Mathematics of Planet Earth 2013

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Mathematics and Geosciences: Global and Local Perspectives

Madrid, November 4th - 8th, 2013

Aula Azul (ICMAT, Campus de Cantoblanco)

Organizing Committee:

- Jesús Ildefonso Díaz (IMI - UCM)
- Francisco José Elorza (UPM)
- José Fernández (IGEO - CSIC)
- Manuel de León (ICMAT - CSIC)
- Rafael Orive (ICMAT - UAM)
- María Luisa Osete (IGEO - UCM)

Introduction:

On the ocassion of the MPE 2013, the ICMAT, CSIC, the UAM ,the UCM and the UPM want to highlight the decisive role Mathematics plays in the study of local as well as global issues in Earth Sciences.The following topics will be addressed:

- Climatology and Paleoclimatology
- Oceanography
- Geomagnetic field
- The Earth's rotation
- Remote sensing
- Natural hazards
- Structure and Geodynamics
- Renewable Energies
- Social and environmental aspects

These topics will be addressed in a global perspective on the Earth as well as in a local point of view on Earth Science

Monday 4		
09:00 - 09:30	Registration	
09:30 - 10:00	Opening	
10:00 - 11:00	A. Fowler	Two differential equations for the future of the planet **(Plenary Lecture)**
11:00 - 11:30	Coffee Break	
11:30 - 12:00	L. Ferragut	Fire Modelling with Data Assimilation **(Invited Lecture)**
12:00 - 12:30	L. Berselli	On the Large Eddy Simulation of some multiphase problems in geophysics **(Invited Lecture)**
12:30 - 12:45	R. Monjarret	Well-posedness and other properties of the two-layer shallow water model with free surface (Communication 1)
12:45 - 13:00	M. A. Martín	Particle size distributions in granular media: selfsimilarity and packing (Communication 2)
13:00 - 15:00	Lunch	
15:00 - 16:00	R. Ababou	Stochastic PDE's for water flow, solute transport and wave propagation phenomena in heterogeneous geologic media **(Plenary Lecture)**
16:00 - 16:30	S. Zlotnik	Real time solution of PDE: reduce basis and the Proper Generalized Decomposition **(Invited Lecture)**
16:30 - 17:00	Coffe break	
17:00 - 17:30	C. Parés	The Hysea Project: a web-based platform for the simulation of geophysical flows **(Invited Lecture)**
17:30 - 18:00	R. Montenegro	Wind forecasting over complex terrain **(Invited Lecture)**
18:00 - 18:30	F. J. Elorza	Assessment of the interactions of three open-loop groundwater heat pump systems in an alluvial aquifer **(Invited Lecture)**

Tuesday 5		
09:30 - 10:30	A. Udías	Mathematics and the solid Earth: A historical perspective (Plenary Lecture)
10:30 - 11:00	D. Stich	Time reversal of seismic wavefields (Invited Lecture)
11:00 - 11:30	Coffe break	
11:30 - 12:00	R. Carbonell	Images of the Ocean with Legacy Seismic Reflection Data (Seismic Oceanography) (Invited Lecture)
12:00 - 12:30	M. Gómez	Smoothed particle hydrodynamics methods applied to geosciences: Study of Extreme Events (Invited Lecture)
12:30 - 12:45	A. Robinson	A mathematical framework for constraining changes in ice sheet thickness during the last interglacial period (Communication 3)
12:45 - 13:00	F. San José	Shape and pore space morphology of soil aggregates with X- ray computed tomography (Communication 4)
13:00 - 15:00	Lunch	
15:00 - 16:00	S. Antontsev	Mathematical Models of Hydrological Cycle (Plenary Lecture)
16:00 - 16:30	C. Vázquez	Investment under uncertainty with environmental effects (Invited Lecture)
16:30 - 17:00	Coffe break	
17:00 - 17:30	A. Fernández	The Negative Binomial Distribution as a Renewal Model for the recurrence of large earthquakes (Invited Lecture)
17:30 - 18:00	E. Buforn	Rupture process of earthquakes (Invited Lecture)

Wednesday 6		
09:30 - 10:30	A. De Santis	Geosystemics: a systemic view of the Earth's magnetic field and possibilities for an imminent geomagnetic transition **(Plenary Lecture)**
10:30 - 11:00	*Posters*	*Several Speakers*
11:00 - 11:30	Coffe break	
11:30 - 12:00	A. M. Mancho	Symmetry and dynamics in a convection problem with temperature-dependent viscosity **(Invited Lecture)**
12:00 - 12:30	P. Zurita	The two paradigms of extratratropical troposphere equilibration **(Invited Lecture)**
12:30 - 12:45	F. Martín-Hdez.	Modeling of superparamagnetic contribution of natural samples derived from the reversal part of hysteresis loop (Communication 5)
12:45 - 15:00	Lunch	
15:00 - 16:00	J. Carrera	Towards a mixing and dispersion transport equation **(Plenary Lecture)**
16:00 - 16:30	J. Fullea	3D coupled geophysical-petrological modelling of the Canary Islands and northwestern African margin lithosphere **(Invited Lecture)**
16:30 - 17:00	Coffe break	
17:00 - 17:30	L. Tello	Mathematical treatment of a global climate energy balance model coupled with a deep ocean model **(Invited Lecture)**
17:30 - 18:00	J. Mallorquí	Adavanced Differential SAR Interferometry (DInSAR) or how the phase of a complex number can be used as a deformation monitoring tool **(Invited Lecture)**

Thursday 7		
09:30 - 10:30	C. Budd	Data assimilation in weather and climate modelling (Plenary Lecture)
10:30 - 11:00	J. Álvarez-Solas	On the role of ocean–ice-sheet interactions for triggering abrupt climate changes: from conceptual to 3D ice-flow modelling (Invited Lecture)
11:00 - 11:30	Coffe break	
11:30 - 12:00	J. Pavón	Regional modeling of the Earth's magnetic field at different spatial and temporal scale (Invited Lecture)
12:00 - 12:30	J. M. Ferrándiz	The Earth rotation: a challenging problem in Mathematics and Physics (Invited Lecture)
12:30 - 12:45	R. Banderas	An interhemispheric oscillation controlling glacial abrupt climate change (Communication 6)
12:45 - 13:00	V. Torralba	Interannual and decadal climate variability over Northeast Brazil using discriminant analysis techniques of filtered rainfall (Communication 7)
13:00 - 15:00	Lunch	
15:00 - 15:30	M. Torta	Geomagnetically induced currents by solar storms: an emerging natural hazard that can be modelled (Invited Lecture)
15:30 - 16:00	E. Suriñach	Quantification of dynamic parameters of mass movements (snow avalanches and rockfalls) by seismo-acoustic measurements (Invited Lecture)
16:00 - 16:30	Á. de la Cámara	Unraveling the geometric structures of the stratospheric flow (Invited Lecture)
16:30 - 17:00	Coffe break	

Friday 8		
09:30 - 10:00	L. Vázquez	Molelization Studies in the Mars Exploration (Invited Lecture)
10:00 - 10:30	L. Álvarez	Cloud motion estimation using multi-channel satellite images (Invited Lecture)
10:30 - 11:00	Á. Castro	Shallow water with vorticity (Invited Lecture)
11:00 - 11:30	Coffe break	
11:30 - 12:00	F. González	Climate simulation and reconstruction in the last two millennia: model-data comparison (Invited Lecture)
12:00 - 13:00	E. Meron	Pattern formation - a missing link in the study of ecosystem response to climate change (Plenary Lecture)
13:00	THE END	

ABSTRACTS

PLENARY SPEAKERS

Aula Azul (ICMAT, Campus de Cantoblanco)

Abstracts (in alphabetical order):

Ababou, Rachid	**Fowler,** Andrew
Antontsev, Stanislav	**Meron,** Ehud
Budd, Chris	**Santis,** Angelo De
Carrera, Jesús	**Udías,** Agustín

STOCHASTIC PDE'S FOR WATER FLOW, SOLUTE TRANSPORT AND WAVE PROPAGATION PHENOMENA IN HETEROGENEOUS GEOLOGIC MEDIA

Rachid Ababou, Université de Toulouse

This lecture will present stochastic PDE's (Partial Differential Equations) to model various "transport" phenomena like water flow, solute transport and wave propagation, in heterogeneous geologic porous media. The material properties are represented by random functions of space $F(x)$ (random fields). The resulting transport PDE's contain random field coefficients, and their solutions are stochastic (randomly heterogeneous).

In this framework, the objectives are to solve the stochastic PDE's, to analyze the behavior of the solutions (fluxes, velocities, pressures, stresses and strains), and to propose an upscaled version of the governing equations with effective or equivalent âmacro-scale" coefficients that incorporate the effects of heterogeneity (e.g., anisotropic macro-permeability tensor Kij).

The methods used for obtaining the random solutions involve the so-called *"sigma-expansion"* method, where *"sigma"* stands for the standard deviation of the random parametersâor of their logarithms (it will be shown that this choice can make quite a difference regarding the robustness of the solution). The perturbation equations are then solved with Green's functions in space, and/or with spectral representation in the space of wavevectors k (*Fourier-Wiener-Khinchin* representation with *Stieltjes* integrals).

Once the random fluctuations or their moments are known, the next task is to implement "relevant" averaging operations, and to study the behavior of averaged macro-scale quantities (mean flux, mean pressure gradient, mean displacement, etc.). Macro-scale governing PDE's can emerge from this upscaling step, e.g., one obtains a mass conservation equation $\mathrm{div}\,(Q) = 0$ combined with a macro-scale Darcy equation $Q = -K\mathrm{Grad}\,(P)$ where macro-permeability K is a 2nd rank tensor embodying the geometric anisotropy of the geologic medium. However, due to nonlinear or stochastic interactions, the macro-scale PDE does not necessarily resemble the original "local scale" stochastic PDE . . . as will be shown.

Through this lecture, several types of phenomena of practical importance will be used as examples: hydrodynamic dispersion of a tracer; single phase flow (Darcy); two-phase flow (Darcy-Muskat); seismic elastic wave dispersion and attenuation. . .

Mathematical Models of Hydrological Cycle

Stanislav Antontsev, CMAF - Universidade de Lisboa

The objective of this talk is to give a survey of the mathematical (qualitative) analysis of general models of mass transport and other interconnected physical processes developing in coupled ows of surface, soil and ground waters. Such models widely are used for forecasting (numerical simulation) of a hydrological cycle for concrete territories. The mathematical models that proved realistic are obtained by combining mathematical models of local processes. The water-exchange models take into account the following factors: water ows in confined and unconfined aquifers, vertical moisture migration with allowing earth surface evaporation, open-channel ow simulated by one-dimensional hydraulic equations, transport of contamination, etc. These models may have different levels of sophistication, ranging from systems of balance equations to systems of nonlinear partial differential equations. We illustrate the type of mathematical singularities which may appear by considering simple coupling models. In the talk are presented investigation of the questions concerning mathematical correctness of the models, such as existence and uniqueness of solutions and the study of they qualitative properties such that asymptotic behavior with respect to time and spatial variables and stability with respect initial data and physical parameters.

Data assimilation in weather and climate modelling

Chris Budd, University of Bath

Data assimilation is the process of systematically including (often noisy) data into a forecast. It is now widely used in numerical weather prediction and its positive impact on the accuracy of weather forecasts is unquestionable. Indeed improvements in our ability to forecast the weather over the last decade are a reflection on the increasing volume of data available, improved computational methods and (significantly) much improved algorithms for incorporating this data into the forecast. However, many problems remain, including dealing with the sheer volume of the data and the inherent complexity of the weather and climate, understanding the effects of data and model error, and of reducing spurious correlations between the data and the forecast.

In this talk I will give a survey of various techniques that are used operationally to implement data assimilation procedures in weather (and climate) forecasting including the Ensemble Kalman Filter, particle filters and the 4D-Var method.

I will discuss their various advantages and disadvantages, the nature of the errors and ways to minimise these. Hopefully I will show that used carefully Data Assimilation techniques can significantly improve our ability to forecast the weather of Planet Earth.

Towards a mixing and dispersion transport equation

Jesús Carrera, Instituto de Diagnóstico Ambiental y Estudios del Agua - CSIC

Solute transport has been traditionally simulated with the advection-dispersion equation (ADE). This equation fails to reproduce many field observations (scale dependence of dispersion, time dependence of kinematic porosity, tailing, etc). Worse, the ADE equates mixing and spreading, which is severe because mixing controls the actual rate of fast reactions (tautologically, those whose rate depends on the rate at which reactants mix). Mixing is controlled by internal disorder within a solute plume, which is driven by heterogeneity in velocity. As such, it is linked to dispersion, which defines the rate of spreading of a solute plume. Still, the distinction between mixing and spreading is important for conceptually accurate transport. Effective transport equations based on non-local formulations look like a promising alternative to the ADE, not only because they overcome the above limitations, but also because they can provide a separation between transport and spreading. Unfortunately, they introduce additional parameters that must be calibrated in each situation. In order to predict mixing from descriptions of hydraulic parameters, we must first understand its dynamics. To this end, we perform detailed simulations of transport through heterogeneous media. We analyze results in terms of mixing, as quantified by the scalar dissipation rate (rate of destruction of concentration variance), and spreading, as quantified by the rate of growth of the 2^{nd} moments of the spatial distribution of concentration. We find that mixing is activated by the shear of solute bodies, which controls the plume spreading rate (dispersion!), but also generates transverse gradients and activates molecular diffusion. That is, mixing and spreading are indeed closely linked. In fact the late time drop in mixing rate is complementary to the increase in spread. These mechanisms are reflected in the characteristic spatial scales, which grow sub diffusively for mixing and super diffusively for spreading, suggesting that full mixing will never be achieved, so that transport will never become fully fickian. However, these findings allow us to define a function quantifying the departure of actual mixing from Gaussian mixing. The basic parameters of this function are defined in terms of the heterogeneity parameters, and can be reproduced by non-local formulations, which provides an approach to define non local transport from the description of heterogeneity

Two differential equations for the future of the planet

Andrew Fowler, Oxford University - University of Limerick

It is generally recognised that Earth's climate over geological but also anthromorphic time is directly associated with the amount of carbon in the atmosphere, and there is concern over the development of climate over the coming centuries, and its effect on weather, ocean acidification, and the like. Much of the theoretical discussion is based on large scale numerical simulations. In this talk I will take a modeller's approach to the problem, and describe. in stark terms, one particular doomsday scenario which is based on the solution of two first order ordinary differential equations. The outlook is not good.

Pattern formation - a missing link in the study of ecosystem response to climate change

Ehud Meron, Ben-Gurion University

Self-organization processes leading to pattern formation phenomena are ubiquitous in nature. Cloud streets, sand ripples, stone patterns and animal-coat patterns are a few examples. Intensive theoretical and experimental research efforts during the past few decades have resulted in a mathematical theory of pattern formation whose predictions are well confirmed by controlled laboratory experiments. There is increasing observational evidence that pattern formation also plays an important role in shaping water-limited landscapes. Depending on the rainfall regime, self-organized vegetation patchiness in the form of nearly periodic spot, stripe and gap patterns has been reported. Supporting these observations are studies of spatially explicit vegetation models that have reproduced many of the observed patterns. In this talk I will review the state of art in studies of vegetation pattern formation, and delineate manners by which pattern formation processes can affect ecosystem response to environmental changes. The latter include gradual and incipient regime shifts induced by droughts and disturbances, the possible emergence of unexpected resonant patterns in water-harvesting practices of vegetation restoration, and mechanisms of species coexistence in stressed environments.

Geosystemics: a systemic view of the Earth's magnetic field and possibilities for an imminent geomagnetic transition

Angelo De Santis, Istituto Nazionale di Geofisica e Vulcanologia, Roma – Università degli Studi "G. d'Annunzio", Chieti

Geosytemics is a way to see and study the Earth in its wholeness, together with the eventual couplings among the subsystems composing our planet. This presentation will provide this view for the Earthâs magnetic field. The main tools used by geosystemics are some non-linear quantities, such as some kinds of entropy. Through them, it is possible to: a) establish the chaoticity and ergodicity of the recent geomagnetic field in a direct and simple way; b) define the most extreme events in its history, as the most rapid and the slowest ones, i.e. jerks and polarity changes (reversals or excursions). In particular, regarding the latter phenomena, with the help of these entropic concepts and together with the use of the theory of critical transitions, some clues can be given for a possible imminent change of the geomagnetic field dynamical regime.

Mathematics and the solid Earth: A historical perspective

Agustín Udías, Universidad Complutense de Madrid

Since antiquity, mathematics has been used to describe the nature and phenomena of the Earth. Already Greek natural philosophers used geometry to determine the length of the Earthâs radius. Newton considered the effects of gravitation and rotation to determine its flatness, confirmed later by precise measurements, and explained ocean tides. In the eighteen century Lagrange and Laplace proposed the Earth gravity potential and solved the differential equations to find its shape, expressed in terms of a sum of spherical harmonics. Motion of earthquakes, which propagates as elastic waves in the Earth, as proposed by Michell in 1760, led to the application of the solutions of the wave equation to their motion. In the late nineteenth century, mathematical elasticity theory developed by Cauchy, Poisson and Kelvin was applied to propagation of elastic waves in the Earth by Lamb, Rayleigh, Wiechert and Love, including its free oscillations. In 1600 Gilbert proposed that the Earth was a large magnet. Gauss in 1839 applied the solution of the equations for the potential of the magnetic field of the Earth in terms of spherical harmonic, separating the internal and external fields. Larmor, Elsasser and Bullard applied the equations of magnetohydrodynamics to the generation of the Earthâs magnetic field by currents in the fluid outer core. First applications of the equations of thermodynamics to the Earth were made in the early twenty century by Rayleigh and Holmes to explain terrestrial heat flow. In the beginning of the twentieth century Holmes and Barrel used the equations of radioactive decay to find the age of the Earth.

ABSTRACTS

INVITED SPEAKERS

Aula Azul (ICMAT, Campus de Cantoblanco)

(List ordered by thematic):

Climatology and Paleoclimatology	**Natural hazards**
Oceanography	**Structure and Geodynamics**
Geomagnetic field	**Renewable Energies**
the Earth's rotation	**Social and environmental aspects**
Remote sensing	

Climatology and Paleoclimatology:

ON THE ROLE OF OCEAN–ICE-SHEET INTERACTIONS FOR TRIGGERING ABRUPT CLIMATE CHANGES: FROM CONCEPTUAL TO 3D ICE-FLOW MODELLING

Jorge Álvarez-Solas, Universidad Complutense de Madrid
(*with A. Robinson and M. L. Montoya*)

Proxy data reveal the existence of pronounced millennial scale climate variability during the last glacial cycle: Dansgaard-Oeschger (D-O) events, consisting in abrupt warming in Greenland, and Heinrich events, periods of extreme cooling in the Northern Hemisphere coeval with increased deposition of ice-rafted debris (IRDs), interpreted as massive discharges of icebergs into the North Atlantic Ocean (3). Heinrich events occurr within temperature minima (i.e. stadials) at the end of socalled Bond cycles, long-term cooling cycles including several progressively colder D-O events. This suggests a causal relation between both which is far from understood. The capabiliy of the Laurentide ice sheet for generating iceberg surges has longly be thought to be due to spontaneous ice-sheet internal processes. Lately, it has been suggested that an ice shelf breakup during cold surface and warm subsurface conditions can trigger a HE. It remained to be shown the efficiency of such ice-shelf breakup mechanism for simulating the iceberg discharges of the whole last glacial period. We here present the first set of simulations carried out with a hybrid ice-sheet–ice-shelf model applied to the glacial Laurentide ice sheet. The analysis of these results demonstrates that the main and crucial forcing for generating iceberg discharges satisfactorily comparing with IRDs is simply the oceanic circulation. The variability of the Labrador Sea subsurface temperatures generates iceberg discharges whose timming is primarily fonction of the ice shelves behavior combined with a non-linear contribution derived from the capability of ice streams to accelerate. This latter depends on the magnitude of the iceshelf buttressing effect but also on the grounding line ice thickness. These results indicate that oceanic circulation variations were responsible for the enigmatic ice purges of the last ice age.

Unraveling the geometric structures of the stratospheric flow

Álvaro de la Cámara, École Normale Superieure
(*with A. M. Mancho, K. Ide, E. Serrano and C. Roberto Mechoso*)

Methods derived from theory of dynamical systems provide a useful framework to describe Lagrangian transport in geophysical flows. A recently proposed Lagragian descriptor, or function M, has already been proven a powerful technique in studies of transport in oceanic flows. Specifically, from an initial time t, the Lagrangian descriptor M measures the arclength of the parcel trajectories advected by the wind field over the interval $[t-\tau, t+\tau]$.

The presentation focuses on applications of this technique to unravel the geometric structures governing transport of air masses in the stratosphere. Special emphasis will be given to gain insights into the dynamical processes responsible for quasi-horizontal transport of air in the Antarctic stratospheric polar vortex. The isolation of the air inside the vortex has important implications on the seasonal development and decay of the ozone hole during the austral spring.

Climate simulation and reconstruction in the last two millennia: model-data comparison

Fidel González Rouco, Universidad Complutense de Madrid
(*with L. Fernández Donado and E. García Bustamante*)

Understanding natural climate variability and its driving factors is crucial to assessing future climate change. The last two millennia allow for comparing instrumental temperature data with a period of time before 1850 AD when forced and internal climate variability can be examined in the absence of large orbital and anthropogenic forcing. More high resolution proxy records exists for this period than for the previous millennia in the Holocene and this has allowed for the development of several high resolution hemispheric scale temperature reconstructions. Additionally, reconstructions of natural (solar, volcanic and land use) and anthropogenic forcing are availableat least since 850 AD and have been used as boundary conditions in transient Atmosphere-Ocean General Circulation Model simulations.

This talk reviews the state of the art in AOGCM modelling of the last two millennia and how these exercises allow, in spite of the large uncertainties, for gaining insight about the relative roles of internal and forced climate variability.

Mathematical treatment of a global climate energy balance model coupled with a deep ocean model

Lourdes Tello, Universidad Politécnica de Madrid

We study the mathematical treatment of a global climate energy balance model for the surface temperature coupled with a deep ocean model which represents the evolution of the temperature with large scale of time and space. One of the main difficulties is related to the boundary condition which is dynamic and diffusive. Another difficulty, when dealing with this type of models, comes from the term representing the feedback effect of the planetary coalbedo which is modeled by a discontinuous function (which we understand in the sense of multivalued graphs of $\mathbb{R}^2$). One interesting characteristic of these global climate models is the sensitivity front variations of parameters. We focus on the Solar Constant to analyze how the steady states depend on it. We present results related to uniqueness and multiplicity of evolution and stationary temperatures and the numerical approximation of the solutions of the coupled model. Some of these results were obtained in collaboration with J.I. Díaz (U .C. M.) and A. Hidalgo (U. P. M.).

The two paradigms of extratratropical troposphere equilibration

Pablo Zurita-Gotor, Instituto de Geociencias - Universidad Complutense de Madrid

Baroclinic eddies are a fundamental component of the global atmospheric circulation that regulate the extratropical climate by transporting heat upwards and polewards. Since this transport occurs in much shorter time scales than the differential radiative heating, baroclinic eddies play a key role in determining the climatological temperature gradients between Equator and Pole and between the surface and the tropopause. Understanding what determines the magnitude of this eddy transport is a classical problem in General Circulation theory with important implications for climate and climate change.

Broadly speaking, two main paradigms have been proposed to explain the determination of the mean thermal structure in the extratropics. Baroclinic adjustment postulates that eddy transport is so efficient as to render the mean state close to some optimal equilibrium (e.g., neutral to baroclinic instability). Some observational support of this idea is provided by the remarkable tendency of the mean isentropic slope in the extratropics to remain nearly constant throughout the seasonal cycle, in spite of the large changes experienced by the mean meridional and vertical isentropic gradients. In the baroclinic adjustment paradigm, the eddy transport is determined by global constraints on the mean state rather than by the strength of the thermal gradients.

In contrast, the turbulent diffusion paradigm assumes that (meridional) eddy heat transport occurs diffusively and is thus controlled by the local temperature gradient. The main difficulty for this kind of theories is that the diffusivity itself is a function of the mean state and cannot be regarded as fixed. Different closures have been proposed for the diffusivity based on the phenomenology of geostrophic turbulence. These suggest that the diffusivity may increase steeply with the isentropic slope, which would prevent the isentropic slope from changing significantly as observed.

In this presentation, I will review these two paradigms and the relation between them and summarize our findings over a number of years using a hierarchy of idealized models of varying complexity.

Oceanography:

Shallow water with vorticity

Ángel Castro, Instituto de Ciencias Matemáticas - Universidad Autónoma de Madrid

In this talk we will study the water waves problem with a flat bottom. We will introduce the vorticity in our analysis. Our interest will be focus in the shallow water regime in which the length of the wave is large compared with the typical dept. The existence of asymptotic solutions with the shallow water parameter goes to zero will be shown.

Geosystemics: a systemic view of the Earth's magnetic field and possibilities for an imminent geomagnetic transition

Moncho Gómez Gesteira, Universidad de Vigo / Universidade de Vigo
(*with A. Barreiro, A. J. C. Crespo and J.M. Domínguez*)

The capabilities of the SPH models to deal with complex scenarios involving real geometries and extreme events are shown for different applications. The model is able to capture the main features of complex flows and allows including objects that can move due to the force exerted by the fluid.

Any function $A(r)$ (pressure, density, velocity, ...) can be approximated by an integral interpolant:

$$A(r) = \int A(r')W(r - r', h)dr'$$

where $W(r - r', h)$ is the weighting function or kernel and h is the smoothing length. In discrete notation, this leads to the following approximation at point a,

$$A(r) = \sum_b m_b \frac{A_b}{\rho_b} W(r - r_b, h)$$

where the summation is over all the particles b within the region of compact support of the kernel function. The mass and density are denoted by m_b and ρ_b respectively, being $V_b = m_b/\rho_b$ the volume of a particle, $r = r_a$ the position vector and $W_{ab} = W(r_a - r_b, h)$ the weighting function (kernel) that depends on the distance between particles a and b.

Typical application cases are the description of the violent collisions between freak waves and offshore structures or coastal flooding under extreme waves will be presented. The method is especially well suited to reproduce the flooding of coastal areas, where water can move cars, pieces of urban furniture or debris.

The HySEA Project: a web-based platform for the simulation of geophysical flows

Carlos Parés, Universidad de Málaga

In last years, the EDANYA group of the University of Málaga has been working in the development of the web-based platform HySea allowing the users to run simulations of geophysical flows from their own computers by using a standard browser. The simulations are run in a CPU/GPU cluster located in the Laboratory of Numerical Methods of the University of Málaga.

These simulations are based on the numerical approximation of the systems of Partial Differential Equations that govern the flows to be studied. So far, the models considered are hydrodynamic depth-averaged models whose PDE systems are nonlinear nonconservative and hyperbolic. The approximations of their solutions are obtained by applying high-order finte volume methods.

In the talk, some of the technical difficulties will be briefly discussed and the different applications of the platform (such as river flows, sea currents, floods, avalanches, tsunami waves, etc.) will be presented.

Geomagnetic field:

Regional modeling of the Earth's magnetic field at different spatial and temporal scale

Javier Pavón Carrasco, Istituto Nazionale di Geofisica e Vulcanologica, Roma

Modeling the Earth's magnetic field is a crucial physic-mathematical approach for understanding the dynamo process which occurs in the outer core. The use of the mathematical functions, as the case of the associated Legendre functions, play an important role in the geomagnetic field modeling due to the potential behavior of the geomagnetic field. In this presentation, we will show how the Spherical Cap Harmonic Analysis (SCHA) can be applied to produce regional models of the Earth's magnetic field at different spatial and temporal scales using various sources of geomagnetic data. The SCHA technique along with other mathematical approaches, as the case of the bootstrap algorithms, has been used to: (a) generate the first regional model for the geomagnetic field in the Northern Hemisphere for the last 14000 years, using the available database of archaeomagnetic and lava flow data. (b) To model the secular variation of the intensity field by using the cross-over marine data over the Northern Atlantic Ocean for the time interval 1960 – 2000.

Geomagnetically induced currents by solar storms: an emerging natural hazard that can be modelled

Miquel Torta Margalef, Observatori de l'Ebre, (OE) CSIC - Universitat Ramon Llull, Roquetes

The electric currents induced in the modern technological systems generated by geomagnetic storms (known as geomagnetically induced currents or GICs) can disrupt or damage the transformers of the high voltage power grids. Such harmful effects have been usually observed only at high geomagnetic latitudes (such as in Canada or Scandinavia). Nevertheless, some transformer failures were even reported in South Africa on the occasion of the Halloween storms of 2003. This fact has encouraged several research groups and agencies to initiate vulnerability assessment studies on power grids located at regions previously considered to have low GIC-risk. To derive the geoelectric field several strategies can be followed. When geomagnetic field variations are obtained sufficiently close to the location where GIC is computed and the characteristics of the source currents are fairly uniform (such as it is the case at a mid-latitudinal region), a simple model which considers a plane wave primary field that propagates vertically downwards, and the Earth with a uniform conductivity, has been shown to be a very reasonable approach for GIC computation. As regards the method for calculating the currents in the earthed conductor network, a matrix based approach, which is based on Ohm's and Kirchhoff's laws, can be straightforwardly applied, because both the electric field and currents can be considered time-independent in comparison with the 50 Hz mains. An assessment of the GIC vulnerability across the entire Spanish power transmission system will be presented. Preferred geomagnetic/geoelectric field directions in which the maximum GICs occur are automatically given from the grid model circuit. To assess the maximum expected GICs in each transformer as a consequence of extreme geomagnetic storms, post-event analysis of data from the Spanish geomagnetic observatories during either the 1989 "Quebec" or the 2003 Halloween storms are performed, although other episodes coincident with very abrupt storm onsets, which have proven to be more hazardous at these mid-latitudes, are analyzed as well. In addition, Ebro Observatory digital geomagnetic data are used to know statistical occurrence probability values to derive the GIC risk at 100-year or 200-year return period scenarios.

<u>The Earth's rotation</u>:

THE EARTH ROTATION: A CHALLENGING PROBLEM IN MATHEMATICS AND PHYSICS

José Manuel Ferrándiz, Universitat d'Alacant / Universidad de Alicante

A suitable knowledge of the orientation and the motion of the Earth in the space is a common need in various fields. It is obvious that knowledge is necessary to carry out astronomical observations, but with the advent of the space age it became essential for making observations of satellites and predicting and determining their orbits and for observing the Earth from the spacecrafts as well. Given the relevant role it plays in Space Geodesy, nowadays Earth rotation is considered as one of the three pillars of Geodesy, the other two being geometry and gravity. Besides, the research on Earth rotation, continued for centuries, has fostered advances in many fields, as Mathematics, Astronomy and Geophysics.

One of the more remarkable features of the problem is the extreme requirements of accuracy that must be fulfilled in the near future, that at the level of a millimetre on the tangent plane to the planet surface, roughly speaking. That challenges all of the methods of solution that have been devised and used up to the date, a selection of which will be presented here together with present unsolved problems.

Remote Sensing:

Cloud motion estimation using multi-channel satellite images

Luis Álvarez, Universidad de Las Palmas de Gran Canaria

Cloud motion estimation from satellite images is an important source of information for weather forecasting and to study the structure and dynamics of hurricanes and severe thunderstorms. Currently, meteorological satellites provide multichannel image sequences including visible, temperature and water vapor channels. In this work we propose to use variational models to estimate cloud motion based on such satellite image sequences. The associated Euler-Lagrange equations yield to a nonlinear system of partial differential equations. We illustrate the performance of the proposed models with numerical experiments on two multichannel satellite sequences of the North Atlantic, one of them from the Hurricane Vince.

Adavanced Differential SAR Interferometry (DInSAR) or how the phase of a complex number can be used as a deformation monitoring tool

Jordí Mallorquí, Univ. Politécnica de Cataluña / Universitat Politècnica de Catalunya

A Synthetic Aperture Radar (SAR) is a coherent imaging sensor able to acquire high resolution images from orbital platforms independently of the weather or sunlight conditions. All its capabilities have made this technique one of the fundamentals for Earth observation over oceans as well as over land. The images obtained from a SAR are complex. The amplitude depends on the scene reflectivity while its phase, among others, is proportional to the two-way distance from satellite to ground and therefore to the geometry of the scene. The combination of two SAR images of the same scene acquired from different orbits, i.e., incidence angles, produces an interferogram. The interferogram is obtained by multiplying one image by the complex conjugate of the other and contains, on a pixel by pixel basis, the phase difference between the two acquisitions. This phase difference can be exploited in combination with the orbital information for each acquisition to derive a Digital Elevation Model (DEM) of the scene. This interferometric processing of SAR data (InSAR) was used for instance by NASA/DLR/ASI for the Shuttle Radar Topographic Mission (SRTM) to obtain elevation data on a near-global scale for generating one of the most complete high-resolution digital topographic database of the Earth. The next step in SAR interferometry has been the detection of Earth surface movements with Differential Interferometry (DInSAR) that has shown excellent results in the last years of research. Initial single interferogram DInSAR techniques have evolved to multi-image techniques which are able to retrieve the deformation movement of the studied areas with, at least theoretically, millimetric precision. The application of such techniques has extended to many forms of surface deformation in seismology, volcanology, anthropogenic subsidence or uplift and glacier monitoring. The latest achievements of these techniques consist in taking advantage of the polarimetric sensors to improve the number of pixels with reliable information. The basic concepts and mathematical tools of InSAR and DInSAR processing will be presented as well as numerous examples of application in many diverse scenarios: urban, volcanic, mines and landslides. The sensors used for generating the results are the commercial satellites ERS1/2, ENVISAT, TerraSAR-X, COSMO-Skymed, RADARSAT-2 and ALOS-PALSAR; the UPCâs ground-based SAR; and the airborne platforms E-SAR (DLR) and ARBRES (UPC).

Modelization Studies in the Mars Exploration

Luis Vázquez, Universidad Complutense de Madrid

The Mars exploration is part of the scientific goal addressed to try to understand the formation, history and evolution of our Solar System. We present a panoramic view of the top ten discoveries of the Mars Exploration Program with the enigmas and open questions. Finally, we consider the modelization associated to the study of the solar radiation at the Mars surface, the planetary boundary layer and the observation of Phobos eclipses.

Natural hazards:

On the Large Eddy Simulation of some multiphase problems in geophysics

Luigi Berselli, Universitá di Pisa

We present some results of a work in progress coming from a collaboration with the National Institute for Geophysics and Volcanology. The main motivation comes from the request to perform reliable and fast numerical simulations of some of the phenomena present in volcanic eruptions and involving especially the transport of mixture between a (slightly) compressible fluid and solid particles. Our results are then applicable to some geophysical applications such as volcanic plumes, jet evolution, but also transport of contaminants in oceanic flows. For the mentioned flows the Reynolds number typically is huge and Direct Numerical Simulations are not feasible. Hence we will consider Large Eddy Simulation Models, which will be applied to Eulerian models, where the particles are modeled, as another continuum interacting in a given way with the flow (Dusty gas and Fast Eulerian models for instance). We will then examine the development of particles in freely decaying turbulence, of a plume, and also of the classical dam break problem, by reporting the numerical results obtained by using OPENFOAM, one of the best known industrial CFD software packages. This is a joint work with M. Cerminara (SNS/INGV) and T. Esposti Ongaro (INGV).

Rupture process of earthquakes

Elisa Buforn, Universidad Complutense de Madrid

The determination of the source mechanism of an earthquake is an inverse problem: from observations (seismograms) we obtain the parameters that define the rupture process. We can use two different approaches: kinematic (more simple) or dynamic models. Kinematic models consider a discontinuity on displacements on a fault plane The dynamic models consider discontinuities the distribution on stresses from which displacements depend. Here we will consider only the kinematic approach. The hypocentre and time origin are estimated previously, but in some cases, from the study of rupture process, we can obtain more detailed information about these parameters. The most simple model to represents the seismic source is a point source and shear fracture or double couple model. In this model, to solve the rupture process we estimated the fault plane orientation defined by three parameters: strike, dip and slip that may be obtained from the polarity of the first motion of P-waves. From body wave modelling we can estimate, in addition to fault plane orientation, focal depth, scalar seismic moment and source time function. A more general model of the seismic source is the moment tensor, in this model the rupture process is defined by the seismic moment tensor components (six or five if we assume isotropic rupture) and focal depth, a total of seven parameter to estimate. For moderate earthquakes ($M > 6{,}5$) the point source is a good approximation, but for larger shocks we need take in account the dimensions of the fault. Using the observations of body waves we can estimate the rupture area of the fault, the rupture velocity, the slip distribution on the fault and the time history of the rupture. In practice the application of these methods vary if we use observations at far field (teleseismic or regional distances) or near field.

The Negative Binomial Distribution as a Renewal Model for the recurrence of large earthquakes

Amalio Fernández Pacheco, Universidad de Zaragoza

We present the Negative Binomial Distribution as a new discrete Renewal Model for the recurrence of large earthquakes. The underlying Markov cycle is discussed, the Parkfield series is fitted and the predictibility of the model is computed using error diagrams.

Fire Modelling with Data Assimilation

Luis Ferragut, Universidad de Salamanca

In recent years, the advances in computational power and the increase in the capabilities of spatial information technologies (remote sensing and geographic information systems, GIS) othe great potential for the effective modelling of wildland fire behaviour. This has intensified the interest in the fire behaviour modelling as can be appreciated in the reviews that have appeared recently on wildland fire modelling. On the other hand Data Assimilation is a technique used to incorporate data into a running model using sequential statistical estimation. An important point is to reach a balance between model complexity and fast execution. In our research group (Numerical Simulation and Scientific Computing, SINUMCC, University of Salamanca) we have developed several fire physical models with the goal to obtain simulation computational time much less than the fire real time. In this presentation we focus on a simplified 2D model with some 3D effects. The model takes into account the moisture content and heat absorption by pyrolisis, the energy convected by the gas pyrolisated through the elementary control volume, the energy lost in the vertical direction and the radiation from the ames above the surface where the fire take place. We couple this model with a local wind model, well adapted to fire modelling, developed by SINUMCC. The topography, the fuel type and mass fraction of it and the meteorological data required by the model (temperature, humidity and wind) are provided via GIS. Concerning Data Assimilation, we have incorporated this thecniques to our fire models. The Ensemble Kalman Filter (EnKF) introduced by Evensen (1994) makes possible to apply Kalman filter to high dimensional discrete systems. The data assimilated are the position of the fire front and the mass fraction of fuel at certain points in the domain. The numerical examples show that this procedure is able to correct the approximations obtained by the model simulations providing more realistic predictions. The process has to be implemented using parallel computing.

Time reversal of seismic wavefields

Daniel Stich, Universidad de Granada

While there is a clear one-way direction of time in everyday life, most governing equations in physics are actually invariant to time reversal. This includes the elastodynamic wave equation. In numerical simulations we can interchange initial and final states and back-propagate a recorded seismic wavefield from the receivers into the Earth, where it will eventually focus where the waves were originated. Time reversal of the seismic wavefield is a forward problem mathematically, but an inverse problem conceptually, with the notable difference that no model parameterisation is required. That is, seismic sources or scatterers may be imaged directly, without any assumptions about the process involved. Here we focus on regional-scale time reversal of the surface wave coda. We image the generation of coda waves at lateral heterogeneity in the lithosphere, acting as surface wave reflectors, as well as at resonating basins, acting as continuous sources of secondary waves. For continuous sources, the energy of the time reversed waves appears to be the most appropriate imaging field. For single scattering, time reversal can be linked to quantitative Born inversion by computing the gradients of the misfit function from correlations between the time reversed and the regular forward wavefields.

Quantification of dynamic parameters of mass movements (snow avalanches and rockfalls) by seismo-acoustic measurements

Emma Suriñach, Universitat de Barcelona / Universidad de Barcelona

Slope descending masses are generators of seismo-acoustic waves. The seismic signals generated by snow avalanches and rock falls are useful for detecting and/or studying avalanche dynamics because of their reproducibility and repetitivity. The generated seismic time series obtained at a point receiver are complex. The mass acts like a moving multi-seismogenic source because of the different types and parts of the avalanche. Moreover, the wave propagation is complex owing to the heterogeneities in the medium and the rugged topography which are usually present in the area of the phenomena. Information from the signals is obtained from analysis in the time and frequency domains using methodology associated with seismological processes. The non stationary behaviour of the signals is considered. Quantification of the energy dissipated, speed and different characteristics of the snow avalanches etc, can be obtained by using the seismic signals generated.

Images of the Ocean with Legacy Seismic Reflection Data (Seismic Oceanography)

Ramón Carbonell, Instituto Jaume Almera - CSIC
(*with G. Buffett*)

Seismic Oceanography is an interdisciplinary research topic that uses the spatial resolution of the reflection seismology to address issues in oceanography. The method is sensitive to the thermohaline structure of the oceans. Where thermohaline refers to temperature and to the salt content, factors which together determine the sound speed and density of sea water. In particular, the results are of interest to physical oceanographers for the study of the ocean's physical attributes including temperature-salinity structure, mixing, internal waves, tides and currents. Seismic reflection profiling is applied to the study of large scale physical oceanographic processes in the Gulf of Cadiz and western Iberian coast, coinciding with the path of the Mediterranean Undercurrent. The multi-channel seismic reflection method provides clear images of thermohaline fine structure with a horizontal resolution approximately two orders of magnitude higher than CTD casting. The seismic data are compared with co-located historical oceanographic data. Three seismic reflectivity zones are identified: North Atlantic Central Water, Mediterranean Water and North Atlantic Deep Water. Seismic evidence for the path of the Mediterranean Undercurrent is found in the near-slope reflectivity patterns, with rising reflectors between about 500 and 1500m. However, the core of the undercurrent is largely transparent. Seismic images show that central and, particularly, intermediate Mediterranean Waters have fine structure coherent over horizontal distances of several tens of kilometers. However, the intensity of the reflectors, and their horizontal coherence, decreases downstream. This change in seismic reflectivity is probably the result of diminished vertical thermohaline contrasts between adjacent water masses, so that double-diffusion processes become unable to sustain temperature and salinity staircases. Comparison of root-mean-square seismic amplitudes with temperature and salinity differences between the Mediterranean Undercurrent and the overlying central waters suggests a causal relationship between observed thermohaline fine structure and true seismic amplitudes. We estimate that, within this intermediate water stratum, impedance contrasts are mainly controlled by sound speed contrasts (a factor between 3.5 and 10 times larger than density contrasts), which are mainly controlled by temperature contrasts (a factor between 1.5 and 5 times larger than salinity contrasts).

3D coupled geophysical-petrological modelling of the Canary Islands and northwestern African margin lithosphere

Javier Fullea, Instituto de Geociencias, CSIC - UCM

In this work we study the present-day thermal and compositional 3D structure of the lithosphere beneath the Canary Islands and north-western African margin. We aim to understand the origin and evolution of Canary and north-African intraplate volcanism and its possible link to the thinned lithosphere imaged beneath the Atlas Mountains. We apply an integrated and self-consistent geophysical-petrological methodology (LitMod) that combines elevation, gravity, gradiometric, geoid, surface heat flow, and seismic data and allows modelling of thermal and compositional heterogeneities within the lithospheric mantle. The code solves simultaneously the heat transfer, thermodynamic, rheological, geopotential, and isostasy (local and flexural) equations in the lithosphere and sub-lithospheric upper mantle. In this way, key mantle properties (e.g. seismic velocities, density) are determined within a self-consistent thermodynamic framework, as a function of the pressure, temperature and compositional conditions. Therefore, this approach is able to generate 3D subsurface models that can simultaneously account for a large number of geophysical and petrological observables, which significantly reduces the uncertainties related to the modelling of these data sets separately or in pairs. In particular, we integrate landbased geophysical-petrological data (e.g. gravity, surface heat flow, topography, seismic tomography, mantle xenoliths) with the recently released purely satellite (land independent) gravity gradient data from the GOCE mission.

Symmetry and dynamics in a convection problem with temperature-dependent viscosity

Ana María Mancho, Instituto de Ciencias Matemáticas

We explore the instabilities developed in a fluid in which viscosity depends on temperature. In particular, we consider a dependency that models the melting and solidification of a magma ocean which is suitable for representing a lithosphere over a convecting mantle. To this end, we study a 2D convection problem in which viscosity depends on temperature by abruptly changing its value up to a factor of 400 within a narrow temperature gap at which magma melts. We conduct a study which combines bifurcation analysis and time-dependent simulations. Solutions are found that are fundamentally related to the presence of symmetry. Among these we find spontaneous plate-like behaviors. The plate-like evolution alternates motions towards either the right or the left, thereby introducing temporary asymmetries on the convecting styles. Further time-dependent regimes are found and described.

Geomagnetically induced currents by solar storms: an emerging natural hazard that can be modelled

Sergio Zlotnik, Universitat Politècnica de Catalunya / Universidad Politécnica de Cataluña – Barcelona Tech

Real time solutions (solution that can be obtained in fractions of seconds) of complex (pde based) problems could make a difference in many disciplines. In the engineering fields it could, for example, help to monitor and predict the behavior of structures in bridges and buildings. In scientific areas it can, among many other things, make possible the solution of inverse problems by evaluating an object function in real time. In recent years, some researchers have proposed the use of Reduced Basis methods in order to achieve the goal of real time solvers. Among these methods the Proper Generalized Decomposition (PGD), has some very interesting features that we will investigate and present in this work. We present the solution of some geology and geophysics related problems where some parameters are unknown or have large errors bounds that cannot be neglected. For example, find the best fitting temperature distribution in a cross section where the temperature (or the flux) at the bottom is unknown. Or find the temperature when the rock diffusivities are known only within a range. Or even, find the temperature distribution in the case where there is a layer of low diffusivity rocks, but the location of this layer is not exactly known. All these problems can be attacked using the PGD method and, after some offline processing, the solution could be found on the fly with an extremely low computational cost.

Assessment of the interactions of three open-loop groundwater heat pump systems in an alluvial aquifer

Francisco Javier Elorza, Universidad Politécnica de Madrid

The open-loop groundwater heat pump system draws water from a well, passes it through a heat exchanger and discharges the water into an injection well. The performance of the system depends on the condition of groundwater, specially temperature and depth, which affect performance of the heat pump and system. Currently, open loop systems are a relatively small sector in the overall ground source heat pump systems market in Spain, but demand for use in larger scale commercial/public buildings in urban environments is increasing. In this case study is shown that numerical heat transport models (as well as geochemical models) are indispensable tools to support scientific and technical research in this area. They are not only valuable for verifying the conceptual understanding of an aquifer system, but can also help to predict the operational performance of system, its impacts on other potential groundwater users and to simulate long-term thermal interference effects.

Wind forecasting over complex terrain

Rafael Montenegro, Universidad de Las Palmas de Gran Canaria

In this paper we introduce a new methodology for wind field forecasting over complex terrain. The idea is to use the predictions of the HARMONIE mesoscale model as the input data for an adaptive finite element mass consistent wind model. The HARMONIE results (obtained with a maximum resolution about 1 Km) are refined in a local scale (about a few meters). An interface between both models is implemented such that the initial wind field is obtained by a suitable interpolation of the HARMONIE results. In addition, measured data can be considered to improve the reliability of the simulations. An automatic tetrahedral mesh generator, based on the meccano method, is applied to adapt the discretization to complex terrains. The main characteristic of the framework is a minimal user intervention. The final goal is to validate our model in several realistic applications in Gran Canaria Island, Spain. These wind simulations can also be used for air pollution modeling.

Social and environmental aspects:

INVESTMENT UNDER UNCERTAINTY WITH ENVIRONMENTAL EFFECTS

Carlos Vázquez Cendón, Universidad de La Coruña / Universidade da La Coruña

The irreversibility of some actions on the environment needs to be considered when starting investment projects (to build a mine, dam, bridge, highway, gas plant or airport, for example) . Among others, this issue jointly with the option of investing money and the capacity to delay a project plays an important role in optimal investment planning. In this work, we deal with the numerical solution of some models related to the opportunity of starting an industrial project that provides some uncertain benefits but also has some instantaneous irreversible effects on the environment. Thus, the implicit uncertain profit associated to the environment stops once the project is initiated. When both the environment and the industrial project benefits are uncertain and governed by stochastic processes, an important problem is to determine if the project has to be started and which will be the joint utility if started at an optimal instant.

The mathematical model can be posed in terms of an obstacle problem associated to an elliptic equation on an unbounded domain. The mathematical analysis and numerical solution requires specific tools. This is a joint work with Íñigo Arregui (Universidade da La Coruña).

List of Communications (in chronological order):

Communication 1: Ronan Monjarret (Institut de Mathématiques de Toulouse)

* Well-posedness and other properties of the two-layer shallow water model with free surface

Communication 2: Miguel Ángel Martín (E.T.S.I. Agrónomos / UPM)

* Particle size distributions in granular media: selfsimilarity and packing

Communication 3: Alexander Robinson (UCM)

* A mathematical framework for constraining changes in ice sheet thickness during the last interglacial period

Communication 4: Fernando San José Martínez (UPM)

* Shape and pore space morphology of soil aggregates with X- ray computed tomography

Communication 5: Fátima Martín-Hernández (IGEO, CSIC-UCM)

* Modeling of superparamagnetic contribution of natural samples derived from the reversal part of hysteresis loop

Communication 6: Rubén Banderas (IGEO, CSIC-UCM)

* An interhemispheric oscillation controlling glacial abrupt climate change

Communication 7: Verónica Torralba (UCM)

* Interannual and decadal climate variability over Northeast Brazil using discriminant analysis techniques of filtered rainfall

Communication 1:

Well-posedness and other properties of the two-layer shallow water model with free surface

Ronan Monjarret, Institut de Mathématiques de Toulouse

Considering n fluids, which are homogeneous, inviscid, incompressible and without surface tension, the 3D Euler equations with long wave assumption provide the multi-layer shallow water model. As salinity is assumed discontinuous, these equations are used to describe the oceans (typical application is the strait of Gibraltar). Here, the two-layer particular case is presented.

First, the existence and unicity of the solution in $H^s(\mathbb{R}^2)$ is analysed, in finite-time, using the criteria and a relaxation model.

Second, the study of the equations leads to the exact field of hyperbolicity of the two-layer shallow water model, depending only on 3 parameters. An important result is that it is divided in two parts. Not only the approximation of the eigenstructure (in each part of the hyperbolicity field), initiated by, but also the conservativity of the relaxation model, permit the improvement of the treatment of the boundary conditions.

Communication 2:

Particle size distributions in granular media: selfsimilarity & packing

Miguel Ángel Martín, Universidad Politécnica de Madrid
(*with F. Muñoz, M. Reyes and F. J. Taguas*)

Here we focus the attention in granular media involving many size particles, in such a way that may be supposed that all grain sizes under a certain size becomes potentially represented. The crucial influence of particle size distribution (PSD) on the random packing structure increase the interest in relating both, either theoretically or by computational methods. On one hand, the statistical similarity property for a grain distribution suggests the use of fractal models for PSD. On the other, a one-parameter model providing a robust simulation model is needed in order to relate such parameter with the porosity of random packings. Finally a consistent computational method is needed. This work includes both, theoretical and computational aspects, in order to study the dependence of a one- parameter fractal model previously established and the packing properties of simulated PSD.

Communication 3:

A mathematical framework for constraining changes in ice sheet thickness during the last interglacial period

Alexander Robinson, Instituto de Geociencias (UCM - CSIC)
(*with J. Álvarez-Solas and M. L. Montoya*)

Over the last few decades, a number of ice cores have been retrieved from the Greenland ice sheet that contain valuable data concerning the last glacial cycle. The conversion of these data into useful proxies is based on our understanding of physical processes translated into mathematical equations. The parameters of these equations are subject to large uncertainty, however, and are often determined via simple regressions on one variable. Here we present a more formal approach to simultaneously optimize for the parameters that relate $\delta^{18}\mathrm{O}$ and the total gas content of an ice core to local climatic conditions. We take advantage of the fact that the paleo data are affected by the same boundary information (e.g., temperature and elevation) and thus can be used in conjunction to reduce the uncertainty range of the estimated parameter and proxy values. As an example, we use time series from the GRIP ice core to derive a transient estimate of the summit elevation of the Greenland ice sheet over the last interglacial period, and we show how additional cores could potentially be used to further improve our results.

Communication 4:

Shape and pore space morphology of soil aggregates with X- ray computed tomography

Fernando San José Martínez, Universidad Politécnica de Madrid
(*with F. J. Muñoz Ortega, F. J. Caniego Monreal, S. Kravchenko and W. Wang*)

The spatial arrangement of soil constituents –usually referred to as soil structure– controls important physical and biological processes in soil-plant-microbial systems, where microbial population dynamics, nutrient cycling, diffusion, mass flow and nutrient uptake by roots take place. Those processes are dominated by the geometry of soil structure and a correct model of this geometry is critical for understanding flow and transport processes in soils, creating synthetic soil pore space for hypothesis and model testing, and evaluating similarity of pore spaces of different soils. In this communication with characterized the geometrical morphology of a key element of soil structures: soil aggregates. Soil aggregates were collected at Long Term Ecological Research (LTER) site located in Michigan (USA) and aggregate tomography images were obtained on the Argonne National Laboratory (USA). Mathematical morphology and Minkowski functionals were used for image processing and measuring the geometrical attributes of their shape and pore space morphology.

Communication 5:

Modeling of superparamagnetic contribution of natural samples derived from the reversal part of hysteresis loop

Fátima Martín-Hernández, Instituto de Geociencias (UCM - CSIC)
(*with G. McIntosh and V. Villasante Marcos*)

Hysteresis loops are commonly measured in paleomagnetic, rock magnetic and environmental magnetic studies. Measurements are typically oriented toward the characterization of the ferromagnetic phases that give rise to irreversible behaviour. However, ferromagnets in a superparamagnetic state contribute to the reversible behaviour of the loop. The superparamagnetic contribution to the hysteresis loop has been computed as one half of the upper plus lower hysteresis branch. After removing the paramagnetic contribution, which is the linear trend after complete saturation of the ferromagnetic phases, the superparamagnetic contribution has been modeled as a series of Langevin functions. A non-linear fitting to the Langevin expression of the magnetization has been used. Each superparamagnetic magnetization curve has been tested to be a distribution of micromagnetization belonging to a distribution by linearizing the problem, although natural samples do not follow this thesis. The model has been tested with a collection of natural soils, volcanic samples from the latest El Hierro eruption and synthetic nanoparticles. The Langevin parameters, magnetization and concentration, correlate reasonable well with susceptibility measurements at two frequencies, a typical estimation of the SP content in rock magnetic studies.

Communication 6:

An interhemispheric oscillation controlling glacial abrupt climate change

Rubén Banderas, Instituto de Geociencias (UCM - CSIC)
(*with J. Álvarez-Solas , A. Robinson and M. L. Montoya*)

The last glacial period was punctuated by abrupt climate changes that are widely considered to result from millennial-scale variability of the Atlantic meridional overturning circulation (AMOC). However, the origin of these AMOC reorganisations remains poorly understood. The climatic connection between both hemispheres suggested by proxies indicates that the Southern Ocean (SO) could regulate this variability through changes in winds and atmospheric CO_2 concentration. Here, we investigate this hypothesis by using a coupled climate model in an experimental setup inspired by proxy data, in which CO_2 and SO windstress respond to AMOC variations. The evolution of the simulated climatic patterns matches the amplitude and timing of the largest events that occurred during the last glacial period. Our results indicate that glacial abrupt climate events are part of an internal interhemispheric oscillation and provide an explanation for the pervasive Antarctic-like climate signal found in proxy records worldwide.

Communication 7:

Interannual and decadal climate variability over Northeast Brazil using discriminant analysis techniques of filtered rainfall

Verónica Torralba, Universidad Complutense de Madrid
(*with B. Rodríguez-Fonseca and E. Mohino Harris*)

Throughout its long history, northeast Brazil has been plagued repeatedly by dramatic periods of drought. Specially, dry periods have been marked by severe social impacts and mass migrations which have affected the entire social and economic Brazilian culture. The present study analyses the interannual and decadal variations of rainfall in Northeast Brazil as well as the associated oceanic forcing with the aim of shedding light to its predictability. Furthermore, the stationarity of the relationship between the SST (Sea Surface Temperatures) variability and observed rainfall at interannual timescales is also analysed. To find out how the rainfall variability is organized in the region, Principal Component Analysis has been applied to four different observational rainfall datasets. This method is applied to the interannual and decadal component of rainfall separately. To isolate decadal variability, the precipitation anomalies time series are filtered using a Butterworth filter. Finally, from the hypothesis posed from the observations, some mechanisms are inferred and checked with AGCM (Atmosphere General Circulation Model) simulations. To this aim, on the one hand sensitivity experiments for the Pacific Niño and Atlantic Niño SST modes are analysed to find the interannual rainfall response. On the other hand, sensitivity experiments for AMO (Atlantic Multidecadal Oscillation), PDO (Pacific Decadal Oscillation) and GW (Global Warming) are used to verify the relationship between these SST anomaly patterns and the decadal component of rainfall.

List of Posters:

Poster 1: Habib Taibi and Mahdi Haddad (CST, Algeria)

- ⋄ Global Mean Sea Level Change from Satellite Altimetry: Trend and seasonality extraction

Poster 2: Habib Taibi and Mahdi Haddad (CST, Algeria)

- ⋄ Trends in global and regional sea level from satellite altimetry within the framework of Auto-SSA

Poster 3: Isabel Vigo (Universidad de Alicante)

- ⋄ North Atlantic Sea Level Variations and the Influence of the Atlantic Multidecadal Oscillation

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- ⋄ Edge Enhancing Diffusion to improve the geodetic determination of the ocean geostrophic currents

Poster 5: Saioa A. Campuzano (UCM)

- ⋄ Non-dipolar and regional effects on the Geomagnetic dipole moment for the last 3000 years

Poster 6: Saioa A. Campuzano (UCM)

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Poster 7: F. Javier Pavón-Carrasco (INGV, Italia)

- ⋄ Statistical analysis of the inclination shallowing observed in palaeomagnetic studies of recent (last 400 yr) lava flows

Poster 8: David Gómez-Castro (UCM)

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Poster 9: Jezabel Curbelo (ICMAT-UAM)

- ⋄ Lagrangian descriptors: construction, performance and applications

Poster 10: Sara Guerrero (IGEO, CSIC-UCM)

- ⋄ Reliability of the AMS ellipsoid based on bootstrap analysis

Poster 1:

Trends in global and regional sea level from satellite altimetry within the framework of Auto-SSA

Habib Taibi and Mahdi Haddad, Center of Space Tecniques (Algeria)

The sea level change is a crucial indicator of our climate. The spatial sampling offered by satellite altimetry and its continuity during the last 18 years are major assets to provide an improved vision of the sea level changes. In this paper, we analyze the University of Colorado database of sea level time series to determine the trends for 18 large ocean regions by mean of automatic trend extraction approach in the framework of the Singular Spectrum Analysis (SSA) technique. Our global sea level trend estimate of $3{,}19$ mm/yr for the period from 1993 to 2010 is comparable with the $3{,}20$ mm/yr sea level rise since 1993 calculated by AVISO Altimetry. However, the trends from the different ocean regions show dissimilar patterns. The major contributions to the global sea level rise during 1993-2010 are from the Indian Ocean ($3{,}78 \pm 0{,}08$ mm/year).

Poster 2:

Global Mean Sea Level Change from Satellite Altimetry: Trend and seasonality extraction

Habib Taibi and Mahdi Haddad, Center of Space Tecniques (Algeria)

The spatial sampling offered by TOPEX and Jason series of satellite radar altimeters and its continuity during the last twenty years are major assets to provide an improved vision of the global mean sea level (GMSL). The objective of this paper is to examine the recent GMSL variations (1993-2012). To this end, a Global mean sea level (GMSL) anomalies time series, obtained from TOPEX, Jason-1 and Jason-2 measurements, is used to determine the trend and seasonal components of GMSL changes, using a simplified form of an unobserved components model (namely UCM). Our GMSL trend gives a rate of $3{,}22 \pm 0{,}4$ mm/year between 1993 and 2012. Although the extracted global trend indicates a rise in the mean level of the oceans, there are marked fluctuations over short periods, which are least partly related to El Niño/La Niña episodes.

Poster 3:

Edge Enhancing Diffusion to improve the geodetic determination of the ocean geostrophic currents

Isabel Vigo, Universidad de Alicante / Universitat d' Alacant
(*with J. M. Sánchez-Reales and O.B. Andersen*)

In this work, we adapt the Edge Enhancing Diffusion (EED) filtering in order to smooth the noise in the higher harmonics degrees of the geoid when determining the SGC from a geodetic MDT. The EED allows us to use complete information about the direction of the flow by determining a structure tensor of the MDT. Then we can weigh the influence of the points along and across the stream current providing a normalized and completely an-isotropic way to filter the MDT attending not just to the gradient variations but to the flow stream direction. We prove how the EED is shown to be more stable and almost independent of local errors. This fact makes this filtering strategy preferred when filtering noisy surfaces. This is demonstrated by comparing both a smooth and a noisy MDT for the North-Western Pacific Ocean. The EED filter provides similar estimation of the currents velocities in both cases. Opposite to that, a non-linear isotropic filter returns results forced by local errors for the noisier case.

Poster 4:

North Atlantic Sea Level Variations and the Influence of the Atlantic Multidecadal Oscillation

Isabel Vigo, Universidad de Alicante / Universitat d' Alacant
(*with J. M. Sánchez-Reales and S. Belda*)

Sea Level trends are often studied as a direct effect of climate change, and considered an indicator of the global warming. Although it has been clearly proven a Sea Level rise over the last decades, some effort has to be paid in order to understand if such trends are part of a longer cycle or are in fact a deterministic trend. In particular, relatively short time-span available from altimetry, combined with regional phenomenon influence, could mislead to conclusions, which are not fully true when we study the regional variability in sea level trends. In order to illustrate such idea we have studied the North Atlantic sea level variations, that shows a dipole pattern with regions where altimetry shows an extreme sea level rise, with a trend for the altimetry period that is twice the rate of sea-level rise for the global ocean and how these are influenced by the Atlantic Multidecadal Oscillation.

Poster 5:

NON-DIPOLAR AND REGIONAL EFFECTS ON THE GEOMAGNETIC DIPOLE MOMENT FOR THE LAST 3000 YEARS

Saioa A. Campuzano, Universidad Complutense de Madrid
(*with F. J. Pavón-Carrasco and M. L. Osete*)

The study of the dipole moment variations is a forefront research topic in Earth's Sciences. It constrains geodynamo simulations and is used to correct the cosmogenic isotopes production informing about the past climate. Traditionally, this dipole moment is obtained directly from the archaeomagnetic database (e.g. Yang et al., 2000; Macouin et al., 2004; Genevey et al., 2008). It is denoted by virtual (axial) dipole moment, V(A)DM, depending on whether the dipole is tilted, VDM, or not, VADM.

Korte and Constable (2005) observed an overestimation of about 19.3% in the V(A)DM obtained by archaeomagnetic methods in comparison with the dipole moment given by the global geomagnetic model CALS7K.2. According with these authors, this can be explained by the lack of homogeneity, both spatial and temporal, of the archaeomagnetic database and the influence of the non-dipolar terms. But a rigorous study of these effects is still missing. In this work, we provide a comprehensive analysis about the factors that, potentially, would affect the estimation of the V(A)DM.

We first analyzed the effect of the non-dipolar terms in the V(A)DM estimations using the global models IGRF-11 (Finlay et al., 2010) and ARCH3K.1 (Korte et al., 2009), being lower of 4% in both cases. Secondly, we used synthetic data generated by global models to study the regional effects produced by the heterogeneous distribution of archaeomagnetic data and the regional weighting scheme proposed by Genevey et al. (2008). This analysis provides an overestimation both the Eurasian data and V(A)DM. Finally, we test the influence of the present spatio-temporal distribution of the archaeomagnetic database in global models generation by using IGRF-11.

Poster 6:

A NEW CONCEPTUAL CLIMATE MODEL OF THE QUATERNARY GLACIAL-INTERGLACIAL CYCLES

Saioa A. Campuzano, Universidad Complutense de Madrid
(*with J. Álvarez-Solas*)

The main characteristic of the Earth's climate during the Quaternary ($\sim$ 3 Myrs BP to present) is the alternance between cold periods (with largely developped ice sheets in North America and Fennoscandia) and warm periods (similar to the last 10000 yrs - the Holocene - where only two large ice sheets shape the globe; Greenland and Antarctica). The study of the deglaciations, their recurrence, appearance and amplitude, so as the periodicity associated to the glacial and interglacial cycles during the last 3 Myrs, has been of a great interest, but relatively poorly studied.

We here describe a new conceptual model based on previous studies carried out by Paillard (1998) and Paillard and Parrenin (2004). The proposed model includes the insolation at the Northern Hemisphere high latitudes as the only external forcing in order to simulate the evolution of the global ice volume across the glacial-interglacial cycles of the last 3 Myrs. In order to simulate the internal processes of the climate system, the model considers a climatic variable which amplifies the non-linearities of the system, favors the existence of thresholds and ultimately allows a succesfull simulation of glacial-interglacial cycles.

Poster 7:

STATISTICAL ANALYSIS OF THE INCLINATION SHALLOWING OBSERVED IN PALAEOMAGNETIC STUDIES OF RECENT (LAST 400 YR) LAVA FLOWS

F. Javier Pavón-Carrasco, Istituto Nazionale di Geofisica y Vulcanologia, Roma
(*with E. Tema, M. L. Osete and R. Lanza*)

The Earth's magnetic field undergoes changes in both space and time at secular scale due to the geodynamo processes that take place in the outer core. For the last century, these variations (the so-called secular variation) have been directly recorded through geomagnetic observatories, repeat stations, satellites, and airborne magnetic surveys, providing an accurate picture of the geomagnetic field behavior. Extending the knowledge of the directional geomagnetic field into the past four centuries is possible thanks to the declination and inclination measurements taken by navigational routes. However, to go back in time, the use of palaeomagnetic data is necessary. From $\sim$1600 AD up to the beginning of the 20^{th} century, both kind of data, i.e. historical and palaeomagnetic data, provide us information of the geomagnetic field variation. This work is focused on the last four centuries ($\sim$ 1600 - 1990 AD), for which both palaeomagnetic and historical data are available. Palaeomagnetic data (from both archaeological artifacts and lava flows) are compared with the predictions of the GUFM1 global model that has been developed based on the historical data from shipboard and navigational cruises. As a first result, such comparison shows a statistical agreement between the archaeomagnetic data and the directions given by the geomagnetic field model. However, when comparing separately the volcanic data with the model predictions, a marked inclination shallowing is observed. These systematically lower inclination values have been already pointed out in local palaeomagnetic studies (Italy, Mexico, and Hawaii) for the last century, by comparing recent lava flows with the present geomagnetic field (IGRF model). Here, we show how this inclination shallowing is statistically presented at world-wide scale for the last 400 yr with a mean inclination deviation of around 3° lower than the historical geomagnetic field model predictions.

Poster 8:

SHAPE DIFFERENTIATION APPLIED TO THE WASTE WATERS CHEMICAL TREATMENT REACTORS

David Gómez-Castro, Universidad Complutense de Madrid
(*with J. I. Díaz*)

We consider a reaction-diffusion mathematical model obtained trough homogenization techniques (Conca, Díaz, Liñán, Timofte (2004)) for double scale composite absorption chemical catalytic reactions which arise in many different contexts of the Chemical Engineering, as for instance in the treatment of waste waters (see, e.g. Felis, Fouilloux, De Bellefon and Schweich (1998)). We analyze, for a Freundlich simplified model, the diffeerent "efficiency" of the shape of the reactor following the definition of such a concept given by Aris in 1957. After analyzing the case of the sphere and cylinders, when the total volume is prescribed, we also consider the case in which the family of reactors does not preserve the volume but fulfill some partial symmetry properties.

Poster 9:

LAGRANGIAN DESCRIPTORS: CONSTRUCTION, PERFORMANCE AND APPLICATIONS

Jezabel Curbelo, Instituto de Ciencias Matemáticas - Universidad Autónoma de Madrid
(*with A. M. Mancho, S. Wiggins and C. Mendoza*)

Lagrangian descriptors are introduced to find phase portraits in dynamical systems with a general time dependence. We discuss a general methodology for constructing Lagrangian descriptors, and we consider several benchmark examples to assess the performance of Lagrangian descriptors in revealing invariant manifolds and other phase space structures. The performance of Lagrangian descriptors is compared with both finite time Lyapunov exponents (FTLEs) and finite time averages of certain components of the vector field. We show the performance of the Lagrangian Descriptors in 2D and 3D flows.

Poster 10:

RELIABILITY OF THE AMS ELLIPSOID BASED ON BOOTSTRAP ANALYSIS

Sara Guerrero, Instituto de Geociencias (UCM - CSIC)
(*with F. Martín-Hernández*)

AMS is a well-known petrofabric indicator for rock deformation (Tarling and Hrouda, 1993). But it presents some some difficulties when the sample has an AMS close to the noise level.

Though some authors have realized different statistical analysis to improve these results, the common technique is the mathematical Bootstrap introduced in paleomagnetism by Tauxe (1991).

The bootstrap is a simple and powerful statistical technique that allows the extension of the analysis of uncertainties to parameters derived from the principal susceptibilities, but it can be overly optimistic. In this review, we analyze the reliability of the AMS ellipsoid based on bootstrap analysis. We determine which parameters the bootstrap technique depends on: kind of distribution or error, measurement's number, iterationsñumber and the variable to which the bootstrap is applied. And we indicate the minimum value of these parameters to obtain a significance level of 95%. Then we show the accuracy we can have using Boostrap's technique depending on the AMS value relative to the instrumentâs accuracy and degree of similarity of the ellipsoid's eigenvalues.

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