Ensemble forecasting for Sochi-2014 Olympics: the COSMO–based ensemble prediction systems

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1. Introduction

In the framework of the forthcoming Winter Olympics and Paralympic Games, taking place in Sochi, Russia, from 7 to 23 February 2014 and from 7 to 16 March 2014, WMO WWRP initiated a dedicated blended Forecast Demonstration/Research and Development Project (FDP/RDP). **FROST-2014** (**F**orecast and **R**esearch in the **O**lympic **S**ochi **T**estbed; http://frost2014.meteoinfo.ru/) aimed at advancing the understanding of nowcasting and short-range prediction processes over complex terrain, since the region of Sochi is characterized by a complex topography, with the Caucasus mountains in the vicinity of the Black Sea (Kiktev, 2011), as shown in Fig. 12, where the main features of the Olympic venues are presented.

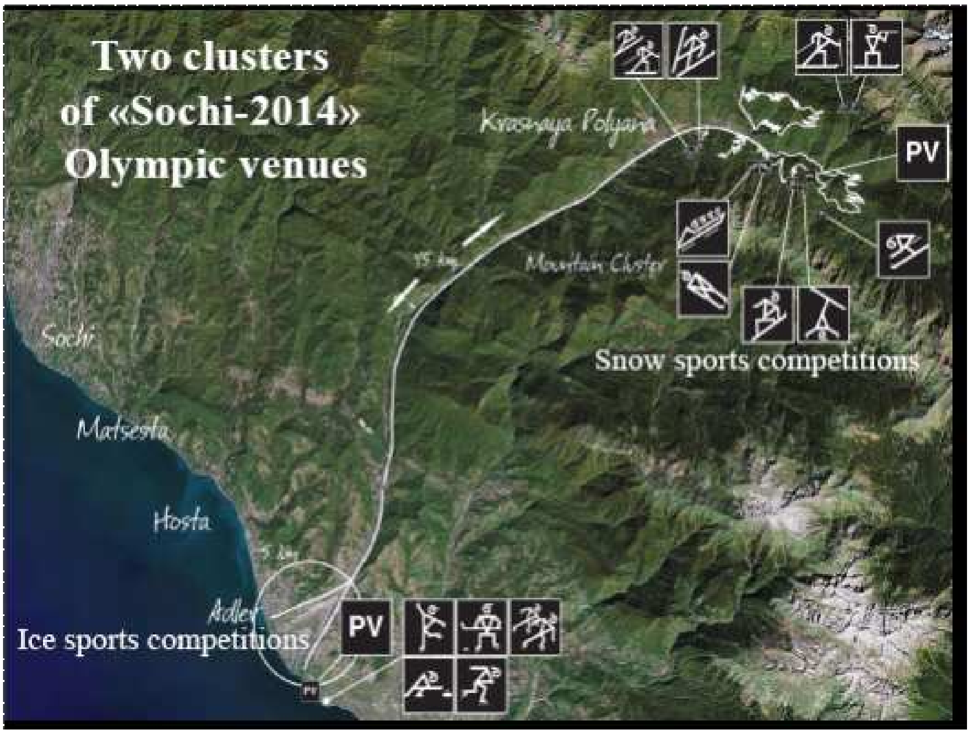

Figure 12: Main features of the Olympic venues for Sochi–2014.

Since Russia belongs to the COSMO consortium (http://www.cosmo-model.org), several activities have also been undertaken within the consortium to support NWP aspects of the FROST-2014 project. The COSMO tasks within FROST-2014 are organized in the framework of the Priority Project CORSO (Consolidation of Operation and Research results for the Sochi Olympic games), which deals with the following topics:

1. deterministic forecasting,
2. probabilistic forecasting:
   (a) FDP part: relocation of COSMO-LEPS (Montani et al., 2011) over the Sochi area, generating a new system named COSMO-S14-EPS ("S" stands for Sochi);
   (b) RDP part: development of a convective-scale ensemble system for the Sochi area, referred to as COSMO-RU2-EPS ("RU2" stands for Russian 2.2 km);
3. post-processing and product generation;
4. verification (development of VERSUS software for probabilistic verification).

As for 2(a), the main activities include the set-up, generation, implementation and maintenance of COSMO-S14-EPS, the convection-parameterized ensemble prediction system based on COSMO model and targeted for the Sochi-area. In addition to providing probabilistic guidance for the prediction of high-impact weather over the Olympic mountainous areas in the short range (up to day 3), COSMO-S14-EPS is also meant to provide both initial and boundary conditions for activity 2(b), linked to the generation of the convective-permitting ensemble, COSMO-RU2-EPS, running on a quasi–operational basis during winter 2013.

2. Methodology and implementation

As previously mentioned, COSMO-S14-EPS is a relocation of COSMO-LEPS over the area interested by the Olympic competitions. As such, it shares some features of the COSMO-LEPS methodology for its generation. On the other hand, computer-time constraints and the interest towards the short-range made it necessary to make some changes. The main characteristics of COSMO-S14-EPS are summarized in Table 5, which also reports some details relative to the global ensemble ECMWF-EPS.
It is worth pointing out that those ECMWF EPS members providing both initial and boundary conditions to COSMO-S14-EPS, are selected via a clustering technique performed between t+48h and t+72h on the basis of four variables (Z, U, V, Q) at three pressure levels (500, 700, 850 hPa). In addition to that, the lower boundary condition for all COSMO-S14-EPS members is taken from COSMO model run in hindcast mode (short-range forecast nested on ECMWF analyses).

TABLE 5: Main features of the present implementations of ECMWF-EPS, COSMO-S14-EPS and COSMO-RU2-EPS.

	ECMWF-EPS	COSMO-S14-EPS	COSMO-RU2-EPS
Hor. res.	$\sim$ 31 km	7 km	2.2 km
Vert. res.	62 ML	40 ML	50 ML
Forecast length	240h	72h	48h
Ensemble size	50+1	10	10
Initial time	00/12 UTC	00/12 UTC	00/12 UTC
Convection	Parameterized	Parameterized	Resolved
Running at	ECMWF	ECMWF	Roshydromet
ICs and BCs	SV ini pert + EDA	from selected ECMWF-EPS members	from COSMO-S14-EPS members
Model perturbations	Stochastic physical tendencies + backscatter	Physical parameterizations	

COSMO-S14-EPS was implemented on ECMWF super–computers in November 2011 and has been running on a regular basis since 19 December 2011 thanks to the billing units provided by the ECMWF Special Project SPCOFROST. COSMO-S14-EPS generates a set of standard probabilistic products, including probability of surpassing a threshold, ensemble mean and ensemble standard–deviation for several surface and upper-air variables. These products are delivered in real time to the Hydrometcenter of Russia (Roshydromet), further disseminated to Sochi forecasters and presented at the FROST-2014 Web-site (`http://frost2014.meteoinfo.ru/forecast/goomap` and `http://frost2014.meteoinfo.ru/forecast/arpa-new/cosmo-s14-eps-maps`). In addition to this, all forecast members for a specially defined area are transferred to Roshydromet where the epsgrams for predetermined points are prepared (see `http://frost2014.meteoinfo.ru/forecast/arpa-new` (authorization required)). The generation of the different types of non-graphical products makes use of

“Fieldextra”, the official COSMO post-processing software (for information about Fieldextra, please refer to `http://www.cosmo-model.org`). The graphical products are prepared using the GRADS package.

In addition to the ensemble products, initial and hourly-boundary conditions (up to t+48h) are provided to Roshydromet for the experimentation with the convection-resolving ensemble COSMO-RU2-EPS, whose main features are also summarized in Table 5.

Figure 13 reports the orography for the three systems of Table 5 and is meant to indicate the potential impact of increased horizontal resolution in the description of orographic and mesoscale-related processes.

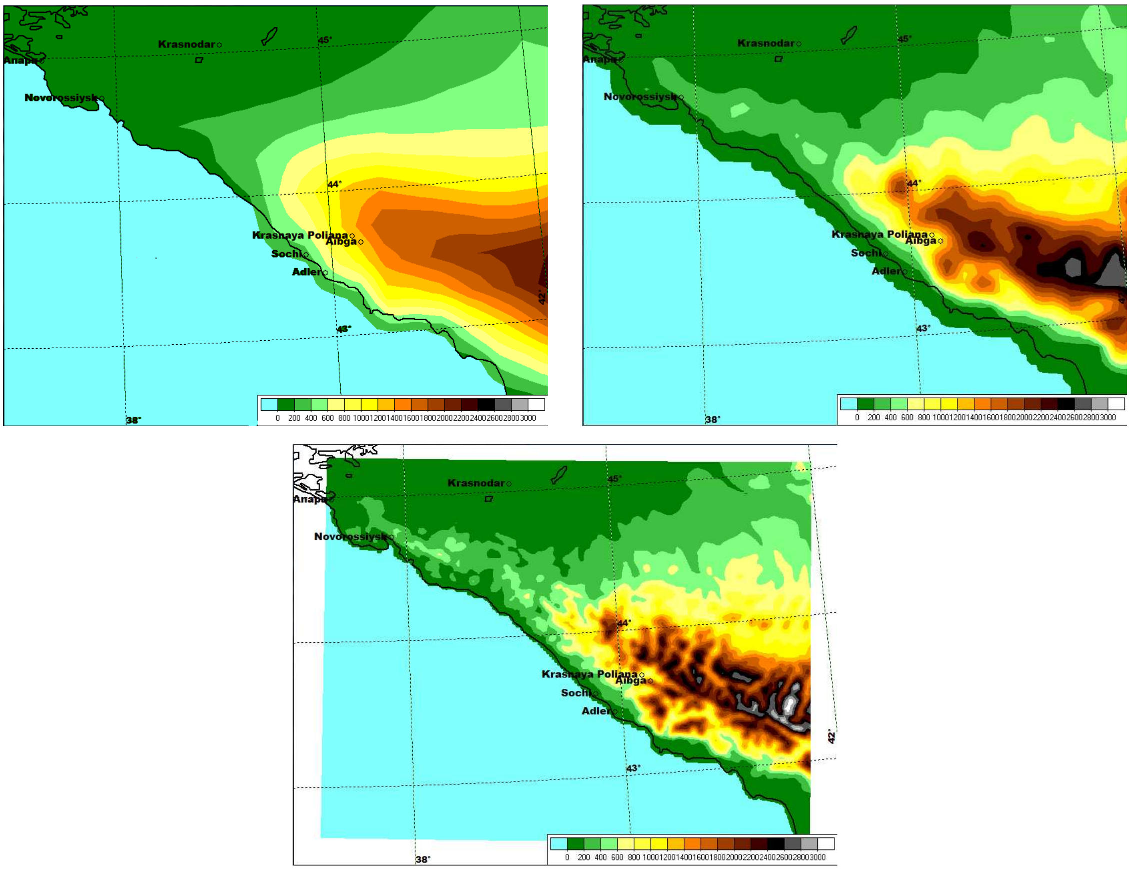

FIGURE 13: Model orography (in m) for ECMWF-EPS (Δx = 31 km, top-left panel), COSMO-S14-EPS (Δx = 7 km, top-right panel) and COSMO-RU2-EPS (Δx = 2.2 km, bottom panel) in the Olympic region.

ECMWF-EPS orography (top-left panel) shows almost no evidence of the valley running for about 40 kilometres from Sochi-Adler, the “Coastal cluster” where ice-sport competitions will take place, towards Krasnaya Polyana, located in the area of the “Mountain cluster” for snow-sport competitions (see also Fig. 12). COSMO-S14-EPS (top-right panel of Fig. 13) already offers a better description of the complex topography of the area, although it has to be pointed out that only with the 2.2 km grid-size of COSMO-RU2-EPS (bottom panel) some important details of the geography (e.g. the eastward turn of the valley after Krasnaya Polyana) can emerge. It is clear that the simple increase of horizontal resolution does not automatically guarantee a better simulation of the flow over orography and an overall higher prediction skill of precipitation. On the other hand, it has already been shown (Montani et al., 2013), that COSMO-S14-EPS outperforms ECMWF-EPS in terms of probabilistic prediction of precipitation events in the short range. These results, although based on only three months, have shown the potential of limited-area ensemble forecasting for the prediction of precipitation with high spatial detail.
In the next section, we analyse the performance of COSMO-S14-EPS and COSMO-RU2-EPS for a number of high-impact weather events occurred during the last winter and we try to assess the impact of higher -resolution in the probabilistic prediction of heavy precipitation and surface temperature.

3. Case-study results

Here, the attention is focused on the performance of the limited-area ensemble prediction systems for two high–impact weather events:

• heavy precipitation event on 13 January 2013 with 21 mm of rain during the day on the coast (Sochi/Adler) and 33 mm of snow-water equivalent in the mountain (Krasnaya Polyana);
• Foehn event on 14-15 February 2013 with a sudden 10–degree warming.

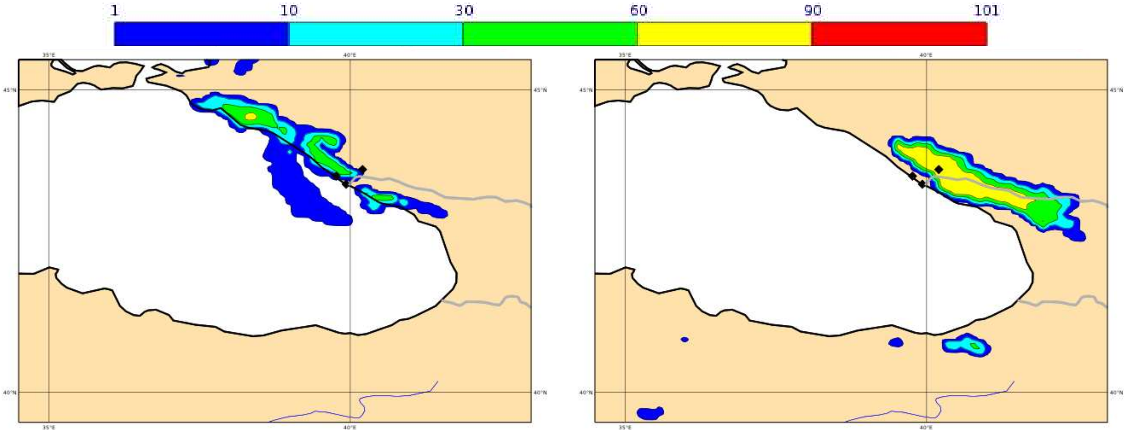

FIGURE 14: COSMO-S14-EPS run starting at 00UTC of 11 January 2013 (48-60 hour forecast range): probability of 12–hour rainfall exceeding 20 mm (left panel) and of 12-hour snowfall exceeding 15 mm of water equivalent. The black squares on the coast denote Sochi and Adler; the black square inland denotes Krasnaya Polyana.

3.1 Heavy precipitation event

Figure 14 reports the performance of COSMO-S14-EPS in terms of probabilistic prediction for two variables: probability of 12–hourly accumulated rainfall exceeding 20 mm (left panel) and probability of 12–hourly simulated snowfall exceeding 15 mm of equivalent water. The ensemble runs start at 00UTC of 11 January and the attention is focused on the 48-60 hour forecast range: it can be noticed that COSMO-S14-EPS provides a quite accurate forecasts giving large probability of heavy precipitation. Despite the steepness of the orography and the length of the forecast range, the system is able to distinguish between the area more likely affected by rainfall (along the coast, left panel) and the region mainly interested by snowfall (in the mountains, right panel). This is an interesting result, as the knowledge of the possibility of this weather event, with an advance of about 2 days, gives organizers the chance of taking counter–measures and relieving the weather-related problems. Let us compare the COSMO-S14-EPS forecasts to COSMO-RU2-EPS. The attention is fixed on the ability of both systems to predict the possible occurrence of heavy snowfall inland. More precisely, we consider the predictability of the following event: "probability of 12h snowfall exceeding 15 mm of equivalent water". In Fig. 15, the left–column (right–column) panels report the performance of COSMO-S14-EPS (COSMO-RU2-EPS) for the forecast ranges 36-48 hour and 24-36 hour (top-row and bottom-row panels, respectively). It can be noticed that the signal by COSMO-S14-EPS forecasts (left–column) is consistent for the different prediction ranges, with a probability of snowfall above 90% in the area actually affected by the weather event. It is also worth pointing out that no snowfall is predicted along the coast at any forecast range (probabilities below 1%), consistently with observations. A straight comparison of COSMO-S14-EPS against COSMO-RU2-EPS forecasts indicates that the higher–resolution ensemble (right–column panels of Fig. 15) provides more detailed information in terms of location of the regions affected or not by heavy snowfall. In the convective–resolving ensemble, the extent of the coastal region not interested by snowfall turns out to be more evident. At the same time, the higher-resolution ensemble is more confident in giving larger probabilities of snow in the mountainous region. Since more and more spatial and time details are usually required to the forecasts for shorter time ranges, COSMO-RU2-EPS seems to have, on the basis of this case study, the potential to provide a larger amount of information to local forecasters and event organizers.

3.2 Foehn event

Sudden temperature changes in the Olympic areas are considered high–impact weather events possibly affecting outdoor competitions. Therefore, the prediction of this type of event is an important benchmark for the usefulness of ensemble prediction systems. Note that the event considered below was regarded as hardly predictable by local forecasters.
Figure 16 shows the evolution of surface temperature in Krasnaya Polyana from 13 to 16 February 2013. Linked to the onset of Foehn winds, a marked increase took place between 13 and 15 February, affecting both day–time and night–time temperatures. On 14 and 15 February, the observed peaks amounted to 6 and 10 ^{o}C, respectively.

As for the ability of COSMO-S14-EPS (the only system analysed in this case study) to predict this temperature

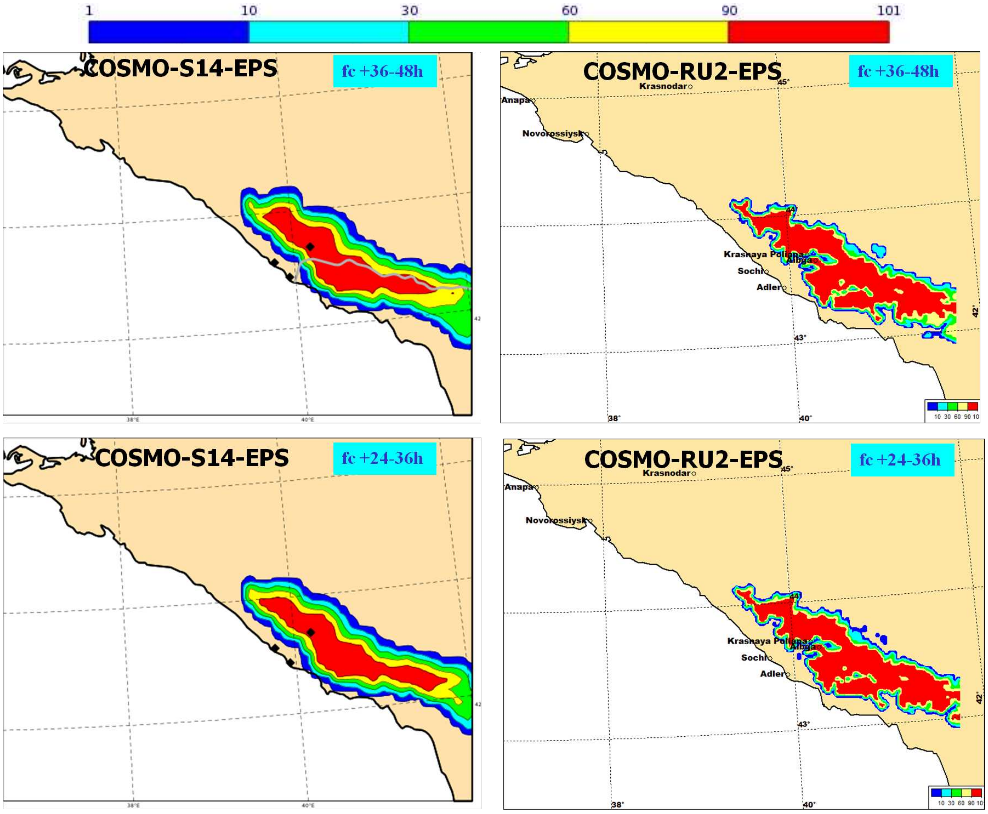

FIGURE 15: Probability of 12–hour snowfall exceeding 15 mm of equivalent water: COSMO-S14-EPS runs starting at 12UTC of 11 January (top-left panel, t+36-48h) and at 00UTC of 12 January (bottom-left panel, t+24-36h) and COSMO-RU2-EPS runs starting at 12UTC of 11 January (top-right panel, t+36-48h) and at 00UTC of 12 January (bottom-right panel, t+24-36h). All forecasts verify at 12UTC of 13 January 2013. As in Fig. 14, the black squares in the left panels denote Sochi, Adler and Krasnaya Polyana.

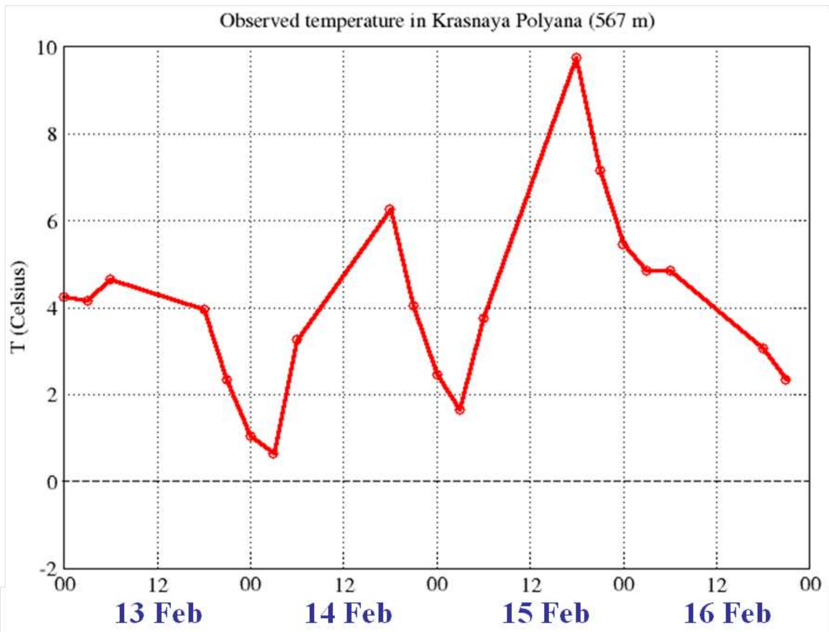

FIGURE 16: Observations of 2-metre temperature in Krasnaya Polyana (data from FROST database).

increase, Fig. 17 reports the meteograms computed over the station point of Krasnaya Polyana, in terms of 2-metre temperature, for different starting times. The top panel of the figure indicates that, already at the 72–hour range (forecasts starting at 12UTC of 12 February), the COSMO-S14-EPS members predict the temperature increase of 14 and 15 February, with peaks close to, or above, 10 ^{o}C. In this panel, as well as in the others, some discrepancies between observed and predicted temperature are evident, but the differences are partly related to the model orography, which locate Krasnaya Polyana at about 941 m, instead of 567 m. The accuracy of 2–metre temperature forecasts seems related, among other factors, to the good prediction of the onset of the Foehn winds, in terms of both location and intensity (not shown).

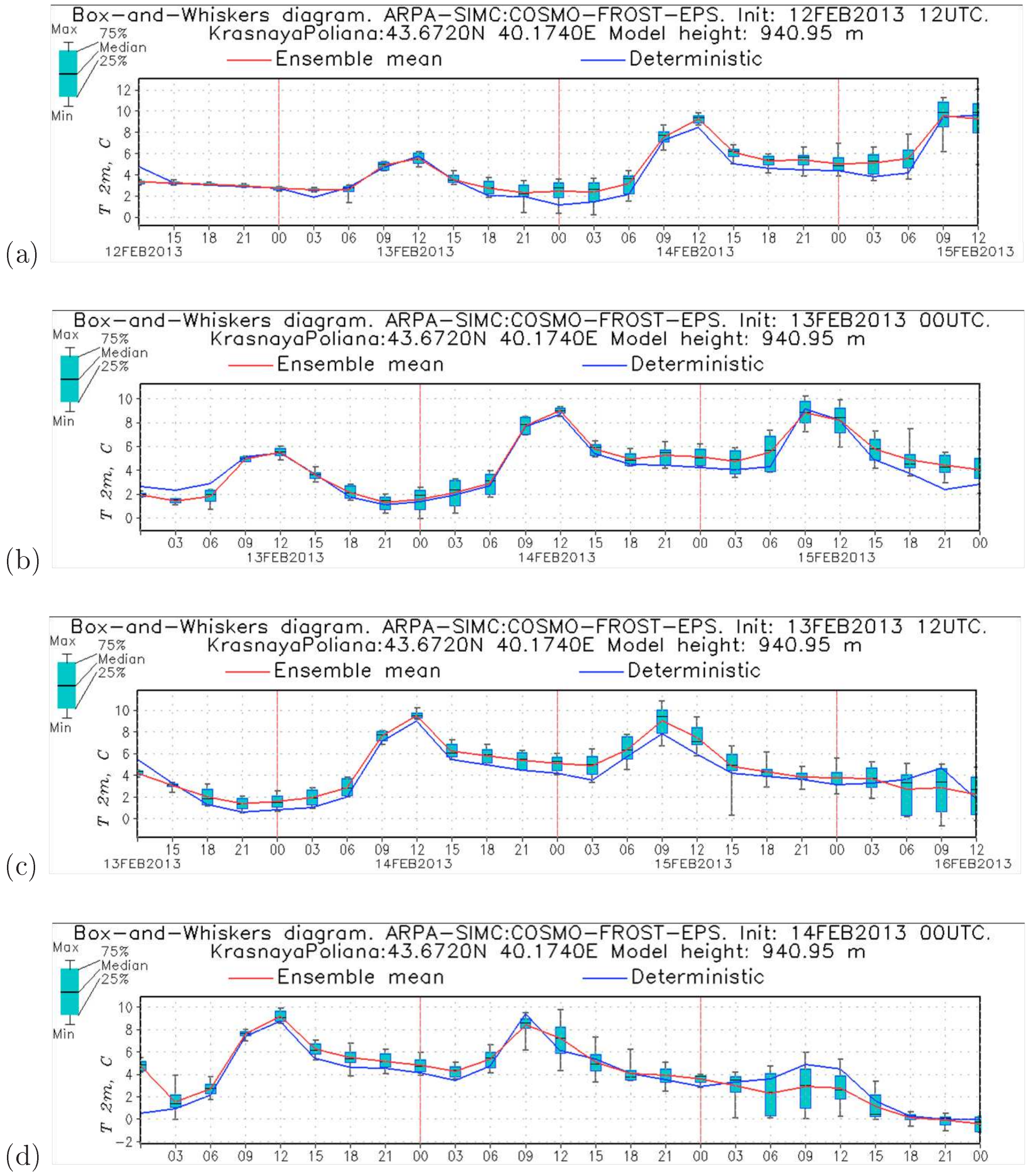

FIGURE 17: Point meteograms in terms of 2–metre temperature over Krasnaya Polyana based on COSMO-S14-EPS and starting at: (a) 12UTC of 12 February, (b) 00UTC of 13 February, (c) 12UTC of 13 February and (d) 00UTC of 14 February.

4. Summary and Outlook

The main results of the ensemble prediction system experimentation within FROST-2014 can be summarized as follows:

- The new COSMO-based ensemble systems over the Sochi-area (COSMO-S14-EPS and *COSMO-RU2-EPS*) were implemented and run on an operational/*quasi–operational* basis;
- COSMO-S14-EPS was shown to be able to capture the possible occurrence of intense and localized weather events in the Olympic venues with a few days in advance;
- COSMO-S14-EPS products are getting more and more used in operational forecasting and the use of probabilistic products among Olympic forecasters is increasing.

As for the future, it is planned to consolidate the generation/transmission/use of probabilistic products from ECMWF to the Sochi forecasters and to quantify the added value of the higher resolution in COSMO-RU2-EPS forecasts.

References

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