Radmila BUBNOVA defended her thesis

Use of the Hydrostatic Pressure Coordinate for Integration of the Elastic Model of the Atmospheric Dynamics in the Framework of the Numerical Weather Prediction System ARPEGE/ALADIN

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ARPEGE/ALADIN is a limited area 3D primitive equation model, which belongs to the integrated NWP ARPEGE/IFS system. Like its global counterpart, the limited area version has a spectral representation of variables in the horizontal, but using double-Fourier series instead of the classical spherical harmonics, in the manner introduced by Machenhauer and Haugen.

In order to be able to work at very fine scales and still have a good representation of the coupling fields provided by its large-scale global counterpart ARPEGE, ALADIN needs a sophisticated and flexible procedure for the generation of its surface and lateral boundary conditions. This development was made general enough to sustain further enhancements like the one described thereafter.

Chosen to be the central part of this thesis work and following the suggestion of Laprise, a nonhydrostatic version of ARPEGE/ALADIN has been developed using hydrostatic pressure as an indépendant variable. The dynamics employ the fully elastic. Euler equations of motion, orography being introduced via a terrain-following hybrid coordinate. Results of the linear analysis of the set of elactic equations indicated that scaled vertical divergence and scaled pressure departure from hydrostatism are better prognostic variables than the primary ones, namely vertical velocity and true pressure.

A semi-implicit scheme has been formulated to control both acoustic and gravity waves. The discrete linear operators appear to have the same form as in the hydrostatic dynamics except for an additional one representing the vertical part of the Laplacian operator. In order to keep an elegant elimination, it was necessary to modify the approximation of logarithmic thcknesses of the model layers for obeying the rule of integration per partes in the development leading to the structure equation. It is noteworthy that the Helmholtz matrix has a tridiagonal form, confirming a local character to the nonhydrostatic dynamics. The representation of the horizontal pressure gradient term fulfils the rules of conservation of energy and angular momentum.

The formulation of the « zero vertical derivative of surface wind » boundary condition requires a special treatment for second order time accuracy in the case of the new set of prognostic variables. The original design of the semi-implicit scheme has been completed by an additional implicit correction of the nonlinear part of the total 3D divergence, a solution which calls for partial iterations of the semi-implicit scheme. Part of this special term shows an overdetermination of its lower boundary condition, a problem that was solved by a vertically adaptative algorithm.

The results of idealized 2D vertical plane numerical simulations of flows over a bellshape mountain are very close to analytically or pseudo-analytically obtained solutions. The examined regimes were used not only for the validation of the novel form of the elastic equations but also for the final choice of discretization algorithms. The 2D vertical plane version ofALADIN was used in a slightly extended context to study one case documented during the PYREX measurement campaign. The model's ability to represent non hydrostatic lee waves was verified in this configuration. A full 3D test of an intensive convective situation in montaneous terrain was performed at the scale where non-hydrostatic effects start to matter without being paramount. The quality of the simulation confirms the potential of the new model but some disturbing results indicate that the parameterization of deep moist convection will need updating for use in such a new even if apparently very familiar context.