# REQUEST FOR A SPECIAL PROJECT 2019–2021

**MEMBER STATE:** Italy


**Principal Investigator[1]:** Chiara Marsigli

**Affiliation:** Arpae SIMC

**Address:** Viale Silvani 6

40133 Bologna

Italy

**Other researchers:** Virginia Poli
Thomas Gastaldo
Andrea Montani
Ines Cerenzia


**Project Title:** **Improving the Convection-permitting ensemble configuration over Italy**

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|---|---|---|
| If this is a continuation of an existing project, please state the computer project account assigned previously. | **SP**ITCONV | |
| Starting year:<br>(A project can have a durationof up to 3 years, agreed at the beginning of the project.) | 2019 | |
| Would you accept support for 1 year only, if necessary? | YES x | NO ☐ |

| **Computer resources required for 2019-2021:**<br>(To make changes to an existing project please submit an amended version of the original form.) | | **2019** | **2020** | **2021** |
|---|---|---|---|---|
| High Performance Computing Facility | (SBU) | 9,200,000 | 9,200,000 | 9,200,000 |
| Accumulated data storage (total archive volume)[2] | (GB) | 500 | 1000 | 1500 |

*Continue overleaf*

[1] The Principal Investigator will act as contact person for this Special Project and, in particular, will be asked to register the project, provide annual progress reports of the project's activities, etc.

[2] If e.g. you archive x GB in year one and y GB in year two and don't delete anything you need to request x + y GB for the second project year etc.

**Principal Investigator:** Chiara Marsigli

**Project Title:** **Improving the Convection-permitting ensemble configuration over Italy**

# Extended abstract

*The completed form should be submitted/uploaded at https://www.ecmwf.int/en/research/special-projects/special-project-application/special-project-request-submission.*

*All Special Project requests should provide an abstract/project description including a scientific plan, a justification of the computer resources requested and the technical characteristics of the code to be used.*

*Following submission by the relevant Member State the Special Project requests will be published on the ECMWF website and evaluated by ECMWF as well as the Scientific and Technical Advisory Committees. The evaluation of the requests is based on the following criteria: Relevance to ECMWF's objectives, scientific and technical quality, disciplinary relevance, and justification of the resources requested. Previous Special Project reports and the use of ECMWF software and data infrastructure will also be considered in the evaluation process.*

*Requests asking for 1,000,000 SBUs or more should be more detailed (3-5 pages).Large requests asking for 10,000,000 SBUs or more will receive a detailed review by members of the Scientific Advisory Committee.*

Starting from 2010, at the Hydro Meteo Climate Service of Arpae Emilia-Romagna research work has been carried out aiming at the development of a Convection-Permitting (CP) ensemble system for Italy, based on the COSMO model.

Research has covered several scientific issues related to the predictability at the convection-permitting scale and to how to best include relevant perturbations in the construction of a CP ensemble to be used operationally. In particular, investigation has covered:

- How to provide perturbed boundary conditions to the CP ensemble. In this field, it has been investigated the issue of the resolution of the coarser-resolution ensemble providing perturbed BCs to the CP ensemble. In particular, the use of BCs from the IFS ensemble to drive an ensemble over Italy at 2.8 km has been studied in comparison with the use of the 7-km ensemble COSMO-LEPS to provide BCs (Marsigli et al., 2014). The issues related to the "jump in resolution" have been analysed and discussed in an ensemble context.
- Model perturbations: the perturbation of the COSMO model at the CP scale had been studied by testing two approaches, the Parameter Perturbation (PP) and the Stochastically Perturbed Parameterization Tendency (SPPT) of the IFS ENS, which was implemented in the COSMO model. For the first one, several parameters of the COSMO model have been perturbed, from the schemes for turbulence, microphysics, shallow convection, land surface. The two types of perturbations have been also combined and their relative role has been assessed.
- How to provide perturbed Initial Conditions using analyses derived from an ensemble data assimilation cycle. The data assimilation has been set-up with the same COSMO model at 2.8 or 2.2 km, using the LETKF- based scheme developed in the COSMO Consortium (KENDA, Schraff et al., 2016; Hunt et al., 2007). The impact of the KENDA analyses as ICs for the ensemble has been studied for different periods characterised by severe weather over Italy.
- Ensemble verification and evaluation of the impact of the different perturbations. The evaluation has also addressed issues like interpretation of probabilities and verification of probabilistic forecasts at high resolution (spatial verification, object verification, user-oriented verification)

Most of these issues have been studied in the framework of Special Projects of ECMWF, mainly the SPITCONV SP (successive SPs), but also the SPITSREP. Therefore, results can be found in the Progress and Final Reports of these Projects.

The intense testing work has lead to the set-up of a pre-operational suite for the COSMO-2I-EPS ensemble in Italy, on the supercomputing resources of CINECA. Now products are prepared daily and delivered to the Operational Room of Arpae. The ensemble consists of 20 runs of the COSMO model at 2.2 km resolution, with 65 vertical levels. It receives Boundary Conditions from COSMO-ME-EPS, the 7 km ensemble run by COMET over the Mediterranean. Initial Conditions are provided by 20 analyses of the KENDA data assimilation cycle, which is also run operationally at CINECA. No model perturbations are currently included.

While the operational run of the ensemble will continue on Italian resources, we need to carry out experiments aimed at improving the ensemble configuration. Internally we do not have computing resources for this task. With this aim, we would like to start a new Special Project on the improvement of the perturbation strategy for our convection-permitting ensemble in the next 3 years.

The scientific motivation behind it is that, even if the ensemble is currently implemented in a state-of-the-art configuration, it is already clear that some issues require further investigation and some parts of the perturbation method should be improved.

**Model perturbations (PP).**

The ensemble as it is now does not have model perturbations. This is due to the fact that recently the COSMO model has undergone many developments in the physics package: new options/schemes have been made available (turbulence, land surface) and several parameters of the physics schemes have received new default values. For this reason, the values assigned to the Parameter Perturbations should be revised, by testing new parameters also belonging to new schemes and testing different values of the old ones. The parameters which may be suitable for perturbations will be indicated by the model developers, together with a possible range of values. Then, the impact of these perturbations has to be tested for a period and for the Italian domain.

This investigation requires the run of the COSMO model at 2.2 km in an experimental suite where initial and boundary conditions are deterministic (the same for all the runs, from the deterministic IFS run) but where different values are assigned to the set of parameters which is believed to be sensitive to perturbations. The method which will be followed is the same adopted in Marsigli et al., 2009. In order to perform a meaningful evaluation, a suite with about 20 runs of the COSMO model has to be run, for the 24 h forecast range, for at least two different months (1 autumn month, where most of the precipitation takes place in Italy and 1 summer month, when the convection mainly interest our area).

One run of this PP testing suite with 20 runs (COSMO at 2.2 km, 65 levels, Italian domain, 24 h forecast range, 1 run per day) costs about 152,000 SBU, therefore 2 months of runs cost about 9.2 M SBU.

**Initial Conditions from Ensemble DA.**

The ensemble data assimilation which has been implemented operationally and which provides the Initial Conditions to the CP ensemble requires further tuning and scientific development. The DA ensemble has shown underdispersion, therefore we aim at inflating the ensemble further and assess the impact on the assimilation. A data assimilation ensemble which does not have enough spread leads to a drift of the analysis and to a not effective use of the observations. For this purpose, we would like to test the impact of additive inflation by using a climatological B-matrix computed with reanalysis run of the COSMO model.

This requires the run of the assimilation cycle (continuous hourly) on at least 2 weeks, with the assimilation ensemble which consists of 20 members. Then, the analyses produced by KENDA should be used as ICs to ensemble runs, for the same 2 weeks period.

One run of KENDA (2.2 km, 65 levels, Italian domain, continuous run) with 20 members costs about 152,000 SBU, therefore for 2 weeks the cost is 2,1 M SBU. The successive ensemble run costs half of this amount, having 10 members instead of 20, but it should be performed in 2 configurations (old inflation vs new inflation), therefore the cost is also 2,1 M SBU.

On top, it is ongoing at Arpae a research work aimed at assimilating radar volumes in KENDA (Gastaldo et al., 2018). Once a set-up is defined for this enhanced assimilation, the new analyses have to be tested also in ensemble mode as Initial Conditions. Therefore, the impact of the new ICs have to be tested on the COSMO-2I-EPS ensemble on at selected cases covering least 2 different months.

One run of the COSMO-2I-EPS ensemble (2.2 km, 65 levels, Italian domain, 24 h forecast range, 1 run per day) with 10 members only (in order to reduce the cost of the testing suite) costs about 76,000 SBU, therefore an experimentation which cover at least 1 month costs about 4.1 M SBU (2 configurations for each run, control and experiment). This is a minimal set-up to test the new ICs, therefore more runs would be needed in particular if interesting cases show up over the Italian domain.

**Higher resolution ensemble test**

Finally, in the 3 years framework it is foreseen to start the testing of the ensemble at 1 km horizontal resolution, since early studies indicated that this resolution brings benefit in the forecast of high impact weather. Tests should be performed with a 10 members ensemble run at 1 km resolution at least for a 24 h forecast range. The cost of this runs will be likely 4 times the cost of an ensemble run of the same size but with half resolution. Therefore the cost of each run will be in the order of 76,000 x 4 SBU per day of test, 304,000 SBUs. A test over 1 month period covering different meteorological situations (convection, fog cases, intense precipitation events) will cost 9,2 M SBU.

**References.**

Gastaldo T., Poli V., Marsigli C., Alberoni P. P. and Paccagnella T., 2018: Data assimilation of radar reflectivity volumes in a LETKF scheme. Under revision in Nonlinear Processes in Geophysics (NPG).

Hunt B. R., Kostelich E. J., Szunyogh I., 2007: Efficient data assimilation for spatiotemporal chaos: A local ensemble transform Kalman filter. Physica D 230: 112–126, doi: 10.1016/j.physd.2006.11.008.

Marsigli C., 2009. Final report on priority project SREPS (Short Range Ensemble Prediction System), COSMO Technical Report, http://www.cosmo-model.org/content/model/documentation/techReports/default.htm.

Marsigli, C., Montani, A., and Paccagnella, T., 2014: Provision of boundary conditions for a convection-permitting ensemble: comparison of two different approaches, Nonlin. Processes Geophys., 21, 393-403, https://doi.org/10.5194/npg-21-393-2014, 2014.

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