LATE REQUEST FOR A SPECIAL PROJECT 2021–2023

MEMBER STATE: Italy

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

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Italy

Other researchers: Thomas Gastaldo, Virginia Poli

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

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SP**ITCONV	
Starting year: (A project can have a duration of up to 3 years, agreed at the beginning of the project.)	2021	
Would you accept support for 1 year only, if necessary?	YES x	NO ☐

Computer resources required for the years: (To make changes to an existing project please submit an amended version of the original form.)		**2021**	**2022**	**2023**
High Performance Computing Facility	(SBU)	9,600,000	9,600,000	9,600,000
Accumulated data storage (total archive volume)[2]	(GB)	1000	2000	3000

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 an annual progress report 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.

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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.

Requests asking for 1,000,000 SBUs or more should be more detailed (3-5 pages).

Following submission by the relevant Member State the Special Project requests the evaluation will be 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.

All accepted project requests will be published on the ECMWF website.

The SPITCONV Special Project has been first submitted in 2011-2013, with the purpose of supporting the development of a convection-permitting ensemble over Italy. The work continued until 2018, thanks to successive Special Projects, which lead to the implementation at Arpae-SIMC, on the CINECA (Bologna) computing resources, of a convection-permitting ensemble over Italy based on COSMO, the COSMO-2I-EPS. The perturbation methodology was tested thanks to the mentioned Special Projects. The ensemble receives initial conditions from a LETKF-based ensemble data assimilation system (KENDA), also implemented and operationally run by Arpae-SIMC. The Boundary Conditons are provided by COSMO-ME-EPS, the 7km ensemble run by COMET. No physics perturbations are applied at the moment.

The last Special Project request was submitted in 2018, for the period 2019-2021. Before the Project start, the Principal Investigator (Chiara Marsigli) stopped her work for Arpae SIMC. This created a problem of human resources at Arpae and the activities foreseen in the Special Project were suspended. Therefore Virginia Poli asked ECMWF to stop the Special Project and the allocated SBUs were de-allocated.
Now the Principal Investigator restarted the collaboration with Arpae, particularly about the management and development of the convection-permitting ensemble. Therefore we now plan to perform the activities described in the application for this Special Project, starting immediately and for the next 2 years.
From now to the end of the year it is planned to perform a test about Boundary Condition (BC) perturbation and start the testing about model physics perturbation.

1. Test about the provision of perturbed Boundary Conditions to COSMO-2I-EPS.

Currently, the ensemble members are nested on the first 20 members of the COSMO-ME-EPS run by COMET. We would like to test the impact of providing BCs from the first 20 members of IFS-ENS, which implies a direct nesting step from a resolution of about 18 km to a resolution of about 2.2 km. Positive results about a direct nesting have been obtained in a previous study (Marsigli et al., 2014) and are confirmed by the current operational implementation of COSMO at 2.2 km at MeteoSwiss (Klasa et al., 2018).
The effect on the 2.2 km model fields will be evaluated subjectively and objectively. The scores for near-surface weather parameters and precipitation will be computed against SYNOP observations and radar composite corrected with raingauges data, respectively.
The evaluation will be performed over a test period of 1 month in the convective period (late Spring). The proposed configuration will be compared against a reference configuration, similar to

the operational one. No data assimilation will be performed in the test in order to save computing resources: the Initial Conditions for the runs will be derived from the same ensemble members providing the Boundary Conditions.

Resources.

COSMO-2I-EPS has a resolution of 2.2 km over Italy, with 65 vertical levels, and it is composed of 20 members. For this test, a 10 member configuration will be adopted, to save computing resources. In order to run the ensemble for 1 month with a +24h forecast range, we need 2,300,000 SBU. Since we need to compare this configuration with the one where BCs are provided by COSMO-ME-EPS, we need to run the ensemble twice, once in a reference set-up and one in an experimental set-up. Therefore we need 4,600,000 SBU for the runs. In order to encompass possible failures and problems, we would like to ask for 4,8 M SBU.

2. Test about the physics perturbation in COSMO-2I-EPS.

Currently, COSMO-2I-EPS has no model perturbations. However, several experiments about model perturbation have been conducted during the development phase of this ensemble, thanks to the computing resources provided by the SPITCON Special Project, indicating a possible beneficial effect of introducing model perturbations.

Two simple perturbation strategies have been selected: the Perturbed Parameters (PP, Marsigli et al., 2009 and 2013), also operational in COSMO-LEPS, and the Stochastic Perturbation of Physical Tendencies (SPPT, Buizza et al., 1999), developed at ECMWF and currently operational in the COSMO model at MeteoSwiss.

During the experimental phase of the COSMO-IT-EPS convection-permitting ensemble (now operational with the name COSMO-2I-EPS), the ensemble was run for selected periods in order to test the model perturbation methodology, assessing its spread/skill relation. The ensemble was run for the month of October 2015, one run per day at 00 UTC, with Initial and Boundary Conditions from COSMO-ME-EPS. Model resolution was 2.8 km and the ensemble had 10 members.

The ensemble was run in 3 different configurations:

- Without model physics perturbation (ensemble **CTRL**)
- With SPPT (Stochastic Perturbation of Physical Tendencies) (ensemble **SPPT**)
- With SPPT and perturbation of dew parameters of the physics schemes (turbulence, microphysics, land surface) (ensemble **SPPT-PP**)

The spread/skill relation of the three configurations in terms of 2m temperature showed that all configurations are underdispersive. Adding the SPPT did not yield an increase of the spread, nor did the parameter perturbation. In previous studies (Marsigli et al., 2009) it was noticed that parameter perturbation may have a highly localized impact, temporally and spatially, and dependent on the weather situation, therefore it is difficult to detect an impact in a statistical evaluation over a period. On top, autumn is a period characterized by strong forcing weather situations over Italy, while it recognized that model perturbations of this kind have mainly impact in weak forcing situations (e.g. see the results and the discussion of the Stochastic Workshop 2021 at: http://www.cosmo-model.org/content/tasks/workGroups/wg7/default.htm).

Encouraging results were obtained in terms of precipitation, verified against radar raingauge data, upscaled to boxes of 0.2 x 0.2 degrees: considering the average precipitation greater than 5mm/6h, the ROC area indicated a better performance of the ensemble with perturbed physics, while the Brier Skill Score showed a mixed behavior. Using spatial methods for the spread-skill relation evaluation in terms of precipitation, it was shown that the physics perturbations have an impact on the spread and that also the addition of Parameter Perturbation is able to increase the diversity of the members at all scales. On top, in selected cases it was detected an impact of the Parameter Perturbation in determining more dispersion in terms the localization and structure of precipitation. A more comprehensive presentation of these results can be found in Marsigli et al. (2019).

A new test of the proposed methodologies is now needed, in order to introduce these model perturbation in the COSMO-2I-EPS ensemble currently operational, in order to complement the BC and IC perturbations.

To this aim, it is needed to test the ensemble perturbations on different periods and in different configurations.
For the first experimental phase (year 2021 and first half of 2022), it is proposed to run the ensemble in 3 configurations:

- Without model perturbation (like in the operational configuration, **reference**)
- With Parameter Perturbation (**PP**)
- With Parameter Perturbation + SPPT (**PP+SPPT**)

The test will be performed on a period characterized by convection and not dominated by strong synoptic forcing. The same month will be used for the experiments on BC and model perturbations (section 1 and 2 of this application).
An analysis of the results will be object of a Master degree thesis, including:

- Subjective evaluation of the ensemble on selected cases
- Objective verification of the ensemble performance in the 3 proposed configurations, for near-surface weather parameters (T2m, Td2m, 10m wind) and precipitation
- Spread-error relation for temperature and wind
- Spread-error relation with spatial methods for precipitation (see Marsigli et al., 2019)
- Analysis of the perturbation growth, e.g. by computing the spectra of the perturbations

In the second half of 2022 and in 2023 the test of model perturbations will continue, depending also on the outcome of the first experimental phase. If the combination of PP and SPPT will give good results, this configuration will be chosen for the operational implementation. If problems are encountered, likely it will be chosen a configuration with Parameter Perturbation only, which have always proven able to introduce little spread without increasing the forecast error.
The second experimental phase will be devoted to study the introduction of model perturbations also in the assimilation cycle. It is recalled that the assimilation is performed with an ensemble based data assimilation (LETKF, KENDA system). The Parameter Perturbation method will be considered as a possible simple way of generating extra spread in the data assimilation cycle. However, this possibility will require a dedicated study, since in the data assimilation issues of temporal consistency between successive assimilation cycles have to be taken into account.

Resources.
COSMO-2I-EPS has a resolution of 2.2 km over Italy, with 65 vertical levels, and it is composed of 20 members. For this test, a 10 member configuration will be adopted, to save computing resources. In order to run the ensemble for 1 month with a +24h forecast range, we need 2,300,000 SBU.
Since we need to run two additional configurations (the reference is the same of section 1), we need to run the ensemble twice. Therefore we need 4,600,000 SBU for the runs. In order to encompass possible failures and problems, we would like to ask for 4,8 M SBU.

The total resources for this Special Project are therefore 9,6 M SBU for the first year. A similar amount is also requested for the successive 2 years.

References.

Buizza, R., M. Miller and T. N. Palmer, 1999: Stochastic simulation of model uncertainties. Q. J. R. Meteorol. Soc., 125, 2887-2908.

Klasa, C., M. Arpagaus, A. Walser and H. Wernli, 2018: An evaluation of the convection-permitting ensemble COSMO-E for three contrasting precipitation events in Switzerland. Quart. J. Roy. Meteorol. Soc., 144, 744-764. doi:10.1002/qj.3245

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Marsigli, C., Montani A. and Paccagnella, T., 2014. “Provision of boundary conditions to a convection-permitting ensemble: comparison of two different approaches.” Nonlinear Processes in Geophysics, 21, 393–403.

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