SPECIAL PROJECT PROGRESS REPORT

Progress Reports should be 2 to 10 pages in length, depending on importance of the project. All the following mandatory information needs to be provided.

Reporting year	2016
Project Title:	Investigation of case studies during Sochi Olympic Games using COSMO-based ensemble prediction systems.
Computer Project Account:	SPCOLEPS
Principal Investigator(s):	Montani Andrea
Affiliation:	Arpae-SIMC
Name of ECMWF scientist(s) collaborating to the project (if applicable)	………………………………………………………….…… ………………………………………………………….……
Start date of the project:	2015
Expected end date:	2017

Computer resources allocated/used for the current year and the previous one
(if applicable)
Please answer for all project resources

		Previous year		Current year	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)	2.000.0000	1.164.043	1.000.000	45.000
Data storage capacity	(Gbytes)	50	40	50	2

Summary of project objectives
(10 lines max)

In 2015, the overall aim was to provide the COSMO-S14-EPS fileds to fill the gaps in the FROST archive for the period 15 January – 15 March 2014. As for this year, the plans are as follows:

1. to investigate the performance of the COSMO-based ensemble systems during the Winter Olympics 2014 by varying the configurations of the ensembles;
2. to investigate the performance of the COSMO-based ensemble systems for old case studies, occurred in 2007 in Europe and where high-density observations were available (namely COPS-DPHASE observational dataset).

Summary of problems encountered (if any)

(20 lines max)

Summary of results of the current year (from July of previous year to June of current year)

This section should comprise 1 to 8 pages and can be replaced by a short summary plus an existing scientific report on the project

The billing units of the project were used to run COSMO-S14-EPS for some missing dates during the Olympic season; this enabled to close the “holes” in the archive of COSMO-S14-EPS so that this model could take part to the unfied Sochi archive containing the forecasts of 6 different limited-area ensemble prediction systems.

This is described in the attached report (SCI-REPORT_spcoleps_2016.pdf).

List of publications/reports from the project with complete references

Astakhova E., Montani A., Kiktev D., Smirnov A., 2016. COSMO-based ensemble forecasting for Sochi-2014 Olympics: archiving the results. COSMO Newsletter No.16, pp 40-45. Available at http://www.cosmo-model.org/content/model/documentation/newsLetters/newsLetter16/default.htm

Summary of plans for the continuation of the project

(10 lines max)

It is planned to test the sensitivity of the forecast skill to the introduction of SPPT in COSMO model and to assess merits/shortcomings of single vs double precision in COSMO runs.

COSMO-based ensemble forecasting for Sochi-2014 Olympics: archiving the results

Elena Astakhova1, Andrea Montani2, Dmitry Kiktev1, Alexander Smirnov1

1 Roshydromet, Moscow, Russia 2 ARPA–SIMC, Bologna, Italy

1 Introduction

The last winter Olympic/Paralympic Games were held in February-March 2014 in Sochi, Russia. The Russian Meteorological Service (Roshydromet) initiated a special international project FROST-2014 (FROST - Forecast and Research in the Olympic Sochi Testbed) related to these Games; it got a status of WMO World Weather Research Programme (WWRP) blended Forecast Demonstration and Research and Development Project (Kiktev et al., 2015a; Kiktev et al., 2015b).

The COSMO activity in FROST-2014 was integrated within a consortium priority project Consolidation of Operation and Research results for the Sochi Olympic Games (PP CORSO) (Rivin and Rozinkina, 2013). PP CORSO finished in 2014. Its results included a successful experience of high-resolution modeling in mountainous areas, improved downscaling/postprocessing procedures for the Sochi region, regular provision of probabilistic forecasts during the Games as well as research in ensemble modeling with different resolutions.

It was realized in 2014 that some additional work was necessary to implement CORSO achievements to COSMO practice and to enable their better usage. That is why the priority task CORSO-A followed PP CORSO. Here only the ensemble component of CORSO and CORSO-A activity will be considered. We shall briefly remind CORSO results, overview the goal of CORSO-A, and summarize its results.

2 Ensemble prediction systems developed in CORSO

Two ensemble prediction systems (EPS) were developed within PP CORSO: COSMO-S14-EPS with a 7-km resolution and COSMO-Ru2-EPS with a 2.2 km resolution (Montani et al, 2013, 2014, 2015). COSMO-S14-EPS (S14 stands for Sochi2014) was created at ARPA-SIMC (Montani et al, 2013) and was a version of COSMO-LEPS system (Montani et al, 2011) displaced from the European area to the Sochi region.

The system was driven by the ECMWF EPS, namely, by its most representative prognostic realizations which were selected by a clustering procedure. The lower boundary condition was a result of COSMO model run in hindcast mode (a short-range forecast nested on ECMWF analyses).

The model-related uncertainties were taken into account in COSMO-S14-EPS by using two different convection parameterization schemes (Tiedtke or Kain-Fritsch, random choice) in different members and also by varying tuning coefficients in parameterizations of sub-grid scale processes (in particular, turbulent). The most essential differences between COSMO-S14-EPS and COSMO-LEPS systems were integration domains (Sochi region or Europe) and ensemble sizes (10 or 16 members, respectively).

The system with a 2.2-km grid size named COSMO-Ru2-EPS ran at Roshydromet and performed a dynamical downscaling of COSMO-S14-EPS increasing the forecast resolution both in horizontal (from 7 to 2.2 km) and in vertical (from 40 to 50 levels).No additional perturbations were introduced neither to initial and boundary conditions nor to the model.

The ensemble has the same size as in COSMO-S14-EPS and was composed of 10 perturbed members with no control. Both EPSs ran operationally during the Olympics/Paralympics, their results were provided to Sochi forecasters and proved to give a valuable support to them.

In fact, the entire length of parallel runs of COSMO-S14-EPS and COSMO-Ru2-EPS was longer than the period of the Games and covered December 2013-April 2014. The forecast results were archived on Roshydromet servers along with initial and boundary conditions generated by COSMO-S14-EPS and later used by COSMO-Ru2-EPS.

3 CORSO-A necessity and goal

It is worth to note here that COSMO ensemble forecasts can be considered a part of a more extensive FROST-2014 archive that included the results of four more ensemble prediction systems (Kiktev et al, 2015; Astakhova et al, 2015).

The two systems, GLAMEPS and HarmonEPS, were presented to FROST-2014 by the Norwegian Meteorological Institute, while ALADIN-LAEF and NMMB-EPS came from the Central Institution for Meteorology and Geodynamics (ZAMG), Austria, and the National Centers for Environmental Prediction (NCEP), USA, respectively.

The EPS resolution was 7 to 11 km except for the convection permitting HarmonEPS with its 2.5 km horizontal step; the ensemble size varied from 7 to 54. Additionally, deterministic forecasts by 9 different systems, nowcasts from 6 systems, and a variety of observational data of different types, including station, radar, profiler data, operational meteorological bulletins, camera snapshots, etc., were aggregated at the FROST-2014 server and available via the project web-site $http://frost2014.meteoinfo.ru$.

By no doubt, this huge amount of forecast and observation data could be very useful for research in the field of short-range limited-area deterministic and ensemble prediction. Remember that the Sochi area is a very complex region with steep mountains lying near the warm Black Sea and forecasting in mountainous regions is still a challenge for numerical weather prediction models.

However, it became clear after the Olympic Games, that in research tasks it would be quite difficult and problematic to use the forecast data in the form presented on the FROST-2014 server because of different coding and organization of data files transferred to Roshydromet by various data providers.

The application of the archive would be much easier if the forecast data were organized following some standard rules. A good idea is to follow TIGGE-LAM project and to prepare a Sochi unified archive using the coding standards and user interfaces adopted in TIGGE-LAM (Paccagnella et al., 2012). TIGGE and TIGGE-LAM data portals are well known and very popular in scientific community and a lot of research has been done using the data presented there.

That is why one of CORSO-A goals was to implement a unified archive of COSMO ensemble forecasts (with 7 and 2.2 km resolutions) for the Sochi area. The archive was expected to be accompanied by the data on initial and boundary conditions for high-resolution ensembles and by a list of important weather events during Olympics and Paralympics.

4 A Unified Sochi archive

The Sochi unified archive covers the period from January 15, 2014 to March 16, 2014. This time interval coincides with the period adopted for verification in FROST-2014 (January 15 - March 15, 2014). The archive contains the ensemble forecasts by COSMO-S14-EPS and COSMO-Ru2-EPS starting at 00 UTC and 12 UTC on the dates within the above-mentioned two-month interval.

The prognostic fields for all members are presented with a 3h time frequency on the original COSMO-model rotated latitude-longitude grid with resolutions 7 and 2.2 km for COSMO-S14-EPS and COSMO-Ru2-EPS, respectively. The accumulated parameters (precipitation and wind gusts at 10 m) are not archived at zero timestep. The data are in WMO-GRIB2 format. The archived parameters and the corresponding coding information are listed in **Table 1**.

The parameter set is slightly different from the TIGGE-LAM high-priority parameters. The Sochi archive does not contain large-scale precipitation, convective inhibition, and convective available potential energy. As static fields (land-sea mask and orography) did not change during the period, they were written to the archive only once.

Table 1: Specification of Sochi archive

Parameter	Abbre-viation	Level	Units	GRIB2 specifics
10 metre U-velocity	10u	10m (103.10)	m s-1	Instantaneous Product Discipline 0 Parameter Category 2 Parameter number 3 paramId 165
10 metre V-velocity	10v	10m (103.10)	m s-1	Instantaneous Product Discipline 0 Parameter Category 2 Parameter number 2 paramId 166
Mean sea level pressure	msl	MSL (101)	Pa	Instantaneous Product Discipline 0 Parameter Category 3 Parameter number 0 paramId 151
Surface air temperature	2t	2m (103.2)	K	Instantaneous Product Discipline 0 Parameter Category 0 Parameter number 0 paramId 167
Surface air dew point temperature	2d	2m (103.2)	K	Instantaneous Product Discipline 0 Parameter Category 0 Parameter number 6 paramId 168
Accumulated precipitation (liquid+frozen, convective+large-scale)	tp	surface (1)	kg m-2	Accumulated from the beginning of the forecast Product Discipline 0 Parameter Category 1 Parameter number 52 paramId 228228
10 metre wind gust in the last 3 hours	10fg3	10m (103,10)	m s-1	Product Discipline 0 Parameter Category 2 Parameter number 22 typeOfStatisticalProcessing 2 paramId 228028
Orography (geopotential height at the surface)	orog	surface (1)	gmp	Instantaneous Control run Product Discipline 0 Parameter Category 3 Parameter number 5 paramId 228002
Land-sea mask	lsm	surface (1)	Propor-tion (0-1)	Instantaneous Control run Product Discipline 2 Parameter Category 0 Parameter number 0 paramId 172

The following ensemble meta-data information is included to the GRIB files

- the ensemble size (GRIB key numberOfForecastsInEnsemble)
- the number of ensemble member (GRIB key perturbationNumber)
- the forecast type (GRIB key dataType = pf/cf, i.e. perturbed/control)

No data for mean sea level pressure is available for COSMO-S14-EPS. Initial and boundary conditions for high-resolution COSMO EPS are available on demand.

All other FROST-2014 forecast data (both deterministic and ensemble) in the Sochi unified archive are coded in the same way. The archive is available at $http://frost2014.meteoinfo.ru$ (authorization required). To download the forecasts, you must switch to Forecasts (upper panel) -Export of gridded ensemble forecasts (right panel), and then select the necessary data using the interface similar to that of TIGGE-LAM data portal (Fig. 1). The necessary data will be prepared in compressed form, the corresponding reference will be sent by e-mail, and then the data can be downloaded.

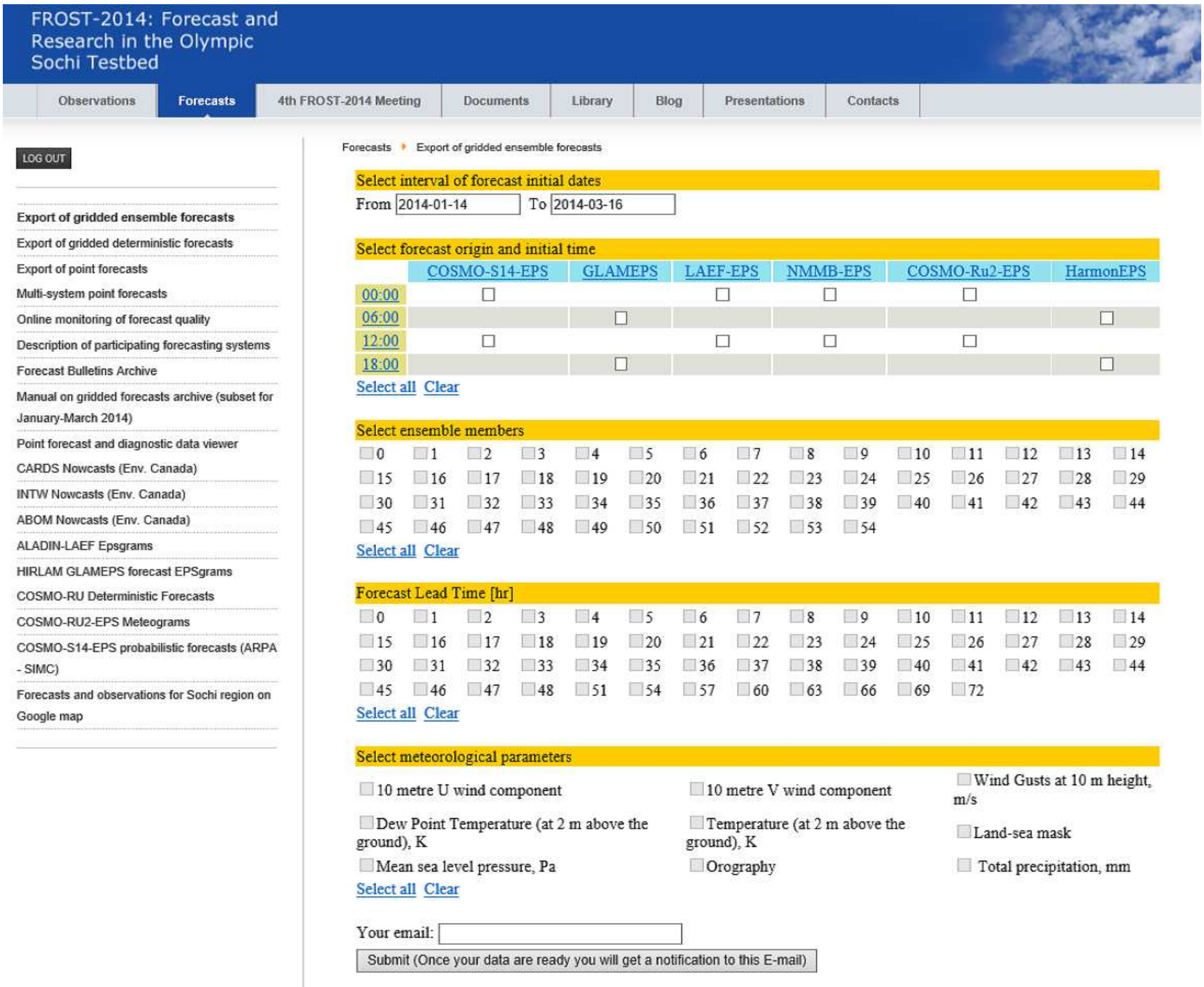

Figure 1: The FROST-2014 Web-interface used to download forecasts from the unified Sochi archive

Table 2: The most interesting cases during the Olympics/Paralympics

Case	Meteorological process/phenomenon	Models' behavior	Impact on competitions
07.02	Foehn	Poor temperature forecast (underestimated by 1.4-3.7^{o}C) by most models at Biathlon Stadium	
10-11.02	Dissipated precipitation	Precipitation in the Mountain Cluster predicted by the majority of systems, but not observed actually	
15.02		Poor forecast of maximum wind speed by most models at Krasnaya Polyana (underestimated by 3.5-7 m/s)	
16.02	Low visibility		Postponed competitions at Laura and Extreme Park
18.02	Cold front	Good precipitation forecast by most models	
22.02	Foehn	Poor temperature forecast by most models (negative forecast errors: -2.4 – -4.4 ^{o}, most markedly at 1500 m)	
11.03	Cold front. Low visibility	Bad description of the behavior of maximum temperature (Tmax) by most models (Tmax forecasted at noon, whereas in reality it was observed in the morning)	Postponed skiing competitions at Roza Khutor
13.03		Poor precipitation forecast by most models above 1500 m	
17.03	Cold front	Underestimation of maximum wind speed by most models above 1500 m	

In addition to the prognostic fields, point forecasts (mean for ensembles) can be exported in csv format for more than 30 stations in the Sochi region. During the Olympics these forecasts were regularly presented at the multi-system page of the FROST-2014 site along with observation data and were considered very useful both by forecasters and researchers. To prepare these forecasts, the nearest grid-point approach was applied. A Web-tool to export observation data was also developed. For more details, please visit $http : //frost2014.meteoinfo.ru$, where you will also find a short description of all FROST-2014 numerical weather prediction systems.

When research deals with the investigation of the skill of different weather prediction systems and of new ways to improve the forecast, it is important to have information about the synoptic situation in the analyzed domain and to select really essential events for case studies. To facilitate research in the field of short-range forecasting, Sochi forecasters prepared a list of cases recommended for detailed consideration. This list supplements the unified archive and is given in **Tab2**.

4 Conclusions

The unified Sochi archive containing forecasts for the area of Olympic Games 2014 for the period from January 15, 2014 to March 16, 2014 was prepared. The forecasts of two COSMO-based ensemble prediction systems, COSMO-S14-EPS and COSMO-Ru2-EPS with resolutions 7 and 2.2 km respectively, are stored in the archive.

The Web-tool to download the forecasts and observations as well as the list of interesting cases for research supplement the archive. The archive is organized in TIGGE-LAM style and is available at $http : //frost2014.meteoinfo.ru$. This work was carried out within the COSMO PT CORSO-A and WWRP FD-P/RDP FROST-2014.

Acknowledgements

The authors are grateful to Tatiana Dmitrieva, Roshydromet, for providing the information on weather cases during the winter 2014 and to Tiziana Paccagnella, ARPA-SIMC, for supporting the work.

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