SPECIAL PROJECT PROGRESS REPORT

Progress Reports should be 2 to 10 pages in length, depending on importance of the project. All the following mandatory information needs to be provided.

Reporting year 2016

Project Title: Probabilistic forecasts for short range in Europe

Computer Project Account: spnogeps

Principal Investigator(s): Inger-Lise Frogner

Affiliation: Norwegian Meteorological Institute

Name of ECMWF scientist(s) collaborating to the project (if applicable) Martin Leutbecher

Start date of the project: 2015

Expected end date: 2017

Computer resources allocated/used for the current year and the previous one

(if applicable)
Please answer for all project resources

	Previous year	**Current year**			
	Allocated	Used	Allocated	Used	
High Performance Computing Facility	(units)	20000000	19150000	20000000	280000
Data storage capacity	(Gbytes)	10000	?	10000	?

Summary of project objectives

(10 lines max)

The objectives are developing and maintaining probabilistic forecasts for short range in Europe, in the cooperation of two European consortia for short-range NWP: HIRLAM and ALADIN. It consists of two main activities: Activity 1: maintaining and developing The Grand Limited Area Modelling Ensemble Prediction System (GLAMEPS), which runs at ECMWF as Time-Critical facility Option 2 (TCF_2) and Activity 2: Experimenting scientifically and technically with ensembles of non-hydrostatic modelling with convection-permitting resolution (HarmonEPS) for the very short range in sub-European domains.

Summary of problems encountered (if any)

(20 lines max)

The working conditions at ECMWF are very good thanks to a helpful and collaborative staff at ECMWF.

Lack of disk space, both for operational GLAMEPS runs, and for running experiments, is sometimes a problem.

Summary of results of the current year (from July of previous year to June of current year)

This section should comprise 1 to 8 pages and can be replaced by a short summary plus an existing scientific report on the project.

Activity 1, GLAMEPS: SBUs from this special project was used for test runs concerning the parallelization of the Alaro and Hirlam forecast runs under the new GLAMEPS domain for version 3 (v3). There have been a lot of test runs with different configurations in order to address the new challenges from:

* increased grid size on a smaller grid mesh
* increased data output frequency (1-hourly model output)

The first tests revealed a significant drop in performance, so it became necessary to reconfigure parallelization geometry, and especially also to configure separate tasks for i/o work. As an example, figure 1 shows runtime/SBU performance for different domain decomposistion of Hirlam forecast runs. The black entries showing results from GLAMEPS version 2 comparison runs, and the colored entries showing performance/cost of the GLAMEPS version 3 runs. The two groups of entries from GLAMEPS version 3 runs represent the slower (large runtime) but cheaper (less SBUs) runs utilizing hyperthreading, and the faster (smaller runtime) but more expensive (more SBUs) runs without hyperthreading. The indicated line represents approximately what would be expected by just taking the new grid geometry of the version 3 domain into account.

The second development for GLAMEPS v3, was the work on implementation of the Hirlam Singular Vector procedure into the GLAMEPS production system.

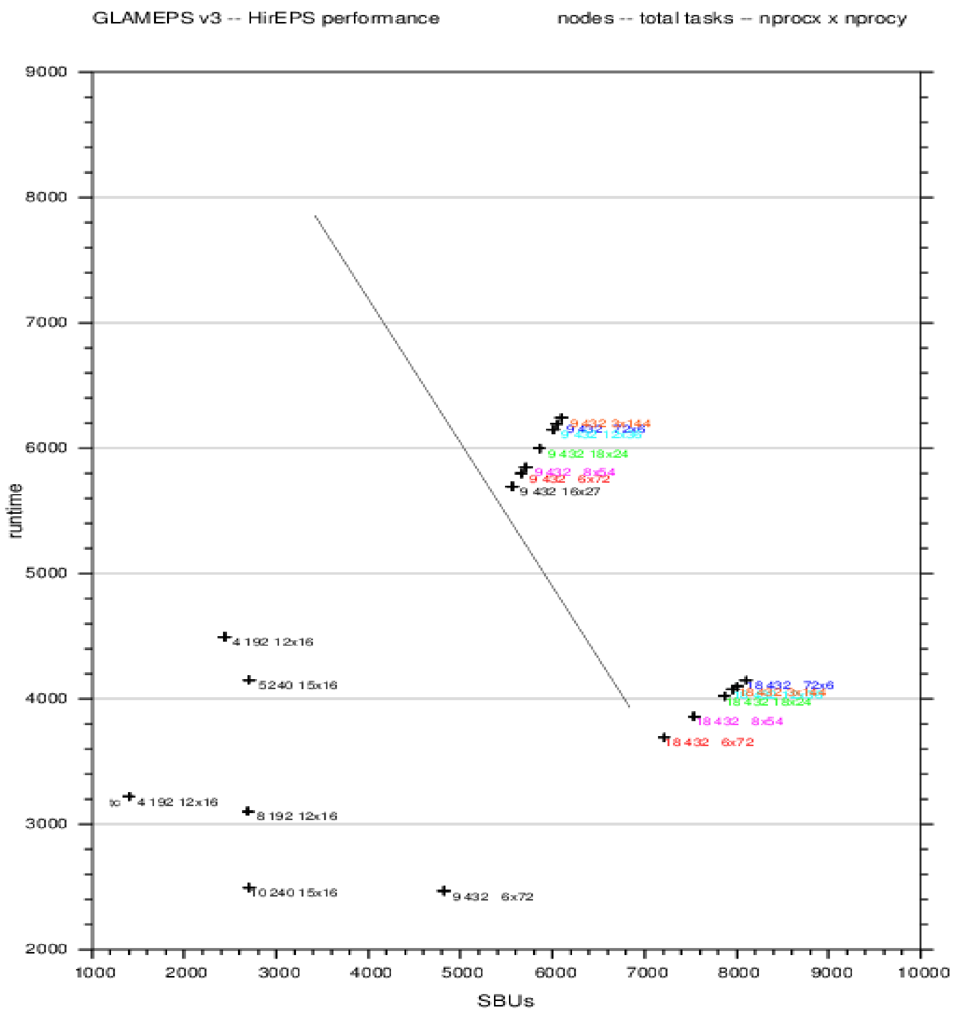


Figure 1: Runtime/SBU performance for different domain decomposistion of Hirlam forecast runs. Expantation in the text.

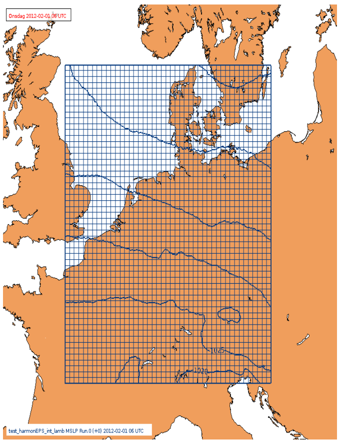
Activity 2, HarmonEPS: Experimenting scientifically and technically with ensembles of non-hydrostatic modelling with convection-permitting resolution (HarmonEPS) for the very short range in sub-European domains.

HarmonEPS is the name of an ensemble prediction systems for the very short range (~36h) on convection-permitting scales. The basic model tool is the non-hydrostatic Harmonie with Arome and/or Alaro physics. HarmonEPS is now at a stage where members states can adapt it for operational needs, and presently a few institutes are close to setting it into operations. At the same time development is ongoing, and a part of the experiments for this has been using spnogeps account. Since reported last year on the use of spnogeps the EDA (ensemble of data assimilations) experiments have been evaluated, and more experiments have been run, and will be shortly presented here as promised in last years report. Also experiments with multi-physics and surface perturbations is included in this report.

<u>EDA:</u>

A three week period in spring 2013 (2013051100 – 2013053118) was chosen for the experiments. The domain is shown in figure 2. A setup of 10 + 1 Arome members, where each were running their own assimilation cycles with perturbed observations, was used. Three different experiments was run:

- Control ensemble, without EDA, labelled «HarmonEPS-Arome» - 10+1 Arome members run the default HarmonEPS-way (but only Arome), that is with 3DVar for control and perturbations from IFS ENS added to this analysis for each member. All members run separate surface analyses.
- «EDANOECPERT» - 10 +1 Arome members, each running their own 3DVar, with perturbed observations. All members run separate surface analyses.
- “EDAWITHECPERT” - a combination of the two above: 10+1 Arome members run the default HarmonEPS-way (but only Arome), but with one 3DVar for each member with perturbed observations. In addition perturbations from IFS ENS added to this analysis for each member. All members run separate surface analyses.



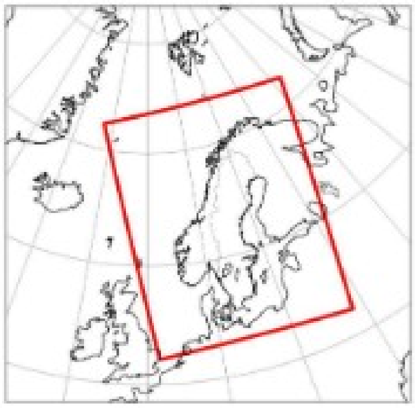


Figure 2: Area used for the EDA experiments (left) and area used for multi-physics experiment and surface perturbation experiments (right).

The same IFS ENS members are used as boundaries in all three experiments, so what we see in the results are the effects of EDA and/or IFS ENS initial perturbations. A three week spin-up run for the control member was run before starting the experiments. Note that EDA as run here does not feed back into DA, it is only used for creating initial perturbations for HarmonEPS.

In Figure 3 spread and skill are shown for the three experiments for two meter temperature (T2m), ten meter wind speed (S10m), mean sea level pressure (Pmsl) and 12 h accumulated precipitation (AccPcp12h). Looking at EDA initial perturbations versus IFS-ENS initial perturbations (black curve versus blue curve) we see that EDA perturbations are generally more effective, the spread is increased (not for Pmsl), but only slightly and for the first 6-9 hours only. However, looking at the combination of the two perturbations (yellow, EDA and IFS-ENS pert) and compare to only EDA perturbations (black) and only IFS-ENS perturbations (blue) we see a clear improvement in spread for the combination of the perturbations. The skill of the three experiments are not very different, maybe a small improvement in skill for EDAWITHECPERT experiment.

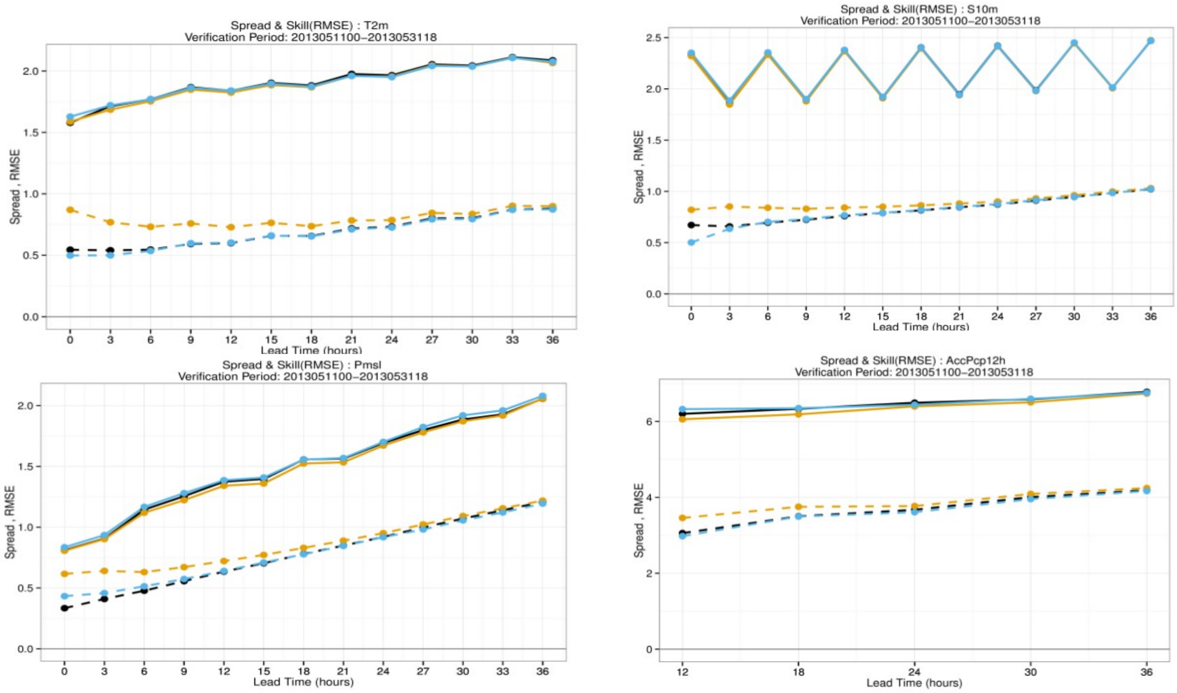


Figure 3: Spread and skill for T2m (upper left), S10m (upper right), Pmsl (lower left) and AccPcp12h (lower right). HarmonEPS-Arome in blue, EDANOECPERT in black and EDAWITHECPERT in orange.

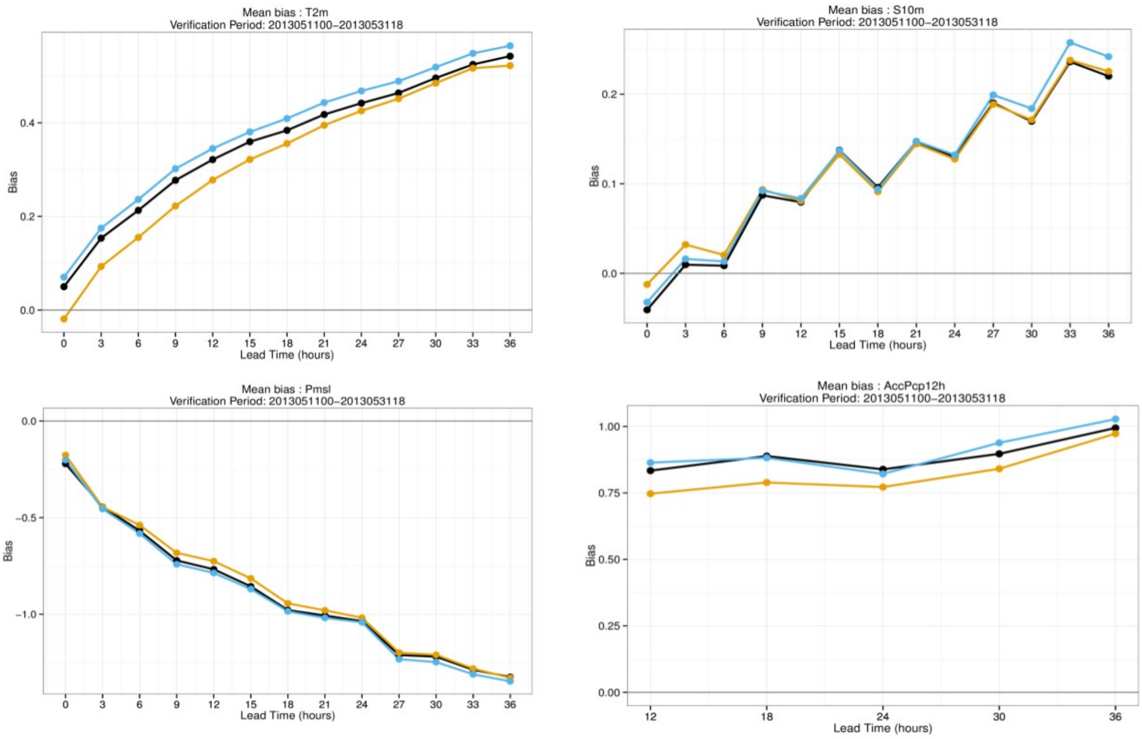


Figure 4: Mean bias for T2m (upper left), S10m (upper right), Pmsl (lower left) and AccPcp12h (lower right). HarmonEPS-Arome in blue, EDANOECPERT in black and EDAWITHECPERT in orange.

The mean bias is shown in Figure 4. For T2m we see that EDA reduces the positive bias and that the combination with the IFS ENS perturbations leads to a further reduction of the bias. Also for AccPcp12h there is a clear reduction in the mean bias for EDAWITHECPERT experiment. For Pmsl and S10m the differences between the experiments are less pronounced.

In Figure 5 the continuous ranked probability score (CRPS) is shown for T2m, S10m, Pmsl and 3 hourly accumulated precipitation (AccPcp3h). Note that CRPS is a negatively oriented score, so the smaller CRPS the better. Also for this score we see that EDA has a small impact for the first few hours of the forecasts, and that the combination of EDA and IFS ENS perturbations has a larger impact and also for a longer time than only using EDA.

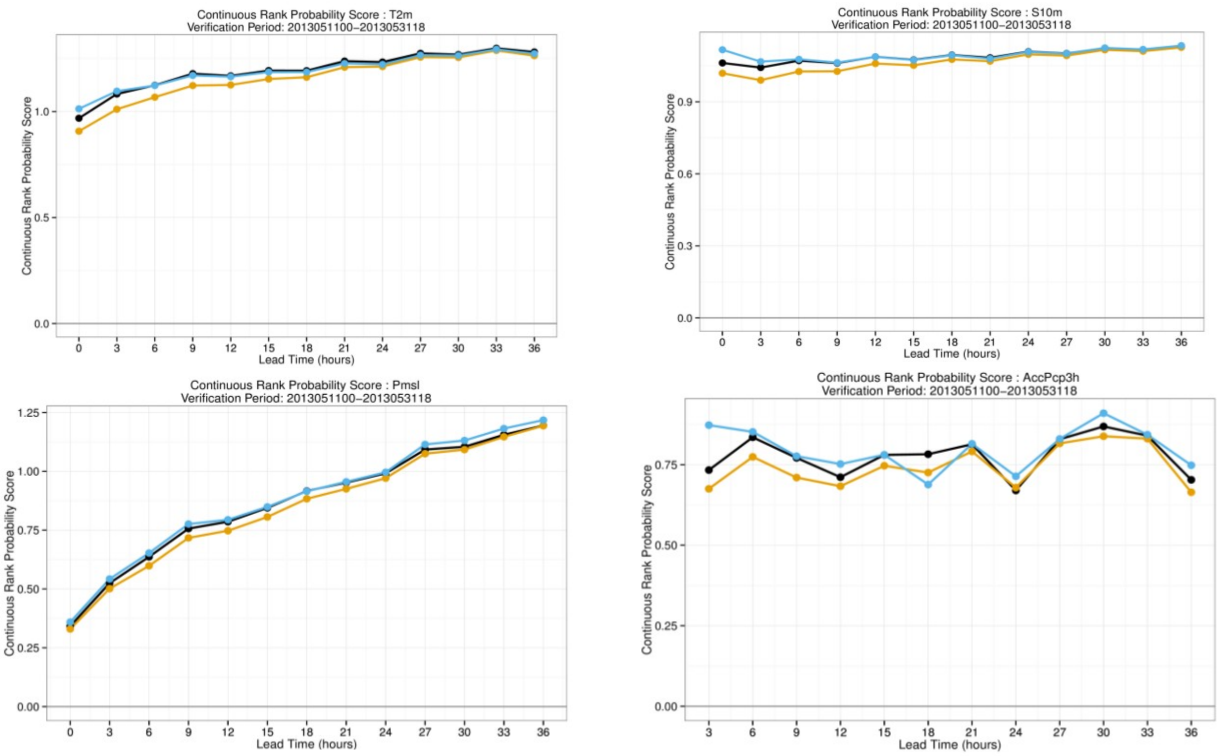


Figure 5: CRPS for T2m (upper left), S10m (upper right), Pmsl (lower left) and AccPcp3h (lower right). HarmonEPS-Arome in blue, EDANOECPERT in black and EDAWITHECPERT in orange.

Also a different approach for perturbing the observations in EDA was tried, but this did not lead to any change in the conclusions (not shown).

<u>Multi-physics:</u>
Several institutes have tried multi-physic in order to account for model error, and have showed improved scores. In this experiment we do the first test with multi-physics in HarmonEPS (Arome) where we utilise different schemes for turbulence, micro-physics and radiation parametrizations that are available in HarmonEPS. A three week period in summer 2015 was run (20150720-20150810) and compared to the basic setup of HarmonEPS with the same number of members and the same boundary conditions and initial conditions. For this HarmonEPS was set up with 8 + 1 members and run over the MetCoOp domain, see figure 2 (the operational domain for the Swedish-Norwegian operational cooperation).

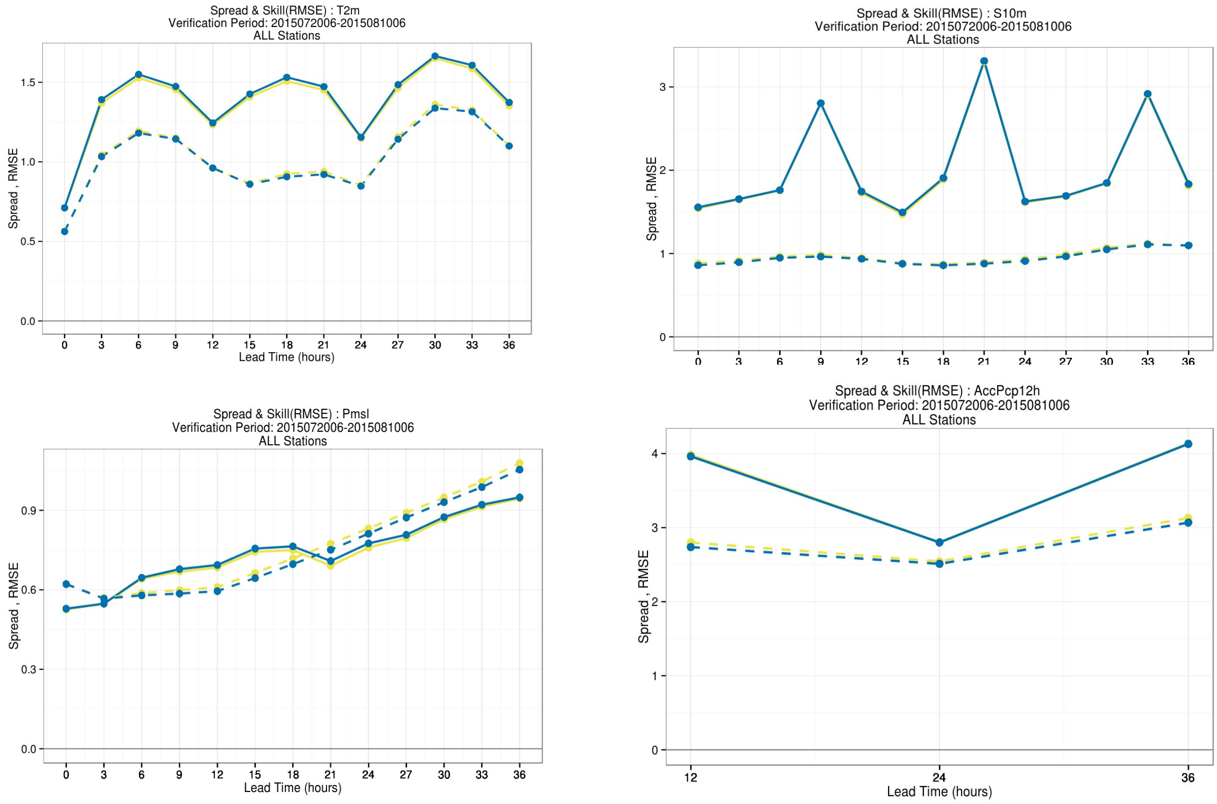


Figure 6: Spread and skill for T2m (upper left), S10m (upper right), Pmsl (lower left) and AccPcp12h (lower right). Reference HarmonEPS in blue, HarmonEPS with multi-physics in yellow.

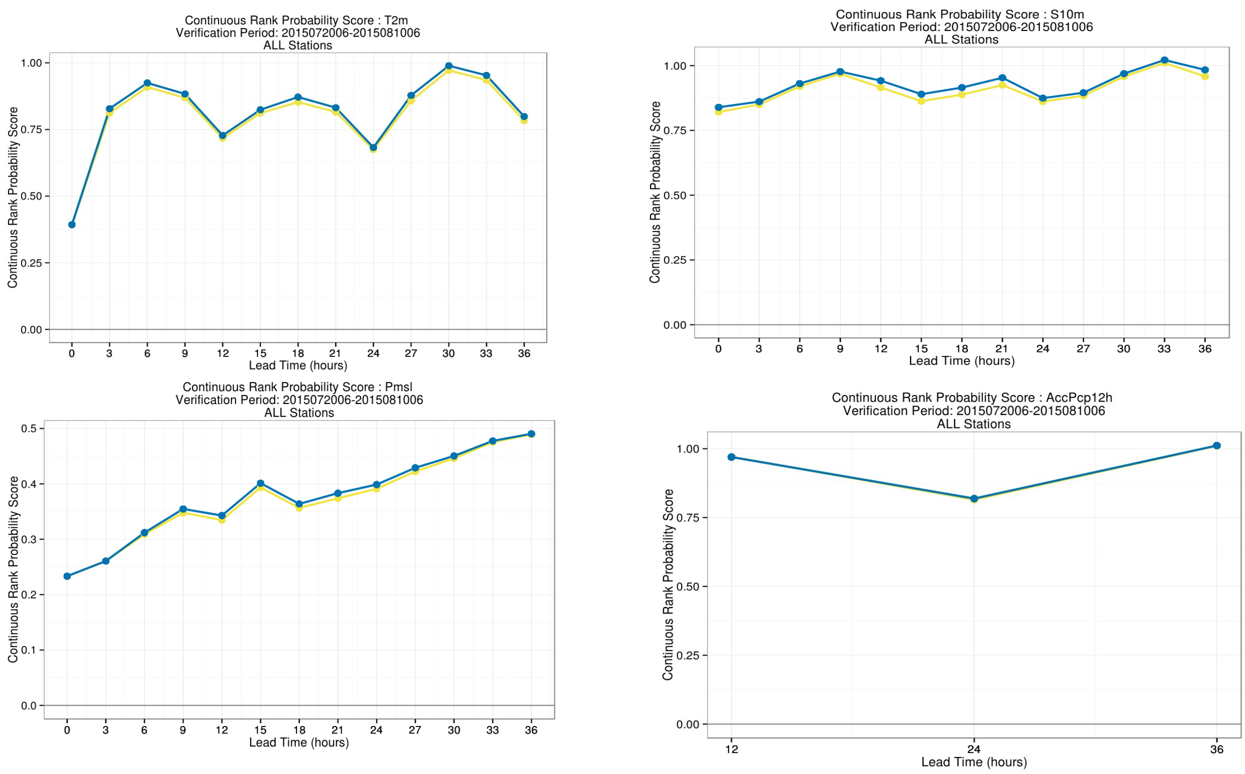


Figure 7: CRPS for T2m (upper left), S10m (upper right), Pmsl (lower left) and AccPcp3h (lower right). Reference HarmonEPS in blue, HarmonEPS with multi-physics in yellow.

In Figure 6 the spread and skill are shown for T2m, S10m, Pmsl and AccPcp12h. There is a tendency for the skill to be better and the spread to be higher for HarmonEPS that includes multi-physic, but the differences are small and we have not tested if they are statistically significant. In Figure 7 the CRPS is shown. CRPS also show a small, but positive effect of multi-physic. When applying multi-physics most probably different members of the ensemble will have different characteristics. Therefore it is important to also look at the deterministic scores of the individual members. We have done this, and as expected this is the case for HarmonEPS with multi-physic (not shown). We also see one clear outlier, and this member should be removed if we decide to continue this approach. Although the impact on the probabilistic scores is small, it can still be that some multi-physics members are better than others in certain situations, and to better predict e.g high impact cases is certainly important even though it does not necessarily show up in the overall statistics. To look at high impact events will be the next step. Maintaining a multi-physic scheme is technically challenging, which is an argument against this approach for describing model error.

<u>Surface perturbations:</u>
Surface is an important source of the uncertainty in convection-permitting ensemble systems like HarmonEPS. A surface perturbation scheme was kindly been provided by F. Bouttier at MeteoFrance (Bouttier et al. 2015). We have used this to do initial experiments with perturbations of surface parameters (e.g. soil moisture, albedo, SST, LAI and soil temperature). Two periods were chosen for the experiments, one summer (same as used in multi-physic experiment described above: 20150720-20150810) and one winter period (20151230-20160119). The area is also here the MetCoOp domain shown in Figure 2. We have run HarmonEPS with 8+1 members, one experiment when only surface is perturbed, and one where also boundaries and initial conditions are perturbed in the default HarmonEPS way (that is using perturbations from the nesting model. In this case differences from the high resolution forecast from ECMWF valid at the same time but with different forecast length, the so called SLAF method). We compare against a control run of HarmonEPS.

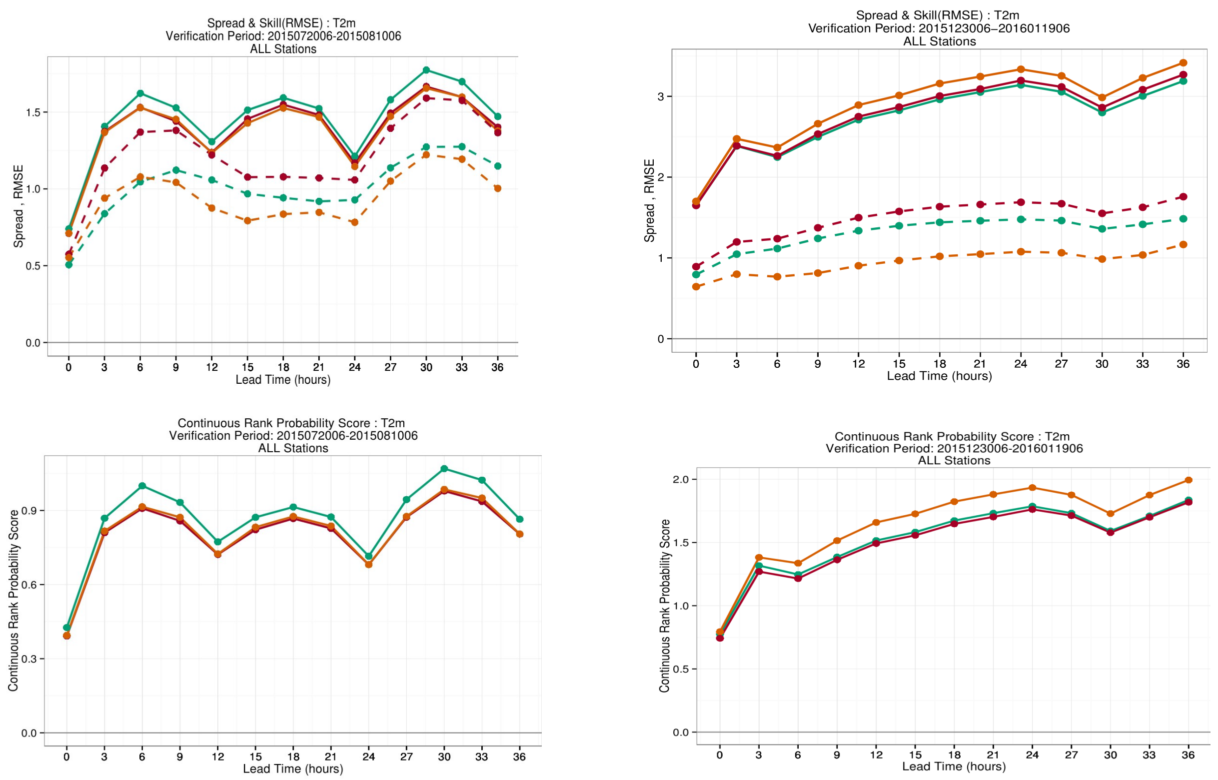


Figure 8: for T2m. Upper left is spread and skill for the summer period, upper right is spread and skill for the winter period. Lower left is CRPS for the summer period, lower right is CRPS for the winter period. The HarmonEPS reference run in orange, HarmonEPS with only surface perturbations in green and with surface perturbations and standard boundary and initial condition perturbations in red.

In Figure 8 spread and skill is shown (top row) and CRPS (bottom row) for the two experiments and the HarmonEPS control run, for both summer (left) and winter (right). It is striking to see that the experiment with only perturbing the surface, and no perturbations to lateral boundaries or initial conditions, actually gives larger spread than the control run of HarmonEPS. However, the best spread and skill relationship is obtained when we have a combination of perturbations to the boundaries, initial conditions and surface (red curve in Figure 8). For CRPS we seen an improvement in including surface perturbations for winter, but not for summer. The results are similar for relative humidity at 2 meters (not shown). For other parameters the impact of the surface perturbations are small (not shown). This work will continue, hopefully we can improve results also for other parameters by refining the surface perturbation code and/or by introducing new surface parameters to perturb.

More experiments have been run in HIRLAM predictability group, and some of them are listed in the application for this project, but they have not used SBUs from spnogeps, and therefore they are not reported here.

References:
Bouttier, F., L. Raynaud, O. Nuissier, and B. Ménétrier, 2015: Sensitivity of the AROME ensemble to initial and surface perturbations during HyMeX. *Quart. J. Roy . Meteor. Soc.*, **EARLY view,** doi:10.1002/qj.2622

List of publications/reports from the project with complete references

There are publications from experiments that are mentioned in the application, but they have not used this special project account, but national resources. So far none from the experiments reported here.

Summary of plans for the continuation of the project

(10 lines max)

GLAMEPS:
Work will continue to upgrade GLAMEPS to version 3:

HarmonEPS:
Many experiments are planned for HarmonEPS, and they are listed in the application for this special project. We focus on developing a system that members states can adapt and run on their home computers. We design a system where we try to account for know uncertainties in all aspects, that is in initial conditions, model, surface and boundaries.
It remains to be seen which of the listed experiments will be performed using spnogeps, and which will be performed using national resources