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	2017-2018
Project Title:	Testing perturbation of surface/soil conditions and of PBL for the prediction of thunderstorms and fog in the framework of the SRNWP-EPS Phase II Project.
Computer Project Account:	spitsrep
Principal Investigator(s):	Chiara Marsigli
Affiliation:	Arpae SIMC
Name of ECMWF scientist(s) collaborating to the project (if applicable)	……………………………………………………….…… ……………………………………………………….……
Start date of the project:	November 2016
Expected end date:	December 2018

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)	9 M	5 M	9 M	10 M
Data storage capacity	(Gbytes)				

Summary of project objectives
(10 lines max)

The aim of the of this Project is to study the sensitivity of convection-permitting ensemble prediction systems to soil conditions and PBL modeling in the prediction of selected phenomena (fog and thunderstorms), in the framework of the SRNWP-EPS II Project.
Each participant to the Research Task of the project tests the impact of their own perturbation method(s) on their own ensemble system and on their own domain. The common focus on the selected weather phenomena (mainly thunderstorms and fog) provides the common basis of this work, allowing a meaningful exchange of the results obtained.
This is achieved through a test of the perturbations on two periods long enough to permit some statistical evaluation and including events relative to the selected weather phenomena.
This Special Project is aimed at executing the ensemble runs which are needed for the tests by a group of Participants: Italy, Norway, Spain and Sweden.

Summary of problems encountered (if any)
(20 lines max)

The SBU asked for the year 2016 have been not used entirely due to the time needed to perform the runs of the experiments. MetCoOp and Italy have used 2/3 of the available SBU, while AEMET did not manage to run the experiments in the first year.
The SBU asked for the year 2017 were completely used to run the experiments by AEMET, due to a mistake in the accounting selection on their side. For this reason, Arpae has then run the experiments on SBU provided from the Spanish accounting and Norway-Sweden cooperation has run the experiments on their own internal machines.
For this reason the report is very similar to the one of the previous year for Norway-Sweden and Arpae (no SBU provided by this project were used by them in 2017).

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

During the first year of the project (2016, November and December) experiments have been run on the ECMWF supercomputer, thank to the SBUs provided by the present Special Project, by two groups: MetCoOp and Italy. In the first half of 2017, instead, experiments have been run by AEMET (Spain).
In the second half of 2017 the SBUs provided by the project has been used by AEMET to run their experiments, while Italy has run the experiments on Spanish SBUs. MetCoOp has run the experiments on internal machines.

MetCoOp

MetCoOp (the cooperation between Norway, Sweden and Finland) have in the context of the SRNWP-EPS Phase II project used computer resources from this special project for testing the impact on fog by perturbing a parameter in the turbulence scheme (HARATU) that represents the transport term of TKE, influencing the top entrainment and with it the clouds. For this we used the convection permitting ensemble prediction system HarmonEPS. The set up was 10+1 ensemble members at 2.5 km horizontal resolution for a two week period in spring 2016 with interesting cases of fog. Perturbing this parameter gave a small, positive improvement on the probabilistic scores compared to a reference experiment without perturbing this parameter. This experiment was reported more extensively in last spitsreps report for 2016-2017 but being this the final report of the project is added also here.

MetCoOp’s fraction of the SBUs for this project has been used for running one experiment where a parameter that represents the transport term of TKE, influencing the top entrainment and with it the

clouds, in the turbulence scheme (HARATU) is perturbed. In this first experiment the parameter is randomly perturbed for each member and each cycle, but kept constant in time and space. In later experimentations we have included one more parameter and also a spatio-temporal correlation pattern for the perturbations.
Extensive experiments with surface perturbations have been carried out, but that is not reported here as that has used SBUs from national resources.

This used resources from another special project (spnogep) and is therefore reported for that project.

The period chosen was 30 May - 15 June 2016, and the area was the MetCoOp domain, see figure below.

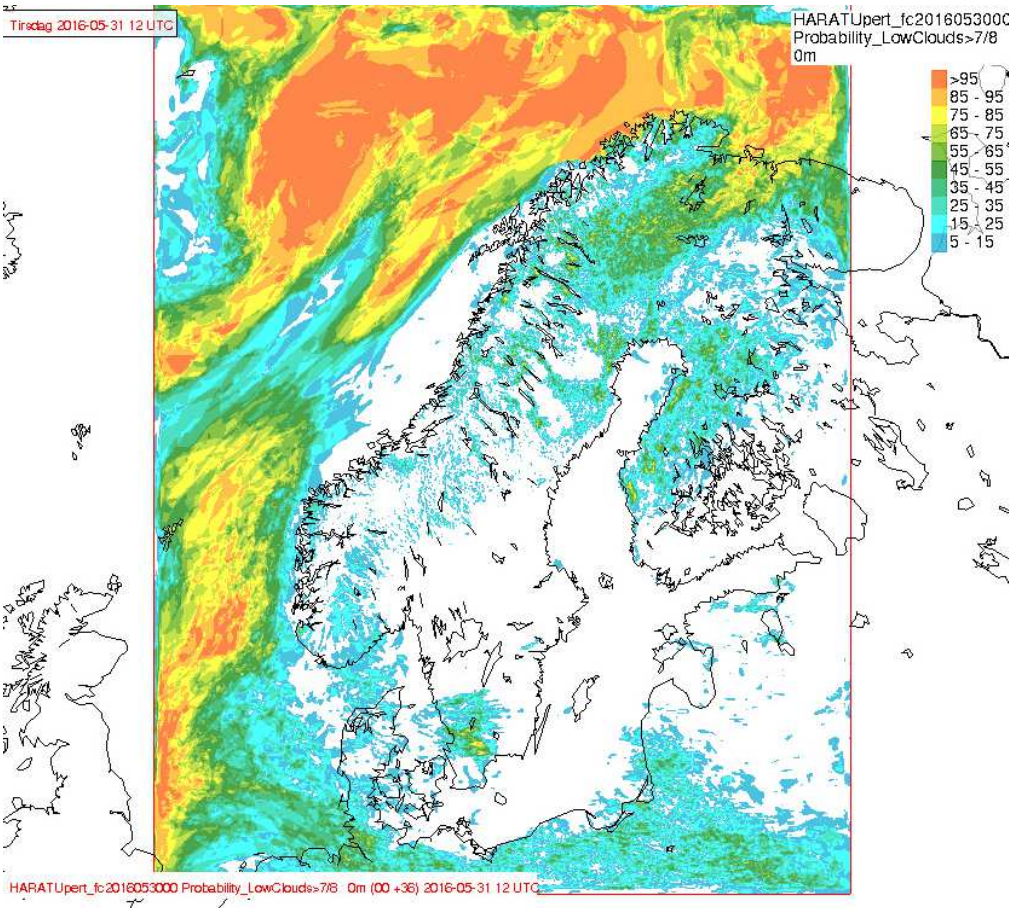


Figure: MetCoOp area used in the experiment. Show is the probability of low clouds from the perturbed experiment for 30 May 2016.

All members have three hourly cycling, but only 00 run was run until +36 h. This period was chosen because it included many cases of thunderstorms in Sweden and Norway, and also interesting cases of fog. The parameter perturbed in the experiment described here is expected to have most influence on fog and low clouds.
A reference run without perturbing this parameter was run on a different account.
In the figure below the Continuous Rank Probability Score (CRPS) for low clouds is shown for the perturbed (blue) and unperturbed (black) runs with HarmonEPS. Note that the score is negatively oriented. The difference is small, but there is a tendency that the perturbed run scores better for night-time, and worse for day-time for day 2.

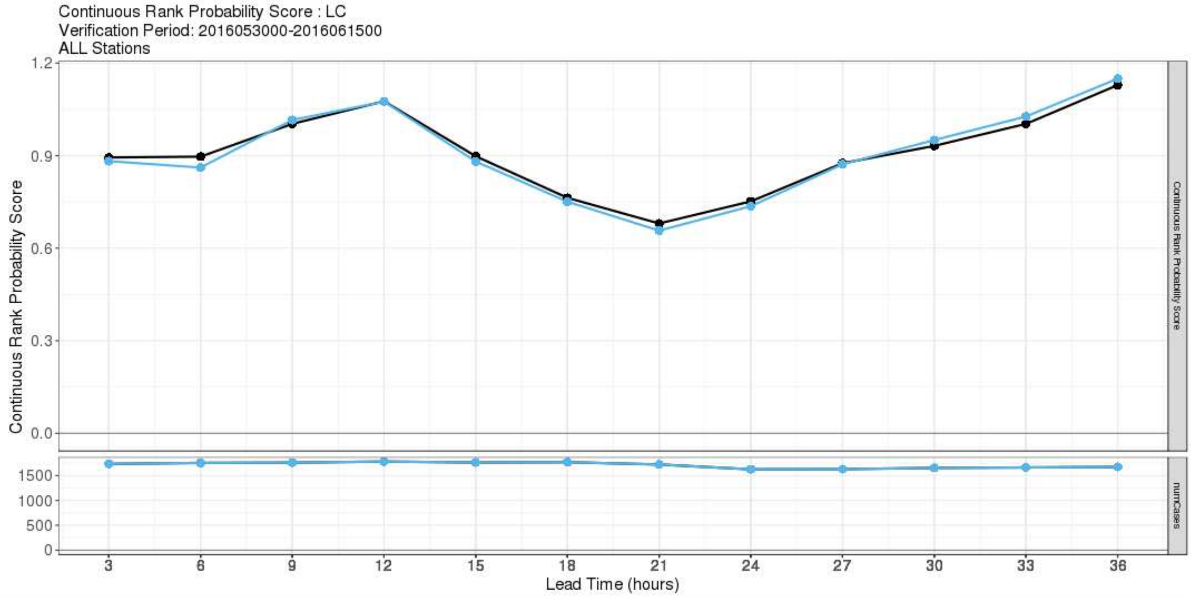


Figure: CRPS for low clouds. Perturbed run (blue), reference run (black).

The economic value is in the figure below for 6h lead time and for the threshold of 0 oktas (no low clouds), and here there is a small improvement of the perturbed experiment. However, the difference between the perturbed and unperturbed runs is in general small.

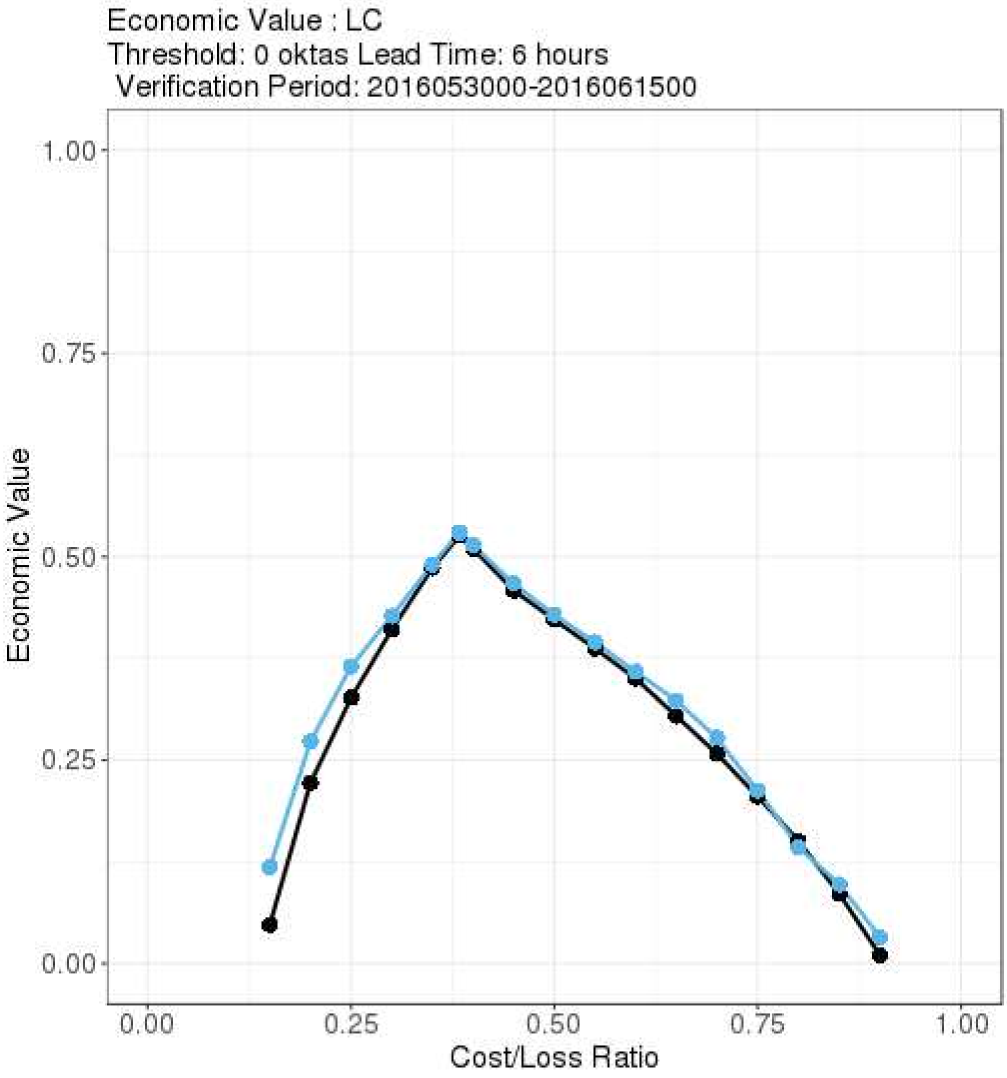


Figure: Economic value as a function of cost-loss ratio. Perturbed run (blue), reference run (black).

The work on parameter perturbations in HarmonEPS will continue with more parameters, and also utilizing a spatio-temporal correlation pattern.

Also in the context of SRNWP-EPS Phase II project, although not using spitsreps SBUs, we have continued the work with uncertain parameters in HarmonEPS, by including 2 different spatio-temporal patterns and more parameters. Extensive testing to find optimal scales (both spatial and temporal) have been carried out, as well as finding optimal perturbation sizes for the parameters. Experiments with surface perturbation scheme in HarmonEPS has also been done within SRNWP-EPS Phase II project, but not with spitsreps SBUs.

Arpae-COMET

In Italy, Arpae SIMC has put in operations the COSMO-2I-EPS ensemble (called COSMO-IT-EPS in its experimental phase). The ensemble is based on the COSMO model, run at 2.2 km (explicit convection), with 65 vertical levels, over Italy. The ensemble has 20 members (10 in the experimental phase), which receive Boundary Conditions from COSMO-ME-EPS, the 10-km ensemble over the Mediterranean area run by COMET.
COSMO-2I-EPS receives ICs from an ensemble data assimilation cycle, using the LETKF scheme developed in the COSMO Consortium (KENDA). The KENDA system has been implemented at ECMWF for testing thanks to the SPITCONV SP (still on-going), where most of the experimentation takes place.
In the future COSMO-2I-EPS will benefit also of model perturbations. Thanks to the same SPITCONV SP, different configurations of the model perturbations have been tested, on the basis of which it has been decided to use in the ensemble a combination of SPPT and physics parameter perturbation.
Currently, no model perturbations are applied in the operational suite.

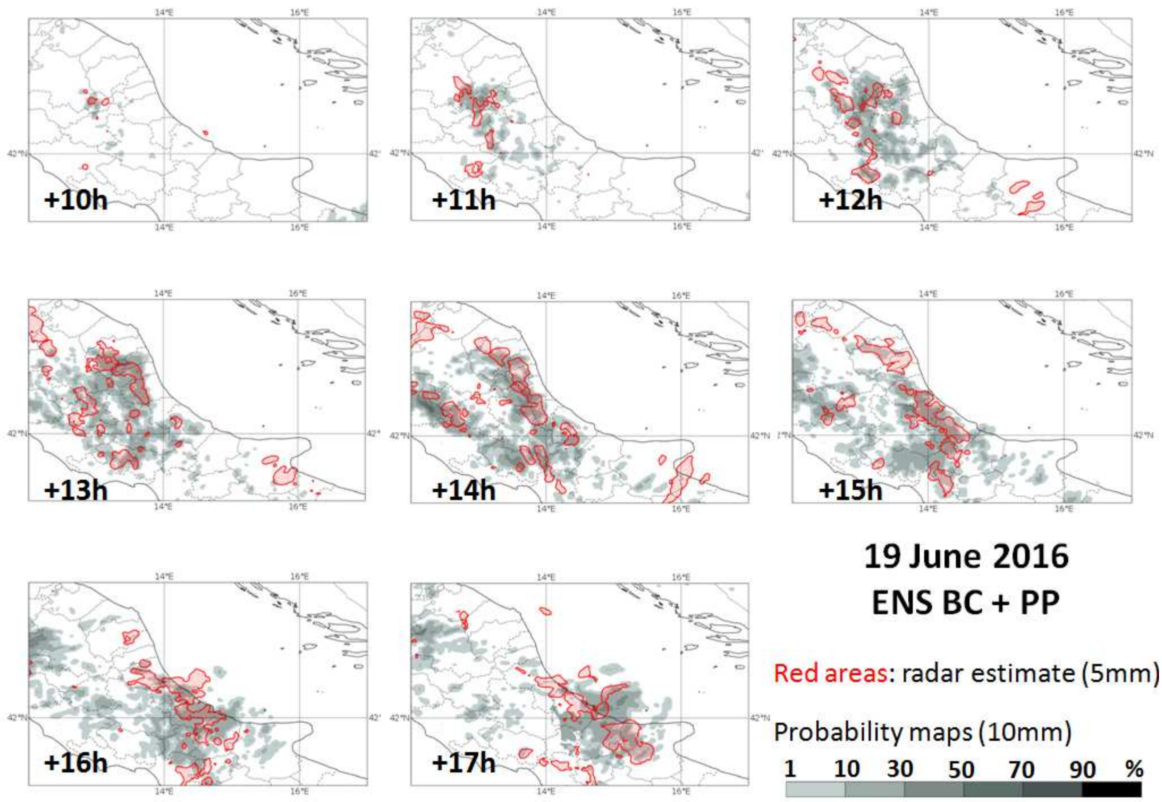
At the end of 2016, the SBUs provided by the present SP SPITSREP have been used to run the COSMO-IT-EPS ensemble on one of the two test period chosen by Italy in the framework of the PBL and soil perturbation testing of the SRNWP-EPS II Project of EUMETNET.
The two periods are respectively characterised by the two types of phenomena object to study in the project: thunderstorms and fog. The thunderstorm period has been defined from 18 June 2016 to 8 July 2016. The fog period is a collection of sub-periods, including several fog episodes (December 2016, February 2017, March 2017).
The experiment carried out at the end of 2016 (which has used 2 M SBUs) has been focussed on the thunderstorm period. The COSMO-IT-EPS ensemble has been run for the entire period (20160618-20160708), with ICs and BCs from ECMWF ENS, in order to test the model perturbations which have been selected for influencing the prediction of the thunderstorms.
In particular, SPPT has been combined with perturbation of parameters, as described above. The selected parameters belong to different physics schemes and are shown in the table below.

member	tur_len	rlam_heat	cloud_num	entr_sc	pat_len	crsmin	thhmin
1	150	1	5.00e+08	0.0003	500	150	0.4
2	150	1	5.00e+07	0.0003	500	150	0.4
3	150	1	5.00e+08	0.0003	500	200	0.4
4	150	1	5.00e+08	0.002	500	150	0.4
5	500	1	5.00e+08	0.0003	500	150	0.4
6	150	0.1	5.00e+08	0.0003	500	150	0.4
7	150	1	5.00e+08	0.0003	1000	150	0.4
8	150	1	5.00e+08	0.0003	500	500	0.2
9	150	1	5.00e+08	0.0003	500	150	0.7
10	150	1	5.00e+07	0.002	500	150	0.4

The parameters are:

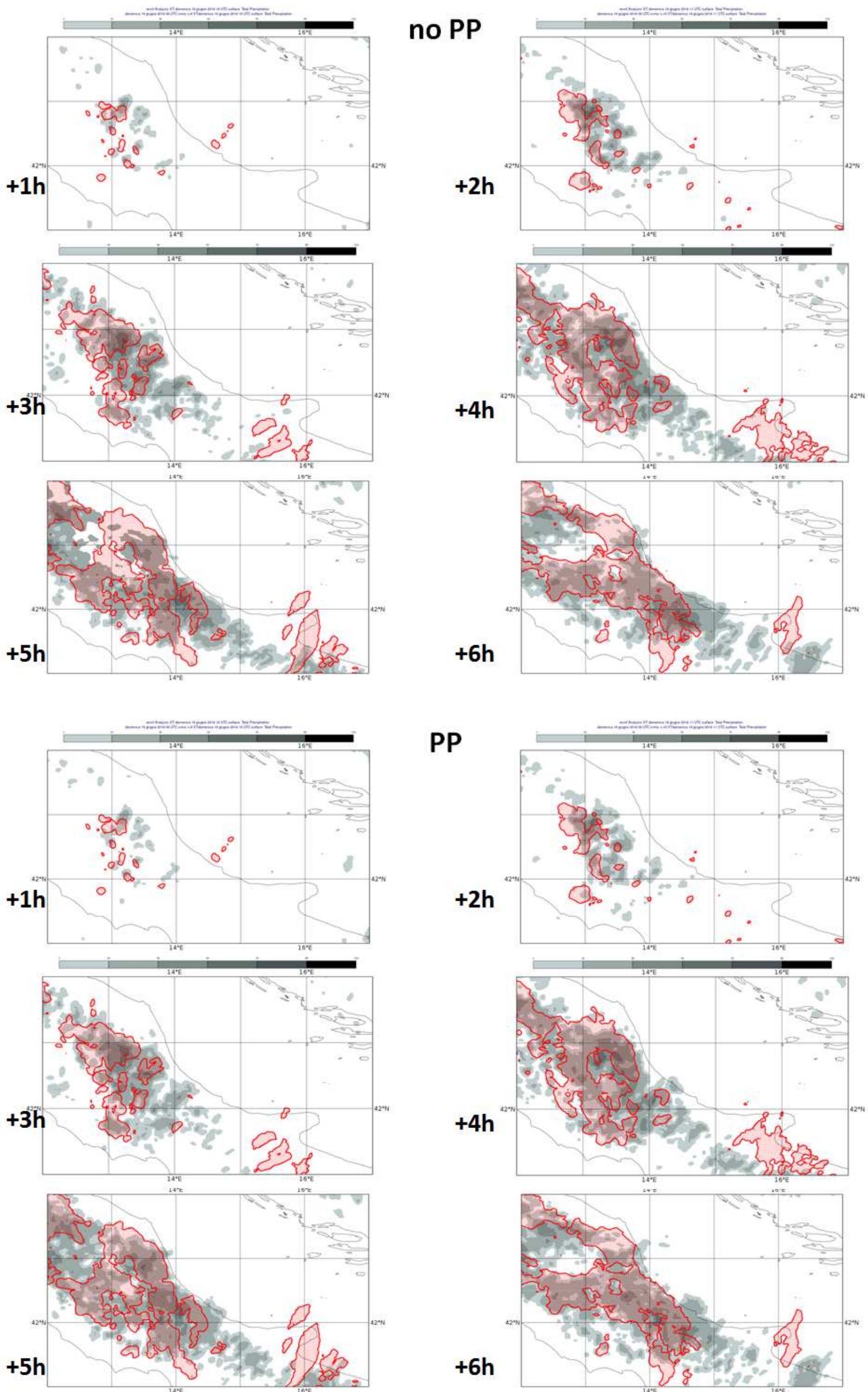
- tur_len: maximal turbulent length scale (m)
- rlam_heat: scaling factor for the thickness of the laminar boundary layer for heat
- cloud_num: cloud droplet number concentration
- entr_sc: mean entrainment rate for shallow convection
- pat_len: length scale (m) of sub-scale surface patterns over land
- crsmin: minimum value of stomatal resistance
- tkhmin and tkmmin: minimal diffusion coefficients for heat (h) and momentum (m)

As an example of the ability of the ensemble in forecasting the onset of a thunderstorm, the case of the 19th of June 2016 is shown, where thunderstorms developed on the Central Apennine. Probability mapes of hourly precipitation exceeding 10 mm / 1h are shown (shaded gray) with superimposed a red contour relative to the 5 mm / 1h as estimated from the Italian radar composite for the same hour. The difference in the chosen thresholds is due to an observed tendency of the radar composite to underestimate the rainfall in this case.



The forecast is not perfect, but the start position of the phenomenon is well kept and the main area of evolution is forecasted by the ensemble with reasonable approximation.

In the following two figures, the hourly probability maps for the first 6 hours of the same events are shown, in two different ensemble configurations: the upper (no PP) in which only a downscaling is performed without adding any physics perturbations, the lower (PP) in which parameter perturbations (see description above) is applied. Here probabilities are relative to the exceedance of 5 mm / 1h, in order to have broader structures, and the radar contour is relative to the 1 mm / 1h threshold.
Small differences can be noticed, with a slightly better signal for the PP ensemble as area coverage, but the main outcome is that the PP method does not influence significantly the performance of the ensemble for this case.



In 2017 new experiments have been made, where the COSMO-IT-EPS ensemble receives the BCs from COSMO-ME-EPS. This is a 40 members ensemble, based on the COSMO model run at 10 km, with BCs from ECMWF ENS and ICs from a LETKF developed by COMET. This setup for the BC is the same followed by the ensemble now operational.

In 2017, different experiments were run, aiming at assessing both the role of perturbed ICs from KENDA and the role of model perturbations (method of Parameter Perturbation). A list of the experiments is here provided:

- Period: 19th of June 2018 to 6th of July 2018
- Runs only of the days with thunderstorms somewhere in the domain (Italy)
- Starting day of the runs (8 events):
    - 19/06 (Central Italy, Apennines)

- 20/06 (Marche region)
- 23/06 (south-east Italy, Basilicata-Puglia region)
- 25/06 (Piemonte region)
- 26/06 (north-east Italy, Friuli region)
- 02/07 (northern Italy, Alps)
- 05/07 (north-east Italy, including Emilia-Romagna)
- 06/07 (Central Italy, including Emilia-Romagna)

- Each day a run of the ensemble was started at 00 UTC, for 48 h, 10 members, 2.2 km, 65 vertical levels
- Configurations:
  - **noPP**: Downscaling from COSMO-ME-EPS, no physics perturbations
  - **PP**: Downscaling from COSMO-ME-EPS, physics perturbations (Parameter Perturbation)
  - **kendaIC_PP**: Initial conditions from the KENDA analyses, physics perturbations (Parameter Perturbation)
- In order to have the initial conditions from the KENDA analyses, a KENDA cycle has also been run, with 20 members and 3-hourly cycles. Conventional observations (SYNOP, TEMP, AIREP) have been assimilated, together with a Latent Heat Nudging of the surface rain rate estimated by the Italian radar network. The assimilation has been run from 19th of June 2018 at 00 UTC to 8th of July 2018 at 00 UTC.

Actually the SBUs to run these experiments (3 M SBUs) were not provided in 2017 by the spitsrep account, since the SBUs were all used by AEMET. Instead, the Spanish colleagues on the account ESEXTERN had provided the needed 3 M SBUs.
In additions, in order to carry out the whole set of experiments, SBUs provided by the Italian Special Project SPITCONV were also used. Therefore the results will be described in the report of that SP.

AEMET

In Spain, AEMET, as a member of the HIRLAM Consortium, runs the convection-permitting high-resolution non-hydrostatic Harmonie-AROME model on a daily basis in their high-performance computing facilities sited in Madrid (Spain).

In the framework of the SRNWP-EPS Project, AEMET decided to run a battery of selected case studies of severe weather that took place over the Iberian Peninsula during the winter season of 2016/2017, the spring season of 2017 and the summer season of 2017.

The final goal was to define optimal surface perturbation strategies for convection-permitting EPS.

The starting points of our investigations were as follows:
- LAMs involve many surface variables and processes. The contribution of each to forecast uncertainty is not well known.
- Barthlott and Kalthoff (2011) showed that convection-permitting forecasts can be sensitive to certain surface fields (e.g. soil moisture).
- It is not clear which surface parameters should be perturbed.
- These parameters are not necessarily the same as the ones identified in lower resolution ensembles (Lavaysse et al., 2013) because the scales and forecast ranges are different.

In order to answer these questions, perturbations have been introduced to capture the major sources of uncertainty in the numerical simulation of surface and subsoil processes. On top, we wanted to study the sensitivity of EPS performance to the combination of different perturbation methodologies (ICs, model error, soil and subsoil fields), taking into account their mutual interactions.

Ensemble configuration

Experiments on surface perturbations have been carried out with the Ensemble Prediction System based on the Harmonie-AROME model: harmonEPS.
Detailed information about the Harmonie-AROME model can be found in the publication: "The HARMONIE-AROME model configuration in the ALADIN-HIRLAM NWP system", which describes the forecast model configuration used in the Reference System (Cy40h1) configuration and it can be accessed at:
http://journals.ametsoc.org/doi/abs/10.1175/MWR-D-16-0417.1.

The model setup and other options for the configuration of the harmonEPS are listed in Table 1.

Table 1: EPS used for the set of experiments based on the Harmonie-AROME model.

Model Setup	**Harmonie-40h1.1** 2.5 km grid spacing 65 vertical levels Same domain for all members AROME Physics
Assimilation	3h 3DVAR for the control member 3h CANARI+OI for the control member 6h CANARI+OI for all members
Forecast Length	3h at 03, 09, 15 and 21 for the control member 36h at 00, 06, 12 and 18 for the control member 36h at 00, 06, 12 and 18 for all members
Perturbation	Initial and boundary perturbations from IFS-ECMWF forecasts (SLAF6h)
Members	1 control member [mbr000] + 10 perturbed members

Experiments on the perturbation of surface fields have been carried out. The perturbation pattern generation is based on the Direct Surface Perturbation Scheme (Bouttier, F., Raynaud, L., Nuissier, O. and Ménétrier, B. (2015): Sensitivity of the AROME ensemble to initial and surface perturbations during HyMeX. Q.J.R. Meteorol. Soc. doi: 10.1002/qj.2622.), implemented on HarmonEPS-40h1.1.

Here is provided a brief description of the procedure:

- The model grid is filled with white noise (uniformly disturbed random number between 0 and 1).

- Spatially smoothed by repeated application of a recursive low-pass filter in both grid directions until a pre-defined correlation length scale is achieved (default ~300 km, 10 iterations).
- After smoothing, the pattern is clipped to have max/min value of ± specified value.
- Perturbation fields are rescaled and clipped with spatially constant values that are tuned for each parameter: the perturbation standard deviations are roughly consistent with the precision at which the surface parameters are known and perturbed values are clipped to constrain them to realistic values.
- The perturbation field is applied either additively or multiplicatively depending on the parameter.

AEMET decided to perturb the Sea Surface Temperature in such a way:

Perturbation	**Parameter**	**Output to SURFEX**	**Std. dev. (+/-)**	**Clip Min.**	**Clip Max.**
SST	SST	SST	1.5+	272 K	350 K

Every case study is formed by a reference run and a set of perturbed sea surface temperature experiments of an ensemble prediction system composed by 10 ensemble members plus a control member, so it needs high quantity of CPU resources and it takes long time to run it.

For this reason, case studies have been at the High Performance Computing Facilities (HPCF) of the ECMWF on the account of the SPITSREP Project.

Perturbation Pattern Generation

The model grid is filled with white noise (uniformly distributed random numbers between 0 and 1), which is spatially smoothed by repeated application of a recursive low pass filter in both grid directions until a pre-defined correlation length scale is achieved (default ~ 300 km, 10 iterations). Perturbation field then is re-scaled with spatially constant values (standard deviation is roughly consistent with the precision at which the surface field is known).
Finally, perturbation field is clipped to constrain it to realistic values. No perturbation is applied where the parameter value is already outside the max and min clipping values.

Next figure shows the structure of the perturbation pattern for the Sea Surface Temperature.

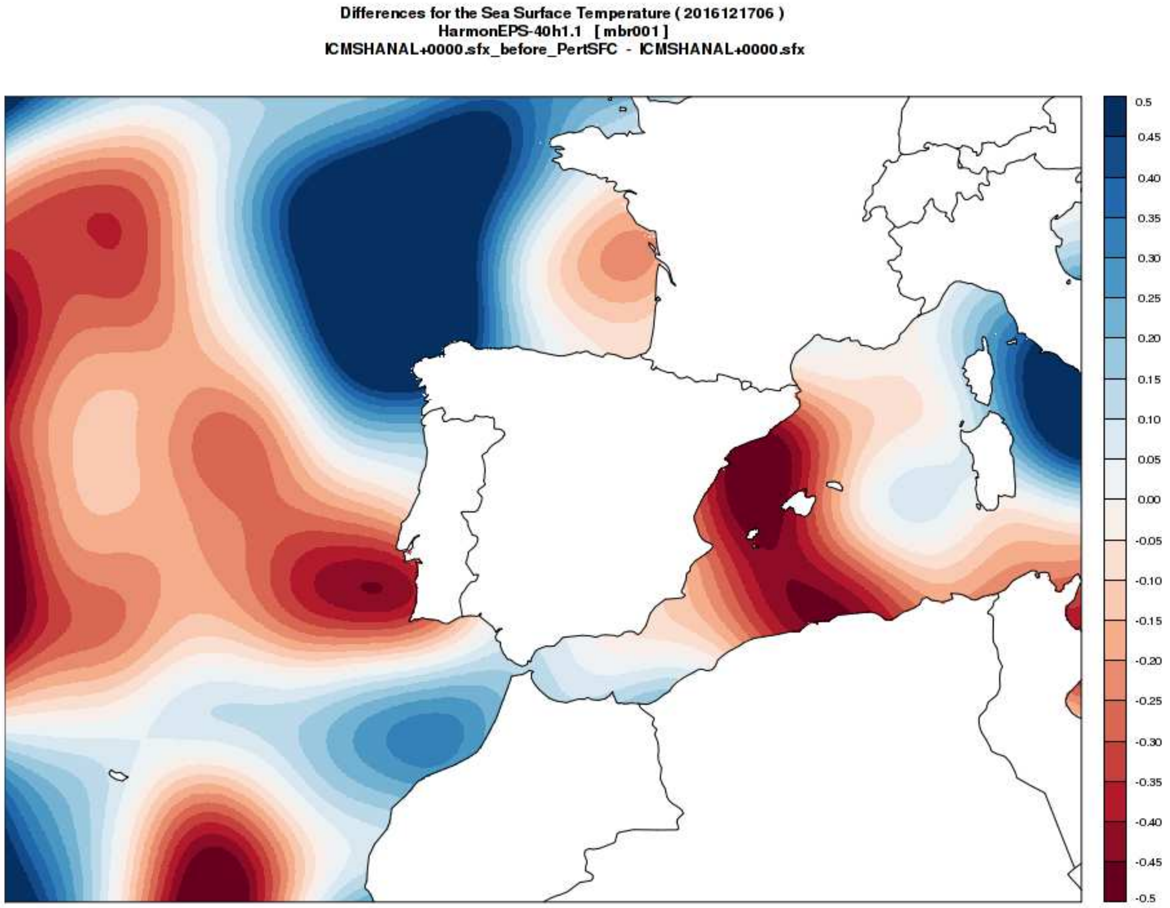


Figure 1: Perturbation pattern for the Sea Surface Temperature.

Next figure shows an example of the analysis for an individual member once the perturbation is applied for the Sea Surface Temperature. Each perturbation is applied to the analysis after the surface data assimilation. It should be noticed how the gradient changes alongside the coast of France and Spain and also in the Western Mediterranean.

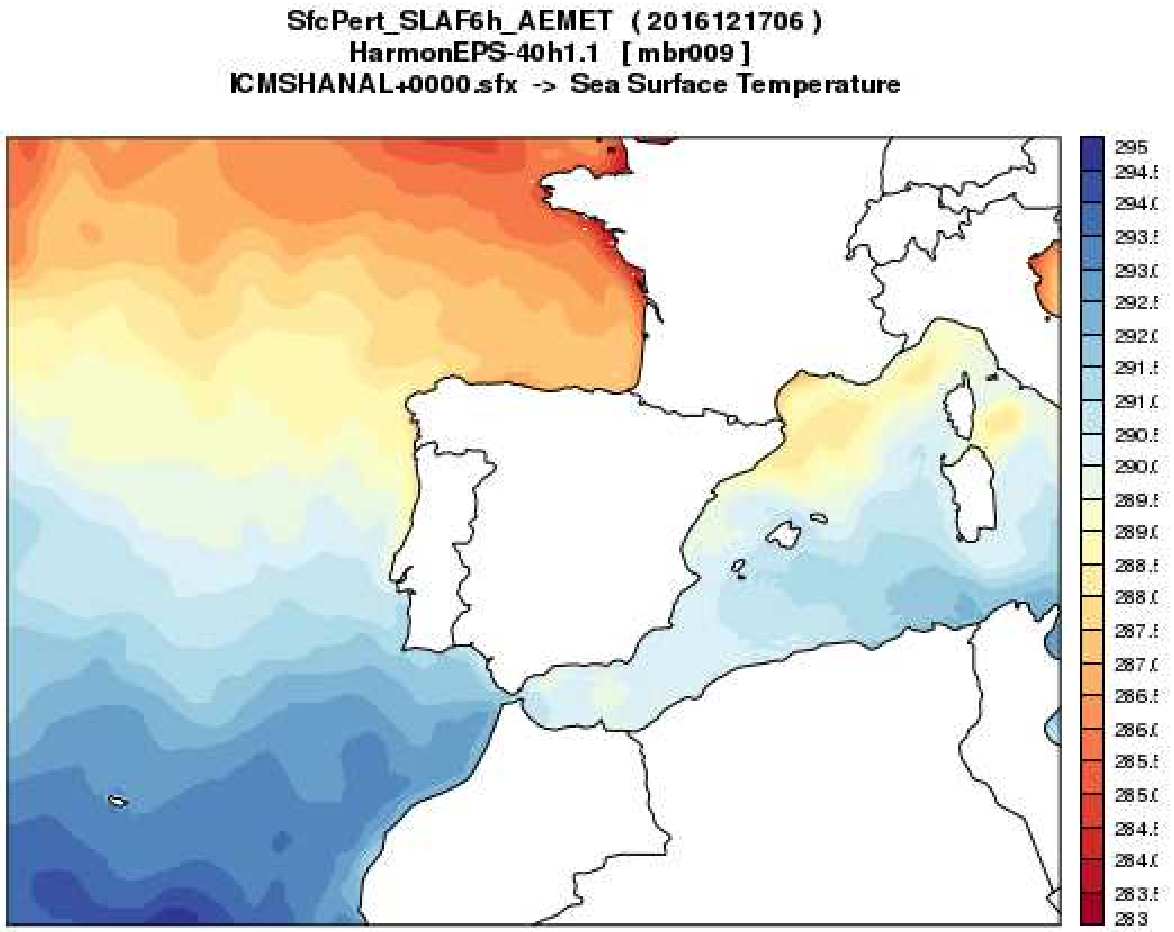


Figure 2: Analysis for an ensemble member once the perturbation pattern was applied.

Experiments

1. ***First Experiments:***

SLAF6h_AEMET [Reference]:

- SLAF IC and BC perturbations: 1 control member + 10 members.
- 3DVAR upper-air data assimilation on the control member with 3h cycling.
- CANARI+OI surface data assimilation on the control member with 3h cycling.
- CANARI+OI surface data assimilation for all members with 6h cycling.

SfcPert_AEMET – as Reference, except:

- No IC and BC perturbations.
- Surface perturbations applied after surface data assimilation.

SfcPert_SLAF6h_AEMET – as Reference , except:

- Surface perturbations applied after surface data assimilation.

2. ***Sensitivity to the Correlation Length Scale:***

SfcPert_SST300km_SLAF6h_AEMET [Reference]:

- SLAF IC and BC perturbations: 1 control member + 10 members.

- 3DVAR upper-air data assimilation on the control member with 3h cycling.
- CANARI+OI surface data assimilation on the control member with 3h cycling.
- CANARI+OI surface data assimilation for all members with 6h cycling.
- Sea Surface perturbation with 300 km correlation length scale.

SfcPert_SST150km_SLAF6h_AEMET – as Reference, except:

- Sea Surface perturbation with 150 km correlation length scale.

3. ***Sensitivity to the Clipping Value and the SST Standard Deviation:***

SfcPert_SST300km_SLAF6h_AEMET [Reference]:

- SLAF IC and BC perturbations: 1 control member + 10 members.
- 3DVAR upper-air data assimilation on the control member with 3h cycling.
- CANARI+OI surface data assimilation on the control member with 3h cycling.
- CANARI+OI surface data assimilation for all members with 6h cycling.
- Sea Surface perturbation with 300 km correlation length scale.

SfcPert_SST150km_SLAF6h_AEMET – as Reference, except:

- Sea Surface perturbation with 150 km correlation length scale.

Case Study 1: 16-20 December 2016

A severe weather episode hit the eastern/south-eastern coast of Spain with persistent rains, strong eastern winds and floods leading to material damages and casualties. Daily precipitation amounts higher than 200 mm were recorded over some places.

Negligible impact on T2m, Pmsl and 10m Wind Speed but with Surface Perturbations the spread was increased as well as a slight improvement on the error for RH2m were observed (Figure 3).

When perturbing only the Sea Surface Temperature, negligible impact for the T2m was observed. Varying the clipping value and the standard deviation causes an impact on RH2m, Pmsl and 10m Wind Speed up to the 24h forecast length but in a different way: worst for RH2m and better for Pmsl and 10m Wind Speed (Figure 4).

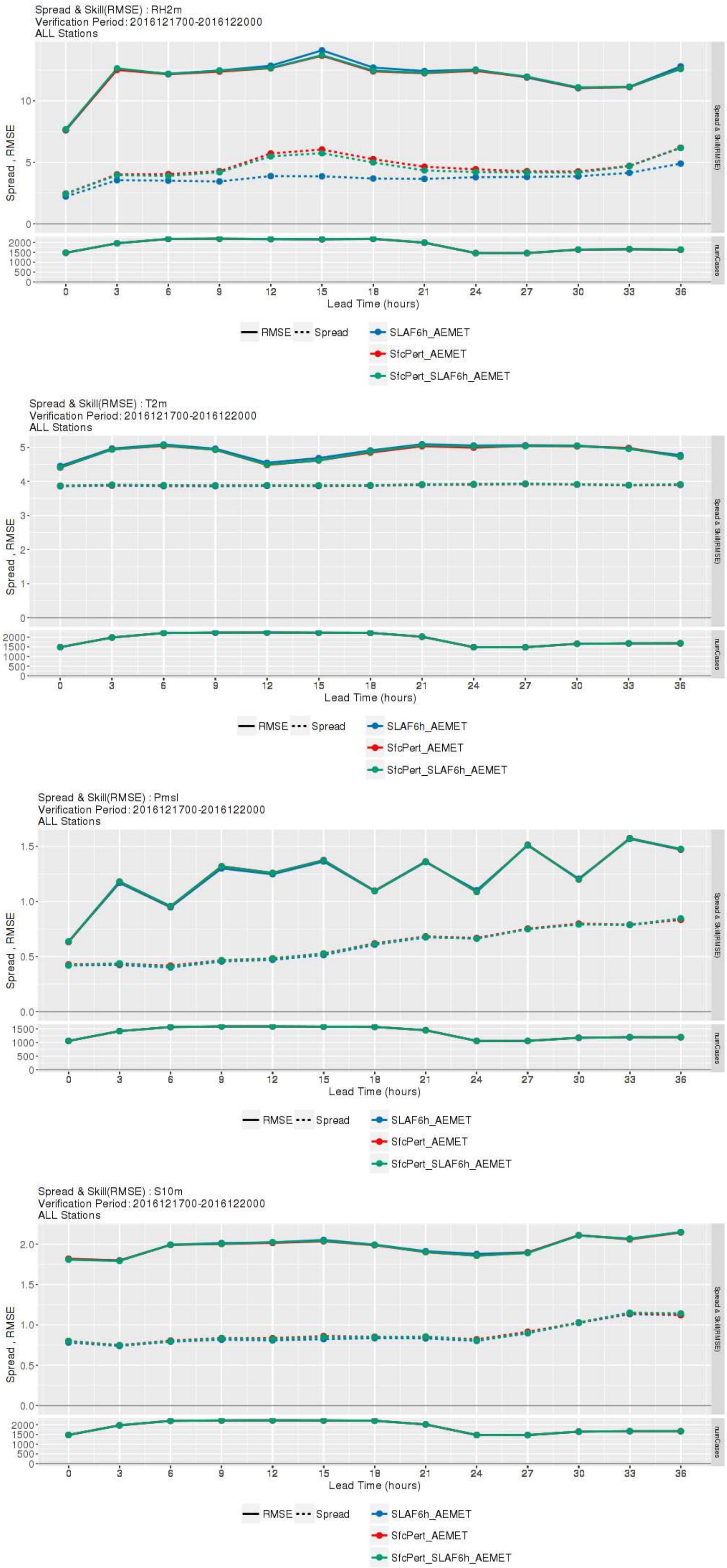


Figure 3: The spread/skill versus the forecast length plots are shown for the T2m, RH2m, 10m Wind Speed and Pmsl. Only SLAF in blue, only Surface Perturbations in red and SLAF along with Surface Perturbations in green.

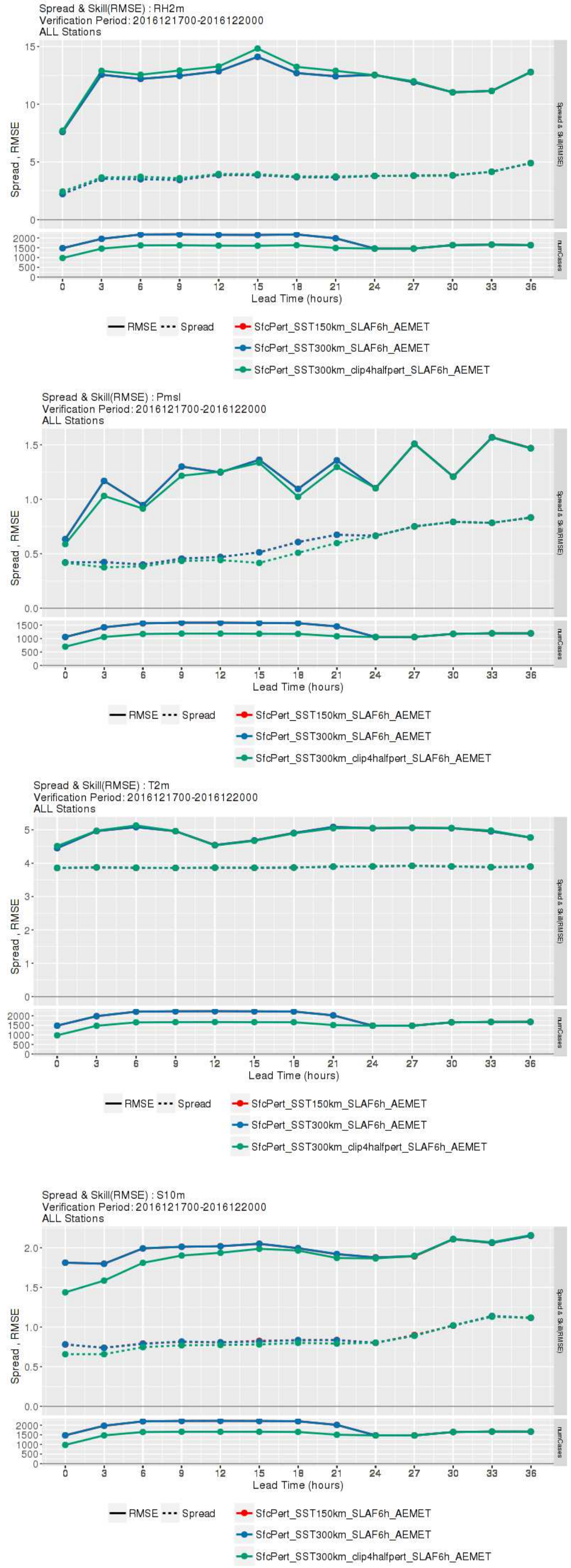


Figure 4: The spread/skill versus the forecast length plots are shown for the T2m, RH2m, 10m Wind Speed and Pmsl. The reference run in blue, reducing the correlation length scale in red and increasing the clipping value as well as halving the standard deviation in green.

Case Study 2: 19 February 2017

The second case study took place in February 2017 over the southern Spain focusing on the city of Málaga. Note the high 10-minutes intensities. The main feature of this episode is the fact that heavy rains were placed at a very local scale, so significant differences on the precipitation amount were observed over some places of the city. Summarizing the verification scores for this episode, we can observe a better spread with Surface Perturbations on RH2m although a worst error than just SLAF and negligible impact on the rest of variables (Figure 5). For this case study, no remarkable differences between experiments perturbing only the Sea Surface Perturbations were observed.

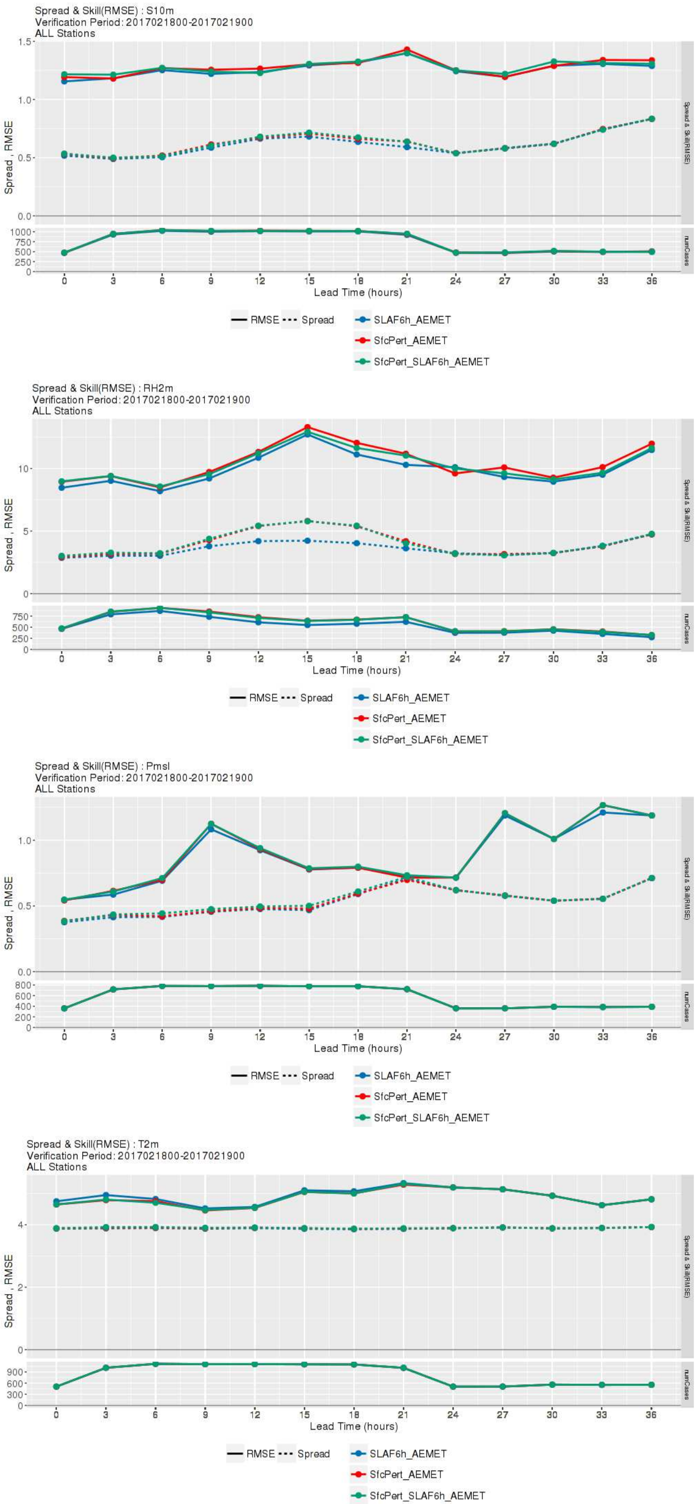


Figure 5: The spread/skill versus the forecast length plots are shown for the T2m, RH2m, 10m Wind Speed and Pmsl. Only SLAF in blue, only Surface Perturbations in red and SLAF along with Surface Perturbations in green.

List of publications/reports from the project with complete references

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Summary of plans for the continuation of the project

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