REQUEST FOR A SPECIAL PROJECT 2018–2020

MEMBER STATE: Finland

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Project Title:

Parameter estimation (EPPES) in HarmonEPS

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.)	2018	
Would you accept support for 1 year only, if necessary?	YES ☒	NO ☐

Computer resources required for 2018-2020:
(To make changes to an existing project please submit an amended version of the original form.)

		2018	**2019**	**2020**
High Performance Computing Facility	(SBU)	15M	20M	20M
Accumulated data storage (total archive volume)[2]	(GB)	10000	20000	30000

An electronic copy of this form must be sent via e-mail to: *special_projects@ecmwf.int*

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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 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

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 will be 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.

Large requests asking for 10,000,000 SBUs or more will receive a detailed review by members of the Scientific Advisory Committee.

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

Background

HarmonEPS (Frogner et al. 2016) is an ensemble prediction system for the short range (~48h) based on the non-hydrostatic HARMONIE-AROME model configuration in the ALADIN-HIRLAM NWP system (Bengtsson et al. 2017). HarmonEPS is a flexible system and includes a range of possibilities to describe uncertainties in different parts of the system. HarmonEPS is operationalized in a few HIRLAM institutes, and e.g. MEPS (Andrae et al. 2017) and COMEPS (Yang et al. 2017) are examples of two different systems that are both based on HarmonEPS.

Developments to improve the description of the uncertainties in HarmonEPS are continuing with regard to initial conditions, lateral boundaries, surface and physics. There are several reasons why model uncertainty arises, e.g. computational constraints lead to simplifications in the description of the processes, and unresolved processes at the sub-grid scale needs to be parameterized. For representation of model uncertainty we are developing a parameter perturbation approach, where sensitive parameters in micro-physics, cloud processes, radiation and turbulence, and possible also surface, are perturbed randomly by a spatio-temporal correlation pattern. This request for a special project concerns finding optimal values for sensitive parameters, and their distribution, to be used in HarmonEPS to improve the probabilistic skill. Typically, ensemble prediction systems are under-dispersive for surface and near-surface weather parameters. See figure 1 for an example from the operational MEPS system (Andrae et al. 2017) from April 2017. Although mean sea level pressure (Pmsl, upper left in figure 1) has a quite good spread-skill relationship (for a well performing system the spread should equal the skill) for the first part of the forecast, this is not the case for two meter temperature (T2m), 10 meter wind speed (S10m) and 12 hourly accumulated precipitation (AccPcp12h). Similar characteristics can be seen for cloud variables in figure 2, total cloud (CCtot), low clouds (LC) and cloud base height (CH) are all under-dispersive. The results in figure 2 are from an experiment with HarmonEPS over the MEPS-domain (see figure 3) for a two and a half week period in spring 2016, for a set-up similar to MEPS.

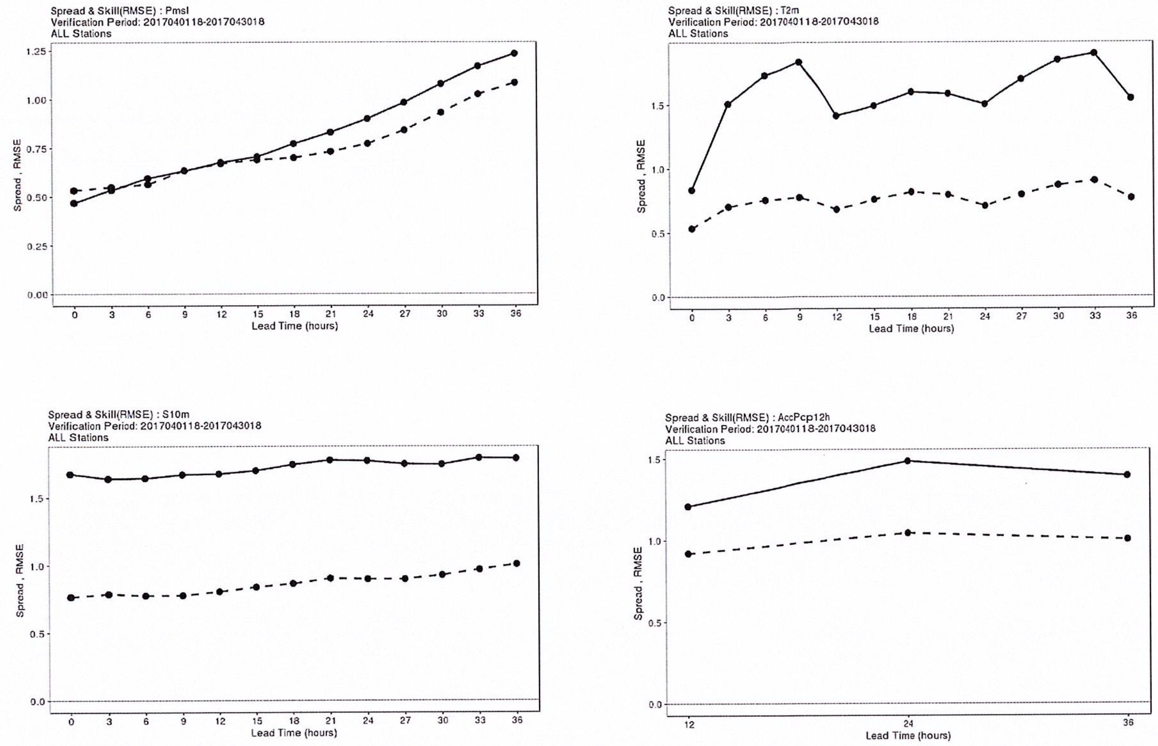

Figure 1: Spread (dashed) and skill (solid) from MEPS for April 2017. Upper left: Pmsl, upper right: T2m, lower left: S10m and lower right: AccPcp12h.

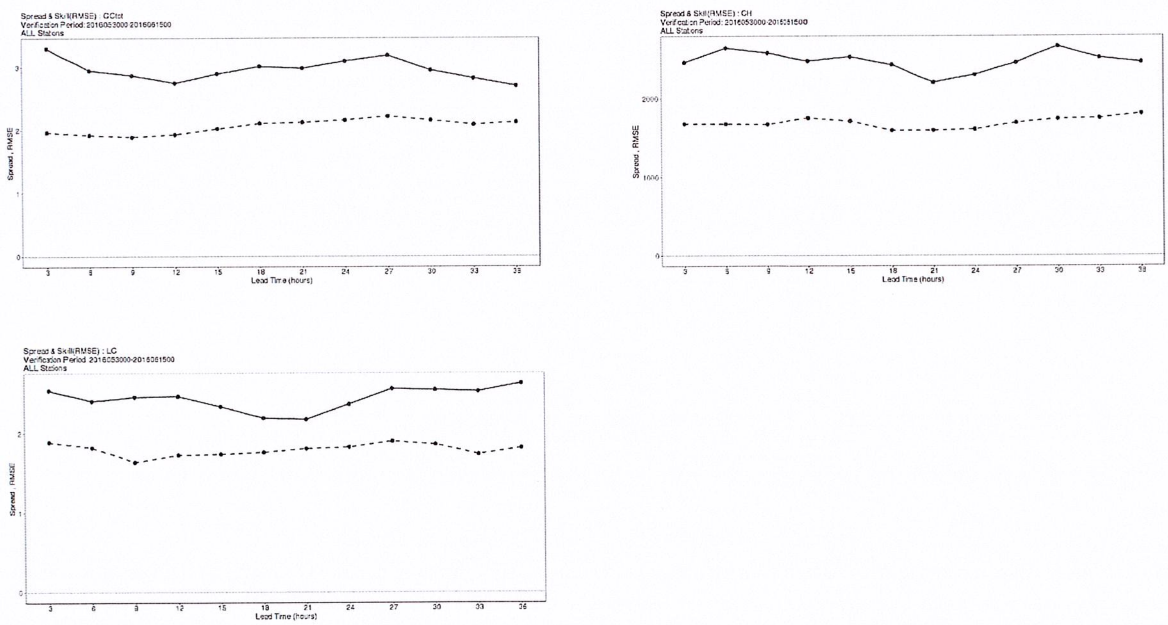

Figure 2: Spread (dashed) and skill (solid) from HarmonEPS for two and a half weeks in spring 2016. Upper left: total cloud cover (CCtot), upper right: cloud base hight (CH) and lower left: low clouds (LC).

It is believed that the approach described in this application, and other developments in other parts of the system that are not subject to this application, can improve the spread of these variables without degrading the RMSE, and hence give a better system.

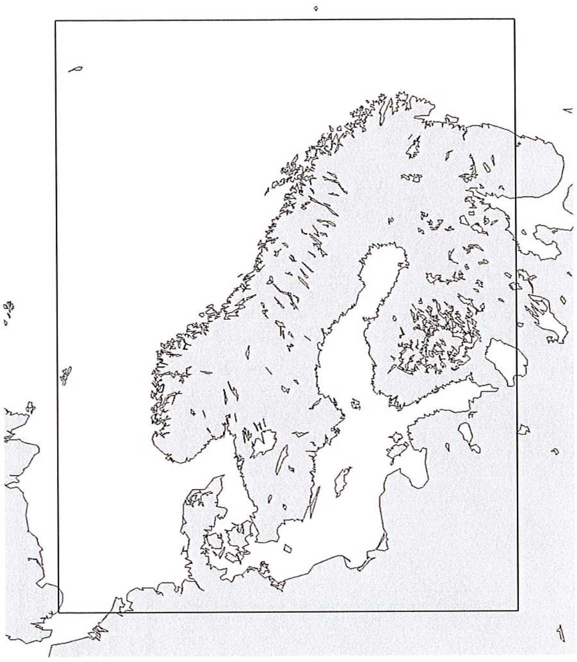

Figure 3: The MEPS domain to be used in this study.

Methods

The method to be used for estimating the sensitive parameters is the Ensemble Prediction and Parameter Estimation System (EPPES). EPPES (Laine, et al. 2012) is a parameter estimation methodology specially designed to utilise model ensemble runs. Ensemble system are launched with perturbed parameter values in addition to initial value and possibly other stochastic perturbations. The EPPES method is unique in the sense that it provides an objective estimation methods for static model parameters from outputs of a full resolution NWP model runs. EPPES has been used to tune ECHAM climate model (Ollinaho, et al. 2013a) and the IFS model at ECMWF (Ollinaho, et al. 2013b).

Algorithmically EPPES is based on sequential importance sampling (SIR) and hierarchical statistical formulation of the uncertainties. It can be used to tune and optimize static closure parameters and also to study the identifiability and uncertainty related to parameterizations and defining stochastic parameterization schemes, too.

A success of the method depends on the proper definition of the cost function that measures the overall predictive skill of the tuned model (Ollinaho, et al. 2014). We have further developed the method to use multi-criteria optimization techniques and utilised ideas from differential evolution algorithms. In the proposed EPPES test runs for the Harmonie limited area model, we target at building the cost function depending on surface variables. The first task in this Special Project is to construct the cost function based on a sensitivity analysis of the selected parameters. The aim is to understand the model response to changes in the parameter values, and to use this information to construct a multi-criteria cost function that is sensitive to changes in the parameter values.

We have already consulted the Harmonie physical parametrizations experts and identified 8 potential parameters from the parametrizations of micro-physics, cloud processes, convection and radiation to be optimised:

1) ice number concentration (ZZW)
2) the conversion rate from cloud liquid water to rain (ZINHOMFACT)
3) threshold for condensation at sub saturation conditions(VSIGQSAT)
4) threshold cloud thickness for stratocumulus/cumulus transition (ZCLDDEPTH)
5) threshold cloud thickness used in shallow/deep convection decision (ZCLDDEPTHDP)
6) fraction of grid with convection (ZFRACB)
7+8) contribution from graupel and snow to ice in radiation (RADGR+ RADSN)

We will screen these parameters by running a set of sensitivity tests. Ultimately 4 of these parameters will be chosen for the optimization phase.

Justification of computer resources needs

For technical tests of EPPES in HarmonEPS a small domain will be used. After the initial tests, the system will be applied on the MEPS-domain (figure 3), it covers 750x960 points with 2.5 km horizontal grid spacing and 65 vertical levels. Running a 48 h model forecast with this setup costs approximately 10000 SBUs. The requested resource of 55MSBUs would be spent as follows:

1) the initial screening of the parameters would be done with 20 2-day forecasts covering two seasons (JJA and DJF). We plan on perturbing each parameter by +/-10% w.r.t the default parameter value. This totals to 8 (parameters) *2 (perturbation) * 2 seasons = 16 experiments, equaling to ~6.5MSBUs.

2) further analysis would be done by additionally perturbing the selected 4 parameters by +/- 50% w.r.t. the default value using the same time period. Data from this and the previous step would then be used to construct the multi-criteria cost function. This step would require additional ~3.5MSBUs.

3) the EPPES parameter estimation itself would be done by running 4 forecasts per day over one of the selected time periods. The parameters would be sampled with a 10-member ensemble. This means we need to perform 3600 model integrations, which equals to ~36MSBUs.

4) The impact of the optimized parameters and their distribution will be evaluated in a three week experiment for each season, which equals to ~6MSBUs.

We expect the remaining resource (~3MSBUs) to be consumed in testing the algorithm and setting up scripts during different phases of the project.

References:

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