SPECIAL PROJECT FINAL REPORT

All the following mandatory information needs to be provided.

Project Title:	Improving the convection-permitting ensemble configuration over Italy
Computer Project Account:	spitconv
Start Year - End Year :	2019 - 2020
Principal Investigator(s)	Virginia Poli
Affiliation/Address:	Arpae -Emilia Romagna Viale Silvani 6 - 40122 - Bologna - Italy
Other Researchers (Name/Affiliation):	Thomas Gastaldo - Arpae Emilia-Romagna Ines Cerenzia - Arpae Emilia-Romagna Giacomo Pincini - Arpae Emilia-Romagna

The following should cover the entire project duration.

Summary of project objectives

(10 lines max)

The aims of the project were:

- to improve the perturbation strategy of the convection-permitting ensemble;
- to use the analyses obtained from the assimilation of radar volumes in KENDA to test them as Initial Conditions;
- to test the ensemble at 1 km horizontal resolution to get benefit in the forecast of high impact weather.

Summary of problems encountered

(If you encountered any problems of a more technical nature, please describe them here.)

The new investigator and colleagues took over from Chiara Marsigli, the special project promoter. The first year mostly served to become familiar with the ECMWF development environment. However, having inherited the project, and having other tasks within Arpae Emilia-Romagna and being the principal investigator on part-time, they were unable to manage this project and dedicate the necessary time to it.

Experience with the Special Project framework

(Please let us know about your experience with administrative aspects like the application procedure, progress reporting etc.)

So far the principal investigator has only compiled a progress report. All the questions asked by e-mail, however, were quick and exhaustive.

Summary of results

(This section should comprise up to 10 pages, reflecting the complexity and duration of the project, and can be replaced by a short summary plus an existing scientific report on the project.)

The focus of the first part of this section is on the convection-permitting ensemble.
At Arpae Emilia-Romagna, the kilometre-scale ensemble data assimilation (KENDA; Schraff et al., 2016) system provides the analyses for the deterministic forecast COSMO-2I and for the 20-member ensemble COSMO-2I-EPS, as described in Gastaldo et al. (2018). Regarding COSMO-2I-EPS, the domain covers Italy and neighbouring countries (Figure 1), the horizontal resolution is 2.2 km and it is initialized each day at 00 UTC with a forecast range of 48 hours. Boundary conditions are provided by the ensemble of the Italian Operational Center for METeorology (COMET), which horizontal resolution is 7 km and the domain covers the Mediterranean Sea and part of Europe. In turns, the ensemble of COMET employs ECMWF-ENS as boundary conditions, which horizontal resolution is 18 km.

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http://www.ecmwf.int/en/computing/access-computing-facilities/forms

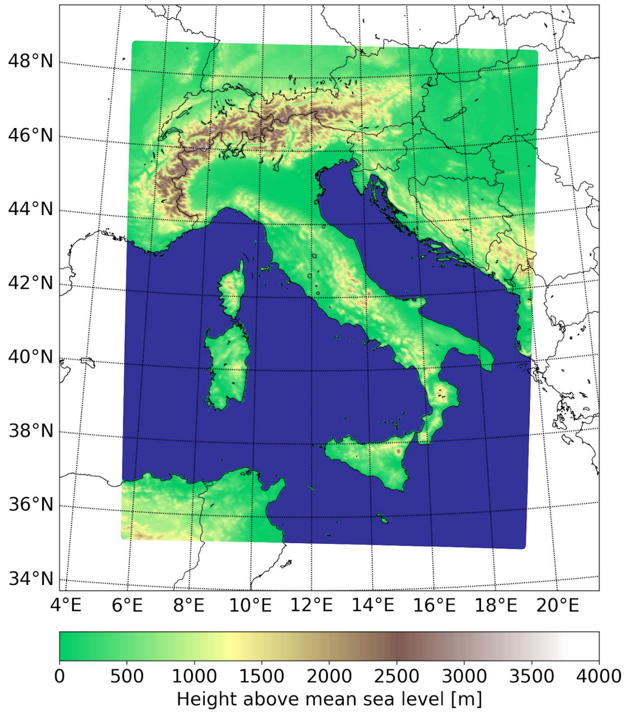

Figure 1: Integration domain of COSMO-2I-EPS with model orography.

The test carried out within this project, which was supposed to be a preliminary test, concerns the boundary conditions for COSMO-2I-EPS.
The pre-operational set-up for COSMO-2I-EPS, referred to as *2ieps_bc_AM,* is replicated in the experiment *2ieps_bc_ECMWF,* with the only difference that boundary conditions from ECMWF-ENS are used instead of employing the ensemble of COMET.

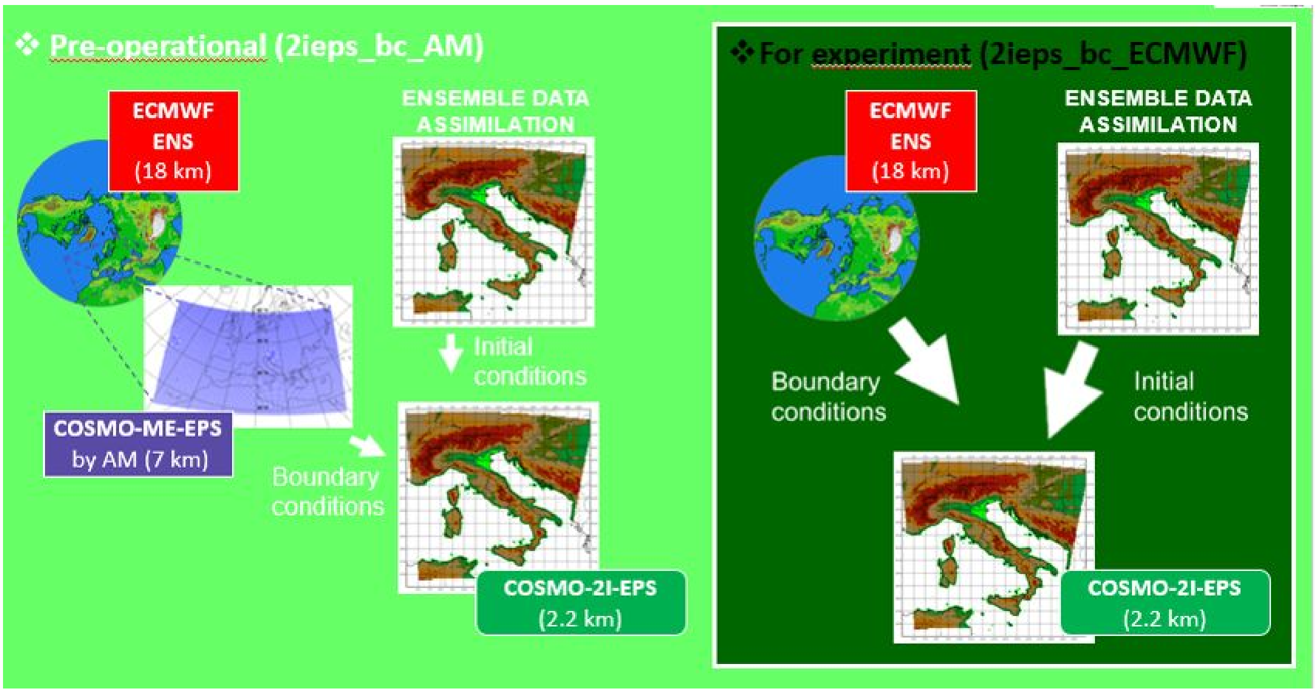

Figure 2: Set-ups used in the two experiments.

The comparison of the two experiments was carried out over the 6 days period between 22 and 27 November 2019, which was characterized by intense precipitation over Northern Italy. Verification has been performed in terms of quantitative precipitation forecast (QPF), considering also ECMWF-ENS and COSMO-LEPS, available at Arpae Emilia-Romagna, as reference.

The variable examined in the verification is the total precipitation over 3 hours, taking into account only the 00 UTC runs and a forecast range of 48 hours. The verification domain is the Italian mainland common to the domain of the four systems of probabilistic forecasting.
Precipitation observations are from the italian network, consisting of more than 5000 stations, whose data are centralized, validated and distributed from the Italian Department of Civil Protection.
In the verification method used, the domain is divided into boxes with dimensions of 0.25°x 0.25°. In each box, the maximum precipitation forecasted by the model is compared with the maximum value recorded by the stations.
For the period considered, several statistical indicators are calculated (Brier Skill Score, Brier Score, percentage of outliers, ROC area, Ranked Probability Skill Score Debiased, Ranked Probability Score) considering 6 different precipitation thresholds (1, 5, 10, 15, 25, 50 mm/6h).

The most significant results are described below.
Ranked Probability Score (RPS): is an extension of RMSE for probabilistic forecasts and multi-category events; it can vary between 0 and 1; the lower the value obtained, the better the performance of the ensemble.

Figure 3: RPS computed for ECMWF-ENS (red line), COSMO-LEPS (blue line), COSMO-2I-EPS with boundary conditions coming from COMET (light green line) and COSMO-2I-EPS with ECMWF-ENS boundary conditions (dark green line). The value of RPS, on the y-axis, is a function of the time of the forecast, on the x-axis.

As can be seen from Figure 3, COSMO-LEPS (blue line) has the best performance for almost all forecast ranges. For COSMO-2I-EPS, changing the boundary conditions leads to improved results. In fact, from the thirty-ninth hour onwards, COSMO-2I-EPS with ECMWF-ENS boundary conditions (dark green line) is the best among the ensemble systems in use at Arpae Emilia-Romagna.

Brier Score (BS): measures the mean square error of a probability prediction, i.e. the error by which a discrete event is predicted. The perfect score is 0. The BS can be decomposed into three components that are relevant for the interpretation of forecast error sources, which are useful for exploring the dependence of probability predictions on ensemble characteristics. The formula of Brier Score is BS = reliability - resolution - uncertainty. Therefore two of these components that make up the BS are the reliability and the resolution that must be respectively "small" and "large" to have a skillful ensemble system.
In Figure 4 the results obtained for the BS, the reliability and the resolution for the 10 mm threshold are shown. It was chosen to display this threshold because it is intermediate among those analyzed both for precipitation intensity and number of occurrences, with which the scores were calculated.

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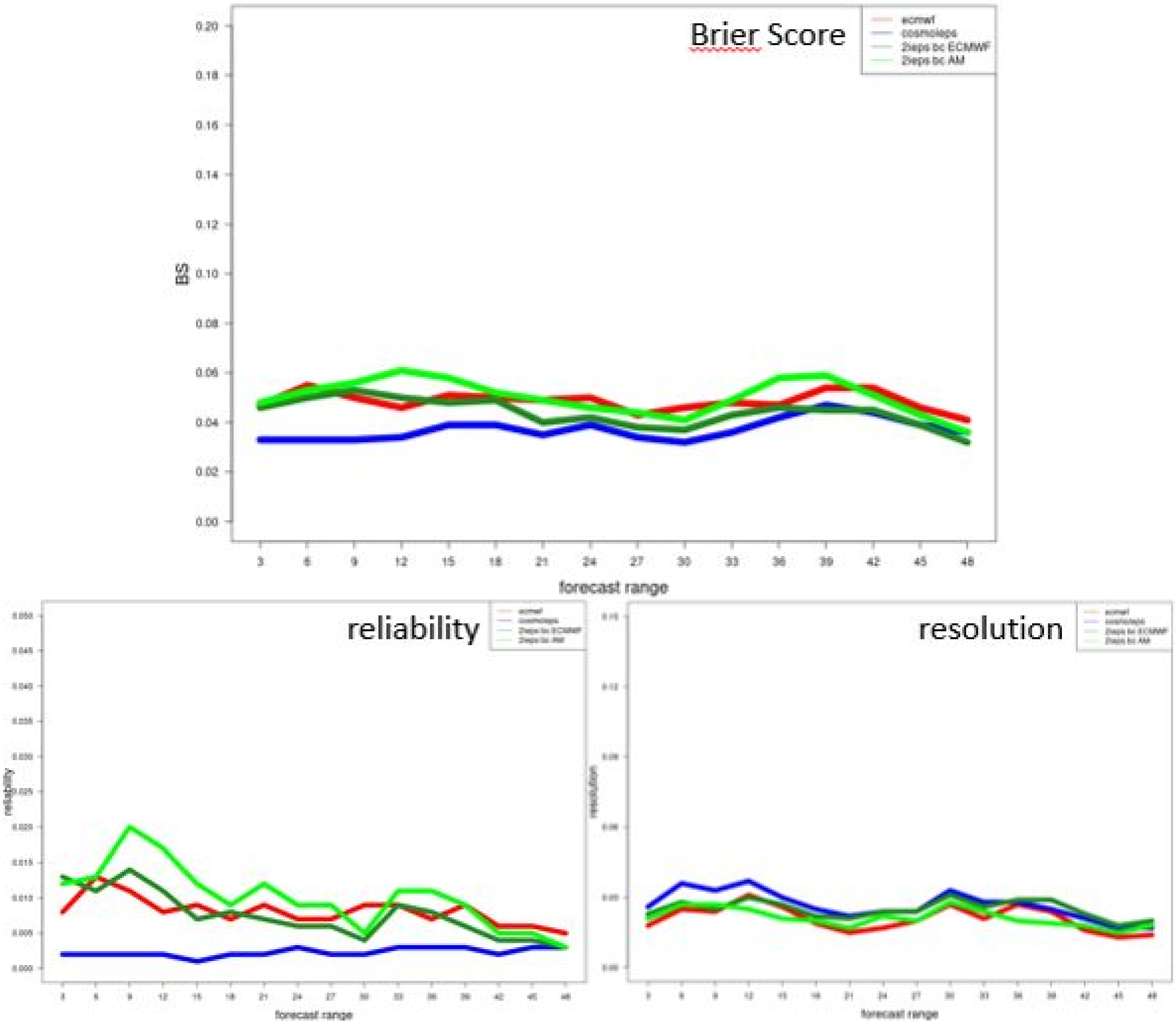

Figure 4: BS, reliability and resolution, for the 10 mm threshold, computed for ECMWF-ENS (red line), COSMO-LEPS (blue line), COSMO-2I-EPS with boundary conditions coming from COMET (light green line) and COSMO-2I-EPS with ECMWF-ENS boundary conditions (dark green line). The score values, on the y-axis, are function of the forecast time, on the x-axis.

The results obtained are similar to those of BS. In fact even in these cases COSMO-LEPS (blue line) has the best performance for almost all the analysed forecast steps and COSMO-2I-EPS based on ECMWF boundary conditions (dark green line) shows a significant improvement compared to the COSMO-2I-EPS with COMET boundary conditions (light green line).

The improvement of the COSMO-2I-EPS scores, using the boundary conditions of ECMWF was partly expected, as it had already been documented in (Marsigli et al., 2014).
This experiment has made it possible to evaluate the goodness of the results in order to be able to carry out again the forecasts for the 1994 flood in the Piedmont region in the northwest Italy. For that date, in fact, the only boundary conditions available comes from the ECMWF's new ERA5 climate reanalysis.

The focus of the second part of this section is on the possible use of the analyses obtained from the assimilation of radar volumes in KENDA to test them as Initial Conditions.
Research carried out in Arpae Emilia-Romagna has shown that the direct assimilation of radar reflectivity volumes leads to a general improvement in forecasting results compared to the use of

latent heat nudging. For this reason it was thought, having compiled on the cca machine the version of COSMO including the radar operator, to perform an OSSE to understand the physical processes underlying this improvement. Unfortunately, for the reasons explained above the OSSE has only remained outlined.

Gastaldo, T., Poli, V., Marsigli, C., Alberoni, P. P., and Paccagnella, T. (2018), Data assimilation of radar reflectivity volumes in a LETKF scheme. Nonlinear Processes in Geophysics, 25: 747–764, https://doi.org/10.5194/npg-25-747-2018

Marsigli, C., Montani, A., Paccagnella, T. (2014), Provision of boundary conditions for a convection-permitting ensemble: comparison of two different approaches. Nonlinear Processes in Geophysics, 21: 393–403, doi:10.5194/npg-21-393-2014

Schraff, C., Reich, H., Rhodin, A., Schomburg, A., Stephan, K., Periáñez, A. and Potthast, R. (2016), Kilometre-scale ensemble data assimilation for the COSMO model (KENDA). Q.J.R. Meteorol. Soc., 142: 1453-1472. doi:10.1002/qj.2748

List of publications/reports from the project with complete references

This poster was supposed to be presented at ICCARUS 2020, the ICON/COSMO/CLM/ART User Seminar, at Deutscher Wetterdienst, then cancelled due to the COVID 2020 pandemic.
https://download.dwd.de/pub/DWD/Forschung_und_Entwicklung/ICCARUS2020/poster/P02Pincini.pdf

Future plans

(Please let us know of any imminent plans regarding a continuation of this research activity, in particular if they are linked to another/new Special Project.)