Development of a COSMO–based limited–area ensemble system for the 2014 Winter Olympic Games

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1 Introduction

Next winter Olympics and Paralympic Games will take place in Sochi, Russia, in a region characterised by complex topography located in the vicinity of the Black Sea. The Olympic Games will take place from 7 to 23 February 2014, while the Paralympic Games from 7 to 16 March 2014. In the framework of these events, WMO is launching two initiatives: a dedicated WWRP FDP (Forecast Demonstration Project) and a dedicated WWRP RDP Research and Development Project) to improve understanding of nowcasting and short-range prediction processes over complex terrain. A new project named **FROST-2014** (**F**orecast and **R**esearch in the **O**lympic **S**ochi **T**estbed; http://frost2014.meteoinfo.ru/) was set-up at the kick-off meeting held in Sochi from 1 to 3 March 2011. Four Working Groups (WGs) were established to deal with the various components of the project, more specifically:

- WG1: observations and nowcasting;
- WG2: NWP, ensembles and assimilation;
- WG3: IT including graphical tools, formats, archiving and telecommunication;
- WG4: products, training, end user assessment and social impacts.

As for WG2, it was agreed that ensembles with resolution about 7 km or coarser could be involved in the project in forecast and demonstration mode (FDP component), while systems with resolution about 2 km would contribute to the project in research mode (RDP component). Within the former component, one of the main activities deals with the set-up, generation, implementation and maintenance of a limited-area ensemble prediction system based on COSMO model and targeted for the Sochi-area.

2 Scientific plan

In the framework of the FDP, it was decided to clone COSMO-LEPS system and relocate it over Russia, centring the domain over the Sochi area, thus generating COSMO-FROST-EPS system. In the past years, COSMO-LEPS (Montani et al., 2011) proved to be a valuable tool for the generation of probabilistic predictions of high-impact weather over complex topography and it is envisaged that COSMO-FROST-EPS can provide useful support to bench forecasters during the Olympic Games. Within FROST-2014, the attention will be focused on those atmospheric variables which play a major role in the outdoor activities of the Olympic Games. More specifically, the probabilistic prediction of wind, wind-gust, precipitation (in various forms), temperature, humidity and visibility will be required for forecast ranges up to three days, depending on the variable.

Phase I: set–up of the system

In this phase, which took place in early 2012, a prototype COSMO-FROST-EPS system was set–up with a configuration similar to COSMO-LEPS application. In order to save computer time, the ensemble size was initially limited to 10 members and the forecast range to 72 hours. Therefore, the main characteristics can be summarised as follows:

- horizontal resolution: 7 km;
- vertical resolution: 40 model levels;
- number of grid points (NX x NY x NZ) = $365 \times 307 \times 40 = 4.482.200$;
- forecast length: 72 hours;
- ensemble size: 10 members,
- initial conditions: interpolated from selected ECMWF EPS members;
- boundary conditions: interpolated from selected ECMWF EPS members;
- initial times of the run: 00UTC and 12UTC.

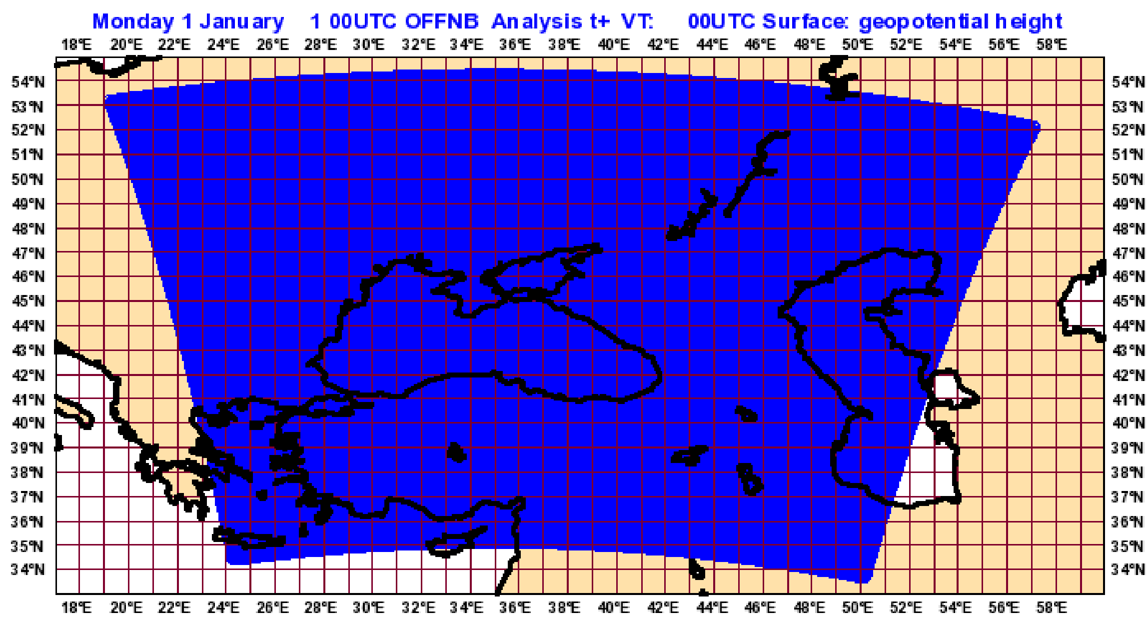

Figure 1: Integration domain for COSMO–FROST–EPS

Fig. 1 shows the integration domain of COSMO-FROST-EPS. The ECMWF EPS members providing initial and boundary conditions to COSMO-FROST-EPS integrations, are selected by means of a clustering analysis / selection of representative members similar to the one used in COSMO-LEPS time-critical application. COSMO-FROST-EPS system produces a set of standard probabilistic products (e.g. probability maps, meteograms, ...) to be delivered in real time to the Met Ops room of the Hydrological and Meteorological Centre of Russia (hereafter, Roshydromet). The generation of the different types of non-graphical products will take advantage of Fieldextra, the official COSMO post-processing software, developed at Meteoswiss (for information about Fieldextra, please refer to http://www.cosmo-model.org).

Phase II: development of the system

This phase is covering late 2012 and early 2013: on the basis of the experience gained in Phase I and on the feedback provided by Roshydromet forecasters, the configuration of COSMO-FROST-EPS will be adapted accordingly; the same applies to the type of products to be generated and delivered. As COSMO-FROST-EPS configuration is thought in a modular way, it could be modified in terms of ensemble size, forecast range and other features with limited effort. In this phase, the complete transition of the system towards the use of GRIB2 format for COSMO-FROST-EPS output files will take place. The set of products to be delivered will have to be consolidated, as well as the procedures of transmission and visualisation.

Phase III: final implementation of the system

This phase will cover the full length of Winter Olympic and Paralympic Games: COSMO-FROST-EPS system should run continuously from November 2013 to March 2014. Generation and transfer of products (forecast fields and/or plots) will have to be reliable and a timely delivery will have to be ensured.

3 Verification results

In this section, we present the first results relative to the performance of COSMO–FROST–EPS. The skill of the mesoscale ensemble is assessed over the period January–March 2012 and compared to that of ECMWF EPS. For both systems, we consider the probabilistic prediction of 12–hour accumulated precipitation exceeding a number of thresholds for several forecast ranges. Table 1 summarises the main properties of COSMO–FROST–EPS and ECMWF EPS, indicating the main differences between the two systems.

Table 1: Main features of the verified systems.

	COSMO–FROST–EPS	ECMWF EPS
EnsembleSize	10 members	51 members
ForecastLength	72h	240h
InitialTime	12 UTC	12 UTC
HorizontalResolution	7 km	25 km
VerticalResolution	40 ML	62 ML

As for observations, it has been decided to use the data obtained from the SYNOP reports available on the Global Telecommunication System (GTS), since this is recognised to be a homogeneous and stable dataset throughout the verification period. In the future, it is planned to verify the performance of COSMO–FROST–EPS over denser observational datasets.
In order to quantify the skill of the system over complex topography, the verification is performed over the domain 40N–50N, 35E–45E. Within this domain, a fixed list of 60 SYNOP stations is considered and the relative reports in terms of total precipitation are used to evaluate the COSMO–FROST–EPS and ECMWF-EPS skill. As for the comparison of model forecasts against SYNOP reports, we select the grid–point closest to the observation. Little sensitivity to the results is found when, instead of the nearest grid–point, a bi-linear interpolation using the 4 nearest points to the station location, is used to generate the model forecasts. Therefore, the results shown hereafter will be relative only to the nearest grid–point method. The performance of both systems is examined for 6 different thresholds: 1, 5,

Table 2: Main features of the verification configuration.

variable:	12–hour accumulated precipitation (18–06, 06–18 UTC);
period:	from 1 January to 31 March 2012;
region:	40–50N, 35E–45E;
method:	nearest grid–point;
observations:	SYNOP reports;
fcst ranges (h):	6-18, 18-30, 30-42, 42-54, 54-66
thresholds:	1, 5, 10, 15, 25, 50 mm/12h;
scores:	ROC area, BSS, RPSS, OUTL;

10, 15, 25 and 50 mm/12h.
The following probabilistic scores are computed over the verification period: the Brier Skill Score (BSS), the Ranked Probability Skill Score (RPSS), the Relative Operating Characteristic Curve (ROC) area and the Percentage of Outliers (OUTL). For a description of these scores, the reader is referred to Wilks (1995) and to Marsigli et al. (2008). The main features of the verification exercise are summarised in Table 2.

The skill of the two systems in terms of prediction of 12–hour accumulated precipitation is summarised in Fig. 2, where the Ranked Probability Skill Score (RPSS) is plotted against the forecast range for both COSMO–FROST–EPS and ECMWF EPS. It can be noticed

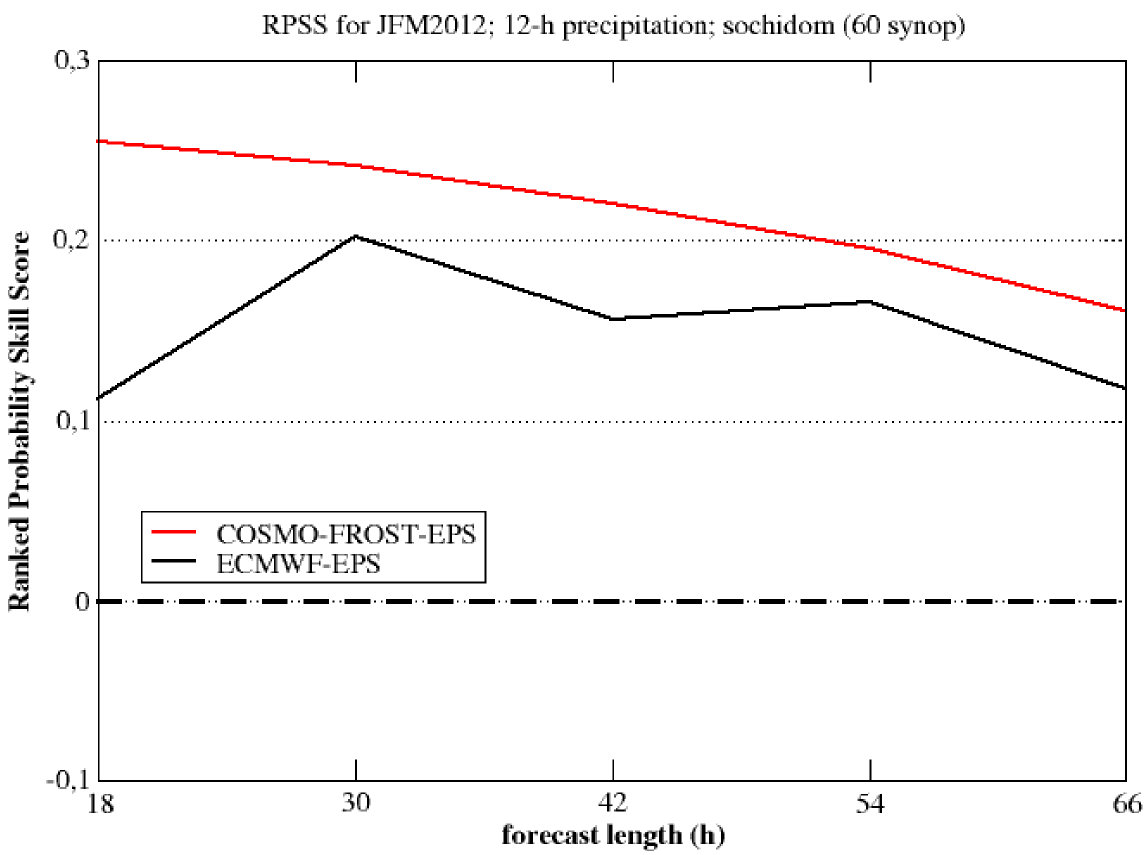

Figure 2: Ranked Probability Skill Score as a function of forecast length for COSMO–FROST–EPS (red) and ECMWF EPS (black), calculated over the 3–month period from January to March 2012.

that COSMO-FROST–EPS has higher RPSS for all forecast ranges. The difference between the two systems is consistent throughout the full forecast range, with a larger gap for the

first day of integration. This implies that, despite the higher ensemble size of ECMWF EPS, the higher resolution of COSMO-FROST–EPS contributes to provide more accurate probabilistic predictions of precipitation.
If the attention is now focused on the performance of both systems for a specific event, most of the above comments still hold. As an example, Fig. 3 shows the scores of COSMO-FROST–EPS and ECMWF EPS in terms of ROC area for the event "12–hour accumulated precipitation exceeding 10 mm". COSMO-FROST–EPS outperforms ECMWF EPS for all forecast ranges, although both systems exhibit a semi–diurnal cycle in the score and tend to provide better guidance for "night–time" precipitation, that is occurring between 18UTC and 6UTC (and corresponding to the ranges 6–18 h, 30–42 h and 54–66 h). As for COMO, this is linked with a too rapid onset of convection, as pointed out by Oberto and Turco (2008) for runs of COSMO in "deterministic mode".

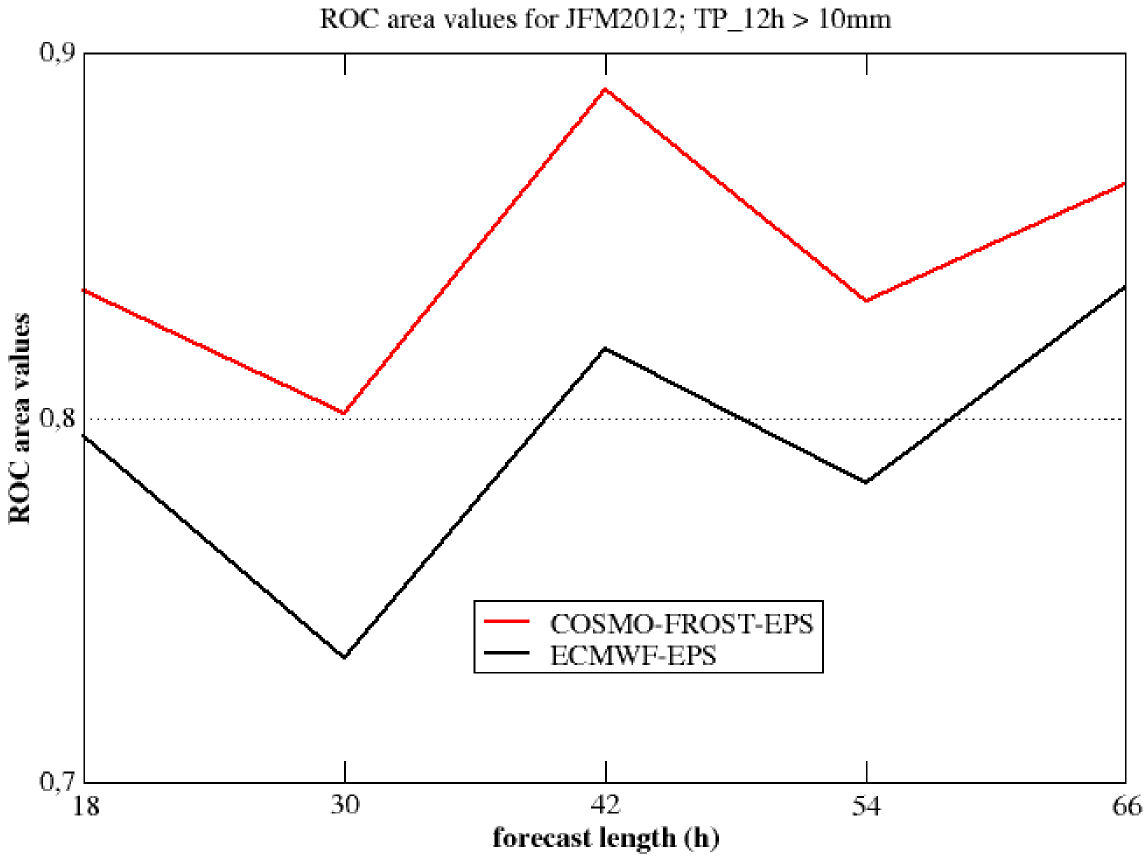

Figure 3: ROC area values for COSMO–FROST–EPS (red) and ECMWF EPS (black) relative to the event "precipitation exceeding 10mm in 12 hours" for the forecast ranges of Table 2. Both scores are calculated over the 3–month period from January to March 2012.

Finally, the attention is focused on the ability of COSMO–FROST–EPS to reduce the number of outliers with respect to ECMWF EPS, thanks to the higher resolution and the better description of mesoscale and orographic–related processes. Fig. 4 shows that COSMO–FROST–EPS has fewer outliers than the global ensemble, with a clear added value of the mesoscale ensemble for short forecast ranges.
According to Talagrand et al. (1999), the value of outliers for a reliable ensemble of size N is given by $2/(N+1)$. These values should not be exceeded. The dashed lines of Fig. 4 indicate these limits for both COSMO–FROST–EPS (red, 18%) and ECMWF EPS (black, 4%). Therefore, it looks as if COSMO–FROST–EPS approaches the theoretical value to larger extent than ECMWF EPS, which seems to have too many outliers in the short range.

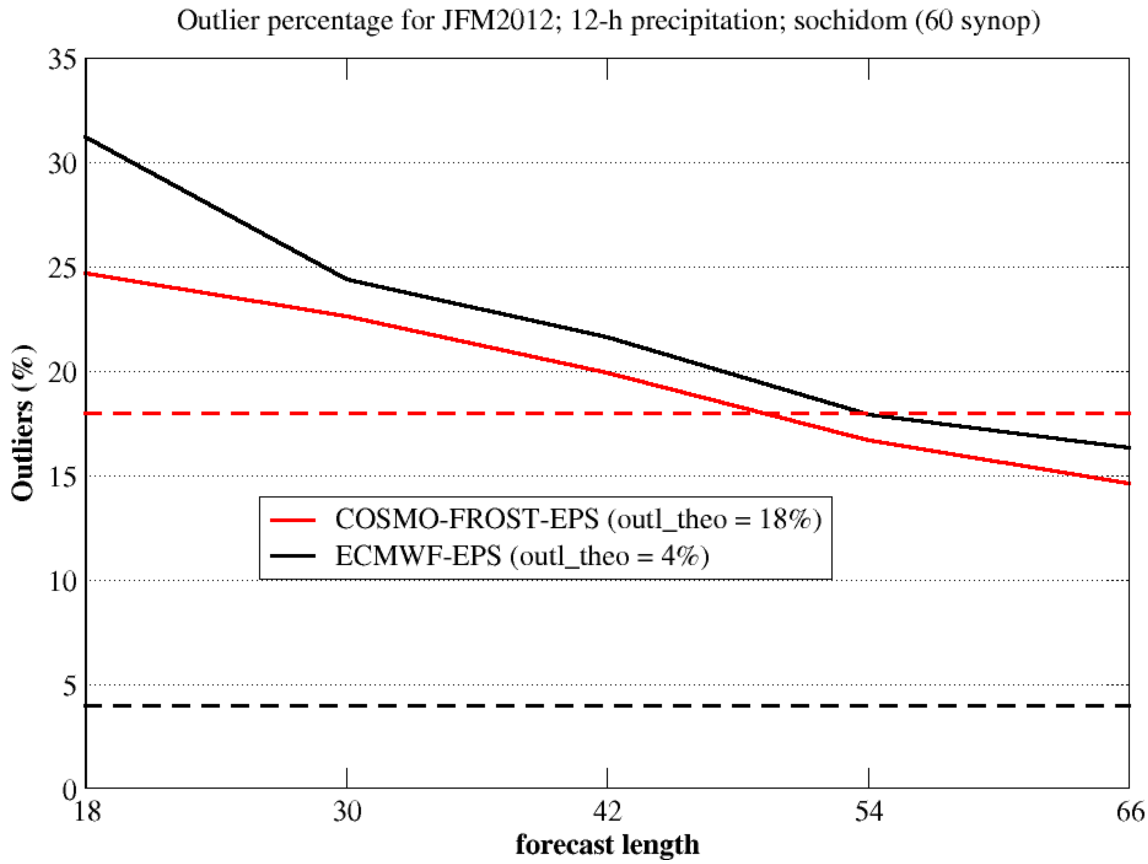

Figure 4: Percentage of Outliers for COSMO–FROST–EPS (red) and ECMWF EPS (black), calculated over the 3–month period from January to March 2012. The red (black) dashed line indicates the theoretical limit of outliers for COSMO–FROST–EPS (ECMWF EPS).

4 Summary and Outlook

COSMO–FROST–EPS is a limited–area ensemble prediction system which is supporting the probabilistic prediction of high–impact weather events for next winter Olympic Games. The system, based on a relocation of COSMO-LEPS, has been shown to provide added value with respect to the driving ensemble as for the probabilistic prediction of precipitation events. Although these results are still preliminary and not yet fully based on a long and statistically significant sample, they already show the potential of the system, which can provide accurate precipitation forecasts with high spatial detail.
In the near future, it is envisaged to perform a verification based on higher–resolution observational datasets and to improve upon the initialisation of the system in terms of soil–moisture and soil–temperature fields.

References

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