Mathematics of the Weather 2017

Tuesday 3 October
-
Thursday 5 October

La Salle de l'Ancre des Mots
Erquy, France

Programme

National Centre for Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL

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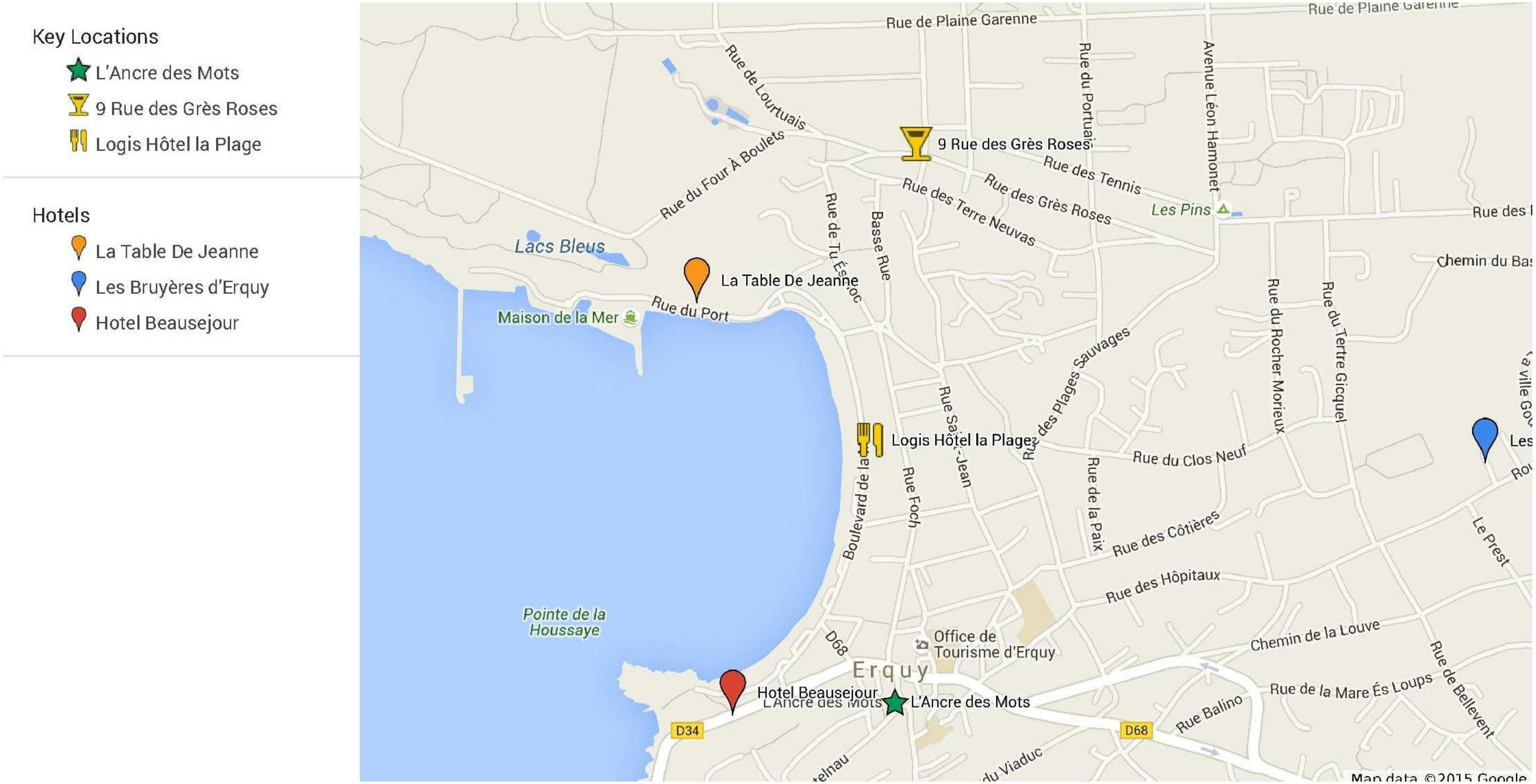
Venues Map and Links



View an interactive version of this Google map at http://bit.ly/MoWTravelMap

L'Ancre des Mots official site http://www.ville-erquy.com/culture-et-patrimoine/l-ancre-des-mots
Hotel La Plage http://www.hotelplage-erquy.com/fr/accueil.html

Travel Map and Links

Erquy

L'Ancre des Mots

Train

Gare de Lamballe

Gare de Saint Brieuc

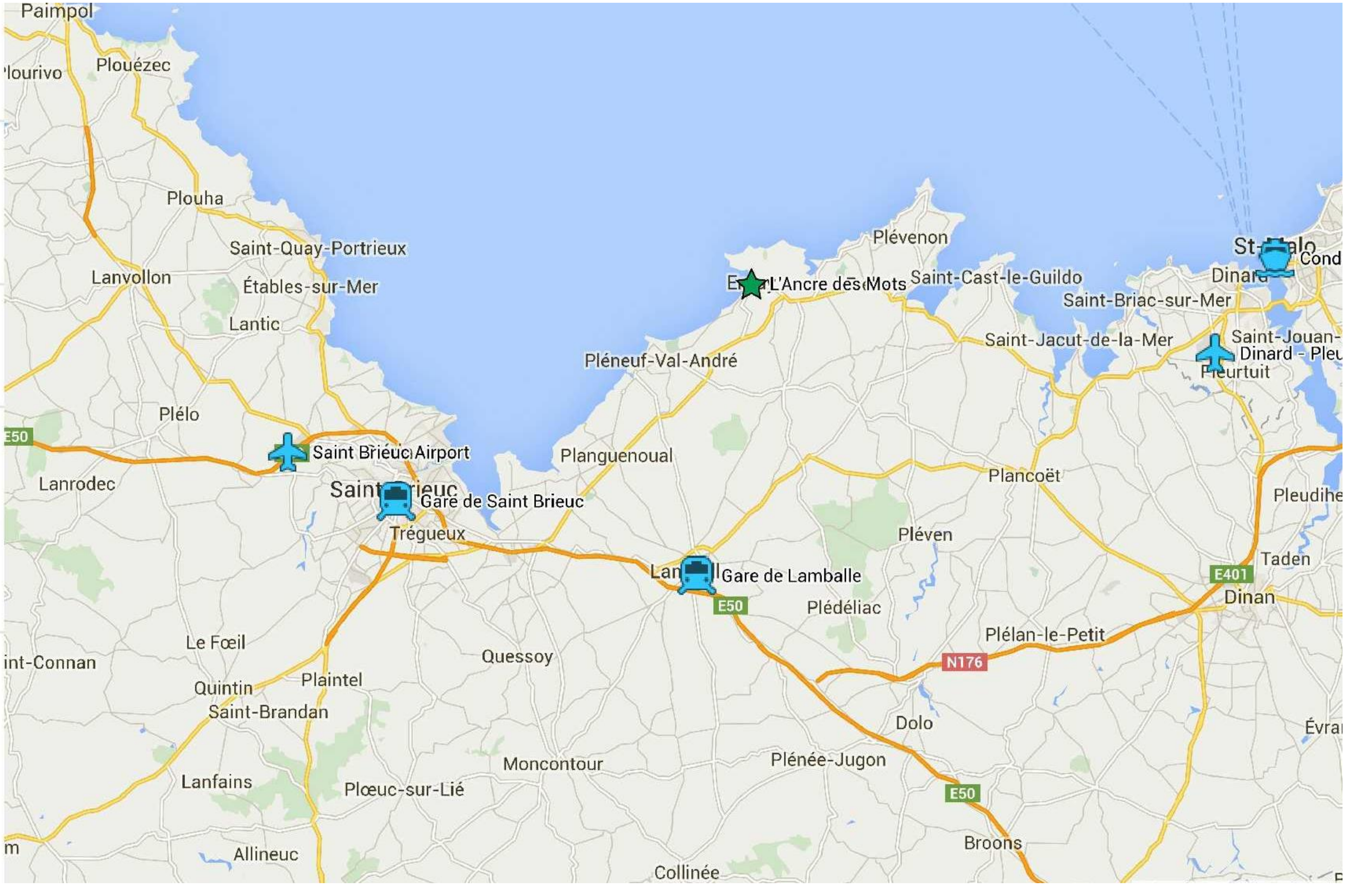
Ferry

Condor Ferries

Airport

Dinard - Pleurtuit - Saint-Malo Airport

Saint Brieuc Airport



View an interactive version of this Google map at **http://bit.ly/MoWVenuesMap**

French national rail travel tickets and information **www.voyages-sncf.com**

Bus travel from Saint Brieuc and Lamballe to Erquy **http://www.tibus.fr**

Condor Ferries St Malo **www.condorferries.fr**

Tuesday 3 October 2017

13:00 - 14:00 Arrival and Registration

Tea and coffee will be served in the foyer

14:00 - 14:40 Session 1: Welcome

Chair: Jurgen Steppeler

14:00-14:10 Welcome by **Alan Gadian** and **Jurgen Steppeler**

14:10-14:30 Address by the **Mayoress of Erquy, Christiane Guervilly**

14:30-14:40 Organisational matters by **Alan Gadian** and **Jurgen Steppeler**

14:40 - 15:20 Session 2: Model Systems

Chair: Pierre Benard

14:40-15:20 **Bill Skamarock**
NCAR, USA
Vertical resolution, model filters, and their impact on modeled atmospheric kinetic energy spectra.

15:20 - 16:00 Afternoon Tea Break

16:00 - 17:20 Session 3

16:00-16:40 **John McGregor**
CSIRO Oceans and Atmosphere, Australia
Two new dynamical cores on the Uniform Jacobian cubed-sphere

16:40-17:00 **Mikhail Tolstykh**
Institute of Numerical Mathematics Russian Academy of Sciences, and Hydrometcentre of Russia, Russia
Global Hydrostatic semi-Lagrangian Atmospheric Model on the Reduced Latitude-Longitude Grid Using Vorticity-Divergence Formulation

17:00-17:20 **Konrad Simon**
University of Hamburg, Germany
Flow-induced Coordinates for Transient Advection-Diffusion Equations with Multiple Scales

18:30 Evening Drinks Reception
Hosted by Professor & Mrs Steppeler

All delegates are warmly invited to join Professor & Mrs Steppeler and the Programming Committee for an evening drinks reception at 9, Rue des Grès Roses, 22430, Erquy

Wednesday 4 October 2017

09:00 - 10:20 Session 4

Chair: John McGregor

09:00-09:40 **Pierre Benard**
Météo-France, France
Circumventing the pole problem of spherical coordinates with local schemes; some applications

09:40-10:20 **Masaki Satoh**
The University of Tokyo, Japan
Recent development of the Nonhydrostatic Icosahedral Atmospheric Model NICAM and future perspective

10:20 - 11:00 Morning Coffee Break

11:00 - 13:00 Session 5: Numerics for HPC Models

Chair: Masaki Satoh

11:00-11:40 **Jurgen Steppeler**
CSC, Germany
Polynomial polygone L-Gelerkin methods and cut cells

11:40-12:00 **Oswald Knoth**
Institute for Tropospheric Research, Germany
ASAM-Unstructured: Code infrastructure and applications

12:00-12:20 **Thomas Dubos**
Ecole Polytechnique / Université Paris-Saclay, France
Energy-conserving finite-difference schemes for the fully-compressible Euler equations in a generalized vertical coordinate

12:20-12:45 **Tan Bui-Thanh**
The University of Texas at Austin, USA
The upwind hybridized discontinuous Galerkin method for dynamical cores

12:45 - 13:45 Lunch with Tea and Coffee

13:45 – 14:00 Afternoon Walk Planning / Discussion

14:00 Afternoon Walk

All delegates are invited to join colleagues on an afternoon walk, exploring the trails and surrounding coastline of Erquy. Led by **Jurgen Steppeler.**

Thursday 5 October 2017 AM

09:00 - 10:20 Session 6

Chair: Alan Gadian

09:00-09:40 **Joseph Klemp**
NCAR, USA
Damping Acoustic Modes in Compressible HEVI and Time-Split Integration Models

09:40-10:00 **Fangxin Fang**
Imperial College London, UK
A Preliminary Simulation of Tropical Cyclone Using An Adaptive Unstructured Mesh Finite-Element Model

10:00-10:20 **Jinxi Li**
Institute of Atmospheric Physics, Chinese Academy of Sciences, China
An Analysis of the Grid Quality and the Advection Errors in the Orthogonal Terrain-Following Coordinate

10:20 - 10:50 Morning Coffee Break

10:50 - 12:30 Session 7

Chair: Joseph Klemp

10:50-11:50 **Joanna Szmelter**
Loughborough University, UK
High-Performance Unstructured-Mesh Based Approach for Nonhydrostatic Flows

11:50-12:10 **Florian Lemarie**
Inria, France
Stability analysis of split-explicit oceanic models

12:10 - 12:30 Poster Summaries

Janek Zimmer
Meteologix AG, Germany

Joerg Kachelmann
Meteologix AG, Germany

12:30 - 14:00 Poster Session with Lunch with Tea and Coffee

Thursday 5 October 2017 PM

14:00 - 15:30 Session 8

Chair: Joanna Szmelter

14:00-14:30 **Roland Potthast** DWD, Germany; **Jurgen Steppeler** CSC, Germany
Work at DWD

14:30-15:00 **Pierre Benard** Météo-France, France
Work at Météo France
Report on NUMA

15:00-15:30 **Young Kwon** KIAPS, South Korea; **Joseph Klemp** NCAR, USA
Work at KIAPS

15:30 - 16:00 Afternoon Tea Break

16:00 - 17:30 Session 9

Chair: Bill Skamarock

16:00-16:30 **Masaki Satoh** The University of Tokyo, Japan
Modelling in Japan

16:30-17:00 **Fedor Mesinger** Serbian Academy of Sciences and Arts, Serbia
Cut-cell Eta: design and skill compared to its driver ECMWF 32-day ensemble

17:00-17:30 **Christopher Eldred** University of Grenoble Rhone Alpes, France
Progress towards a non-hydrostatic structure-preserving atmospheric dynamical core with consistent parameterizations

17:30 - 18:00 Close and Thanks

Jurgen Steppeler and **Alan Gadian**

19:30 Conference Dinner at Hotel la Plage

All delegates are warmly invited to join the Programming Committee for the Conference Dinner at Hotel la Plage, 21 Boulevard de la Mer, 22430, Erquy

Programme Summary

Tuesday 3 October 2017

13:00-14:00	Arrival and Registration
14:00-14:40	Session 1: Welcome
14:40-15:20	Session 2
15:20-16:00	Afternoon Tea Break
16:00-17:20	Session 3
18:30	Drinks reception hosted by Professor and Mrs Steppeler 9, Rue des Grès Roses, 22430, Erquy

Wednesday 4 October 2017

09:00-10:20	Session 4
10:20-11:00	Morning Coffee Break
11:00-12:20	Session 5
12:45-13:45	Lunch
13:45-14:00	Afternoon Walk Planning / Discussion
14:00	Afternoon Walk in Erquy

Thursday 5 October 2017

09:00-10:20	Session 6
10:20-10:50	Morning Coffee Break
10:50-12:30	Session 7
12:30-14:00	Poster Session including Lunch
14:00-15:30	Session 8
15:30-16:00	Afternoon Tea Break
16:00-17:30	Session 9
17:30-18:00	Close and Thanks
19:30	Conference Dinner Hotel la Plage, 21 Boulevard de la Mer, 22430, Erquy

Abstracts

Alphabetical Order

Bénard, Pierre

Meteo-France, CNRM-GAME, France

Circumventing the pole problem of spherical coordinates with local schemes; some applications

The use of spherical coordinates with lat-lon grids to solve meteorological equations on the sphere is known to rise numerical problems gathered under the name of "pole problem". For local space-discretisations, this coordinates leads either to strong constraint on the time-step for unreduced lat-lon grids, or to strong accuracy constraints near the pole for reduced lat-lon grids. Non-local discretisations are not totally free of these problems but they may be solved more easily.

For operational purpose, Meteo-France (together with ECMWF) uses a global model based on the spectral transform method, but the bottleneck of communications for this method on future computing architectures strongly suggests to consider the use of local discretisations for future applications. During past years, a demonstration Shallow-Water model has been built to examine whether the pole problem could be circumvented for the case of an unstaggered reduced lat-lon grid. Since grid points are not aligned meridionally, the solution of governing equations not only requires discrete derivative operators but also zonal interpolation operators. It has been found that provided a high degree of accuracy is maintained near the pole for derivative and interpolation operators, and a very careful attention paid to pole boundary conditions, the pole problem may be circumvented in a similar manner than in spectral discretisations.

A possible formulation of discretized governing equations will be described, and results obtained with demanding test-cases for Shallow-Water equations (e.g. Scott et al. 2016) will be presented.

Also will be presented, as an application, a numerical determination of Rossby modes of nonlinear Shallow-Water equations on a rotating sphere (these modes has not been exposed to date and could serve as a test-case in replacement of the traditionally used Haurwitz waves which are irrelevant for this governing system).

Bui-Thanh, Tan

The University of Texas at Austin, Aerospace Engineering and the Institute of Computational Engineering and Sciences, USA

The upwind hybridized discontinuous Galerkin method for dynamical cores

We will present several new developments on the emerging Hybridized Discontinuous Galerkin (HDG) method. First, starting either from the Godunov upwind idea or from the Rankine-Hugoniot condition we derive a unified HDG framework for linear PDEs that allows one to uncover new HDG methods and recover most of the existing ones for a large class of PDE including the Friedrichs' systems. Analysis and numerical results for the unified framework will be presented. Second, we will present an IMEX scheme for the HDG method with application to atmospheric sciences. Third, we will present a multilevel HDG solver that is promising to be one of the fast and parallel solvers for large-scale problem. Fourth, we will present an iterative HDG (iHDG) method that exploits current and future multi-threaded computing system with massive concurrencies. We provide both theoretical justification and numerical results to support the iHDG idea. Several test cases and models for the dynamical core will be presented to demonstrate the potential of the HDG approach on current and future extreme-scale computing systems.

Dubos, Thomas
Ecole Polytechnique / Université Paris-Saclay, Lab. Met. Dyn / IPSL, France

Energy-conserving finite-difference schemes for the fully-compressible Euler equations in a generalized vertical coordinate

We explore a Hamiltonian approach to the issue of stable spatial and temporal discretization of the fully compressible Euler equations using their vector-invariant form in a non- Eulerian vertical coordinate. A horizontally-explicit, vertically-implicit (HEVI) time discretization is adopted, exploiting the Hamiltonian structure of the equations in order to identify those terms of the equations of motion that need to be treated implicitly.

A novel treatment of the lower boundary condition in the presence of orography is introduced: rather than enforcing a no-normal-flow boundary condition, which couples the horizontal and vertical velocity components and interferes with the HEVI structure, the round is treated as a flexible surface with arbitrarily large stiffness, resulting in a decoupling of the horizontal and vertical dynamics and yielding a simple implicit problem which can be solved efficiently. Standard test cases suggest that an effective horizontal acoustic Courant number close to 1 is achieved.

Eldred, Christopher
University of Grenoble Rhone Alpes, AIRSEA/LJK/IMAG/INRIA, France

Progress towards a non-hydrostatic structure-preserving atmospheric dynamical core with consistent parameterizations

The equations of inviscid, (moist-)adiabatic fluid dynamics are Hamiltonian, and this structure underlies many of the most basic principles that we know about geophysical fluid flows, such as conservation laws. Recent work has indicated that this structure can be extended to include diabatic processes (such as dissipation and moist processes) through the use of a metriplectic formulation, which combines a Hamiltonian structure for the inviscid, adiabatic dynamics with a metric structure for the viscous, diabatic dynamics. This formulation inherently satisfies both the 1st and 2nd law of thermodynamics. Guided by the philosophy that we are not discretizing arbitrary PDEs but building a representation of a physical system, it is possible to also satisfy these laws in the discrete case (and also obtain many other desirable properties) by retaining key elements of the underlying metriplectic structure in the numerical model, A very general approach to the design of such models is outlined: the combination of a metriplectic formulation for the continuous equations with a mimetic spatial discretization and an energy-conserving Poisson time integrator. Utilizing this approach the resulting model has many desirable properties such as energy conservation to machine precision, physics parameterizations consistent with the 1st and 2nd laws of thermodynamics, curl-free pressure gradients and the absence of spurious stationary computational modes (all in the presence of both temporal discretization and physics parameterizations). This talk will present progress towards a concrete realization of this philosophy: a high order, metriplectic, structure-preserving atmospheric dynamical core built using compatible Galerkin methods following the approach above. Emphasis will be on the existing hydrostatic Hamiltonian model, with the non-hydrostatic, metriplectic version currently under development discussed as time permits.

Fang, Fangxin

Imperial College London, Department of Earth Science and Engineering, UK

A Preliminary Simulation of Tropical Cyclone Using An Adaptive Unstructured Mesh Finite-Element Model

This study presents the first application of an unstructured adaptive finite-element model (Fluidity) to simulation of a tropical cyclone. Fluidity is a computational fluid dynamics open source model capable of numerically solving the 3D compressible Navier-Stokes equation using a dynamically adaptive mesh.

To evaluate the performance of adaptive meshes in numerical weather prediction, the tropical cyclone case has been setup without parameterization of cumulus convection and carried out using adaptive unstructured meshes with the minimum and maximum mesh sizes of 0.5 km and 50 km respectively. The mesh is dynamically adapted where the fine resolution is in the central area of tropical cyclone in which convective clouds and larger-scale motions are treated explicitly. For simplicity, the tropical cyclone is setup with an assumption of circular symmetry. The initial condition is taken from Yamasaki (1977). The open lateral boundaries are incorporated that permitting gravity wave to propagate out of the domain with little reflection.

In this tropical cyclone numerical case, the unstructured tetrahedral meshes are adapted automatically with the solutions of velocity, potential temperature and water vapor in time and space. The grids are denser where the gradients of variable solutions are higher and the grids in the rest of the domain are relatively sparse while maintaining the promising accuracy and saving the computational resources. The simulation provides the structures of the disturbance similar to the real tropical cyclone; realistic horizontal velocity fields having inflow concentrated near the surface and outflow in the upper computational domain.

Reference:
M. Yamasaki, 1977: A preliminary experiment of the tropical cyclone without parameterizing the effects of cumulus convection. Journal of Meteorological Society of Japan, 55(1): 11-31.

Giraldo, Frank

Naval Postgraduate School, Mathematics, USA

The Galerkin Numerical Modeling Environment (GNuMe)

In this talk I will describe the GNuMe framework that we have been developing and using to test geophysical fluid dynamics models. GNuMe is, in essence, a modeling environment that contains local element-based numerical discretization methods (spectral elements and discontinuous Galerkin methods), as well as a suite of time-integrators (explicit, fully-implicit, and implicit-explicit methods). GNuMe contains the Non-hydrostatic Unified Model of the Atmosphere (NUMA) which is being used inside of the U.S. Navy's NEPTUNE weather prediction system. NUMA is a 3D compressible Navier-Stokes solver specifically designed for atmospheric flows on both Cartesian and spherical domains (i.e., for both regional and global simulations). GNuMe also contains a non-hydrostatic ocean modeling component (NUMO) based on the incompressible Navier-Stokes equations. In this talk, I will update you all on the status of the GNuMe project in general and on the current state of affairs with both the NUMA atmospheric and NUMO ocean modeling components. One key point of GNuMe is that it can be run on any type of hardware (e.g., Intel Xeon Phis, Nvidia GPUs, etc.).

Klemp, Joseph
NCAR, MMM Laboratory, USA

Damping Acoustic Modes in Compressible HEVI and Time-Split Integration Models

Although the equations of motion for a compressible atmosphere accommodate acoustic waves, these modes typically play an insignificant role in atmospheric processes of physical interest. In numerically integrating the compressible equations, it is often beneficial to filter these acoustic modes to prevent their artificial growth. In horizontally explicit vertically implicit (HEVI) and split-explicit time integration schemes, off-centering the vertically implicit numerics can effectively damp vertically propagating acoustic modes, but further filtering may be required to attenuate horizontally propagating modes having large vertical wave length. Here, a new technique is proposed for filtering the 3-D divergence that may damp acoustic modes more effectively that filters previously implemented in the Weather Research and Forecasting (WRF) Model and the Model for Prediction Across Scales (MPAS). With this approach, a divergence damping term is added as a final adjustment to the horizontal velocity equations after completing the vertically implicit portion of the time step. In this manner the divergence used in the filter term can have exactly the same numerical form as that used in the pressure equation. Analysis of the dispersion equation for this form of the filter documents its stability characteristics and confirms that it effectively damps acoustic modes with little artificial influence on the amplitude or propagation of the gravity-wave modes that are of physical interest. Some specific aspects of the implementation of the filter in MPAS are discussed and results are presented to illustrate some of the beneficial aspects of suppressing acoustic noise.

Knoth, Oswald
Institute for Tropospheric Research, Department Modelling of Atmospheric Processes, Deutschland

ASAM-Unstructured: Code infrastructure and applications

In my talk I will give an overview about a fully unstructured grid model ASAM-Unstructured to solve the compressible Euler equations with special emphasis on numerical weather application. The intension is to have a code which can handle the full zoo of global unstructured grid proposed in the past for triangulating the sphere and but can be used also with different of cartesian like grids with boundary following coordinates or cut cells. Whereas at the moment mostly finite volume/finite difference spatial discretization are implemented also low order composite finite element will be implemented in the future. Beside the spatial discretization we will review in more detail the different options to integrate the equation in time. These methods range from fully explicit, split-explicit up to fully implicit Rosenbrock-W-methods. Numerical examples will illustrate the current state of my code development.

LEMARIE, Florian

Inria, Laboratoire Jean Kuntzmann, France

Stability analysis of split-explicit oceanic models

Evolution of the oceanic free-surface is responsible for the propagation of fast surface gravity waves which approximatively propagates at speed $\sqrt{gH}$ (with g the gravity and H the local water depth). In the deep ocean, this phase speed is roughly two orders of magnitude faster than the gravest internal gravity waves. The steep stability constraint imposed by those fast surface waves on the time-step of numerical models is handled using a mode splitting between slow (internal / baroclinic) and fast (external / barotropic) motions to allow the possibility to adopt specific numerical treatments in each component.

The barotropic mode is traditionally approximated by the vertically integrated flow because it has only slight vertical variations. However, the implications of this assumption on the stability of the splitting are not well documented. In this talk, we describe a stability analysis of the mode splitting technique based on an eigenvector decomposition using the true (depth-dependent) barotropic mode. This allows us to quantify the amount of dissipation required to stabilize the approximative splitting. We show that to achieve stable integrations, the dissipation usually applied through averaging filters, can be drastically reduced when incorporated at the level of the barotropic time stepping. The benefits are illustrated by numerical experiments. In addition, the formulation of a new mode splitting algorithm using the depth-dependent barotropic mode is introduced.

Li, Jinxi

Institute of Atmospheric Physics, Chinese Academy of Sciences, State Key Laboratory of Numerical Modeling for Atmospheric Sciences and Geophysical Fluid Dynamics, China

An Analysis of the Grid Quality and the Advection Errors in the Orthogonal Terrain-Following Coordinate

We analyse the relationship between the grid quality and the advection errors in the orthogonal terrain-following coordinate (OTF-coordinate) compared with those in the basic terrain-following coordinate (BTF-coordinate) and the hybrid terrain-following coordinate (HTF-coordinate) to explore the reason for the reduction of advection errors by the OTF-coordinate relative to the other two coordinates. At first, we compare the grid quality of the BTF-coordinate, the HTF-coordinate and the OTF-coordinate with three rotation parameters (the power, hyperbolic and general rotation parameters), in terms of three basic grid quality indexes which are the skewness, the aspect ratio and the smoothness. We find that the OTF-coordinate with the general rotation parameter own the highest grid quality among all these coordinates. Secondly, we use a grid quality index (skFOAM) from AtmosFOAM model to further investigate the grid quality and the advection errors in different coordinates. We find out that the skFOAM can manifest the comprehensive effect of the basic three grid quality indexes used earlier. Comparing the effects of all these four grid quality indexes in a series of advection experiments using the above three coordinates, the OTF-coordinate just reduce the advection errors through reducing the skFOAM. Finally, a kind of experiment of sloping terrain using the BTF-coordinate and the OTF-coordinate with a constant rotation parameter is implemented to investigate whether the more the grid quality is, the smaller the advection errors are. The experimental results show when the direction of velocity and the vertical layer are parallel, the advection errors in the two coordinates are constantly the same whatever their grid qualities are. Moreover, the larger the terrain slope is, the greater the reduction of the advection errors by the OTF-coordinate is.

McGregor, John
CSIRO Oceans and Atmosphere, Australia

Two new dynamical cores on the Uniform Jacobian cubed-sphere

The Conformal-Cubic Atmospheric Model (CCAM; McGregor 2005a) was the first atmospheric GCM to be formulated on a cubed-sphere grid. CCAM employs semi-Lagrangian, semi-implicit dynamics, which handles the finer resolution near the vertices without a time step penalty. It also uses reversible staggering in the horizontal (McGregor 2005b) to achieve good dispersion properties and good kinetic energy spectra. The Miller and White equations permit a very economical treatment of non-hydrostatic behaviour for CCAM.

Recently the CCAM code has been generalized to utilize the Uniform Jacobian (UJ) variation of the cubed-sphere grid. This grid is derived from the conformal-cubic grid to provide equal area for every grid cell. Since the grid lines are no longer orthogonal, covariant and contravariant velocity components are required. Apart from the complications of the velocity components, most of the CCAM semi-Lagrangian approach may be used, including reversible staggering of the contravariant velocity components to switch between values at cell centres and cell edges. The solver for the Helmholtz equation is a little more complicated than for CCAM.

A second dynamical core has also been developed on the UJ grid. This version employ the primitive equations in conservative form, which has extra appeal for climate studies and for modelling trace gases and chemistry. Split-explicit time stepping is used, with small time steps for the "fast" gravity waves processes and longer time steps for the "slow" advective processes and the physical parameterizations. Flux-corrected-transport is employed to better preserve any sharp gradients in the advected fields. It also employs the reversible staggering technique for the contravariant wind components

Both new dynamical cores produce very acceptable climatologies. The climatologies of CCAM and the new dynamical cores will be compared and their relative advantages and disadvantages discussed.

Mesinger, Fedor
Serbian Academy of Sciences and Arts, Mathematics, Physics and Geo-sciences, Serbia

Cut-cell Eta: design and skill compared to its driver ECMWF 32-day ensemble

While used operationally at NCEP the Eta did well in tests of its vertical coordinate and precipitation scores. Comparing the Eta/EDAS against WRF-NMM/GSI it did better in precipitation scores (Mesinger and Veljovic, in press; MV2017 further on).

In response to the problem of flow separation in the lee of bell-shaped topography discovered by Gallus and Klemp the Eta was refined to use a simple cut-cell scheme (MV2017).

In a recent experiment the Eta was driven by ECMWF 32-day ensemble members. Two verification scores were used on 250 hPa winds and both showed advantage of the Eta, in particular during the first 10 days when the ensembles had about the same resolution. The Eta advantage was very prominent during days 2-6 when a major upper-tropospheric trough was crossing the Rockies. Rerunning the ensemble with the Eta switched to sigma advantage over ECMWF was shown as well, although not to such a degree.

Here we show an illustration of the improvements resulting in this conspicuous advantage of the Eta, and present verification via the number of "wins" according to our scores. At day 4.5 there were two jet streaks over our domain; one across northern Alaska, and the other stretching along eastern U.S. and into Atlantic. On average maps for the 21 members, Eta and also Eta/sigma positions of both were more accurate than those of their driver members. Eta however was more accurate than the Eta/sigma in positioning the streak across the U.S. and towards the tip of Greenland.

The advantage of the Eta was even more striking in the number of wins. During this 2-6 day time 4 times the Eta had all 21 members placing the strongest winds more accurately than their driver members. Eta/sigma was mostly "winning" these placement scores also, but not to that extent. Eta, on the other hand, showed a prominent advantage over the Eta/sigma. Still, we find the degree of the advantage of the Eta/sigma over ECMWF somewhat puzzling, and suggest a number of candidate reasons.

Satoh, Masaki
The University of Tokyo, Atmosphere and Ocean Research Institute, Japan

Recent development of the Nonhydorstatic Icosahedral Atmospheric Model NICAM and future perspective

This lecture overviews mathematical aspects of recent development and future perspective of the Nonhydorstatic Icosahedral Atmospheric Model NICAM and (Satoh et al. 2014, 2017). NICAM adopts the icosahedral grid structure with the A grid type specification of prognostic variables of density, three components of momentum, total energy, and water categories together with other tracers. In the vertical, the Lorenz staggering grid is used with a rigid lid at the top of the specific height. The terrain following coordinate or the hybrid coordinate can be used. Data assimilation system is available with applying local ensemble transform Kalman filter to NICAM: NICAM-LETKF. NICAM is coupled with a tri-polar global ocean model COCO using a generalized coupler called Jcup, and now NICAM-COCO is available to study atmosphere-ocean interactive processes in various spatial and temporal scales.

For the vertical discretization, NICAM adopts the terrain following coordinate system as the most of global and regional atmospheric models, but it is known that this approach requires smoothing out steep topography to achieve numerical stability. We newly developed a scheme to simulate flows over steep topography introducing a thin-wall approximation on a terrain following approach. In this scheme, topography is separated into two parts: a smooth part for a terrain-following approach and the deviation from the smooth part for a thin-wall approximation. The smooth part is constructed by a threshold of local maximum gradient of topography and is used for definition of the terrain-following coordinates. The deviation part is used for a thin-wall approximation. We use this scheme to simulate flows over mountains with multi-scale shape composed of exponential and cosine functions. Comparing with the original terrain-following approach, the new scheme reduces spurious modes and improves distortion of large-scale gravity waves.

Simon, Konrad
University of Hamburg, Department of Mathematics, Germany

Flow-induced Coordinates for Transient Advection-Diffusion Equations with Multiple Scales

Simulation over a long time scale in climate sciences as done, e.g., in paleo climate simulations require coarse grids due to computational constraints. Unresolved scales, however, significantly influence the coarse grid variables. Such processes include (slowly) moving land-sea interfaces or ice shields as well as flow over urbanic areas. Neglecting these scales amounts to unreliable simulation results. State-of-the-art dynamical cores represent the influence of subscale processes typically via subscale parametrizations and often employ heuristic coupling of scales.

Our aim is to improve the mathematical consistency of the upscaling process that transfers information from the subgrid to the coarse prognostic scale (and vice-versa). We investigate a new bottom-up techniques for advection dominated problems arising in climate simulations. Our tools are based on ideas for multiscale finite element methods for elliptic problems that play a role, in oil reservoir modeling and porous media in general. Modifying these ideas is necessary in order to account for the transient and advection dominated character that are typical for flows encountered in climate models.

We present a new Garlerkin based idea to account for the typical difficulties in climate simulations. Our modified ideas employ a change of coordinates based on a coarse grid characteristic transform induced by the advection term in order to account for appropriate subgrid boundary conditions for the multiscale basis functions which are essential for such approaches. We present results from sample runs for a simple advection-diffusion equation with rapidly varying coefficients on several scales.

Skamarock, Bill

NCAR, USA

Vertical resolution, model filters, and their impact on modeled atmospheric kinetic energy spectra.

One of the unsolved questions in atmospheric dynamics concerns the energetics responsible for the k^(-5/3) scaling observed in the mesoscale portion of the atmospheric kinetic energy (KE) spectrum (where k is the horizontal wavenumber). Models reproduce the observations-based spectrum for both the synoptic-scale k^(-3) and mesoscale k^(-5/3), and given the limitations of the observations, modeling-based studies are the primary approach for examining the mesoscale dynamics of the spectrum.

We are computing atmospheric spectra for global NWP forecasts and for idealized global simulations using the atmospheric component of the Model for Prediction Across Scales (MPAS) in order to study the dynamics associated with the spectrum. As in past studies, we find a mesoscale region in the model spectrum when resolution is sufficiently fine, and we see the divergent component is an increasingly larger portion of the total KE in the mesoscale region of the spectrum as one moves progressively higher in the atmosphere.

The model spectra show significant sensitivity to filtering, and we find that a model's effective resolution decreases with increasing height in the stratosphere. We also see significant sensitivity of the spectra to model vertical resolution, and the MPAS stratospheric spectra are not close to convergence when the vertical grid spacing is greater than a few hundred meters. Unresolved inertia-gravity waves with short vertical wavelengths appear responsible for the lack of convergence when the vertical grid spacing is inadequate.

In this talk we will present results illustrating the response of model energetics to filters and vertical resolution, and we will discuss the implications for atmospheric modeling applications in weather and climate given that current operational weather and climate model configurations do not resolve the mesoscale KE, particularily in the stratosphere.

Steppeler, Jurgen

CSC, Germany

Polynomial polygone L-Gelerkin methods and cut cells

L-Galerkin methods use a field representation by continuous piecewise polynomials on polygonal cells. The original Galerkin method is non-local, which causes problemes for implementation, in particular with massively parallel computers. Newer L-Galerkin methods are local and therefore much more practical for modeling. The only L-Galerkin currently in practical use is the spectral element method, which is based on quadrature approximation. Alternative L-Galerkin methods are proposed, allowing larger time-steps and a regular collocation grid. These applications use polynomials of high degree, 3 or higher. Linear or piecewise constant basis functions can be used to emulate the C-grid finite difference method. This representation can be used to derive finite difference equations for cut cell discretization. The cut cell discretization can be used to obtain an accurate representation of the lower boundary conditions. Some popular approximations can be shown to be non-consistent and non-convergent. Such problems can be solved using a C-grid scheme where the densities are defined at the corners of cells, rather than at the centers. A consistent cut cell scheme for the cell center grid is possible with a non-conserving scheme.

Sunkisala, Anusha
Univeristy of Hamburg, Numerical methods in Geosciences, Germany

Coupling concepts based on Schwarz domain decomposition methods

In earth system models (ESM) a number of sub-components, like atmosphere, oceans, terrestial and cryospheric systems are coupled. For long term climate simulations, the coupling mechanism is crucial for maintaining accuracy and conservation properties of the system. It can be assumed that the coupling accuracy influences the general system's sensitivity to perturbations as well as its convergence to realistic solutions. Therefore, a mathematically consistent algorithm and structure preservation of the exchanged quantities play an important role for achieving relevant simulation results.

My research focuses on adaptation of Schwarz domain decomposition methods to idealized ocean atmosphere coupling to obtain a stable and consistent coupling method. The idea of Schwarz decomposition methods is to separate the original problem on a domain into sub-domains (sub-problems) which can be solved separately. An iterative process is then applied to achieve convergence to the solution of the original problem. I started with the implementation of Schwarz decomposition methods to 1D elliptic and parabolic equations as toy models to better understand these methods and to extend this type of method for atmosphere and ocean coupling.

Szmelter, Joanna
Loughborough University, Wolfson School, UK

High-Performance Unstructured-Mesh Based Approach for Nonhydrostatic Flows

The presentation will discuss the developments of a fully unstructured (and hybrid) mesh class of models for non-hydrostatic flows with emphasis on simulating inertia gravity waves. Global and limited area atmospheric models will be presented. The methodology employs an edge-based, finite volume discretisation within the non-oscillatory forward-in-time (NFT) framework based on the unstructured mesh Multidimensional Positive Definite Advection Transport Algorithm (MPDATA) and elliptic (Krylov) solvers. It allows integration of the generic physical form of the governing PDEs formulated on arbitrary hybrid computational meshes discretising the generalised curvilinear framework of the computational space and uses a co-located arrangement for all the prognostic variables. For global models its application in the hybrid MPI-OpenMP finite volume module (FVM) dynamical core module of the ECMWF's Integrated Forecasting System (IFS) will be summarised. It is based on a non-hydrostatic solver for compressible Euler equations under gravity on a rotating sphere. FVM utilises meshes derived from the octahedral reduced Gaussian grid; where an unstructured mesh finite-volume discretised horizontal mesh is supplemented by a structured vertical coordinate and employs a flexible data structure framework ATLAS developed at ECMWF. For limited area models the approach will be evaluated for a range of soundproof nonhydrostatic flow solvers. Simulations of stratified orographic flows and the associated gravity-wave phenomena in media with uniform and variable dispersive properties will be presented. They verify the developments and demonstrate the efficacy of the implicit large eddy simulation operating on unstructured meshes for study of stratified turbulent flows.

Tolstykh, Mikhail

Inst. of Numerical Mathematics Russian Academy of Sciences, and Hydrometcentre of Russia, , Russia

Global Hydrostatic semi-Lagrangian Atmospheric Model on the Reduced Latitude-Longitude Grid Using Vorticity-Divergence Formulation

SL-AV (Semi-Lagrangian, based on the Absolute Vorticity equation) is the global hydrostatic atmospheric model developed at the Institute of Numerical Mathematics and used for operational medium-range and seasonal forecasts at Hydrometeorological centre of Russia. The current model version has horizontal resolution of about 20 km (over Russia), and meets operational requirements with only 288 processor cores. The model incorporates the following choices:

- semi-implicit semi-Lagrangian formulation allowing to use large time-steps;
- unstaggered horizontal grid requiring only one upstream trajectory per grid cell;
- vorticity-divergence formulation to obtain good inertia-gravity and Rossby wave propagation properties;
- direct solvers for elliptic-type problems using Fast Fourier Transforms in longitude;
- variable resolution in latitude, allowing to increase resolution over Russia.

This model version in the configuration with 13 km horizontal resolution scales up to 9072 computational cores, accelerating by the factor of 8.1 with respect to 504 cores (45% efficiency).

We plan to increase the horizontal resolution up to 10 km and the number of vertical levels up to 100. This pose the following problems:

- using the horizontal grid with quasi-uniform spacing;
- increasing the model code scalability.

Our choice of quasi-uniform grid is the reduced lat-lon grid. The motivation is the ease of implementation and small grid imprinting.

Increasing parallel scalability means abandoning Fourier representation in longitude that leads to the data transposition for elliptic solvers. We have developed local approximation for meridional derivatives at the reduced grid and geometric multigrid solver for Helmholtz and Poisson problems.

We also need dry-air and tracer mass conservation for long-range predictions. The finite-volume SL algorithm is implemented, extending 2D conservative cascade scheme of (Nair et al., 2002) to 3D reduced grid case.

Zimmer, Janek

Meteologix AG, Germany

Benefits and remaining issues while running a kilometer-scale model in an operational environment [Poster Presentation]

For over 2 years now, the "SwissHD" model is in operation for several nested domains in Europe and other parts of the globe. Running a mesoscale model at such a high resolution of around 1 km significantly improves temperature and wind forecasts over complex terrain, similar findings are presented for smaller-scale convective cells and features when compared to coarser-scale models (>4km grid cell size).

Several improvement packages have been implemented related to model physics, i.e. parametrizations including snow cover, temperature inversions or clouds and fog. Nonetheless a few systematic issues remain unsolved. They include overestimated mixing in sheared flow conditions, exaggerated gravity-wave activity and rapid downstream propagation and clustering of convective systems. It is hypothesized that they originate from the interaction of model dynamics and physical packages, which is discussed for several case studies.

Mathematics of the Weather 2017

Tuesday 3 October 2017

13:00-14:00	Arrival and Registration
14:00-14:40	Session 1: Welcome
14:40-15:20	Session 2
15:20-16:00	Afternoon Tea Break
16:00-17:20	Session 3
18:30	Drinks reception hosted by Professor and Mrs Steppeler 9, Rue des Grès Roses, 22430, Erquy

Wednesday 4 October 2017

09:00-10:20	Session 4
10:20-11:00	Morning Coffee Break
11:00-12:20	Session 5
12:45-13:45	Lunch
13:45-14:00	Afternoon Walk Planning / Discussion
14:00	Afternoon Walk in Erquy

Thursday 5 October 2017

09:00-10:20	Session 6
10:20-10:50	Morning Coffee Break
10:50-12:30	Session 7
12:30-14:00	Poster Session including Lunch
14:00-15:30	Session 8
15:30-16:00	Afternoon Tea Break
16:00-17:30	Session 9
17:30-18:00	Close and Thanks
19:30	Conference Dinner Hotel la Plage, 21 Boulevard de la Mer, 22430, Erquy

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