOL (Using mathematical MODeling to improve ECOLogical services of prairial ecosystems, started in 2009 under the direction of C. Mony, Univ. Rennes 1), whose goal is to develop computational ecological modeling of terrestrial plants communities via the simulation of a prairie in relation with environmental data. This project focuses on developing an original tool-box that takes advantage of complementary mathematical disciplines (partial differential equations, individual-based stochastic modelling...) to assess ecological problems. Simulations will be extensively processed using distributed computing and webcomputing. Our target application concerns the setup of herbal strips around intensive cereal fields for purificating water from extra nitrate and pesticides, imposed by the European Common Agricultural Policy. http://ecobio.univ-rennes1.fr/modecol/gb/description.php
- S. Herrmann, D. Talay and E. Tanré are member of the ANR MANDy (Mathematical Analysis of Neuronal Dynamics, started in 2009 under the direction of M. Thieullen, Univ. Paris 6). This project, which gathers mathematicians and neuroscientists, aims at developing mathematically rigorous approaches to neuroscience considering single neurons as well as interconnected neuronal populations. Our target is to conduct the mathematical analysis of existing models where there is still much work to be done and to enrich the modelling by proposing new models. See http://www.proba.jussieu.fr/pageperso/thieullen/MANDy/accueil.html for a more complete description of this project.
- P.-E. Jabin is member of the ANR MONUMENTALG (MOdélisation mathématique et simulations NUMériques pour la dégradation biologique des MONUMENTs et pour la prolifération des ALGues) on the dispersion of toxic algae, starting in 2010 (resp. M. Ribot, Univ. Nice – Sophia Antipolis).
- A. Lejay is member of the ANR ECRU (Exploration des Chemins RUgueux, started in 2009 under the direction of M. Gubinelli, Univ. Paris Dauphine), whose aim is is to explore new directions in the field of rough paths. http://www.ceremade.dauphine.fr/~mgubi/ecru/index.html
- A. Lejay is member of the ANR SIMUDMRI (Simulation du signal d'IRM diffusion dans tissus biologiques) which started in November 2010 (resp. Jing-Rebecca Li, INRIA Rocquencourt).

6.1.2. Contracts with ADEME

Local modeling for the wind velocity Since 2005, M. Bossy was member of a collaboration with the Laboratoire de Météorologie Dynamique (Université Paris 6, École Polytechnique, École Normale Supérieure), funded by the French Environment and Energy Management Agency (ADEME), concerning the modeling and the simulation of local wind energy resources. We collaborate with P. Drobinski and T. Salameh (LMD). The second phase of this collaboration started in October 2007 with two new partners: A. Rousseau (MOISE team, INRIA Grenoble – Rhône-Alpes) and F. Bernardin (CETE Clermont-Ferrand). We investigate a new numerical simulation method of the wind at small scales. Thanks to boundary data provided at large scales by the weather forecasting code *MM5*, we propose a Langevin model to describe the behavior of stochastic particles. This model called *SDM* (Stochastic Downscaling Method) is adapted from previous works introduced by S.B. Pope [57] (see http://sdm.gforge.inria.fr/Accueil/index.en.php).

Carbon value and carbon tax in the context of renewable energies deployment Since January 2009, M. Bossy was member of a collaboration funded by the French Environment and Energy Management Agency (ADEME), involving the Center for Applied Mathematics (CMA) at Mines ParisTech, and COPRIN and TOSCA teams at INRIA Sophia Antipolis. It focuses on a short term carbon value derived from the so-called financial *carbon market*, the European Union Emission Trading Scheme (EU ETS), which is a framework for GHG emissions reduction in European industry. The Ph.D. thesis of L. Violeau is part of this project.

The objective of this project is to study the compatibility and complementarity of a carbon tax and a target for renewable energy deployment. As a first step, we are developing a method for assessing the EU ETS value. We consider the constraints related to emission allowances distributed through national plans of allocation (NAP) and the mechanisms of taxes that are taking place. The work will focus on electricity producers, key players in the market in its first phase (NAP-I, 2005-2007). The impact of the *Renewable Energies* park of the electricity producers on their own carbon value will be particularly studied.

We have selected the financial concept of indifference price as a relevant methodology to assess the European Union Emission Trading Scheme (EU ETS) value. In this setting, modelling strategies of production and emission of market quotas rely on stochastic optimal control problems and associated Hamilton-Jacobi-Bellman equations. This year, we implemented the numerical resolution of the HJB equation for various electricity spot price models.

We also started to study a game theoretic approach based on the Nash equilibrium concept for the coupled electricity and carbon markets (see the 2010 Activity Report of the COPRIN team).

6.1.3. Industrial contracts

- The TOSCA team has two contracts with GDF-Suez, one on Monte Carlo methods for the prediction of failures of pipes and the other on the hedging of power plants.
- D. Talay and E. Tanré are involved in a contract with CA-CIB (ex-CALYON), which concerns
  - the study of the liquidity risk in the interest rate options market;
  - the minimization of the hedging error in Gaussian models (thanks to stochastic algorithms).

7. Other Grants and Activities

7.1. National Initiatives

- A. Lejay is a member of the ANR ECRU and SIMUDMRI (see Section 6.1.1).
- N. Champagnat is a member of the ANR MANEGE and MODECOL (see Section 6.1.1).
- S. Herrmann, D. Talay and E. Tanré are members of the ANR MANDy (see Section 6.1.1).
- P.-E. Jabin is member of the ANR MONUMENTALG (see Section 6.1.1).
- D. Talay is the Vice-President of the Fondation d'Entreprise Natixis which aims to contribute to develop research in quantitative finance.
  He also serves as a member of the Scientific Committee of the Foundation, jointly with M. Crouhy (President, Natixis), N. El Karoui (École Polytechnique), P.-L. Lions (Collège de France), J.-P. Laurent (Université Claude Bernard, Lyon).

7.2. European Initiatives

- M. Deaconu visited Fabio Nobile at Politecnico di Milano in November 2010.
- A. Lejay is member of the Marie Curie Action *multifractionality* (France, Ukraine, United Kingdom, Israël).
- TOSCA participates to the NCCR FINRISK (Financial Risk) forum launched by the Swiss National Science Foundation and managed by the University of Zürich.

7.3. International Initiatives

- D. Talay is the international coordinator of the MathAmsud program 08MATH05 — *Stochastic Analysis and Mathematical Physics Research Network* which started in 2009, and also involves M. Bossy, A. Lejay and E. Tanré.
- A. Lejay spent two weeks in Santiago and Valaparaíso to work with R. Rebolledo and S. Torres within the MathAmSud program.
- E. Tanré spent two weeks in Chile at the Pontificia Universidad Catòlica de Chile in November within the MathAmSud program.

8. Dissemination

8.1. Animation of the scientific community

M. Bossy serves as a member of the Scientific Committee of the *École Doctorale "Sciences Fondamentales et Appliquées"* of the Université de Nice – Sophia Antipolis.

M. Bossy is responsible for the *Suivi Doctoral* Committee of INRIA Sophia Antipolis – Méditerranée. She is also responsible for the *Formation par la recherche* at INRIA Sophia Antipolis – Méditerranée.

M. Bossy serves as a member of the *Cours et Colloques* Committee of INRIA Sophia Antipolis – Méditerranée and serves as a member of the *Commission Consultative Paritaire Scientifique* of INRIA.

M. Bossy has been a member of the Committee for junior permanent research positions of INRIA Sophia Antipolis –Méditerranée.

N. Champagnat is elected member of the *Comité de Centre* and represents researchers at the *Comité des Projets* of INRIA Sophia Antipolis – Méditerranée.

M. Deaconu is member of Comité des Projets of Centre de Recherche INRIA Nancy – Grand Est, of the Conseil de Laboratoire of Institut Élie Cartan and of the Commission des Développements Technologiques of Centre de Recherche INRIA - Nancy Grand Est, since January 2009.

M. Deaconu was member of the Committee for junior permanent positions of INRIA Nancy – Grand Est.

M. Deaconu and A. Lejay are permanent reviewers for the *Mathematical Reviews*.

P.-E. Jabin is the coordinator for the University of Nice of the Erasmus Mundus Master program Mathmods. He is also in charge of the internships for the Master 2 program IMEA.

A. Lejay has been elected as *General Secretary* of the Société des Mathématiques Appliquées et Industrielles in June 2010.

A. Lejay is one of the three editors of the *Séminaire de Probability*, to be published yearly in the series *Lecture Notes in Mathematics*, Springer.

A. Lejay is an elected member of the *Commission du personnel* of Institut Elie Cartan, Nancy.

A. Lejay is a nominated member of the *Commission du personnel* (COMIPERS) of INRIA Nancy – Grand Est.

D. Talay has served from July as the Scientific Deputy of INRIA Sophia Antipolis — Méditerrannée.

D. Talay serves as an Associate Editor of: *Stochastic Processes and their Applications*, *Annals of Applied Probability*, *ESAIM Probability and Statistics*, *Stochastics and Dynamics*, *SIAM Journal on Numerical Analysis*, *SIAM Journal in Financial Mathematics*, *Journal of Scientific Computing*, *Monte Carlo Methods and Applications*, *Oxford IMA Journal of Numerical Analysis*, *Stochastic Environmental Research and Risk Assessment*.

D. Talay served in November as a member of the AERES evaluation committee of the IRMAR Institute of Mathematics in Rennes.

E. Tanré was president of the CUMIR (Comité des Utilisateurs des Moyens Informatiques, Recherche) at INRIA Sophia Antipolis – Méditerranée until October.

8.2. Animation of workshops

P.-E. Jabin organized the 2010 edition of the *Cours Poupaud* in March in Nice, with L. Szekelyhidi as speaker, entitled *From Isometric Embeddings to Turbulence*.

8.3. Teaching

M. Bossy gave a 15h course on *Continuous Probabilistic Models with Applications in Finance* in the Master 2 IMAFA (*Informatique et Mathématiques Appliquées à la Finance et à l'Assurance*, *Ecole Polytechnique Universitaire*, Univ. Nice – Sophia Antipolis), and a 9h course on *Risk management on energetic financial markets* in the Master *Ingénierie et Gestion de l'Energie* (École des Mines de Paris) at Sophia-Antipolis. M. Bossy also gave a 12h course on *Particle Methods* at the Master 2 *Probabilité et Applications* at Université Paris 6.

N. Champagnat gave a 12 h course on *Finite Difference Methods for Parabolic PDEs and Numerical Linear Algebra* and a 15 h course and 16 h of exercice class on *Continuous Probabilistic Models with Applications in Finance* in the Master 2 IMAFA (*Informatique et Mathématiques Appliquées à la Finance et à l'Assurance*, *Ecole Polytechnique Universitaire*, Univ. Nice – Sophia Antipolis).

Madalina Deaconu gave a 33h course on "Stochastic Modeling" in Master 2 IMOI and a 21h Master course in "Monte Carlo Methods" at École des Mines de Nancy.

P.-E. Jabin, in addition to his regular teaching activity as a half-time professor in Univ. Nice – Sophia Antipolis, gave a Master course in Ecole Polytechnique of Tunis on Bio-Mathematics.

A. Lejay gives a 15 h lecture on *Monte Carlo method* in Master 2 *Mathematiques Fondamentales et Appliquées* in Université Henri Poincaré.

N. Perrin gave 40h of exercice classes on *Integration and probabilities* in the Licence 3 MASS (*Mathématiques Appliquées aux Sciences Sociales*) at Univ. Nice – Sophia Antipolis, and 30h of exercice classes on *Probability* in the Licence 2 BIM (*Bio-Info-Maths*) at Univ. Nice – Sophia Antipolis.

D. Talay has a part time position of Professor at École Polytechnique. He also teaches *Stochastic Flows and Applications* at Univ. Paris 6 (Master degree in Probability).

E. Tanré gave a 30 hours course on numerical stochastic methods in the Master 2 MathMods – Erasmus Mundus and a 15 hours course in the Master IMAFA (*Informatique et Mathématiques Appliquées à la Finance et à l'Assurance*, *Ecole Polytechnique Universitaire*, Univ. Nice – Sophia Antipolis).

8.4. Ph.D. theses and habilitations

Mireille Bossy defended her habilitation entitled *Méthodes particulaires stochastiques et modèles stochastiques lagrangiens; Discrétisation d'EDS avec condition de bord; Quelques modélisations et méthodes numériques pour la finance* at INRIA Sophia Antipolis – Méditerranée in April [11].

Viet Dung Doan defended his PhD thesis entitled *Grid computing for Monte Carlo based intensive calculations in financial derivative pricing applications* at INRIA Sophia Antipolis – Méditerranée in April [12].

Julian Tugaut defended his PhD thesis entitled *Processus auto-stabilisants dans un paysage multi-puits* at Univ. Henri Poincaré in July 2010 [13].

8.5. Participation to congresses, conferences, invitations...

M. Bossy gave talks at the *Séminaire de mathématiques appliquées du Collège de France* in Paris in May, an invited lecture at the Workshop on *Kolmogorov equations in Physics and Finance* in Modena, Italy in September, a Seminar talk at the ORFE Dept. of Princeton University in October and a talk at the Workshop on *Stochastic methods for Navier-Stokes, MHD and Gyrokinetic simulations* at CEA, Cadarache in November.

N. Champagnat gave talks at the Workshop of the ANR MODECOL *Modeling Clonal Plant Growth: from Ecological Concepts to Mathematics* in Rennes in June, at the IMS 2010 Conference in Gothenburg (Sweden) in August, at the probability and statistics seminar in Univ. Montpellier 2, the probability seminar in Univ. Paris 6–7 and the mathematical biology seminar in Univ. Lyon 1 in December.

M. Deaconu gave a talk in the *PDE seminar* of the Department of Mathematics at Indiana University in November.

P.-E. Jabin gave talks at the *Intensive Research Month on Hyperbolic Conservation Laws and Fluid Dynamics* in Parma University, Italy in February, at the Winter School and 9th ICOR on *PDE and Mathematical Biology* in La Habana, Cuba in February, at the 2010 Annual Kinetic FRG Meeting on *Kinetic Description of Multiscale Phenomena* in Brown University, Providence in May, at the DSPDEs'10 Conference on *Emerging Topics in Dynamical Systems and Partial Differential Equations* in Barcelona in June, at the Conference of the "Fédération Normandie-Mathématiques" in Univ. Caen on *EDP, physique mathématique, mathématiques et applications* in October and at the Confernece on *PDEs in kinetic theories: kinetic description of biological models* in Edinburgh in November.

A. Lejay gave a talk to the École CEA-INRIA-EDF *Homogénéisation périodique et stochastique, aspects théoriques et numériques* at INRIA Rocquencourt in December.

A. Lejay gave a talk in the workshop *multifractionality* in Kiev in October, at the *Journées de probabilités 2010* and a the workshop *Rough Paths and Partial Differential Equations* at the Isaac Newton Institute, Cambrdige in April.

A. Lejay gave a talk at the probability seminar of Univ. d'Évry in June.

A. Lejay was a member of the PhD jury of A. Deya at Université Henri Poincaré in September.

S. Maire gave talks at the *9th International Conference on Monte Carlo and Quasi-Monte Carlo Methods in Scientific Computing (MCQMC 2010)* at Warsaw in August and at the *Kolloquim "Numerik und Stochastik"* at Mainz Univ. in November.

D. Talay gave several invited lectures: in January, at the *44th Journée des Séminaires actuariels de l'ISA Lyon et ISA-HEC Lausanne*; in June, at the *9th Workshop on stochastic analysis and related fields a conference in honor of A.S. Üstünel* in Paris; in September, at the Workshop *Kolmogorov equations in Physics and Finance* in Modena (Italy); in November, at the Workshop *Analysis and Probability* in Nice; in December, at the International Research Forum *What can the academic commutinity learn from the global crisis?* in Hong-Kong. He gave a mini-course at the CEA-EDF-Inria School *Simulation of hybrid dynamical systems and applications to molecular dynamics* in Paris in September. Finally, he organized an invited paper session at the IMS Annual Meeting in Gothenburg (Sweden).

E Tanré gave a seminar talk at the Pontificia Universidad Catòlica de Chile in November.

8.5.1. Invitations

M. Bossy was invited two weeks by P. Carmona at the ORFE Department at Princeton University in October.

T. Brustle and Jie Zhang (Univ. of Sherbrook, Canada) have visited the TOSCA project-team in Sophia Antipolis as part of a sabbatical program until June.

M. Deaconu was invited one week by Roger Temam at Indiana University, Bloomington in November 2010.

J. Fontbona (Universidad de Chile) has been visiting the team in Sophia Antipolis for five days in July.

A. Ganz (Pontificia Universidad Católica de Chile) has been visiting the team in Sophia Antipolis for 2 weeks in July.

P.-E. Jabin was invited one month at the University of Maryland and 3 weeks at Cambridge University for a semester on kinetic equations in November.

J.-F. Jabir (Univ. Santiago Chili 1) is visiting the TOSCA project-team since November.

J.-M. Lasry (Univ. Paris Dauphine and Calyon) has been visiting the TOSCA project-team in Sophia Antipolis one month between July and August.

N. Lescot has spent three months in the team in Sophia Antipolis until March.

S. Maire was invited one week in Mainz University, Germany in November.

A. Rousseau (MOISE team, INRIA Grenoble – Rhône-Alpes) has been visiting the team twice for three days in April and November.

M. Tahmasebi (Univ. of Teheran) has been visiting the TOSCA project-team in Sophia Antipolis for four months until April.

The TOSCA *seminar* organized by N. Champagnat in Sophia Antipolis has received the following speakers: Vlad Bally (Univ. Marne-la-Vallée), Amandine Véber (ENS Paris et Univ. Paris 11), Pierre Bertrand (INRIA Saclay et Univ. Clermont Ferrand), Ludovic Goudenège (ENS Cachan — Antenne de Bretagne), Roman Potsepaev (Schlumberger), Sebastien Darses (CMI-LATP, Univ. Aix-Marseille I), George Labahn (Univ. of Waterloo, Ontario, Canada), Florent Malrieu (Univ. Rennes 1), Jean-François Jabir (Univ. Chile, Santiago), El Hadj Aly Dia (Univ. Paris-Est) and Eric Moulines (ENST, Paris).

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