Numerical experiments with finite difference schemes using data of regional atmospheric model COSMO-RU

D. Yu. Alferov (dalferov@mecom.ru), G. S. Rivin (Gdaly.Rivin@mecom.ru)
Hydrometcenter of Russia, Moscow, Russia

There are three basic classes of finite-difference schemes used for numerical weather prediction: explicit, implicit, and semi-implicit. A large series of numerical experiments demonstrate some advantages of semi-implicit methods under certain conditions. Some work has been already made to introduce semi-implicit methods into the regional atmospheric model COSMO-RU [3]. In order to find out the effect of this modification we have compared the explicit and semi-implicit schemes for a barotropic model using the COSMO-RU objective analysis data and boundary conditions updating with interpolated hourly results of 24 hour COSMO-RU prediction on each step. This article contains a brief description and results of this work.

Equations and numerical schemes

The barotropic model is represented by the following equations in the Cartesian coordinate system:

$$\frac{\partial u}{\partial t} - Qv + \frac{\partial K}{\partial x} = -\frac{\partial \Phi}{\partial x},$$

$$\frac{\partial v}{\partial t} + Qu + \frac{\partial K}{\partial y} = -\frac{\partial \Phi}{\partial y},$$

$$\frac{\partial \Phi}{\partial t} + \frac{\partial(\Phi u)}{\partial x} + \frac{\partial(\Phi v)}{\partial y} = 0,$$

$$K = \frac{1}{2}\left(u^2 + v^2\right),$$

$$Q = f + \frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}.$$

Here u and v are wind components in the x- and y-directions, Φ is the geopotential, f is the Coriolis parameter, K is the kinetic energy, and Q is the vertical component of the absolute vorticity.

The Arakawa A grid was used for the explicit scheme, while the Arakawa B grid was applied for the semi-implicit scheme.

Filtering methods

To avoid computational noise in data fields near the boundaries, we can move several grid rows closer to the boundaries. For better noise suppression, we can use weighted averaging of neighboring values. We use the following formula:

$$\varphi^*_{k,l} = \frac{a\varphi_{k,l} + b\left(\varphi_{k,l+1} + \varphi_{k-1,l+1} + \varphi_{k+1,l} + \varphi_{k+1,l+1} + \varphi^*_{k,l-1} + \varphi^*_{k-1,l-1} + \varphi^*_{k-1,l} + \varphi^*_{k+1,l-1}\right)}{100},$$

$$a < 100,\ b = \frac{100 - a}{8},$$

where φ is the initial field and φ^* is the modified field.

COSMO-RU model

The COSMO-RU model [1, 2, 4] uses a second-order leapfrog HE-VI (horizontally explicit, vertically implicit) and a two time-level second- and third-order Runge-Kutta split-explicit schemes. A three time-level 3-dimensional semi-implicit scheme is also inserted into the model, but has not been properly tested yet. The variant of the model used for comparison in this work uses a 350×310 grid with a grid step of 14 km in rotated spherical coordinates (rotated coordinates of the southwest corner are 19° S, 19° W, and the geographical coordinates of the rotated North pole are 35° N, 145° W).

Numerical experiments

We took the 500 hPa geopotential height and horizontal wind components (for 2010/01/30) at 500 hPa as initial data.

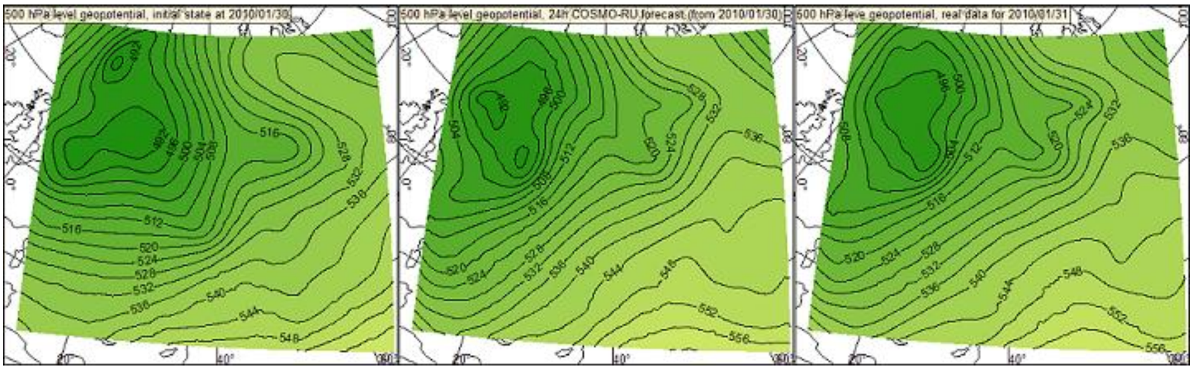

Fig. 1. 500 hPa geopotential height (dam): initial state at 00 UTC 2010/01/30, 24-h COSMO-RU forecast (using a second-order leapfrog HE-VI scheme) and COSMO-RU objective analysis at 00 UTC 2010/01/31. The model time step is 80 seconds.

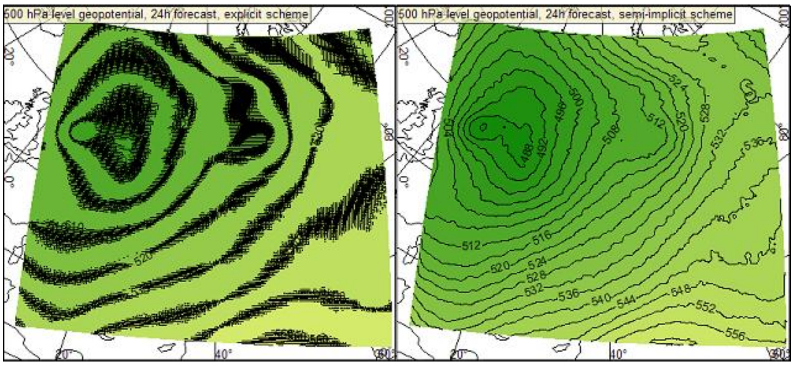

Fig. 2. Left picture: The 24-hour forecast of 500 hPa geopotential height (dam) using the explicit scheme. The maximum difference from the corresponding objective analysis is about 17 dam. We used here the averaging filter at every 7th step. The time step was 18 sec. Right picture: The same but for the semi-implicit scheme. The maximum difference from the objective analysis is about 15.6 dam. The time step was 180 sec, and no filtering was applied.

As we see from these experiments, the semi-implicit scheme shows the best results even with much larger step (180 seconds instead of 18). So we can say that the semi-implicit scheme can be useful to make the calculations in the COSMO-RU model faster. In the nearest future we plan to introduce the semi-implicit method into the COSMO-RU model.

References

1. Doms G., Schaettler U. *A description of the non-hydrostatic regional model LM. Part I: Dynamics and Numerics.* Deutscher Wetterdienst, November 2002, 134 p.
2. Schaettler U., Doms G., Schraff C. *A description of the non-hydrostatic regional model LM. Part VII: User's Guide.* Deutscher Wetterdienst, December 2009, 142 p.
3. Vilfand R. M., Rivin G. S., and Rozinkina I. A. *Mesoscale short-term regional weather forecasting in the Hydrometeorological center of Russia on the example of COSMO-RU model.* Russian Meteorology and Hydrology, 2010, Vol. 35, No. 1.
4. http://www.cosmo-model.org/