Study of different formulations for continuity equation in the SL-AV NWP model

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The SL-AV (semi-Lagrangian, absolute vorticity) model [1] is currently used at the Russian Hydrometeorological Research Centre to produce 10-days forecasts in parallel with the operational spectral Eulerian model. The resolution of the SL-AV model is 0.9 degrees in longitude, 0.72 degrees in latitude, 28 vertical sigma-levels.

In certain meteorological situations, the orographic resonance can be seen in model forecasts, despite all the undertaken measures known from literature (Eulerian treatment of orography [2], SETTLS scheme [3]). The model formulated in vertical σ–coordinate employs the continuity equation formulation from [4], which can be written without Tanguay-Ritchie modification [2] as

$$\frac{d\left(\ln p_s\right)}{dt} + D + \frac{\partial \dot\sigma}{\partial \sigma} = 0\,,$$

where D - is the horizontal divergence on σ-surface.

It was decided to study the effect of another formulation of continuity equation. It was changed to the one of the ECMWF model [5]. Adapting it to the sigma-coordinate and SL-AV two-time-level semi-implicit scheme gives

$$\left(1-\sigma_T\right)\left(\ln p_s\right)^{n+1} = \sum_{k=1}^{NLEV} \Delta\sigma_k \left\{\left(\ln p_s\right)_{*,2}^n + \Delta t\left[-\sum_{j=1}^{NLEV}\left(\vec{V}_j\cdot\nabla\ln p_s\right)\Delta\sigma_j + \vec{V}_k\cdot\nabla\ln p_s\right]^{n+1/2}\right.$$

$$\left. -\frac{\Delta t}{2}\left[\left(\sum_{j=1}^{NLEV}\Delta\sigma_j D_j\right)^{n+1} + \left(\sum_{j=1}^{NLEV}\Delta\sigma_j D_j\right)_*^n\right]\right\}$$

where $\vec{V}$ is the horizontal velocity, *NLEV* - number of vertical levels, the (*n+1/2*)-time level term is discretized along the trajectory with SETTLS scheme; here again the modification [2] is omitted for simplicity, for the same reason temporal decentering is omitted, though both things are present in the actual model.

The discretization of thermodynamic equation still follows [4], however, the term containing sigma-dot on (*n+1*)-th time level now uses its value recalculated at the beginning of the next time step.

To test this modification, two 48-hours forecasts starting from the first of November 2004, 12UTC, were carried out. The initial data are the uninitialized analysis of SL-AV OI-based data assimilation and thus may contain already traces of orographic resonance.

Fig.1 depicts isolines of 48-hours forecast for 500 hPa geopotential in the part of Asia obtained with the "standard" formulation of continuity equation, and Fig. 2 presents the same field obtained with the modified formulation of continuity equation. One can see a sensitivity of the resulting field to the changes in the discretization of continuity equation.

This effect will be studied in more details with two series of assimilation runs and forecasts on their basis using these two formulations of continuity equation.
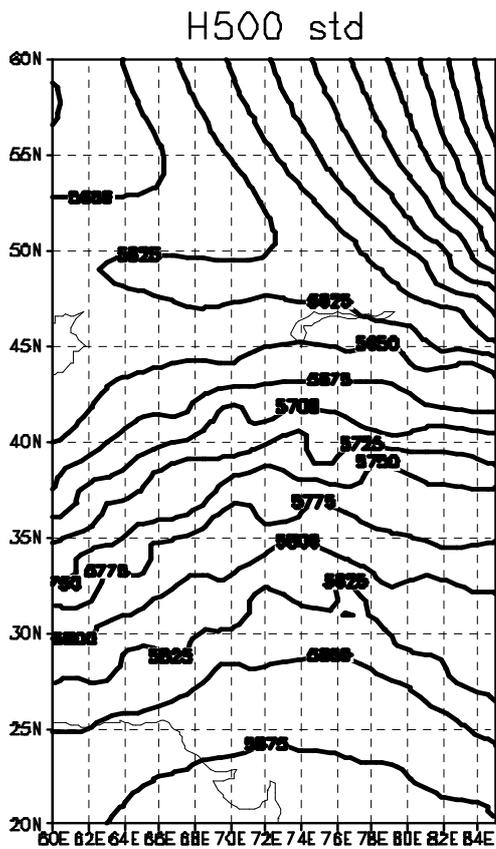
H500 std
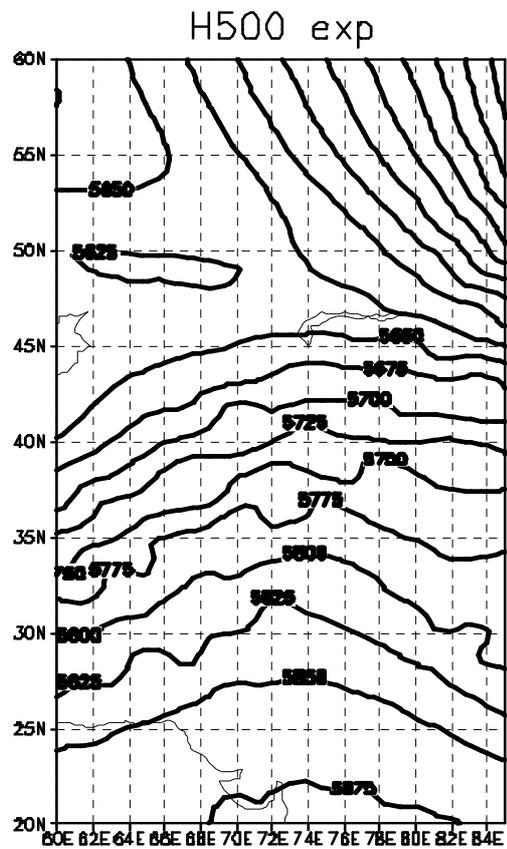
H500 exp

Fig.1 .

Fig.2.

References

1. Tolstykh M.A. Semi-Lagrangian high-resolution atmospheric model for numerical weather prediction. Russian Meteorology and Hydrology, 2001, N 4, p. 1-9.
2. Ritchie H and Tanguay M.A. A comparison of spatially averaged Eulerian and Semi-Lagrangian treatments of mountains. Mon. Weather Rev., 1996, v. 124, p 167-181.
3. Hortal M. The development and testing of a new two-time-level semi-Lagrangian scheme (SETTLS) in the ECMWF forecast model. Q. J. Roy. Met. Soc., 2002, v. 128, 1671-1688.
4. Bates J.R., Moorthi S., Higgins R.W. A global multilevel atmospheric model using a vector semi-Lagrangian finite-difference scheme. Mon. Weather Rev., 1993, v. 121, p. 244-263.
5. Ritchie H., Temperton C., Simmons A., Hortal M., Davies T., Dent D., Hamrud M. Implementation of the Semi-Lagrangian method in a high-resolution version of the ECMWF forecast model. Mon. Weather Rev., 1995, v. 123, p. 489-514.