Model error representation in HarmonEPS

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In HarmonEPS you have the possibility to perturb:

- Initial conditions using nesting model and/or observation perturbations (EDA)
- Surface initial conditions (slightly modified MF code)
- LBCs using nesting model

For model uncertainty we have

- multi-physics - with its pros and cons
- SPPT - with not too convincing results in earlier tests

It is about time we get a scheme for model uncertainty that performs better - decided to investigate SPPT in more depth and in parallel to develop SPP

A paper about HarmonEPS at cy40h.1.1.1 recently published in WAF: DOI: 10.1175/WAF-D-19-0030.1

What is SPPT and what is SPP?

SPPT - Stochastic Perturbation of Parameterisations Tendencies:

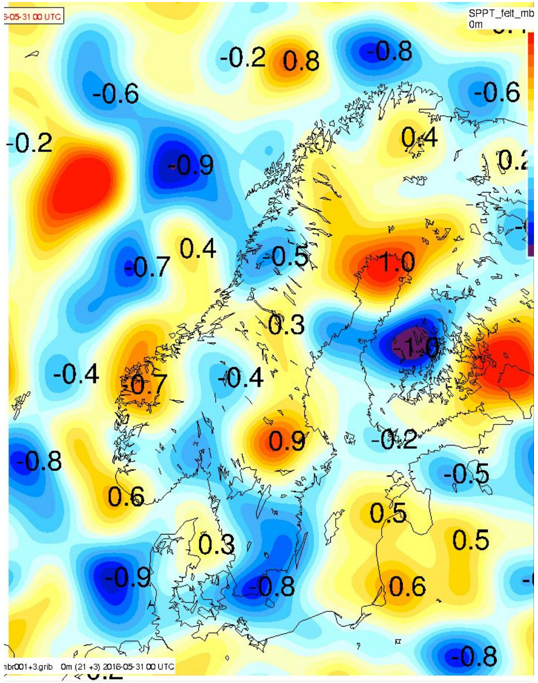
- Perturbing the output of the *net physic tendencies* with 2D random multiplicative noise in a different way for each ensemble member

SPP - Stochastically perturbed parameterizations:

- Perturbing *uncertain parameters* in the parameterizations.
- SPP samples a log-normal distribution for the parameters with independent distributions for each parameter and variable
- Perturbations evolve in time and space according to a pattern generator as for SPPT

Experimental setup

- A clean setup to test the effect of the model perturbations
  - only model is perturbed (by SPPT or SPP).
  - LBCs, analysis, surface are the same for all members
- Many experiments needed, so necessary to have as “slim” experimentation as possible
  - 6 + 1 ensemble members
  - Initial tests for one week in May/June 2016: 2016053000-2016060500
  - +36h
- For SPPT tested effect of spatial and temporal scale of perturbations, tested effect of standard deviation
- For each parameter in SPP find optimal pdf for the perturbations

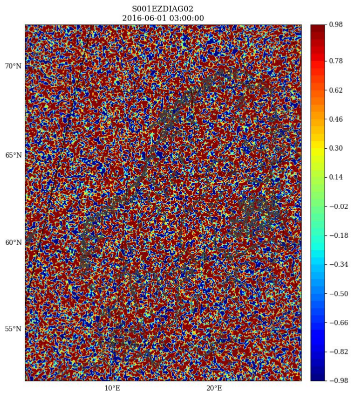


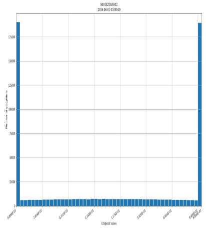
A new pattern generator in HarmonEPS - SPG

- Due to problems with the default pattern generator for SPPT in LAM we switched to SPG - Stochastic Pattern Generator (Tsyrulnikov and Gayfulin, 2017)
- It accounts for ‘proportionality of scales’
- It can be extended to 3D (currently it is 2D in HarmonEPS)
- It does not have the problems of the default pattern generator - you can control the spatial scales and distribution is as expected

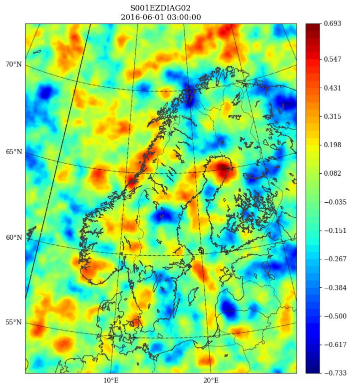
In the following we use SPG for both SPPT and SPP

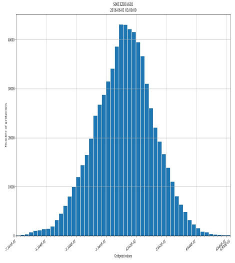
Example of pattern and histogram from **original pattern generator** - spatial scale is set to 100km (SDEV=0.7)



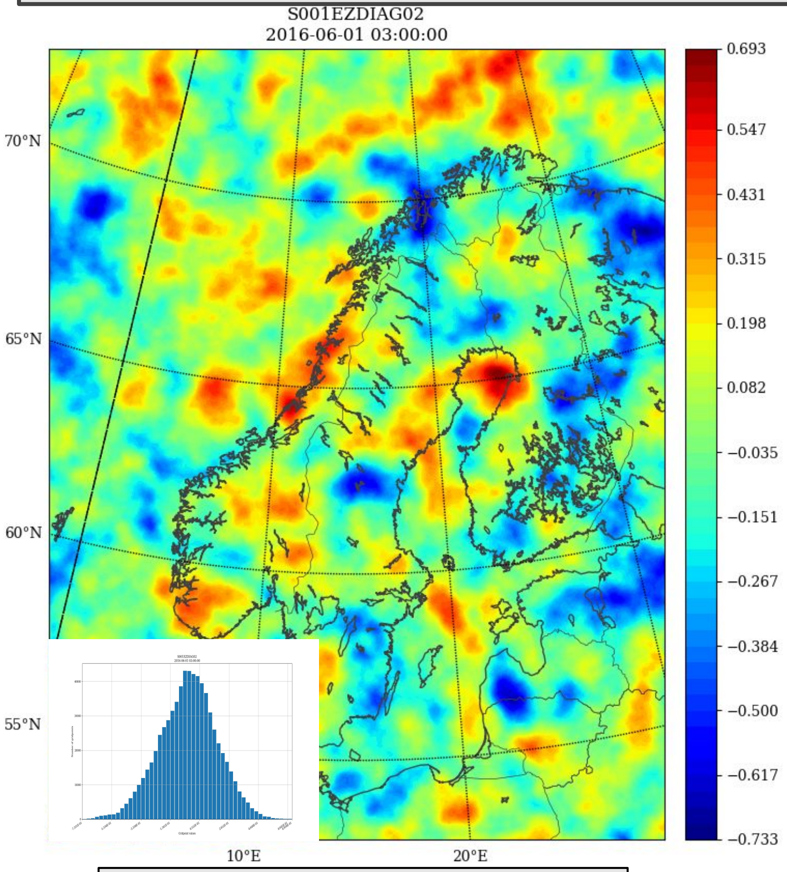


Example of pattern and histogram from **SPG** - spatial scale is set to 100km

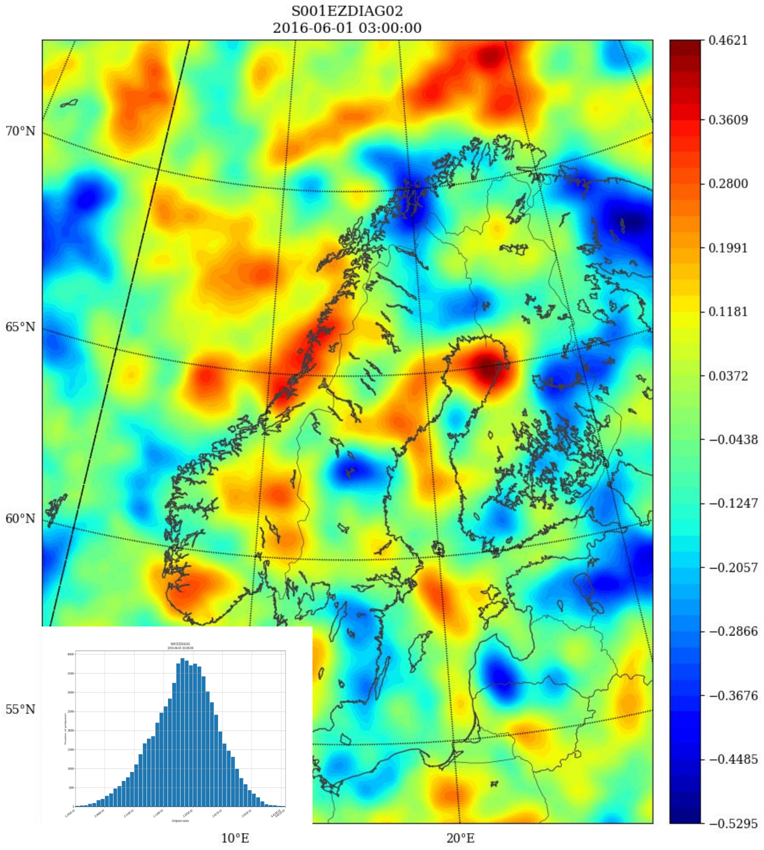




In SPG you can control the large and small scales



Pattern 100km, Q=0.5

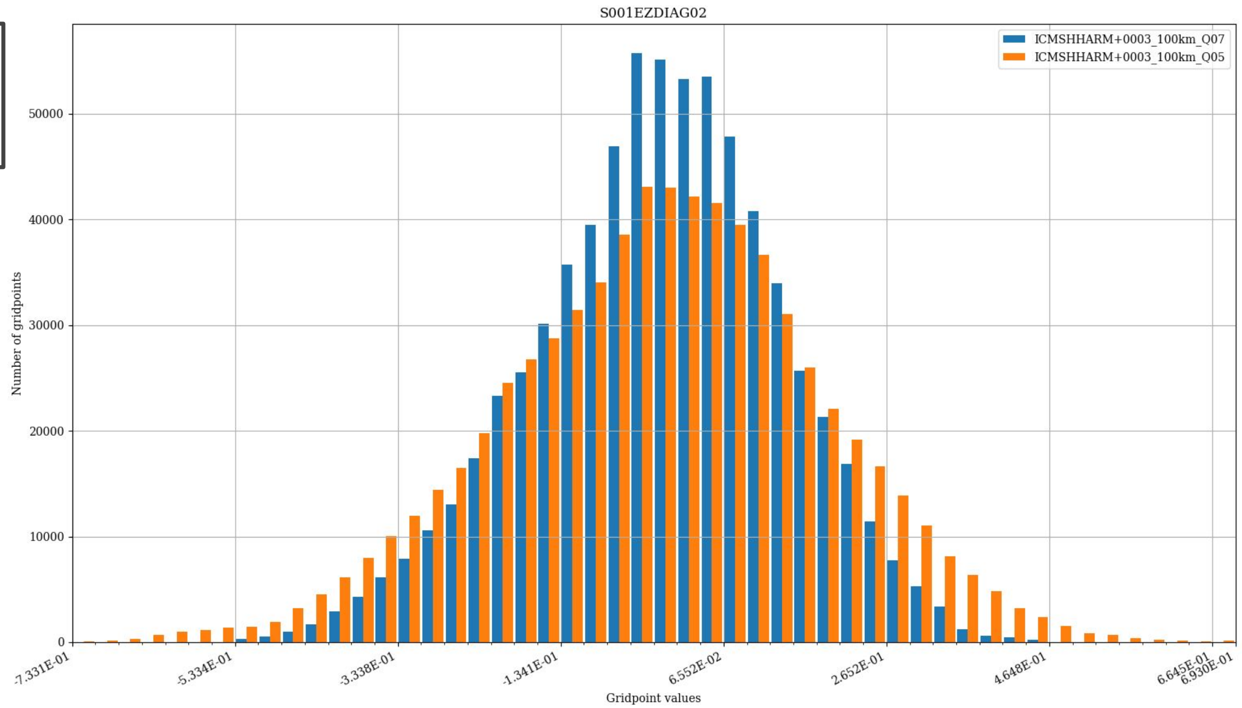


Pattern 100km, Q=0.7

The larger Q, the smoother the realizations - in the sense that they have less small-scale “noise”.

Impact on distribution of changing Q

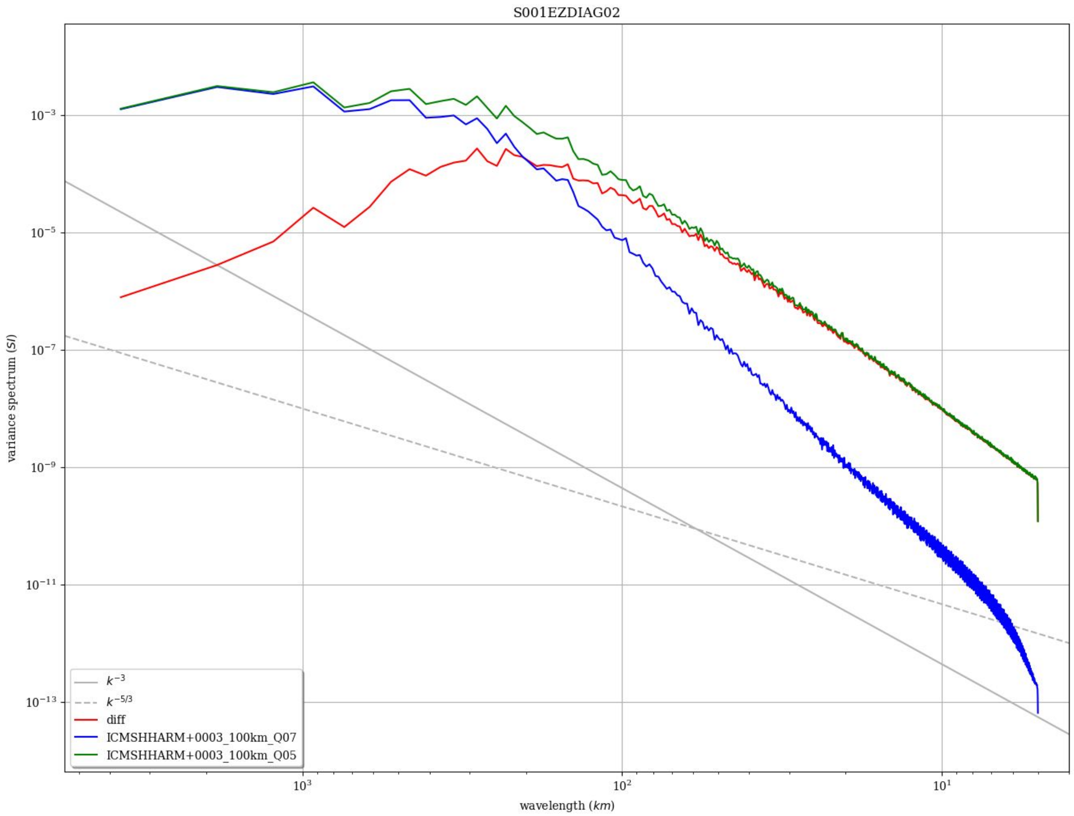
100km Q0.7
100km Q0.5



More small scale “noise” (Q0.5) gives more extreme values than the smoother field with Q0.7

Impact on variance spectra when changing Q (100km)

Q0.5
Q0.7
Difference



Q clearly changes the variance spectrum, the effect of increased Q is less information on smaller scales - as expected

SPPT testing

Numerous tests have been carried out on the control parameters of SPPT

https://hirlam.org/trac/wiki/HarmonieSystemDocumentation/EPS/SPPT

- Spatial scale correlation parameter: range 100 km - 1800 km (Q=0.5)
- Temporal scale correlation parameter: range 1h - 24h
- Standard deviation of the perturbation: range 0.1 - 1.0

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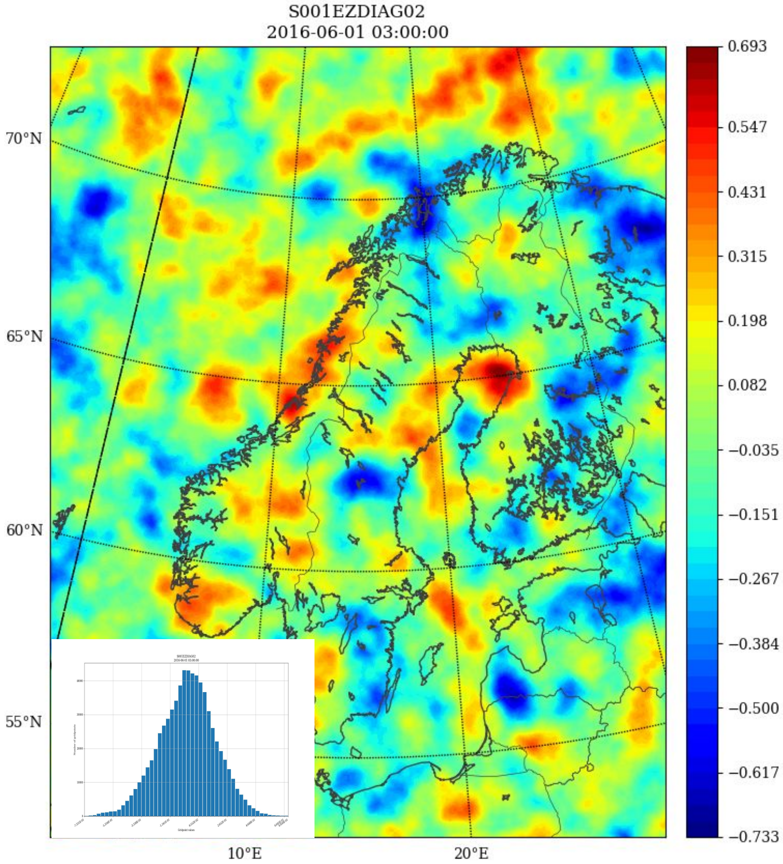
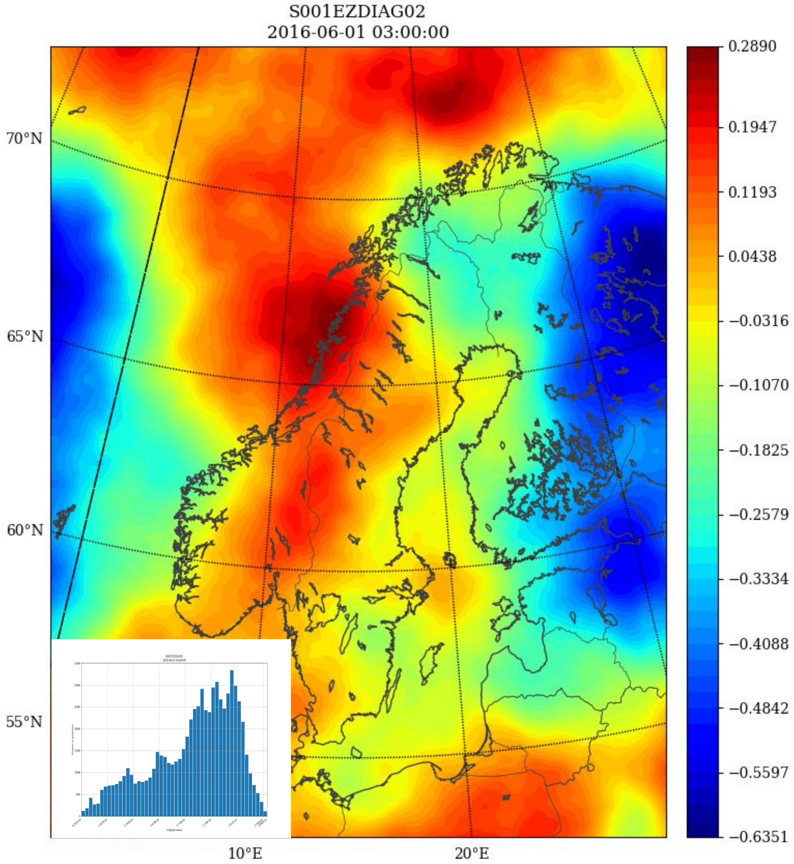
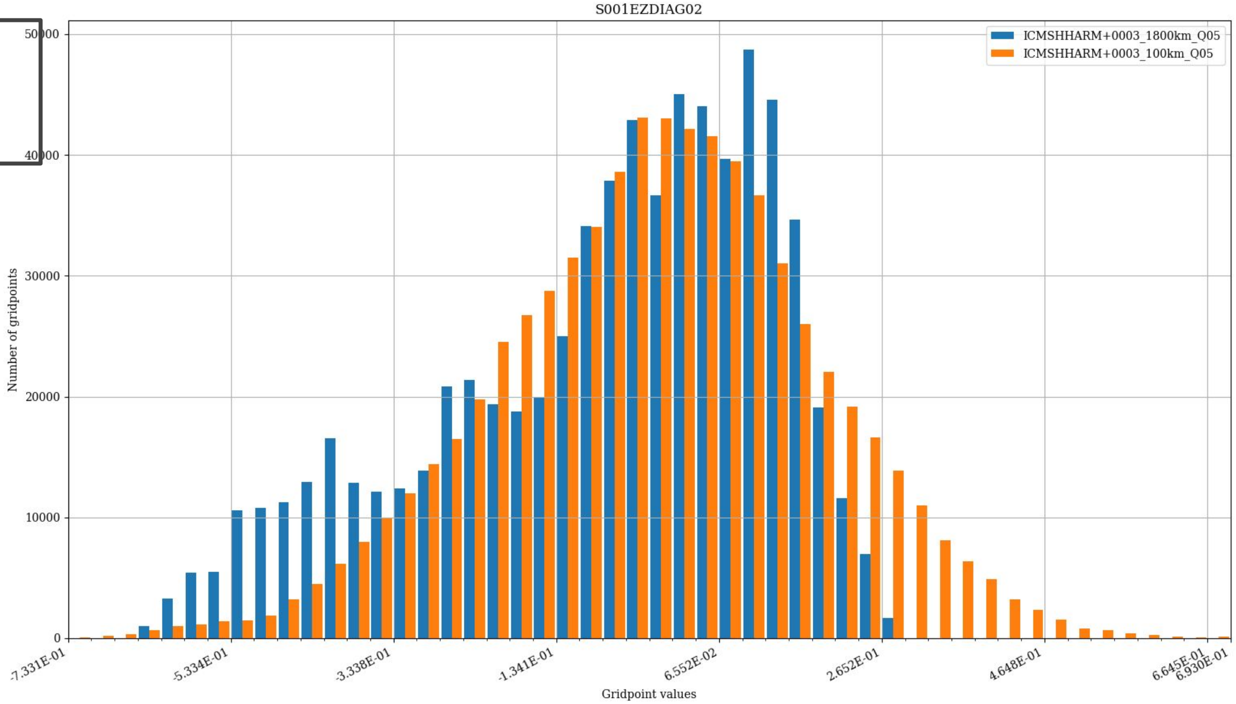
SPG pattern for 100km vs 1800km - both Q=0.5



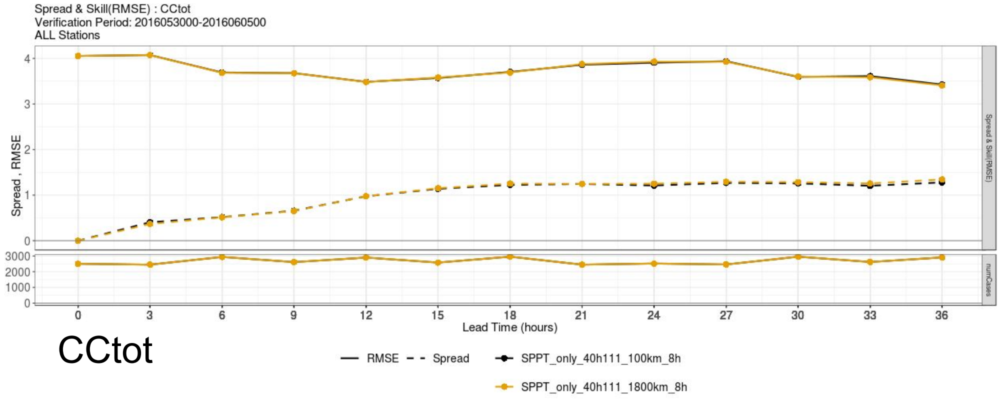


Impact on distribution

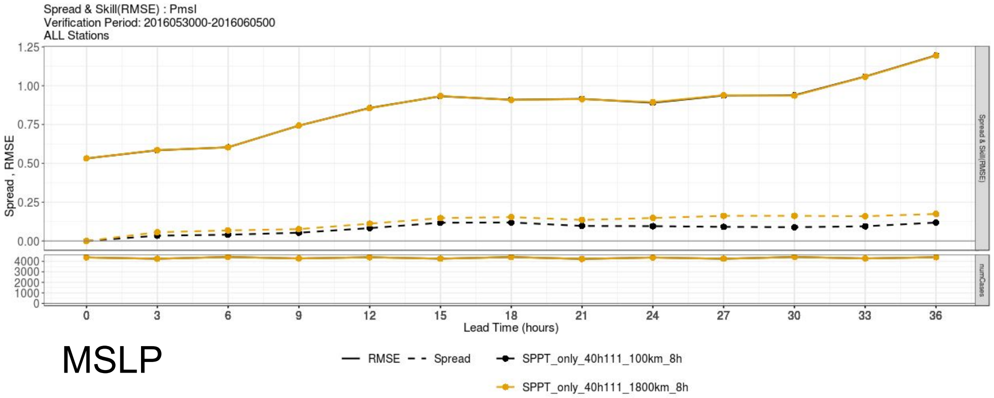
1800km Q0.5
100km Q0.5



SPPT and spatial length scale (Q=0.5)



CCtot



MSLP

Total Cloud Cover

Spatial length scale (100 - 1800 km)

Mean-Sea-Level Pressure

Spatial length scale (100 - 1800 km)

Little sensitivity to modifying this control parameter but larger scale gives slightly larger spread for MSLP. 100, 600 and 1200km slightly less T2m RMSE

- **In the following 1800 km is used.**

SPPT testing

Numerous tests have been carried out on the control parameters of SPPT

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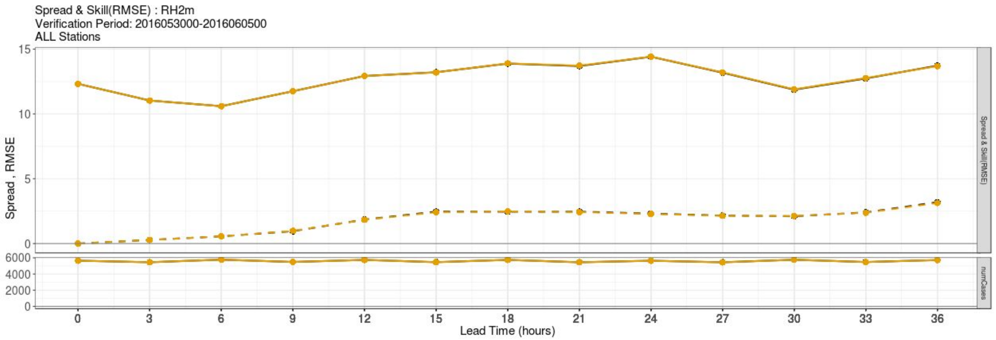
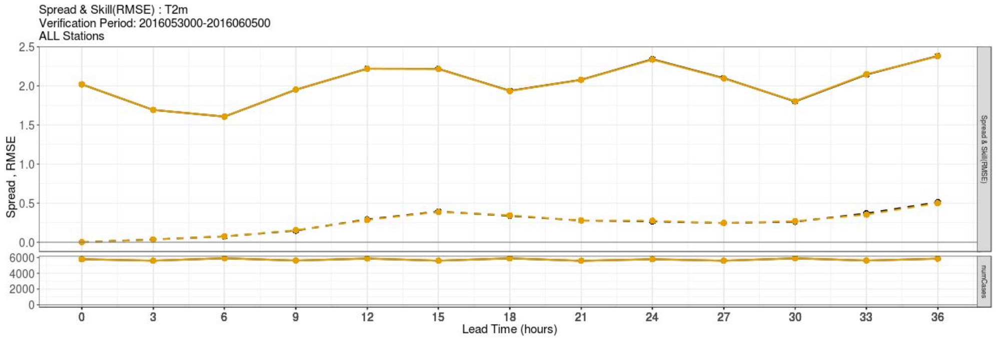
- Spatial scale correlation parameter: range 100 km - 1800 km (Q=0.5)
- Temporal scale correlation parameter: range 1h - 24h
- Standard deviation of the perturbation: range 0.1 - 1.0

SPPT and temporal length scale



RH2m



T2m

2-metre relative humidity

Temporal scale (8h - 18 h)

2-metre temperature

Temporal scale (8h - 18h)

Very little sensitivity to modifying this control parameter.

-In the following 8h is used.

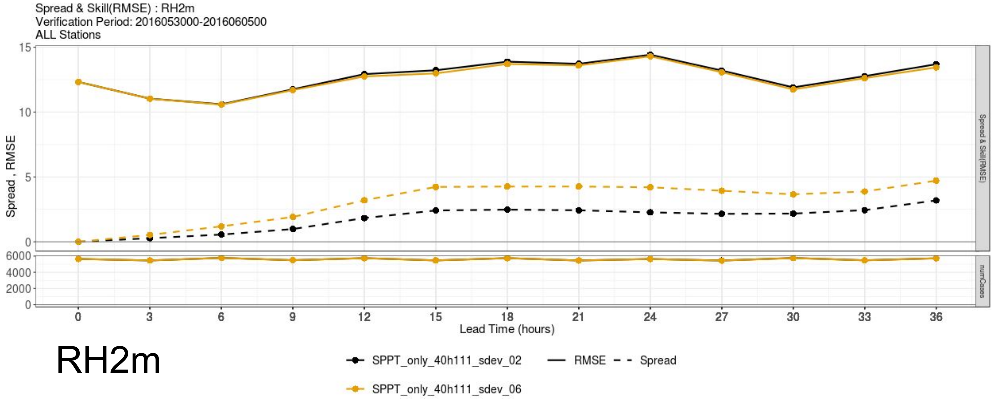
SPPT testing

Numerous tests have been carried out on the control parameters of SPPT

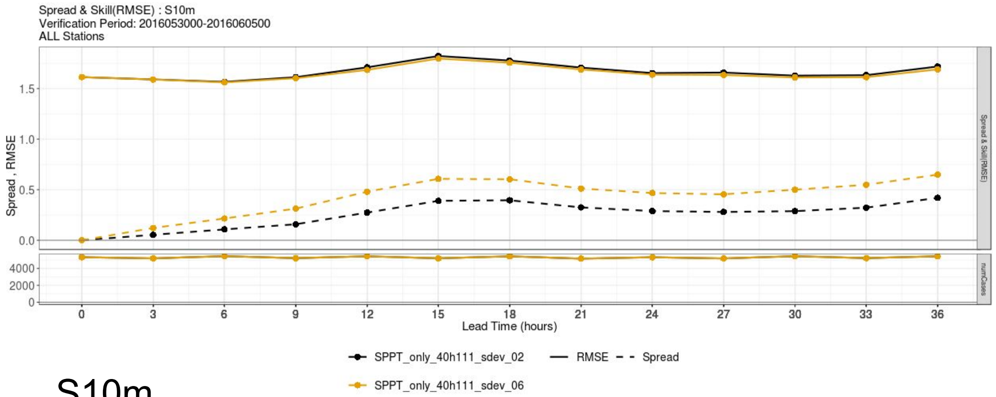
https://hirlam.org/trac/wiki/HarmonieSystemDocumentation/EPS/SPPT

- Spatial scale correlation parameter: range 100 km - 1800 km (Q=0.5)
- Temporal scale correlation parameter: range 1h - 24h
- Standard deviation of the perturbation: range 0.1 - 1.0

SPPT and standard deviation of perturbation



RH2m



S10m

2-metre relative humidity

SDEV=0.2,CLIPPING RATIO=5.0 (default)
SDEV=0.6,CLIPPING RATIO=1.65

(keeping the clipping at 1:
SDEV*CL-RATIO=1.0)

10-metre wind speed

SDEV=0.2,CLIPPING RATIO=5.0 (default)
SDEV=0.6, CLIPPING RATIO=1.65

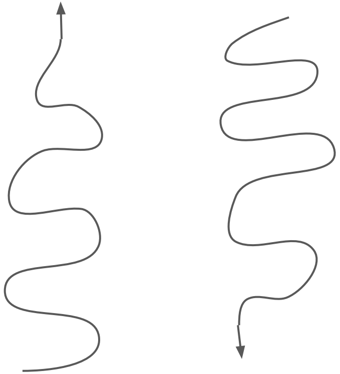
Large sensitivity to this control parameter.
Increase in spread when using updated SDEV and CLIPPING RATIO

SPP - currently 14 parameters implemented

https://hirlam.org/trac/wiki/HarmonieSystemDocumentation/EPS/SPP

7 for clouds and microphysic

3 for turbulence



4 for radiation (2 tested)

SPP - sensitivity to parameter pdf’s

Example: **VSIGQSAT**

Default, deterministic value is 0.03

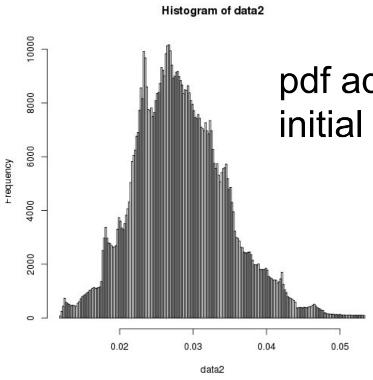
Advice: interval of perturbation 0 - 0.06

Adjust the pdf in accordance with this - as a starting point

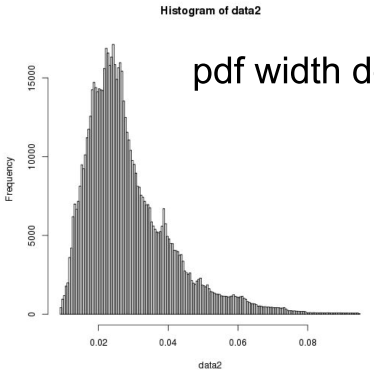
Test sensitivity to width of distribution, by doubling or quadrupling it ….

Check the impact on the scores

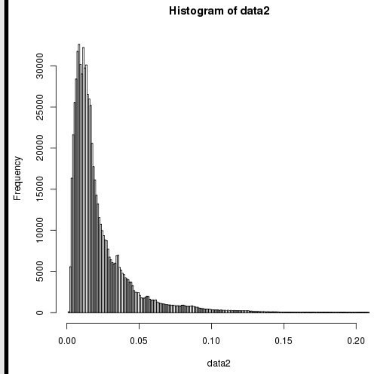
Done separately for all parameters, summer and winter



pdf adjusted to initial advice

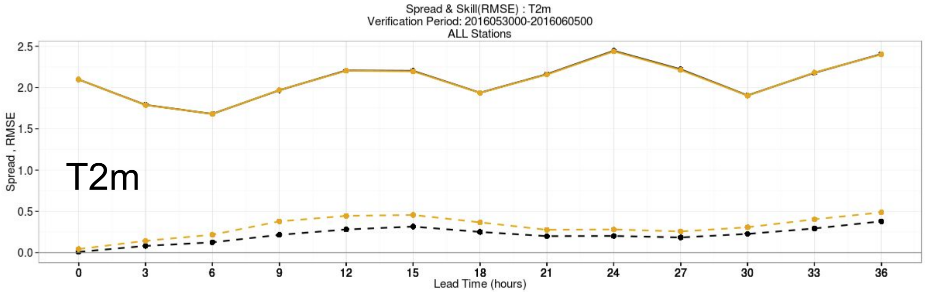


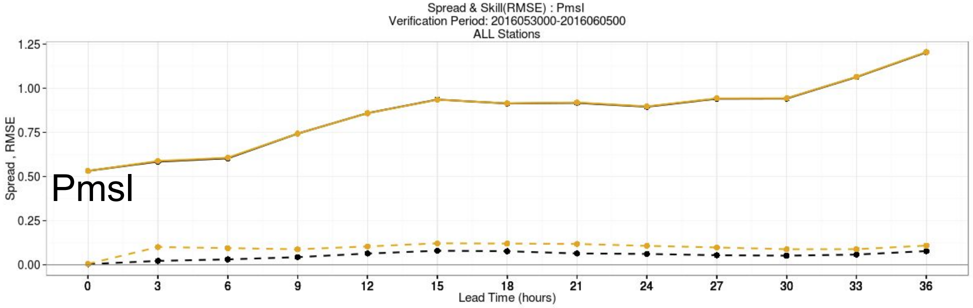
pdf width doubled



pdf width quadrupled

Example: Impact of width of pdf for one parameter (saturation limit sensitivity)
Spread and skill

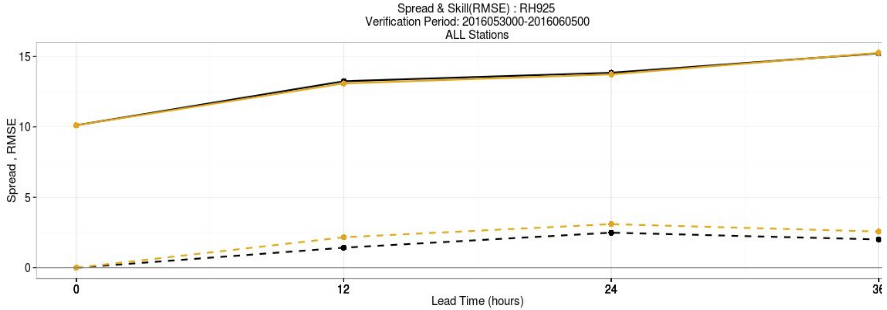


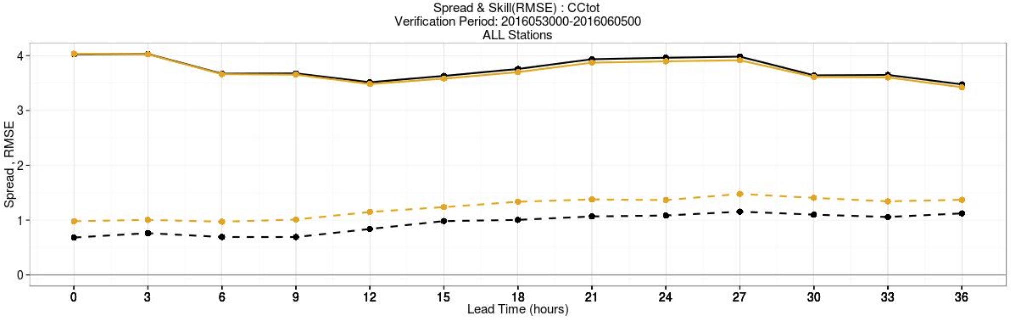


___ double
___ quadruple

CCtot

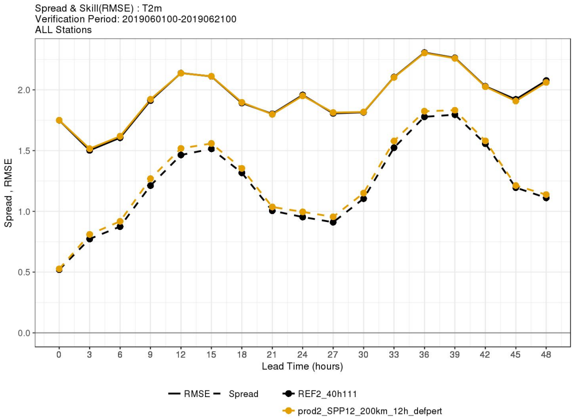
RH925



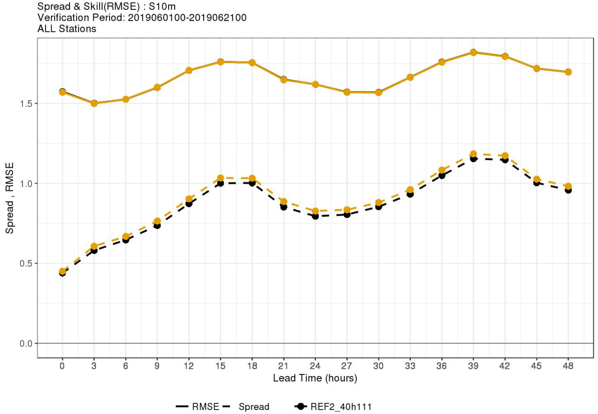


SPP in full HarmonEPS vs REF

21 days in June 2019



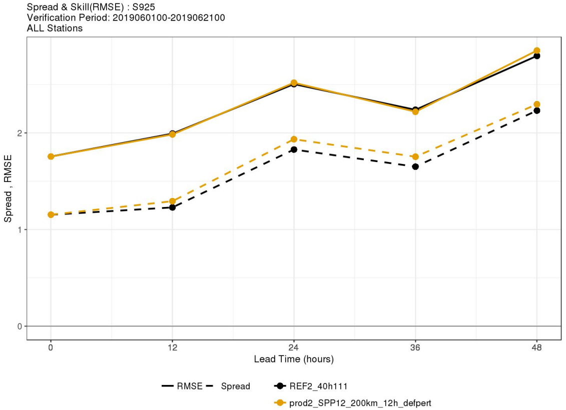
T2m



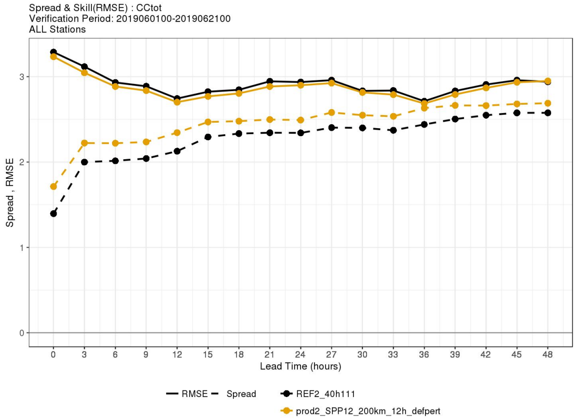
S10m

REF

SPP

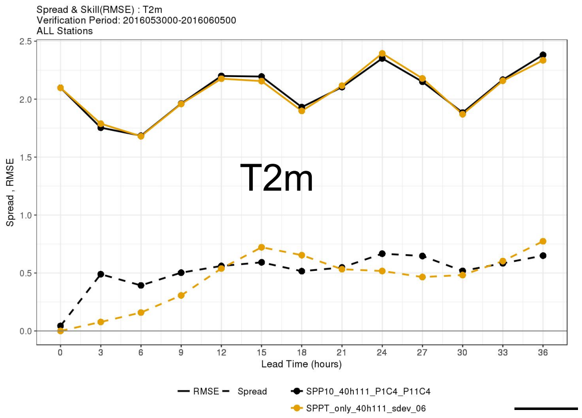


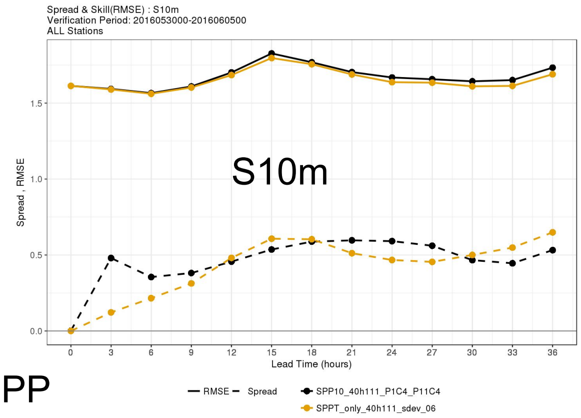
S925

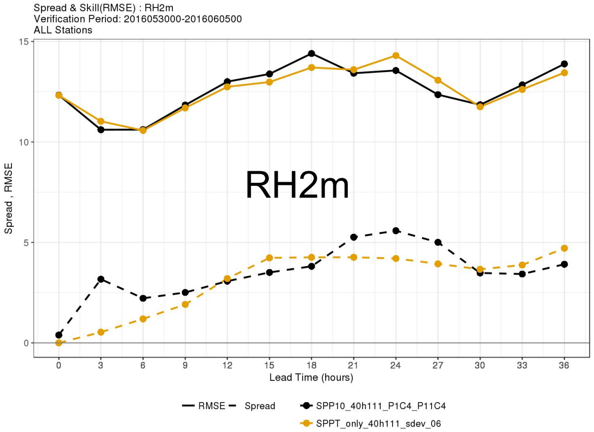


CCtot

Comparison of SPPT and SPP (no other perturbations)

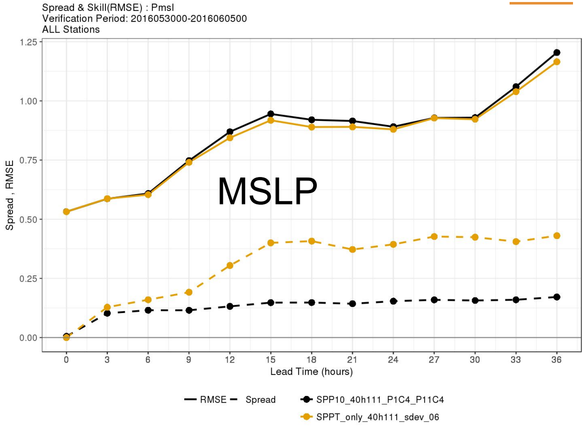


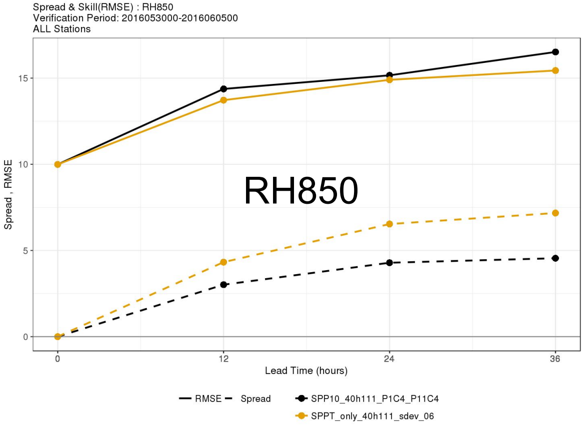


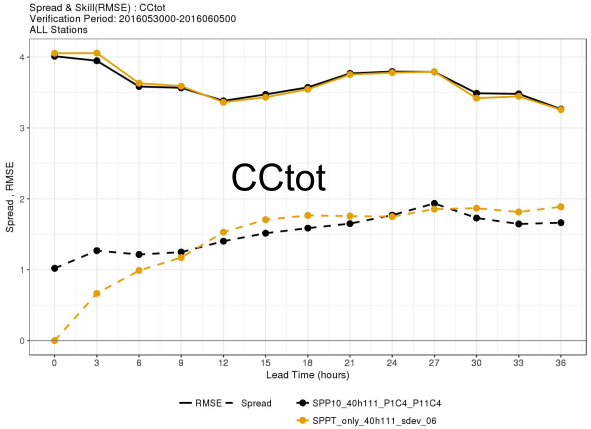


SPP

SPPT







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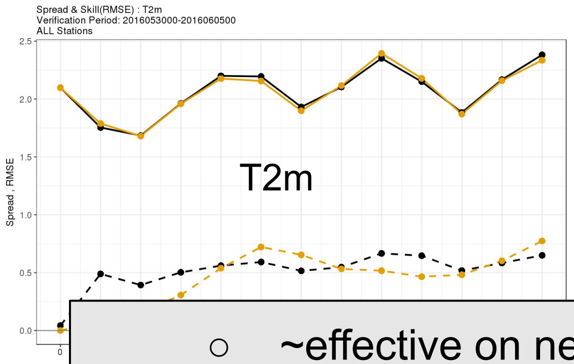
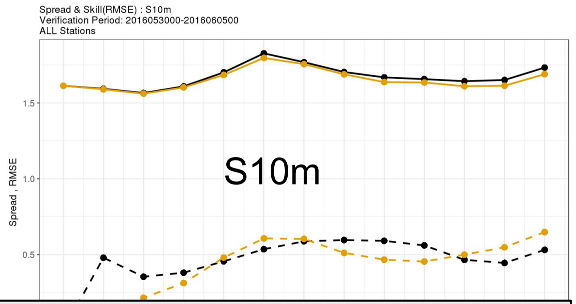
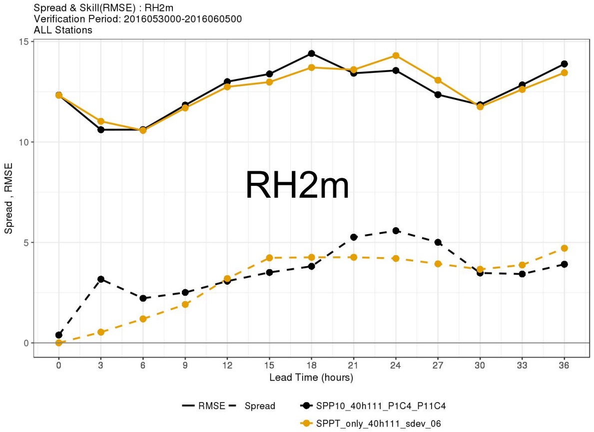
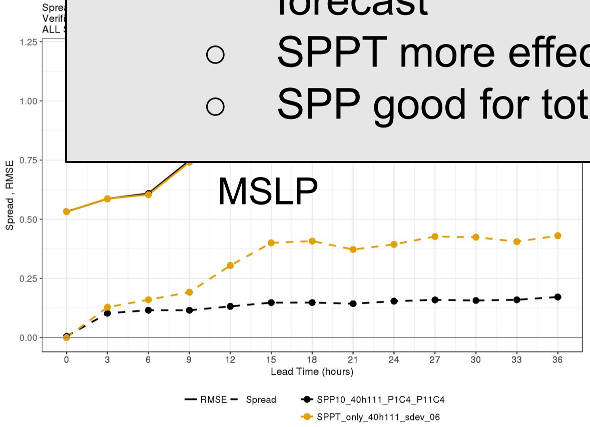
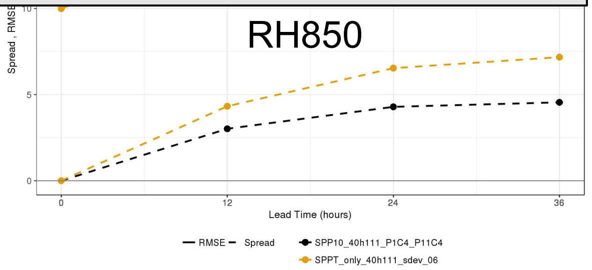


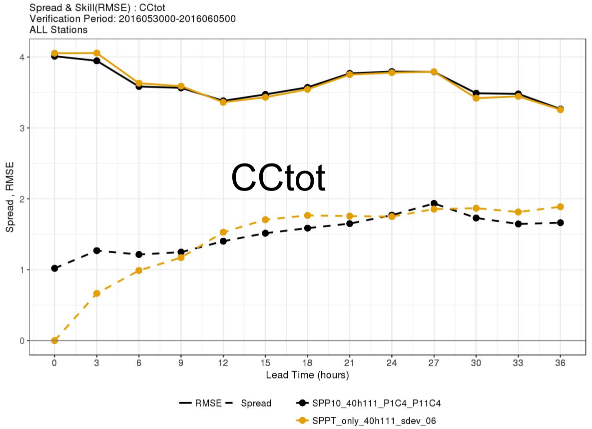




- ~effective on near surface parameters
- SPP more effective in the beginning of the forecast
- SPPT more effective for upper air
- SPP good for total cloud cover







Conclusions

- SPG allowed us to play with the SPPT settings and to increase the SDEV
- SPPT now looks promising in HarmonEPS
- SPP (with limited number of perturbed parameters) is promising
- SPP and SPPT comparison
  - ~ same effect on the overall spread for near surface parameters
  - SPP more effective in the beginning of the forecast
  - SPPT more effective for upper air
  - SPP good for total cloud cover

Further work on SPPT and SPP

SPPT:

- Test in full HarmonEPS setup for winter and summer
- Better adjusting the PBL and upper atmosphere SPPT tapering
- Perturb independently each parameterisation

SPP:

- Continue tests in full HarmonEPS setup
- Include and test more parameters
- Perturb SLHD
- Using different distribution, spatial and temporal scales for different parameters

For both:

- Combine SPP and SPPT
- Optimize time-spatial scales in SPG for use in HarmonEPS
- Extend SPG to 3D?
- Further develop tendency diagnostics

Thank you for your attention!