



Activity Report 2011

Team PUMAS

Plasma, tUrbulence, Modeling, Approximation
and Simulation

RESEARCH CENTER
Sophia Antipolis - Méditerranée

THEME
Computational models and simulation

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Team PUMAS

Keywords: Scientific Computation, Numerical Methods, Flow Modeling, MagnetoHydroDynamics, Environment

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2. Overall Objectives

2.1. Overall Objectives

Turbulence often called “the last unsolved problem in classical statistical mechanics” from a citation by Richard Feynman is a fundamental feature of fluid flows. Its correct description impacts such diverse fields as weather prediction and ocean dynamics, aircraft and ship design or transport and instabilities in plasmas to cite but a few.

The challenge of understanding and modeling turbulence has been with us for more than 100 years with very modest results. Since the 1941 Kolmogorov theory [25], no universally valid successful theory has emerged in this field. This is certainly due to the fact that a universal theory of turbulence does not exist and that instead one has to face very different mechanisms with very different properties.

However, with emerging multi-teraflop and soon petaflop computers, some direct numerical simulation of fluid turbulence is becoming possible. This is specially true in application domains like transport in Tokamaks where some internal mechanism forbids the size of the turbulent eddies to go below certain limits (here, the Larmor radius). In other application areas such as classical aerodynamics, although direct numerical simulations are still out of reach, attention is becoming focused on unsteady processes and instabilities requiring the use of models beyond the RANS ones (“Reynolds averaged”).

The main objective of the PUMAS team is to contribute to the development of innovative numerical tools to improve the computer simulations of complex turbulent or unstable flows. Although not strictly restricted to these areas, we plan to develop these researches for three main application domains that are Plasma Physics, Large Eddy Simulation and hybrid models in Fluid turbulence and environmental flows.

3. Scientific Foundations

3.1. Plasma Physics

Participants: Hervé Guillard, Boniface Nkonga, Afeintou Sangam, Richard Pasquetti, Audrey Bonnement, Marie Martin, Cédric Lachat, Laure Combe.

In order to fulfil the increasing demand, alternative energy sources have to be developed. Indeed, the current rate of fossil fuel usage and its serious adverse environmental impacts (pollution, greenhouse gas emissions, ...) lead to an energy crisis accompanied by potentially disastrous global climate changes.

Controlled fusion power is one of the most promising alternatives to the use of fossil resources, potentially with a unlimited source of fuel. France with the ITER (<http://www.iter.org/default.aspx>) and Laser Megajoule (<http://www-lmj.cea.fr/>) facilities is strongly involved in the development of these two parallel approaches to master fusion that are magnetic and inertial confinement. Although the principles of fusion reaction are well understood from nearly sixty years, (the design of tokamak dates back from studies done in the '50 by Igor Tamm and Andreï Sakharov in the former Soviet Union), the route to an industrial reactor is still long and the application of controlled fusion for energy production is beyond our present knowledge of related physical processes. In magnetic confinement, beside technological constraints involving for instance the design of plasma-facing component, one of the main difficulties in the building of a controlled fusion reactor is the poor confinement time reached so far. This confinement time is actually governed by turbulent transport that therefore determines the performance of fusion plasmas. The prediction of the level of turbulent transport in large machines such as ITER is therefore of paramount importance for the success of the researches on controlled magnetic fusion.

The other route for fusion plasma is inertial confinement. In this latter case, large scale hydrodynamical instabilities prevent a sufficient large energy deposit and lower the return of the target. Therefore, for both magnetic and inertial confinement technologies, the success of the projects is deeply linked to the theoretical understanding of plasma turbulence and flow instabilities as well as to mathematical and numerical improvements enabling the development of predictive simulation tools.

3.2. Turbulence Modelling

Participants: Alain Dervieux, Boniface Nkonga, Richard Pasquetti.

Fluid turbulence has a paradoxical situation in science. The Navier-Stokes equations are an almost perfect model that can be applied to any flow. However, they cannot be solved for any flow of direct practical interest. Turbulent flows involve instability and strong dependence to parameters, chaotic succession of more or less organised phenomena, small and large scales interacting in a complex manner. It is generally necessary to find a compromise between neglecting a huge number of small events and predicting more or less accurately some larger events and trends.

In this direction, PUMAS wishes to contribute to the progress of methods for the prediction of fluid turbulence. Taking benefit of its experience in numerical methods for complex applications, PUMAS works out models for predicting flows around complex obstacles, that can be moved or deformed by the flow, and involving large turbulent structures. Taking into account our ambition to provide also short term methods for industrial problems, we consider methods applying to high Reynolds flows, and in particular, methods hybridizing Large Eddy Simulation (LES) with Reynolds Averaging.

Turbulence is the indirect cause of many other phenomena. Fluid-structure interaction is one of them, and can manifest itself for example in Vortex Induced Motion or Vibration. These phenomena can couple also with liquid-gas interfaces and bring new problems. Of particular interest is also the study of turbulence generated noise. In this field, though acoustic phenomena can also in principle be described by the Navier-Stokes equations, they are not generally numerically solved by flow solvers but rather by specialized linear and nonlinear acoustic solvers. An important question is the investigation of the best way to combine a LES simulation with the acoustic propagation of the waves it produces.

3.3. Astrophysical and Environmental flows

Participants: Hervé Guillard, Boniface Nkonga.

Although it seems inappropriate to address the modeling of experimental devices of the size of a tokamak and for instance, astrophysical systems with the same mathematical and numerical tools, it has long been recognized that the behaviour of these systems have a profound unity. This has for consequence for instance that any large conference on plasma physics includes sessions on astrophysical plasmas as well as sessions on laboratory plasmas. PUMAS does not intend to consider fluid models coming from Astrophysics or Environmental flows for themselves. However, the team is interested in the numerical approximation of some problems in this area as they provide interesting reduced models for more complex phenomena. To be more precise, Let us give some concrete examples : The development of Rossby waves ¹ a common problem in weather prediction has a counterpart in the development of magnetic shear induced instabilities in tokamaks and the understanding of this latter type of instabilities has been largely improved by the Rossby wave model. A second example is the water bag model of plasma physics that has a lot in common with multi-layer shallow water system.

To give a last example, we can stress that the development of the so-called well-balanced finite volume schemes used nowadays in many domains of mathematical physics or engineering was largely motivated by the desire to suppress some problems appearing in the approximation of the shallow water system.

Our goal is therefore to use astrophysical or geophysical models to investigate some numerical questions in contexts that, in contrast with plasma physics or fluid turbulence, do not require huge three dimensional computations but are still of interest for themselves and not only as toy models.

4. Software

4.1. FluidBox

Participants: Boniface Nkonga [contact], Hervé Guillard.

FluidBox is a software dedicated to the simulation of inert or reactive flows. It is also able to simulate multiphase, multi-material and MDH flows. There exist 2D and 3D dimensional versions. The 2D version is used to test new ideas that are later implemented in 3D. Two classes of schemes are available : A classical finite volume scheme and the more recent residual distribution schemes. Several low Mach number preconditioning are also implemented. The code has been parallelized with and without domain overlapping. The linear solver PaStiX is integrated in FluidBox. A partitioning tool exists in the package and uses Scotch. At present the software is only a private project but some parts of FluidBox are expected to be in the public domain by the end of the year.

4.2. PlaTo

Participants: Hervé Guillard [contact], Laure Combe.

¹Rossby waves are giant meanders in high altitude wind that have major influence on weather. Oceanic Rossby waves are also known to exist and to affect the world ocean circulation

The development of PlaTo (A platform for Tokamak simulation) (<http://www-sop.inria.fr/pumas/plato.php>) is being supported by an ADT action of the D2T. PlaTo is a suite of data and softwares dedicated to the geometry and physics of Tokamaks and its main objective is to provide the Inria large scale initiative “FUSION” teams working in plasma fluid models with a common development tool. The construction of this platform will integrate the following developments.

1. A (small) database corresponding to axi-symmetrical solutions of the equilibrium plasma equations for realistic geometrical and magnetic configurations (ToreSupra, JET and ITER). The construction of meshes always takes considerable time. Plato will provide meshes and solutions corresponding to equilibrium solutions that will be used as initial data for more complex computations.
2. A set of tool for the handling, manipulation and transformation of meshes and solutions using different discretisations (P1, Q1, P3, etc)
3. Numerical templates allowing the use of 3D discretization schemes using finite element schemes in the poloidal plane and spectral Fourier or structured finite volume representations in the toroidal plane.
4. Several applications (Ideal MHD and drift approximation) used in the framework of the Inria large scale initiative “FUSION”.

This year, after a definition of the PlaTo architecture, the points 1. and 2. have been developed.

4.3. PaMPA

Participants: Cécile Dobrzynski [Bacchus], Hervé Guillard, Laurent Hascoët [Tropics], Cédric Lachat, François Pellegrini [Bacchus].

PaMPA (“Parallel Mesh Partitioning and Adaptation”) is a middleware library dedicated to the management of distributed meshes. Its purpose is to relieve solver writers from the tedious and error prone task of writing again and again service routines for mesh handling, data communication and exchange, remeshing, and data redistribution. An API of the future platform has been devised, and the coding of the mesh handling and redistribution routines is in progress. PaMPA will be used as a base module for the PLATO solvers, to balance dynamically, refine and coarsen its distributed mesh.

5. New Results

5.1. Numerical methods

5.1.1. Finite volume methods in curvilinear coordinates

Participants: Hervé Guillard, Boniface Nkonga, Afeintou Sangam.

Finite volume methods are specialized numerical techniques for the solving of divergence equations in strong conservation forms of the form

$$\frac{\partial S}{\partial t} + \text{div}T = 0 \quad (1)$$

where S is a scalar or a vector while T is a vector or a second-order tensor. Using textbook formulas for the expression of the divergence operator in curvilinear coordinates, the use of these coordinate systems instead of the Cartesian one can lead to a loss of the strong conservation form of the equations and introduce a source term in (1). Actually, this is unnecessary and one can show that whatever the system of curvilinear coordinate used, there exists a strong conservation law form of the system. However, when vector equations have to be considered (that is if S is a vector and T a tensor), it is necessary to extract from (1) scalar equations for the components of the vector S and this may destroy the strong conservation form of the equation. Following the work done in [12] where a general method (i.e that does not depend on the curvilinear system used) based on the projection of the discretized vector system have been designed, we have studied this year its application to cylindrical coordinates in the case where the geometry is a torus. This approach is robust and accurate for problems that take place for instance inside tokamak devices for magnetic confinement fusion or in toroidal plasmas occurring in stars and galaxies to take another examples. The method is now implemented in the PlaTo software.

5.1.2. Entropy preserving schemes for conservation laws

Participants: Christophe Berthon [University of Nantes], Bruno Dubroca [CEA/DAM/CESTA and University of Bordeaux 1], Afeintou Sangam.

Entropy preserving schemes for conservation laws

In collaboration with C. Berthon of University of Nantes, and B. Dubroca of CEA/DAM/CESTA and University of Bordeaux 1, we have established a new technique that proves discrete entropy inequalities of finite volume methods to approximate conservation laws. This technique is free of additional numerical models such as kinetic and relaxation schemes. Moreover, our results leads to a full class of entropy preserving schemes for general Euler equations [11]. This proposed technique has been successfully applied to two intermediates states scheme for 10-moments equations with laser source-term in context of Inertial Fusion Confinement. Moreover, the derived procedure is now extended to Saint-Venant model.

5.1.3. Mesh adaptation Methods

Participants: Anca Belme [Projet Tropics], Hubert Alcin [Projet Tropics], Alain Dervieux, Frédéric Alauzet [Projet Gamma, INRIA-Rocquencourt].

This activity results from a cooperation between Gamma, Tropics, Pumas, and Lemma company. See details in Tropics and Gamma activity reports. Its concerns Pumas's subject through the current applications of mesh adaptation to flows with interfaces and the starting application of mesh adaptation to Large Eddy Simulation. It is also planned to use mesh adaptation for simplified plasma models in the context of ANEMOS ANR project.

5.1.4. Parallel CFD algorithms

Participants: Hubert Alcin [Tropics], Olivier Allain [Lemma], Anca Belme [Tropics], Marianna Braza [IMF-Toulouse], Alexandre Carabias [Tropics], Alain Dervieux, Bruno Koobus [Université Montpellier 2], Carine Moussaed [Université Montpellier 2], Hilde Ouvrard [IMF-Toulouse], Stephen Wornom [Lemma].

Pumas is associated to the ANR ECINADS project started in end of 2009, devoted to the design of new solution algorithms for unsteady compressible flows, adapted to scalable parallelism and to reverse (adjoint) Automatic Differentiation. See in the activity report of Tropics. The newer two-level deflation algorithm is currently applied to a simplified plasma model in the context of ANEMOS ANR.

5.2. Plasma physics

5.2.1. Analysis of the drift approximation

Participants: Hervé Guillard, Afeintou Sangam, Philippe Ghendrih [IRFM, CEA Cadarache], Yanick Sarazin [IRFM, CEA Cadarache], Patrick Tamain [IRFM, CEA Cadarache].

Drift approximation consider the slow evolution of the fields in the vicinity of a tokamak equilibrium. These models are typically used to study the micro-instabilities that are believed to be responsible of turbulent transport in tokamaks. Since the drift asymptotic uses a “slow” scaling of the velocity field, the resulting models are significantly different from the full MDH models. This is particularly true with respect to the computation of the electric field that is given by an Ohm’s law in MHD models whereas it is computed by a vorticity-like evolution equation in drift approximations. Drift asymptotic models are extremely interesting from a computational point of view since they save substantial CPU time and computer memory. However, the mathematical and numerical properties of these models are essentially unknown. We have begun a detailed study of the derivation of these models from two-fluid Braginskii-type models in order to establish the range of applicability of these asymptotic models, understand their mathematical properties and relations with the reduced MHD models and design appropriate numerical methods for their approximations.

5.2.2. *Stabilized C1-Finite Element Method for MHD*

Participants: Boniface Nkonga, Marie Martin.

Reduced MHD models are often used in plasma physics and therefore fast compressible waves are not taken into account. In the context of Elms instabilities investigations, full and extended MHD models are to be considered within the framework of high order finite element approximation. In order to obtain predictive simulations with reduced, full and extended MHD models, it is crucial to design numerical strategies that can face some difficulties related to the use of the classical Galerkin methods for convection dominated flows. We have developed a general VMS stabilization strategy for time dependent implicit scheme, which can be applied to MHD models in order to preserved the global accuracy of the initial Galerkin formulation and enforce physical properties as monotony and positivity. Higher order of continuity shape functions are important for accuracy and also help to obtain more robustness of the stabilization as there is no more singularities on elements edges. Numerical implementation and preliminary validations has been performed using C1-Bell shapes functions for triangular meshes. Order five accuracy of the theory is recovered for specific boundary condition. Improvement for general boundary condition is still an open issue. The next step is to combine this Bell shapes functions in the poloidal direction with B-splines functions to achieve accurate representation of complex torus as ITER.

5.2.3. *Two fluid modelling of the Scrape-Off-Layer Plasma*

Participants: Audrey Bonnement, Hervé Guillard, Richard Pasquetti.

A two fluid physical model has been developped in close collaboration with researchers from IRFM. It is based on an hypothesis of stationary magnetic field and the electrostatic and electroneutrality assumptions. However the usual drift assumption, e.g. used in the CEA code TOKAM3D (thesis of P. Tamain), is not used. On the basis of the conservation equations of density, electron and ion velocities, electron and ion temperatures and electrical charges, a set of 10 nonlinear coupled partial differential equations (PDE) can be set up. Our investigations rely on the development of two solvers for this set of PDE. In the frame of her thesis, A. Bonnement (co-direction H. Guillard and R. Pasquetti, financial support of INRIA and PACA region, industrial partner ASSYSTEM) uses a Finite volume / element (FV/FE) approach. The other code, developed by R. Pasquetti, focuses on the use of high order approximations: a spectral element method (SEM) is used in the poloidal plane whereas Fourier expansions are used in the toroidal direction. Each of these codes has allowed in 2010 to solve strongly anisotropic diffusion equations in 2D and axisymmetric 3D geometries for the FV/FE code and in 2D and fully 3D for the Fourier-SEM code. The FV/FE code has also been used to carry out a study of radiative layers evolution in a 2D annular configuration but also in a realistic 3D ITER configuration.

Works carried out during the year 2011 are described hereafter: – On the basis of a Godunov scheme, the FV/FEd approach has been extended to solve the axisymmetric Euler, Navier-Stokes or Braginskii like systems in the jet-tokamak geometry. With respect to Navier-Stokes, the Braginskii system is characterized by anisotropies in the transport coefficients. The mesh is unstructured : A finite element approximation is used for the diffusion terms whereas for the convective terms a finite volume approximation is used on the dual mesh. We have especially focused on the treatment of the toroidal geometry. We have also focused on the

implementation of the so-called Bohm conditions, which are enforced by imposing that at the limiter the fluid velocity is colinear to the magnetic field and that the « parallel Mach number » equals or is greater than one. In these studies the governing equations are completed by constant force terms in order to model the Lorentz forces as well as sources of mass and energy. Such forcing terms allow to preserve an equilibrium state, e.g. obtained on the basis of simulations that make use of the drift assumption (see next paragraph). We have then introduced perturbations of this equilibrium state to study the evolution of the different variables (density, velocity and temperature). Various perturbations have been used to this end, fully random in order to check the stability of the equilibrium or on the contrary localized, in order to roughly model the injection of pellets inside the SOL. It is planned that Audrey Bonnement will defend her thesis in Spring 2012.

The SEM-Fourier 3D code has been extended to solve the full set of governing equations. The unknowns are then the density, the velocity of the center of mass, the electric current and potential, the ion and electron internal energies. In time, this set of PDE is solved by using an IMEX (Implicit – Explicit) approach, based on the combination of an explicit Runge-Kutta scheme for the flux terms and on a DIRK (diagonal implicit Runge Kutta) for the Lorentz terms, which indeed lead to an unconditionally unstable scheme if treated explicitly. A projection method is used to enforce the divergence free constraint of the current, so that an additional solve of a Poisson equation is required to obtain the potential. The Bohm conditions are here implemented by enforcing that the ion pressure is such that the parallel Mach number shows the expected value, i.e. equal or greater than one. The main difficulty that we presently meet is that the initial condition that we use does not correspond to an equilibrium state, so that instabilities quickly develop till yielding an unsteady flow not consistent at the limiter with the Bohm condition. Detailed analyses of these results are presently carried out with Sebastian Minjeaud (new CNRS researcher of the LJAD) to provide relevant explanations of the observed phenomena.

5.2.4. Drift approximation modelling of the Scrape-Off-Layer Plasma

Participants: Marco Bilanceri, Hervé Guillard.

Based on a fluid model using the drift velocity approximation, a simulation method have been designed to compute the flow in the scrape-off-layer of a Tokamak. The variables used by the model are the particle number, the parallel (to the magnetic field) velocity and the electric potential. The spatial approximation uses a finite volume/finite element approach and is therefore easy to apply to complex geometries. Bohms boundary conditions are used on the divertor plates of the machine. The figure 1. shows the density in a poloidal cut where the influence of the separatrix can be clearly seen.

5.3. Fluid Turbulence

5.3.1. Hybrid RANS-LES models

Participants: Anca Belme [Tropics], Alain Dervieux, Bruno Koobus [University of Montpellier 2], Carine Moussaed [University of Montpellier 2], Hilde Ouvrard [IMF-Toulouse], Maria-Vittoria Salvetti [University of Pisa], Stephen Wornom [Lemma].

The purpose of our works in hybrid RANS/LES is to develop new approaches for industrial applications of LES-based analyses. In the foreseen applications (aeronautics, hydraulics), the Reynolds number can be as high as several tenth millions, a far too large number for pure LES models. However, certain regions in the flow can be much better predicted with LES than with usual statistical RANS (Reynolds averaged Navier-Stokes) models. These are mainly vortical separated regions as assumed in one of the most popular hybrid model, the hybrid Detached Eddy Simulation model. Here, “hybrid” means that a blending is applied between LES and RANS. The french-italian team has designed a novel type of hybrid model. This year, the new model has been adapted to very high Reynolds number. Our benchmark is the flow past a circular cylinder, an ECINADS test case. Reynolds number as high as 3 Millions could be passed with good prediction of main properties like mean drag, root mean square of lift fluctuation, base pressure.

5.3.2. Acoustics

Participants: Anca Belme [Tropics], Ilya Abalakin [IMM-Moscou], Alain Dervieux [Tropics], Alexandre Carabias.

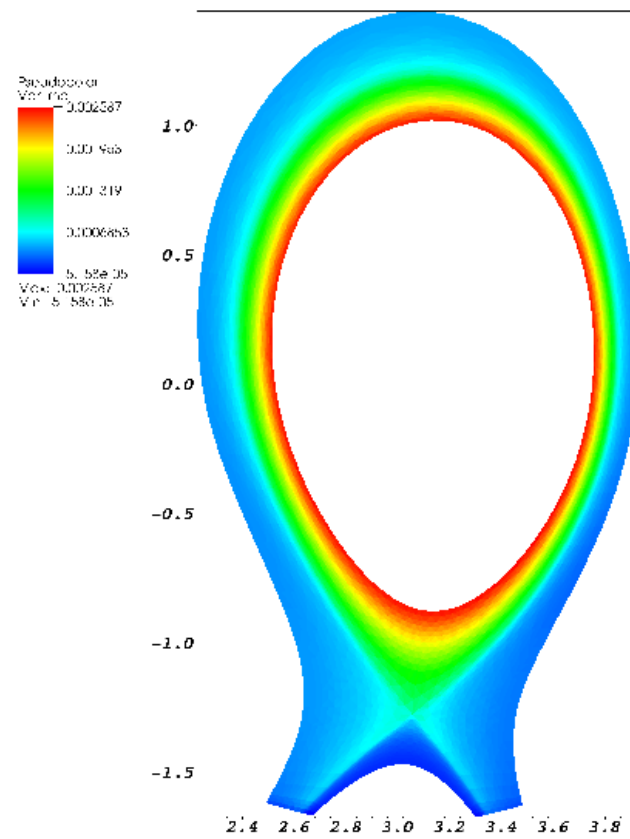


Figure 1. Density plot in a poloidal section of a jet-like Tokamak.

A method for the simulation of aeroacoustics on the basis of these models has been designed and developed by a cooperation between the Computational Aeroacoustics Laboratory (CAL) of Intitute for Mathematical Modeling at Moscow and INRIA. Further applications has been developed by the Russian team from the two common numerical scheme, the Mixed-Element-Volume at sixth-order, and the quadratic reconstruction scheme. This year the cooperation is concentrated on the study by Alexandre Carabias of a new quadratic reconstruction scheme, which extends the one developed by Hilde Ouvrard and Ilya Abalakin. A second research topic was the calculation of acoustic propagation with unsteady mesh adaptation.

5.4. Environmental flows

5.4.1. Mobile bed and sediment transport

Participants: Hervé Guillard, Boniface Nkonga, Marco Bilanceri, Maria-Vittoria Salvetti [University of Pisa, Italy], Imad Elmahi [University of Oudja, Morocco].

The numerical approximation of a model coupling the shallow-water equations with a sediment transport equation for the morphodynamics have been studied. In shallow-water problems, time advancing can be carried out by explicit schemes. However, if the interaction with the mobile bed is weak, the characteristic time scales of the flow and of the sediment transport can be very different introducing time stiffness in the global problem. For this case, it is of great interest to use implicit schemes. The time integration strategy that we have devised is based on a defect-correction approach and on a time linearization, in which the flux Jacobians are computed through automatic differentiation. The aim of the present work is to investigate the behaviour of this time scheme in different situations related to environmental flows. This work has been presented in [18] and [19]

6. Partnerships and Cooperations

6.1. National Actions

6.1.1. ANR ESPOIR

The ANR ESPOIR (Edge Simulation of the Physics Of Iter Relevant turbulent transport) associates the PUMAS team with the M2P2, LPIIM and LATP laboratories in Marseille and IRFM in Cadarache to investigate edge plasma turbulence. The numerical simulation of the plasma wall interactions requires efficient codes and thus the development of advanced numerical methods and solvers. The aim of this project is to study different numerical strategies for edge plasma models in the real geometrical and magnetical configurations corresponding to the future Iter machine.

6.1.2. ANEMOS : ANR-11-MONU-002

ANEMOS : Advanced Numeric for Elms : Models and Optimized Strategies associates JAD Laboratory/Inria (Nice, Manager), IRFM-CEA (Cadarache), “Maison de la Simulation (Saclay)” and Inria EPI Bacchus (Bordeaux)

Elms are disruptive instabilities occurring in the edge region (SOL) of a tokamak plasma. The development of Elms poses a major challenge in magnetic fusion research with tokamaks, as these instabilities can damage plasma-facing components, particularly divertor plates. The mitigation or suppression of large Elms is a critical issue for successful operation of ITER. Goal for ANEMOS is to develop and improve numerical tools in order to simulate physical mechanisms of Elms and qualifies some strategies for their control. We then need to design efficient numerical strategies on the most advanced computers available such as to contribute to the science base underlying of proposed burning plasma tokamak experiments such as ITER.

6.2. International Grants

6.2.1. 3+3 Euro méditerranée project Mhycof

This project associates the University Ibn Zohr, Agadir, the Mohamedia Engineering school, the university of Oujda in Morocco, the University of Pisa (Italy) the Universidad de Zaragoza (Spain), the Polytechnic school of Tunisia, the university of Paris 13 and Inria Sophia-Antipolis to develop numerical modelling of coastal flows.

6.2.2. Bilateral Scientific Relations

6.2.2.1. Institute of Mathematical Modeling, Moscow : Acoustics

Participants: Alain Dervieux, Tatiana Kozubskaya [IMM-Moscow], Ilya Abalakin [IMM-Moscow].

The long-term scientific collaboration with IMM on acoustics focussed this year on new reconstruction schemes for noise propagation with linear and non-linear hyperbolic models.

6.2.2.2. Ingegneria Aerospaziale, university of Pisa : Turbulence Modeling & Environmental flows.

Participants: Hervé Guillard, Alain Dervieux, Bruno Koobus [Montpellier 2], Simone Camarri [University of Pisa], Maria-Vittoria Salvetti [University of Pisa].

The long-term scientific collaboration with the Department of Ingegneria Aerospaziale at university of Pisa has concerned during last years complex fluid flows with cavitation. It continues with the development of hybrid models for turbulent flows and a common work on the transport of sediment in shallow water flows in the context of the EuroMed 3+3 project MHyCoF.

6.2.2.3. Texas A & M : High order methods

Participants: Jean-Luc Guermond [Texas A & M University], Richard Pasquetti.

This collaboration involves the development of techniques to compute solutions of non-linear hyperbolic problems by the use of artificial viscosity. The main idea is here to introduce a non-linear viscous term whose strength is derived from the residual of the entropy equation associated to the considered PDE.

6.2.2.4. University of Pilsen, Czech Republic

Participants: Petr Vanek [University of Pilsen], Hervé Guillard.

The collaboration with the University concerns the development of algebraic multigrid solvers for large scale problems encountered in physics modelling and engineering.

7. Dissemination

7.1. Animation of the scientific community

7.1.1. Conference Program Committees

- On behalf of GAMNI, H. Guillard is member of the Committee "Computational Fluid Dynamics" of ECCOMAS : European Community of Computational Methods in Applied Sciences
- H. Guillard was member of the scientific committee of the FVCA6 conference held in June 2011 in Prague - Czech republic.

7.1.2. Editorial activities

- H. Guillard has been the guest editor in charge of the section Fusion Plasma of the special issue of the Journal of computational physics (Volume 231, Issue 3, February 2012) devoted to Computational Plasma physics.

- E. Sonnendrucker (EPI CALVI) and H. Guillard have been editors of the proceedings of NMCF09 (Numerical Models for Controlled Fusion 09) in a special issue of the journal Discrete and Continuous Dynamical Systems, Series S DCDS-S 5-2 April 2012.
- E. Cancès, N. Crouseilles, H. Guillard, B. Nkonga and E. Sonnendrücker have been editors of the proceedings of CEMRACS'10 research achievements: Numerical modeling of fusion in the journal ESAIM: Proceedings Vol. 32 (October 2011)

7.1.3. Ph.D. thesis and HDR Committees

Alain Dervieux was in the PhD jury of

- Géraldine Olivier, Paris 6, 22 april 2011
- Anca Belme, University of Nice, 8 december 2011

and acted as “rapporteur” for the PhD Thesis of :

- Thibaud Marcel, Toulouse, 16 november 2011

Hervé Guillard was in the PhD jury of :

- Damien Fournier, PhD Thesis, "Analyse et Développement de Méthodes de Raffinement hp en Espace pour l'Equation de Transport des Neutrons ", University of Provence, October 10 2011

and acted as “rapporteur” for the PhD Thesis of :

- Floraine Cordier, "Numerical methods for limit problems in two-phase flow problems", Université Paul Sabatier, Toulouse, 14 Novembre 2011
- Walid Kheriji, “Méthode de correction de pression pour les équations de Navier-Stokes compressibles”, University of Provence, 28 Novembre 2011
- Pierre-Elie Normand, " Application de méthodes d'ordre élevé en éléments finis pour l'aérodynamique", Université de Bordeaux 1, 13 Décembre 2011

Boniface Nkonga was as chair in the PhD jury of

- M. KRAUSHAAR, Institut National Polytechnique de Toulouse.
- A. RATNANI, Université de Strasbourg.

acted as “rapporteur” for the PhD Thesis defences of

- J. VERGHAEGEN, Université de Marseille, 2011,
- G. OLIVIER, Université Pierre et Marie CURIE (Paris VI).

and as “rapporteur” for the HDR defence of

- G. TCHUEN, Univ. of Provence, Marseille.

R. Pasquetti was in the PhD jury of the following thesis defences:

- Laura Lazar, University of Nice, 19-04-2011
- Luca Biancofiore, University of Nice, 06-06-2011
- Adel Haddad, (Chair), University of Provence, 15-12-2011

7.2. Teaching

7.2.1. Doctoral formation

- H. Guillard is member of the "école doctorale" ED 353 council : Sciences pour l'Ingénieur : Mécanique, Physique, Micro et Nanoélectronique of the university of Provence.

7.2.2. Summer schools and tutorials

- B. Nkonga, “Magnetized plasma : About the Braginskii’s Fluid Model”, *3rd summer school of the Large Scale Initiative "FUSION"*, Paris, September 26-30, 2011

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Major publications by the team in recent years

- [1] I. ABALAKIN, A. DERVIEUX, T. KOZUBSKAYA. *On the accuracy of direct noise calculations based on the Euler model*, in "Computational Aeroacoustics", G. RAMAN (editor), Multi-Science Publishing, Brentwood, UK, 2008, p. 141-166.
- [2] B. BRACONNIER, B. NKONGA. *Relaxation method for low Mach number compressible multiphase flow*, in "Journal of Computational Physics", 2009, vol. 228(16), p. 5722-5739.
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Articles in International Peer-Reviewed Journal

- [11] C. BERTHON, B. DUBROCA, A. SANGAM. *A local entropy minimum principle for deriving entropy preserving schemes*, in "SIAM Journal of Numerical Analysis", 2012, accepted for publication.

- [12] A. BONNEMENT, T. FAJRAOUI, H. GUILLARD, M. MARTIN, A. MOUTON, B. NKONGA, A. SANGAM. *Finite volume method in curvilinear coordinates for hyperbolic conservation laws*, in "ESAIM:Proc.", 2011, vol. 32, p. 163-176.
- [13] A. BOURGEADE, B. NKONGA. *Numerical simulations of the focal spot generated by a set of laser beams*, in "ESAIM: Proc.", 2011, vol. 32, p. 1-17.
- [14] J. GUERMOND, R. PASQUETTI, B. POPOV. *Entropy viscosity method for non-linear conservation laws*, in "J. of Comp. Phys.", 2011, vol. 230 (11), p. 4248-4267.
- [15] L. LANCIA, M. GRECH, S. WEBER, J.-R. MARQUES, L. ROMAGNANI, M. NAKATSUTSUMI, P. ANTICI, A. BELLUE, N. BOURGEOIS, J.-L. FEUGEAS, T. GRISMAYER, T. LIN, P. NICOLAÏ, B. NKONGA, P. AUDEBERT, R. KODAMA, V. T. TIKHONCHUK, J. FUCHS. *Anomalous self-generated electrostatic fields in nanosecond laser-plasma interaction*, in "Phys. Plasmas", 2011, vol. 18(1).
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- [24] H. OUVRARD, M. SALVETTI, S. CAMARRI, S. WORNOM, A. DERVIEUX, B. KOOBUS. *LES, variational multiscale LES and hybrid models*, F. MAGOULES (editor), CRC Press, Boca Raton, London, New York, Washington D.C., 2012, to appear.

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