HarmonEPS developments - SPP and SPPT

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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 is submitted to WAF

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

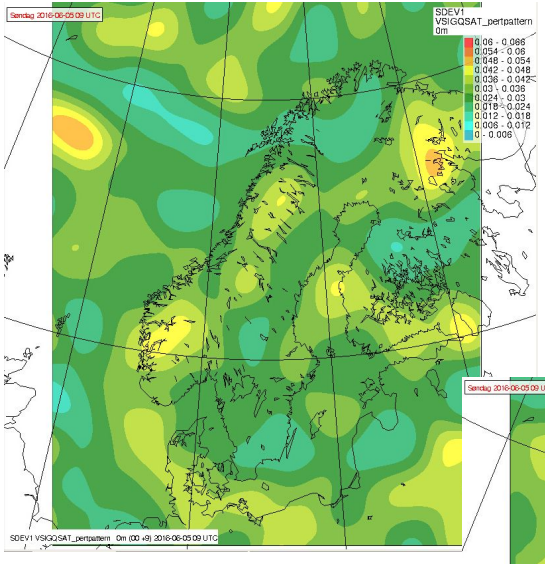
SPP - Stochastically perturbed parameterizations:

- 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

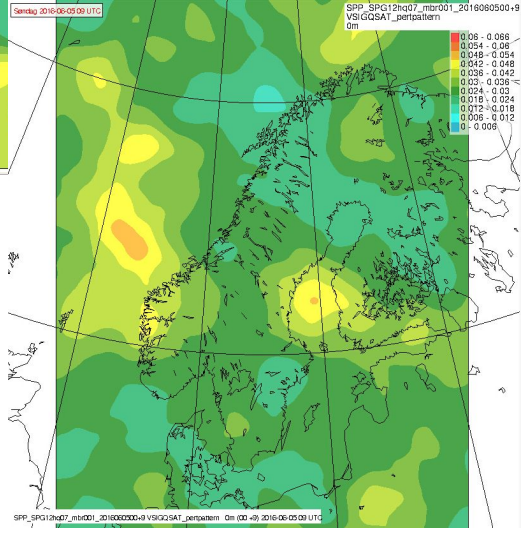
A new pattern generator

- 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!

In the following we use SPG for both SPPT and SPP



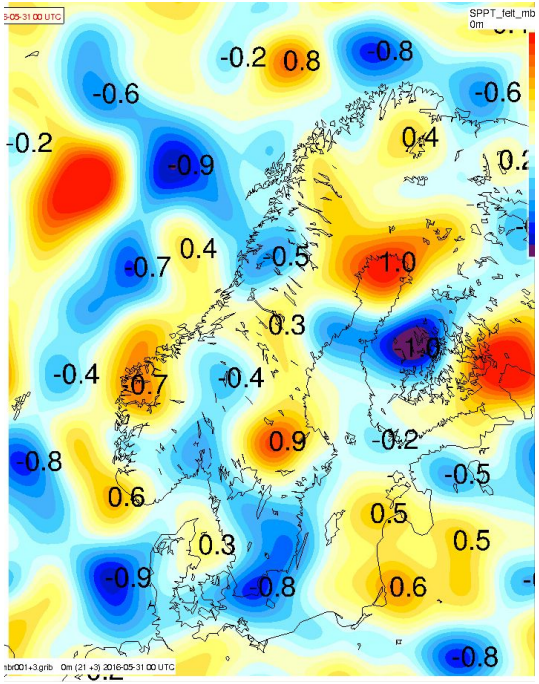
Example of pattern from default pattern generator - spatial scale is set to 2000km!



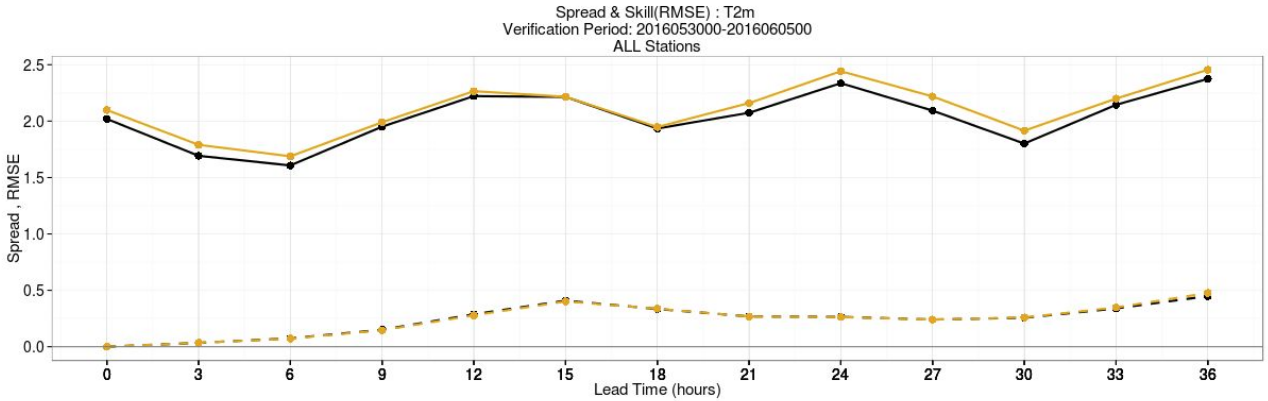
Example of pattern from SPG -
spatial scale is set to 200km!

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 2016: 2016053000-2016060500
  - +36h
- For SPPT so far mainly tested effect of spatial scale of perturbations
- For SPP tested time scale and tuned each parameter



SPPT and spatial scale (temporal = 8h)



___ 100 km
___ 200km

Tested: 100km, 200km, 400km, 600km, 800km, 1000km, 1200km, 1500km, 1800km

The effect of changing the spatial scale is small - for T2m we see a difference, and 100km, 600km and 1200km are better than the other scales tried

___ 100 km
___ 600km

SPP - currently 12 parameters implemented

cy40h1.1.1 - HarmonEPS branch

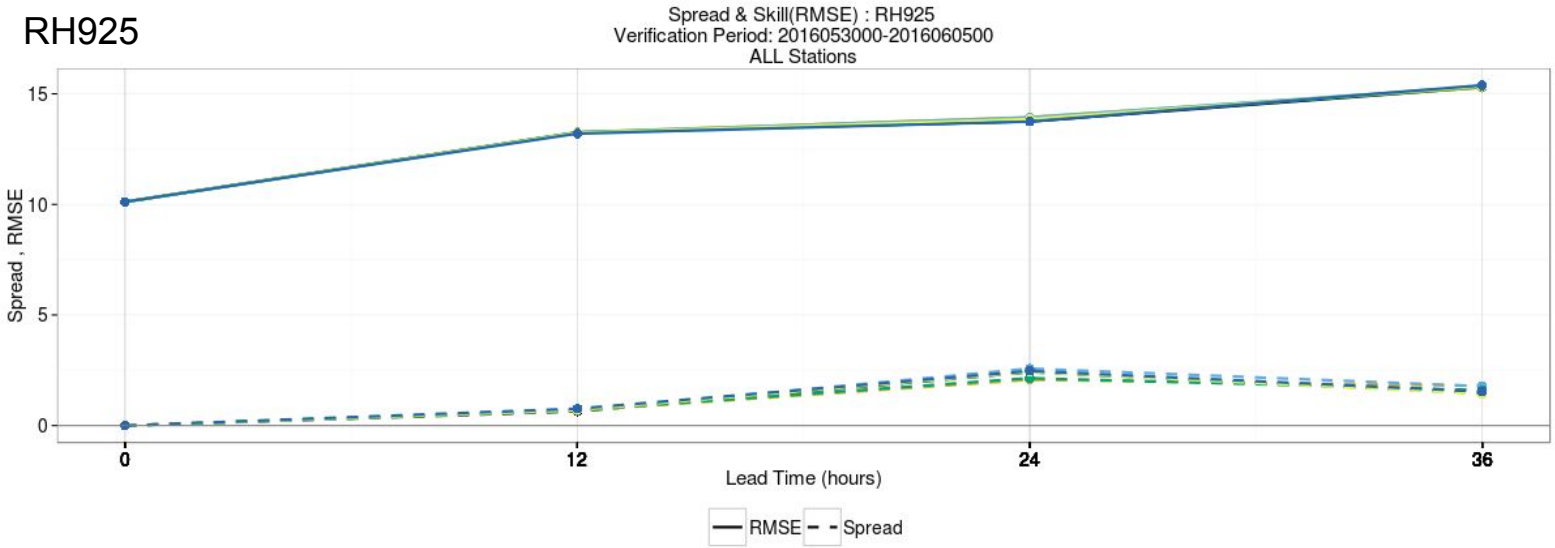
7 for clouds and microphysic, 2 for radiation and 3 for turbulence

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

Perturbation	Description	Perturbs	Default mean value	Recommended range by physics experts
LPERT_PSIGQSAT	perturb saturation limit sensitivity	VSIGQSAT	changed from 0.02 to 0.03	0-0.06
LPERT_CLDDPTH	perturb threshold cloud thickness for stratocumulus/cumulus transition	RFRMIN(19)	2000	1000-4000
LPERT_CLDDPTHDP	perturb threshold cloud thickness used in shallow/deep convection decision	RFRMIN(20)	4000	1000-8000
LPERT_ICE_CLD_WGT	perturb cloud ice content impact on cloud thickness	RFRMIN(21)	1	0-2
LPERT_ICENU	perturb ice nuclei	RFRMIN(9)	1	0.1-10
LPERT_KGN_ACON	perturb Kogan autoconversion speed	RFRMIN(10)	10	2-50
LPERT_KGN_SBGR	perturb Kogan subgrid scale (cloud fraction) sensitivity	RFRMIN(11)	changed from 1 to 0.5	0.01-1 (bigger than 0 and less than 1)
LPERT_RADGR	perturb graupel impact on radiation	RADGR	changed from 0 to 0.5	0-1
LPERT_RADSN	perturb snow impact on radiation	RADSN	changed from 0 to 0.5	0-1
LPERT_RFAC_TWOC	perturb top entrainment	RFAC_TWO_COEF	2	0.5-3
LPERT_RZC_H	perturb stable conditions length scale	RZC_H	0.15	0.1-0.25
LPERT_RZL_INF	Asymptotic free atmospheric length scale	RZL_INF	100-	30-300

SPP and temporal scale

RH925



Tested 1h, 6h, 12h, 24h, 36h, frozen in time
All with spatial scale of 200km
9 parameters in this test
Effect of temporal scale is small.
We use 12h in further tests

SPP - sensitivity to parameter pdf's

Example:

VSIGQSAT

Default, deterministic value is 0.03

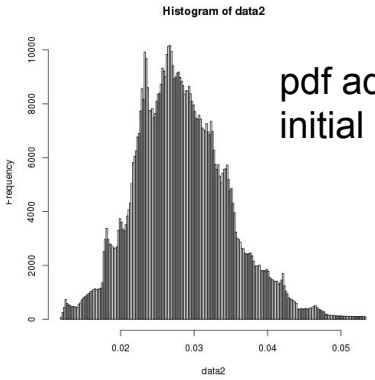
Advice: interval of perturbation 0 - 0.06

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

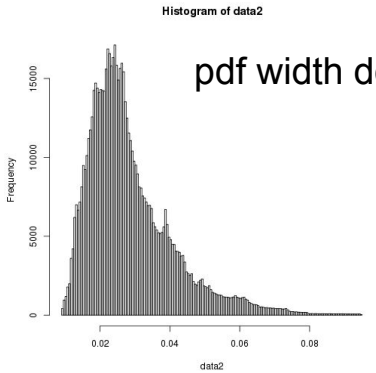
Test sensitivity to width of distribution, by doubling or quadrupling it ….

Check the impact on the scores

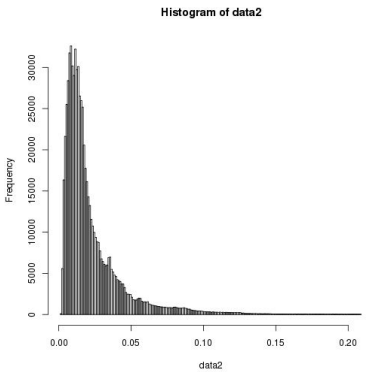
Done separately for all parameters



pdf adjusted to initial advice

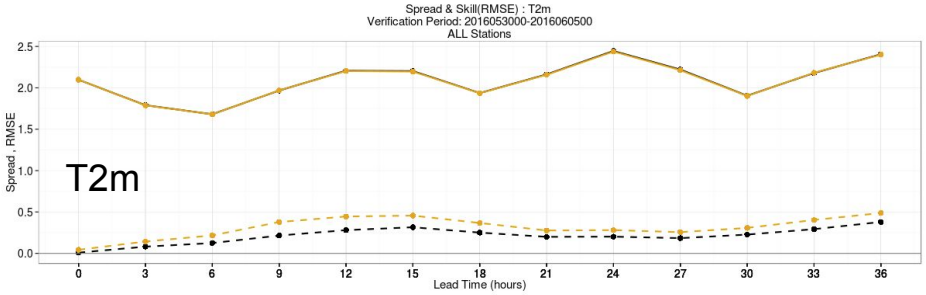


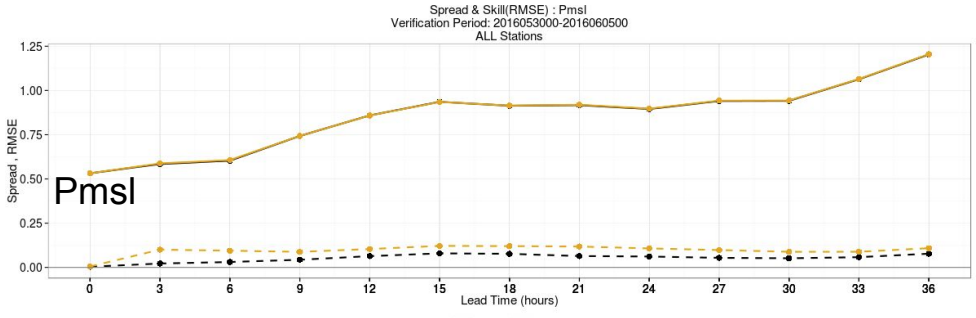
pdf width doubled



pdf width quadrupled

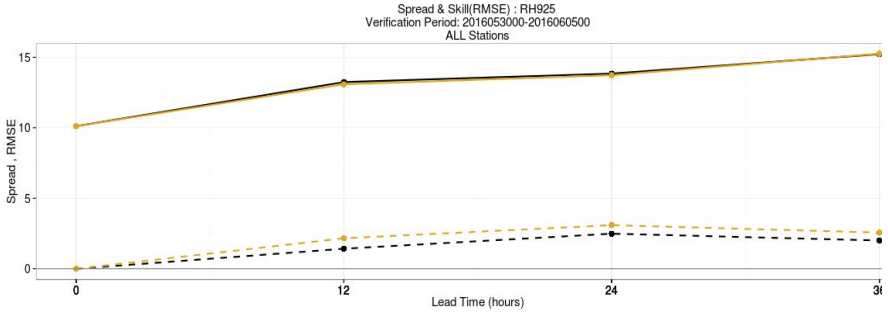
Example: Impact of width of pdf for one parameter (VSIGQSAT) Spread and skill



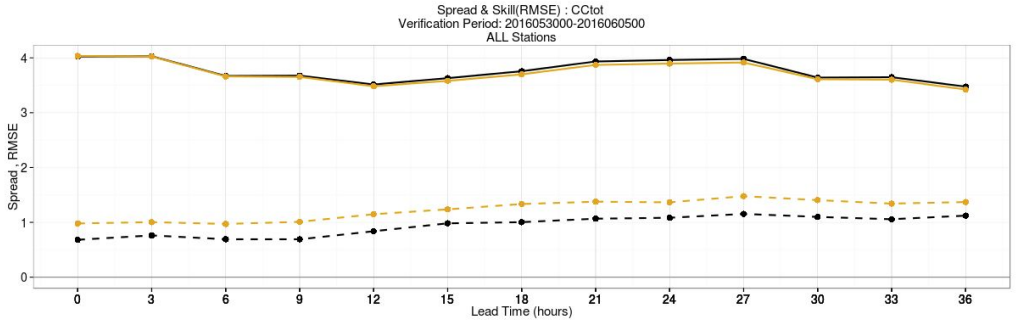


___ double
___ quadruple

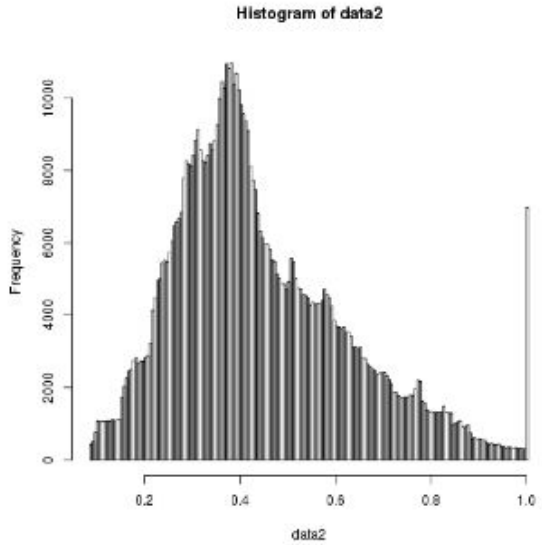
RH925



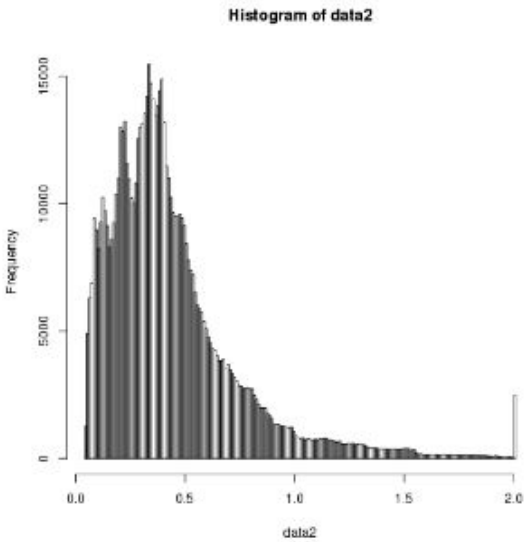
CCtot



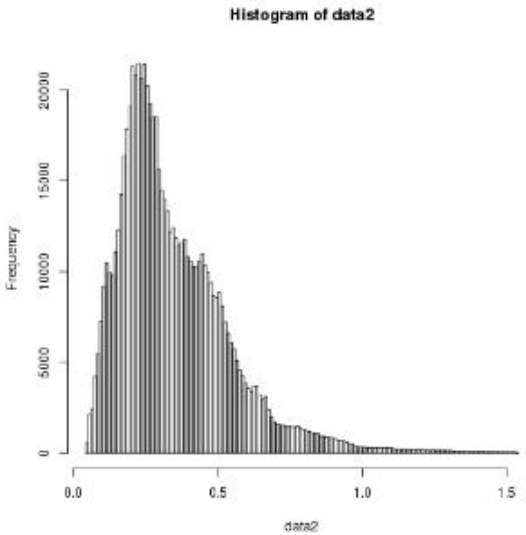
For some parameters we apply clipping not to exceed physically meaningful limits:



Kogan subgrid scale (cloud fraction) sensitivity



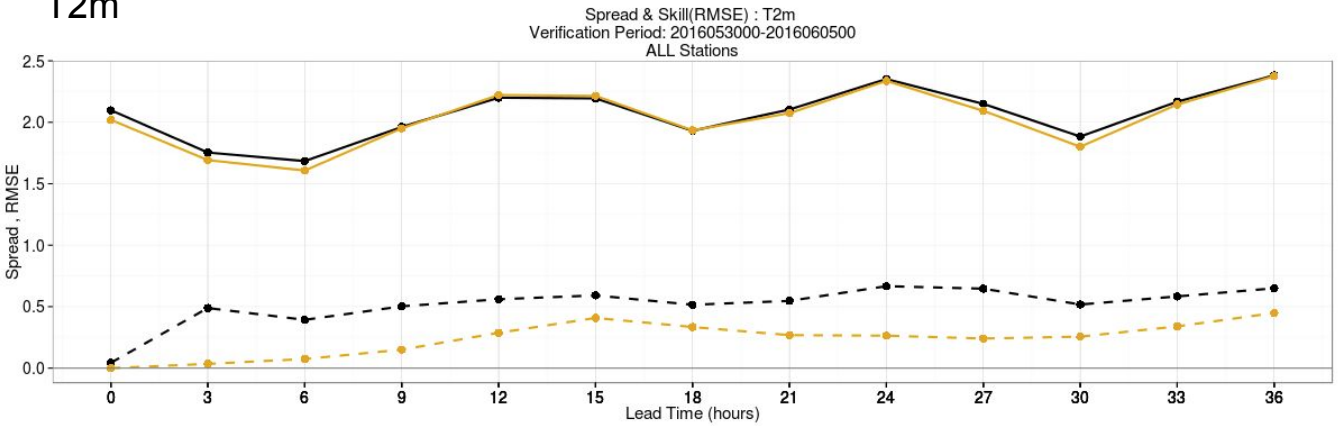
graupel impact on radiation



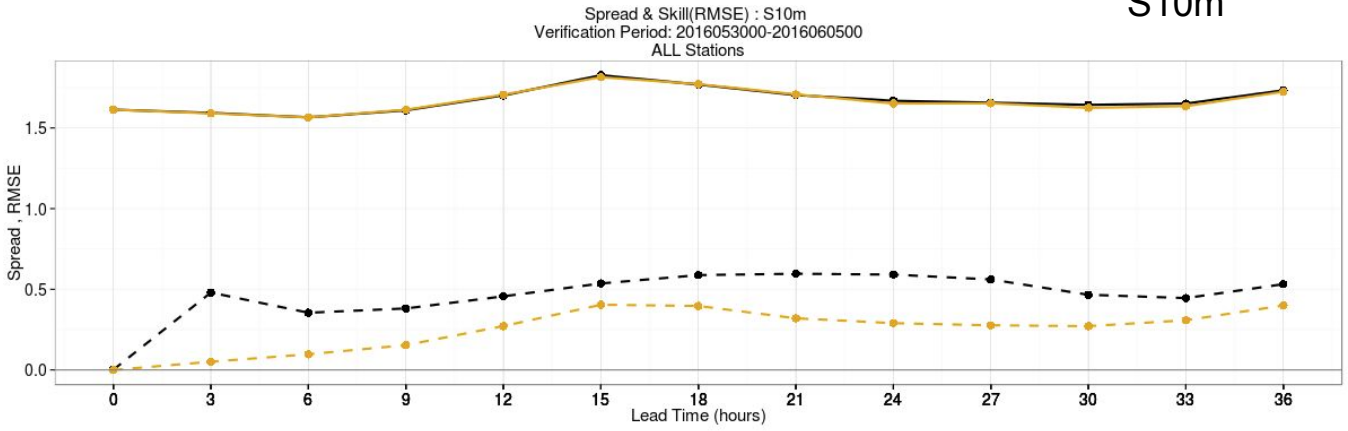
snow impact on radiation

Comparing SPPT and SPP with 10 parameters

T2m



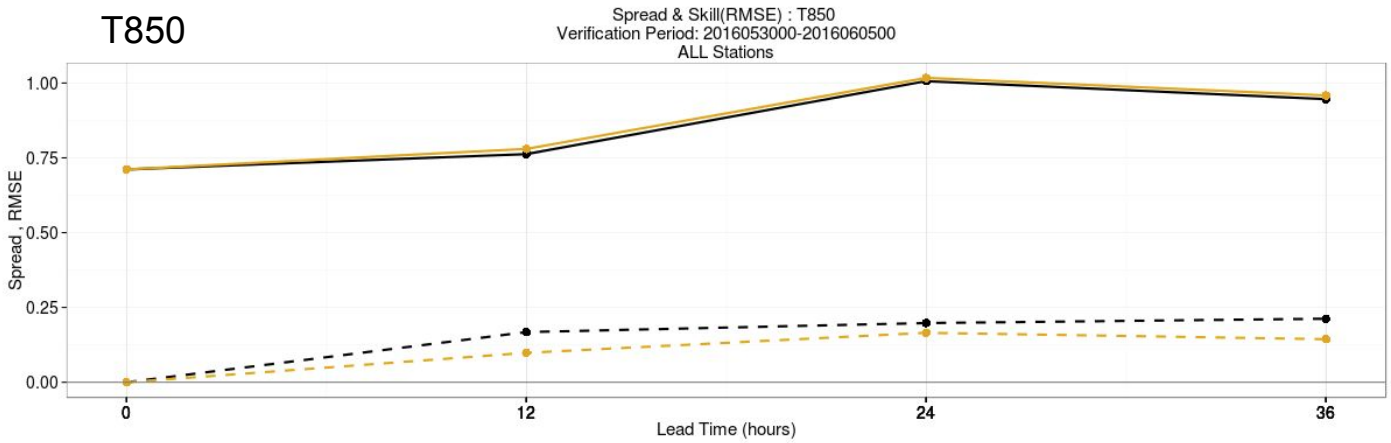
S10m



SPP
SPPT

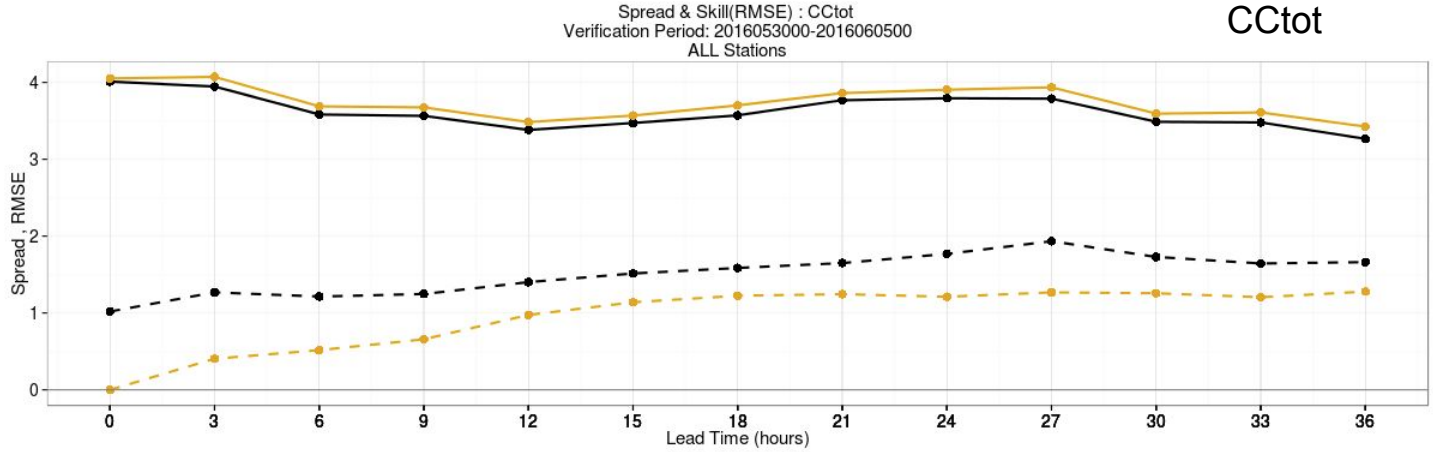
Comparing SPPT and SPP with 10 parameters

T850



With the current setup of SPPT and SPP we get higher spread and equal or better RMSE with SPP than with SPPT

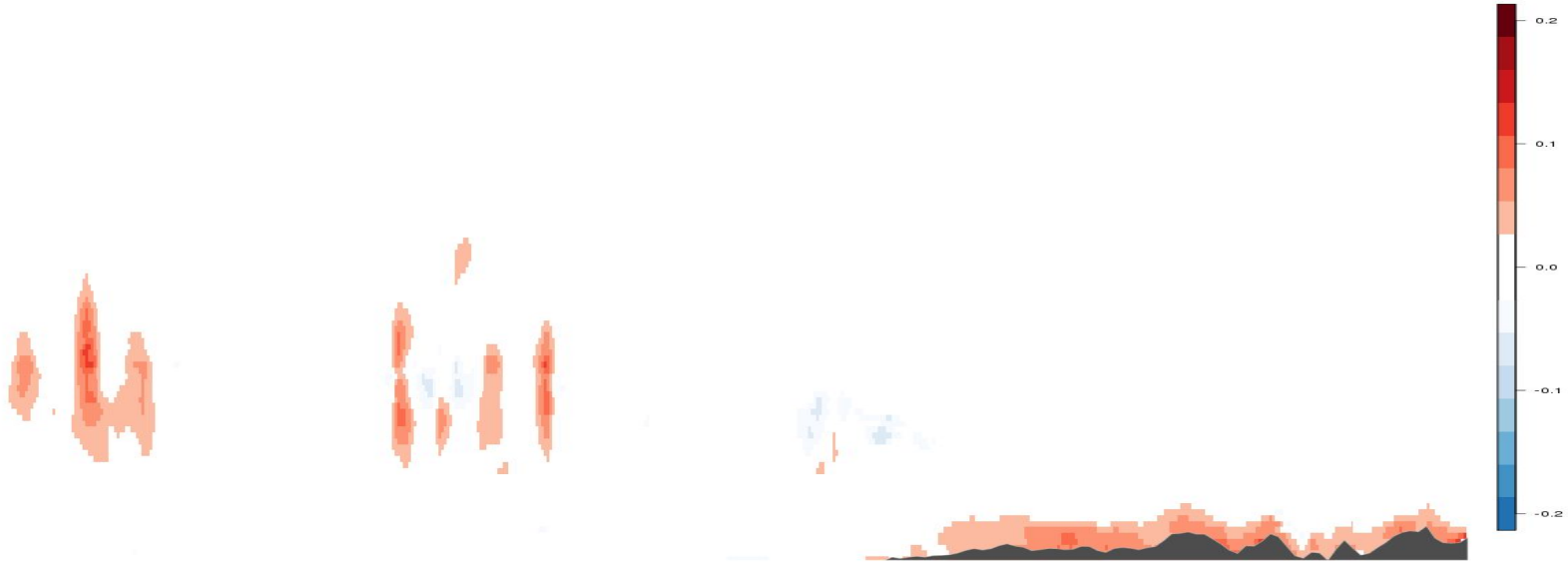
CCtot



SPP
SPPT

Looking closer at the differences between SPPT and SPP - using tendency output

T tendencies for control run (SPP = SPPT)



2016053000 +33h

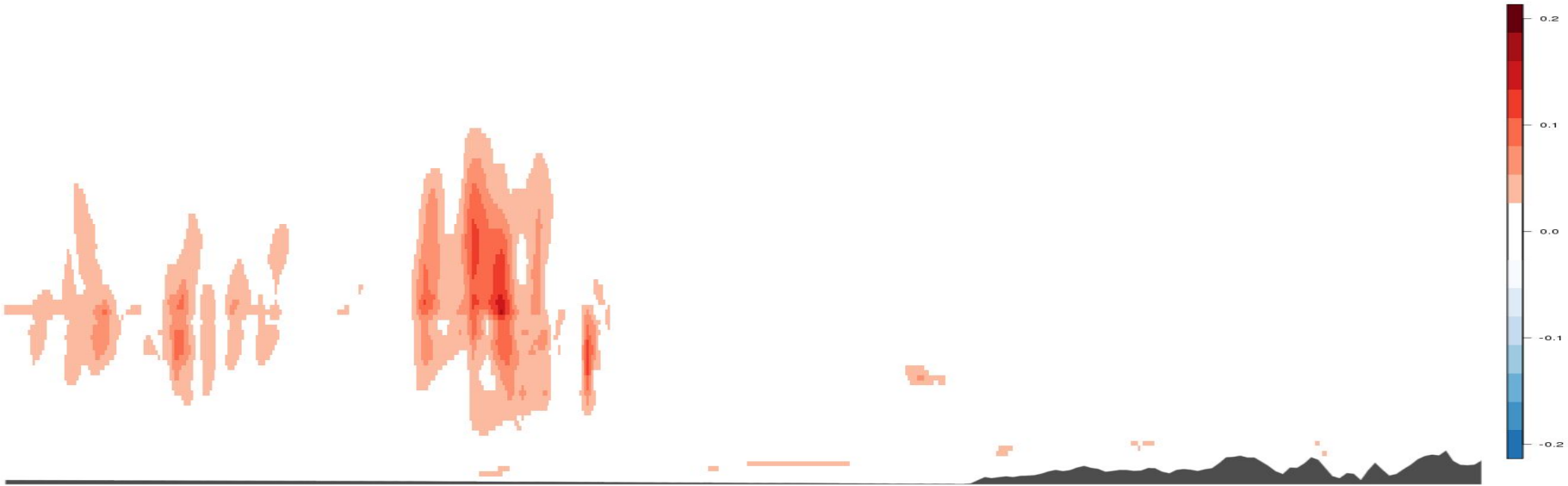
Looking closer at the differences between SPPT and SPP - using tendency output

T tendencies SPPT: SDEV

2016053000 +33h

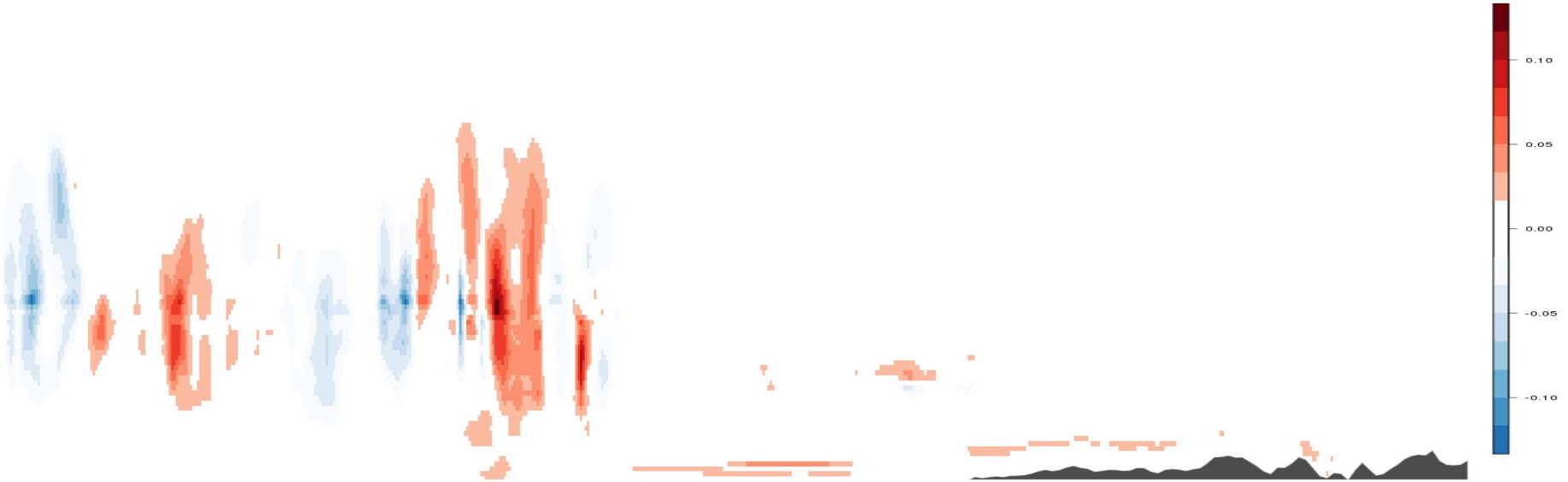
Looking closer at the differences between SPPT and SPP - using tendency output

T tendencies SPP: SDEV



2016053000 +33h

Difference in SDEV of T tendencies between SPP and SPPT

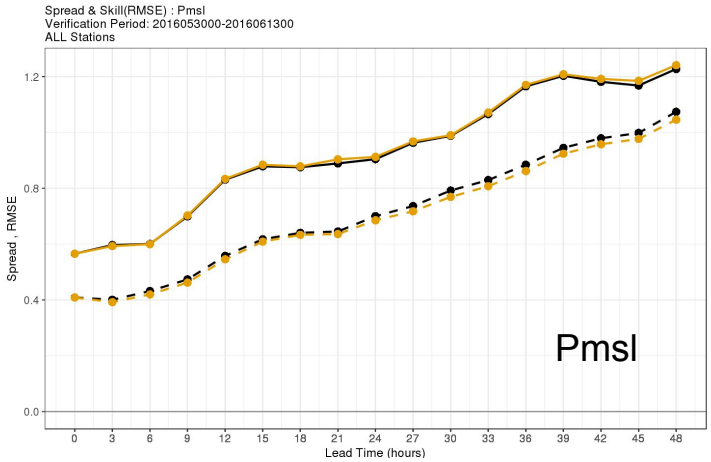


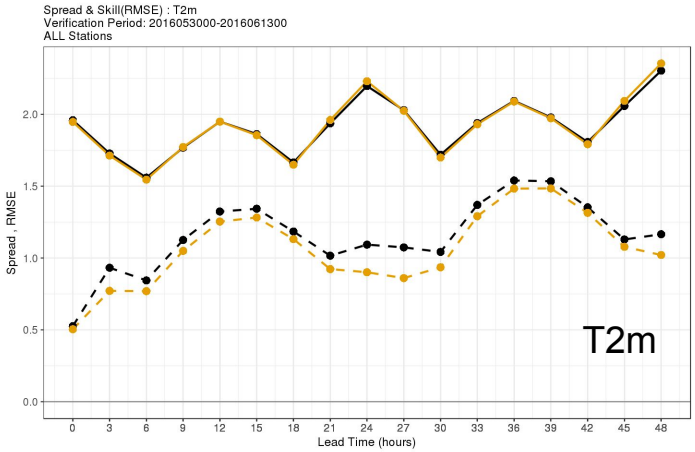
2016053000 +33h

Testing SPP in full HarmonEPS setup

- 6 + 1 members
- Period extended to 15 days: 2016053000-2016061300
- Forecast length extended to +48h
- MetCoOp area
- Comparing two experiments:
  - REF - standard HarmonEPS setup with initial, surface and boundary perturbations
  - SPP - as REF but with SPP parameter perturbations added

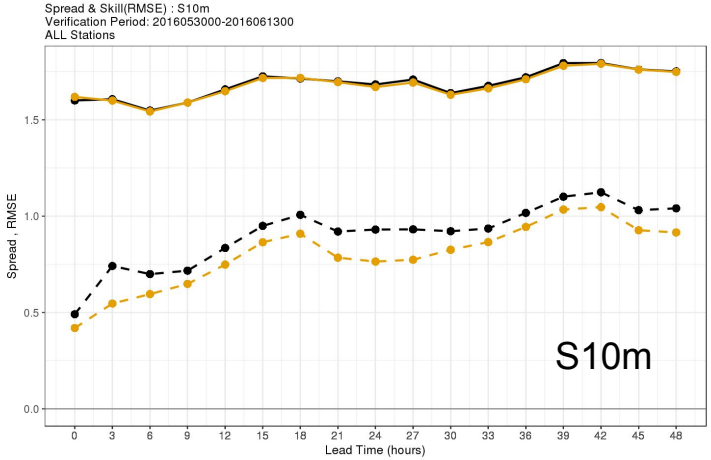
Spread and skill - surface

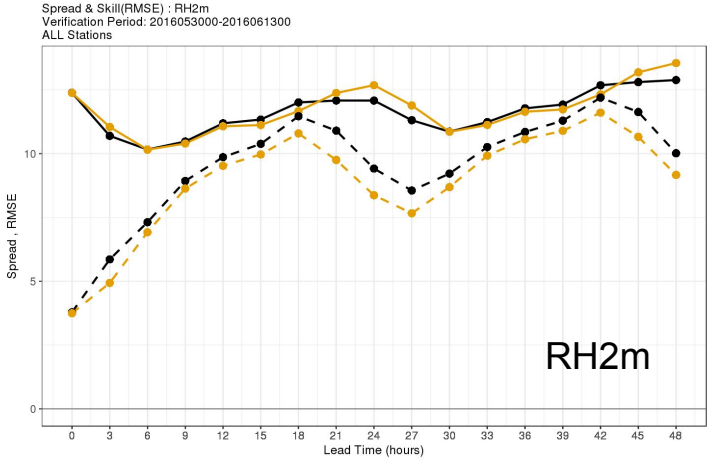




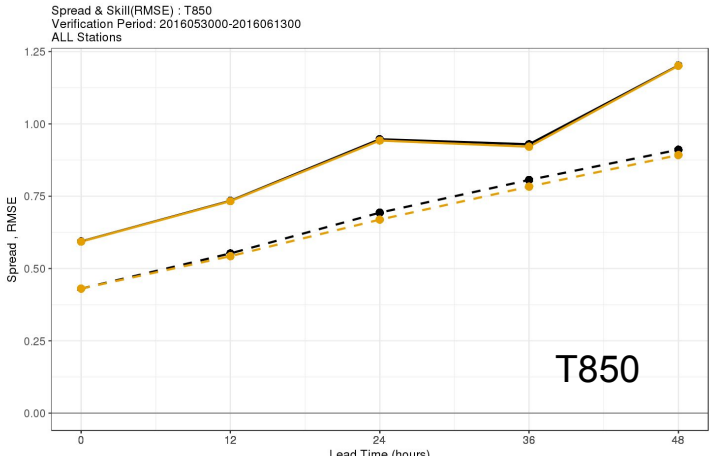
REF
With SPP

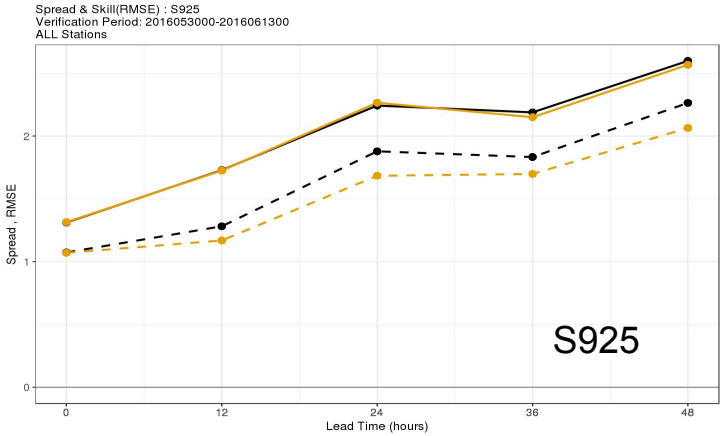
Increased spread with SPP and about the same RMSE



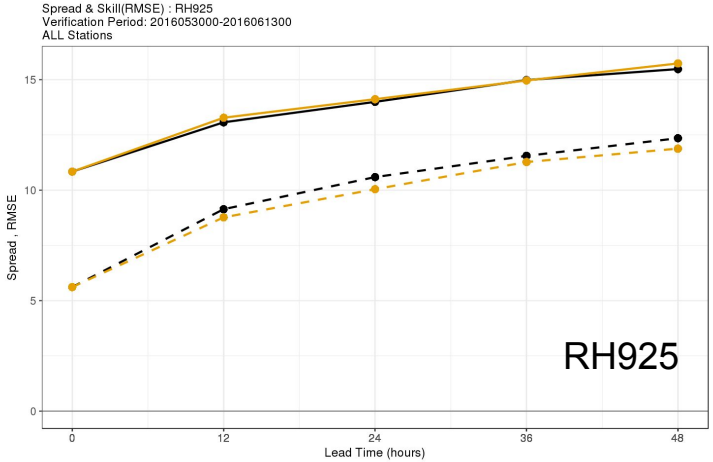


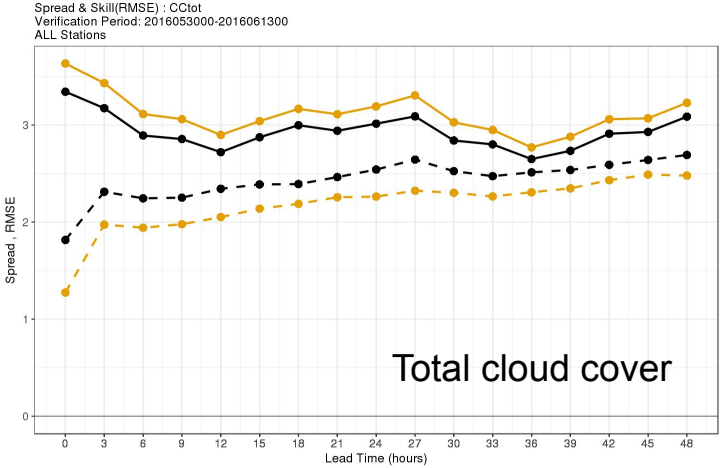
Spread and skill - upper air





REF
With SPP

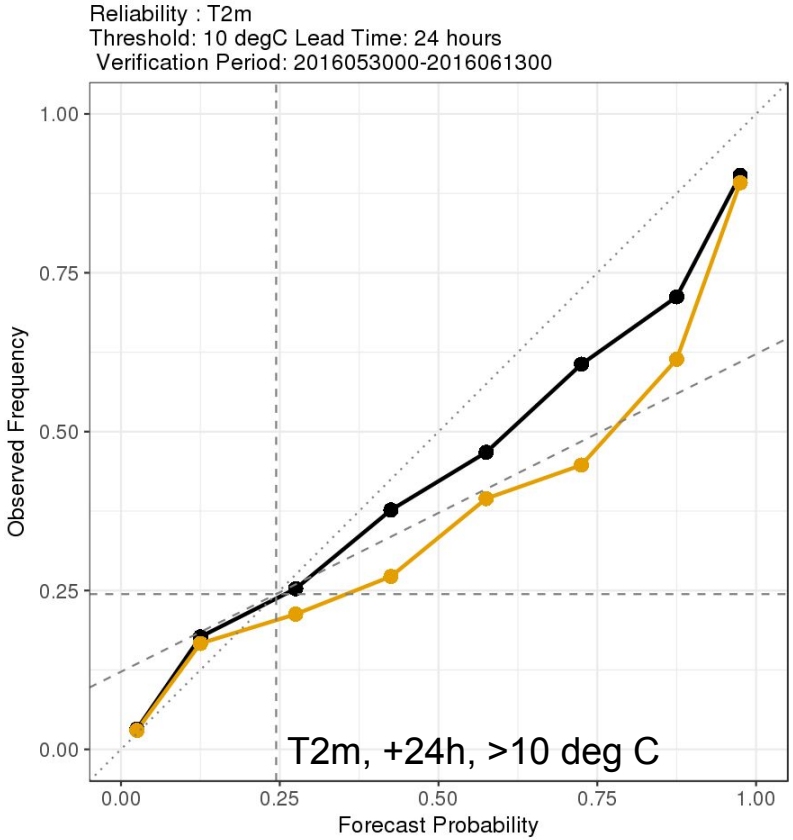


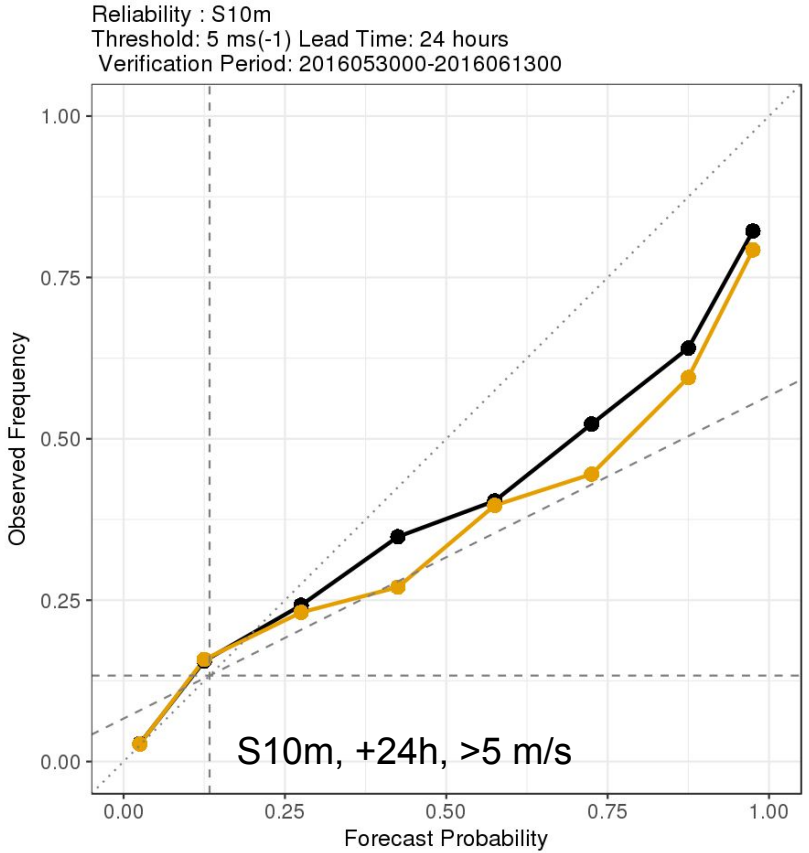


Increased spread with SPP and about the same RMSE, except for total cloud cover where also RMSE is considerably reduced

Reliability

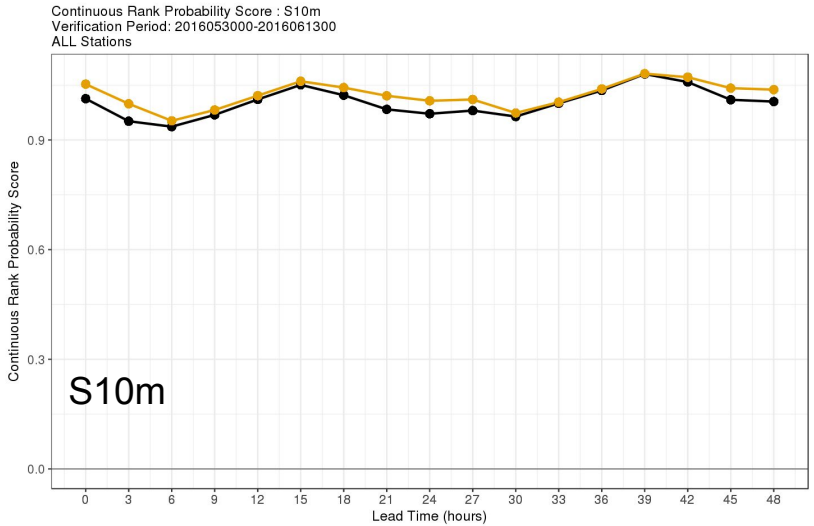
REF
With SPP

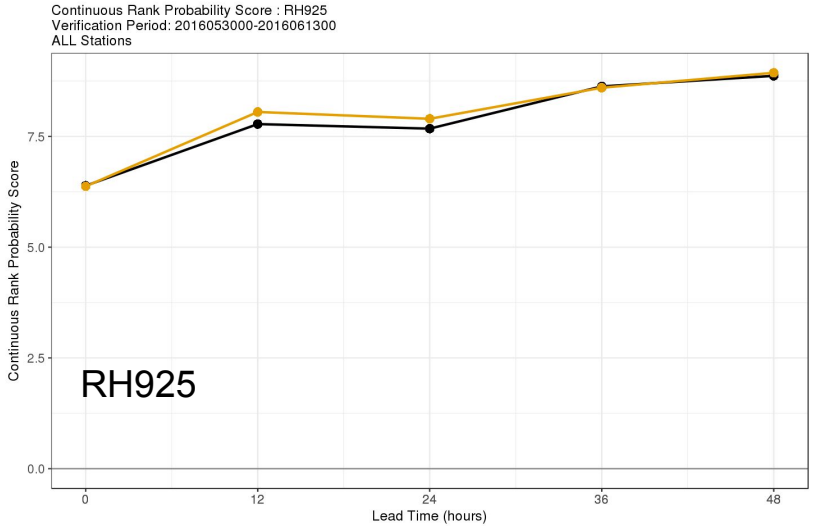


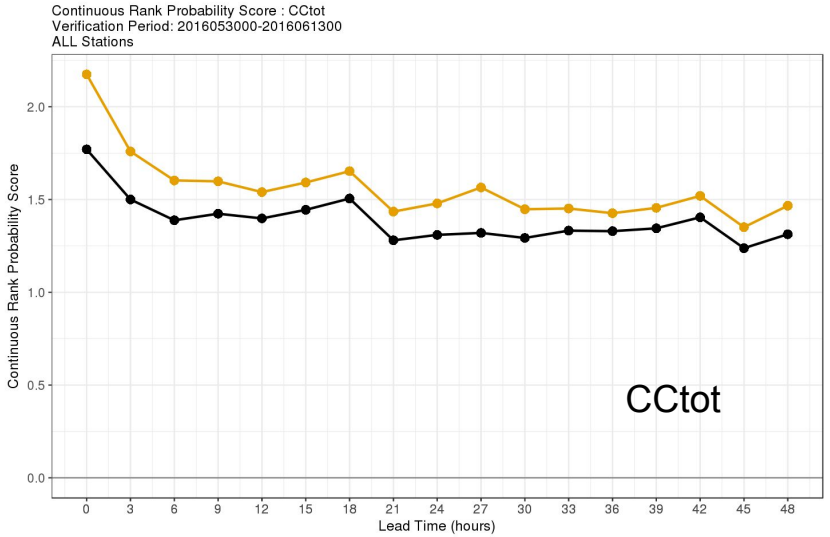


CRPS

REF
With SPP







We get encouraging results from including SPP in HarmonEPS!

Further work on SPPT and SPP

SPPT:

- SPPT perturbation amplitude tuning
- Better adjusting the PBL and upper atmosphere SPPT tapering
- Perturb independently each parameterisation
- Perturb independently each variable?

SPP:

- Test on a winter period
- Include and test more parameters
- Perturb SLHD
- Using different spatial and temporal scales for different parameters

For both:

- Optimize time-spatial scales in SPG
- extend SPG to 3D
- Combine SPP and SPPT

Thank you for your attention!