SPECIAL PROJECT PROGRESS REPORT

Reporting year	2016
Project Title:	Initial and lateral boundary perturbations for Convective Permitting Ensemble Prediction Systems
Computer Project Account:	spnokolt
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Name of ECMWF scientist(s) collaborating to the project	Not applicable
Start date of the project:	2016-01-01
Expected end date:	2017-12-31

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

		Previous year		Current year	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)			20M	19M (95%)
Data storage capacity	(Gbytes)			2500GB	0GB

Summary of project objectives

The aim of the project is to explore strategies for initial condition perturbations and lateral boundary conditions/perturbations for CPEPSs. The methods that will be tested are Scaled Lagged Average Forecasting (SLAF) and the use of perturbations based on IFS-ENS. A first goal is to establish the quality of the new HARMONIE version harmonie-40h1 with respect to the current operational one, harmonie-38h1.2.

Summary of results of the current year

Activity 1: Evaluation of the latest model cycle

The Harmonie system includes two main physical parameterization packages, AROME and ALARO and AROME is the one used in the operational deterministic runs within MetCoOp, the operational NWP cooperation between Norway and Sweden. ALARO may however be of interest to use as a way to increase the spread in an ensemble system. Since there is no operational reference the quality of ALARO has not been evaluated to the same extent as AROME within this study.

On major important change between the current operational version, harmonie-38h1, and the new one, harmonie-40h1, is the introduction of a new turbulence formulation, HARATU. The new scheme addresses the over prediction of wind, low clouds and fog experienced in the current version. In addition the new version brings some updates in radiation with smaller meteorological impact.

For the validation of AROME three periods have been tested as can bee seen in table 1. In summary we can conclude that 40h1 shows an improvement when it comes to wind speed and cloud cover and some degradation for especially winter time temperatures.

Table 1: Summary scores for important weather parameters for three month long periods. The scores shows the difference between 40h1 and 38h1 where + indicates an improvement, - a degradation and N no significant change.

Paramter at +24h	Summer 2014	Winter 2015	Autumn 2015
MSLP-bias	N	+	-
MSLP-stddv	N	N	N
V10m-bias	++	++	++
V10m-stddv	+	+	+
T2m-bias	-	++	+
T2m-stddv	N	-	+
Cloud-bias	+	++	++
Cloud-stddv	N	-	+
Precipitation freq bias	-	++	+

Activity 2: Best practise for initial and lateral boundary perturbations

The ensemble system used in MetCoOp is an offspring of harmonEPS developed within the HIRLAM programme. For simplicity we will hereafter refer to the system as MEPS as in MetCoOp EPS.

Data from IFS is used to create initial or boundary perturbations for MEPS. In this study we investigate two different ways of using the IFS data. In the IFS-ENS case we simply use the first 10 member and the initial perturbations are created by adding the differences of IFS-ENS control and a member to the analysis of the MEPS control member. The boundaries are used as is for each selected member. Since model level data is not archived for IFS-ENS we have been using a set of boundary data stored by GLAMEPS, the European EPS system run by the HIRLAM and ALADIN programmes.

In case of SLAF (Kalnay, 2003), the perturbation, initial or boundary, is created by taking HRES forecasts valid at the same time but with different forecast lengths and initial times.

$$I\_m = A\_c + K\_m * (IFS\_0 - IFS\_N)$$

Where I_m is the initial perturbation, A_c is the control analysis, K_m a scaling factor, IFS_0 is the latest available IFS forecast and N is the forecast length for an earlier forecast valid at the same time. The forecast lengths used for lagging is shown in table 2. The perturbation is scaled with K_m to get equally sized perturbations independent of forecast lengths and to have pairs of negative and positive perturbations. The method is attractive from an operational point of view since it doesn't require any extra boundary data to be transferred from ECMWF to in this case Swedish or Norwegian HPC resources.

A period from 20th July to 10th of August 2015 has been used to study the performance of MEPS using either IFS-ENS only or HRES with SLAF perturbations. A summary of the different experiments done can be seen in table 3. If we compare MEPS used with SLAF perturbations to IFS-ENS data we find a clear benefit of using SLAF in terms of the spread/skill relationship for T2M, RH2M, U10M and 12h precipitation, fig 1.

Looking more carefully on the distribution of the MEPS members using the SLAF perturbation a number of deficiencies were found. One is that the different perturbations had very different size in terms of their standard deviation. The absolute level of the perturbations is of course tunable but there should not be any differences between different members over time. This problem is addressed in the SLAF_rescale experiment where K_m is changed as shown in table 2. A part from equally sized perturbation the net effect is a more healthy spread-skill relationship for MSLP, fig 2. The second problem is the clustering between the different members using positive or negative perturbations seen in figure 3. Depending on the sign of K_m the members gather on either side of the mean. This can be understood by looking at the MSLP bias from IFS for the given period (not shown). Since IFS has a increasing bias over the forecast length used the same bias will be introduced through the perturbations. A cure of this problem is to use shorter forecast lengths and construct the perturbations by two consecutive forecasts 6 hours apart.

$$I\_m = A\_c + K\_m \, (IFS\_N - IFS\_N\text{-}6)$$

where IFS_N is a forecast with length N and IFS_N-6 is a 6h shorter forecast, both valid at the same time as the analysis. Naturally K_m has to be retuned again for each pair of members to retain the same size of perturbations. With this construction most of the clustering seen in figure 3 is gone as can bee seen in figure 4.

As an attempt to increase the spread of the ECMWF members the initial perturbations where scaled with a factor of 1.4. This number is not arbitrary but chosen so that the size of the perturbations should be of the same size as for the SLAF experiment. Hence, the difference in spread we see in MEPS does not differ due to differences in the size of the perturbations. On average the impact of this was very small, fig 5. Picking the first 10 IFS-ENS members may not be the best choice in terms of optimizing the ensemble spread. The member selection method developed by Montani (2011) was used to find the most representative members for each cycle. The clustering was targeted using wind, temperature and humidity from 850, 700 and 500 hPa for forecasts at 24 and 36h. In figure 5 we can see a small improvement in the spread for T2M and 12h precipitation but it's still less than with SLAF. For MSLP the spread becomes to large and it's clear that the choices of the levels used for clustering has to be revised.

One striking difference between the SLAF and the IFS-ENS experiments is the difference in T2M bias seen in figure 6. A map for the bias characteristics of MEPS using IFS-ENS data is shown in figure 7. It's clear the most of the cold bias seen is related to stations along the coast. A further examination shows that there are differences in the SST that can explain the differences.
For operational data SST from the analysis is used. Since the SST field is coded as missing data over land the field itself can be used as a land sea mask. For IFS-ENS data SST from each member has been used. In this case however SST is 0 degrees over land and the land sea mask algorithm doesn't work as intended.

Table 2: Scaling factor used for the different lags used in SLAF

LAG:	0	6	12	18	24
Original K:	0	+/- 1.75	+/- 1.5	+/- 1.25	+/- 1.0
Rescaled K:	0	+/- 1.75	+/- 1.35	+/- 1.10	+/- 0.8

Table 3: Experiment summary

Name	**Description**
SLAF_MetCoOp	Initial SLAF experiment
SLAF_rescale	As SLAF_MetCoOp but with rescaled perturbations
SLAF_6h	SLAF but with perturbations created with 6h differences
ECLBC_MetCoOp	Initial ECMWF-ENS experiment using first X members.
ECLBC_K14_MetCoOp	As ECLBC_MetCoOp but with rescaled perturbations
IFENS_clustering_fix	ECMWF-ENS boundaries select to maximize the spread.

Summary of plans for the continuation of the project

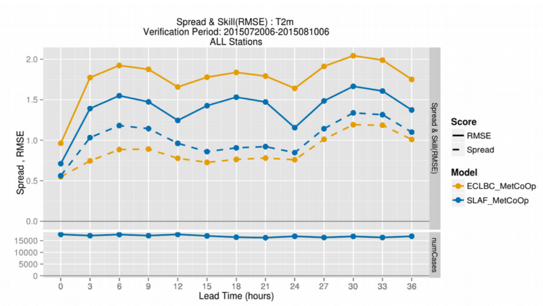
Given the problems found in the usage of SST it is still uncertain if we may conclude that SLAF is a better method than using pure or clustered IFS-ENS data. Further experimentation will be done with corrected interpolation methods. We will also run a more recent period which includes the updates done in CY41R1 for both the high resolution run and ENS.

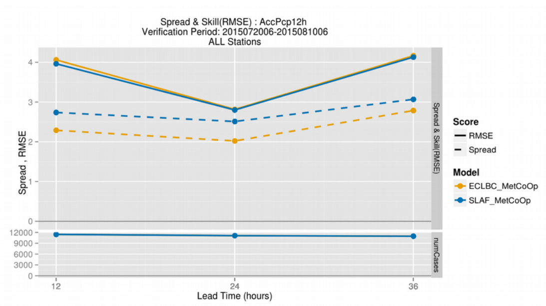
The choice of levels and forecast lengths used in the meber method will also be revisited to find a combination more suitable for a CPEPS such as MEPS.

References

Kalnay, E, 2003: Atmospheric modeling, data assimilation and predictability, Cambridge University Press, p237.

Montani, A., D. Cesari, C. Marsigli, and T. Paccagnella, 2011,
Seven years of activity in the field of mesoscale ensemble forecasting by the COSMO-LEPS system: main achievements and open challenges.Tellus, 63A, 605-624.





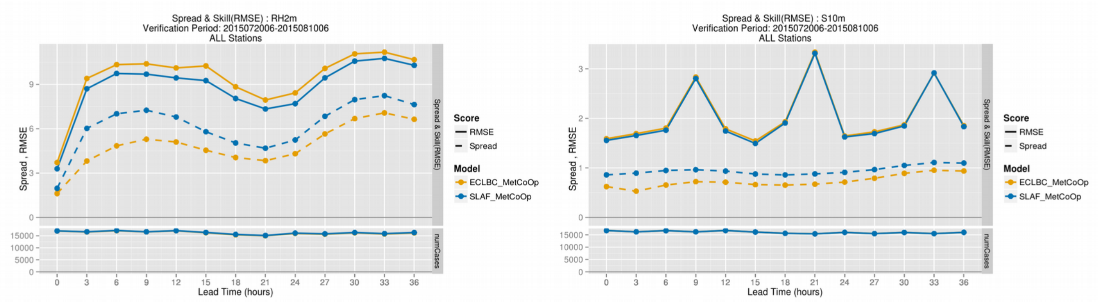


Figure 1: Skill (solid) and spread (dashed) for T2M, RH2M, U10M and 12h precipitation for MEPS using IFS-ENS (yellow) and HRES with SLAF (blue) data respectively.

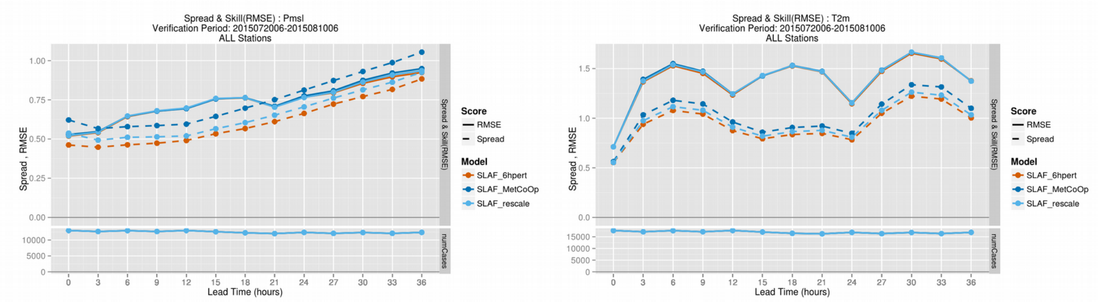


Figure 2: Skill (solid) and spread (dashed) for MSLP and T2M for three configuration of HRES SLAF experiments. Original setup SLAF_MetCoOp (dark blue), with rescaled K SLAF_rescale (light blue) and with updated pertubation formulation SLAF_6hpert (orange).

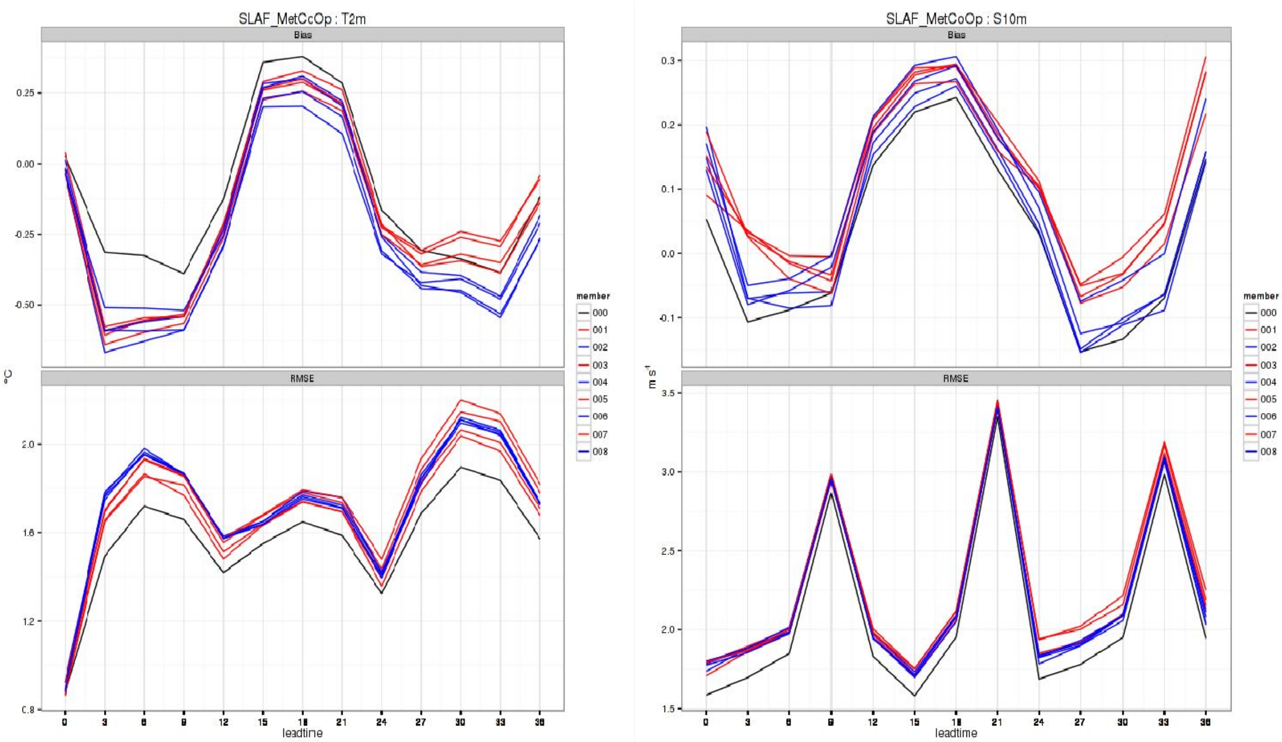


Figure 3: Bias (top) and RMSE (bottom) per ensemble member for T2M (left) and U10M (right) for original SLAF setup. Odd members has a positive K_m whereas even has a negative K_m.

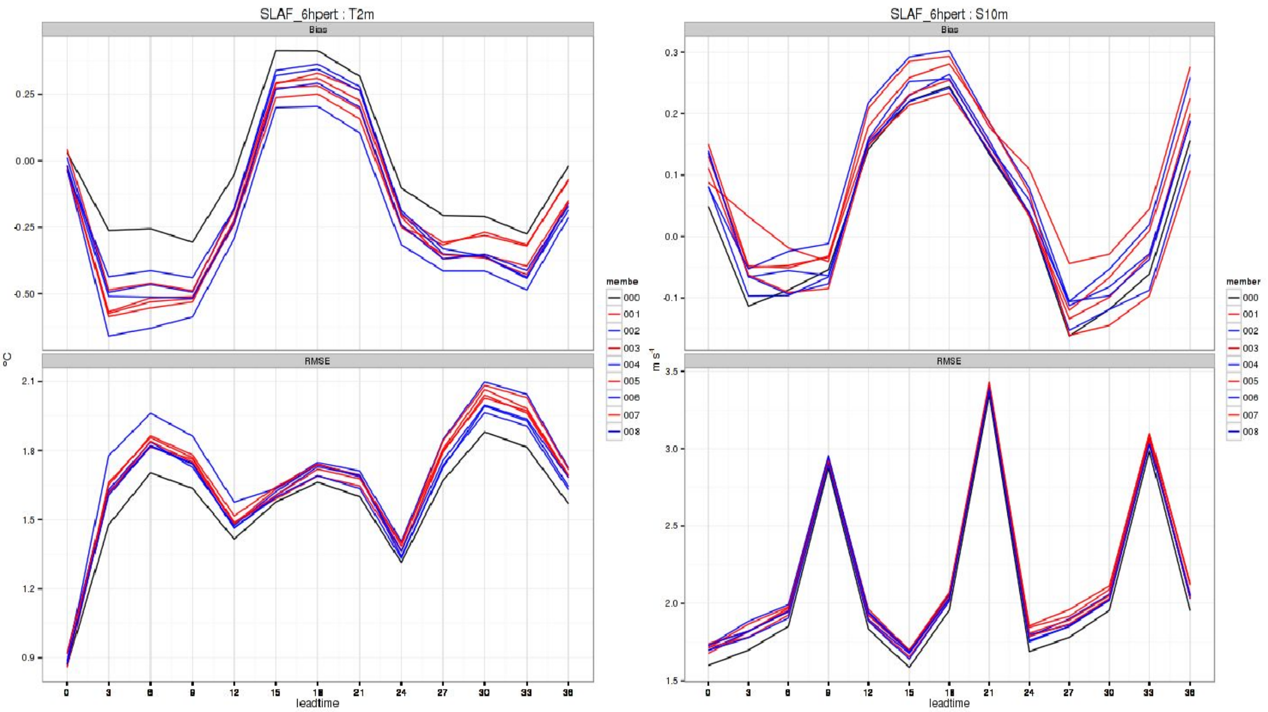


Figure 4: Bias (top) and RMSE (bottom) per ensemble member for T2M (left) and U10M (right) for SLAF setup using 6h forecast length differences for perturbations (SLAF_6hpert). Odd members has a positive K_m whereas even has a negative K_m.

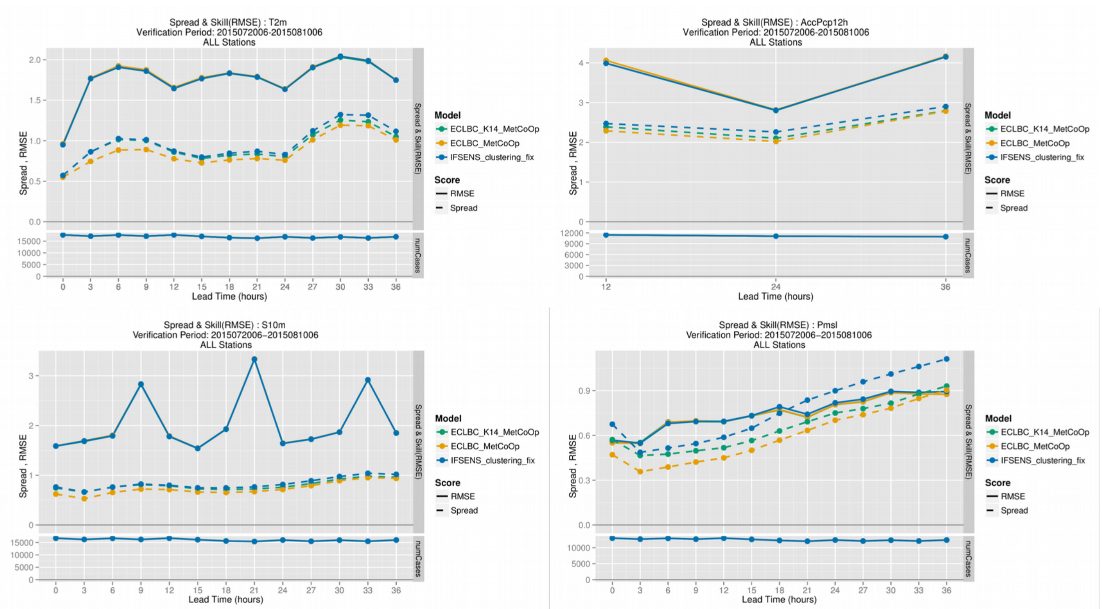


Figure 5: Skill (solid) and spread (dashed) for T2M, 12h precipitation, U10M and MSLP for MEPS using IFS-ENS boundaries. Original setup ECLBC_MetCoOp (yellow), with scaled perturbations ECLBC_K14_MetCoOp (green) and with member selection method IFSENS_clustering_fix (blue).

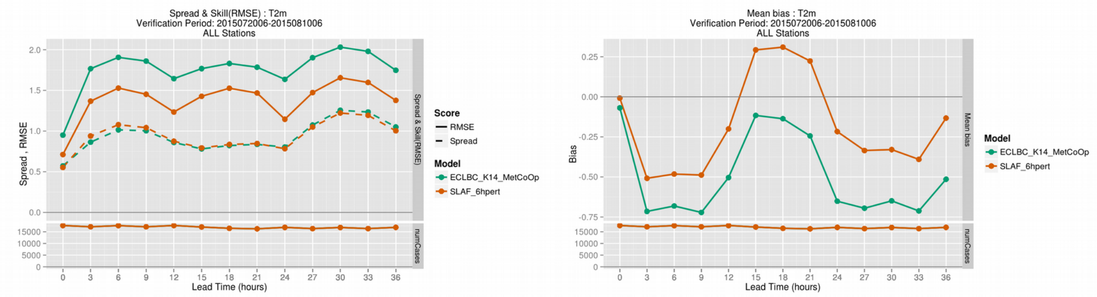


Figure 6: Left: Skill (solid) and spread (dashed) for T2M for MEPS using IFS-ENS (green) and using HRES SLAF (orange). Right: Average T2M bias for MEPS using IFS-ENS (green) and using HRES SLAF (orange).

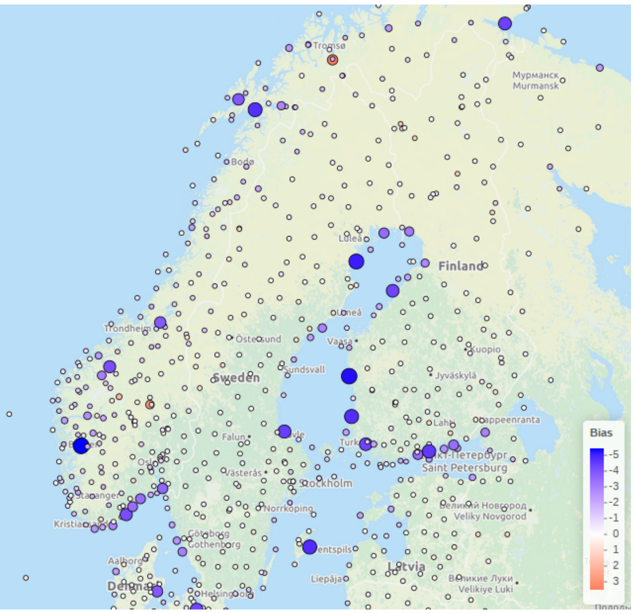


Figure 7: T2M bias characteristics for MEPS using IFS-ENS.