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	2017
Project Title:	Short-Range Ensemble Prediction System
Computer Project Account:	**SP** ITLEKF
Principal Investigator(s):	Lucio Torrisi
Affiliation:	COMET - Italian Air Force Operational Met. Center
Name of ECMWF scientist(s) collaborating to the project (if applicable)	Francesca Marcucci
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)	8000000	8000000	9000000	0
Data storage capacity	(Gbytes)				

Summary of project objectives

(10 lines max)

The goal of this project is to improve the existing short-range ensemble prediction system, based on the Ensemble Kalman Filter (EnKF) approach (COMET-LETKF [1] [2]) for the data assimilation component (estimation of the initial conditions) and the COSMO regional model (www.cosmo-model.org) for the prognostic one, in the framework of a comprehensive plan for development of a new set of tools for the probabilistic forecast.

Summary of problems encountered (if any)

(20 lines max)

No real problem was encountered, neither technical nor conceptual.

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

The atmospheric short-range ensemble prediction system (COSMO-ME EPS) based on the COMET-LETKF analysis and the COSMO model is running operationally at the Italian Air Force Meteorological Service (pre-operational since July 2013).

The relevant characteristics of the atmospheric COSMO-ME EPS are:

- Domain and resolution: COSMO model is integrated 40 times on the same domain of the COMET-LETKF system.
- IC and BC: initial conditions are derived from the COMET-LETKF system; lateral boundaries conditions are from the most recent IFS deterministic run perturbed using ECMWF-EPS.
- Model error: stochastics physics perturbation tendencies.
- Forecast range: 72 hours at 00/12 UTC.

During the third year of the project, different calibration methods have been evaluated in order to correct the bias of the existing ensemble and the derived uncertainty information of the precipitation field. The aim of the work is to provide to our forecasters the best possible support for specific operational applications.

Calibration is a post-processing technique used to reduce systematic uncertainties of probabilistic forecasts, so that the ensemble forecast statistical properties become similar to those of the observations (reference dataset). In this way, the probabilistic forecasts are corrected using the errors of the past probabilistic forecasts. The choice of the most appropriate method is a function of the variable to be calibrated, the ensemble features and the possible uses of the forecasts. The effectiveness of calibration depends on the training dataset length. A greater number of available historical data (reforecast dataset) is needed for a better performance of a calibration method. Because the small COSMO-ME EPS historical dataset, only two methods (quantile-to-quantile mapping QQM [3] and Local quantile-to-quantile transformation LQQT [4]) have been chosen as a starting point. Both methods need a smaller training period with respect to other algorithms proposed in literature. QQM and LQQT methods are used to calibrate the QPF (quantitative precipitation forecast) of each ensemble member so that correspondent rain field maintains their spatial features.
In this project the two methods have been implemented using R language and tested over a 1 month period.

The purpose of the QQM approach is to ensure that the calibrated forecasts have the same marginal distribution of the observations. For each grid cell and each member, the reforecast dataset and the corresponding observations are sorted in ascending order for the period (season) of the target date. Then, the corresponding cumulative probability distributions are generated. The not-calibrated QPF quantile of the target date is identified in the reforecast dataset CDF. The observed value with the same quantile in the corresponding CDF of the observations is the daily calibrated QPF. This method allows only the bias correction but not improvement of deficiencies in spread corrections. In fig 1 the maps of the differences between the calibrated and raw forecast probability of 6 hours cumulated precipitation greater than 0.2 mm and 10 mm are shown for a single event.

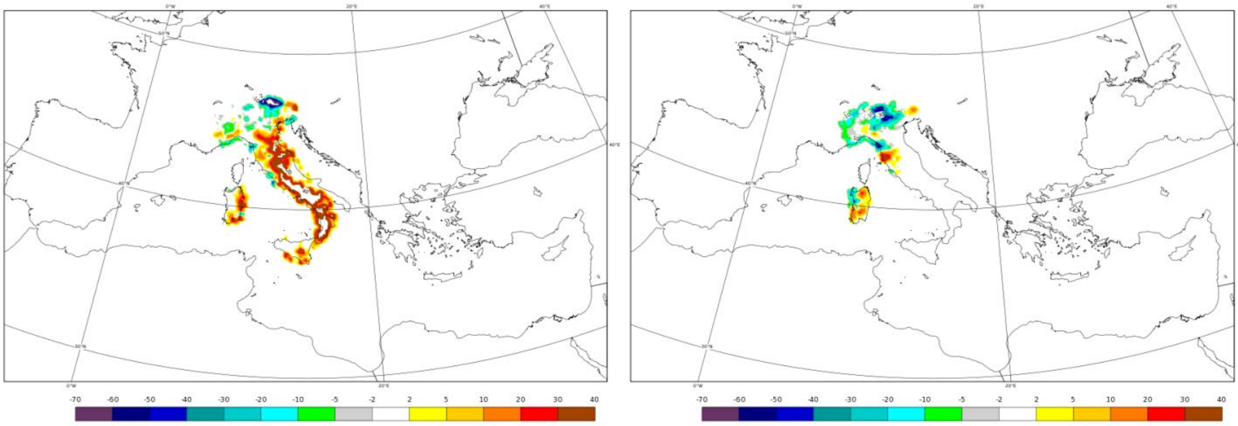

Fig 1 Test of QQM method: maps of the differences between the calibrated and raw forecast probability of cumulated 6hours precipitation greater than 0.2 mm (left) and 10 mm (right) for a single event.

The LQQT method proposed by Bremnes (2007) is based on the same idea of QQM algorithm, but it has been introduced to works properly with not continuous variables such as precipitation. Following the QQM methodology the pairs of reforecast and observations have been constructed, but the calibrated forecast *p'* is obtained from the raw forecast *p* by a linear transformation $p'(p)=a_0+a_1\,(\mathbf{F}-p)$, where **F** are the reforecast series. The coefficients are obtained by minimization of the function

$$\sum_{i=i_0}^{n}(G_i - m(F_i))^2 W(F_i, p) \quad , \tag{1}$$

where G is the observations climatology, i_0 is the number of sorted pairs with zero values both for G and F, and W is the weighting function. W has been chosen for our test as follows:

$$W = (0.42 + 0.5\cdot\cos(\pi\cdot dd) + 0.08\cdot\cos(2\pi\cdot dd))^2 \quad , \tag{2}$$

where

$$dd = \frac{\mathbf{F} - p}{3\cdot std(\mathbf{G})} \tag{3}$$

The calibrated probability of precipitation for thresholds of 0.2 mm and 1 mm has been computed for different test cases with LQQT method. Results for a single event (the same as fig.1) are shown in fig.2. The LQQT method seems to correct less than the QQM approach the ensemble precipitation forecasts and, by contrast, it seems to correct more for heavy precipitation.
The differences of two methods are shown in fig.3 for the t+36h forecast probability of 6 hours cumulated precipitation greater than 0.2 mm (00UTC run of 14 november 2014). In this case comparison with real observations shows that the QQM calibrated ensemble gives unrealistic high precipitation probability over south of Italy.
A first objective comparison of the two methods have been done using the continuous rank probability score (CRPS) computed over a longer period (00UTC run for november 2014) as a function of lead time. Results (fig.4) show that lower value of the CRPS are obtained with the

LQQT method. An extension of the investigation period is planned, in order to have a more statistically robust result.

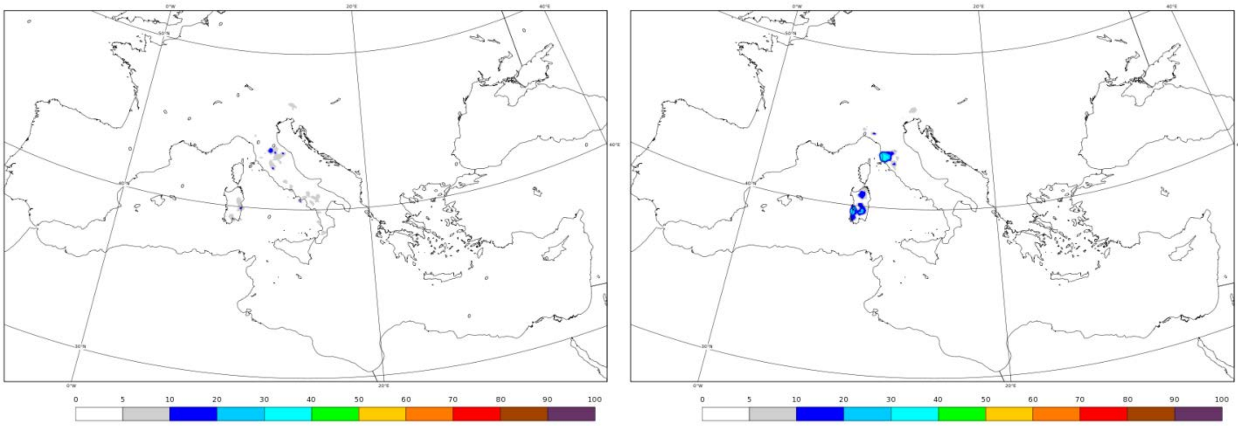

Fig 2 Test of LQQT method: maps of the differences between the calibrated and raw forecast probability of cumulated 6hours precipitation greater than 0.2 mm (left) and 10 mm (right) for a single event.

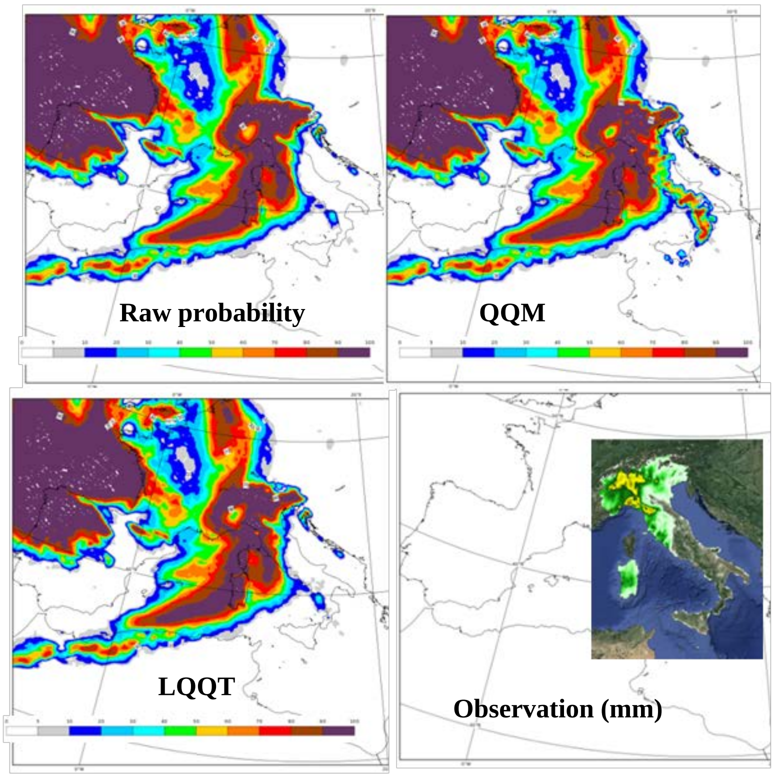

Fig 3. Comparison between the t+36h forecast probability of 6 hours cumulated precipitation greater than 0.2 mm (00UTC run of 14 november 2014) for raw, QQM and LQQT calibrated ensemble. Observation for the same day are given

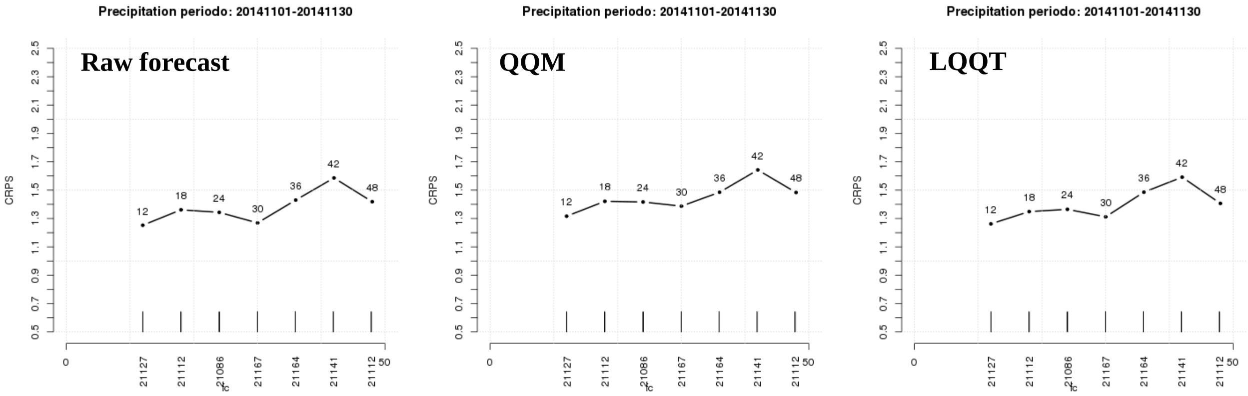

Fig 4. Comparison of CRPS score (00UTC run for november 2014) as a function of lead time of 6 hour cumulated precipitation forecast for raw ensemble (left), QQM calibrated ensemble (centre) and LQQT calibrated ensemble (right).

List of publications/reports from the project with complete references

[1] Bonavita M, Torrisi L, Marcucci F. 2008. The ensemble Kalman filter in an operational regional NWP system: Preliminary results with real observations. *Q. J. R. Meteorol. Soc.* 134: 1733-1744.
[2] Bonavita M, Torrisi L, Marcucci F. 2010. Ensemble data assimilation with the CNMCA regional forecasting system. *Q. J. R. Meteorol. Soc.* 136: 132-145.
[3] B. Thrasher, E. P. Maurer, C. McKellar, and P. B. Duffy: Technical Note: Bias correcting climate model simulated daily temperature extremes with quantile mapping, Hydrol. Earth Syst. Sci., 16, 3309–3314, doi:10.5194/hess-16-3309-2012, 2012.
[4] Bremnes, J. B.: Improved calibration of precipitation forecasts using ensemble techniques. met.no report 04/02007, 2007.
[5] Flowerdew, J.: Calibration and combination of medium-range ensemble precipitation forecasts. Forecasting Research Technical Report 567, MetOffice, 2012.
[6] Flowerdew, J.: Calibrating ensemble reliability whilst preserving spatial structure. Tellus A 2014, 66, 22662, http://dx.doi.org/10.3402/tellusa.v66.22662, 2014.

Summary of plans for the continuation of the project

(10 lines max)

Plans for the last period of the project comprise evaluation of performances of the two implemented methods (QQM and LQQT) through the computation of new scores (i.e. brier score and continuous rank probability score). Implementation and test of different calibration methods are also planned. Possible candidates are methods that calibrate directly the forecast probability, such as the reliability calibration proposed in [5,6].