Experience in using COSMO-Ru1 for the meteorological support of the Sochi 2014 Olympic Games

M.Shatunova, D. Blinov, A. Bundel, G. Rivin, I. Rozinkina

Hydrometeorological Center of Russia

Development of the version of COSMO model with grid spacing of 1.1 km for the weather forecast during the Sochi Olympics 2014 was a RDP of the Priority Project CORSO (*Consolidation of Operation and Research results for the Sochi Olympic games*). The main goal of this project was to enhance and demonstrate the capabilities of COSMO-based systems of short-range numerical weather prediction in winter conditions for mountainous terrain. Scientists from Russia, Germany, Italy, Switzerland and Greece have participated in the project.

1. Domain, technology and output

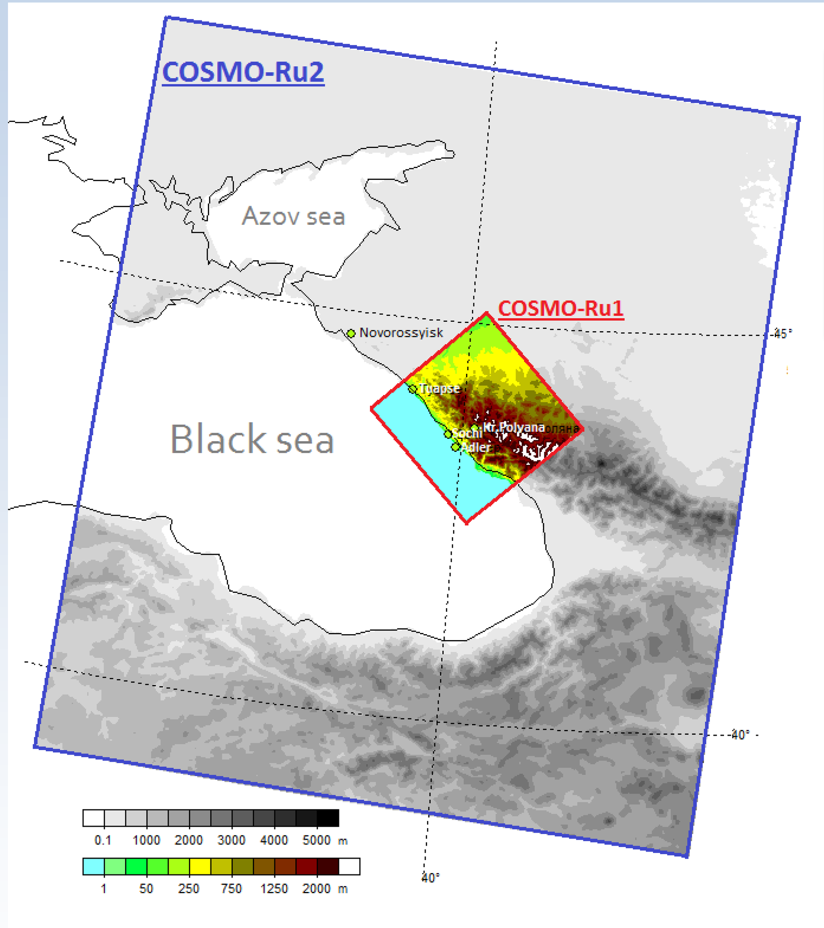


Fig. 1.1. COSMO-Ru1 domain nested into COSMO-Ru2 domain. Models orography.

COSMO-Ru1
Domain: 209 km x 209 km
Grid: 190 x 190 x 50
Grid size: 1.1 km
Time step: 5 s
Forecast: up to 36 h

COSMO-Ru2
Domain: 900 km x 1000 km
Grid: 420 x 470 x 50
Grid size: 2.2 km
Time step: 20 s
Forecast: up to 42 h

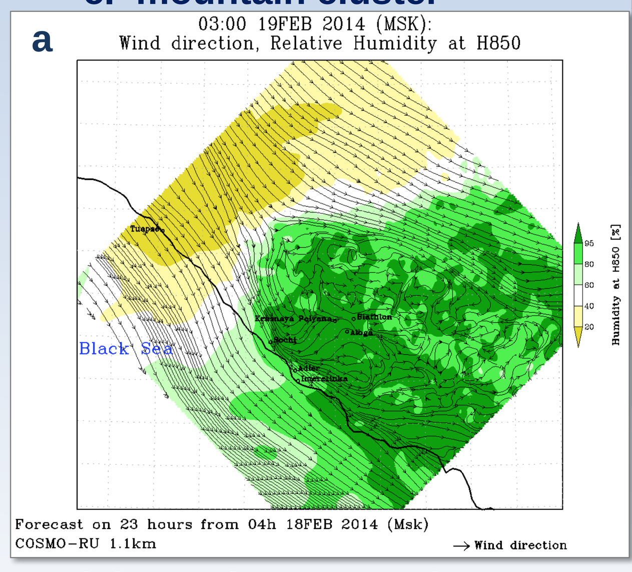
From January, 29, 2014 COSMO-Ru1 runs in operational mode 4 times per day.

In order to meet the requirements of forecasters and to assimilate as much observation data as possible for the period of the Olympic games COSMO-Ru1 run from COSMO-Ru2 forecast -6h.

E.g. for the forecasts with start time 18 UTC model began to run at 23:15 UTC, so the results sent to at 00 UTC (4:00 local time) to forecasters morning briefing.

For the forecasters use model output products were provided in form of *forecast charts* for the main meteorological parameters and their combinations and *meteograms* for the sites of interest. *Forecast charts* were produced for several regions (fig. 1.2):

a. whole model domain,
b. Sochi region,
c. mountain cluster



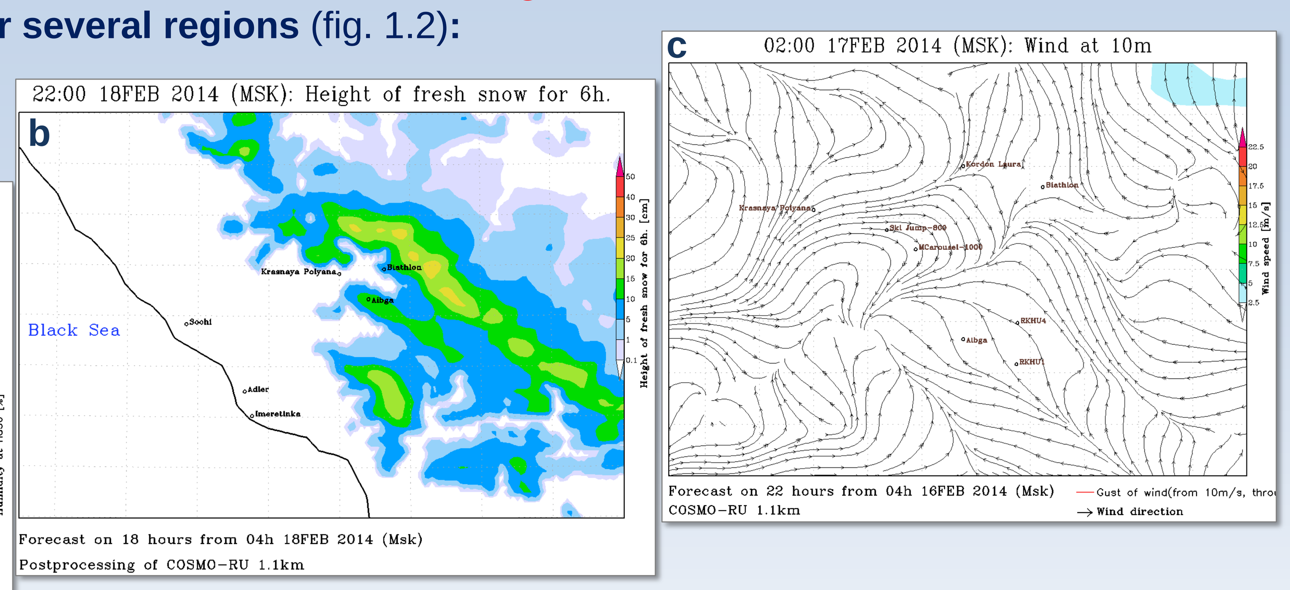
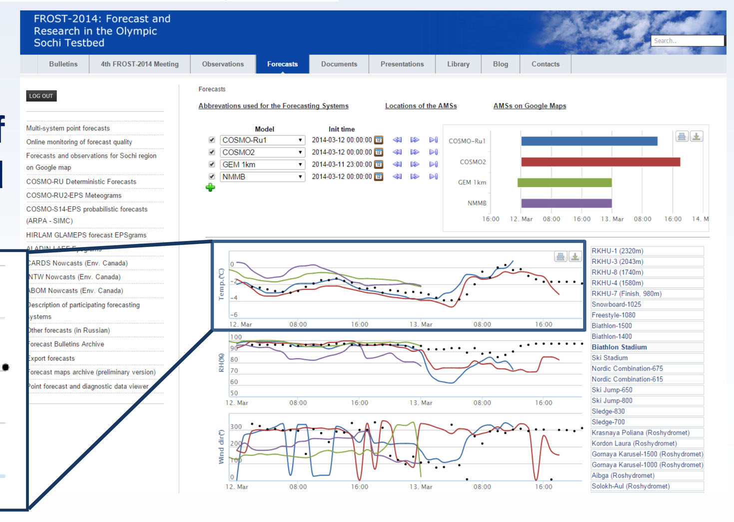


Fig. 1.2. Examples of the forecast charts for different regions.

Model results were also presented on special web-site of the FROST project along with COSMO-Ru2, COSMO-Ru7 and other models forecasts (fig. 1.3).



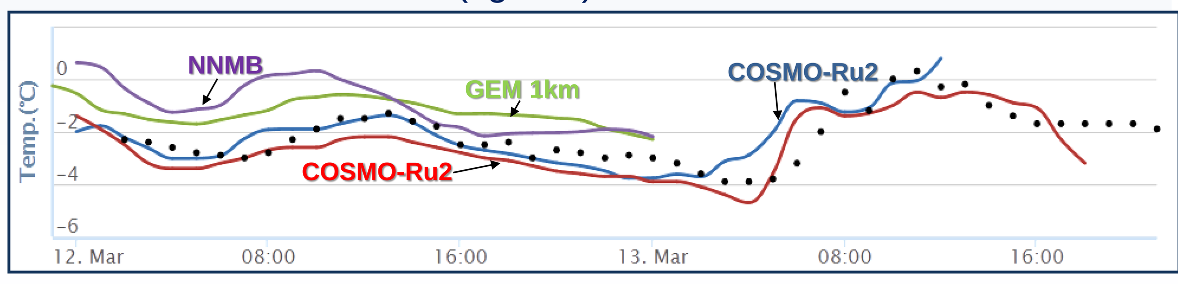


Fig. 1.3. COSMO-Ru1 forecasts on FROST web-site. Here is T2m forecasts for Biathlon Stadium by COSMO-Ru1 (blue), COSMO-Ru2 (red), GEM 1 km (green), NNMB (violet) and observation data (black dots).

2. New orography

Initially COSMO-Ru1 model orography was based on the *GLOBE* (*The Global Land One-km Base Elevation Project*) data (NOAA/NGDC).

Rather large difference (*up to 500 m*) between model's grid height and observation points height, and high resolution ASTER data also, forced us to correct model orography.

New orography for COSMO-Ru1 is based on the *ASTER* (*Advanced Spaceborne Thermal Emission and Reflection Radiometer*) data that has resolution 1" (~ 30 m) (METI/NASA).

With new ASTER-based orography:

- *T2m and wind forecast* have been *improved* for the most sites (fig. 2.1);
- slightly improvement of the precipitation forecast was noticed;
- there are changes in the precipitation amount, its space and time distribution.

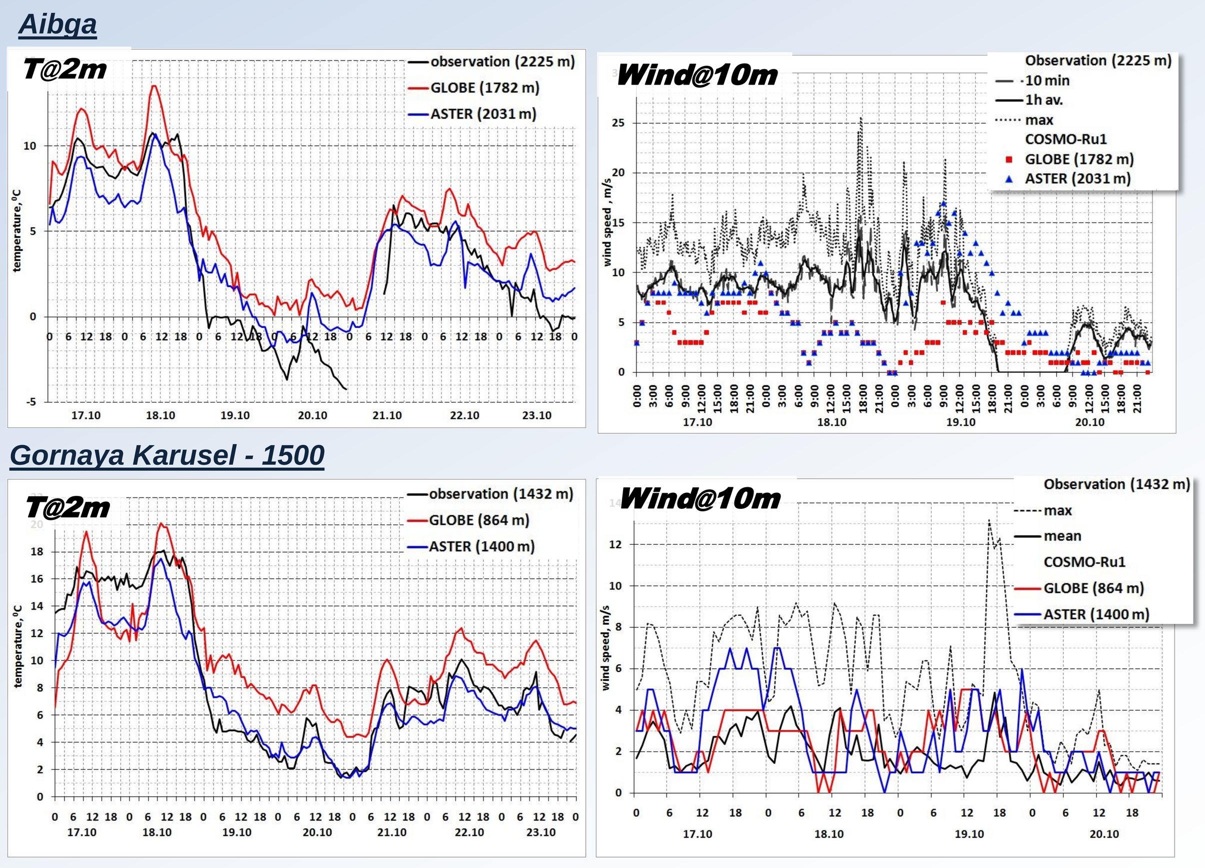


Fig. 2.1. Row of 24h temperature and wind speed forecasts (start from 00 UTC) by COSMO-Ru1 with two variant of the model orography in comparison with observations.

3. Verification by VERSUS

Verification was made for the period of the Olympic and Paralympic games (February-March, 2014).

- Study of the *resolution effect* on the forecast quality has revealed that wind direction, wind speed and wind gusts are better predicted by COSMO-Ru1 (fig.3.1). There is no evident effect on temperature an relative humidity forecast.
- *Conditional verification* of temperature forecast for the points located below 1200 m shown higher errors for Clear sky cases (fig. 3.2). More conditional verifications are needed.
- Traditional *point-to-point precipitation scores* are rather high for COSMO-Ru1 (fig. 3.3). Several cases of intense precipitation were forecasted well.

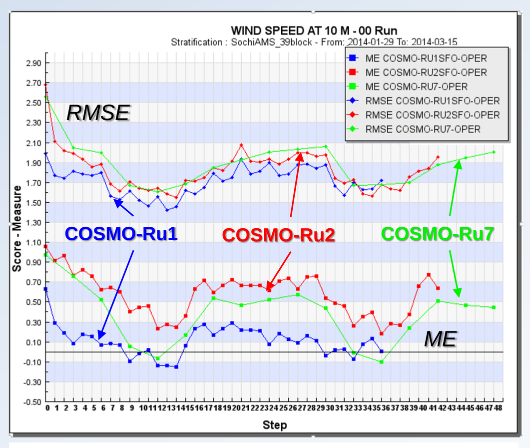


Fig. 3.1. COSMO-Ru1, COSMO-Ru2, and COSMO-Ru7 wind speed verification during 29.01-15.03.2014 in the Sochi region.

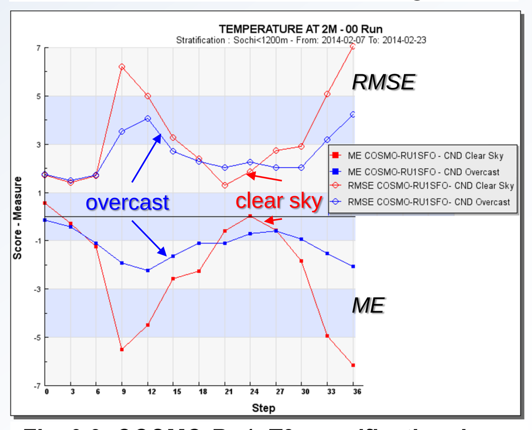


Fig. 3.2. COSMO-Ru1, T2m verification, lower than 1200m, conditioned on observed TCC.

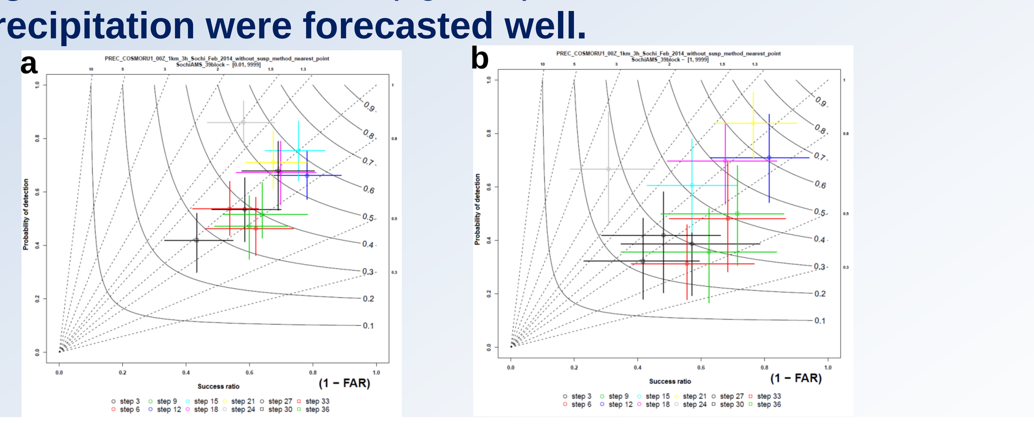


Fig. 3.3. Performance diagrams for the COSMO-Ru1 for a 3-h rainfall exceeding the threshold of 0.01 mm/h (a) and 1 mm/h (b) for February for the entire Sochi region. Lines indicate 95% confidence intervals.

4. Case studies

Low visibility case on February, 16-17, 2014

On February, 16-17 there were favorable conditions for the fog formation due to adiabatic cooling of the moisture air during it rise along the slope of the valley and conservation of the fog for a long period of time. At an altitude of 1000 -1500 m low visibility was observed from 14-15 UTC (17-18 h local time) on February, 16 till 12-13 UTC (15-16 h local time) on February, 17.

Observed minimum visibility values were 25 m (Gornaya Karusel-1500, h=1434 m), 29 m (Biathlon Stadium, h=1470 m), 44 m (Roza Khutor-4, h=1580 m).

Competitions in biathlon and snowboard were postponed due to low visibility.

Subsequent decrease of the relative humidity and increase in wind led to the dissipation of the fog.

On the very next day, February 18, visibility was poor due to heavy snowfall (*see the other case study*) and observed relative humidity reached 95-100%.

COSMO-Ru1 forecast for relative humidity (fig. 4.1) and wind (fig. 4.2) allowed forecasters to predict changes in visibility ("good visibility window") and determine the time for the competitions.

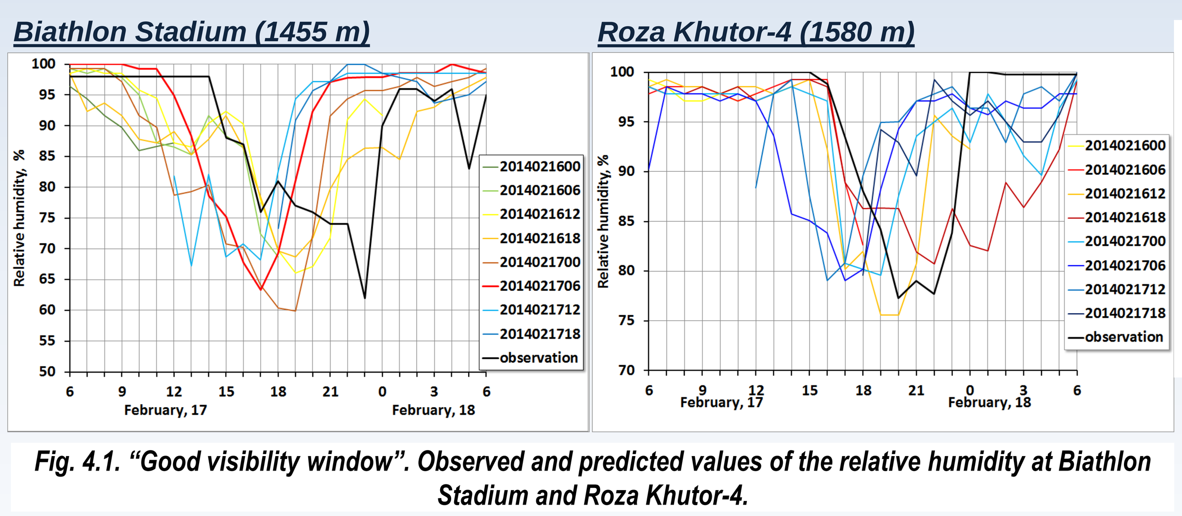


Fig. 4.1. "Good visibility window". Observed and predicted values of the relative humidity at Biathlon Stadium and Roza Khutor-4.

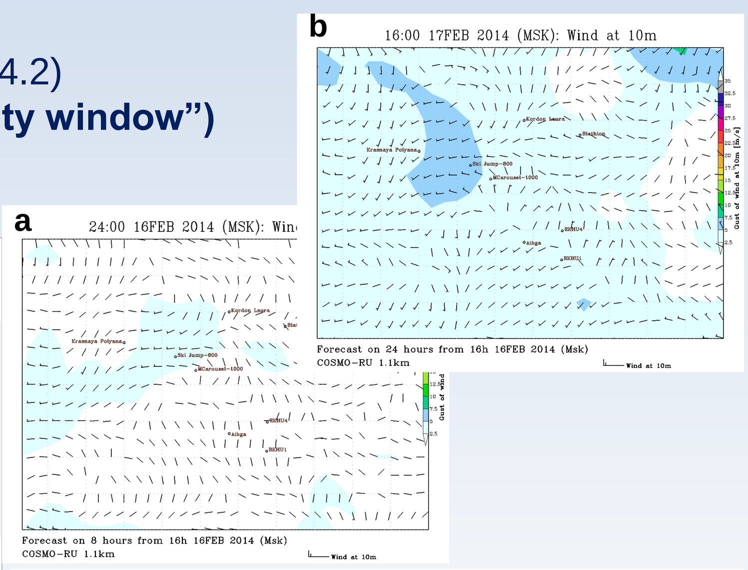


Fig. 4.2. Wind at 10 m forecast for the mountain cluster.
a) fc+8h (low visibility observed),
b) fc+24h (observed improved visibility)
Start from 16.02.2014, 12 UTC.

Cold front with heavy precipitation on February, 18, 2014

Local intensification of the cold front passed Sochi region on February, 18 was accompanied by heavy precipitation. Maximum total daily precipitation observed in the mountain cluster was 38.4 mm/24 h (Roza Khutor-4).

COSMO-Ru1 predicted spatial distribution of the precipitation quite accurately (fig. 4.3 & fig.4.4) as well as temporal distribution (fig. 4.5). As for total daily precipitation forecast is in agreement with the observation for the sites located in the bottom of the valley. But for the sites located on the slopes or highlands above 900 m there is significant underestimation of total daily sum (*see table below*).

There are errors in mean value of the precipitation rate - predicted values were too low compared with observations.

In this case very high snowfall rate was observed but was not predicted by COSMO-Ru1 model. In the table maximum precipitation rate value obtained from 10 min averaged data for observation while COSMO-Ru1 model provides forecast once per hour.

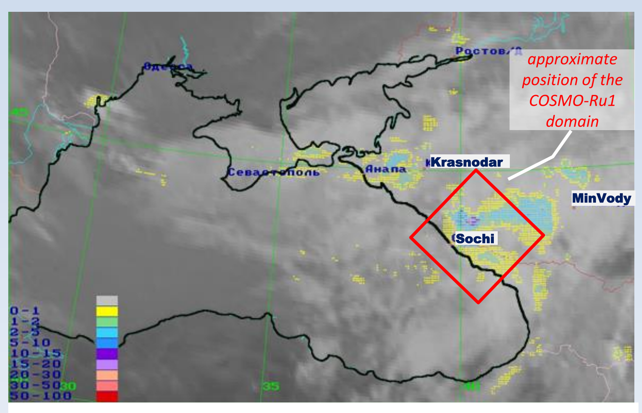


Fig. 4.3. METEOSAT-7. Precipitation rate (mm/h) 18.02.2014, 13 UTC.

Site	Total sum, mm/24h		Prec.rate, mm/h			
	Forecast	Observation	Forecast		Observation	
			mean	max	mean	max
Kr.Polyana (h=564 m)	29.3	29.4	1.2	3.0	1.2	4.2
Kordon Laura (h=570 m)	32.6	37.5	1.3	2.9	1.6	4.8
Sledge-700 (h=701 m)	20.4	21.4	0.8	2.4	1.0	4.2
Roza Khutor-7 (h=980m)	20.3	32.7	0.9	2.5	1.4	8.4
G.Karusel-1000 (h=978 m)	17.3	26.3	0.7	2.5	1.1	3.6
Biathlon Std. (h=1455 m)	20.1	34.7	0.8	2.4	1.5	4.8
Roza Khutor-4 (h=1580 m)	21.6	38.4	0.9	2.7	1.6	6.6

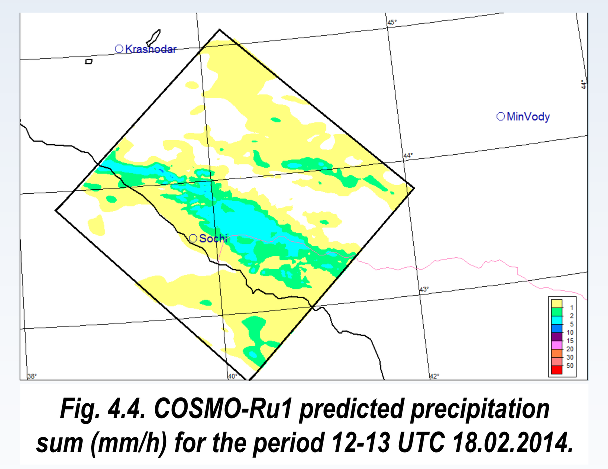


Fig. 4.4. COSMO-Ru1 predicted precipitation sum (mm/h) for the period 12-13 UTC 18.02.2014.

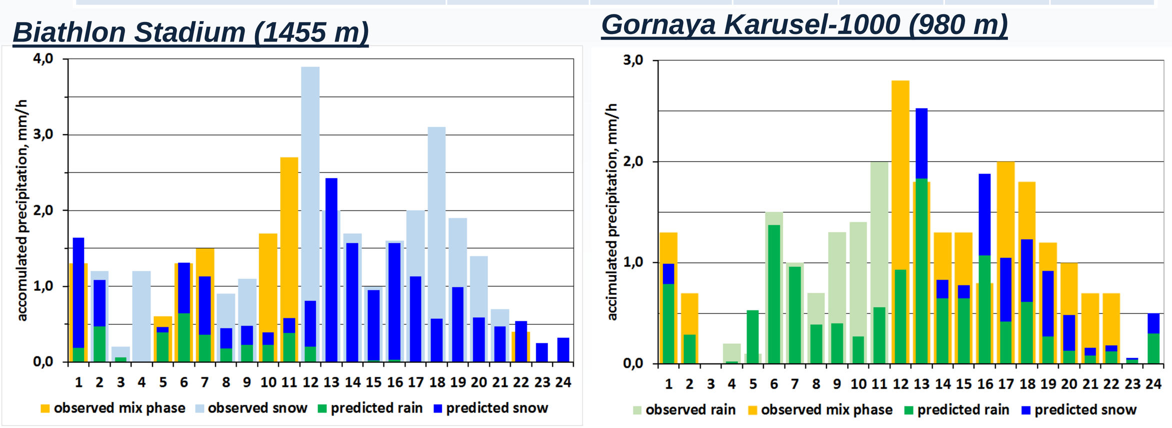


Fig. 4.5. Comparison of the forecasted accumulated precipitation and its phase with observation

Predicted phase composition of precipitation was evaluated using PWD (Present Weather Detector) data (fig. 4.5). Forecast is consistent with the observation for all evaluated sites.

Conclusions

- The use of COSMO-Ru1 model output with high spatial resolution allowed operational forecasters in Sochi kept up to date forecasts for sports competitions.
- Combined "Relative humidity + stream lines" maps were very useful to forecasters for predicted of the lenses of wet/dry air location and transfer.
- COSMO-Ru1 model allowed to give a detailed forecast of the change in visibility during the day due to fog formation / dissipation or heavy snowfall.
- Phase composition of precipitation was predicted reliably.
- There are errors in the determination of the time of beginning, peak and end of the events. Peak in precipitation, change in relative humidity were found to be shifted by 1-4 hours in the forecasts.

Corresponding author: Marina Shatunova, gbert@yandex.ru

The results of the CORSO project are summarized in the presentation (*http://www.cosmo-model.org/content/tasks/achievements/default.htm*).