REQUEST FOR ADDITIONAL RESOURCES IN THE CURRENT YEAR FOR AN EXISTING SPECIAL PROJECT

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MEMBER STATE: Spain

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Project title: Exploring the Predictability Limits of Severe Weather in the Western Mediterranean: Use of Ensemble Data Assimilation Systems, Stochastic Techniques and Sensitivity Calculation Methods

Project account: **SPESHOMA**

Additional computer resources requested for		**2021**
High Performance Computing Facility	(units)	10000000
Data storage capacity (total)	(Gbytes)	20000

Continue overleaf

[1] The Principal Investigator is the contact person for this Special Project

Technical reasons and scientific justifications why additional resources are needed

This special projects tackles the predictability of high-impact events (e.g., heavy precipitation, flash floods, large hail, intense winds) in the Mediterranean basin by means of advanced ensemble generation methods. Despite recent scientific and technical progresses have contributed to improve the predictability of such extreme events, the forecast of socially relevant aspects of convective systems, such as intensity, location, and timing remains challenging. Accurately predicting these aspects is crucial to provide civil protection agencies with useful guidance in order to prevent human and material losses.

Along this special project, diverse ensemble generation strategies based on either initial condition perturbations or stochastic parameterizations were tested. In particular, the bred vector tailored ensemble perturbation method was designed and evaluated. The technique is based on orthogonalising bred perturbations at each rescaling time and applying an exponential transformation to initial condition perturbations in order to target them to sample errors across all relevant scales for short-range mesoscale forecasting. Results revealed that this strategy improves ensemble spread and skill compared to the traditional breeding method (Hermoso et al., 2020).

Furthermore, the impact of introducing model error by means of stochastic techniques was also investigated. More specifically, the WRF implementation of the stochastically perturbed physics tendencies (SPPT; Berner et al., 2015) was used. Since this implementation does not introduce perturbations to microphysical processes, which can considerably impact storm development, a new methodology was designed by the members of this special project in order to account for uncertainties in the microphysics parameterization. Relevant parameters within the NSSL 2-moment scheme (Mansell et al., 2010) for convective development and evolution, namely cloud condensation nuclei concentration, graupel and hail fall speed factor and saturation percentage for initial cloud formation were perturbed. The method designed follows the random parameter strategy (McCabe et al., 2016) consisting in modifying the selected parameters along forecast lead time. This evolution is governed by a first-order autoregressive process, analogous to SPPT, but in this case no spatial modification was considered. The introduction of microphysics perturbations resulted in an increased ensemble spread compared to the popular multiphysics strategy, based on different parameterization suites for each ensemble member, and also compared to SPPT. In addition, ensemble including stochastic perturbations, especially those containing microphysics perturbations outperformed a multiphysics-based ensemble when local orography and deep moist convection played a significant role (Hermoso et al., 2021).

Building upon these previous findings, the tasks planned for the next months are devoted to investigating optimal combinations of initial and model error perturbations. The specific tasks pursue two main goals: (i) identify the contribution of each type of perturbation to ensemble performance, and (ii) combine stochastic perturbations with data assimilation techniques.

In previous experiments, the impact of initial and model perturbations was investigated independently in order to better isolate the specific effect of each type of perturbation. However, operational ensemble prediction system must sample all relevant sources of uncertainty. Therefore, in order to design ensemble generation strategies capable to improve the predictability of severe weather in the Mediterranean, which in turn can be operationally implemented, all relevant error sources ought to be considered. In this regard, the proposed tasks consist of analysing the effect of each individual perturbation strategy (initial conditions, boundary conditions, model physics) as well as the impact of combining multiple perturbations. It is noteworthy that under the highly nonlinear regime of convective-scale the application of different perturbations may not result into an increased ensemble spread or a better ensemble skill. Indeed, experiments conducted with multiple stochastic schemes (SPPT and microphysics perturbations) did not produce a significant benefit compared to using only one technique. This behaviour was also observed when combining initial condition and model perturbations and in particular cases lead to counteracting effects. Specific tasks proposed are the following:

Task 1) Analysis of the impact of individual perturbations as a function of lead time for different extreme episodes over the western Mediterranean: this study will enable identifying the optimal perturbations depending on the meteorological situation and forecast range. More specifically, this task involves running various ensemble experiments only introducing initial condition (downscaling or tailored bred vectors) or model error perturbations (stochastic parameterizations) for different high-impact events. Cases have already been selected by inspecting precipitation data from the GES DISC database (Huffman et al., 2019).

Task 2) Evaluation of the combination of multiple perturbations: ensemble characteristics will be characterized for the same cases considered in the previous task when various uncertainty sources are included. The benefit of considering all relevant uncertainties (i.e., initial/boundary conditions and model errors) will be quantified. Furthermore, identification of situations for which sampling multiple error sources leads to a reduced ensemble spread or skill can also be conducted.

Considering the aim of this research related to extreme events, convection-permitting resolution must be adopted in order capture the initiation and evolution of convective systems, although precise simulation of their intensity and location is extremely challenging. Therefore, horizontal resolution $\leq$ 2.5 km should be applied to the proposed experiments to provide useful results in this context. In addition, moderate ensemble size (50 members) must be implemented in order to sample a wider region in phase space and thus be able to capture risk scenarios. The specific activities proposed rely on the use of the WRF-ARW model, well known in the HPC community for its scalability and up-to-date standards in scientific programming and performance. The simulation domain for each case study (750x500 grid points) has a horizontal resolution of 2.5 km and 50 vertical levels. Moreover, SPPT uses Fast Fourier Transform to analyse and determine the spectral properties of the perturbations. Bred vector experiments require a spin-up period after each breeding cycle is started in order to obtain balanced fields suitable to crate initial condition perturbations. Based on the resources consumed to perform these tasks for one case study, the estimation of resources for each experiment is the following:

1) ~1 million SBU for downscaling experiments

2) ~4 million SBU to create bred perturbations and run an ensemble forecast with bred initial condition perturbations.

3) ~4 million SBU for all experiments including stochastic perturbations (only stochastic perturbations and combined with downscaling or bred vectors).

Considering current granted resources for this special project (12 million SBU), all designed experiments can only be completed for only 1-2 cases. The requested 10 million SBU will allow us to consider a wider sample of case studies and obtain higher statistical significance of the results.

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