Milestone experiment: stratified and rotating turbulence in the Coriolis platform

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Strongly stratified turbulence is a possible interpretation of oceanic and atmospheric measurements. However, this regime has never been produced in a laboratory experiment because of the two conditions of very small horizontal Froude number $F_h$ and large buoyancy Reynolds number $R$ which require a verily large experimental facility. We present a new attempt to study strongly stratified turbulence experimentally in the Coriolis platform. The flow is forced by a slow periodic movement of an array of six vertical cylinders of 25 cm diameter with a mesh of 75 cm. Five cameras are used for 3D-2C scanned horizontal particles image velocimetry (PIV) and stereo 2D vertical PIV. Five density-temperature probes are used to measure vertical and horizontal profiles and signals at fixed positions. We will show that we managed to produce strongly stratified turbulence at very small $F_h$ and large $R$ in a laboratory experiment. We will present how we used open-source and open-science methods and tools for this study.

Dust-loaded vortices in protoplanetary disks

Pierre Barge LAM

Anticyclonic vortices can grow in protoplanetary disks due Rossby wave or baroclinic instabilities. Solid particles embedded in the gas are easily trapped by such vortices and tend to concentrate in their core. We will present numerical simulations to describe the confinement of the solid particles and the turbulent evolution of the vortex due to the back reaction of the particles.

Numerical modelling of rough Rayleigh-Bénard convection

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We present direct numerical simulations of buoyant convection over a rough heated plate placed in a Rayleigh Bénard cell. The roughness is introduced by a set of cubic obstacles regularly spaced, modelled by using an immersed boundary method. This study aims at clarifying interactions between the large scale circulation filling the box, plume emission and the enhancement of the heat transfer. The simulations are performed in a box-shaped cell at fixed Prandtl number ($Pr = 4.38$) with the Rayleigh number $Ra$ ranging from $5 \times 10^5$ to $10^9$. As expected, results show an increase of heat transfer (measured by the Nusselt number $Nu$), when the mean thermal boundary-layer thickness becomes comparable with the obstacle height; in agreement with previous experimental and numerical studies from the literature (for example [2, 1]). By varying $Ra$, we investigate the successive regimes of the turbulent heat transport, from inactive roughness to a regime with an increase of the heat transfer scaling. Fluctuation dynamics and boundary layer structure near roughnesses will be reported (figure 1). References
Large deviation theory and rare event computations in geophysical fluid dynamics

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Résumé:
For some aspects of geophysical fluid dynamics, rare dynamical events may play a key role. In the recent past, new theoretical and numerical tools have been developed in the statistical mechanics community, in order to specifically study such rare events. Those approaches are based on large deviation theory for complex dynamical systems. We will present applications in two classes of problems. The first class of problems are rare trajectories that suddenly drive the complex dynamical system from one attractor to a completely different one. As an example we will discuss very rare transitions between attractors with respectively two or three alternating jets in barotropic turbulence. The second class of problems are extreme events that have huge impacts, for instance extreme heat waves. We will discuss the probability of extreme heat waves for the Earth dynamics (primitive equation turbulence).

Rotating turbulent flows to investigate zonal jets on the gas giants

The strong east–west jet flows on the gas giants, Jupiter and Saturn, have persisted for hundreds of years. Yet, experimental studies cannot reach the planetary regime and similarly strong and quasi-steady jets have been reproduced in numerical models only under simplifying assumptions and limitations. Two models have been proposed:
a shallow model where jets are confined to the weather layer and a deep model where the jets extend into the planetary molecular envelope. Here we show that turbulent laboratory flows naturally generate multiple, alternating jets in a rapidly rotating cylindrical container. The observed properties of gas giants' jets are only now reproduced in a laboratory experiment emulating the deep model. In parallel, we adopt the approach of complete three-dimensional Global Climate Models (GCMs) solving for hydrodynamical Navier-Stokes equations and setting a Saturn's like "shallow-forcing" climate model. Our findings demonstrate that long-lived jets can exist in our laboratory and numerical experiments with comparable statistical flow properties than the one observed on the gas giants.

* Claude Cambon
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We first present a rapid review of work carried out in collaboration with Aziz Salhi (Tunis), Thierry Lehner (Observatoire Paris -Meudon) and Fabien Godeferd (LMFA), among others. In the most general case, the quasi-linear dynamics of the fluctuation field is studied in the presence of constant shear rates S, of rotation (Coriolis parameter f) of density stratification (Brümt-Wäsala N frequency) and of field. The SSA (Shearing Sheet Approximation, see Balbus & Hawley 1998) to represent the local effect of the differential rotation in the rotating disc of Taylor-Couette type for a simple model of accretion disc by the combination of S and f. Linear stability is governed by the square sign of the epicyclic frequency f (f-S) and is modified by the radial or axial stratification (N) and the axial magnetic field (B). The generalized scattering laws are established for exponential instability, and we identify ranges of parameters for transient growth that can contribute to the transition to turbulence more efficiently than exponential instabilities, in the Chagelishvili et al. (A & A, 2003). Beyond the quasi-linear approximations, we present the first results of a model with strong fluctuation-fluctuation interaction of EDQNM type (Eddy Damped Quasi-Normal Markovian, Orszag 1970) for rotating shear. The current study applies to linearly stable (f (fS)> 0) and unstable (f (fS) <0) situations by overlapping the strategy of study and modeling stable stratified cases (N2> 0) and unstable (N2 <0), with recent results (Burlot et al., 2015).

*Antoine Campagne

Title: Weak gravity wave turbulence in the Coriolis platform.
Authors: Antoine Campagne, Quentin Aubourg, Roumaissa Hassaini, Ivan Redor, Nicolas Mordant

Ocean surface can be described as a large ensemble of nonlinear gravity waves. In the limit of vanishing nonlinearity, the Weak Wave Turbulence theory applied to surface gravity waves predicts provides a possible explanation of such system. This theory predicts a net energy transfer towards small scales (large temporal frequencies) through 4-waves interactions.

Our recent experimental study of nonlinear gravity waves provided a carefully analyzes the wave-wave interactions. By computing high order correlations, we highlighted the presence of significant 3-waves coupling which is precluded by the theory but we observed no 4-waves correlation. This first study suggests a lack of statistical convergence as a possible explanation for this observation. We present a similar laboratory experiment dedicated to probe the statistical properties of turbulent gravity waves with a much larger dataset. An isotropic state of interacting gravity waves is maintained in the Coriolis facility (13 m diameter circular wave tank) by exciting waves at 0.6 Hz by wedge wavemakers. Measurements of the surface elevation is performed with a stereoscopic technique (resolved both in space and time) and capacitive probes. We identify the active nonlinear interaction processes thanks to a significantly higher statistical convergence of 3-waves and 4-waves correlations.

*Yuli D Chashechkin

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Differential fluid mechanics

The system of equations of a state and for the conservation of matter, momentum, energy and concentration of matter with physically justified boundary conditions on solid walls and a free surface analyzed taking into account the compatibility condition determining its rank and the order of the linearized version. In a media with a weak dissipation, the complete solution of the linearized system includes regularly and singularly perturbed functions that describe dynamics, global and fine structure of flows. Some effects of non-linearity leading to generation of new components were analyzed. The constructed solutions of the theory of internal wave problems agree with the data of numerical solutions of the complete set and laboratory experiments on the generation of periodic or attached waves and patterns of flow around obstacles. Limiting cases and extrapolations on the environment are discussed.

References


Submesoscale eddies and the dispersion of a tracer patch

Mathieu Morvan and Xavier Carton

Laboratoire d’Océanographie Physique et Spatiale – IUEM – UBO 29280, Plouzané, France

First we perform a simple study of dispersion using a fixed advecting flow (a line of vortices) in a 2D model; it shows the various regimes (trapping, ejection, chaotic dispersion) of tracer evolution. Then we use a 3D (hydrostatic) fluid flow model, at high resolution, to study the effect of a row of large vortices on coastal topography. The eddy friction on the topography, and the detachment of small (submesoscale) eddies, are evidenced. They wrap the tracer and carry it away from the topography. The influence of the large eddy flow on the formation of small eddies, on their shape and lifetime, and on tracer dispersion are discussed. Data from measurements at sea are used to assess the realism of these results.

Andrés Castillo-Castellanos

2-D Reduced model for severely confined Rayleigh-Bénard convection
Andrés Castillo-Castellanos1,2,4, Anne Sergent 2,3 & Maurice Rossi 1,4
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We consider Rayleigh-Bénard convection cells with a severe lateral confinement for tranversal aspect ratios $1=128 ? 1=8$. Fully resolved 3-D DNS for $Pr = 4:38$ and $Ra = 10^7 ? 10^9$ are obtained using the Basilisk code [5]. Increasing the degree of confinement, a transition of regime is observed towards a gradual loss of three-dimensionality, the formation of turbulent vertical channels [1], and thereafter the appearance of a nearly conductive regime [3, 4]. For this regime, we perform an energetic analysis in terms of different global energy transfer rates in a similar way that in [2]. In addition, we developed a 2.5-D reduced model with inertial corrections using a weighted residuals method. This simplified model is able to reproduce different flow patterns inside the confined regime (figure 1). The DNS and the simplified model provide similar results for the average Nusselt number as a function of $Ra$ and $??$, and agree with previous DNS results [4]. This is also valid for the comparison of fluctuations (RMS temperature and velocities).

References

*Pierre-Philippe Cortet

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2, Laboratoire LEGI, CNRS, Université Grenoble Alpes, France

I will present PIV measurements of the wake of inertial waves produced by a cylinder in horizontal translation in a fluid rotating around the vertical axis. We will discuss the effects of the size and shape of the moving object and of the non-linearities as a function of the Rossby and Reynolds numbers. This situation notably finds applications in the wake produced by a current over a ridge topography.

* Thierry Dauxois

Instabilities of Internal Gravity Wave Beams,

Thierry Dauxois

Work done in collaboration with Sylvain Joubaud, Philippe Odier and Antoine Venaille
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Internal gravity waves play a primary role in geophysical fluids: they contribute significantly to mixing in the ocean and they redistribute energy and momentum in the middle atmosphere. Until recently, most studies were focused on plane wave solutions. However, these solutions are not a satisfactory description of most geophysical manifestations of internal gravity waves, and it is now recognized that internal wave
beams with a confined profile are ubiquitous in the geophysical context.

We will discuss the reason for the ubiquity of wave beams in stratified fluids, related to the fact that they are solutions of the nonlinear governing equations. We will focus more specifically on situations with a constant buoyancy frequency. Moreover, in light of recent experimental and analytical studies of internal gravity beams, it is timely to discuss the two main mechanisms of instability for those beams. i) The Triadic Resonant Instability generating two secondary wave beams. ii) The streaming instability corresponding to the spontaneous generation of a mean flow.


* Bruno Deremble

Eddy-mean flow interaction in a multiple-scale ocean model

Quasi-geostrophic (QG) dynamics has been the theoretical workhorse in physical oceanography for the last several decades. However, QG suffers in realism in at least two potentially important ways. First, while the beta effect appears in the potential vorticity, elsewhere, the Coriolis parameter appears as a constant. Second, mean state stratification is specified and assumed independent of horizontal position. To overcome these two limitations, we use a multiple scale expansion to derive a quasi-geostrophic equation forced by a large-scale planetary geostrophic solution. Instabilities in the large-scale flow generate small-scale eddies, which then evolve according the non-linear dynamics away from their generation site. The average feedback of these oceanic eddies is to rectify the large-scale flow by flattening the isopycnal surfaces and maintain a sharp western boundary current.

* Davide Faranda

"Detecting changes in the dynamical properties of the North Atlantic atmospheric circulation in the past 150 years via a dynamical systems approach".

Davide Faranda
LSCE - CNRS

It is of fundamental importance to evaluate the ability of climate models to capture the large-scale atmospheric circulation patterns. In the context of a rapidly changing climate, it is equally crucial to quantify the robustness of the modeled changes in the large-scale atmospheric dynamics. Here we approach this problem from an innovative point of view based on dynamical systems theory. We characterize the atmospheric circulation over the North Atlantic in the CMIP5 historical simulations (1851 to 2000) in terms of two instantaneous metrics: local dimension of the attractor and stability of trajectories. We then use these metrics to compare the models to the 20CR reanalysis over the same historical period. The comparison suggests that: i) all the models capture the mean attractor properties and models with finer grids perform better; ii) extremes of the dynamical systems metrics match the same large-scale patterns in most of the models; iii) changes in the attractor properties observed for the 20CR reanalysis - studied by dividing the 1851-2000 period into 3 subperiods of 50 years each - are not reproduced by the models; iv) some models present significant changes in the dynamical systems metrics over time but there is no agreement on the direction and on the intensity of the shifts.

* Benjamin Favier

Rayleigh-Bénard convection with a melting boundary

Benjamin Favier, Laurent Duchemin

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We present direct numerical simulations of Rayleigh-Bénard convection where the top rigid boundary can melt. This is achieved by coupling a phase-field approach, classically used for microscopic solidification problems, and a pseudo-spectral code able to solve the Boussinesq equations. We discuss the dynamical evolution of the topography associated with the advective heat flux, and how it back reacts on the flow structure and stability. This simple model is a first step toward considering more general dynamical melting problems, including turbulence in the fluid phase and binary mixtures.

*Eduard Fereisl

Mathematical in fluid mechanics

We discuss solvability of systems of PDE's arising in modeling the motion of fluids. Several concepts of solutions will be introduced and their relevance in applications and numerical experiments examined. We also show examples how the theory can be applied to the study of singular limits.

*Philippe Fraunié

High resolution measurements of the sea upper layer

Philippe Fraunié, Denis Bourras, Hubert Branger, Guillemette Caulliez, Jean Luc Devenon, Ivane Pairaud, Alexei Sentchev,

Field and laboratory measurements of fine structure in the ocean – atmosphere interface and ocean surface layer are presented. Especially, HF radars, instrumented drifted floating systems and underwater autonomous vehicles are deployed to investigate secondary flows and transient Ekman layers.

* Sébastien Fromang

Shear-driven instabilities and shocks in the atmospheres of hot Jupiters

Sébastien Fromang

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Hot Jupiters are giants gaseous planets orbiting very close to their central star. Because of the extreme irradiation they receive, the dynamics of the atmosphere is different from anything known on Earth or in the solar system. In the past few years, general circulation models of the atmosphere of hot Jupiter have indeed shown in particular the existence of a supersonic eastward equatorial jet, raising the question of the jet stability and the possible presence of shocks in hot Jupiter atmospheres, an issue widely discussed in the literature in the past few years but not yet settled.

In this talk, I will present the results of a series of high resolution simulations specifically designed to address these issues. I will show that the jet is indeed destabilized by two instabilities of Kelvin-Helmoltz type respectively associated with the meridional and vertical velocity shears. These instabilities induce significant flow variability and weak shocks in the upper layers of the atmosphere and may affect their temperature-pressure profile as well as the internal structure of hot Jupiters.
We present a study on the path instability of a freely ascending air bubble in water and silicon oil at varied Bond numbers (ratio of body forces to surface tension) and Galileo numbers (ratio of gravitational force to viscous force) close to the onset of instability. Below a certain threshold of the Galileo number, the path of the bubble remains straight. But above a critical Galileo number (related to the size of the bubble) a new regime sets in and the bubble changes its shape and follows a zigzagging path. Our experimental investigations of the path instability of bubbles are compared to recent numerical simulations taking fully into account the shape deformation and oscillation of shape of the rising bubbles. These simulations changed our understanding of the origin of instability at the onset.

In our experimental set up, bubbles of variable size are released in a rectangular tank filled with silicon oil known to present no problem of surface impurities. Bubble path is recorded by a fast camera and is post-processed to determine the size and shapes of the bubbles and their trajectory in the fluid. Bond and Galileo numbers are calculated based on the volume of bubble and on the physical properties of the working fluid used.

* C. Gissinger,

Magnetically-driven oceans on Jovian satellites

C. Gissinger, L. Petitdemange

During the last decade, data from Galileo space missions have added strong support for the existence of subsurface liquid oceans on several moons of Jupiter. For instance, it is now commonly accepted that an electrically conducting fluid beneath the icy crust of Europa’s surface may explain the variations of the induced field measured near the satellite.

These observations have raised several important questions regarding the size and the salinity of the subsurface liquid shell. It is also unclear how the salty water remains liquid, and the hydrodynamics of such oceans is mostly unknown. These questions are of primary importance since Europa is often considered as a good candidate for the presence of life beyond the Earth.

Here, we present the first numerical modeling of the magnetohydrodynamic (MHD) flow generated in Europa’s interior: due to Jupiter’s rotation with respect to Europa and the inclination of Jupiter’s magnetic dipole moment, we show that the Lorentz force induced by the time-varying Jovian magnetic field is able to generate an oceanic flow of a few km/h. We obtain a scaling law for the prediction of the mean oceanic velocity, the surface magnetic field and the total heating generated inside the ocean of Europa. Finally, by comparing our model to Galileo observations, we make predictions on both the thickness and the electrical conductivity of the ocean of different Jovian’s satellites.

* Philippe Gondret

Laboratory generation of a tsunami wave by a granular collapse

Manon Robbe-Saule, Cyprien Morize, Yann Bertho, Alban Sauret and Philippe Gondret

Laboratoire FAST - CNRS : UMR7602,
We present small-scale laboratory experiments on the tsunami wave generation by the sudden collapse of an initial granular column. Both instantaneous granular front and water surface are tracked from video image processing and allow for a detailed analysis of the grain/water/air interaction and a measurement of the size of the created wave. Many physical parameters are varied such as the width and height of the initial granular column and the water depth. The results are analysed in terms of scaling laws for the wave amplitude as a function of the initial mass and aspect ratio of the granular collapse.

* Jonathan GULA

Energy transfer in high-resolution realistic ocean simulations

Jonathan GULA

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The focus is on scale interactions in realistic ocean flows, at the surface and in the interior. These interactions involve energy transfer between the mesoscales (>30 km), submesoscales (<30 km) and internal waves (including near-inertial waves, lee waves, and internal tides). We use regional realistic simulations with the model CROCO at submesoscale-resolving resolution (from dx = 750 m to 200 m) over different regions of the ocean (Gulf Stream, Sargasso Sea, Mid-Atlantic Ridge, Subpolar gyre, etc.) including realistic topography, high-frequency winds and tidal forcings. We discuss the energy budgets and energy fluxes for the different regions (corresponding to different oceanic regimes) and their seasonal variations. The different sources of internal waves are further analyzed by running simulations with/without high-frequency wind forcings and with/without tidal forcings. Finally we investigate the non-hydrostatic effects on internal waves propagation and breaking, and their impact for the energy budget.

* Taoufik Hmidi

Analytical and numerical studies of relative equilibria for quasi-geostrophic shallow water model

Taoufik Hmidi

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We shall discuss analytical and numerical aspects of long-lived structures for QGSW model. We prove in particular the existence of simply connected patches (potential vortices uniformly distributed in planar simply connected sets) rotating with uniform angular velocities and with m-fold symmetry. We shall also investigate the global structure of the two-fold branch living close to Kirchhoff ellipses for large Rossby deformation radius.
This is a joint work with D. Drtischel and C. Renault.

*Dominique Jault (ISTerre)

Torsional Alfvén waves in a rotating spherical shell: transmission and reflection in the Earth's outer core

The indirect detection of torsional Alfvén waves riding in the Earth's core has allowed to estimate that the magnetic field intensity within the core is a few mT. In the Earth's core torsional waves consist of geostrophic motions coupled by the background magnetic field but the torsional wave equation has long been studied in other contexts: it governs also the propagation of long gravity waves in a channel of varying depth and width. We can learn from the transmission and reflection of sound in a tube of varying cross section too. However, reflection of the torsional waves at the core equator and at the TC, the imaginary cylinder circumscribing the solid inner core, and transmission at the TC are specific to these waves. I will discuss these mechanisms, which give important informations on top of the typical intensity of the Earth's field, such as the electrical conductance of the lowermost mantle, next to the core.

*Laurent Lacaze

Numerical modeling of immersed granular flows

Laurent Lacaze, Edouard Izard, Joris Bouteloup, Thomas Bonometti

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Modeling granular flows immersed in a viscous fluid remains a challenging task due to the large range of spatial scales involved in these systems, i.e. from the description of the flow around each individual grain to the scale of deformation of the granular medium. These granular flows are involved in many natural hazards such as avalanches or debris flows, and the prevention of the associated risk still suffers a complete set of parametrization for large scale models dedicated to geophysical applications. It thus requires a description of the physical process at the grain scale including grain-grain interaction and fluid-grain interaction. We present a study on the granular collapse immersed in a fluid as a canonical configuration of such geophysical applications. A description of the flow is given at two different scales using Immersed-Boundary-Methods/Discrete-Element-Method (IBM/DEM) and Average-Navier-Stokes/Discrete-Element-Method (ANS/DEM) approaches. The granular phase is therefore always modeled using a Lagrangian description including the modeling of multi-grains contact. On the other hand the fluid phase is solved either at the grain scale (IBM) or at the scale of several grains (ANS). These two approaches allow to extract the main features of the flow from a different perspective as a function of the non-dimensional Stokes number, and also to confront closure models needed in the ANS method to the resolved IBM method.

*Raphael Laguerre

Poster

Precession driven dynamos in spherical shells at moderate Ekman number

R. Laguerre, J. Noir, N. Schaeffer, D. Cébron, V. Dehant
Precession has been proposed as an alternative power source for planetary dynamos and principle of future dynamo experiments. Previous hydrodynamic studies suggested that precession can generate very complex flows in planetary liquid cores. In the present study we aim at shedding some light on the influence of an inner core onto the precessional instabilities. We investigate numerically the flow in the outer liquid core at moderate Ekman numbers (~1e-5) driven by the precession of the mantle and the inner core. Following the work by Lin et al.[1], we derive the stability diagram of the flow for a wide range of control parameter. The route to turbulence through resonance of inertial modes and the possibility of inverse cascade of energy giving rise to large scale vortices in the bulk of the flow are also studied in details. Following the pioneering work of A.Tilgner[2], the dynamo effect is demonstrated numerically in precession driven flow in spherical shells. First conclusions about the behaviour of the dynamo at low Ekman numbers and low Prandtl numbers are drawn.

[1], A. Tilgner, “Precession driven dynamos”, Physics of Fluids 17, 034104 (2005)

* Eric Lajeunesse

Equilibrium morphology of laminar rivers
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The flow of a viscous fluid over a bed of plastic sediment spontaneously generates single-thread channels. With time, these analogues of alluvial rivers reach a reproducible steady state, exhibiting a well-defined width and cross section. In the absence of sediment transport, their shape conforms with the threshold hypothesis which states that, at equilibrium, the combination of gravity and flow-induced stress maintains the bed surface at the threshold of motion. If the river transports sediments, gravity pulls the moving grains towards the center of the channel. Because of bed roughness, these moving grains follow a random walk in the transverse direction. Consequently, sediments diffuse towards the less active areas of the bed, thus counteracting gravity by continuously rebuilding the river banks. As the sediment discharge increases, this balance requires a wider and shallower channel, until the river becomes unstable. Based on these experimental observation, we propose a theory explaining how the channel selects its size and slope for given flow and sediment discharges.

*Guillaume Lapeyre: Relative Dispersion in QG and SQG Turbulence

Statistical properties of turbulent fluids depend on how local are the energy transfers among scales, i.e. whether the energy transfer at some given scale is due to the eddies at that particular scale, or it is due to eddies at larger (nonlocal) scale. This locality in the energy transfers may have consequences on the relative dispersion of passive particles but this is still poorly understood. Two quasigeostrophic models are well known that may represent either nonlocal scale interactions or local scale interactions: the standard barotropic (QG) model and the surface quasi-geostrophic (SQG) model.

We examine the relative dispersion statistics for each class of model, both as a function of time and as a function of scale, and compare to
predictions based on phenomenological arguments. We also contrast these results with spectral energy transfers that are observed for each model in order to see if localness in energy cascades is related with localness of relative dispersion regimes.

*Michael Le Bars

Inertial and internal-inertial waves in planetary interiors: excitation and non-linearities

Thomas Le Reun, Michael Le Bars, Benjamin Favier, Alex Grannan, Jon Aurnou

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Libration and tides are relevant alternatives to convection in order to drive strong flows in planetary fluid layers, related for instance to dissipation in sub-surface oceans and to dynamo generation in planetary cores. We will review our recent experimental and numerical studies on instability processes responsible for the excitation of those flows, as well as their non-linear saturation. In particular, we will describe a new regime of inertial-wave turbulence that is expected in the geophysical limit, with unconventional temporal and spatial repartition of the energy.

*S. Le Dizès

Internal shear layers in a stratified and rotating fluid: structure and meanflow correction.

IRPHE, CNRS, Aix Marseille University, Centrale Marseille

In a stratified and rotating fluid, internal shear layers are systematically generated when an object oscillates at a frequency between the buoyancy frequency and the vorticity of the fluid. In this talk, I first show that these viscous layers have a generic self-similar structure in the limit of large Reynolds numbers. Then, I consider the reflection of these layers on a boundary. I show that a strong meanflow correction is generated close to the reflection point. I provide its asymptotic structure in the limit of large Reynolds numbers according to the boundary inclination. I finally discuss applications of the results in the context of oceanography (tide) and planetary interiors (libration).

* Patrice Le Gal

The Barostrat Instability: the baroclinic instability in a rotating stratified fluid

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The differentially heated rotating annulus is a widely studied experimental apparatus for modeling large-scale features of the mid-latitude atmosphere (planetary waves, cyclogenesis). In the classic set-up, a rotating cylindrical tank is divided into three coaxial sections: the innermost domain is kept
at a lower temperature, whereas the outer rim of the tank is heated. The working fluid in the annular gap between thus experiences a radial temperature difference. These boundary conditions imitate the meridional temperature gradient of the terrestrial (or more generally planetary) atmosphere between the poles and the equator. The Coriolis effect arising due to the rotation of the tank modifies this convective pattern and yields a strong zonal flow with directions alternating with depth. Then at large enough values of the rotation rate, this azimuthally symmetric basic flow becomes unstable and leads to the well known baroclinic instability with the formation of cyclonic and anticyclonic eddies in the full water depth. In the present work, we study a modified version of this experiment, in which besides the aforementioned radial temperature difference – a vertical salinity stratification characterized by a buoyancy frequency $N$ – is also present. Whereas the baroclinic instability experiments are classical models of mid-latitude atmospheric dynamics, our aim here is to create a juxtaposition of convective and motionless stratified layers in the laboratory. We expect therefore that our original experimental arrangement can mimic the tropospheres and stratospheres of planetary atmospheres or the surface turbulent sea layers above deeper stratified waters. Let us stress in particular that the exchange of momentum and energy between these layers by the propagation of internal gravity waves for instance is a major issue in atmospheric sciences, in particular for the parametrization of subgrid hydrodynamics scales of weather forecast models.

*Leo Maas

Waves shaped by geometry

Leo Maas (Utrecht University & NIOZ, Netherlands Inst. for Sea Research) In Geophysical and Astrophysical Fluids, anisotropic factors as gravity and rotation manifest themselves in hydrostatic and cyclostrophic equilibria, which provide elasticity to these fluids. Perturbations of these equilibria therefore experience restoring buoyancy and Coriolis forces, respectively, which lead to linear internal waves. These waves obey a dispersion relation, complementary to that for surface waves. They couple the wave’s frequency to the wave vector direction, instead, as for surface gravity waves, to its magnitude. This is symptomatic for waves in anisotropic media. Together with a nonuniform shape of a fluid domain it leads to many features (such as non-Snellian reflection; spatial, spectral and parametric selfsimilarity, and wave attractors) that are normally associated with nonlinear dynamics.

Here it will be argued that the importance of the shape of fluid domains, and the appearance of quasi-nonlinear features, is not restricted to internal waves, but may pervade classical linear wave problems too.

* Florence Marcotte

UMR 7190, à l'Institut Jean le Rond d'Alembert de l'UPMC.

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Abstract: Mixing is an ubiquitous process in environmental flows. In order to better understand the mechanisms involved in achieving well-mixedness of a stratified flow, we investigate the optimisation of mixing in stratified, 2D Poiseuille flow by means of a fully non-linear direct-adjoint looping method, where the initial perturbation leading to maximal mixing efficiency over a given time horizon is determined. A recent study by Foures et al. (2014) has demonstrated that the widely-used approach consisting in maximizing the time-averaged kinetic energy surprisingly results in largely sub-optimal suppression of a passive scalar variance. We extend these results to the case of an active scalar and show how
buoyancy modifies the optimal-mixing strategy.

*Claire Menesguen, LOPS

Destabilization of an oceanic meddy-like vortex: energy transfers and significance of numerical settings

The increase of computational capabilities led recent studies to implement very high resolution simulations that gave access to new scale interaction processes, particularly those associated with the transfer of energy from the oceanic mesoscales to smaller scales through an interior route to dissipation. In this context, we study spin down simulations of a mesoscale interior vortex unstable to a mix baroclinic-barotropic instability. Even though the global energy is almost conserved, some energy is transferred down to dissipation scales during the development of instabilities. However, in our parameter regime, this is not a substantial direct cascade sustained by unbalanced dynamics. Rather than exploring the physical parameter range, we clarify numerical discretization issues that can be detrimental to the physical solutions and our interpretation of fine scale dynamics. Special care is given to determining the effective resolution of the different simulations. We improve it in our PE finite-difference model (CROCO) by a factor of 2 by implementing a 5th-order accurate horizontal advection scheme. We also explore a range of grid aspect ratios $dx/dz$ and find that energy spectra and fluxes converge for aspect ratios that are close to $N/f$. However, convergence is not reached in the PE model when using a fourth-order centered scheme for vertical tracer advection (standard in ROMS-family codes). The scheme produces dispersion errors that triggers baroclinic instabilities and generates spurious submesoscale horizontal features. This spurious instability shows great impact on submesoscales production and the energy cascade, emphasizing the significance of numerical settings in oceanic turbulence studies.

* Yves MOREL

New integral properties for Potential Vorticity and applications to the ocean dynamics.

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Since the work of Ertel (1942), Potential Vorticity (PV) is a recognized as a key quantity to study AGFD and in particular to understand geophysical turbulence. Many processes can indeed be explained by combining PV conservation properties and the PV inversion principle. Diabatic processes transform PV but this transformation is subject to constraints that allow to use “PV thinking” even when there exists mixing. As a Lagrangian quantity, PV evolution is more naturally examined along isopycnic/isentropic surfaces (for aspect or inversion), which unfortunately complicates its calculation: diagnosing PV along isopycnic surface often requires numerical interpolations whose associated errors can be too strong to obtain a proper view of the PV evolution. Most validation of realistic models using PV thus remains qualitative. Similarly, PV is also not easily measured in situ.

We propose new diagnostics and integral constraints, based on an original expression of PV, which we believe allows easier calculation and interpretation of PV evolution. We discuss the application of these results to study:
- the role of turbulence on the general circulation;
- the generation of PV at the bottom boundary layer;
- the link between surface density anomaly and interior PV anomalies of vortices.

*Viswa Moturi

Plumes visualization in Rayleigh-Bénard turbulent convection

Viswa Moturi, Denis Funfschilling, Jan Dusek

Poster presentation

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This project is intended to visualize the thermal plumes in a cylindrical turbulent Rayleigh-Bénard convection (RBC) cell by PLIF (Planar Laser Induced Fluorescence). Plumes are the main way to carry heat between the hot and cold thermal boundary layers of RBC cells. Most of the temperature gradient across the cell is located in the boundary layers. The plumes are coherent structures that have a mushroom-like form, when viewed from the side and a sheet-like form when viewed from above. The PLIF technique is based on the ability of some fluorescence dyes to have a temperature dependent fluorescence. By measuring the fluorescence of the dyes with a high sensitive camera, after a proper calibration and the use of appropriate filters, it is possible to calculate the temperature field. This technique relies strongly on the temperature sensitivity of the fluorescent dye.

* Stefano Musacchio

Inverse and direct cascades in thin fluid layers

Stefano Musacchio

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The dynamics of of turbulent flows confined in thin fluid layers exhibits a transition from two-dimensional to three-dimensional turbulence as the thickness of the layer is increased. The transition is characterized by the development of an intermediate regime in which two-dimensional and three-dimensional features coexist. In particular, the turbulent cascade of kinetic energy splits in two parts. A fraction of the injected energy is transferred toward large scale in a 2d-like inverse cascade, while the remnant is transferred toward small scales in a 3d-like direct cascade. This phenomenon is due to the presence of a quasi-invariant, the enstrophy, which is conserved by the large-scale dynamics. We discuss how this scenario is affected by the presence of a stable density stratification and by rotation. In particular we show that rotation enhances the inverse cascade by suppressing the enstrophy production. On the contrary, the stable stratification provides a fast mechanism to dissipate energy trough the direct cascade of potential energy, which causes a suppression of the inverse energy cascade.

*Jerome Noir

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„Spin-up in a straight cylinder with small scale topography“
Topographic anomalies are likely to cover the Core-Mantle boundary of telluric planets as well as the bottom of the ice shell on icy satellites. The range of wave lengths can go from thousands of kilometres to hundreds of meters. In this study, we present results from a preliminary experiment aimed at investigating the coupling and dissipation arising from the topography. We use a simple spin-up experiment in a straight cylinder with bottom lego-based topography. We monitor the fluid-container resynchronisation time as a proxy for the dissipation. We observe an enhanced coupling for topographies of various horizontal wave numbers with a maximum for one in particular. Remaining open questions will guide the next generation of experiments.

* Caroline Nore

Numerical simulation of the Von-Karman-Sodium dynamo experiment

Caroline Nore with Daniel Castanon Quiroz, Loïc Cappanera and Jean-Luc Guermond

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We present hydrodynamic and magnetohydrodynamic (MHD) simulations of liquid sodium flow in the Von-Karman-Sodium (VKS) set-up. The counter-rotating impellers made of soft iron used in the successful experiment of 2006 are realistically modeled by means of a pseudo-penalization method and of a new algorithm based on the induction field. Hydrodynamic simulations are performed at high kinetic Reynolds numbers using a Large Eddy Simulation technique and results compare well with the experimental data: at small impeller rotation frequencies, the flow is laminar and steady or slightly fluctuating; at large frequencies, small scales fill the bulk and a Kolmogorov-like spectrum at large azimuthal wavenumbers is obtained. Near the tips of the blades the flow is expelled and takes the form of intense helical vortices. The equatorial shear layer acquires a wavy shape due to three coherent co-rotating radial vortices as observed in hydrodynamic experiments. MHD computations are performed and show that, at fixed kinetic Reynolds number, increasing the magnetic permeability of the impellers lowers the critical magnetic Reynolds number for dynamo action and, at fixed impeller magnetic permeability, increasing the kinetic Reynolds number decreases the critical magnetic Prandtl number (ratio of the critical magnetic Reynolds number and the kinetic Reynolds number). Our results support the conjecture that the critical magnetic Reynolds number tends to a constant as the kinetic Reynolds number tends to infinity. The resulting dynamo is a mostly axisymmetric axial dipole with an azimuthal component concentrated in the impellers as observed in the VKS experiment.

*Ludovic Petitdemange

Modélisation des champs magnétiques planétaires et stellaires

L’effet dynamo est le principal mécanisme capable de maintenir l’activité magnétique des planètes et des étoiles. Ces champs sont générés par l’écoulement d’un fluide conducteur de l’électricité au sein de ces systèmes en rotation comme la Terre. De nombreuses études numériques ont ainsi cherché à comprendre la génération du champ magnétique terrestre dans le noyau fluide externe en analysant les propriétés des champs magnétiques générés par la convection d’un fluide Boussinesq dans une coquille sphérique en rotation. Cependant, cette approche n’est pas vraiment respectée pour décrire la convection dans des systèmes stratifiés tels que les intérieurs stellaires, dont la zone convective est potentiellement

Dynamo action, i.e. the self-amplification of a magnetic field by the flow of an electrically conducting fluid, is considered to be the main mechanism for the generation of the magnetic fields of stars and planets. Intensive and systematic parameter studies by direct numerical simulations using the Boussinesq approximation revealed fundamental properties of these models. However, this approximation considers an incompressible conducting fluid, and is therefore not adequate to describe convection in highly stratified systems like stars or gas giants. A common approach to overcome this difficulty is then to use the anelastic approximation, that allows for a reference density profile while filtering out sound waves for a faster numerical integration. Through a systematic parameter study of spherical anelastic dynamo models, we investigate the influence of the stratification on the dynamo mechanisms, and compare them with previous results obtained in the Boussinesq approximation. We discuss the influence of the density stratification on the field geometry and the field strength. Our results are in overall agreement with the previous geodynamo studies, and thus the main established results seem to be still relevant to the study of stellar dynamos.

*Franck Plunian

Helicity-driven turbulence
by Mouloud Kessar, Franck Plunian, Rodion Stepanov and Guillaume Balarac

We solve the Navier-Stokes equations with two simultaneous forcings. One forcing is applied at a given large scale and it injects energy. The other forcing is applied at all scales belonging to the inertial range and it injects helicity. In this way we can vary the degree of turbulence helicity from nonhelical to maximally helical. We find that increasing the rate of helicity injection does not change the energy flux. On the other hand, the level of total energy is strongly increased and the energy spectrum gets steeper. The energy spectrum spans from a -5/3 Kolmogorov scaling law for a nonhelical turbulence, to a -7/3 non-Kolmogorov scaling law for a maximally helical turbulence. In the latter case we find that the characteristic time of the turbulence is not the turnover time but a time based on the helicity injection rate. We also analyze the results in terms of helical modes decomposition. For a maximally helical turbulence one type of helical mode is found to be much more energetic than the other one, by several orders of magnitude. The energy cascade of the most energetic type of helical mode results from the sum of two fluxes. One flux is negative and can be understood in terms of a decimated model. This negative flux, however, is not sufficient to lead an inverse energy cascade. Indeed, the other flux involving the least energetic type of helical mode is positive and the largest. The least energetic type of helical mode is then essential and cannot be neglected.

*Bérengère Podvin

Precursor for wind reversal in a Rayleigh-Bénard cell
Bérengère Podvin(1) et Anne Sergent(1,2)
We investigate reversals in a 2D turbulent Rayleigh-Bénard cell. POD analysis of the numerical simulation shows the existence of a precursor event, corresponding to the action of a specific POD mode, which disconnects the core region from the boundary layers before the onset of the reversal. A five-mode POD-based model predicts correctly the behavior of the POD modes observed in the simulation, and in particular the precursor event. The predictions of the model suggest that reorganizations of the large-scale circulation in the simulation are not purely random occurrences, but could be part of a cycle reminiscent of the one displayed by the model, and open up the possibility that large-scale reorganizations could be anticipated to some extent.

* Yannick Ponty
Ferro-enhanced turbulent dynamo

Yannick Ponty
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We present a direct numerical simulation (DNS) version the Von Karman flow, forced by two rotating impellers. The cylinder geometry and the rotating objects are modelled via a penalization method and implemented in a massive parallel pseudo-spectral Navier-Stokes solver. We included the magnetic induction equation inside the fluid and solid system in order the study the dynamo effect. We will present several common features with the VKS dynamo experimental campaigns, as the observed magnetic mode (m=0) and the variation with the magnetic permeability.

The magnetic and current behaviour near and inside the impellers will be detail. Dynamic behaviours along the saturation regime as reversals will be also discuss. We conclude about the opportunity to used similar penalisation techniques in geophysics and astrophysics.

* Stéphane Popinet
Quadtree-adaptive global atmospheric/oceanic modelling on parallel systems

Stéphane Popinet
Institut Jean le Rond d'Alembert
UPMC/CNRS (INSIS)
Paris

I will present initial results for a three-dimensional, hydrostatic, global atmospheric model combining quadtree, horizontal adaptivity on a cubed sphere grid with a standard, layered vertical discretisation. This model is implemented within the Gerris framework (http://gfs.sf.net) and thus automatically inherits attributes such as data parallelism and load-balancing. For large-scale atmospheric simulations, I will show that quadtree-adaptivity leads to a large gain in the scaling exponent relating computational cost to the resolution of sharp frontal structures.

*Jérémy Rekier
An efficient numerical framework adapted to rapidly rotating objects : application to the rotational modes of the Earth.
J. Rekier, S. Triana, A. Trinh, R. Laguerre, V. Dehant
We present a general framework to easily numerise systems of linear time evolution PDEs appearing in geophysical contexts in the frequency domain using a full spectral scheme. The code relies on a symbolic decomposition onto spherical harmonics in the angular directions and a numerical decomposition onto ultraspherical polynomials in the third coordinate. The resulting very sparse matrices can then be processed by the numerical method preferred to the user. The ensuing flexibility makes it easy to adapt and improve any submitted model step by step. Particular attention has been paid to the ease to add field variables and equations. The code can equally accommodate spherical and spheroidal coordinates. We give an example of use of our framework in the study of the coupled dynamics of a fluid core coupled to the rotation of its planetary mantle using the coupled Liouville-Navier-Stokes system of equations and provide early results. We further show another example of use in the study of quasi non-linear mode interaction in rotating fluids.

* Michel Rieutord

Some key questions raised by fast rotating stars

Michel Rieutord

Institut de Recherches en Astrophysique et Planétologie (IRAP)
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Intermediate mass stars (above 2 solar masses) and massive stars (above 8 solar masses) are young objects that most frequently own a fast rotation. This means that they are centrifugally distorted and that Coriolis acceleration is a dominant force governing the internal flows. In the stably stratified envelope, main flows are composed of a general circulation that is associated with a differential rotation analog of the thermal wind on Earth. In addition it is believed that this differential rotation drives a small scale turbulence that contribute to the mixing of element in such stars, a crucial issue for stellar and galactic evolution. I shall present the most advanced stellar models that presently represent such stars, which are self-consistent solutions of the steady compressible Navier-Stokes equation, for a self-gravitating plasma including nuclear reactions, and stress the fundamental pending questions that are raised by this modelling.

*Germain Rousseaux

Observation of Stimulated Hawking Radiation at a Hydraulic Black Hole Horizon

Léo-Paul Euvé and Germain Rousseaux

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Black is Black. A black hole does not emit light classically (from inside). After our observation of spontaneous and stimulated Hawking radiation by a hydraulic white hole¹, and our numerical and experimental observation of a wormhole travel², we will present our experimental measurements of the scattering by a trans-critical flow of a co-moving water wave. A pair of positive and negative energy water waves analogous to the pair of particle and anti-particle appears by mode conversion close to the region where the flow becomes trans-critical on the top of a dedicated obstacle. The latter plays the role of an effective space-time whose curvature is mimicked by the flow gradients. We test the famous theoretical prediction of Stephen Hawking dating from 1974 on the (quantum) spontaneous emission of astrophysical black holes by probing the corresponding (classical) stimulated emission. We shed light (water waves) on the horizon
of the (analogue) black hole and we show that the horizon reflects light backwards when stimulated from outside. Black and White is Grey...

* Julien Salort

Turbulent thermal convection is ubiquitous in nature. It is a complex problem because the flow is forced at several scales, because of the presence of both large scale circulation and small scale plumes. In addition, the difference of density induced by temperature adds an ingredient in the basic equations, so that turbulence could be different from the case of pure mechanical forcing. Mixing is, in principle, different and probably increased by the structure of the plumes.
We use two laboratory model systems: the Rayleigh-Bénard cell, which consists in a fluid layer heated from below and cooled from above, and the heat pipe, which consists in a channel between an hot chamber and a cold chamber. These flows model two limit types of forcing: the former is strongly influence by the boundary conditions, the latter by the turbulence in the bulk. There are several methods to investigate those systems: global heat transfer measurements and scaling laws, or small-scale properties and Lagrangian tracking.

* Nathanaël Schaeffer

Turbulent geodynamo simulations
Nathanaël Schaeffer, Dominique Jault, Henri-Claude Nataf, Alexandre Fournier

We present an attempt to reach realistic turbulent regime in direct numerical simulations of the geodynamo. We rely on a sequence of three convection-driven simulations in a rapidly rotating spherical shell. The most extreme case reaches towards the Earth’s core regime by lowering viscosity (magnetic Prandtl number Pm=0.1) while maintaining vigorous convection (magnetic Reynolds number Rm>500) and rapid rotation (Ekman number E=1e-7), at the limit of what is feasible on today’s supercomputers.
A detailed and comprehensive analysis highlights several key features matching geomagnetic observations or dynamo theory predictions -- all present together in the same simulation -- but it also unveils interesting insights relevant for Earth’s core dynamics.

* Daniel Schertzer

Cascades, Lévy-Clifford algebra of generators of vector multifractals to analyse and simulate intermittent flows
Daniel Schertzer and Ioulia Tchiguirinskaia

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Geophysical flows are both intermittent and vector fields. Multifractals were a major breakthrough in nonlinear geophysics to quantify and simulate intermittency. However, they have been limited for too long to scalar-valued fields, e.g. the energy flux, whereas interactions between velocity components are of prime interest, including for most applications such as wind energy and rainfall monitoring.
By stochastically combining orthogonal rotations and mirror symmetries we obtain a Clifford algebra of Lévy-stable generators of a continuous in scale cascades. These cascades define vector multifractal fields having both robust algebraic and universal statistical properties.
* François G. Schmitt

François G. Schmitt

The scale question in turbulence-plankton interactions in marine sciences: interplay between modelization of turbulence and population dynamics

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The objective of this contribution is to discuss the problem of scales when dealing with the interactions between marine turbulence and plankton population and behaviour. The scales involved go from the phytoplankton cells (around 10 microns for the smallest) to thousands of kilometres, 11 orders of magnitude. Planktonic animals (phytoplankton and zooplankton) are well adapted to their turbulent environment, and are able to have specific behaviour in relation with the biogeochemical and dynamical properties of their surrounding. Turbulence models cannot be used to consider such coupling, since they are not reliable, and also since they deal with grid size much too large to consider interactions with planktonic species. We advocate here the used of direct numerical simulations (DNS) to consider the relations with plankton and turbulence on the numerical side, at small scales, together with experimentations in the lab, and also with field observations. Intermittent and scaling properties, and coupling, between velocity fields and plankton concentration, can be studied through direct field observation and DNS.

* Benoît Semin

A model experiment of the quasi-biennial oscillation

Benoît Semin

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The quasi-biennial oscillation is the periodic reversal of the wind in the lower equatorial stratosphere. The period of the oscillation is 28 months on average, and is not linked to the year duration. This wind is known to be generated by atmospheric waves, in particular internal gravity waves. We have set up an experiment which reproduces this phenomenon. Linearly stratified salty water is located between two plexiglas cylinders. Internal gravity waves are generated in the fluid using 16 membranes located at the top of the fluid. Each membrane oscillates sinusoidally in the vertical direction, in opposition of phase with its two neighbors: the wave is stationary in the azimuthal direction. When the amplitude of the forcing is large enough, a mean flow is generated, and oscillates with a period which is much larger than the wave period. This oscillation of the mean flow is similar to the one observed in the atmosphere.

* Shafer Smith

Active and Passive Submesoscale Stirring
The advent of satellite ocean color measurements in the 1970s revealed multiscale variability in surface chlorophyll suggestive of stirring by fronts, filaments and small vortices at scales an order of magnitude smaller than mesoscale eddies. In situ measurements of fluorescent tracers injected in the thermocline in the 1990s highlighted the evolution of three dimensional filaments with similar scales - and such structures seem to be ubiquitous in temperature and salinity fields. Relative dispersion statistics from some surface drifter measurements in the 2000s indicate the presence of energetic submesoscale currents. And yet, the specific mechanisms that determine the scales and dynamics of these submesoscale features in tracers and particle dispersion remains an open problem. For example, while small-scale features in tracers may certainly be directly generated by submesoscale dynamical features like Mixed-Layer Instability, mesoscale shearing and straining against existing gradients can produce similar fine scale tracer features. In this talk I will review a range of observed and modeled features of submesoscale tracers and particles, and discuss the dynamics that may be responsible for setting them, highlighting the difficulty in attribution without detailed measurements of the associated velocity field.

*Aymeric Spiga LMD

: Exploring convection in planetary atmospheres with high-resolution meteorological models

I will show research carried out with mesoscale modeling and large-eddy simulations which were used to investigate how convective motions develop in planetary atmospheres, in conditions never (or seldom) explored in the existing literature: within dust storms and water-ice clouds on Mars, and within sulfuric acid clouds on Venus. I will discuss results and possible extensions to other planetary atmospheres.

* Chantal Staquet

Chantal Staquet

"Mixing by lee waves in the deep ocean"

Joint laboratory and numerical experiments have been performed to explore the contribution to mixing of a geostrophic current flowing on a topography in a stably stratified rotating fluid. Mixing can be induced by the wake of the topography and, depending upon the flow parameters, by radiated lee waves as well. This talk will focus on the mixing induced by the latter field and on the underlying mechanisms.

*Simon  Thalabard

Non-Markovian phenomenologies for turbulent dispersion

Simon  Thalabard

Laboratoire Joseph Louis LAGRANGE (LAGRANGE) - CNRS : UMR7293, Université Côte d’Azur (UCA), Observatoire de la Cote d’Azur (OCA) Boulevard de l’Observatoire B.P. 4229 06304 Nice Cedex 04 - France - France

Long established modelling of turbulent dispersion relies on the use of eddy diffusivities and associated FP equations that allows for example to describe Richardson's t^3 law for pair separation. However, the t^3 law does not substantiate by itself the transport mechanism, and DNS have evidenced the existence of strong deviations to Richardson-type self-similar decay. Such deviations can be described using non-markovian phenomenologies that explicitly account for the existence of non-trivial Lagrangian correlations, and the crossover between the short time “ballistic” asymptotics (Batchelor regime) and the inertial time behavior a la Richardson. I will discuss several examples of such non-markovian models and illustrate their skills using DNS data. I will also discuss whether and how non-markovianity can be used to account for the assymmetry between the backward and the forward Lagrangian statistics.
* Vladimir Tseitline

"Understanding dynamics of planetary polar vortices with "enhanced" rotating shallow water model"

Vladimir Tseitline (Zeitlin),
Laboratoire de Meteorologie Dynamique,
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Abstract: I will show how the phase transitions of water and of CO2 can be incorporated into a rotating shallow water (RSW) model, and how such "enhanced" RSW model helps to understand salient features of polar vortices on Saturn and Mars.

*Sandro Vaienti

Sandro Vaienti
Université de Toulon et Centre de Physique Théorique
de Marseille (UMR 7332)

We discuss recent results of statistical nature for non-autonomous (time-dependent) dynamical systems, with particular emphasis on limit theorems (central limit theorem, large deviations), and on the occurrence of rare events. Applications to concrete physical examples are presented.

* Antoine Venaille

Topological Origin of Equatorial waves
Antoine Venaille
Univ Lyon, Ens de Lyon, Univ Claude Bernard, CNRS, Laboratoire de Physique, F-69342 Lyon, France

Symmetries and topology are central to an understanding of physics. Topology explains the precise quantization of the Hall effect and the protection of surface states in topological insulators against scattering by non-magnetic impurities or bumps. Recently topologically protected edge excitations have been found in artificial lattice structures that support classical waves of various types. However, the interplay between discrete symmetries and the topology of fluid waves has so far played little role in the study of the dynamics of oceans and atmospheres. Here we show that, as a consequence of the rotation of the Earth that breaks time reversal symmetry, equatorially trapped Kelvin and Yanai waves have a topological origin, manifesting as equatorial edge modes in the rotating shallow water model. These unidirectional edge modes are guaranteed to exist by the non-trivial global structure of the bulk Poincaré modes encoded through the first Chern number of value ±2, in agreement with the correspondence between behavior deep in the bulk and edge excitations of a physical system. The waves are protected against static perturbations by time scale separation from other modes that inhibits scattering. Thus the oceans and atmospheres of Earth and other rotating planets share fundamental properties with topological insulators. Such waves have been manifest in nature all along but their topological origin went unrecognized. As equatorially trapped Kelvin waves are an important component of the El Nino Southern Oscillation, our results demonstrate that topology plays an unexpected role in Earth’s climate system. Collaboration with Pierre Delplace (ENS de Lyon) and Brad Marston (Brown University)
Reference: https://arxiv.org/abs/1702.07583
Internal wave focusing by a slender ring

Bruno Voisin

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Owing to their conical geometry, internal gravity waves are focused by any forcing with horizontal curvature, focusing being all the more effective as the forcing is close to axisymmetric. In order to quantify this phenomenon, we consider the oscillations of a horizontal circular ring in a uniformly stratified fluid. A linear model of the generated waves is proposed, on the assumption that the ring is slender, namely of large aspect ratio. The results are applied to a torus and to circular Gaussian topography at the ocean bottom. Both full and partial rings are considered, and both subcritical and supercritical topographies. For the torus, the predictions are compared with the recent experiments by Ermanyuk, Shmakova & Flór (JFM 2017). The focusing efficiency is characterized in terms of the amplification ratio and wave steepness at the foci, and the oceanic relevance of the results is discussed.