Surface perturbations in HarmonEPS

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What is perturbed at the surface?

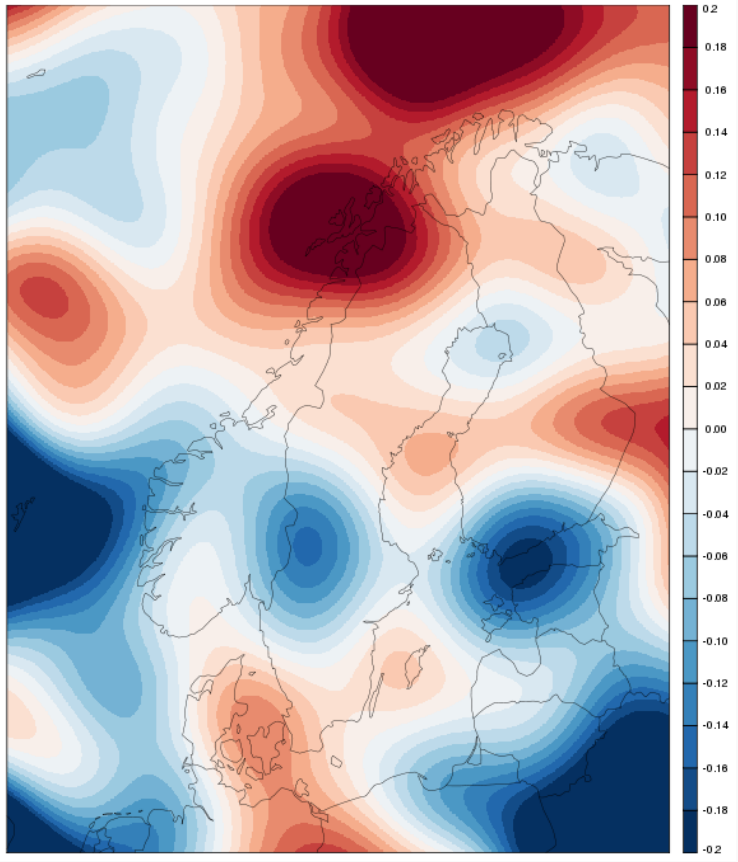
A selection of surface fields are perturbed in the surface analysis file from SURFEX - both prognostic and physiographic:

- Surface temperature (SST and top 2 soil layers)
- Surface moisture (top 2 soil layers)
- Vegetation fraction
- Leaf Area Index
- Soil thermal coefficient
- Roughness length over land + fluxes over the sea
- Albedo
- Snow depth

How the perturbation pattern is generated

- Model grid is filled with white noise
- 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 ~300km, 10 iterations).
  - After smoothing, pattern is clipped to have max / min value of ± specified clipping value
- Perturbation fields are rescaled and clipped with spatially constant values that are "tuned" for each parameter: the perturbation std. 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.

Example perturbation field



Application of the perturbations

Perturbation field (α) is applied either additively or multiplicatively depending on the parameter (x):

Additive : $x' = x + \alpha$

Multiplicative : $x' = x(1 + \alpha)$

α is the (clipped) filtered noise * user specified standard deviation

Clipping is done after the perturbation is applied:

No perturbation applied where parameter value is already outside the max and min clipping values

where ($x' < clipMin$) $x' = clipMin$

where ($x' > clipMax$) $x' = clipMax$

Field perturbations

Perturbation	Parameters	Output to SURFEX	std. dev (+ / x)	clipMin	clipMax
VEG	VEG	VEG	0.1 x	0.01	0.95
LAI	LAI	LAI	0.2 x	0.1	6.0
CV	CV	CV	0.1 x	0.5×10^{-5}	4.0×10^{-5}
Z0	(Z0VEG) (SST)	PERTZ0LAND* PERTSEAFLUX**	0.2 x	0.05 0.05	4.0 4.0
ALB	(ALBNIR_ISBA)	PERTALB*	0.1 x	0.5	1.5
TS	SST TG1 TG2	SST TG1 TG2	1.5 +	272 240 240	350 350 350

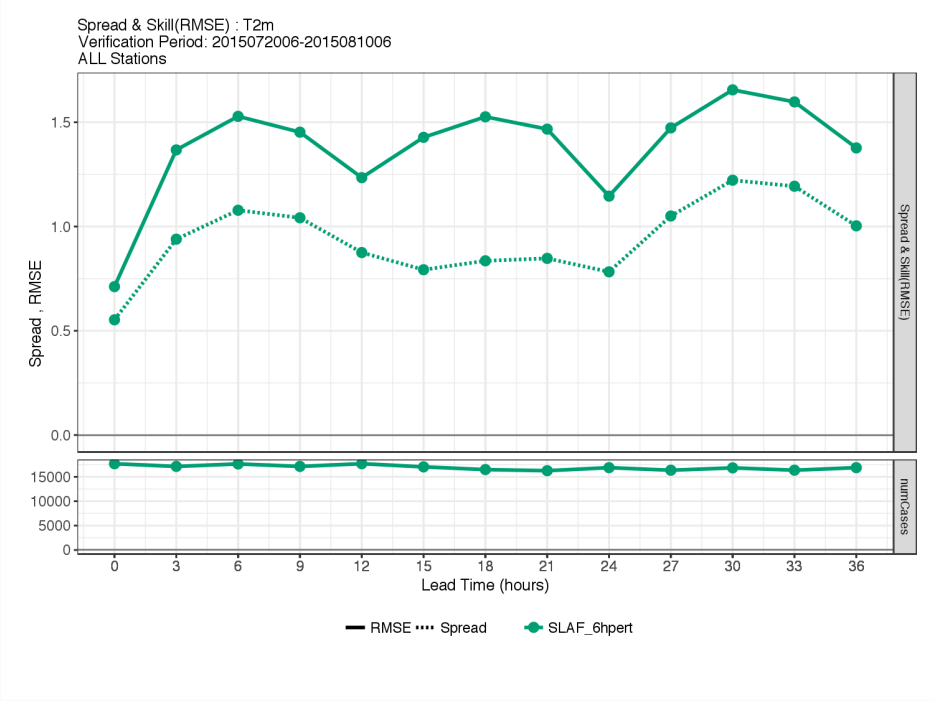
Field perturbations

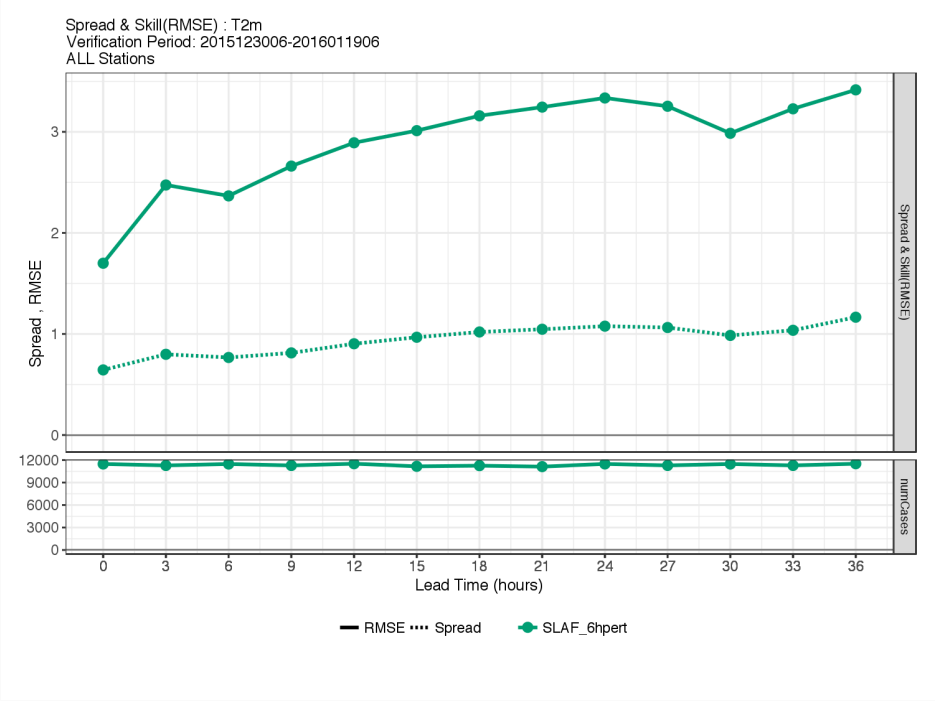
Perturbation	Parameters	Output to SURFEX	std. dev (+ / x)	clipMin	clipMax
WG	WG1 WG2	WG1 WG2	0.1 x	0.001 0.001	0.6 0.6
SNOW	WSN_VEG1	WSN_VEG1	0.5 x	0.1	500.0

First experiments

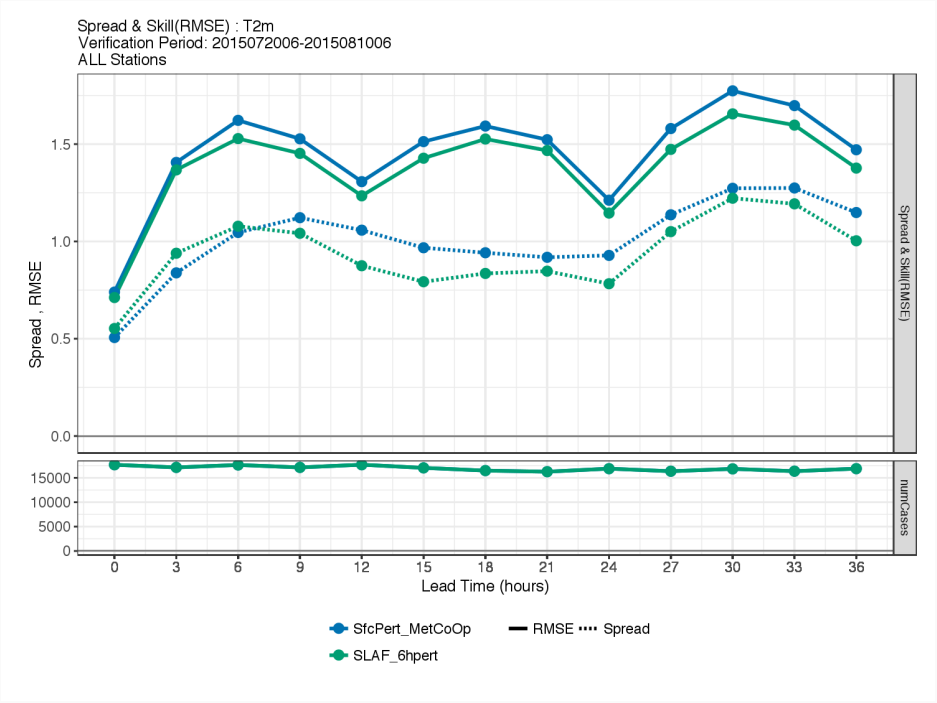
- **Reference (SLAF_6hpert)**
  - SLAF IC and BC perturbations : 10 +1 members
  - 3DVAR upper air data assimilation on control member with 3h cycling
  - OI surface data assimilation for all members with 6h cycling
- **SfcPert_MetCoOp** - as reference except
  - No IC and BC perturbations
  - Surface perturbations applied after OI surface data assimilation
- **SfcPert_SLAF_MetCoOp** - as reference + SfcPertMetCoOp
  - SLAF IC and BC perturbations
  - Surface perturbations applied after OI surface data assimilation

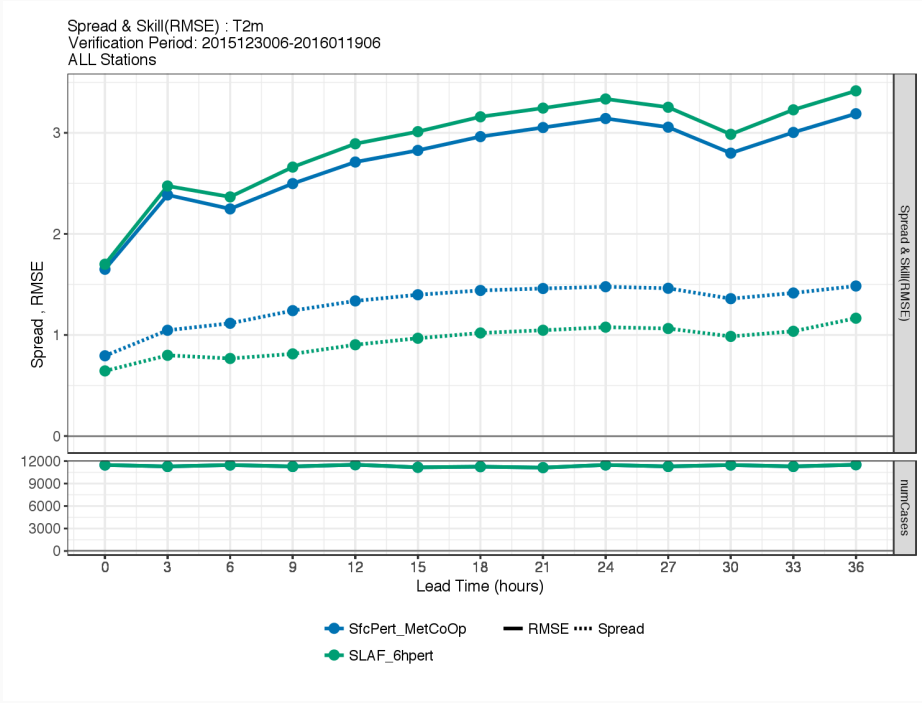
T2m spread-skill



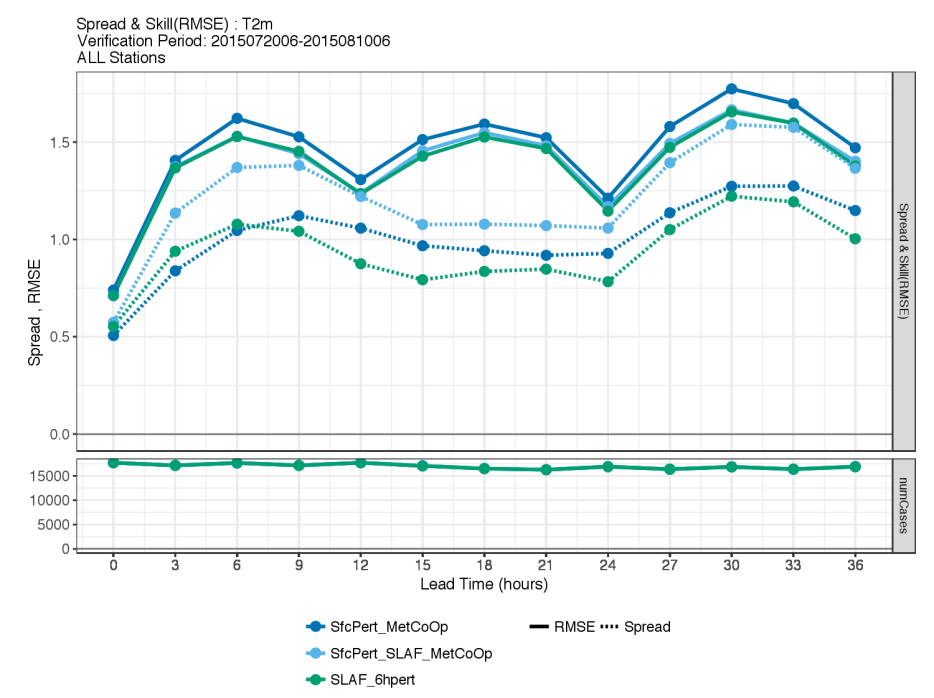


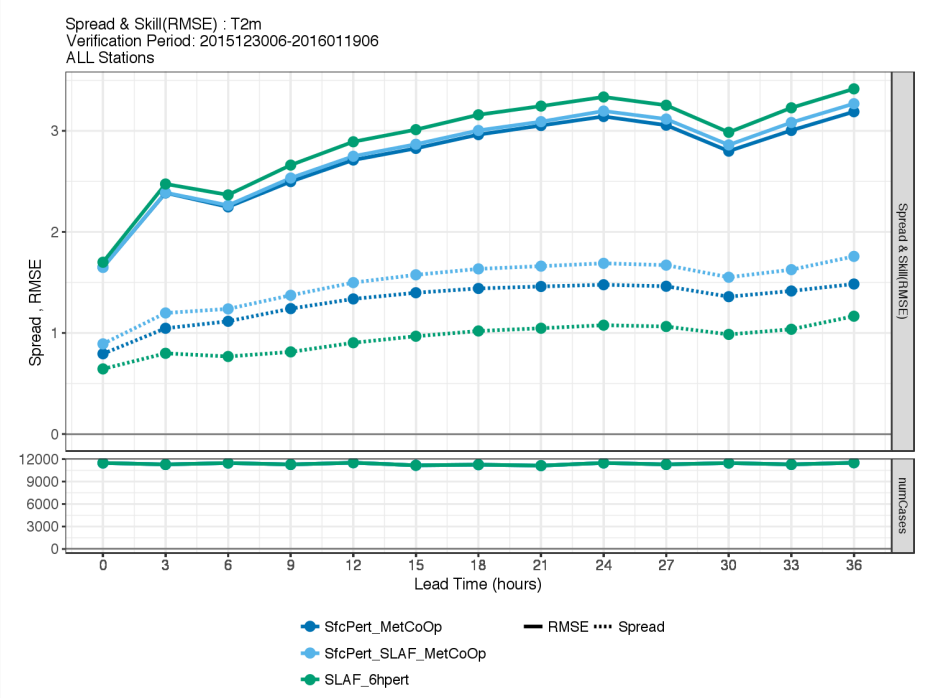
T2m spread-skill



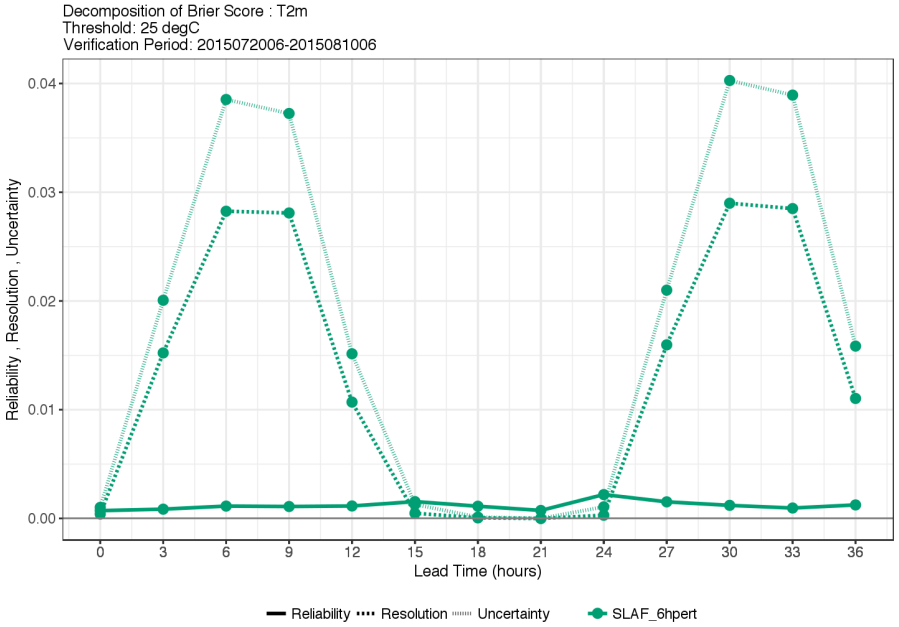


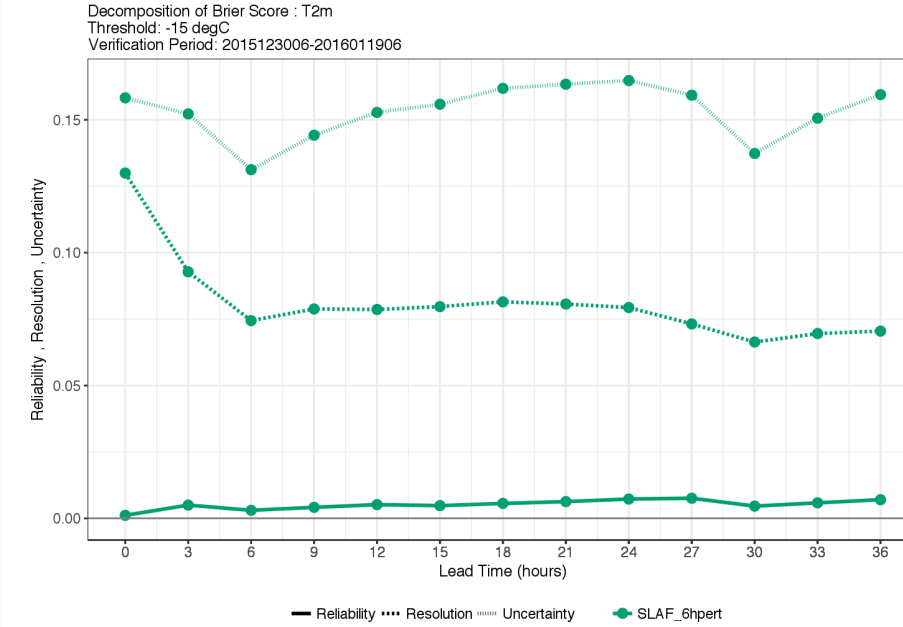
T2m spread-skill



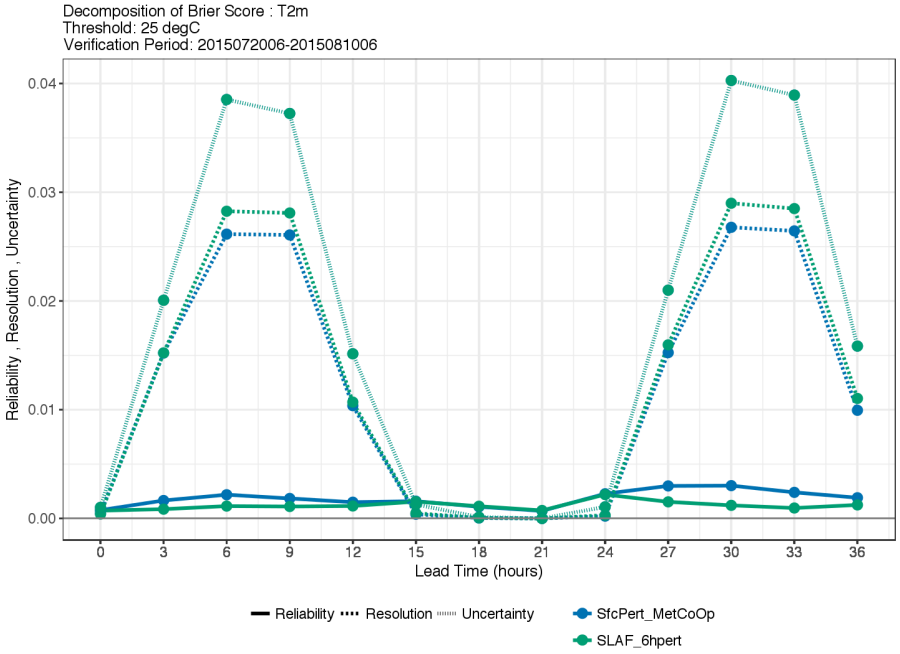


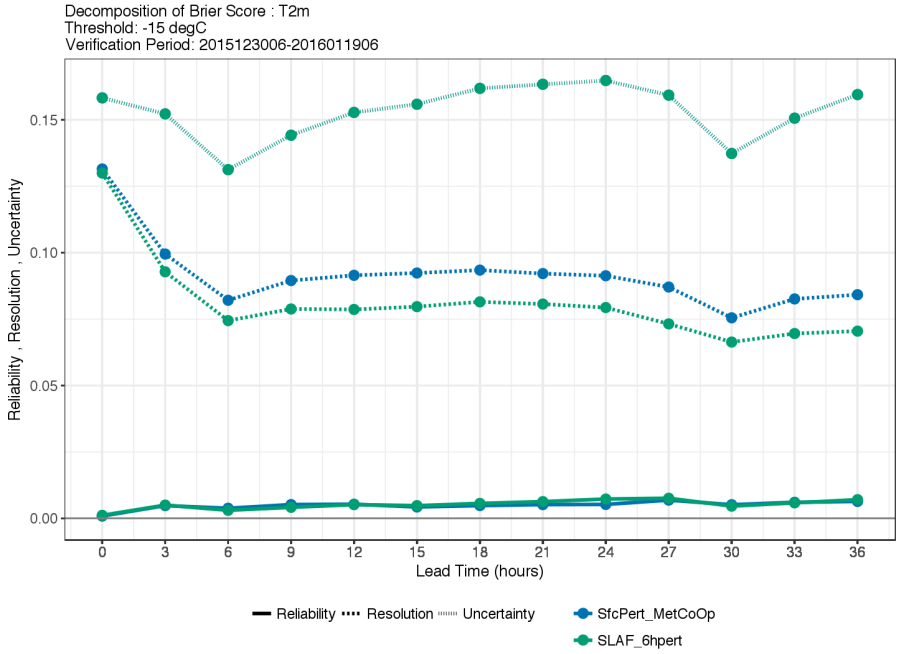
T2m extremes



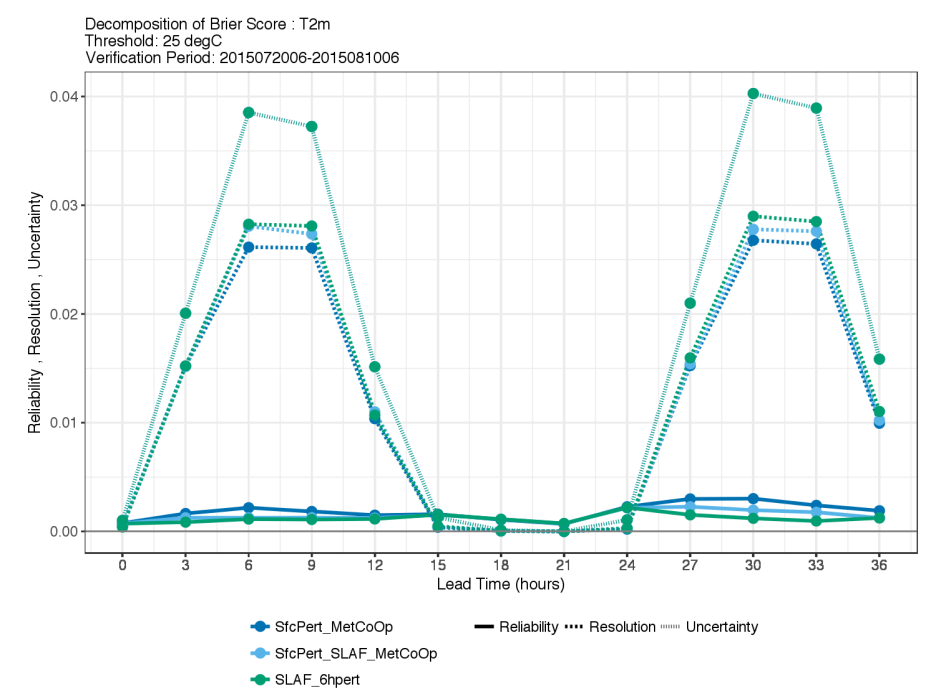


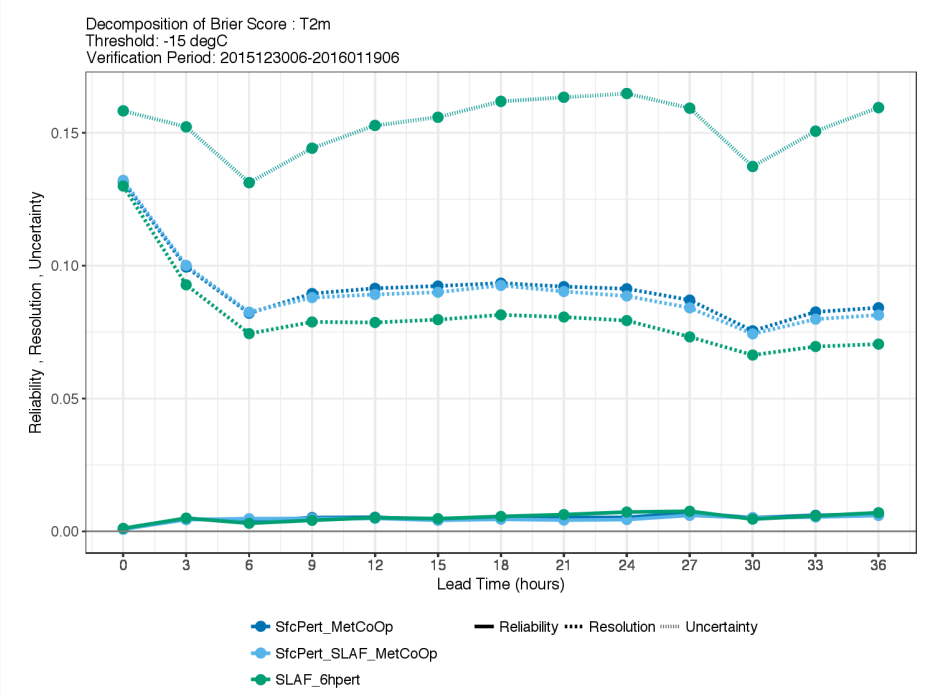
T2m extremes



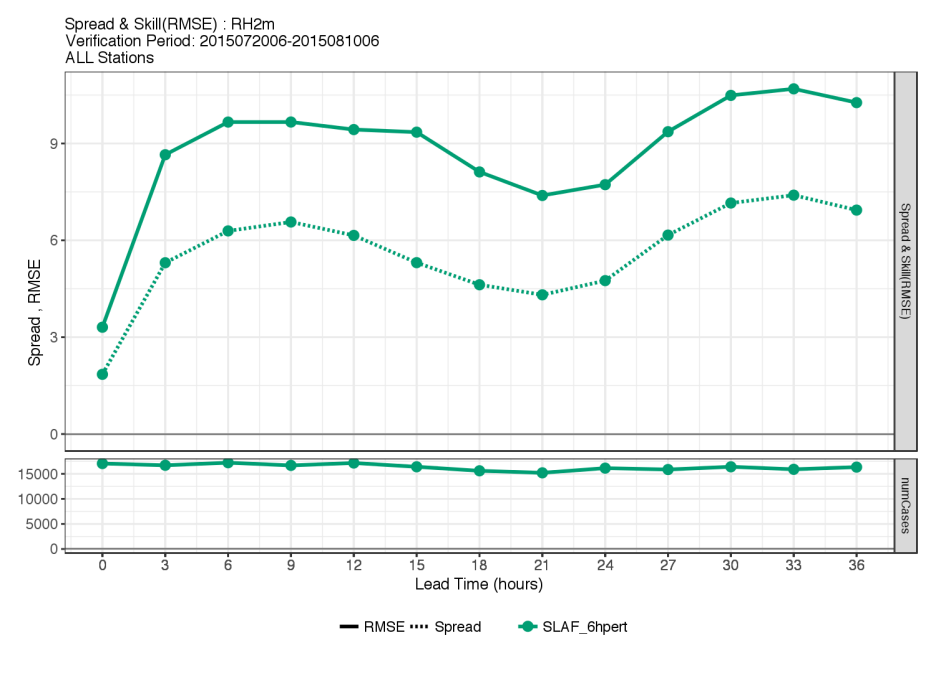


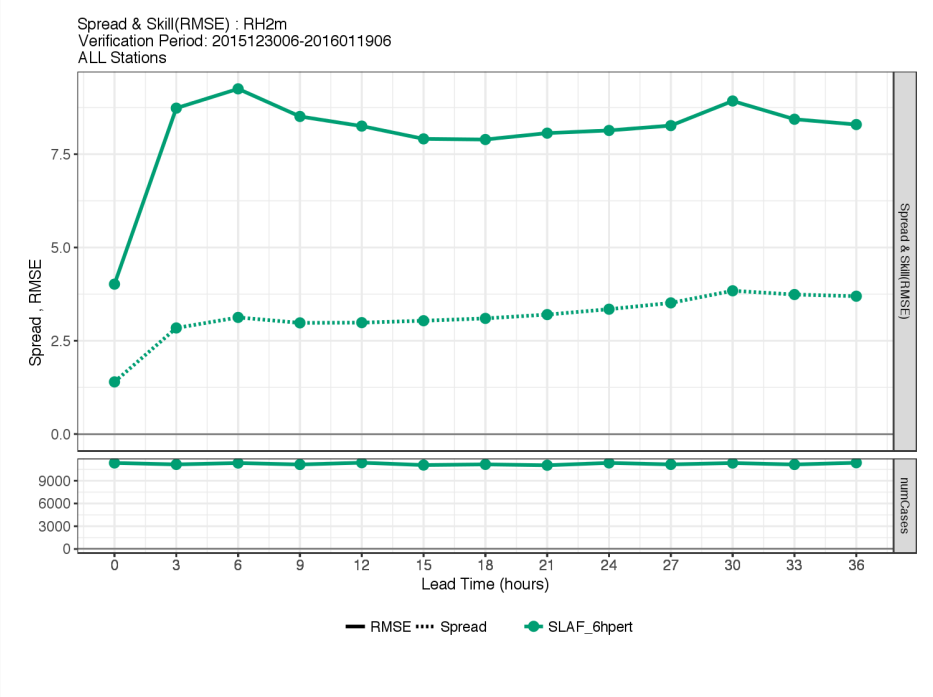
T2m extremes



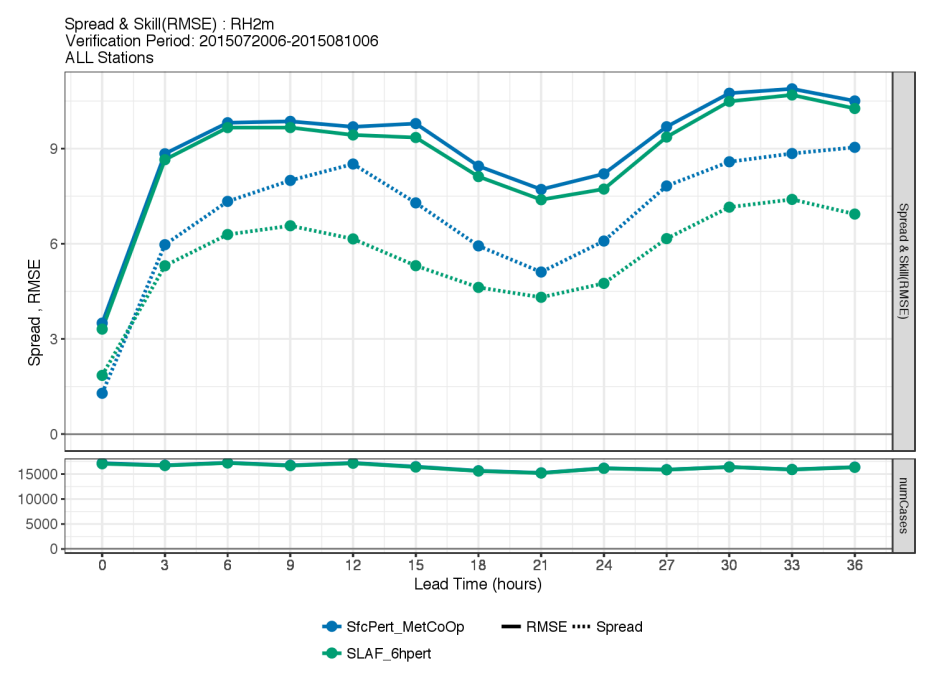


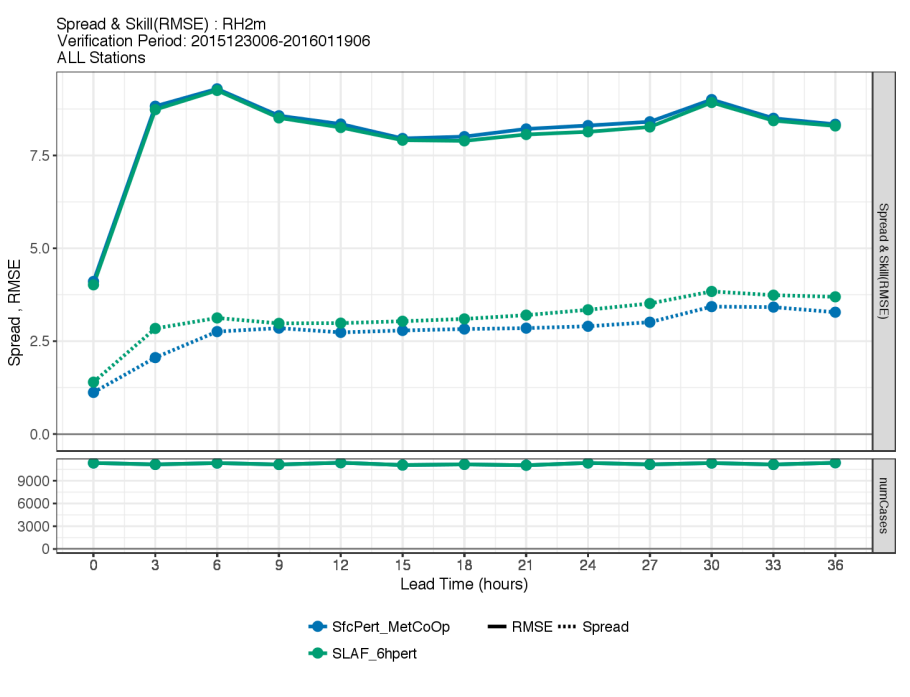
RH2m spread-skill



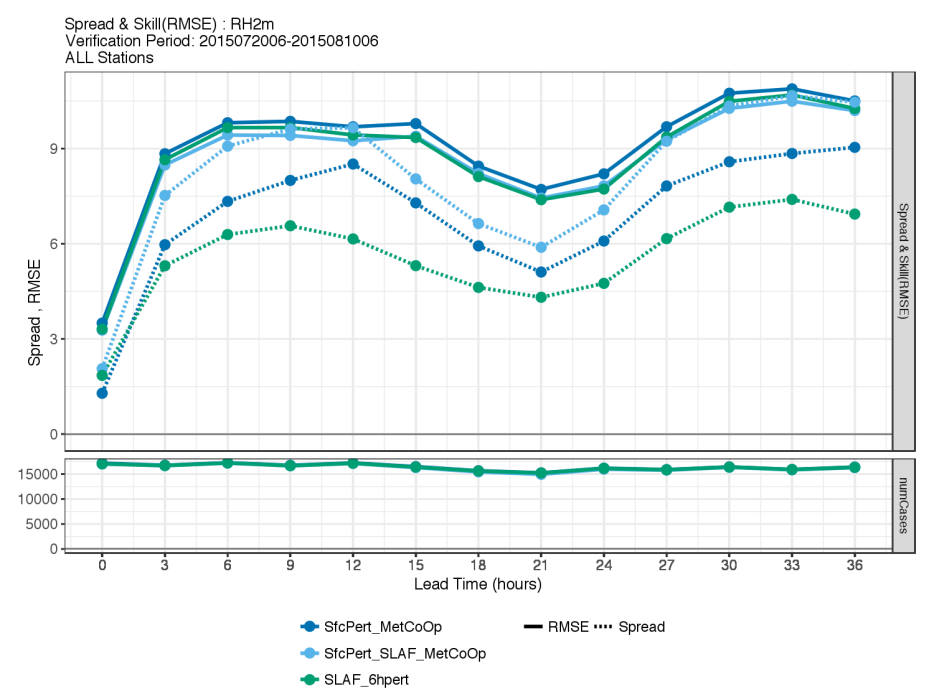


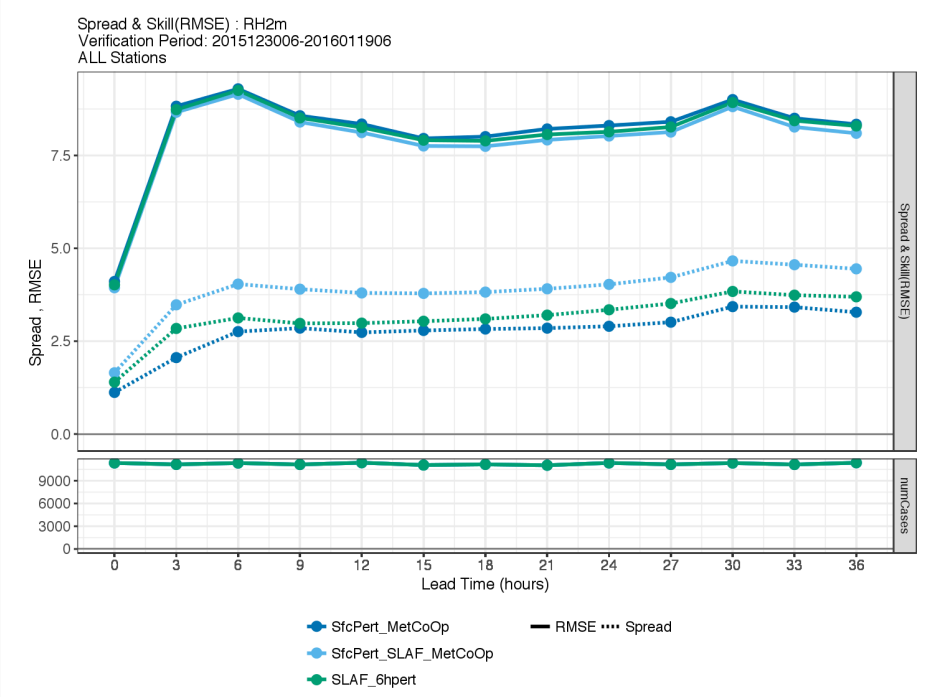
RH2m spread-skill





RH2m spread-skill





Effects of surface perturbations

Summer

Alone

- Increased spread in T2m and RH2m, but worsened RMSE.
- Loss of resolution and reliability for high temperatures.

With SLAF

- Further increases in spread for T2m and RH2m, no significant effect on RMSE.
- Resolution and reliability partially recovered for high temperatures.

Winter

Alone

- Increased spread and improved RMSE for T2m, but reduced spread and slightly worsened RMSE for RH2m - potentially due to frozen soil.
- Improved resolution for extreme low temperatures.

With SLAF

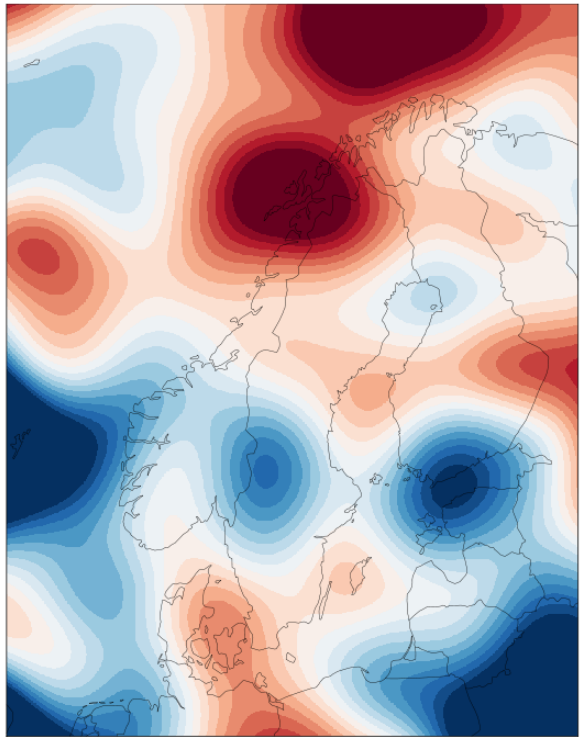
- Further increases in spread for T2m and improved spread for RH2m
- Very small drop in resolution for extreme cold temperatures

Sensitivity to correlation length scale

- Original surface perturbation experiments were done with a correlation length scale of approx 300km in the random perturbation fields.
- What happens if we half the correlation length scale, effectively adding perturbation energy with smaller spatial scales?

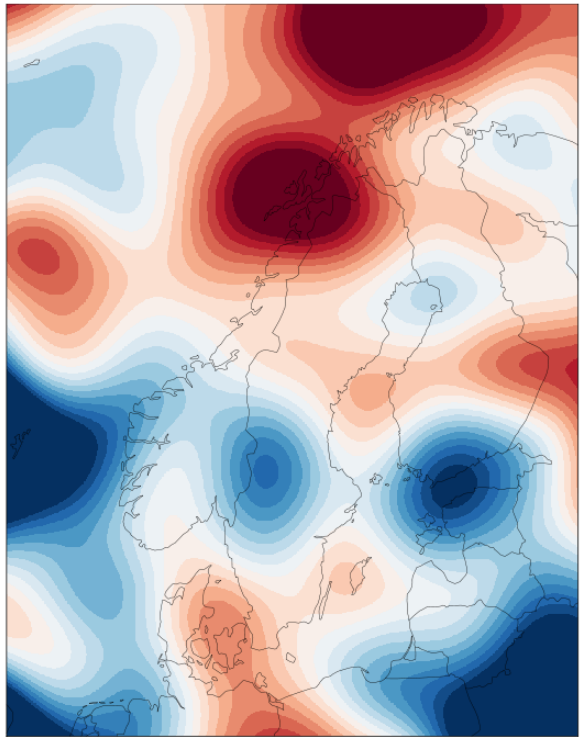
Halving the correlation length scale of the perturbation fields

300km

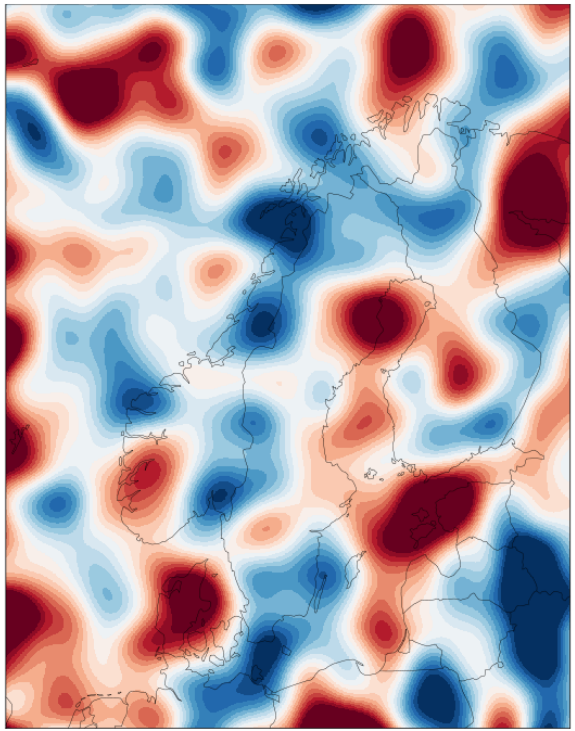


Halving the correlation length scale of the perturbation fields

300km



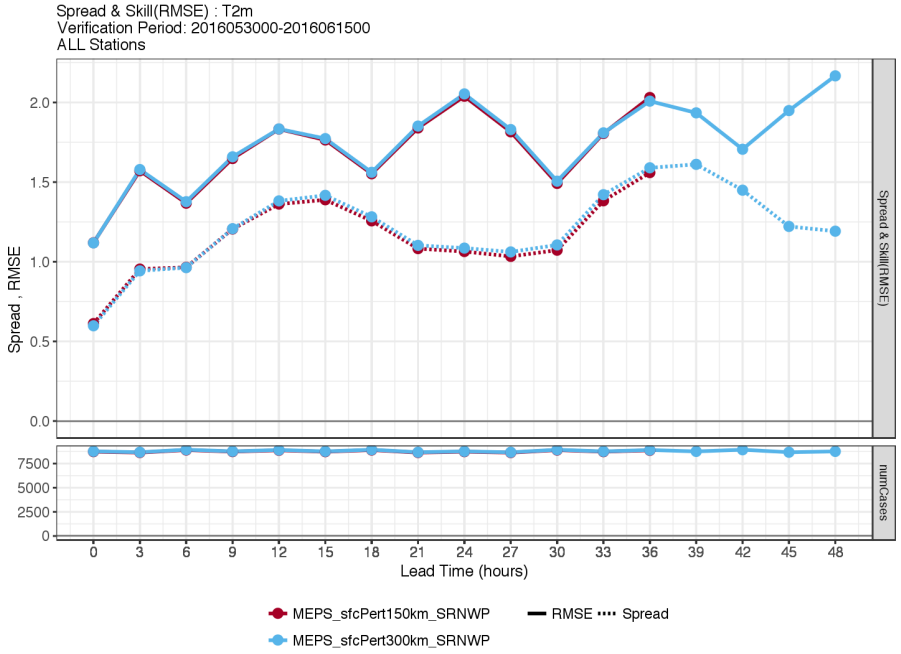
150km

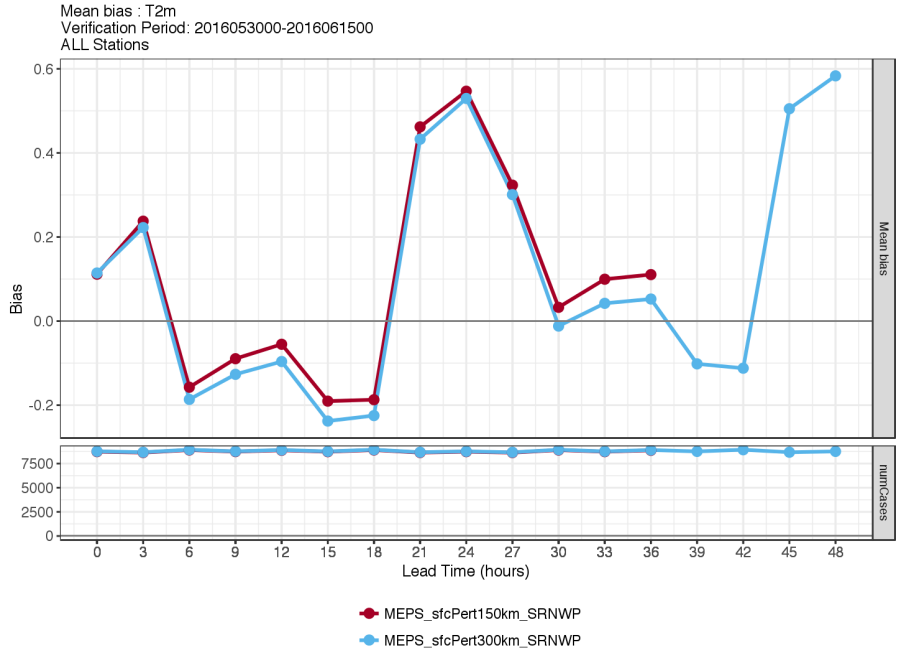


Experiments

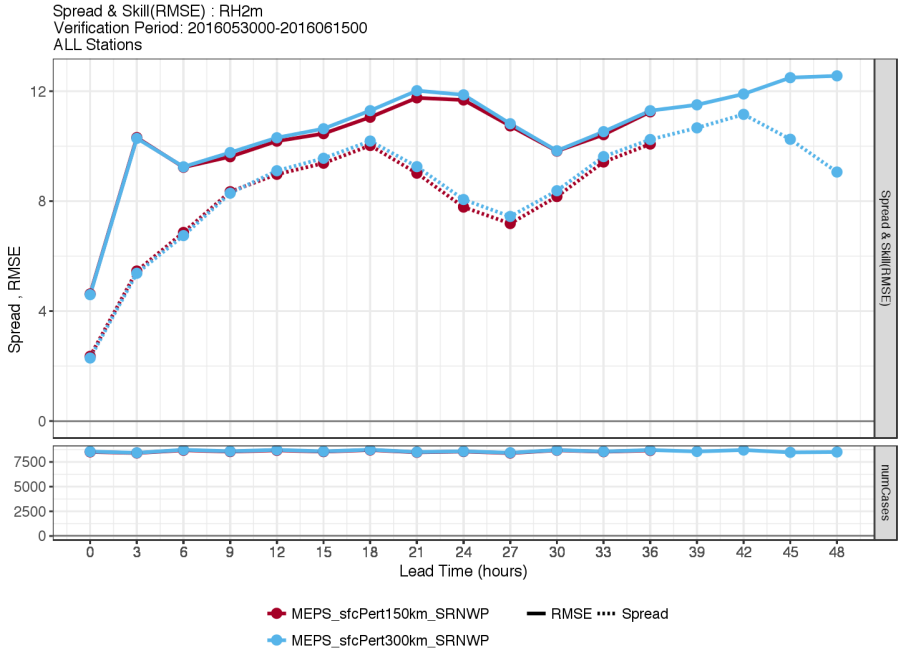
- Reference (MEPS_sfcPert300km_SRNWP)
  - SLAF IC and BC perturbations : 10 + 1 members
  - 3DVAR upper air data assimilation on control member with 3h cycling
  - OI surface data assimilation for all members with 6h cycling
  - Surface perturbations with 300km correlation length scale
- MEPS_sfcPert150km_SRNWP
  - As reference, but surface perturbations with 150km correlation length scale

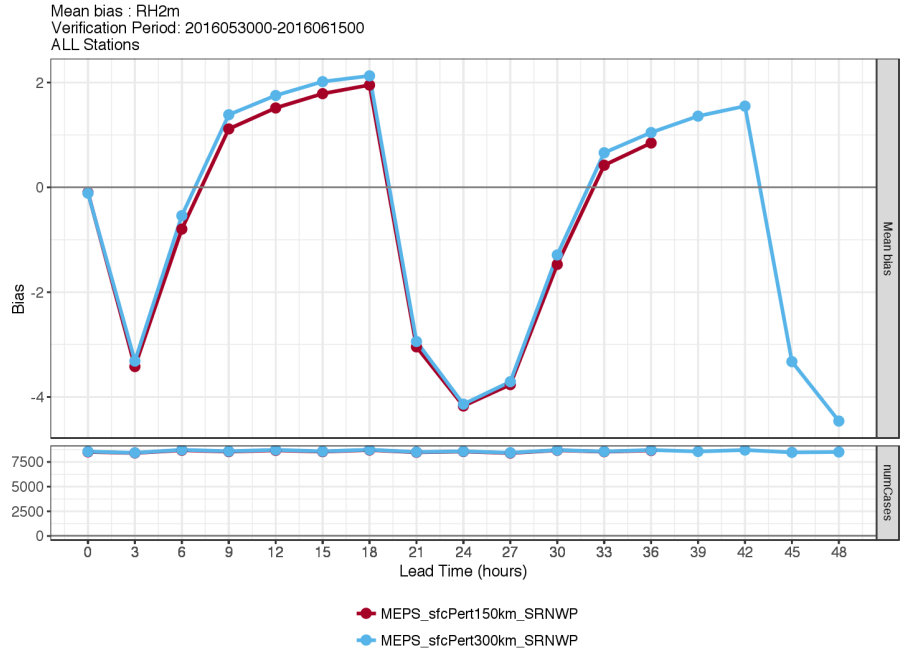
T2m


Spread & Skill(RMSE) : T2m
Verification Period: 2016053000-2016061500
ALL Stations
Spread , RMSE
Spread & Skill(RMSE)
numCases
Lead Time (hours)
MEPS_sfcPert150km_SRNWP
MEPS_sfcPert300km_SRNWP
RMSE
Spread

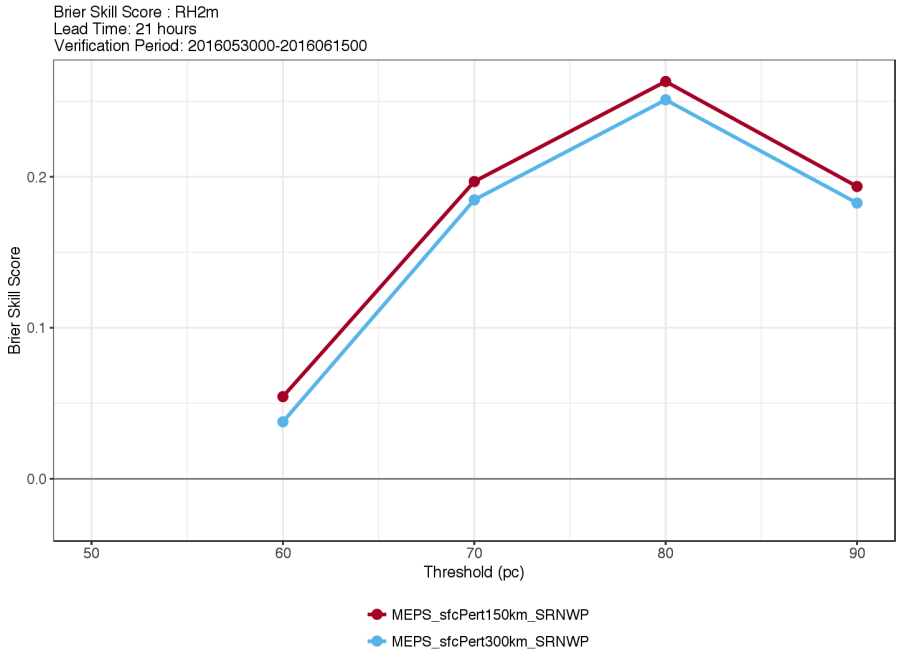

Mean bias : T2m
Verification Period: 2016053000-2016061500
ALL Stations
Bias
Mean bias
numCases
Lead Time (hours)
MEPS_sfcPert150km_SRNWP
MEPS_sfcPert300km_SRNWP

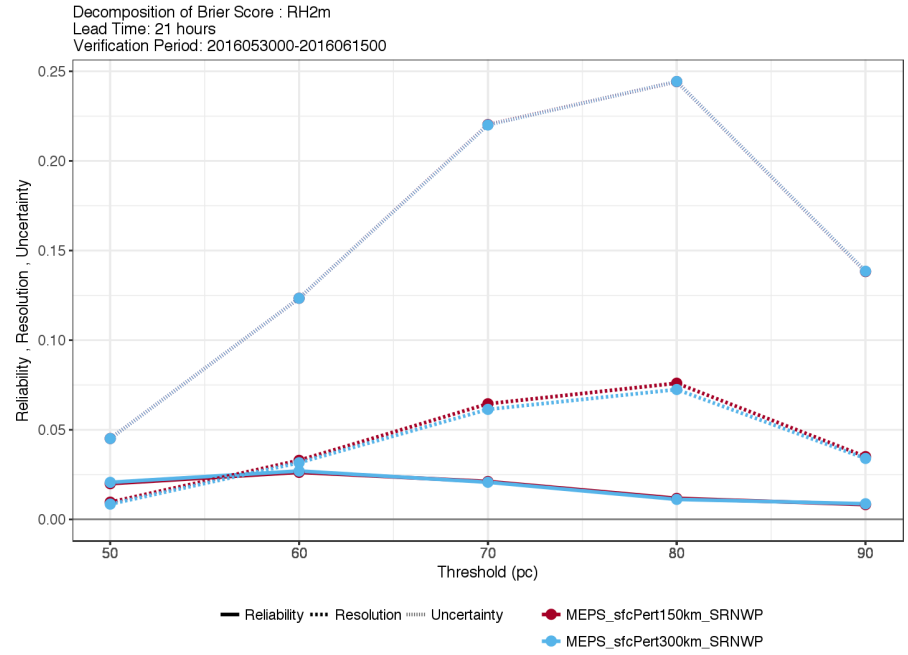
RH2m


Spread & Skill(RMSE) : RH2m
Verification Period: 2016053000-2016061500
ALL Stations
Spread , RMSE
Spread & Skill(RMSE)
numCases
Lead Time (hours)
MEPS_sfcPert150km_SRNWP
MEPS_sfcPert300km_SRNWP
RMSE
Spread


Mean bias : RH2m
Verification Period: 2016053000-2016061500
ALL Stations
Bias
Mean bias
numCases
Lead Time (hours)
MEPS_sfcPert150km_SRNWP
MEPS_sfcPert300km_SRNWP

RH2m (night-time)



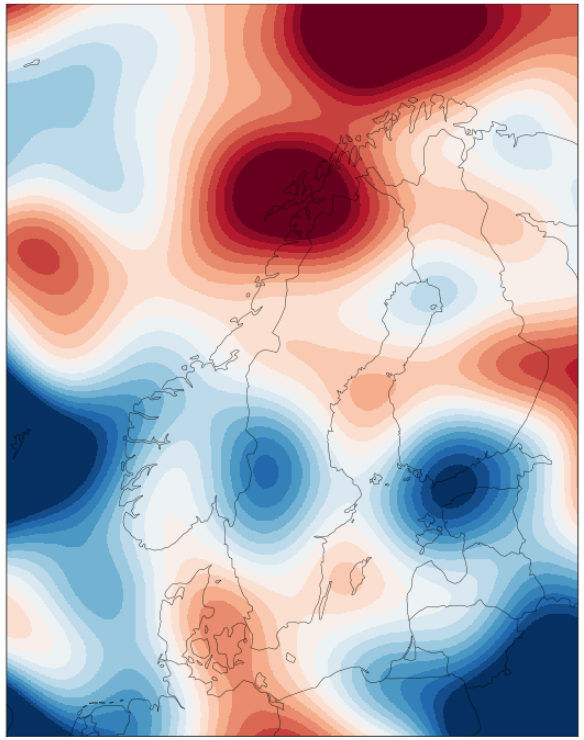


Effects of halving correlation length scale

- Negligible impact on T2m
  - Slight improvement of day-time bias for day 1
- Small impact on RH2m
  - Slightly reduced RMSE in first 24 hours
  - Improved day-time bias
  - Improved BSS for all thresholds in first part of night - resolution is improved

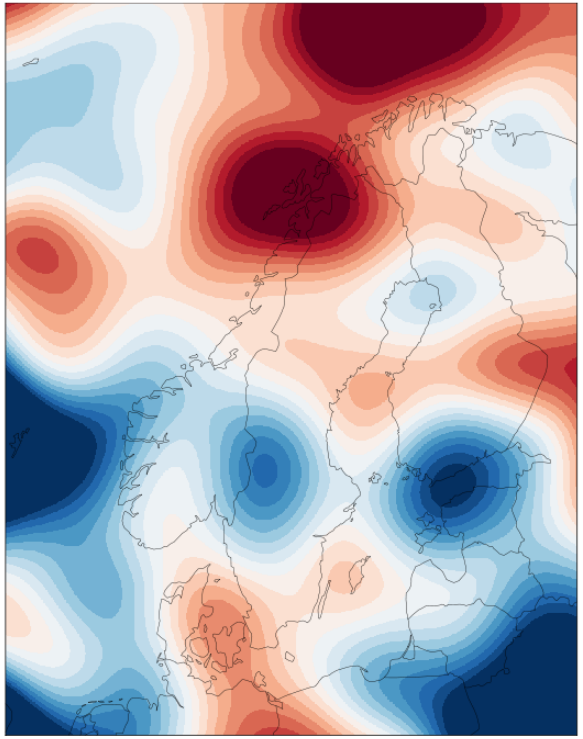
Increasing clipping of random fields to ±4 with parameter standard deviations halved

Clipping at ±2

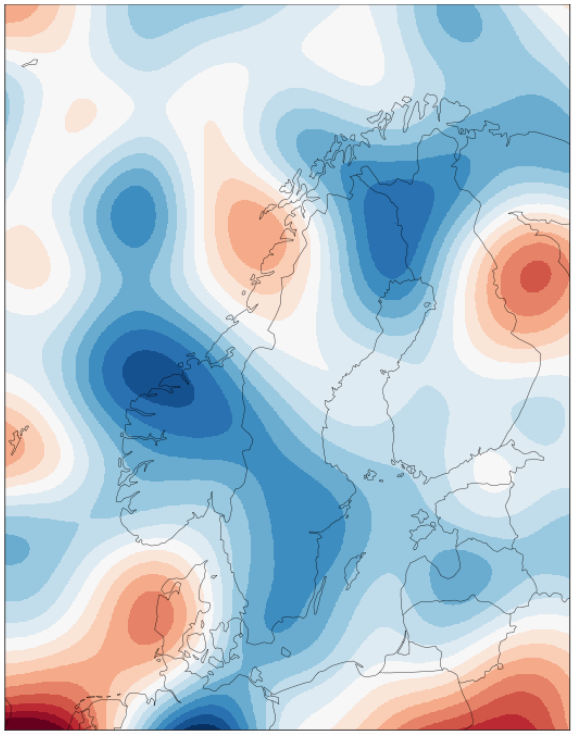


Increasing clipping of random fields to ±4 with parameter standard deviations halved

Clipping at ±2



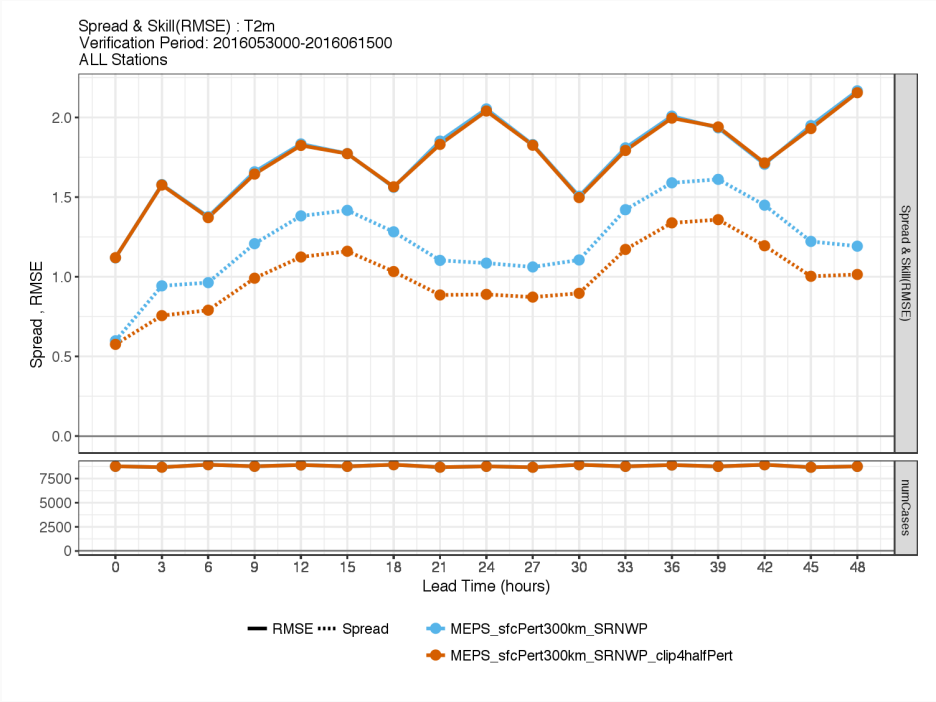
Clipping at ±4 perturbations halved



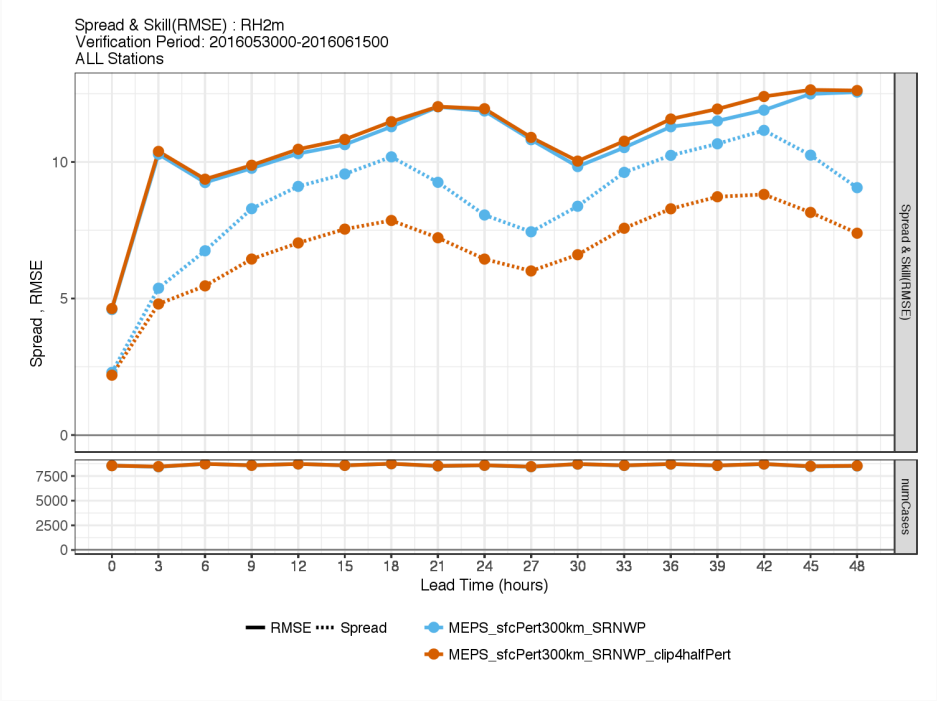
Experiments

- Reference (MEPS_sfcPert300km_SRNWP)
  - SLAF IC and BC perturbations : 10 + 1 members
  - 3DVAR upper air data assimilation on control member with 3h cycling
  - OI surface data assimilation for all members with 6h cycling
  - Surface perturbations with 300km correlation length scale
- MEPS_sfcPert300km_SRNWP_clip4halfPert
  - As reference, but surface perturbations random field clipped at ±4 and perturbation standard deviations halved

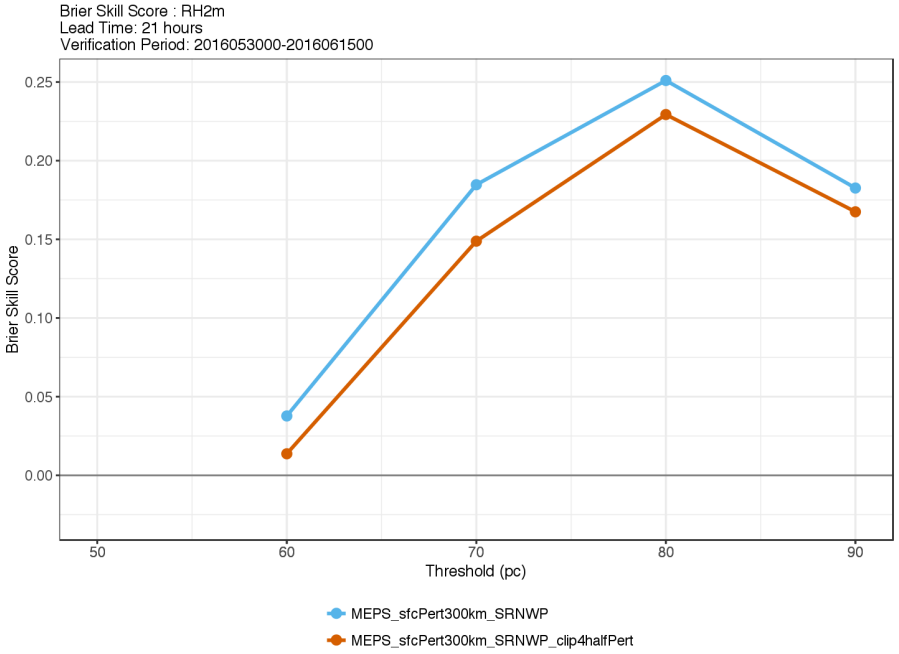
T2m

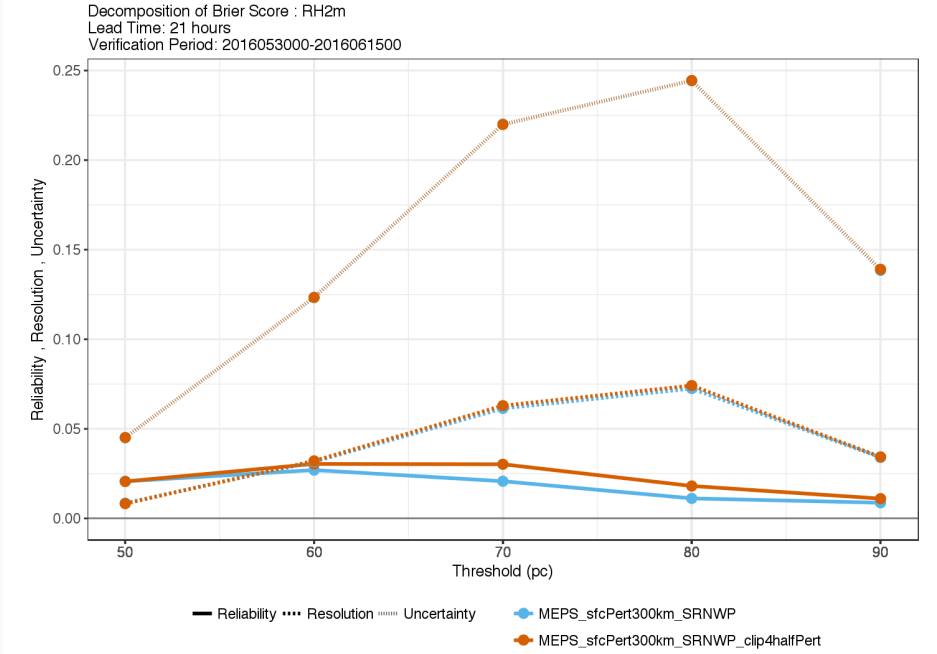

Spread & Skill(RMSE) : T2m
Verification Period: 2016053000-2016061500
ALL Stations
Spread , RMSE
2.0
1.5
1.0
0.5
0.0
Spread & Skill(RMSE)
7500
5000
2500
0
numCases
0
3
6
9
12
15
18
21
24
27
30
33
36
39
42
45
48
Lead Time (hours)
RMSE
Spread
MEPS_sfcPert300km_SRNWP
MEPS_sfcPert300km_SRNWP_clip4halfPert

RH2m


Spread & Skill(RMSE) : RH2m
Verification Period: 2016053000-2016061500
ALL Stations
Spread , RMSE
10
5
0
Spread & Skill(RMSE)
7500
5000
2500
0
numCases
0 3 6 9 12 15 18 21 24 27 30 33 36 39 42 45 48
Lead Time (hours)
RMSE
Spread
MEPS_sfcPert300km_SRNWP
MEPS_sfcPert300km_SRNWP_clip4halfPert

RH2m (night-time)





Effects of increasing clipping and halving perturbations

- Reduced spread for T2m and RH2m
  - Perturbation magnitudes too small?
- Worse night-time BSS due to loss of reliability

Summary

- **Surface perturbations** result in much improved spread for T2m and RH2m
  - Impact on other parameters is small - suggests temperature and moisture perturbations are most important
- Slightly worse performance for “extreme” warm temperatures
- Improved resolution for extreme cold temperatures
- **Shorter correlation length scale** leads to slight improvements for day 1 forecasts of T2m
- … and better resolution for RH2m around dusk
- **Higher clipping value with reduced standard deviations** results in perturbations that are too small
- … and loss of reliability for RH2m around dusk

Future experiments

- Surface temperature and soil moisture perturbations only
- Surface data assimilation on control only
- Perturbations of soil ice content
- More sophisticated perturbations to snow
- More experiments with length scale (?)