SPECIAL PROJECT FINAL REPORT

All the following mandatory information needs to be provided.

Project Title:	Parameter estimation (EPPES) in HarmonEPS
Computer Project Account:	spfiolli
Start Year - End Year :	2018 - 2018
Principal Investigator(s)	Pirkka Ollinaho
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Other Researchers (Name/Affiliation):	Ulf Andrae - SMHI Inger-Lise Frogner - MetNo Janne Kauhanen - FMI

The following should cover the entire project duration.

Summary of project objectives

(10 lines max)

The original purpose of this Special Project was to apply the Ensemble Prediction and Parameter Estimation System (EPPES; Laine, et al. 2012) to estimate uncertain parameters in HarmonEPS (Frogner et al. 2016). Due to changes in the PI's work status during 2018, the earlier outlined research plans had to be discarded. Since the original plan would have required the applied 3 years to be meaningful, we changed the research targets for the 2018 resource allocation:

1) Developing HarmonEPS model uncertainty representation

2) Generating ensemble initial states for the OpenIFS-model

Summary of problems encountered

(If you encountered any problems of a more technical nature, please describe them here.)

Experience with the Special Project framework

(Please let us know about your experience with administrative aspects like the application procedure, progress reporting etc.)

We have been very pleased with the support from ECMWF during the project.

Summary of results

(This section should comprise up to 10 pages, reflecting the complexity and duration of the project, and can be replaced by a short summary plus an existing scientific report on the project.)

Developing HarmonEPS model uncertainty representation.

We redirected our research efforts into implementing the Stochastically Perturbed Parametrizations (SPP; Ollinaho et al., 2017) in the HarmonEPS framework. The SPP scheme is representing model uncertainties in an ensemble by introducing stochastic noise to a chosen set of sub-grid scale processses. These processes are in NWP models represented by a numeric value determining the efficiency or rate of change of the specific process. These so-called closure parameters have a large impact on the model forecast skill, but constraining their values requires a lot of tuning efforts. The SPP framework tries to assess the forecast uncertainties related to these closure parameters.

Our research efforts have continued beyond the Special Project end date, and we currenly have implemented the possibility to perturb 14 parameters in the SPP framework (Table 1).

Table 1: Parameter list and description.

PSIGQSAT	saturation limit sensitivity
CLDDPTH	threshold cloud thickness for stratocumulus/cumulus transition
CLDDPTHDP	threshold cloud thickness used in shallow/deep convection decision
ICE_CLD_WGT	cloud ice content impact on cloud thickness
ICENU	ice nuclei
KGN_ACON	Kogan autoconversion speed
KGN_SBGR	Kogan subgrid scale (cloud fraction) sensitivity
RADGR	graupel impact on radiation
RADSN	snow impact on radiation
RFAC_TWOC	top entrainment
RZC_H	stable conditions length scale
RZL_INF	asymptotic free atmospheric length scale
RLWINHF	Long wave inhomogeneity factor
RSWINHF	Short wave inhomogeneity factor

We have tested the impact of the SPP perturbations on the HarmonEPS ensemble skill for 12 of these parameters in a 1-week long summer period (30th of May to 5th of June 2016). We are currently running the tests for a winter period to confirm that the perturbations are acting similarly regardless of the season.

Figure 1 shows an example how we have approached the task of constructing the SPP framework for HarmonEPS. In both of the experiments shown in the figure, we apply SPP perturbations to a single parameter only (PSIGQSAT). The experiments differ in the size of the perturbations: one is conducted with small perturbations (black) and the other with large perturbations (orange). In the case of PSIGQSAT, the larger perturbations lead to a more skillful ensemble. We have repeated these (and other) tests for most of the parameters shown in Table 1, and with this information constructed a (preliminary) setup for perturbing multiple parameters at the same time.

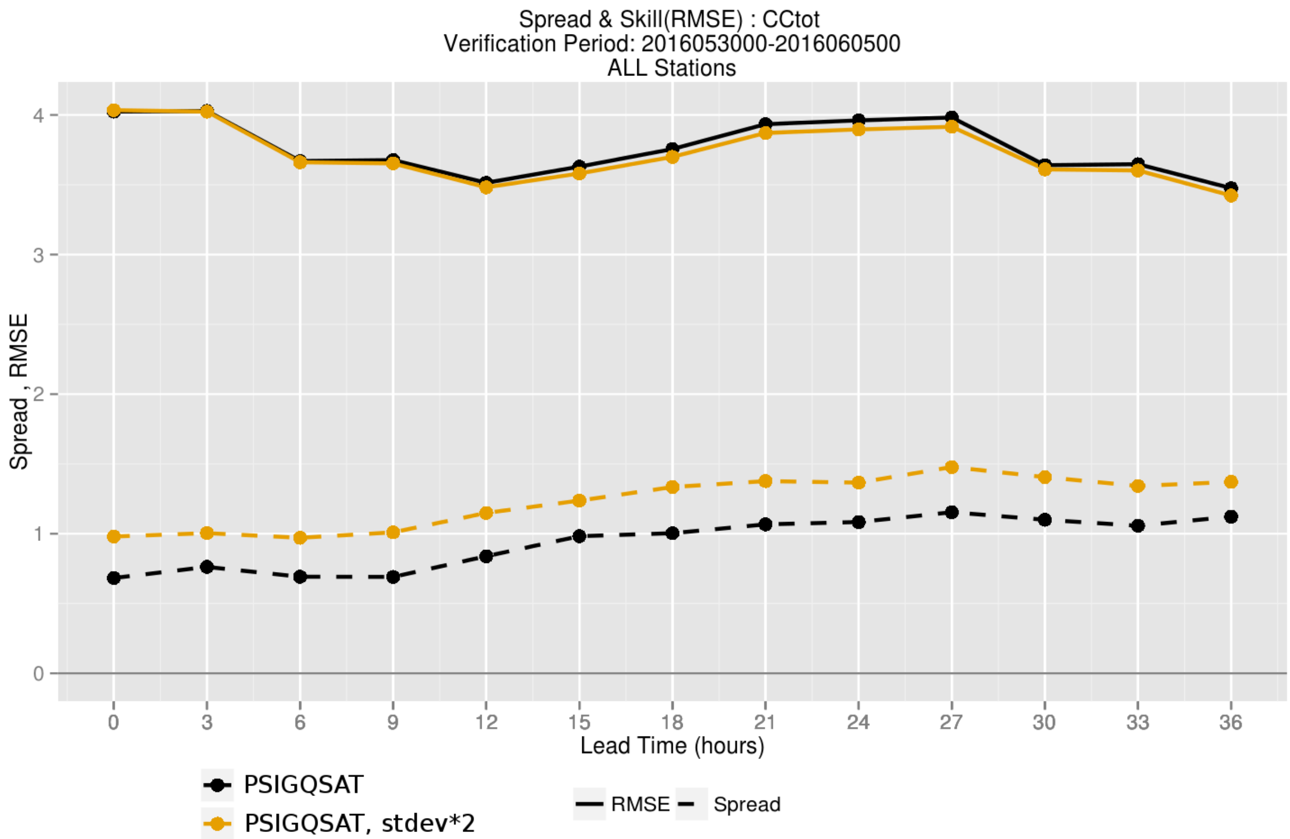

Figure 1: Ensemble spread (dashed) and ensemble mean RMSE (solid) of total cloud cover. Shown are an experiment perturbing a single parameter (PSIGQSAT) with a small standard deviation for the perturbations (black) and an experiment with a larger standard deviation (orange).

In Figure 2 we asssess the skill of this (preliminary) setup. The comparison is done against the operational HarmonEPS setup run by the MetCoop-consortium (consisting of Norway, Sweden and Finland), called in short "MEPS". MEPS does not currently have a model uncertainty representation, so including one is likely to increase the skill of the system. Indeed, the increased skill of the ensemble is quite evident in Figure 2. The improvements are also clearly seen in other forecast fields (not shown).

We conclude that the work started within the Special Project framework has led to a very promising venue for the HarmonEPS community to further develop and explore. Finding a final SPP setup for an operational setting is the goal of future research efforts, although this still requires running quite a few expensive research experiments. To reach this goal, a new Special Project will be submitted in this summer's Special Project call. The application is led by Ulf Andrae and Inger-Lise Frogner.

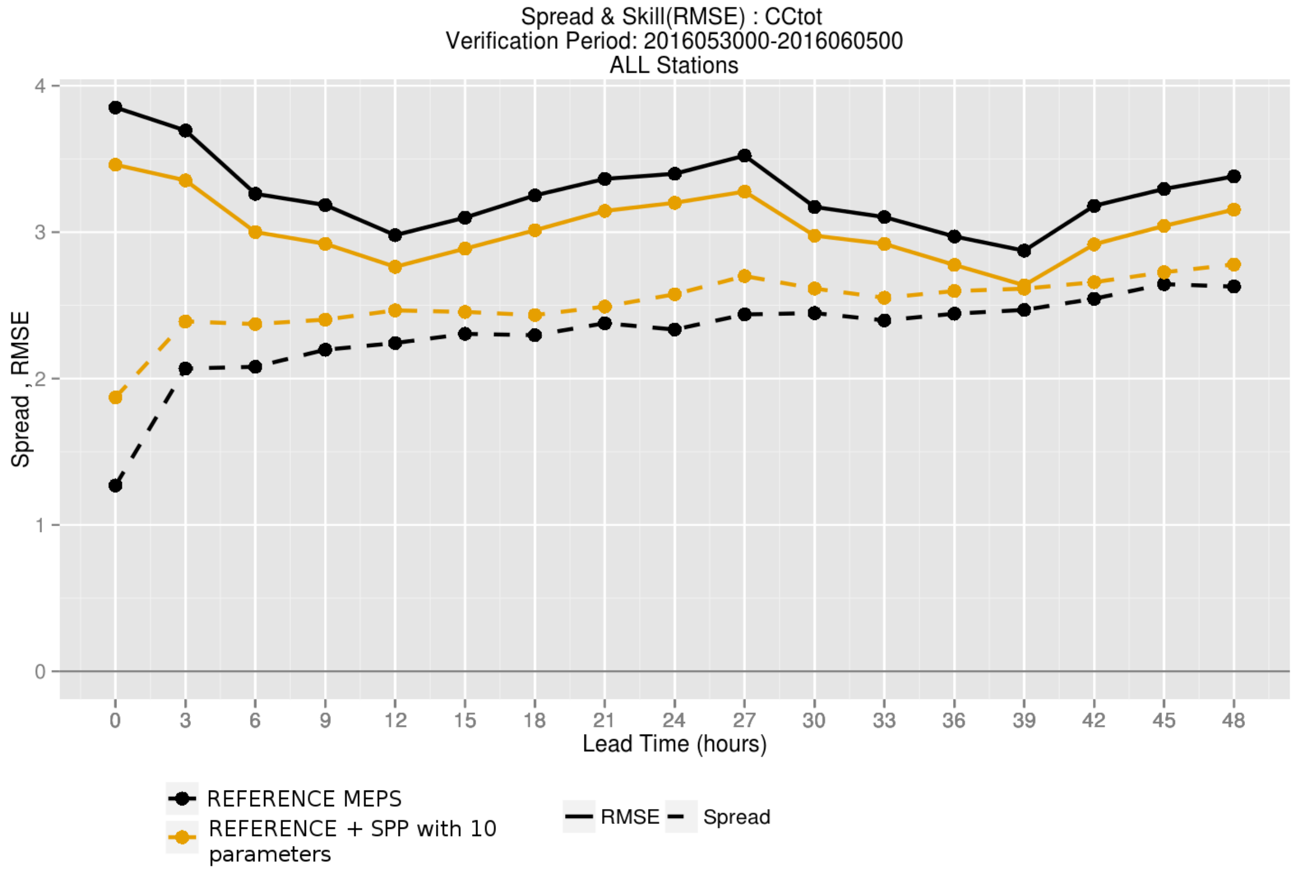

Figure 2: Ensemble spread (dashed) and ensemble mean RMSE (solid) of total cloud cover. Shown are the operational MEPS ensemble skill (black) and an experiment where SPP perturbations with 10 parameters are added to the operational system (orange).

Ensemble initial states for OpenIFS

A smaller part of the allocated resource was used to generate ensemble initial states for the OpenIFS-model. These initial states have been used to finalize the parameter estimation algorithm EPPES discussed in the original research plan. We have constructed a framework for running so-called convergence tests for parameter estimation algorithms. The purpose of the convergence tests is to provide an easy and straightforward way to assess 1) are the targets for the estimation process well constrained, 2) how to speed up the converge of the estimation, and 3) how to reach convergence with as little computational resources as possible. These developments are currently being tested with two closure parameters from the IFS convection scheme with OpenIFS. The work will later expand to estimate drag related closure parameters first in OpenIFS, and then in IFS (on-going collaboration with Irina Sandu and Peter Bechtold from ECMWF).

The second purpose for constructing the initial states was to provide the academic world means to run meaningful ensemble forecasting experiments. So far its only been possible to run ensembles with some sort of representation for the model uncertainty part, but assessing the role of the initial state in forecast uncertainty has been very limited. The dataset consists of operational IFS ensemble initial states starting from 1st of December 2016 and extening to 30th of November 2017. The initial states were generated with IFS CY43R3 (the upcoming OpenIFS cycle), and contain 50+1 ensemble initial states as per the operational ensemble of ECMWF. The dataset contains initial states for three different model resolutions, TL159/TL399/TL639. A manuscript is currently under work to document the ensemble skill of OpenIFS when using these initial state perturbations. Once completed, the dataset will be made freely available through an ftp-server.

Figure 3 illustrates how the skill of an OpenIFS ensemble using only initial state perturbations behaves with changing resolutions. The score used here is the so-called fair version of Continuous Ranked Probability Score, fair-CRPS. The score estimates what would the CRPS be if the ensmble size would near infinity. Unexpectedly, the higher the resolution of the ensemble the better the associated skill is as well.

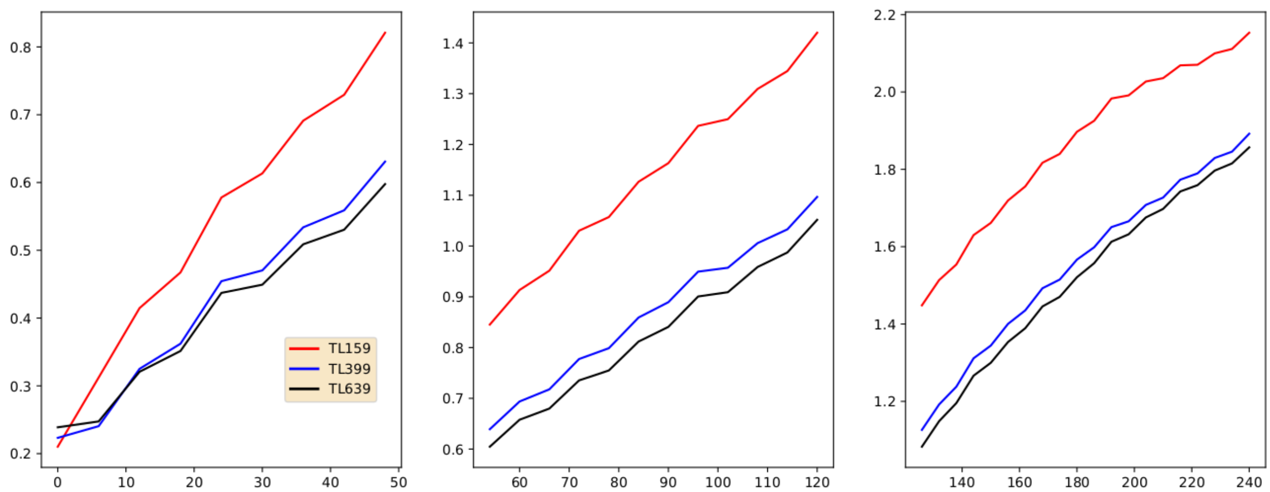

Figure 3: Fair-CRPS of temperature at 850hPa level for Northern extra-tropics. OpenIFS ensembles run with TL159 (red), TL399 (blue) and TL639 (black) resolutions. The x-axis is diveded into forecast ranges of 0-48h, 54-120h and 126-240h. Mean of 27 start dates.

To showcase the usefulness of the dataset, we present a short case study of OpenIFS forecast skill in simulating Damrey typhoon that made landfall in Vietnam 00UTC 4th of November 2017. In Figure 4, the observed and simulated tracks of Damrey typhoon are shown for the deterministic model (top; black line), and for 20 ensemble forecasts started from different initial states (bottom). The runs were conducted with TL639 resolution and started on 00UTC 2nd of Nov. The deterministic forecast ends up forecasting the typhoon on a too southerly track and propagates it too slowly. Although the ensemble tracks are also mostly taking a too southerly track, we begin to see some ensemble members starting to solve better the landfall location and timing, thus providing critical information about the typhoon evolution.

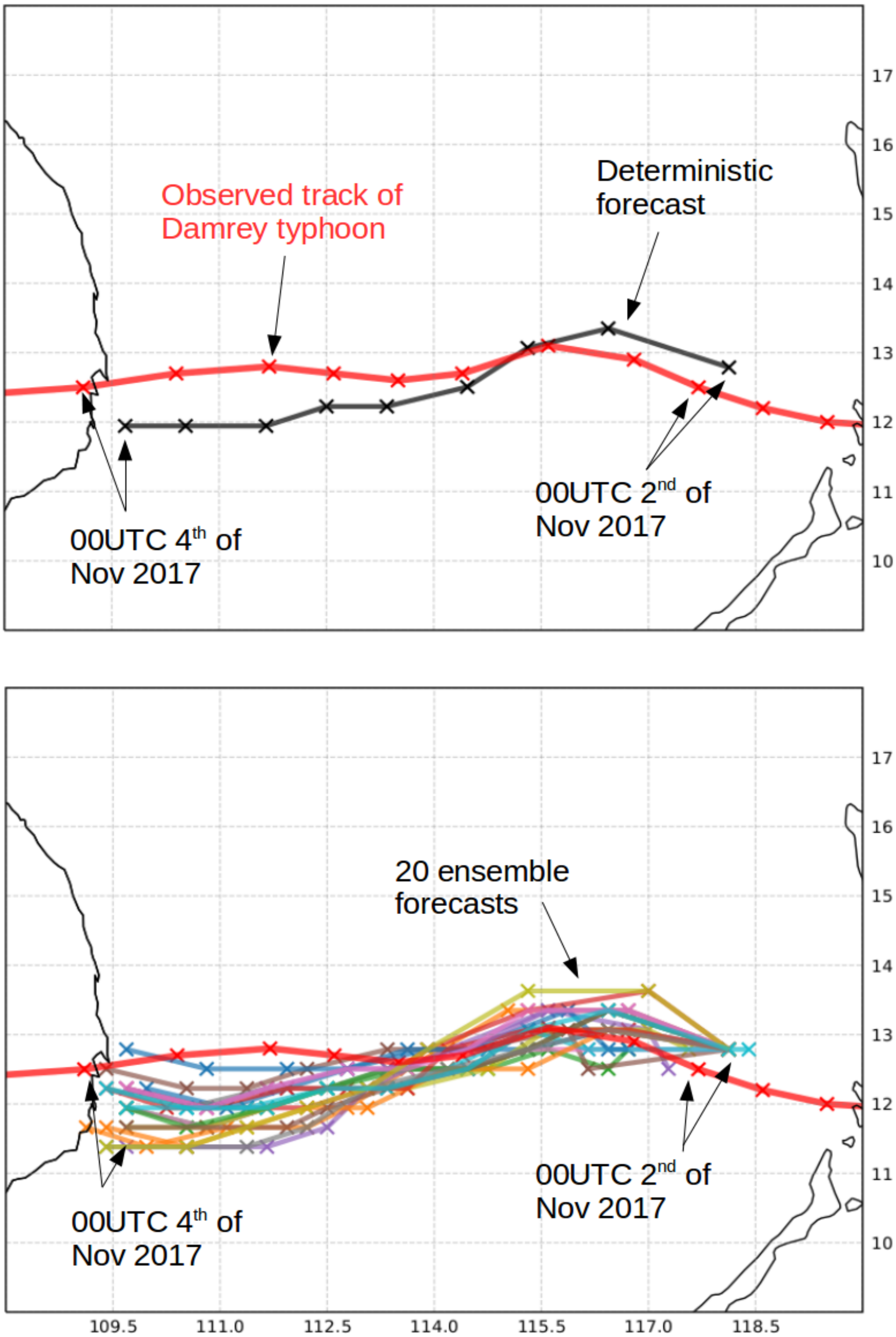

Figure 4: Damrey typhoon off the coast of Vietnam. Top figure shows the observed track of Damrey and a TL639 resolution OpenIFS forecast initialized at 00UTC 2nd of Nov. The bottom figure is also showing the observed track (red), but instead of the deterministic run, 20 different ensemble forecast initialized at 00UTC 2nd of Nov are shown. The track is constructed by simple picking the mean sea-level pressure minimum at 6h forecast intervals.

List of publications/reports from the project with complete references

Manuscripts in preparation:
1. Stochastically Perturbed Parametrizations in HarmonEPS

2. Ensemble initial states for OpenIFS

Seminar presentations:
Frogner, I-L, 2019: HarmonEPS developments -SPP and SPPT. Hirlam All Staff meeting, Madrid, Spain.
Ollinaho, P., 2019: Ensemble prediction with OpenIFS. OpenIFS workshop, Reading, UK.

Future plans

(Please let us know of any imminent plans regarding a continuation of this research activity, in particular if they are linked to another/new Special Project.)

Once thoroughly tested, the SPP model uncertainty representation will be used in the operation HarmonEPS that the national forecasting centers of Norway, Sweden and Finland are running co-operatively (MEPS).

A new Special Project will be submitted in this summer's Special Project call to help in achieving the above mentioned goal.