Section 5

Development of and studies with regional and smaller-scale atmospheric models, regional ensemble, monthly and seasonal forecasting

Operative Hydrodynamic-Statistical Forecast of St. Jude Storm and of other Dangerous Storm Winds over the Territory of Russia and Europe on the Base of the Regional Model of Russia

E.V.Perekhodtseva

Hydrometeorological Research Center of Russia
email: perekhod@mecom.ru

The development of successful method for automated hydrodynamic or statistical well-in-advance forecast (from 12 hours to two days) of dangerous storm winds with the velocity V>24m/s, including squalls and tornadoes, is actual problem till recently. The operative meteorologists in Russia have used objective physic-statistical forecast of squalls, tornadoes and the wind with the velocity V>19m/s and automated hydrodynamic-statistical forecast of dangerous wind (V>24m/s) on the base of hemispheric model of Russia (the author – Perekhodtseva E.V.). The areas 300x300km on the European part of Russia were used for the testing and for the verification of this hydrodynamic-statistical forecast [3]. The result was very successful. The value of Pirsy-Obukhov criterion for the forecast even to 36h ahead was equal T=0.9, the warning of the dangerous wind was equal P=93% for the North-West region. The values of T in other regions of Russia was successful too (T>0,075) [4]. Nowadays there is no successful hydrodynamic model for the forecast of such storm wind in Russia.

The statistical model of the summer storm wind (V>24m/s) recognition

The meteorological situation involved the dangerous phenomena – the squalls, tornadoes and wind with the velocity V>24m/s is submitted as the vector $\mathbf{X}(A)=(x_1(A), x_2(A), \ldots x_n(A))$, where n – the quantity of the empiric potential atmospheric parameters (predictors). The values of these predictors for the dates and towns, where these phenomena were, give us the set $\{\mathbf{X}(A)\}$ – the learned sample of the phenomena A presence. The learned sample of the phenomena A absence or the phenomena B presence ($\{\mathbf{X}(B)\}$) was obtained for such towns, where the atmosphere was instability, but the velocity values were not so high. The recognition model of the sets $\{\mathbf{X}(A)\}$ and $\{\mathbf{X}(B)\}$ was constructed with the help of Byes approach [1,3]. Before the problem of the sets $\{\mathbf{X}(A)\}$ and $\{\mathbf{X}(B)\}$ recognition it was compressed the predictors space without the information losses by our algorithm of the mean correlation matrix **R** diagonalization. The informative predictors - representatives from each of blocks of **R** and some independent predictors are given vector-predictor of the dimension n=7 (from 38 potential predictors). For this purpose we have estimated the most informative predictors using the criterion by Mahalanobis distance $\Delta^2=(m_i(A)-m_i(B))\uparrow 2/\sigma^2$ [1,2,4]. We have obtained follow informative vector-predictor:

$$(V_{700}, T_{ea}, Td_{ea}, H_{1000}, T_{300}, dT/dn_{ea}, Iw).$$

The values of the discriminant function $F(\mathbf{X})$ and $P(\mathbf{X})$ were calculated for this vector-predictor in the nodes of the greed 150x150km of the hemispheric model. The forecast probabilities $P(\mathbf{X})$ of dangerous wind were calculated by: $P(\mathbf{X})=100/(1+\exp(-F(\mathbf{X}))$.

The automated hydrodynamic-statistical forecast of storm wind on the base of the regional model forecasts

Nowadays the output data of the regional model (in rectangular mesh 75x75km) were used for the storm wind forecast in the before developed discriminant function $F(\mathbf{X})$ for the new hydrodynamic-statistical forecast of dangerous wind. The prognostic area is the area with the probability values $P>P_{thr}$ =65% (for the summer) and P>60% for the cold period. The result of the independent automated station verification of this new forecast of these seldom phenomena during warm period of year 2010-2011 are submitted in [ ]. The quantity of meteorological stations with these phenomena cases was 109 from all tested cases at the European Part of Russia (50233). The warning of the phenomenon was equal 57%, the warning of the phenomenon absence was equal 85%, and criterion T was equal T=0,42.

The hydrodynamic-statistical forecast of the St. Iuda storm.

This forecast method was applied successful to the forecast of storm wind over the North and Norway seas for the forecast of wind waves, deep connected with storm wind [5]. So this storm wind forecast is calculated operative two times per day over Europe. Here the map of the dangerous wind forecast to 28.10.2014 with the earliness 36h. The forecast probabilities P are very high. The area with P=95%-85% is very great. Really, the observed velocity over the North Sea was equal V=190km/h.. Next day storm have visited East Europe and Russia (St. Petersburg and other cities) with the velocity V>25m/s. A lot of countries have a great losses at the period 28-29.10.2013. We have these successful forecasts to these days. Thus this hydrodynamic-statistical forecast of storms is successful help in the synoptic work.

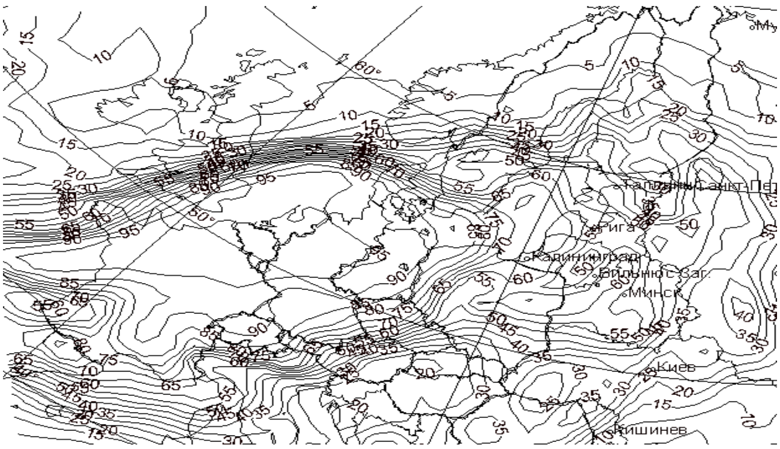

Fig.1 The storm wind forecast area to the date 28.10.2013. to 36h ahead. This area is occurred by the isoline of the probability **P**=60%.

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Cloud resolving simulation of a local heavy rainfall event on 26 August 2011 observed by the Tokyo Metropolitan Area Convection Study (TOMACS)

Kazuo Saito, Masaru Kunii and Kentaro Araki
Meteorological Research Institute, Tsukuba, Japan

On 26 August 2011, a local heavy rainfall event occurred in the Tokyo metropolitan area. In Tokyo and Kanagawa prefectures, very intense rains more than 90 mm hr-1 were observed (Fig. 2a) and several houses were inundated. This heavy rainfall event was caused by a mesoscale convective system (MCS) which was triggered by low level convergence, and its characteristics were captured by a dense observation network deployed by the Tokyo Metropolitan Area Convection Study (TOMACS; Nakatani et al., 2013). The merging of two misocyclones were studied by Saito et al. (2013) using data from a high-density ground weather observation network of TOMACS and the Doppler radar for the airport weather system of JMA. A rapid scan special observation was conducted by the Meteorological Satellite Center of JMA for this event. Figure 1a shows a visible satellite image at 1210 JST of 26 August 2011 taken by the rapid scan observation. Sea breeze fronts from the east coast of the Kanto Plain and the Bay of Tokyo intruded inland in the morning, and collision of the two fronts triggered an MCS. These behaviors of sea breezes were also confirmed by the dense surface observation network of JMA and the Atmospheric Environmental Regional Observation System (AEROS; for their characteristics as surface observation, see Nishi et al. (2014)) of the Japanese Ministry of Environment (Fig. 1b).

Despite its relatively larger spatial scale as a local rainfall in Japan and existence of low level convergence by a synoptic front, the operational mesoscale model (MSM) of JMA failed to predict this intense rainfall event (Fig. 2b). Studies on model physics, predictability, and data assimilation should be conducted to improve the forecast.

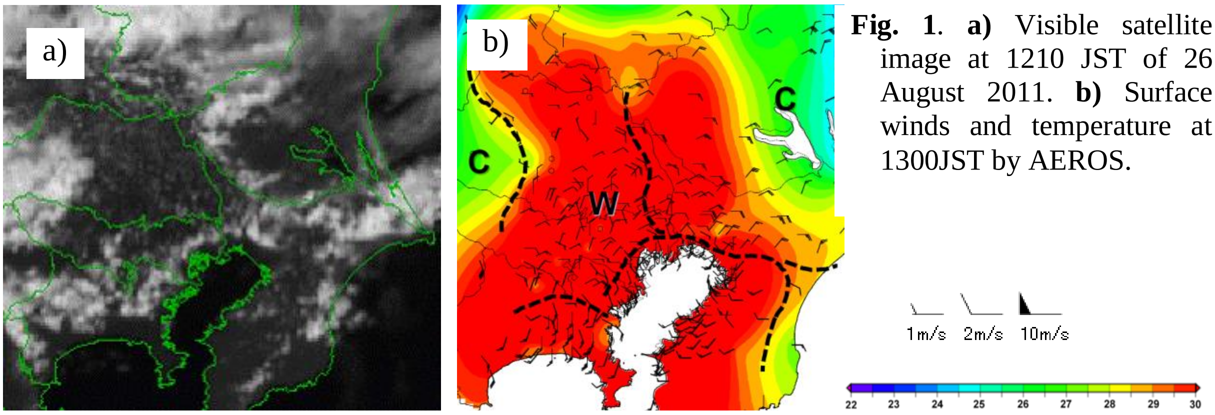

Fig. 1. a) Visible satellite image at 1210 JST of 26 August 2011. **b)** Surface winds and temperature at 1300JST by AEROS.

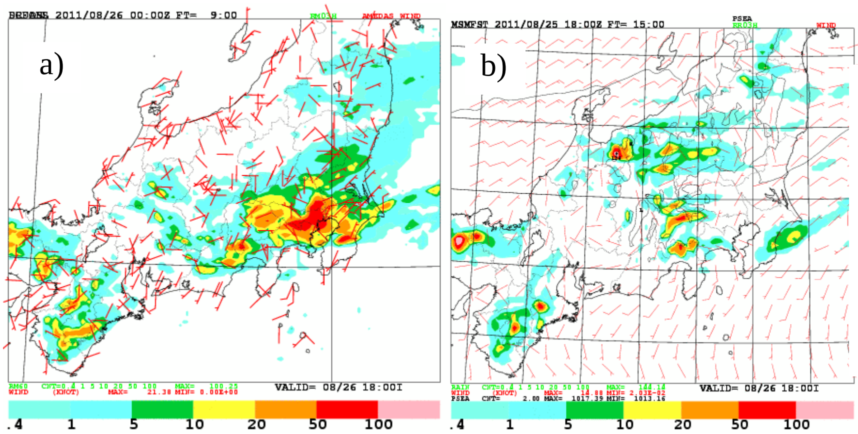

Fig. 2. a) Observed precipitation for 15-18 JST, 26 August 2011. **b)** Three-hour accumulated precipitation for 1500-1800 JST by MSM. Initial condition is 1800 UTC 25 August 2011 (FT=15).

Numerical experiments for this event have been performed. As a first trial, a simple downscale experiment from the operational mesoscale 4D-VAR analysis of JMA was conducted using the JMA nonhydrostatic model (NHM; Saito, 2012) with horizontal resolutions of 10 km and 2 km. Figure 3a shows three-hour accumulated precipitation for 1500-1800 JST by the 2 km NHM initiated at 1800 UTC 25 (0300 JST 26) August. Initial and boundary conditions were supplied from the 10 km NHM whose initial time was 1200 UTC (2100 JST) 25 August. The intense rainfalls appeared, but its position was in southwestern part of the Kanto Plain. A mesoscale ensemble forecast was also conducted using perturbations derived from the JMA one-week global ensemble prediction system (WEP) at 1200 UTC 25 August. However, only a few members intensified the rainfall around Tokyo and some fake precipitations appeared in the north of the Kanto Plain (figure not shown).

In NHM, the model cloud amount to compute radiation processes is evaluated from relative humidity considering subgrid scale partial condensation. Magnitude of the subgrid fluctuation is determined by the MYNN3 turbulent closure model. Recently, JMA has changed the lower limit of the fluctuation in their operational local model (LFM) to ameliorate an overestimation tendency of the cloud amount. When the lower limit was changed, surface temperatures increases about 1 C in southern part of the Kanto Plain, and it modified the position of low level convergence which triggered the MCS (figure not shown).

An additional experiment was conducted using an initial value perturbation by the mesoscale singular vector method (MSV; Kunii, 2010) based on the tangent linear and adjoint models of NHM. Figure 3b is the corresponding precipitation by the 2 km NHM for 1500-1800 JST, where perturbations from member 'P04' by MSV were added to the initial condition of the outer 10 km NHM. Fake precipitations in the north of the Kanto Plain were reduced, and the 2 km NHM captured the heavy precipitation in Tokyo and an associated cyclonic circulation around MCS. Figure 3c shows horizontal convergence at 1000 hPa and surface winds at 1500 JST by the simulation. Intrusion and collision of the two sea breeze fronts from the east coast of the Kanto Plain and the Bay of Tokyo were well reproduced.

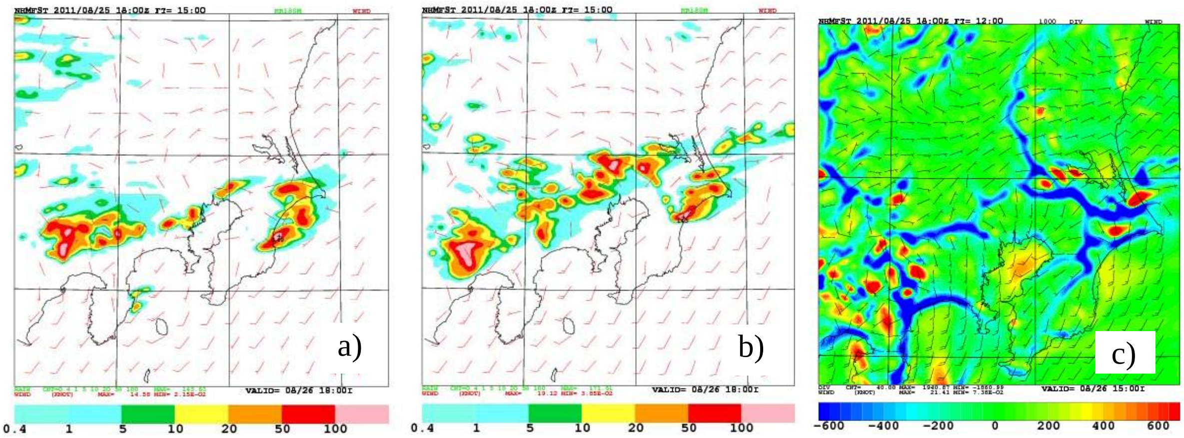

Fig. 3. a) Three-hour accumulated precipitation for 1500-1800 JST by the 2 km NHM (FT=15). **b)** Same as in a) but the limit of subgrid fluctuation of partial condensation in NHM was reduced, and by ensemble member P04 with the MSV method. **c)** Horizontal convergence at 1000 hPa and surface winds at 1500 JST by the simulation.

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Super high-resolution simulation of the fine-scale tornado structure

Wataru Mashiko
Meteorological Research Institute, JMA, 1-1 Nagamine, Tsukuba, Ibaraki 305-0052, Japan
(E-mail : wmashiko@mri-jma.go.jp)

1. Introduction

Detailed structure of tornadoes has not been clarified enough because of difficulties in collecting observational data with fine spatial and temporal resolutions. Most of previous studies have been conducted by photogrammetric analyses, laboratory experiments and idealized simulations such as a large eddy simulation, which contains calculational errors or some obvious unrealistic aspects. In this study, we performed downscale experiments with realistic conditions for Tsukuba supercell tornado (2012) using nested grids with as small as 10-m horizontal grid spacing to resolve the fine-scale tornado structure. The Tsukuba tornado rated F3 on the Fujita scale, which is one of the most destructive tornadoes ever in Japan, hit Tsukuba City in eastern Japan on 6 May 2012 and caused severe damage. The main objective in this study is to understand the detailed structure of a severe tornado and the dynamics which govern the smaller-scale disturbances within a tornado.

2. Model description and experimental design

The numerical model used in this study is the Japan Meteorological Agency Nonhydrostatic Model (JMA-NHM; Saito et al. 2006), which is operationally used in JMA. It is based on fully compressible equations with a map factor. Unlike previous numerical studies on tornadoes, this simulation includes a full physics model that parameterizes surface processes and starts from a realistic initial condition obtained from an operational regional analysis of JMA that adopts a four-dimensional variational data assimilation system.

Quadruply nested one-way grids are used to conduct super high-resolution simulation with a horizontal gird spacing of 10 m (NHM10m). The NHM10m contains 4001 x 3001 grid points in the horizontal and 250 vertical levels with grid intervals of 10 m near the surface. The initial time is 12:02 JST (= UTC + 9 hours) on 6 May 2012, and the integration time is 18 min. The initial and boundary conditions are provided from the simulation results with 50-m horizontal gird spacing (NHM50m), which successfully simulated a supercell tornado (Fig. 1).

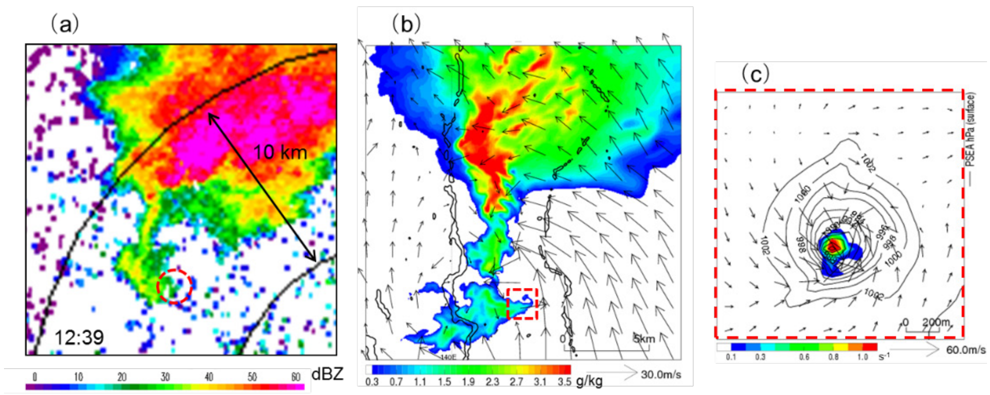

Fig. 1. (a) Radar reflectivity observed by C-band radar about 15 km away from storm center. Red circle indicates tornado location. (b) Horizontal distribution of the mixing ratio of hydrometeors (sum of rainwater, snow, and graupel) at a height of 1 km simulated by NHM50m. Arrows denote storm-relative winds. (c) Vertical vorticity at a height of 10 m simulated by NHM50m. The displayed area corresponds to the red rectangle in (b). Contour lines denote sea level pressure at intervals of 2 hPa.

3. Simulation results

Figure 2 shows the time series of minimum sea level pressure and maximum wind velocity within a simulated tornado from the rapid intensifying stage to decaying stage. Minimum pressure reaches 937 hPa (pressure deficit; 65 hPa), and maximum ground-relative surface wind speeds exceed 70 m s^{-1} around 12:15 JST.

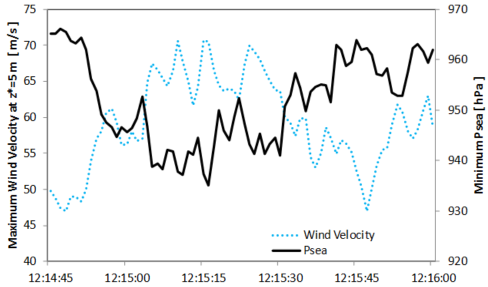

Fig. 2. Time series of minimum sea level pressure and maximum wind velocity at a height of 5 m.

During the rapid intensifying stage, the vortex core region accompanying large vertical vorticity contracted and was gradually occupied by downdraft (Fig. 3). After that, the central downdraft intensified, and multiple vortices formed with an increase of horizontal dimension of a tornado. Thus, it is evident that the simulated tornado evolved from one-celled to two-celled tornado and subsequently exhibited multiple vortices, which are consistent with a tornado-like vortex evolution in laboratory experiments. Figure 4 illustrates an asymmetric structure of a tornado at 12:16 JST when most significant multiple vortices formed. There exist two prominent cyclonic subvortices associated with pressure deficit. Although subvortices locally intensify winds owing to the superposition of the velocity field associated with the small-scale subvortex and the larger-scale tornado, the strongest wind is found in the shrinking stage prior to multiple vortices.

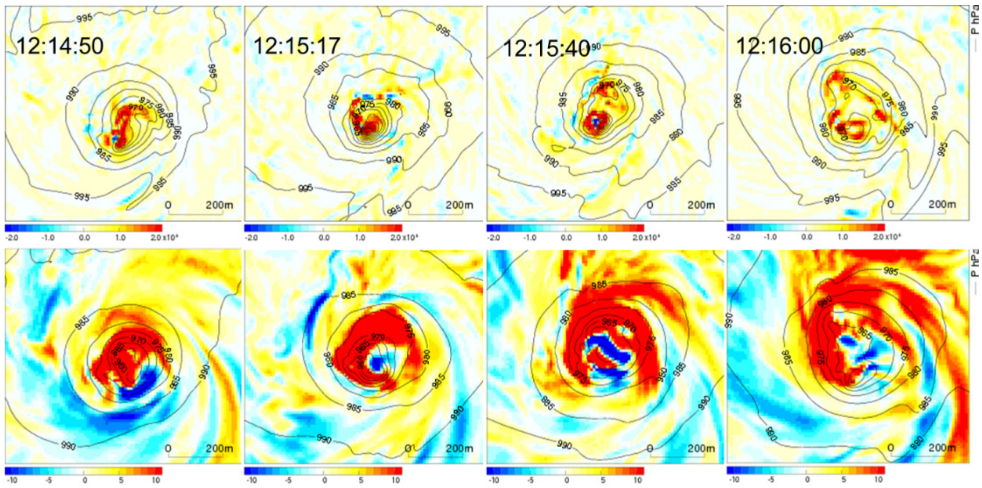

Fig. 3. Evolution of vertical vorticity at a height of 26 m (upper panels) and vertical velocity at a height of 79 m (lower panels). Contour lines indicate pressure at intervals of 5 hPa.

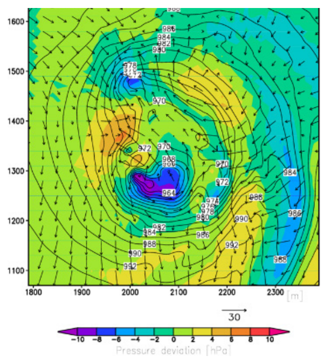

Fig. 4. Asymmetric structure at a height of 26 m at 12:16 JST. Shaded colors show pressure perturbation, and arrows denote asymmetric winds. Contour lines indicate pressure at intervals of 2 hPa.

Acknowledgements

Parts of the results were obtained by using the K computer at the RIKEN Advanced Institute for Computational Science (Proposal number hp120282).

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

Andrea Montani, C. Marsigli, T. Paccagnella

ARPA–SIMC (HydroMeteoClimate Service of Emilia-Romagna), Bologna, Italy
E-mail: amontani@arpa.emr.it

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 launched two dedicated initiatives: a WWRP Forecast Demonstration Project (FDP) and a WWRP Research and Development Project (RDP). Both components are part of the **FROST-2014** project (**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 characterised by complex topography, with the Caucasus mountains in the vicinity of the Black Sea (Kiktev, 2011). 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. The COSMO tasks within FROST-2014 are organised in the framework of the Priority Project CORSO (Consolidation of Operation and Research results for the Sochi Olympic games), which deals, among other topics, with the relocation of COSMO-LEPS (Montani et al., 2011) over the Sochi area, generating a new system named COSMO-S14-EPS. As for this topic, the main activities include the set-up, generation, implementation and maintenance of COSMO-S14-EPS, the convection–parameterised ensemble prediction system based on COSMO model and targeted for the Sochi-area.

Methodology and implementation

COSMO-S14-EPS shares several 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 summarised in Table 1, which also reports some details relative to the global ensemble ECMWF-EPS as well as to COSMO-RU2-EPS, the convection-permitting ensemble which takes both initial and boundary conditions from COSMO-S14-EPS.

Table 1: Main features of ECMWF-EPS, COSMO-S14-EPS and COSMO-RU2-EPS.

	ECMWF-EPS	COSMO-S14-EPS	COSMO-RU2-EPS
Hor./vert. res.	~30 km / 62 ML	7 km / 40 ML	2.2 km / 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	Parameterised	Parameterised	Resolved
ICs and BCs	SV ini pert + EDA	from selected ECMWF-EPS members	from COSMO-S14-EPS members

COSMO-S14-EPS was implemented on ECMWF super–computers in November 2011 (Montani et al., 2013) and has been running on a regular basis since 19 December 2011. It 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 Met Ops room of the Hydrological and Meteorological Centre of

Russia. In addition to this, initial and hourly-boundary conditions (up to T=48h) are provided for the experimentation with COSMO-RU2-EPS, whose main features are also summarised in Table 1. In the next section, we analyse the performance of COSMO-S14-EPS for a case of high-impact weather occurred during the last winter and we try to assess the usefulness of high–resolution in the probabilistic prediction of heavy precipitation.

Case-study results

The attention is focused on the performance of COSMO-S14-EPS for the heavy precipitation event of 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). Fig. 1 reports the per-

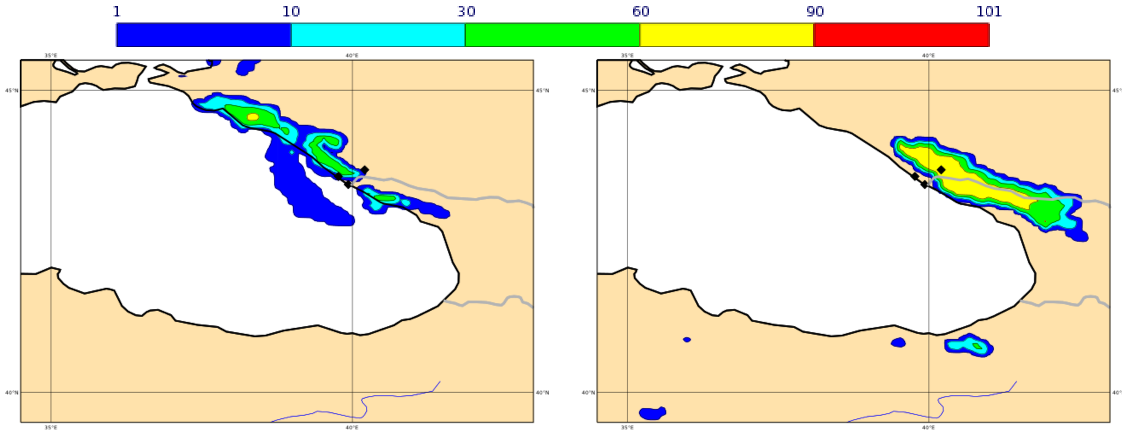

Figure 1: COSMO-S14-EPS run starting at 00UTC of 11 January 2013 (48-60 hour forecast range): probability of 12–hour rainfall exceeding 20 mm (left panel) and of 12-hour snowfall exceeding 15 mm of water equivalent. The dots on the coast denote Sochi and Adler; the dot inland denotes Krasnaya Polyana.

formance of the system 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. 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 mountain, right panel). This is an important result, as the knowledge of the possibility of this weather event, with an advance of about 2 days, would give organisers the chance of taking counter–measures and relieving the weather-related problems.
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 value of a blended deterministic/probabilistic approach.

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