Fresh snow depth postprocessing at Hydrometcenter of Russia (exemplifying COSMO-Ru)

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1 Introduction

Present-day atmospheric models make it possible to get quite accurate forecasts of meteorological characteristics.Various kinds of precipitation take an important place among meteorological elements. Success in prediction of more and more realistic values of precipitation sums are particularly connected with rapidly developing technologies of operational numerical forecast based on non-hydrostatic mesoscale models with grid resolution about several km.

Due to modeling algorithms of atmospheric link of hydrological cycle, model precipitation is considered to be a mass of water which reached earth surface (taking into account its phase state) for given time period, i.e. accumulated water equivalent. According to WMO regulations, information about fallen precipitation is received from synoptic measurement network in the same terms, as well as general-purpose weather forecasts are made.

Due to stated structure "data-numerical forecast-general-purpose weather forecast", in case of falling of solid or mixed precipitation users (transportation, electricity supply networks, community facilities, organization of winter sports events, etc.) are not provided with greatly demanded information about depth of snow layer after snowfall which has already taken place or predicted. As a rule, for fresh snow depth determination simple empirical dependences based on assumption of constant values of its density are used in operational synoptic practice. Differences in density depending on air temperature are not considered (review in [1]). Use of more valid difficult dependencies should be provided on the basis of automated technology.

Snow depth measurements are held at hydrometeorological stations (HMS) and sent once a day through communication link in international exchange. Such a discreteness of measurements is not satisfactory for exact determination of snow depth in the train of snowfalls, as during this period of time snow cover could experience significant changes (snow could dense, melt, be blown by wind). In some regions there are automated meteorological stations (AMS), for example, in Sochi region in Russia, which measure snow depth with high time discreteness (once in 10 minutes). Yet, as the practice of their using has shown, these data should have thorough quality control because reliability of these data is very sensitive to accuracy of setting, operation conditions and regularity of technical service of AMS. That's why information about snow from AMS can't always be directly used in operational practice.

Nowadays results of calculations of non-hydrostatic mesoscale atmospheric models with grid resolution about several km are widely used by specialists while weather forecast forming. For visual representation of atmospheric modeling results postprocessing is applied. Calculation of density of falling snow with the use of parametric dependencies may be included into systems of postprocessing of operational modeling technologies. The work is dedicated to the description of technological chain in the framework of postprocessing of COSMO-Ru system and aspects of testing of results done for the mountain cluster region of winter Olympic Games Sochi-2014 for the period of its holding based on that chain.

2 Goals

The main goal was to propose users of mesoscale forecast system COSMO-Ru output a new type of information – snow increment for several hours. In order to achieve this goal a number of algorithmic and technological issues needed to be solved.

Forming of suggestions and testing of algorithm for fresh snow density calculation (hence, its layer thickness) referred to algorithmic tasks, combination of calculation of this characteristic with existing elements of postprocessing of COSMO-Ru operational system – to technological. Additional task was to analyze success of fresh snow depth calculation due to COSMO-Ru (with the proposed algorithm included into its postprocessing) on snow observations at AMS and HMS of North-Caucasian region during the period of winter Olympic Games Sochi-2014 holding. Technological aspects consist in work over combination of calculations according to the proposed module with operationally functioning postprocessing systems of COSMO-Ru.

COSMO-Ru postprocessing allows providing users with model output as tables and meteograms of a wide range of meteorological elements changing in time for given points as well as forming fields of different meteorological elements on grids in the form of maps of these elements' fields. While forming tables-meteograms, fresh snow depth could be calculated on the basis of elements' values included in the table.

The peculiarity of technological changes during present work was the fact that in the framework of preparation of meteorological support for Sochi-2014 at Hydrometcenter of Russia algorithm of model air temperature (2 meters) correction for mountain region based on moving amendments connected with differences between model and actual relief heights (for points for which meteograms are prepared) was proposed and implemented. It's obvious that when big differences occur, such a temperature amendment should be taken into account in calculations of fresh snow depth, especially at temperatures close to zero.

For output processing in grid nodes the program module of universal postprocessing FieldExtr[3] with very wide set of functions and possibilities (interpolation on different grids, diagnostic calculations of different characteristics, comparison and correction of some meteorological elements and so on) was developed in COSMO consortium.

One of the tasks of the present work was to adapt and to implement the proposed algorithm of fresh snow depth calculation on the basis of air temperature data into FieldExtra, what in future could allow providing users with calculated information in the form of maps.

3 Results of algorithm of fresh snow depth calculation implementation into COSMO-Ru system postprocessing

Before the start of winter Olympic Games Sochi-2014 since 3 February 2014 prognostic maps of fresh snow depth began to prepare at Hydrometcenter of Russia based on forecasts of precipitation sums obtained from COSMO-Ru model versions with grid resolution of 7 km (COSMO-Ru7), 2.2 km (COSMO-Ru2) and 1.1 km (COSMO-Ru1). Maps were formed according to operational forecasts data at 00, 06, 12 and 18 UTC.

Also values of fresh snow depth were recorded in meteograms for stations situated in North-Caucasian region. Prognostic values were calculated taking height-corrected air temperature into consideration.

The technological branch of fresh snow postprocessing and its output in the framework of COSMO-Ru system postprocessing are shown in figure 1.

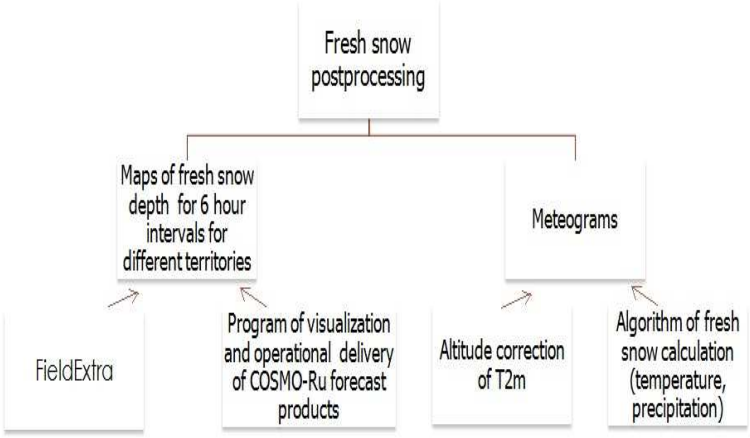

Figure 1: The scheme of fresh snow depth calculation at Hydrometcenter of Russia (based on mesoscale model COSMO-Ru).

Output is meteograms for stations and maps of fresh snow depth for 6-hour intervals prepared for versions COSMO-Ru7, COSMO-Ru2 and COSMO-Ru1 four times a day with the use of FieldExtra.

As can be observed in figure 2 there are significant differences in calculations according to different COSMO-model versions.

The fact that relief detailing and its model heights for this region turned to be principled for precipitation phase prediction, as here large elevation and temperature drops are observed.

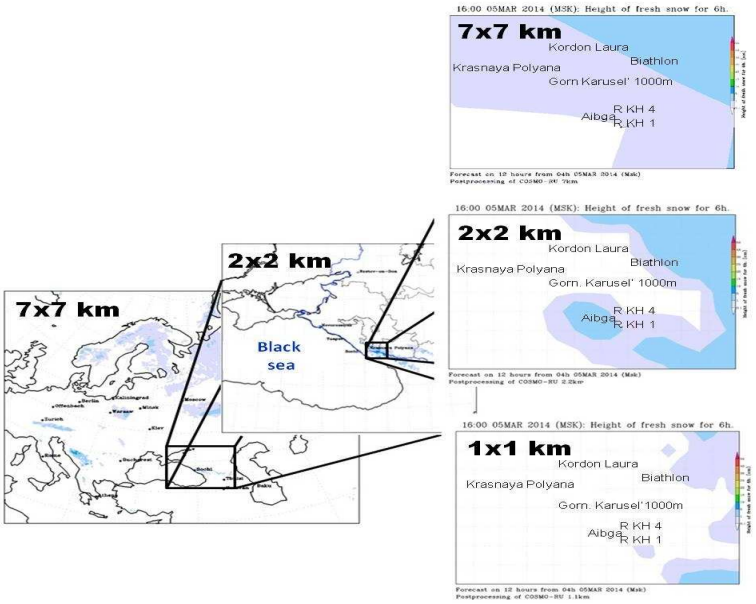

Figure 2: 12h-forecasts of fresh snow fallen for the last 6 hours according to COSMO-Ru7, COSMO-Ru2 and COSMO-Ru1. Start – 00 UTC 5 March 2014

And while relief smoothing in case of coarser resolution (COSMO-Ru7), area with negative air temperatures occurred to be larger in comparison with more detailed modeling (COSMO-Ru2, COSMO-Ru1), when definition of relief led to more accurate specification of extended valleys and relatively small highlands regions, for which snow falling was typical.

In addition testing done in [2] pointed out to lower precipitation sums formed by COSMO-Ru1 in comparison with COSMO-Ru2. Maps of fresh snow depth and meteograms were used for initial quality estimation of work of the proposed system as well as hourly measurements from AMS situated at different levels on the mountain resort Roza Khutor and daily measurements from three HMS (Aibga, Kordon Laura, Gornaya Karusel'-1500) located in the region of winter Olympic Games Sochi-2014 holding.

Complexity of testing realization was determined by several factors: firstly, snowfalls were observed only several times during winter season 2013/2014; secondly, model data could be compared with measurements only at some stations.

During winter Olympic Games Sochi-2014 holding there were three cases with significant snowfalls: 17-19 February, 21 February and 26-28 February. Let's have a look at the main peculiarities in fresh snow depth reproduction by COSMO-Ru in the region of winter Olympic Games Sochi-2014 holding.

Preliminary results showed a big variability of snowfall forecasts for the same period started at different instants of time, and the latest forecast was not always the best in comparison with others started before. Based on quite detailed analysis of time-distribution intensities inside snowfall period it's turned out impossible to conclude forecast with what lead time is more successful and what forecast is more accurate: obtained by model version with the resolution of 2.2 km or 1.1 km.

Yet in general the best agreement with snowfall measurements was observed in case of all realizations averaging. Comparison with similar calculations found at website *www.snow-forecast.com* [4] showed systematic underestimation of represented fresh snow values and results more close to reality calculated in the framework of COSMO-Ru1 and COSMO-Ru2 systems. Example of analysis of one snowfall case according to observations at Roza Khutor is shown in table 1.

The proposed system gives more successful fresh snow depth forecast with account of hight-corrected air temperature than in case of using of air temperature received from standard version of COSMO-Ru model. The example is shown in fig.3 for station Aibga. Before noon and partly during afternoon 4 March 2014 COSMO-Ru2 predicted precipitation in the form of rain.

Yet height-corrected temperature turned to be a little bit lower than initially calculated temperature, that's why fresh snow depth was reproduced in postprocessing system. According to observations in the night from 3 to 4 March 2014 precipitation under weakly negative temperature were observed, and snow depth didn't

Table 1: Fresh snow depth (cm) according to observations at AMS Roza Khutor 4, forecasts from COSMO-Ru2 and COSMO-Ru1 and data from website www.snow-forecast.com. 18 February 2014.

Observations	Forecast start (day hour)						Website data
	mean	17 00	17 06	17 12	17 18	18 00	
28.2	COSMO-Ru2						12.0
	27.6	30.0	39.5	22.1	25.4	21.3	
28.2	COSMO-Ru1						12.0
	23.8	17.0	24.9	40.8	19.9	16.8	

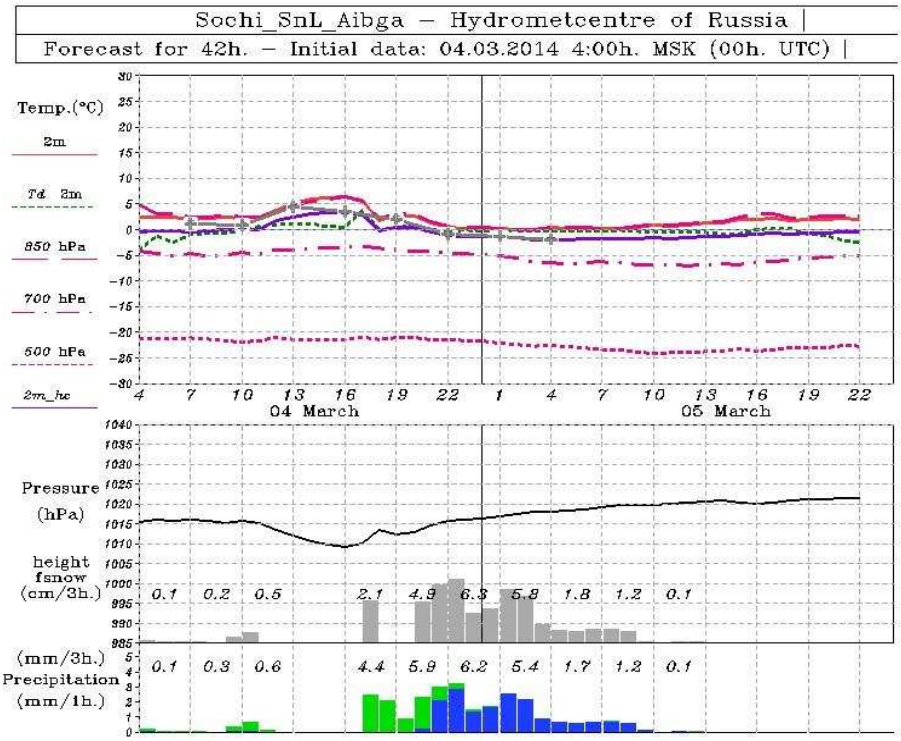

Figure 3: The example of meteogram obtained from COSMO-Ru2 model for station Aibga. Forecast start – 00 UTC 4 March 2014. Grey columns show hourly sums of fresh snow, numbers above – its 3-hour sums. Blue columns indicate hourly precipitation sums in the form of snow, green – in the form of rain. Height-corrected air temperature is pictured in solid violet line, air temperature – in solid pink line

change during the day. This proves the fact that postprocessing system properly predicted type of precipitation (snow): in case of rain falling snow depth had to reduce (snow sank). 12-hour precipitation sum at 3 UTC 5 March was 4 mm and gave 2 cm increment in snow depth for the day.

In the evening 4 March and in the morning 5 March observes fixed snow showers at temperatures from weakly positive to weakly negative. So, the proposed algorithm of fresh snow depth calculation on the basis of height-corrected air temperature reproduced the fact of snow falling rather realistically.

Maps of fresh snow depth can be created for any territory which coincides with the calculated grids of COSMO-Ru model versions (fig.2), for example, for the region including most part of the European territory of Russia. Meteograms containing fresh snow depth forecasts were prepared in January-March 2014 for North-Caucasian region for the purpose of specifying this meteorological element at points (stations). Analogous meteograms with fresh snow depth data can be obtained for stations located in other regions.

The testing showed that the developed system reproduces fresh snow depth quite realistically. Note that

COSMO-Ru provides the fact of precipitation falling as snow reliably, but quantitative estimations depend on forecast interval.

4 Conclusions

The system of prediction of fresh snow depth in the framework of COSMO-Ru postprocessing is developed and realized at Hydrometcenter of Russia. The system includes preparation of fresh snow depth maps for 6-hour intervals four times a day according to model versions with the resolutions of 7, 2.2 and 1.1 km, as well as fresh snow forecasts for stations as an addition to meteodrams.

Preliminary analysis of snowfalls occurred in North-Caucasian region in February 2014 showed that COSMO-Ru output connected with fresh snow characteristics could be used when weather forecast making. This output was used by weather forecasters in the framework of meteorological support of winter Olympic Games Sochi-2014, in particular for completion of daily bulletins and competitions planning.

References

[1] Kazakova E.V., Chumakov M.M., Rozinkina I.A. The algorithm of fresh snow depth calculation intended for postprocessing of atmospheric modeling systems (exemplifying COSMO) *Proc. of Hydrometcenter of Russia*, 2013, no. 350, **164-179**(in Russian).

[2] Shatunova M.V., Rivin G.S. Model COSMO-Ru1 with high space resolution: influence of external parameters on modeling results *Proc. of Hydrometcenter of Russia* , 2014, no. 352, **150-167**(in Russian).

[3] http://www.cosmo-model.org/content/support/software/default.htm

[4] www.snow-forecast.com