REQUEST FOR A SPECIAL PROJECT 2020–2022

MEMBER STATE: Sweden

Principal Investigator[1]**:** Ulf Andrae

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Carl Fortelius, FMI

Project Title:

Operationalization of SPP and further improvements of EDA, boundary and surface perturbation in MEPS

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SP** ___________________	
Starting year: (A project can have a duration of up to 3 years, agreed at the beginning of the project.)	2020	
Would you accept support for 1 year only, if necessary?	YES ☒	NO ☐

Computer resources required for 2020-2022:
(To make changes to an existing project please submit an amended version of the original form.)

		2020	2021	2022
High Performance Computing Facility	(SBU)	16M	16M	16M
Accumulated data storage (total archive volume)[2]	(GB)	30000	60000	90000

Continue overleaf

Principal Investigator: Ulf Andrae

Project Title: Operationalization of SPP and further improvements of EDA, boundary and surface perturbation in MEPS

Extended abstract

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[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] These figures refer to data archived in ECFS and MARS. 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.

Introduction

This application is on behalf of Finland, Norway and Sweden for testing of EPS components in MEPS.

MetCoOp, the operational NWP cooperation between Finland, Norway and Sweden, has been running an operational convective permitting ensemble forecasting system (MEPS) since late 2016. MEPS presently consists of 1 + 9 members and is run 4 times a day over the orange domain seen in Figure 1. MEPS is based on HarmonEPS (Frogner et. al 2019). HarmonEPS is the limited area, short-range, convection-permitting ensemble prediction system developed and maintained by the HIRLAM consortium as part of the shared ALADIN-HIRLAM system (Termonia et al. 2018, Bengtsson et al. 2017). HarmonEPS includes a range of different perturbation methodologies to account for uncertainties in the initial conditions, forecast model, surface and lateral boundary conditions. HarmonEPS is principally developed by HIRLAM, but for operationalization in MEPS extensive testing and tuning is still required.

Ensemble forecasting is nowadays a natural part of any NWP system. For a limited area model we may think of three sources of uncertainties; boundaries, initial conditions and model uncertainties, all of which needs to adequately addressed to have a reliable and skillful EPS.

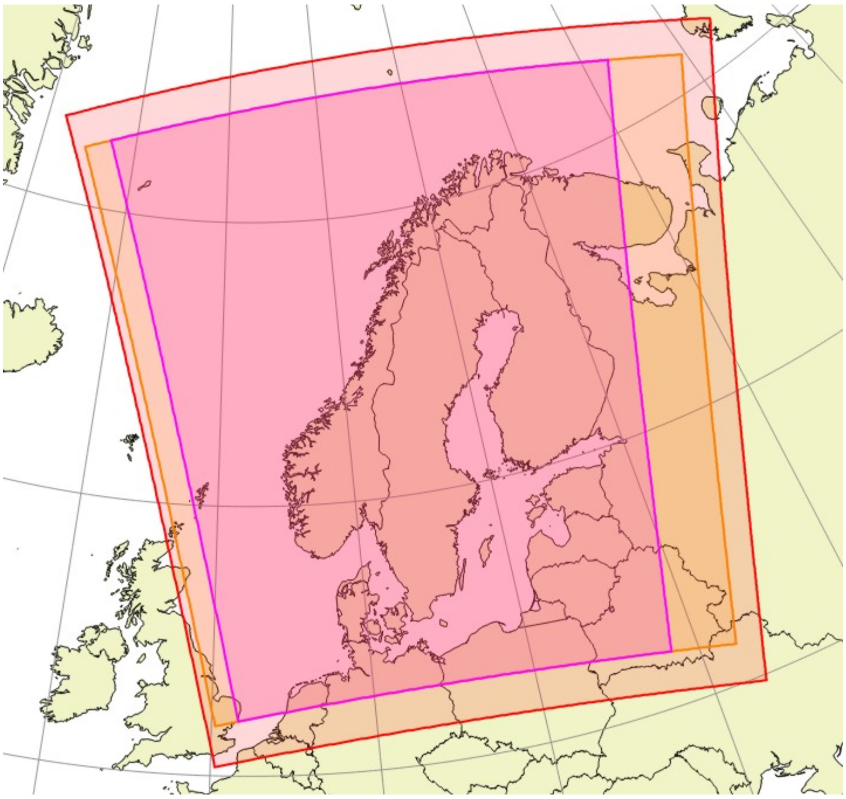

Figure 1: MEPS integration areas. From smallest to largest area represents previous (B), current (C) and future (D) domain.

Model uncertainty:

There are several ways to account for model uncertainties available in HarmonEPS, ranging from multi-physics and multi-model to Stochastic Perturbation of Parameterisations Tendencies (SPPT, Buizza et al. 1999) and Stochastically Perturbed Parameterizations scheme (SPP; Ollinaho et al. 2017). SPPT is based on perturbing the output of the net physic tendencies with 2D random multiplicative noise separately for each ensemble member. In SPP uncertain parameters in the parameterizations are perturbed, and the perturbations evolve in time and space according to the same pattern generator as used in SPPT. An example of how a parameter may be varied is shown in Figure 2. This is for a parameter representing saturation limit sensitivity, and it has a default value of 0.03 (= deterministic value) and in this case it varies in time and space between 0.00 and 0.06 where a higher value allows for easier condensation for humidity levels below saturation. Some parameters are very sensitive to the width of the pdf, others not. But common to all is that this is something that needs to be tuned and tested. In Figure 3 the sensitivity of the parameter in Figure 2 is shown for doubling the pdf width and for quadrupling it. For this particular parameter quadrupling the width gives higher spread while keeping the RMSE at the same level, resulting in a better spread-skill relationship. Currently fourteen parameters are implemented in HarmonEPS SPP, and work is ongoing to implement and test more parameters. The work to identify sensitive and uncertain parameters from the parametrizations of micro-physics, cloud processes, convection and radiation is done in close cooperation with HARMONIE-AROME physics experts. Perturbations to the dynamics will also be included. Before making SPP operational in MEPS we need to test the combination of several parameters over all seasons and also in combination with the other perturbations already in MEPS or planned to be introduced in MEPS. Some parameters in SPP may be more active in some seasons than in others, and hence a setup of SPP which is optimal in one season is not necessarily optimal in others. We have also seen that introducing new perturbation methodologies in combination with already existing methodologies can lead to excessive spread for some weather parameters, or undesirable increase in RMSE. Hence extensive testing of the combinations over several seasons is required before operationalization. A combination of SPP and SPPT may be considered for MEPS, if shown to be beneficial, and this will also require testing over different seasons.

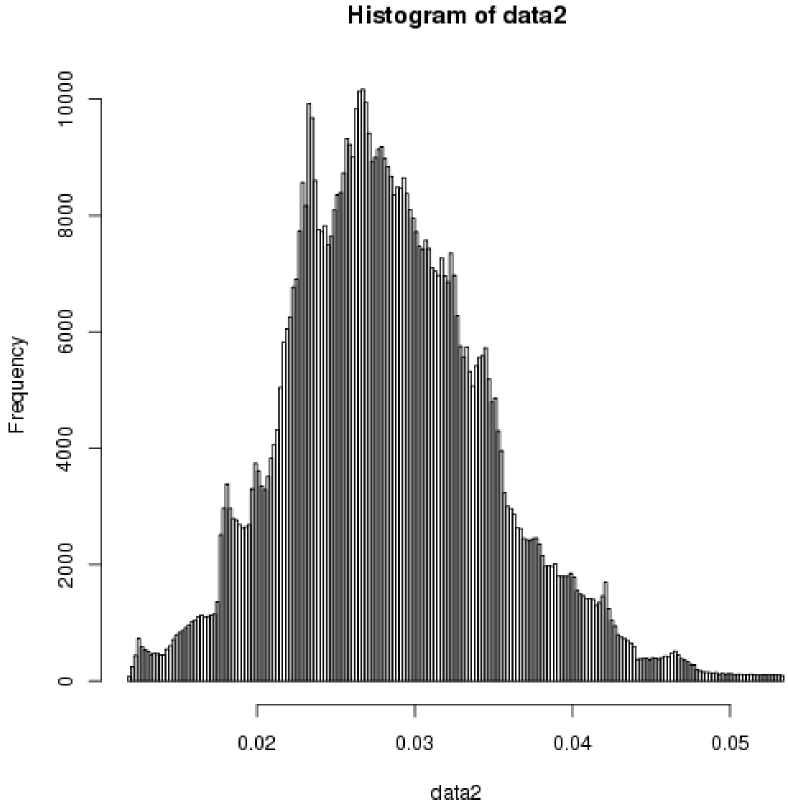

Figure 2. Example of how the pdf of a parameter is varied in SPP.

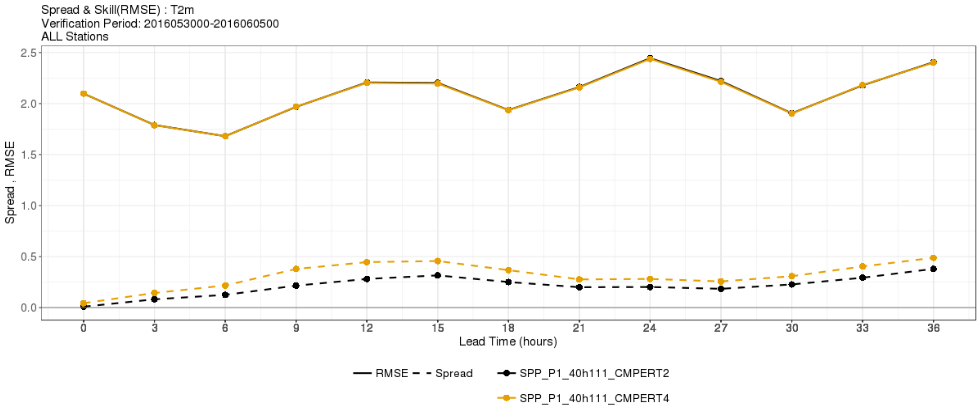

Figure 3. Example of sensitivity of with of pdf for the parameter in Figure 2.

Initial condition uncertainty:

In MEPS we are currently accounting for initial condition uncertainty by adding perturbations from the nesting model on top of our own analyses (method called PertAna). MEPS is currently nested in IFS HRES using the SLAF method (Ebisuzaki and Kalnay 1991; Hou et al. 2001). The perturbations are simply the differences between two IFS HRES forecasts:

$$IC\_m = A\_c + K\_m * (IFS\_N – IFS\_N\text{-}6)$$

where IC_m is the initial condition for member m, A_c is the MEPS control analysis, K_m a scaling factor for member m, IFS_N is a HRES forecast with length N and IFS_N-6 is a 6 h shorter HRES forecast, both valid at the same time as the analysis. K_m is set so that the members have a similar perturbation magnitude. This has proven to be a very beneficial approach for increasing the spread in MEPS, however it also has the undesirable effect that it introduces noise due to unbalanced fields resulting from this perturbation methodology. In figure 4 the climatology for hourly precipitation of MEPS for 2017-2018 for 125 stations in Norway is shown. We clearly see the different behaviour in the perturbed members as opposed to the control, with more precipitation in the first ~5 hours, then less for the next 5 before the members approach the control. EDA (ensemble data assimilation) where the observations are perturbed is also available in HarmonEPS, and it is currently being tested in MEPS. HarmonEPS EDA is set up to run one 3DVAR analysis with perturbed observations per member at the same resolution. The ensemble members then start directly from each EDA member. In the current setup of EDA it has proved necessary to keep a reduced amplitude PertAna when introducing EDA not to degrade the scores. However, it is possible to inflate the EDA perturbations and before making EDA operational in MEPS we will test different combinations of PertAna and EDA with the aim to reduce PertAna as much as possible.

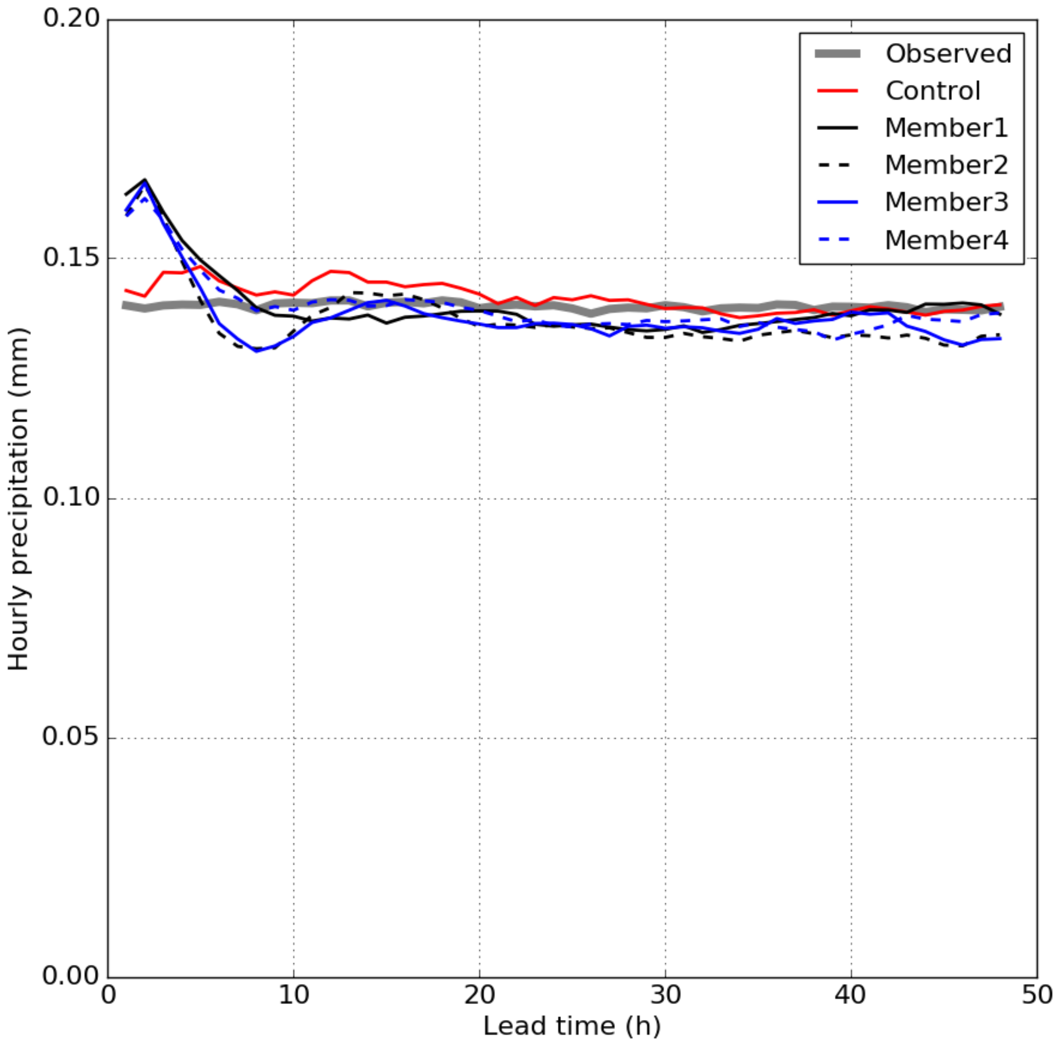

Figure 4: 1h precipitation climatology for MEPS for 2017-2018 for control and 4 first members.

Lateral boundary conditions and cycling strategy:

MEPS is currently run in a traditional way, where all 1 + 9 members run simultaneously four times a day. To better and more evenly use the available computer resources, a version of MEPS is currently being tested that distributes the members running 3 members every hour and then lagging over the last six hours to create the full ensemble. The members are divided into three streams, with three hourly cycling in each stream to avoid spin up problems (see figure 5). In this way we can afford to run more members. The perturbation methodologies in HarmonEPS have been developed and tested using traditional cycling, and when introducing this new cycling strategy it has proven necessary to test that they work and score as expected. In MEPS we also aim to switch the nesting from using IFS HRES to using IFS ENS. The subsequent improvements, previously seen in HarmonEPS tests are, however not seen when applying the new cycling strategy. Figure 6 shows spread and and RMSE of mean sea level pressure for operational MEPS (black), experimental MEPS (yellow), and IFS ENS (orange). We see that we get increased RMSE for the experimental MEPS. At present it is not clear what is the cause of this and tests need to be done to understand if this arises from the use of ENS, if it is due to the new cycling strategy or the lagging, or to a combination of many factors.

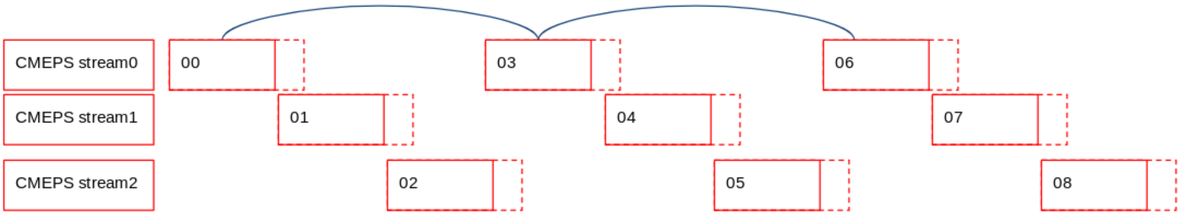

Figure 5: A potential continuous production suite.

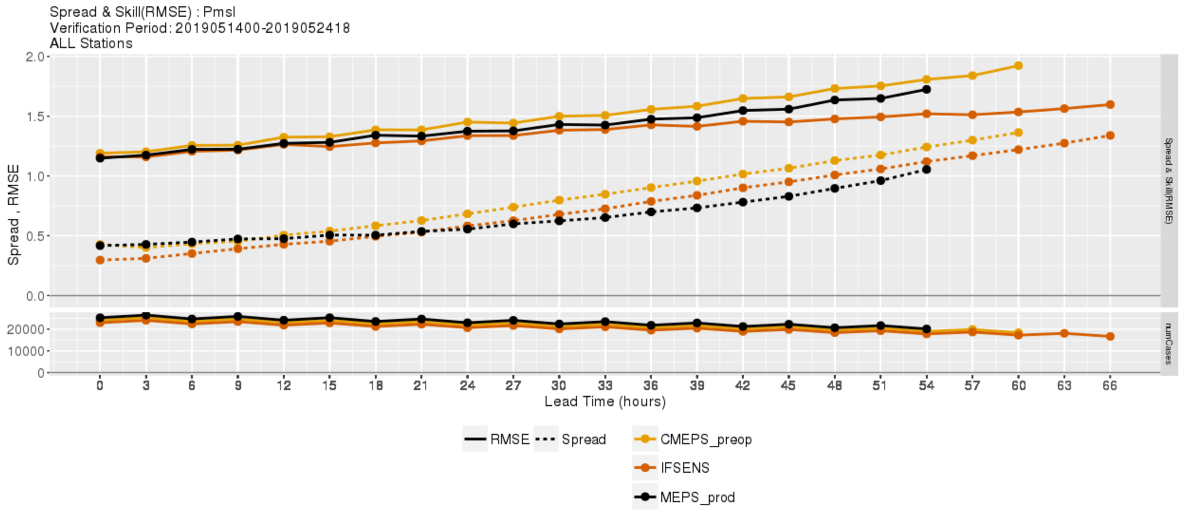

Figure 6. Spread and skill of mean sea level pressure for operational MEPS (black), experimental MEPS (yellow) and IFS ENS (orange) for 10 days in May 2019.

Surface perturbations:

In HarmonEPS surface perturbations are applied to account for uncertainties in the turbulent fluxes emanating from interactions between the surface and the atmosphere. These uncertainties may come from both the specification of static physiographic fields and the analysis of prognostic surface parameters in the initial conditions. The method used to apply the surface perturbations is taken from Bouttier et al. (2016). Work has recently started in Hirlam to refine the surface perturbations to make them more realistic. Currently the perturbation fields all have the same spatial scale, regardless of parameter. It may be more realistic to perturb different parameters at different spatial scales depending on the parameter. Furthermore, uncertainties in vegetation fraction and leaf area index may depend on both vegetation type and season and so different perturbations could be applied dependent on those factors. Work is ongoing in HarmonEPS to investigate these issues and to explore perturbing other surface parameters, such as soil ice content in the winter and sea ice concentration / extent. When this work is more mature, it is natural to test it in MEPS with the aim of making it operational. We believe this to be possible in the latter part of the period for this special project application.

Justification of computer resources needed:

The experiments will be run with a reduced set up to save SBUs. This includes running 8 out of 12 members and over a smaller area (B) than what is used in operations (see figure 1). We will also restrict the long forecasts only to be launched once a day. With such a setup the cost per simulated day would be 145T SBU or 2.0M SBU for a two week period. The experiments planned include as stated in the text above tuning of SPP and possibly the combination with SPPT, testing EDA and PertAna together, testing new cycling and new nesting strategy and testing more realistic surface perturbations. We ask for 16M SBUs per year which is sufficient to run 8 experiments per year. For eg. SPP testing this allows us to run 2 SPP experiments per season provided that we use additional national resources for the reference experiments.

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