Séminaire Vendredi 11 Avril 11h00 / Seminar Friday April 11, 11:00 AM

Conférencier/Lecturer: Janusz Pudykiewicz

Sujet/Subject: Towards new models for numerical weather prediction

Présentation/Presentation: Anglais / English

Lieu/Room: Grande salle du premier étage CMC

Résumé/Abstract:

Numerical simulation of the atmosphere entering the second century of its development will certainly lead to new numerical models complementing the existing systems based on spectral and finite difference techniques. The evolution of these new models will likely follow the path which could be summarized briefly in the following way: removal of shallow atmosphere approximation, arbitrary geoid shape, Euler equations, spatial discretization based on flexible finite volume schemes, new time integration schemes.

One of the elements of the design of new models is the selection of the horizontal discretization. This problem was addressed in the innovative manner by A. Staniforth in the design of the Global Environmental model (GEM). The rectangular grid selected in this model allowed the use of a very high resolution over the selected region. Alternative approaches to the variable resolution using the rectangular grids were also suggested in air quality modelling. Despite the significant work performed with variable resolution rectangular meshes, there have also been other trends to design grids with different geometries. In particular the work with triangular and hexagonal grids have been performed in the quest for grids which are more adaptive and flexible than the traditional rectangular meshes. There are numerous examples of grids designed along this line. One of the best known examples is the OMEGA model which was developed by D. Bacon and used extensively in the weather and air pollution related research.

The central issue in the development of new models of the atmosphere is the design of a positive definite, mass conserving solver for the nonlinear equations describing geophysical fluids with complex sources and sinks representing physical processes and

chemical reactions. The main desired properties of the ideal solver are: algorithm applicable in arbitrary geometry, no splitting of the advection and chemical kinetics, elimination of the pole problem in spherical geometry, applicability of the method for small scale problems (i.e. street canyon modelling), moderate stability restriction (advective Courant numbers around 1-2). The solver satisfying the above listed requirements is build upon the concept of finite volume technique. Although the technique could be easily used on grids with very different geometries, the initial attention was focused on triangular meshes. The main advantage which we can derive when using the finite volume methodology with geodesic mesh is the ability of the grid system to cover the entire surface of the planet in almost uniform manner. The grid is thus ideally suited for the performing of the global scale cloud resolving runs provided that the proper computing platform is available.

We have just have completed test runs with the Finite Volume model using a set of shallow water equations coupled to chemical reactions. The system could be used for both the assessment of the accuracy of the numerical solvers developed and some research problems involving transport and chemistry of stratospheric ozone. Based on the framework developed using a relatively simple shallow water system, we have gone further in the development of a 3-D nonhydrostatic global system. One of the main problems being investigated is the selection of the time integration scheme. The considered options include the traditional semi-implicit method introduced by A. Robert in the early seventies as well as the new emerging approaches based on a class of Runge-Kutta-Rosenbrock solvers. The mesh system selected for the study is adaptable: the resolution could be enhanced over a selected region in a very flexible manner thanks to the properties of the triangular tessellation. The model is equipped with a chemical module and therefore permits accurate simulation of the transport of cloud water, moisture and reactive scalar fields. Preliminary testing has been performed using relatively coarse global meshes of the order of 50 km. In order to fully evaluate the methodology, we plan to continue the development of the system using a global 10 km grid with the resolution enhanced over any specific region down to 1 km and ultimately over the entire globe.

The increase of the model resolution will not eliminate all predictability problems. On the contrary, we can expect the further increase of uncertainties and errors if the classical paradigm of physical parameterizations is not updated. One of possible approaches to the problem is the development of physical parameterization packages based on the concepts derived from the theory of lattice Boltzmann cellular automata. In such an approach, the model variables in addition to traditional grid resolved quantities, will include probability distributions for subgrid-scale quantities. The examples of variables treated in this manner are cloud variables which cannot be handled in a deterministic manner even in the anticipated global convective-scale resolving models.