Scores of Initial Data for Limited-Area Modeling System COSMO-Ru from GME/ICON Global systems during 2012-2022 years: evaluation and peculiarities

D. Blinov[1], A. Revokatova[1,2], I. Rozinkina[1], G. Rivin[1,3]

[1)]Hydrometeorological Research Center of the Russian Federation, 13-1, Bolshoy Predtechensky lane, Moscow, 123376, Russia
[2)]Yu. A. Izrael Institute of Global Climate and Ecology, Glebovskaya 20B, Moscow 107258, Russia
[3)] Lomonosov Moscow State University, GSP-1, Leninskie Gory, Moscow 119991, Russia
*Correspondence: denisblinov@ya.ru, revokatova@gmail.com; gdaly.rivin@mail.ru; inna.rozinkina@mail.ru

Introduction

A limited-area numerical weather prediction (NWP) requires initial and boundary conditions, which often are prepared by interpolation of results of global weather forecasting systems. Hydrometeorological Center of Russia has been using the limited area NWP system COSMO-Ru since 2009 [1], for forecasting up to 5 days. The COSMO model [cosmo-model.org] is a core of the COSMO-Ru system. The results of global models of the German weather service (DWD) GME and ICON [2,3,4] have been used as initial and boundary conditions. During period 2012-2022 the global forecasting system of DWD was cardinally upgraded: at 2015 model ICON replaced GME in operational runs, subsequently some improvements in ICON model and in conjugate Data Assimilation system (DAS) have been introduced.

The authors of this paper analyzed errors of the COSMO-Ru zero lead time forecasts for the period 2012-2022 w.r.t. measurements from synoptic and aerologic stations on the territory of Russia. The variability of scores in dependence on regions and on different criteria as seasons, day times, and orography was analyzed and some typical features were detected.

The results of this study are important to understand the quality of initial data for limited-area modelling provided by the DWD global modelling system and to estimate possible effects of further implementation of the regional data assimilation in COSMO-Ru which is currently under development at the Hydrometcenter of Russia.

Methodology

The results of DWD global modeling systems (DGM, mesh size is 13.2 km), for zero lead time (in fact – the product of included into DGM global Data assimilation system (DAS)) were transformed by COSMO-Ru system to the analyzed parameters at pre-specified vertical levels and in grid-boxes of COSMO-Ru13ENA configuration of COSMO model. The results were interpolated to the measurement points. The values of temperature and dew point at 2m height, wind velocity (module, direction, gusts) at 10m, pressure reduced to the sea level, cloudiness, parameters on standard geopotential surfaces from 1000 to 50 hPa were analyzed. The COSMO-Ru13ENA has the same horizontal mesh size as DGM products, but the coordinates of boxes are different. Using the archive of COSMO-Ru13ENA forecasts (available since 2012) we analyzed the time evolution of the quality of initial data as well as minimized the uncertainty in the results associated with the use of different grid sizes.

The "forecast – observations" pairs were obtained using the nearest neighbor method. We examined the data for two seasons: Winter (DJF) and Summer (JJA) for the European territory of Russia (ETR) and its parts: Central Federal District (Central part of ETR) and South Federal District (North Caucasia). Some data for Siberia and Far East where also assessed. The analysis showed that the errors are generally larger in Siberia and the Far East in comparison with ETR. In this paper we provide the results for ETR only.

Results

1 ***Near-surface weather parameters***. The measured by meteorological network weather parameters are not used as initial data for model runs. They are not modeled directly but produced in a diagnostic manner. Nevertheless, these values at zero lead time can reflect a quality of initial data, taking into account some uncertainties related to the impact of the limited-area model producing them. Thus, the fields (first, the mean sea level pressure and wind at 10 m) obtained for mountain regions (e.g., Caucasia) with using the model relief showed the largest differences with observations.

Analyzing the scores for ***Temperature and Dew Point at 2m height over land surface (T2m, TD2m)*** we note large RMSE values for the data from 00:00 UTC runs and smaller values for 12:00 UTC in both seasons. The effect is most pronounced in summer. (Probably, this can be related to some problems in parametrizations under stable conditions as 00:00 UTC corresponds to night for ETR). Additionally, it's worth to note the evident improvement in modeling thermal conditions at the soil surface and the bottom model levels since 2014 that affect the quality of T2m (Fig. 1).

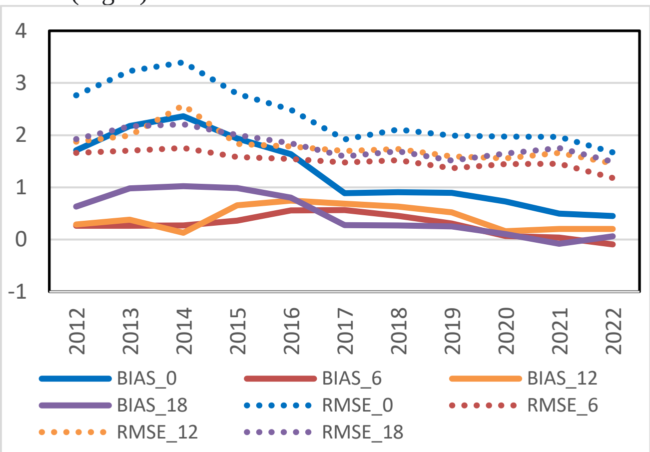

Fig. 1. T2m values for Summer: RMSE (dotted line) and BIAS (solid line). The UTC time of initial data is shown by colors.

The ***Cloudiness*** at zero lead time is mostly overestimated with its average error varying from 10 to 20%. However, for the data from 12:00 UTC (the warmest day time in European Russia), an efficient gradual improvement took place since 2015. For start fields of ***Pressure reduced to Sea level (PMSL***) we can't see important trends of RMSE during the last 10 years. The BIAS changed from negative (2012, 2013) to positive (since 2014). The quality of initial data at 00:00 UTC often seems to be "the worst", while the data at 06:00 and 18:00 UTC was the best (Fig. 2).

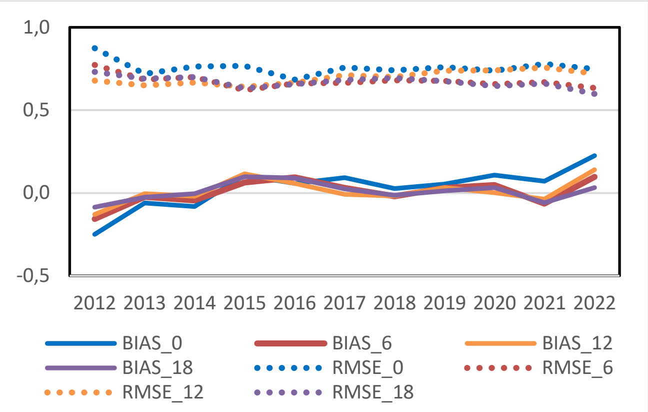

Fig. 2. PMSL values for Winter: RMSE (dotted line) and BIAS (solid line). The UTC time of initial data is shown by colors.

No clear conclusion could be made about the trends detected during the analyzed period. For 00:00 and 18:00 UTC the BIAS and RMSE decreased. ***The maximum V10m values within a radius of 30 km around the measurement points*** at 18:00 UTC in the summer have a noticeably larger RMSE than the ones from 00:00, 06:00 and 12:00. Besides, BIAS at 18:00 UTS is negative (***maximum V10m values underestimated***), while BIAS at 00, 12, 18 UTS tend to be positive after 2017 year. The winter data got worse since 2015, and the quality of the data for all initial times seem to be close to each other.

2. The errors of **free atmosphere fields** (interpolated to standard geopotential surface levels) do not demonstrate so strong dependence on daytime as most part of near-surface weather parameters (excluding the 1000 hPa level with the largest error). A comparison with radiosonde data reflects the quality of the initial data for modeling more objectively. The common features for the vertical profiles of the mean absolute error (MAE) for ***temperature*** are as follows: the maximum near the earth surface, a sharp decrease in the 1000-925 hPa layer, a gradual decrease in the 925-400 hPa layer, and a subsequent increase at the upper levels (as example, Fig.3). The MAE values at 1000 hPa are 1-1.1°C. The vertical profiles of error in the dew point temperature differ significantly from the temperature errors only at lower levels - there is no pronounced decrease in MAE from 1000 to 925 hPa. The MAE values from 1.2 to 2.4°C are maintained from the lower level up to 300 hPa, then it starts to grow. The analysis of temperature fields showed small changes in the free atmosphere errors from year to year for most layers and a decrease in large errors in upper-atmosphere fields after 2017 (Fig.3). Analysis of errors **of geopotential heights** showed a trend for their reduction over the analyzed period, more evident for layers up to 200 hPa. (Fig.3). **The assessment of vertical profiles of wind speed errors showed that** the interannual values are quite close, with errors in the range of 1.5–2 m/s up to a height of 100 hPa. A significant increase in errors is observed above 100 hPa in some years.

Summary

The errors of zero lead time COSMO-Ru13ENA forecasts (being inherently the transformed initial data from GME/ICON Global systems during 2012-2022), demonstrate different behavior depending on dominant physical processes forming specific meteorological fields. The main features are as follows.

- *A daily amplitude* of errors of fields *of near – surface parameters*: For the European part of Russia the 00:00 UTC runs (night time) demonstrate the maximal errors of *T2m* and *TD2m*, the greatest in winter, while the errors of *Psea* and *V10m* have maxima for 12:00 UTC runs, more pronounced in summer. Despite the fact that the above-listed fields are not directly taken from the initial data, the factors that caused the peculiarities of their errors can lead to differences between forecasts with long lead times (24 h or longer) started from initial data for different UTC times and valid at the same moment as well as to seasonal variations of forecast skill.
- *Seasonal variations:* In winter, larger errors demonstrate temperature, geopotential, and wind speed fields; in summer, wind direction, total cloudiness, and sea level pressure.
- *Variations in the vertical:* The biggest errors in all analyzed parameters (except for the V10m module) were found at bottom levels (up to 925 hPa) and at levels above 100 hPa.
- *An improvement of data quality* during the whole period (2012-2022) for the most part of the analyzed meteorological parameters. The step-like inter-year changes reflect the development of DWD global technology of Data assimilation and modelling, first – the transition from GME to ICON forecasting systems in 2015 and its further improvement.

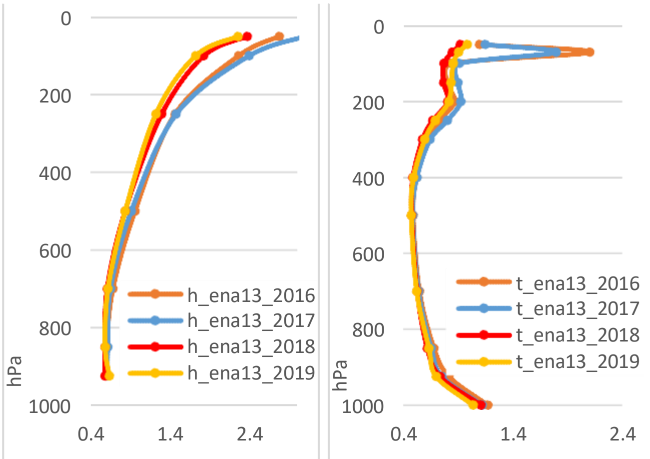

Fig 3. MAE of Geopotential (left) and Temperature (right) (Winter)

References

1. Rivin G. S., Rozinkina I. A., Astakhova E. D. et al. COSMO-Ru high- resolution short-term numerical forecasting system, its development and applications // Hydrometeorological research and forecasts. - 2019. - No. 4 (374). - pp. 37-53.
2. Majewski D., Liermann D., Prohl P., Ritter B., Buchhold M., Hanisch T., Paul G., Wergen W., 2002: The operational global icosahedral- hexagonal grid point model GME: Description and high-resolution tests. Mon. Wea. Rev. – 2002. – 130. – P.319–338.
3. Zängl, G., D. Reinert, P. Ripodas, and M. Baldauf. The ICON (ICOsahedral Non-hydrostatic) modelling framework of DWD and MPI-M: Description of the non-hydrostatic dynamical core. // Q. J. R. Meteorol. Soc. – 2015. №141. – P. 563–579.
4. Schraff, C., H. Reich, A. Rhodin, A. Schomburg, K. Stephan, A. Perianez, and R. Potthast, 2016: Kilometre-scale ensemble data assimilation for the COSMO model (KENDA). Q.J.R. Meteorol. Soc., 142, 1453–1472.