Perturbing terminal fall speeds of precipitation in Harmonie EPS

Zalakaros, 31 March 2025

Sibbo van der Veen

KNMI

Motivation

- Fall velocities impact convection dynamics through changing 3D buoyancy fields
- $T_v = \frac{\mathrm{T}.(1+\frac{r_v}{\varepsilon})}{1+r_v+r_l+r_i} \approx \mathrm{T}\ .(1+0.608*r_v - r_l - r_i)$

- Hydrometeor fall velocities lack spread in the Harmonie model:

Hydrometeor mass spectra in Harmonie imply fall velocity spectra, <u>but only bulk velocities are used in vertical advection</u>

Hydrometeor parameterizations in Harmonie

- *The following expressions do apply for rain, snow and graupel in Harmonie:*

- Size spectrum: $\mathrm{n(D)} = \mathrm{N_0}.\lambda^{\mathrm{x+1}}.\mathrm{e}^{-\lambda \mathrm{D}}$ ***(1)***
- $n(D)\,dD$ is particle number concentration in interval (D; D+dD)
- and: $\boldsymbol{\lambda} = \left(\frac{\mathbf{r}.\boldsymbol{\rho}_{\mathbf{dref}}}{\mathbf{a}\boldsymbol{N_0}\Gamma(\boldsymbol{b}+\mathbf{1})}\right)^{\frac{\mathbf{1}}{\mathbf{x}-\mathbf{b}}}$ ***(2)***
- *(r is mixing ratio rain, snow or graupel)*
- Mass-diameter relationship: $\mathrm{m(D)} = \mathrm{a}.\mathrm{D}^{\mathrm{b}}$ ***(3)***
- Terminal fall velocity v: $\mathrm{v(D)} = \left(\frac{\rho_{00}}{\rho_{\mathrm{dref}}}\right)^{0.4}.\mathrm{c}.\mathrm{D}^{\mathrm{d}}$ ***(4)***

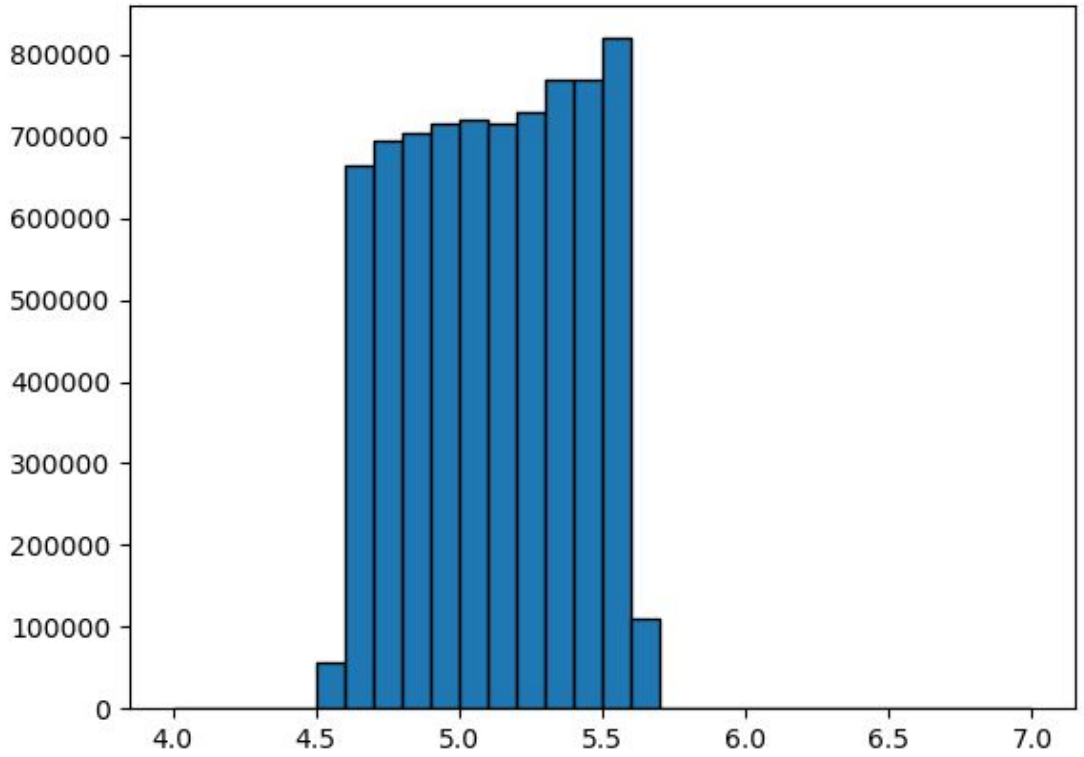
Hydrometeor parameterizations in Harmonie

- With the following constants (i is precipitation type):

	Snow	Graupel	Rain
x_i	1	-0.5	-1
$N_{0,i}$	5	5.10^5	8.10^6
a_i	0.02	19.6	$524=\frac{\pi.\rho r}{6}$
b_i	1.9	2.8	3
c_i	5.1	124	842
d_i	0.27	0.66	0.8

- **Table 1** $(\boldsymbol{\rho_r} = 1000\,\frac{\mathrm{kg}}{\mathrm{m3}}\ \ for\ rain)$

Uniform distribution of C (snow)



Uniform distribution of C for rain and graupel in similar way,
maximum change ~10%

Settings of SPP parameters

- Correlation length scale: 200 km
- Time scale: 12 h
- CMPERT: 0.2
- 6 members

1. Tuning in Single Precision (SP), version 46.

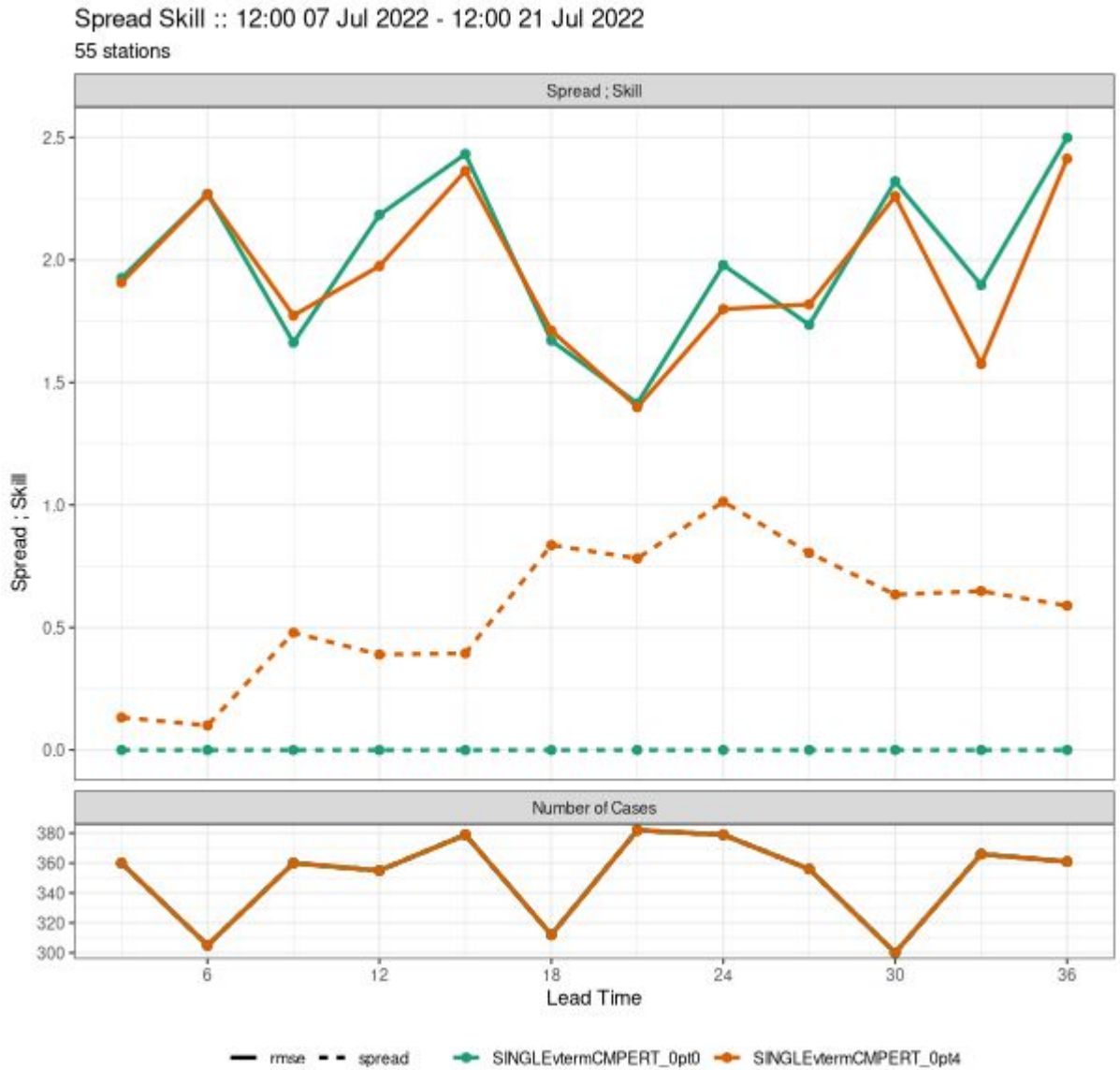
- tau: 43200 s
- XLCOR 200 km
- Pseudo uniform distribution
- CMPERT=0.2

Terminal fall velocity v: $\mathrm{v(D)} = (\frac{\rho_{00}}{\rho_{dref}})^{0.4} . \mathrm{c}. \mathrm{D}^{\mathrm{d}}$

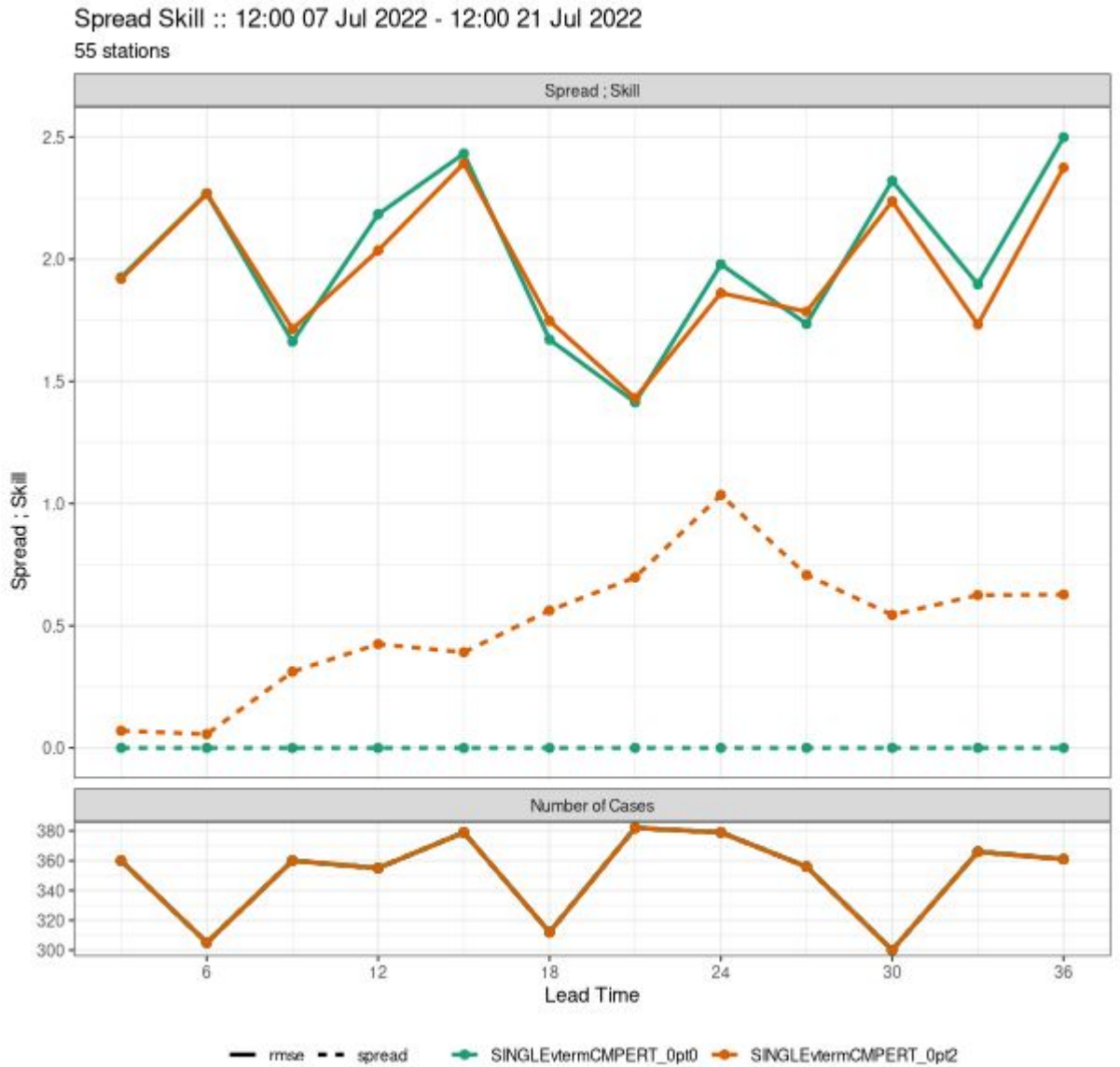
Model output to be verified:

- AccPcp3h
- Cctot
- Gmax
- T2m
- RH2m

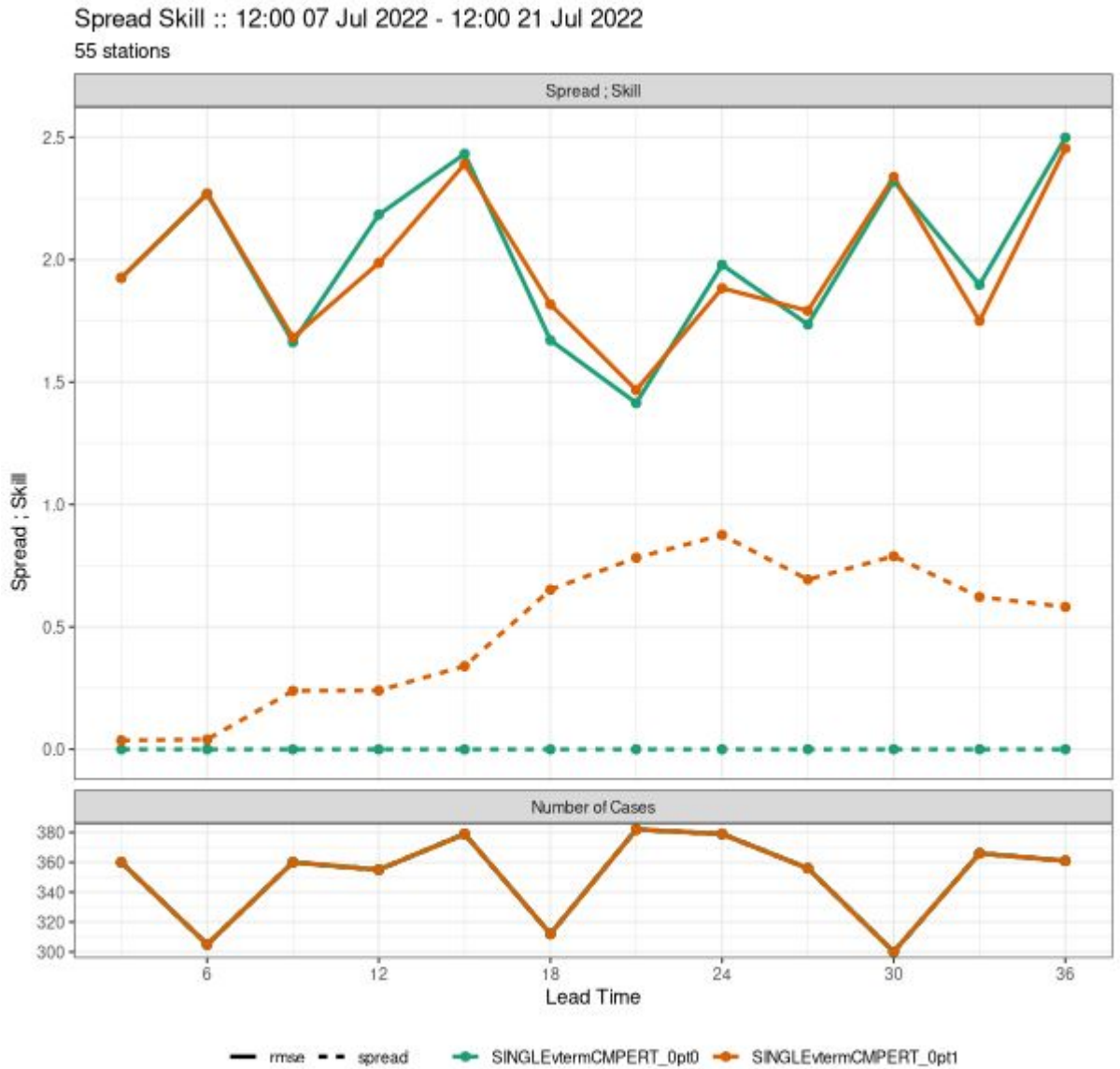
AccPcP3h: CMPERT=0.4



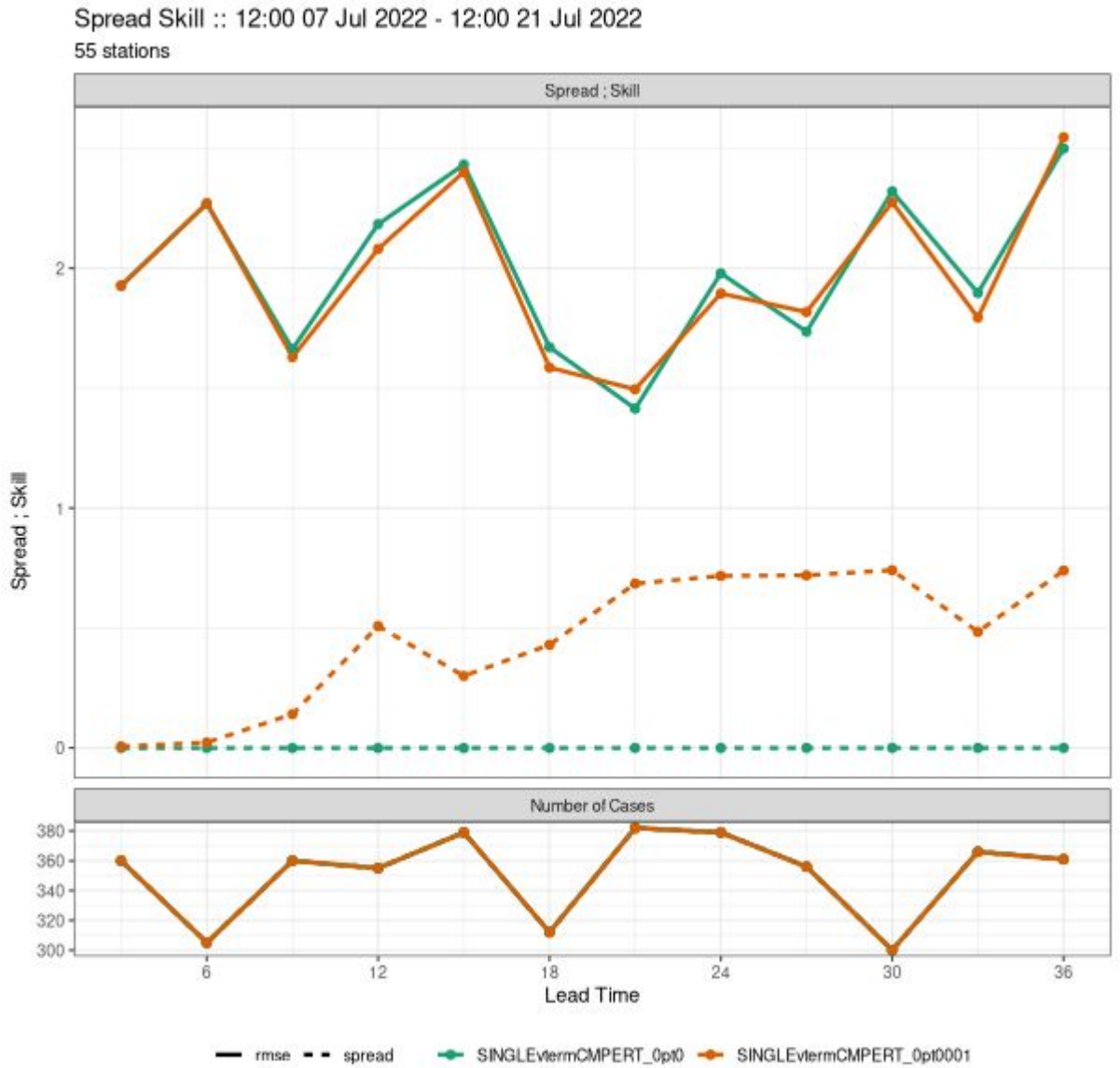
AccPcp3h: CMPERT=0.2 (max. 10 % variation)



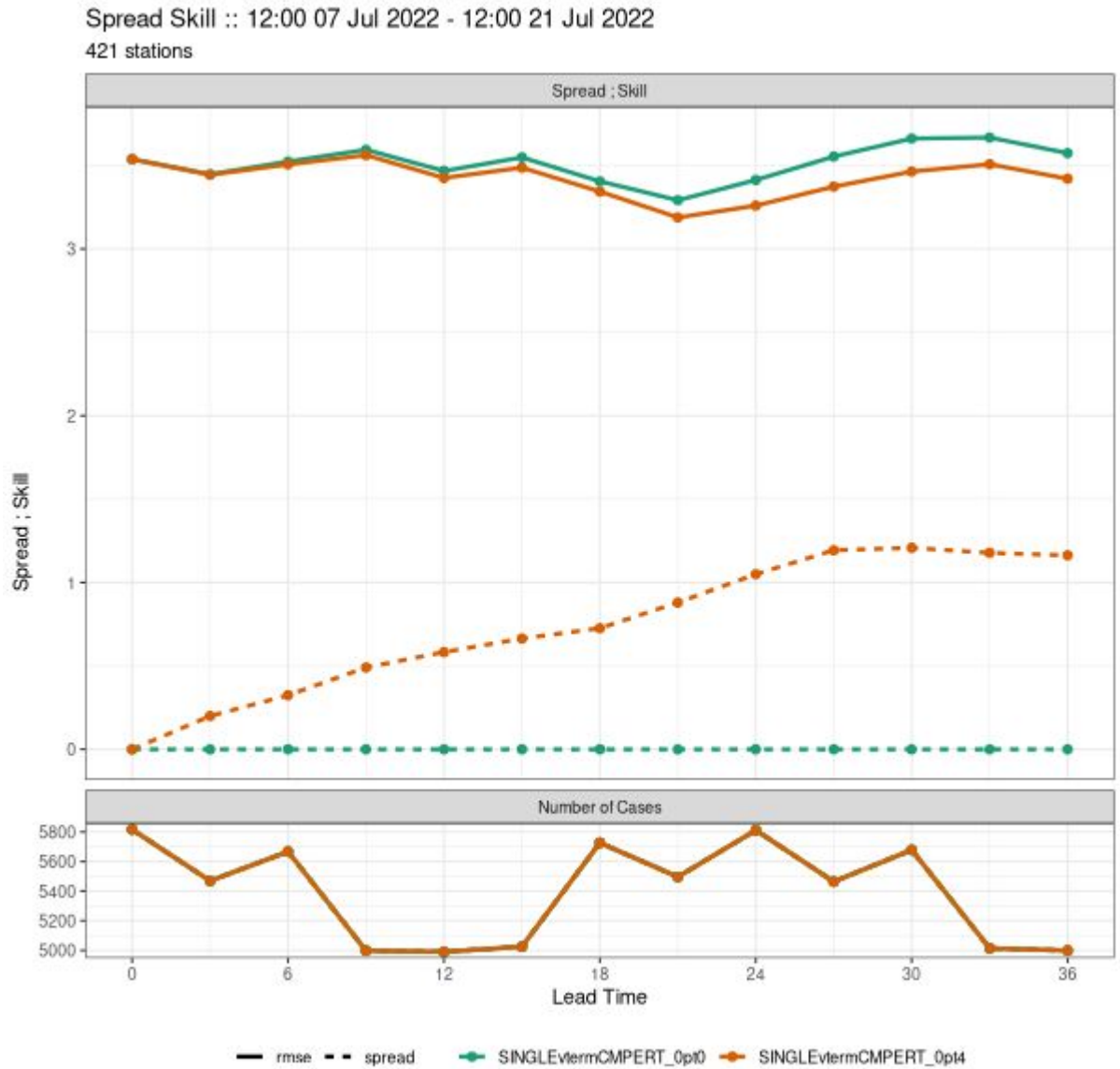
AccPcp3h: CMPERT=0.1 (max. 5 % variation)



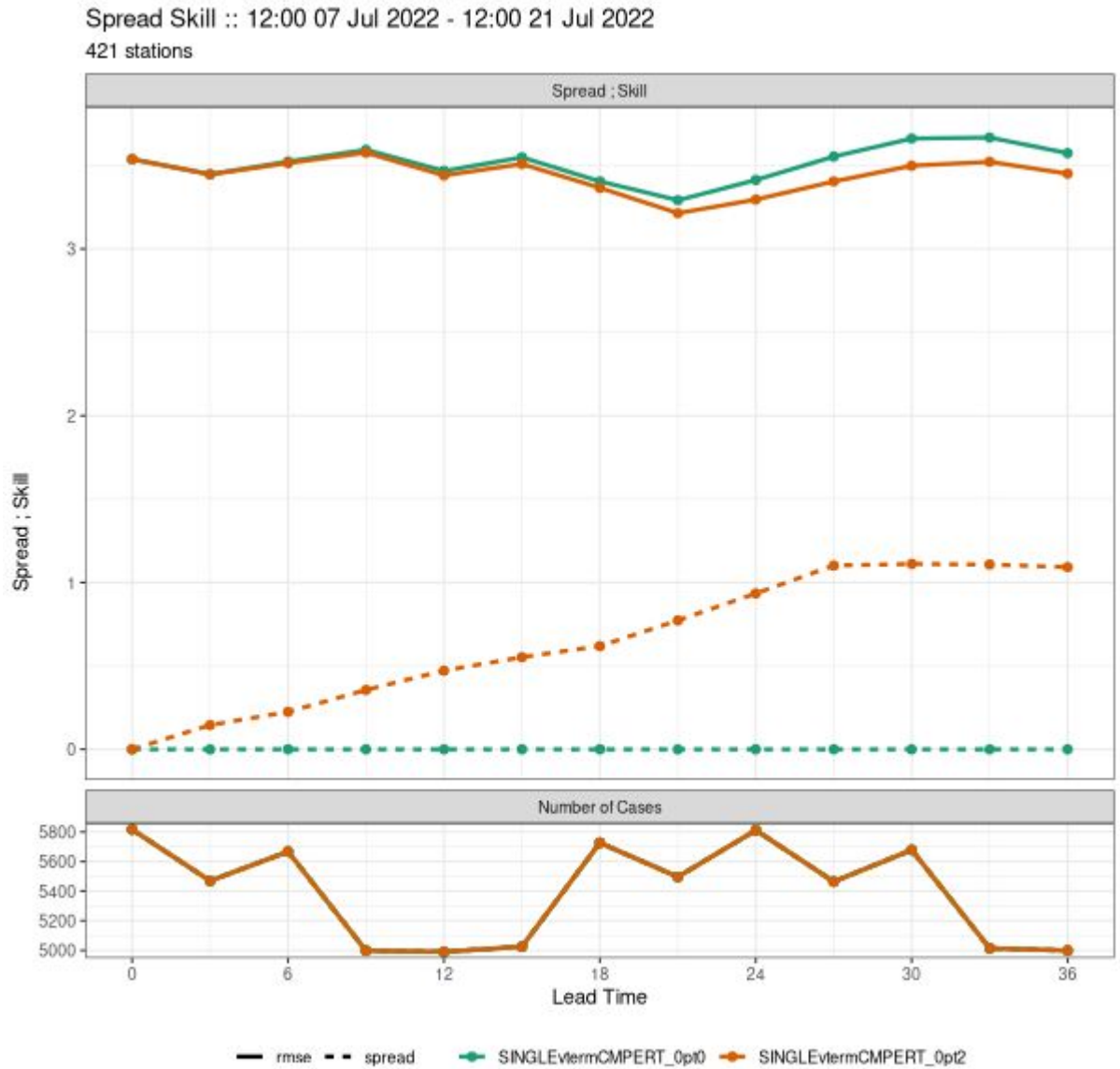
AccPcp3h: CMPERT=0.0001 (max. 0.005 % variation)



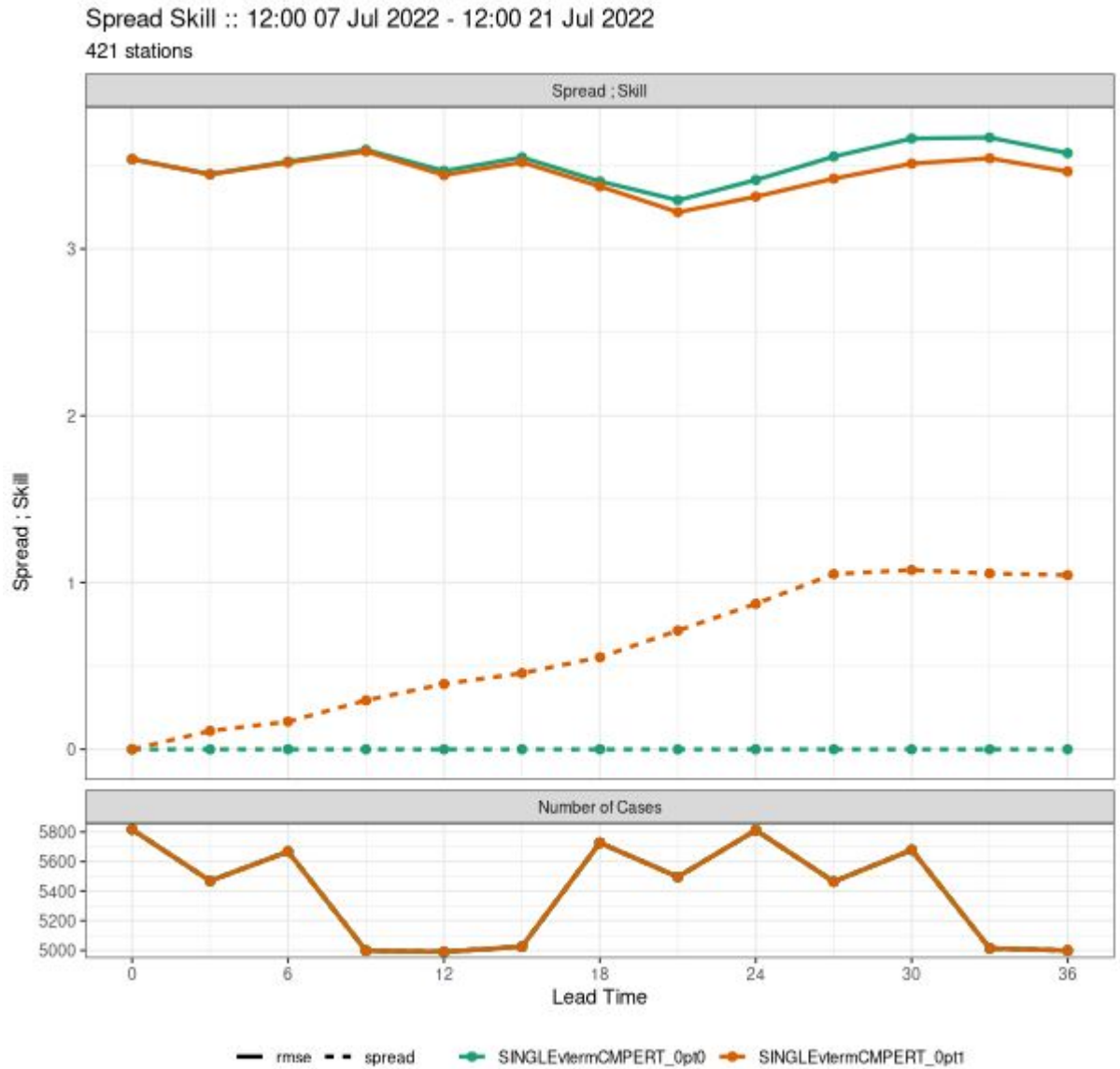
Cctot: CMPERT=0.4



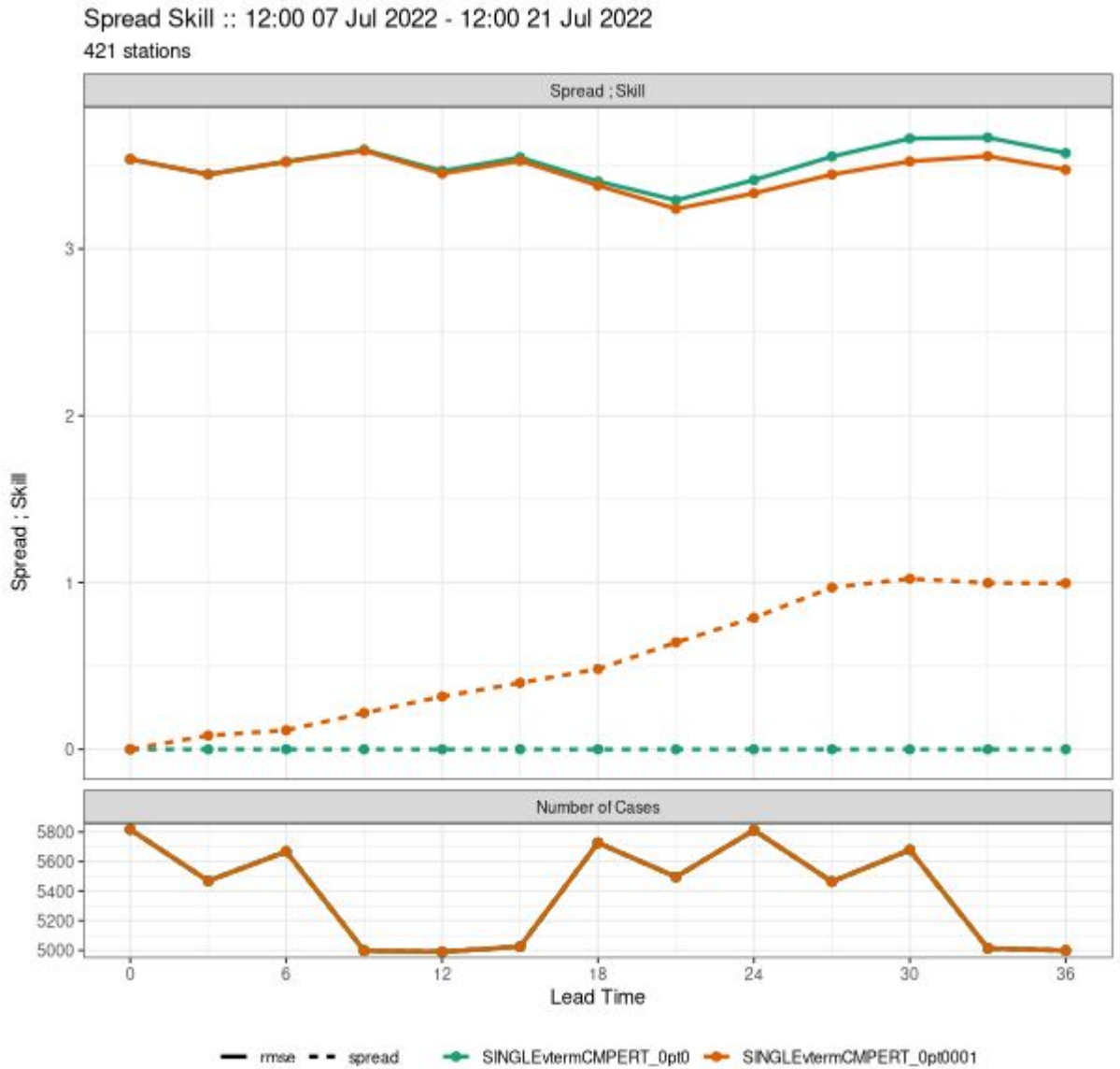
Cctot: CMPERT=0.2



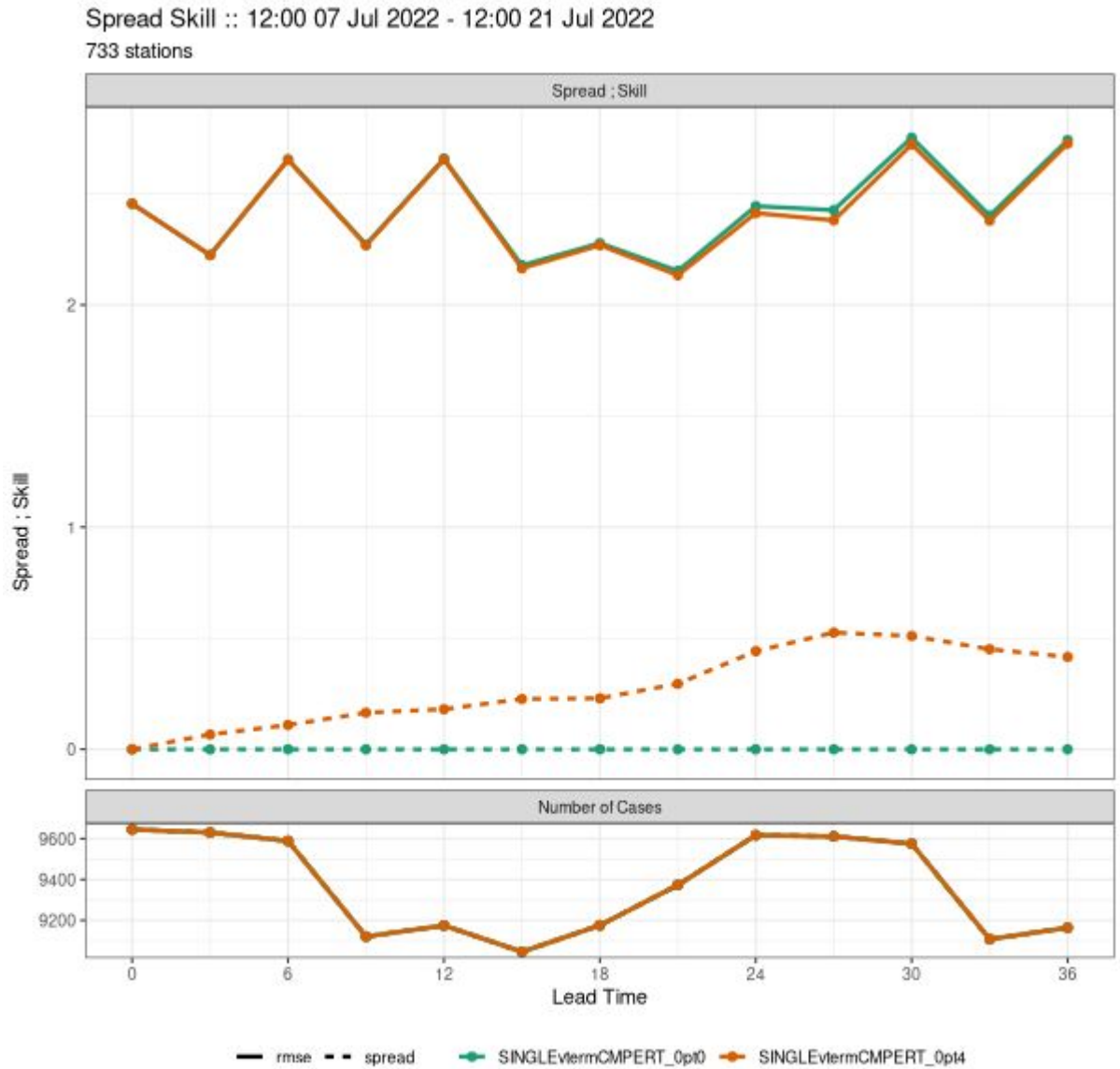
Cctot: CMPERT=0.1



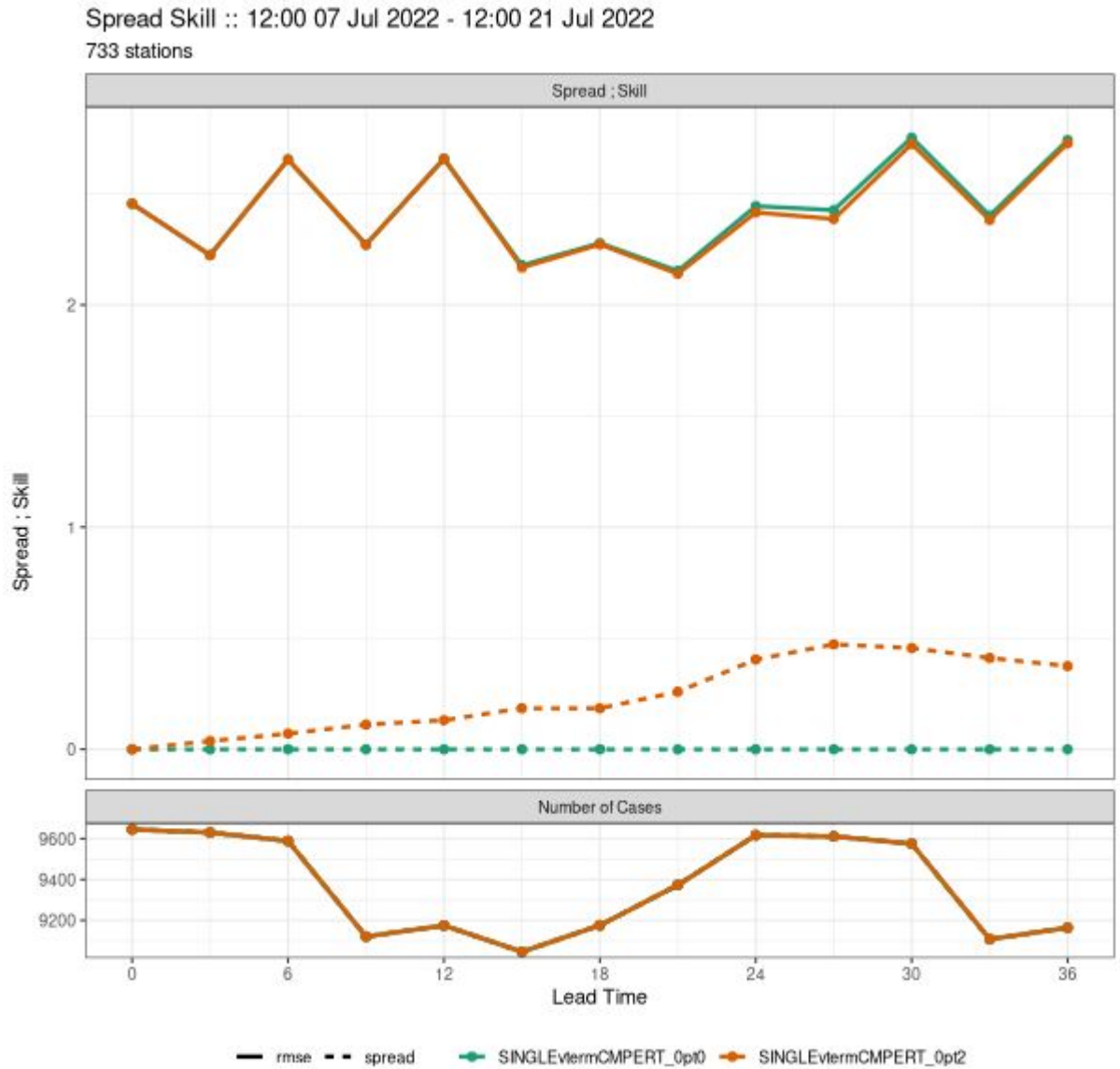
Cctot: CMPERT=0.0001



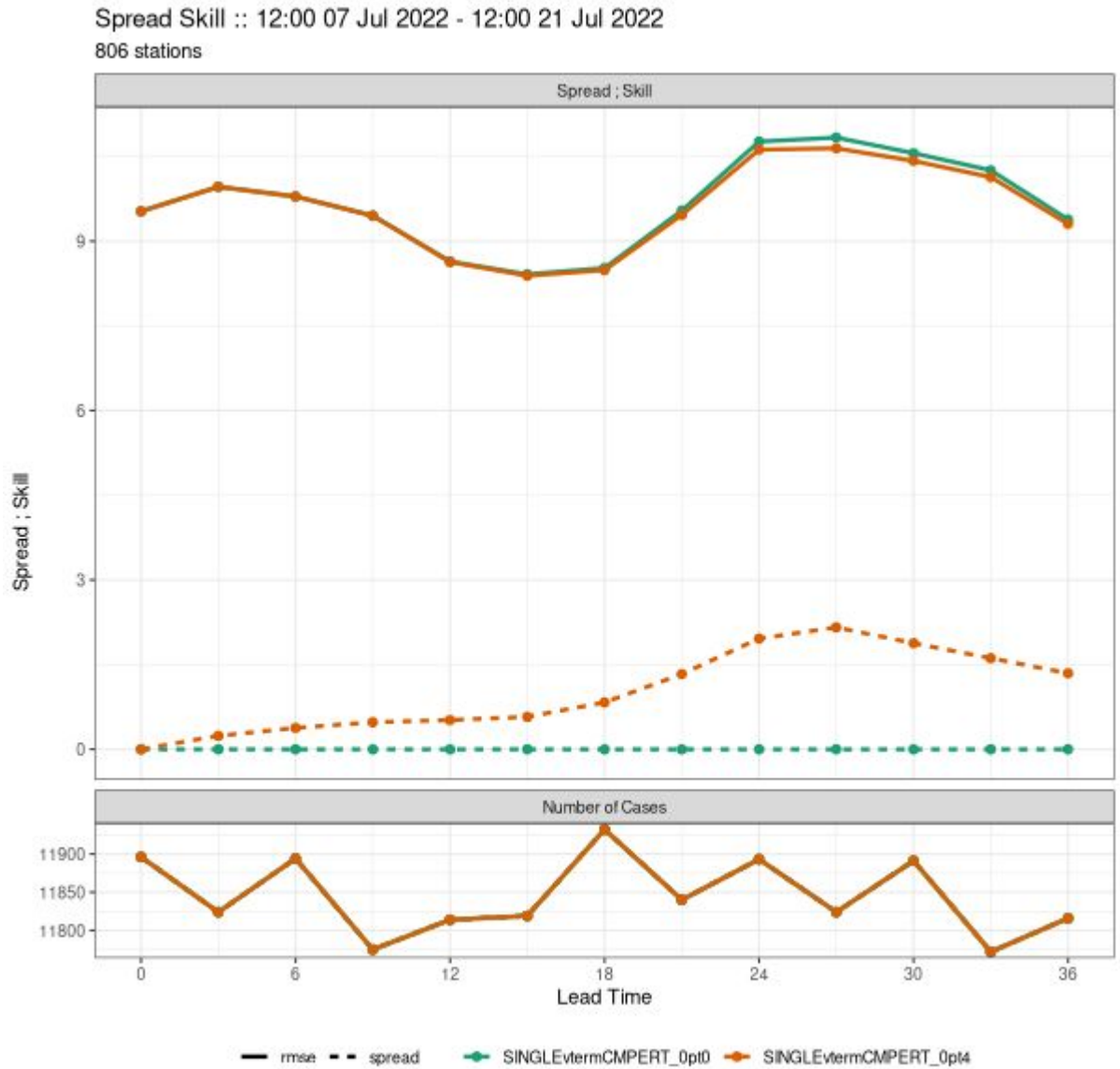
Gmax: CMPERT=0.4



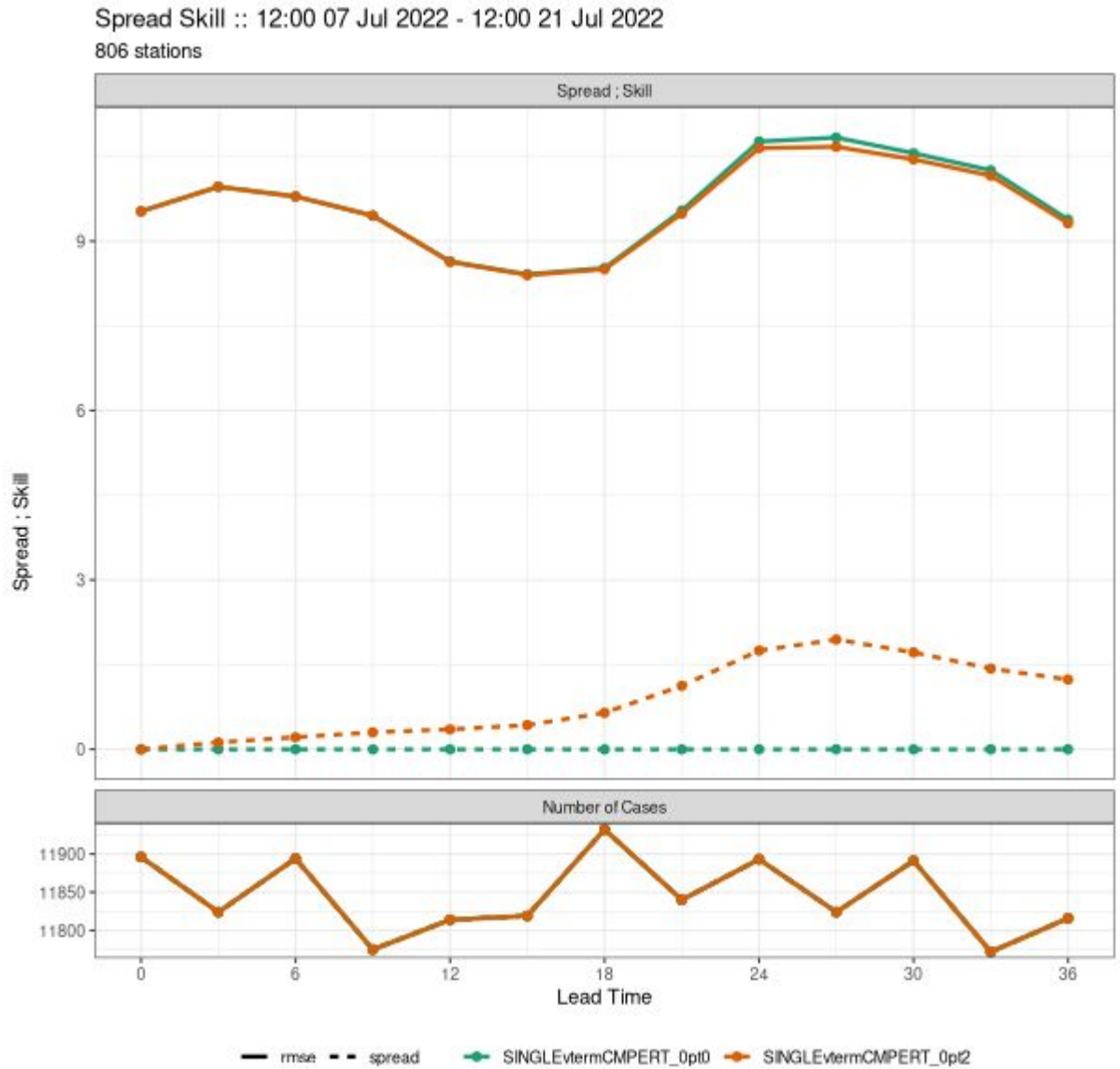
Gmax: CMPERT=0.2



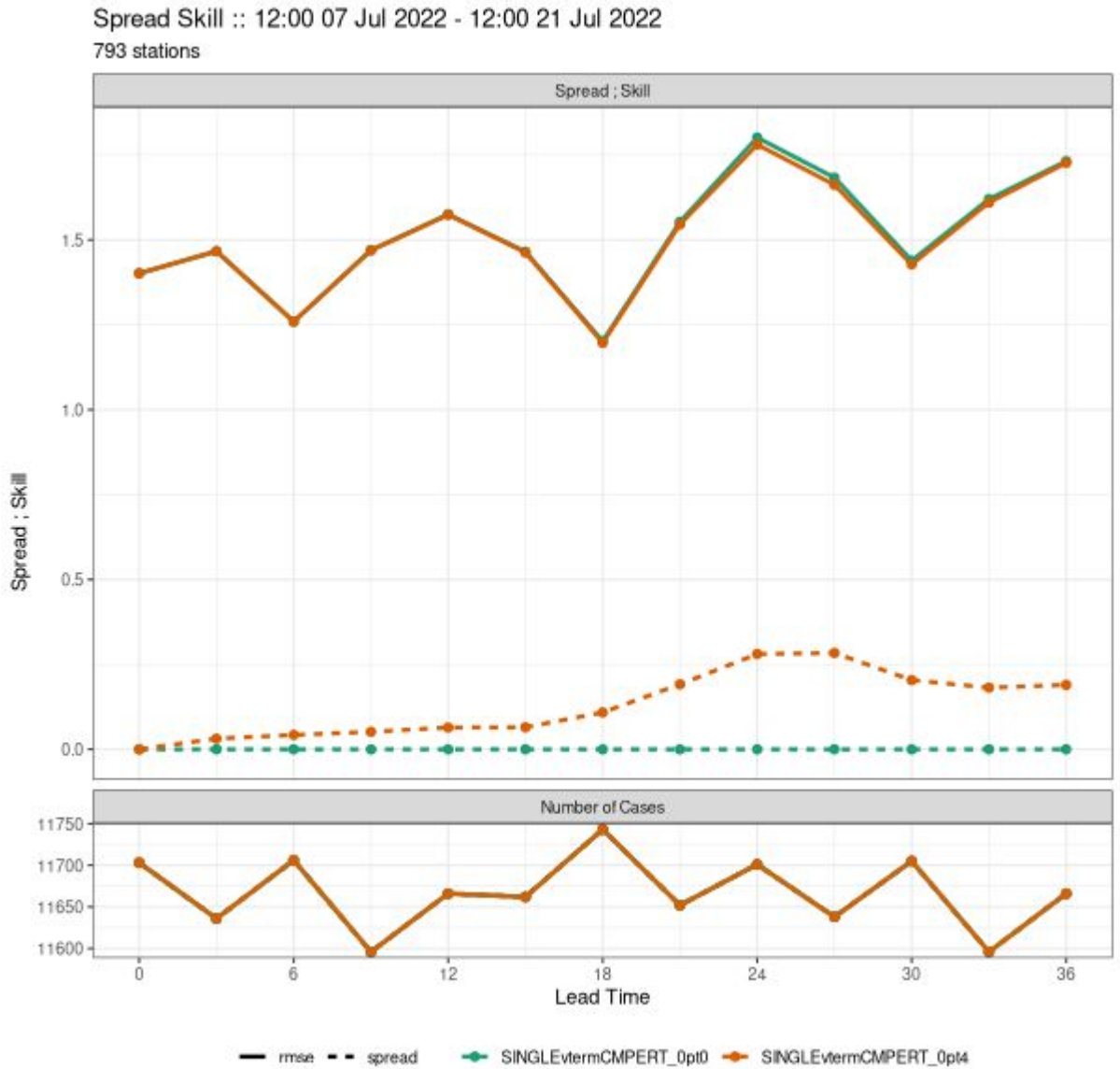
RH2: CMPERT=0.4



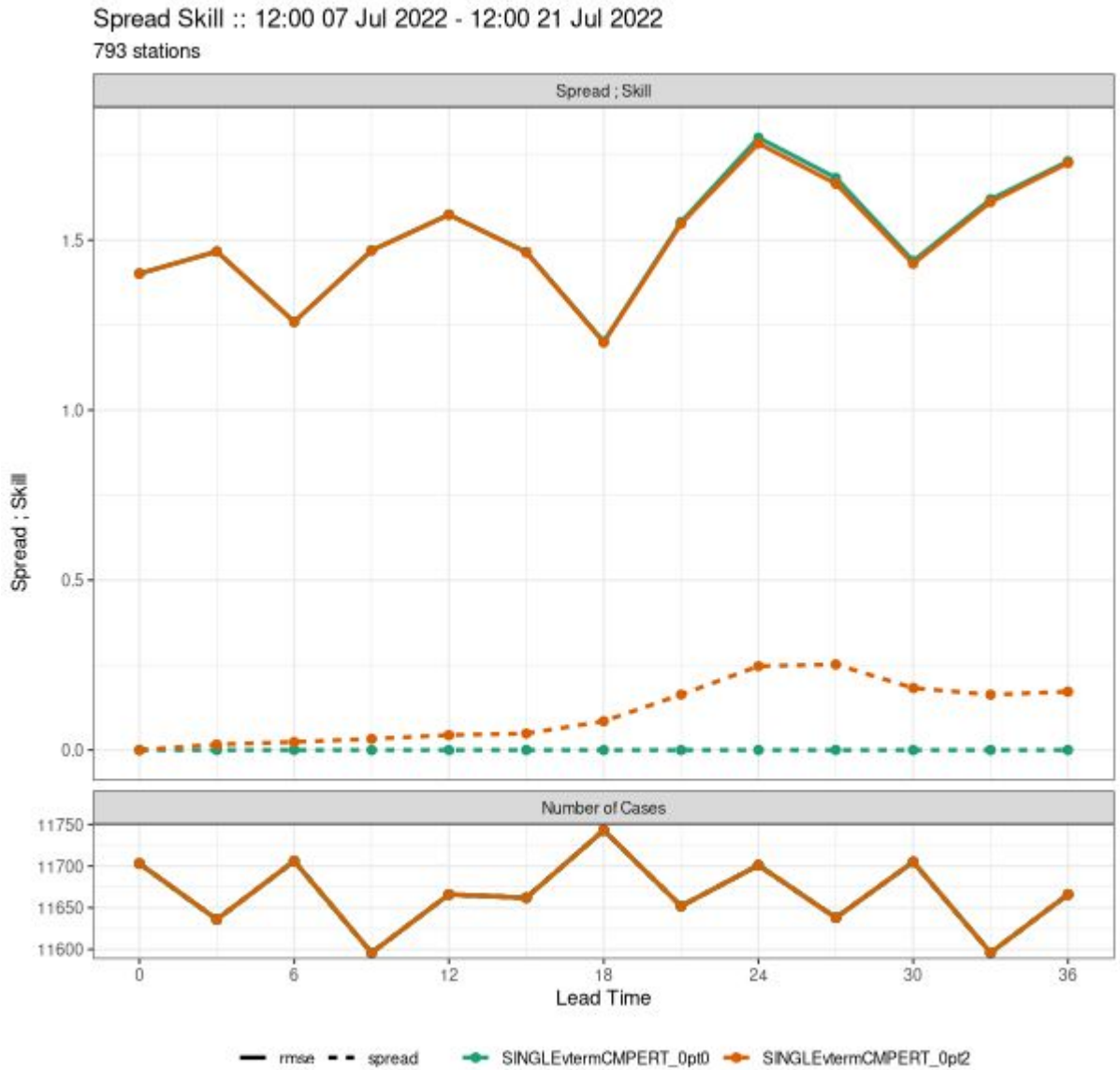
RH2m: CMPERT=0.2



Tm2: CMPERT=0.4



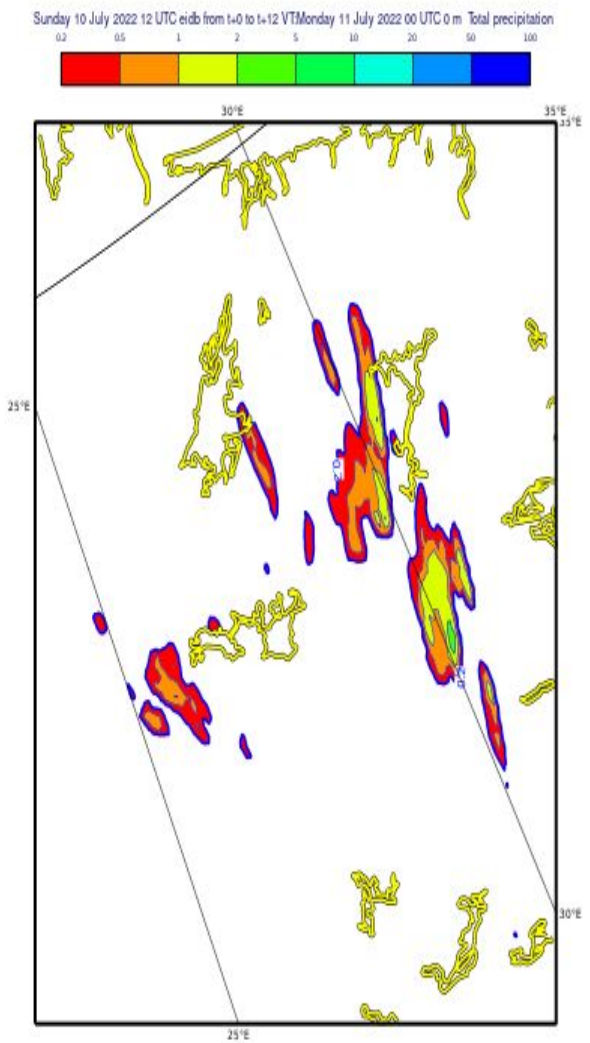
T2m: CMPERT=0.2



Why considerable spread if extremely weak perturbations?

- -> it happens in convective areas. See e.g. 10 July 2022 in northern Scandinavia:

Spread when CMPERT=0.0001

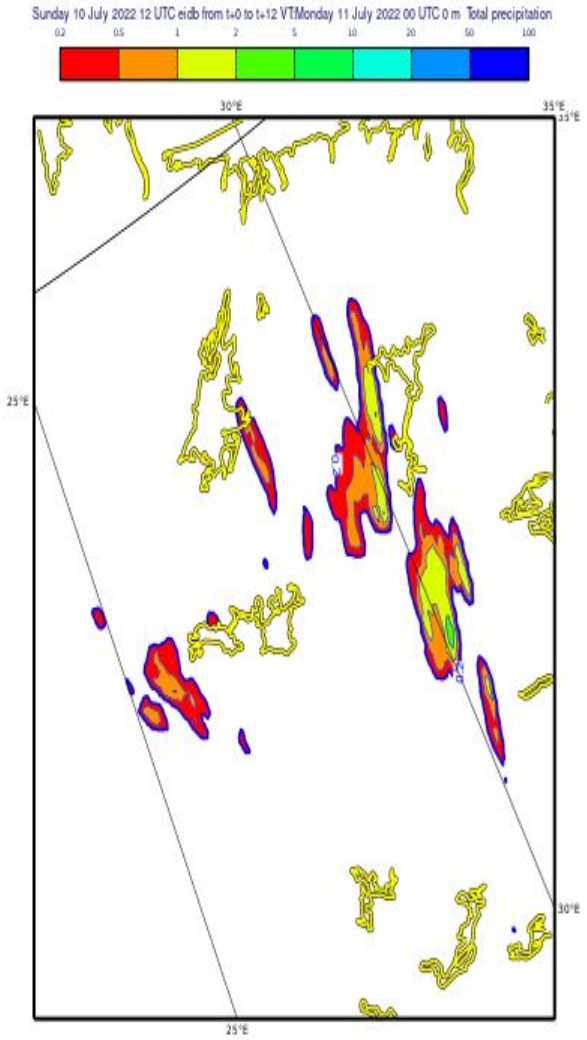


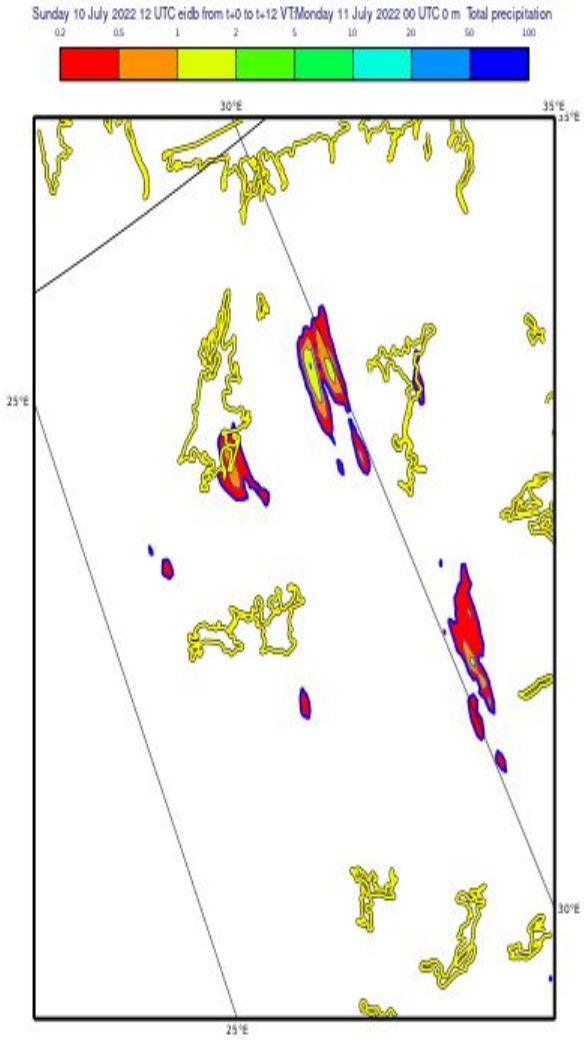
Butterfly effect?

Or maybe SP causes the spread?

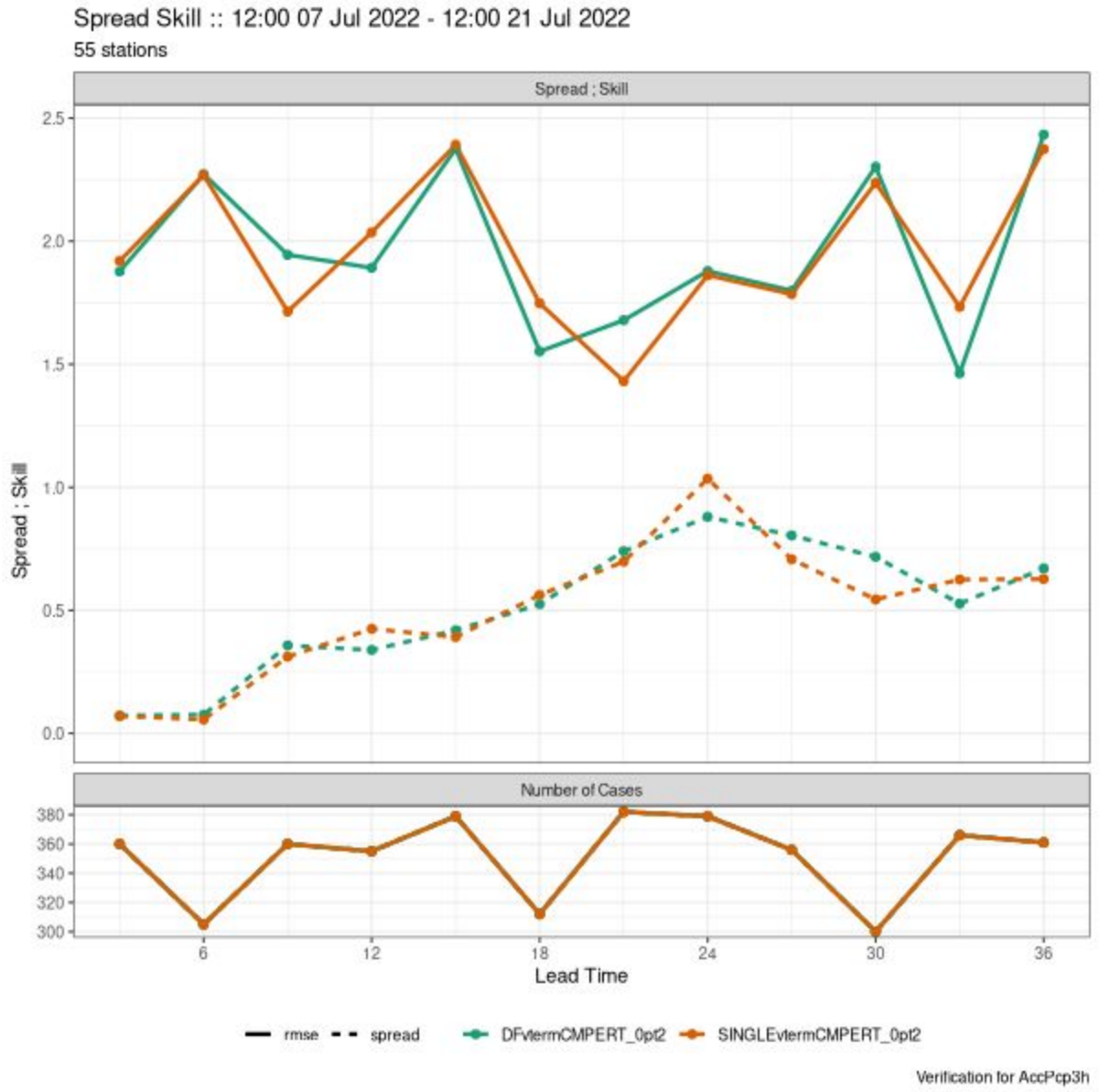
Tuning to be repeated in DP

Spread when CMPERT=0.0001 SP: left DP: right

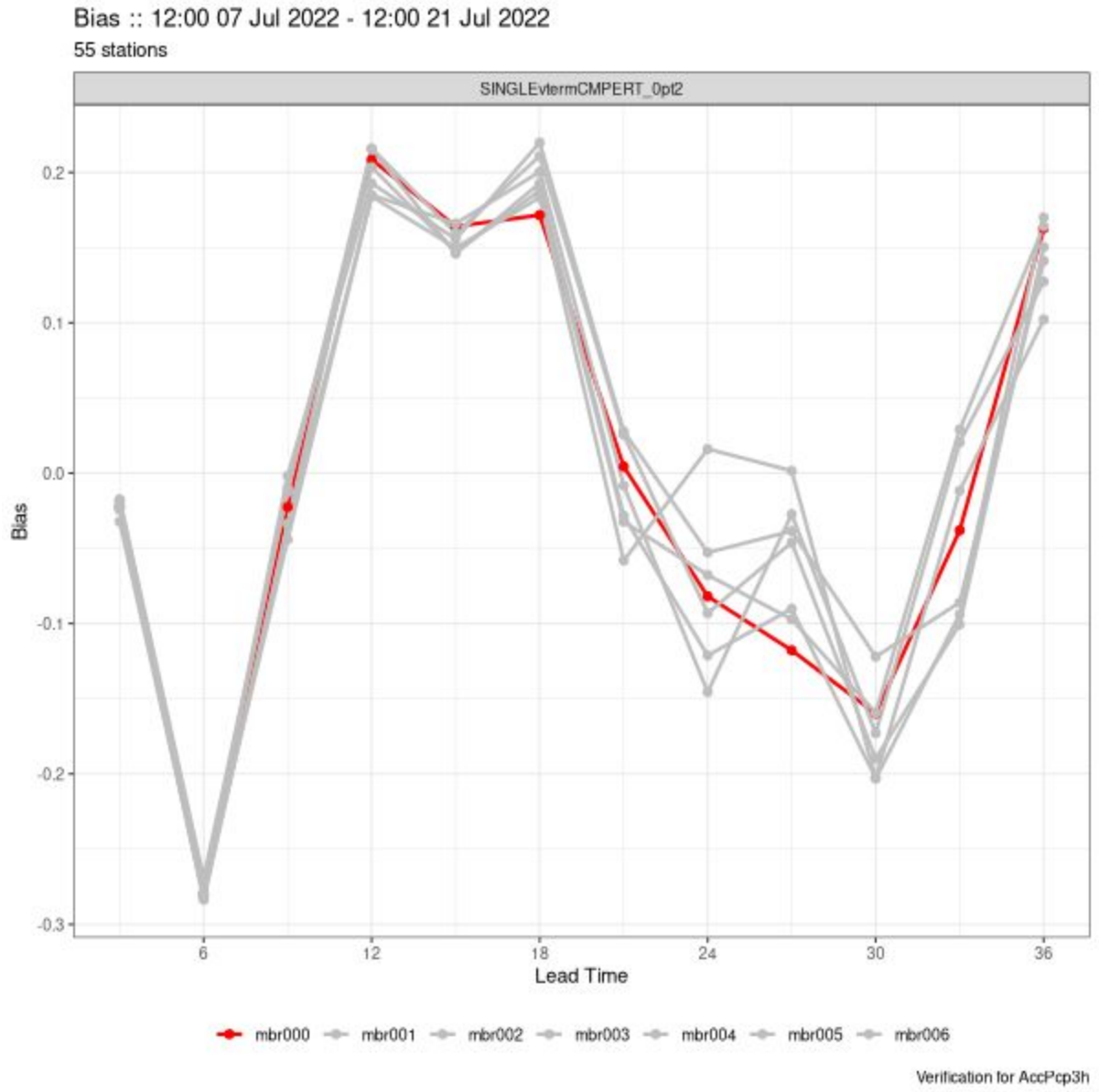




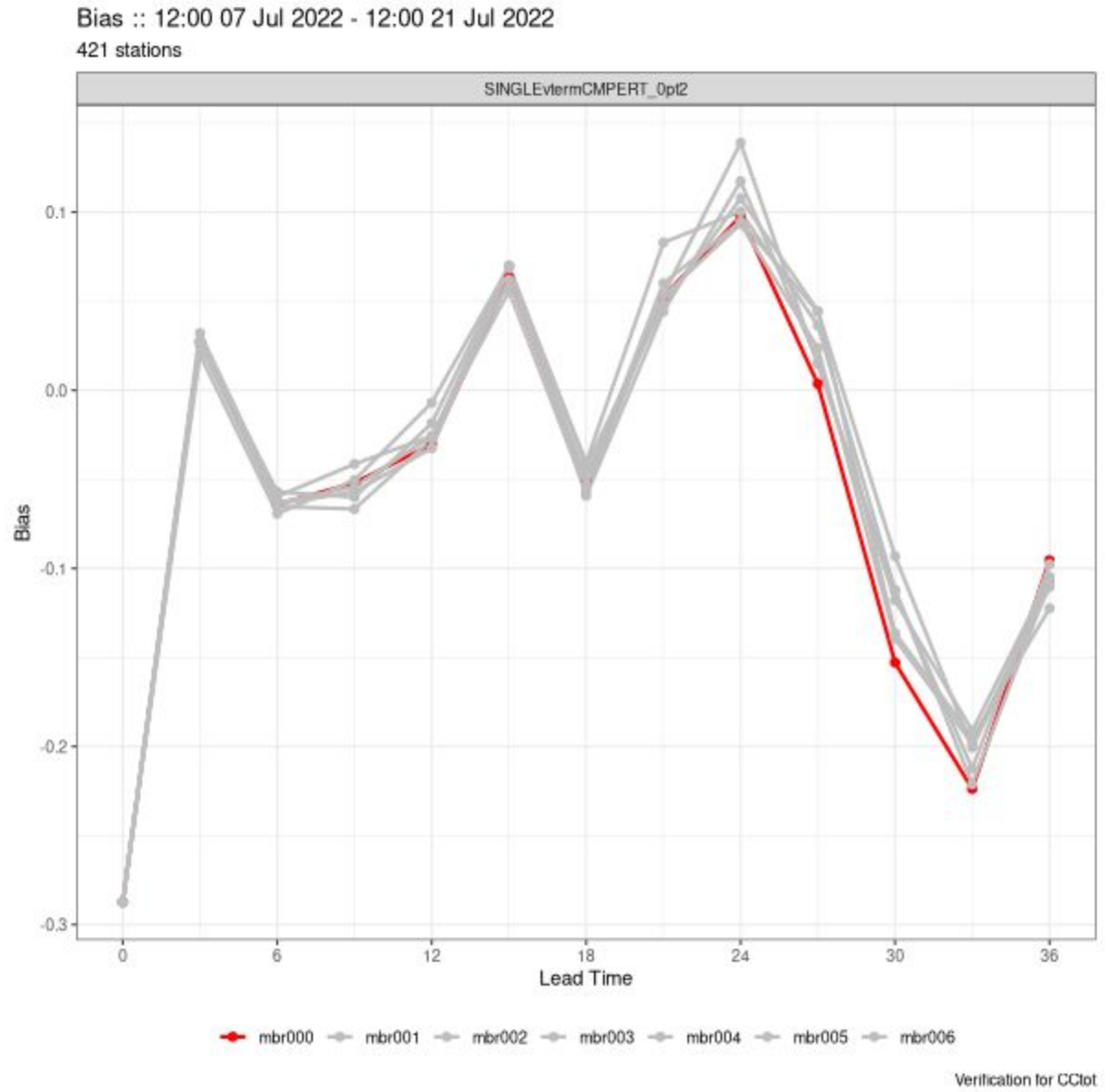
SP vs. DP AccPcp3h



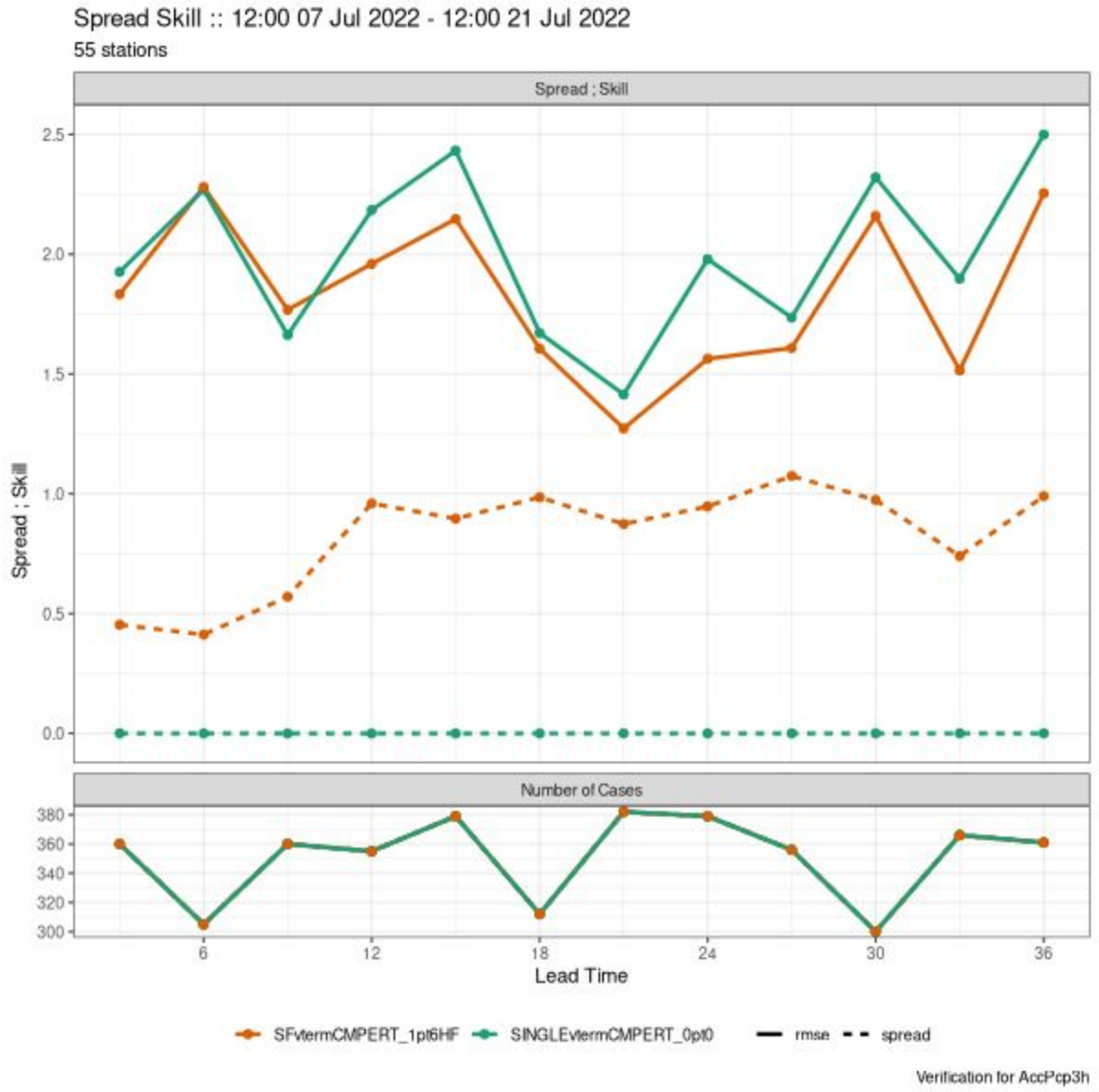
Bias AccPcp3h



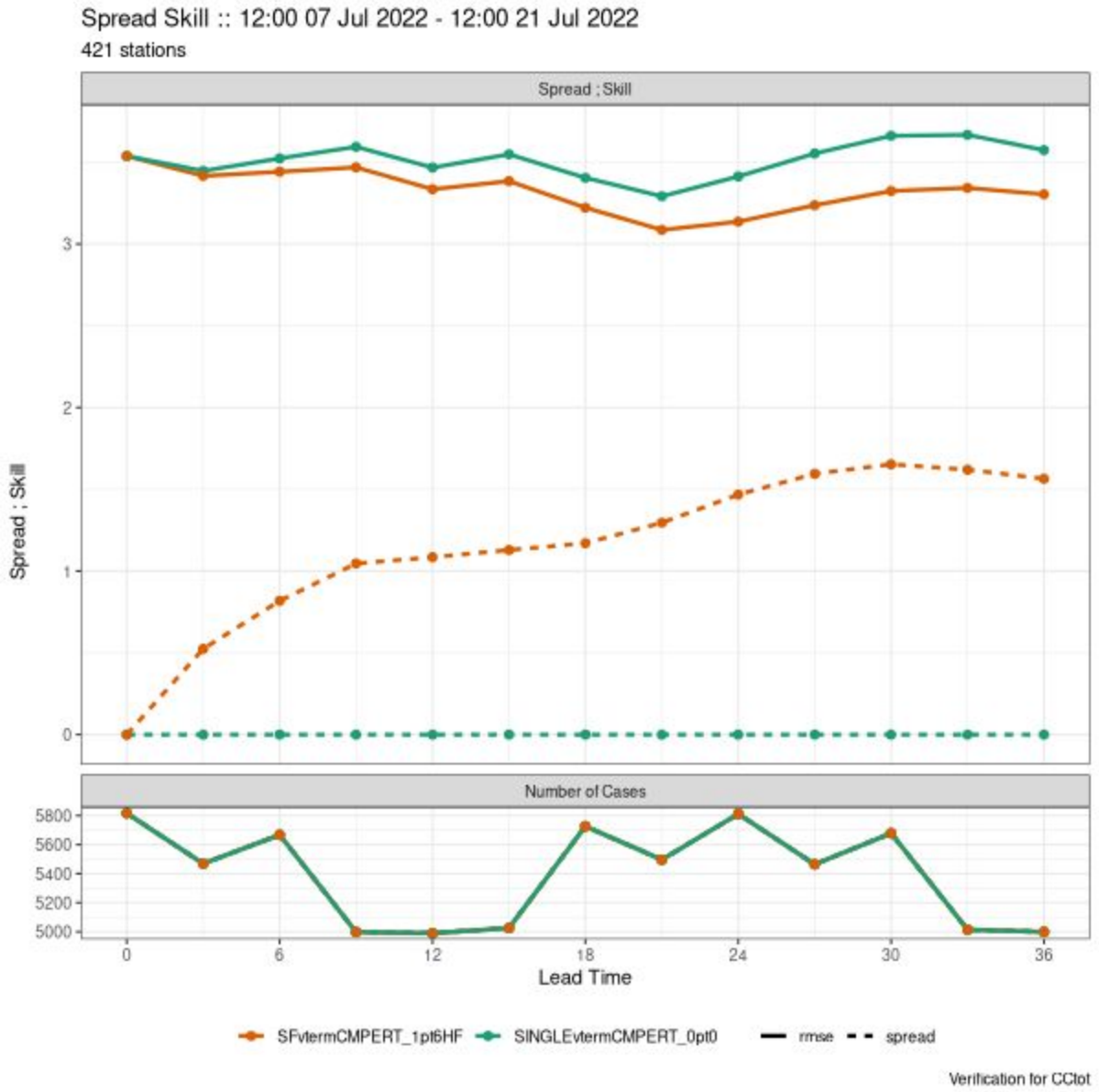
Bias CCtot


Bias :: 12:00 07 Jul 2022 - 12:00 21 Jul 2022
421 stations
SINGLEvtermCMPERT_0pt2
Bias
0.1
0.0
-0.1
-0.2
-0.3
0
6
12
18
24
30
36
Lead Time
mbr000
mbr001
mbr002
mbr003
mbr004
mbr005
mbr006
Verification for CCtot

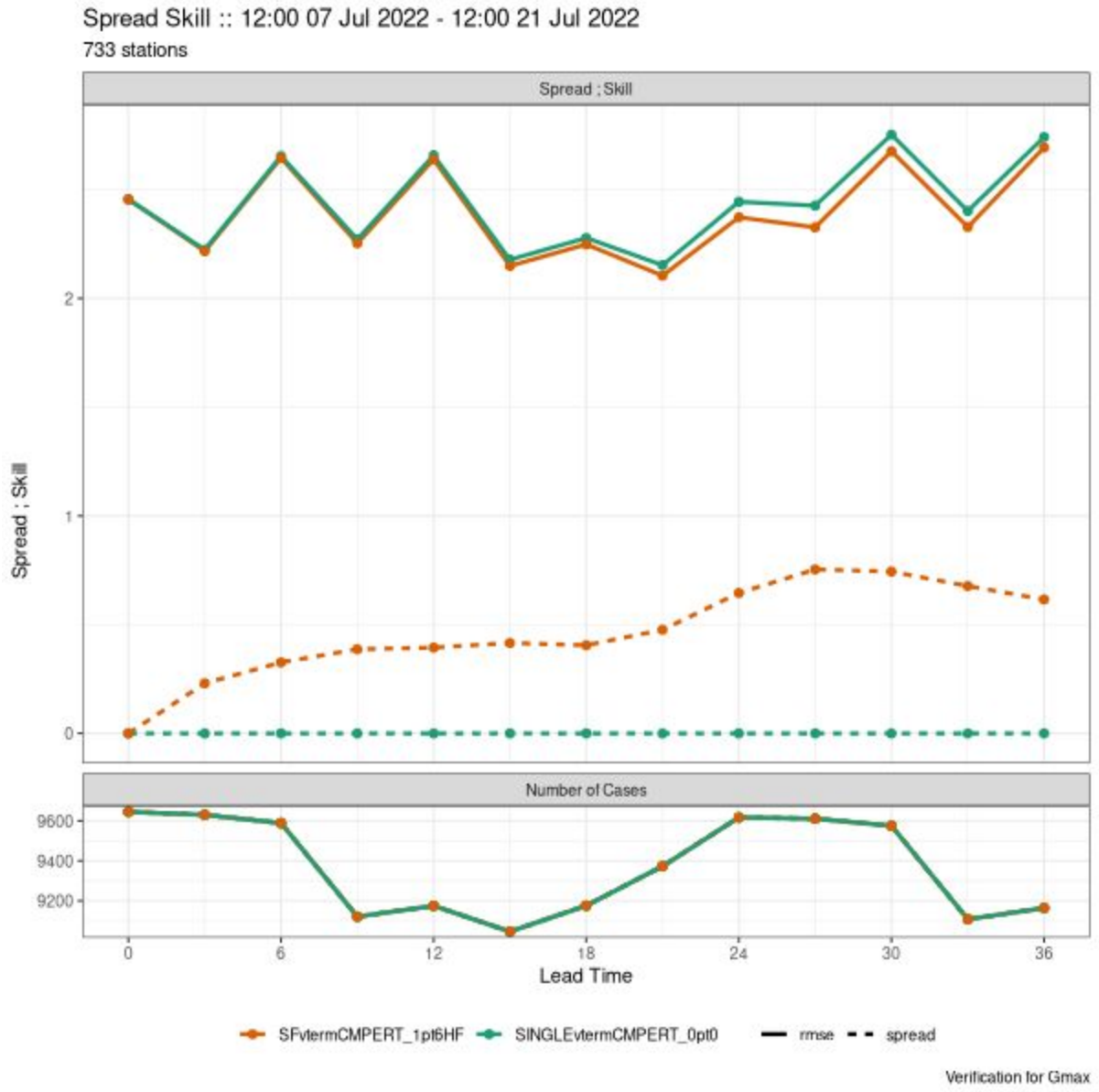
CMPERT=1.6 AccPcp3h



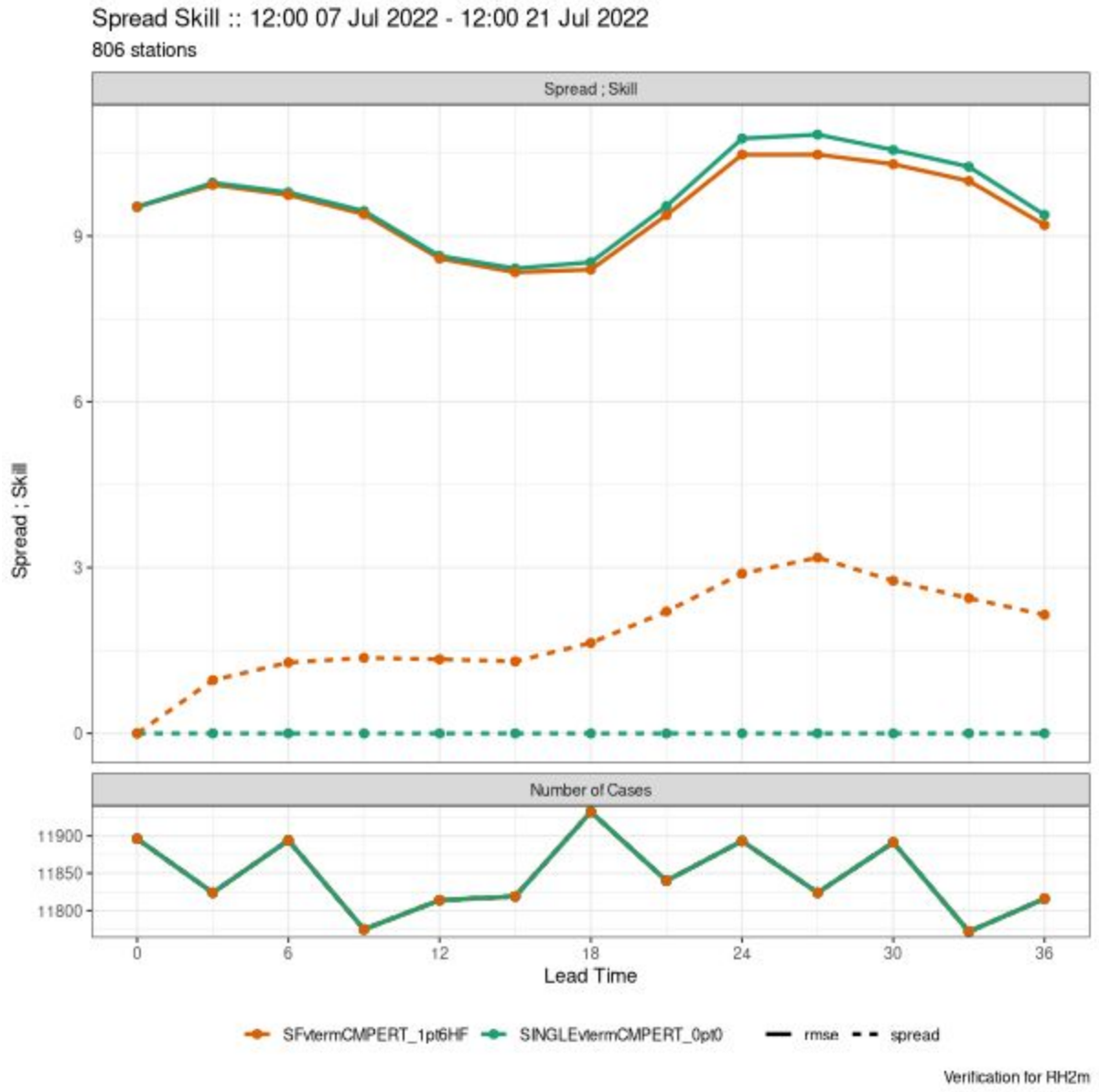
CMPERT=1.6 CCtot



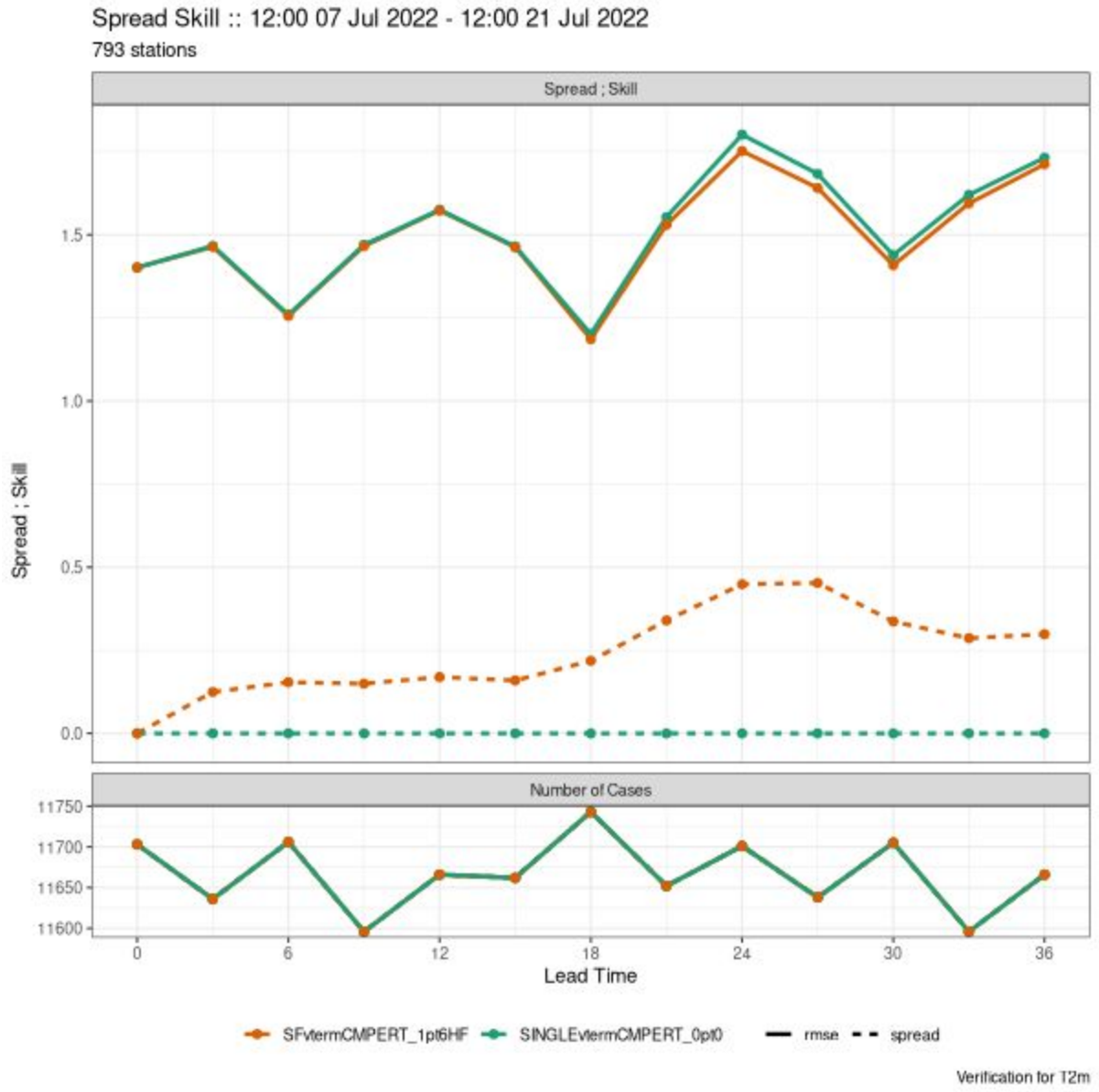
CMPERT=1.6 Gmax



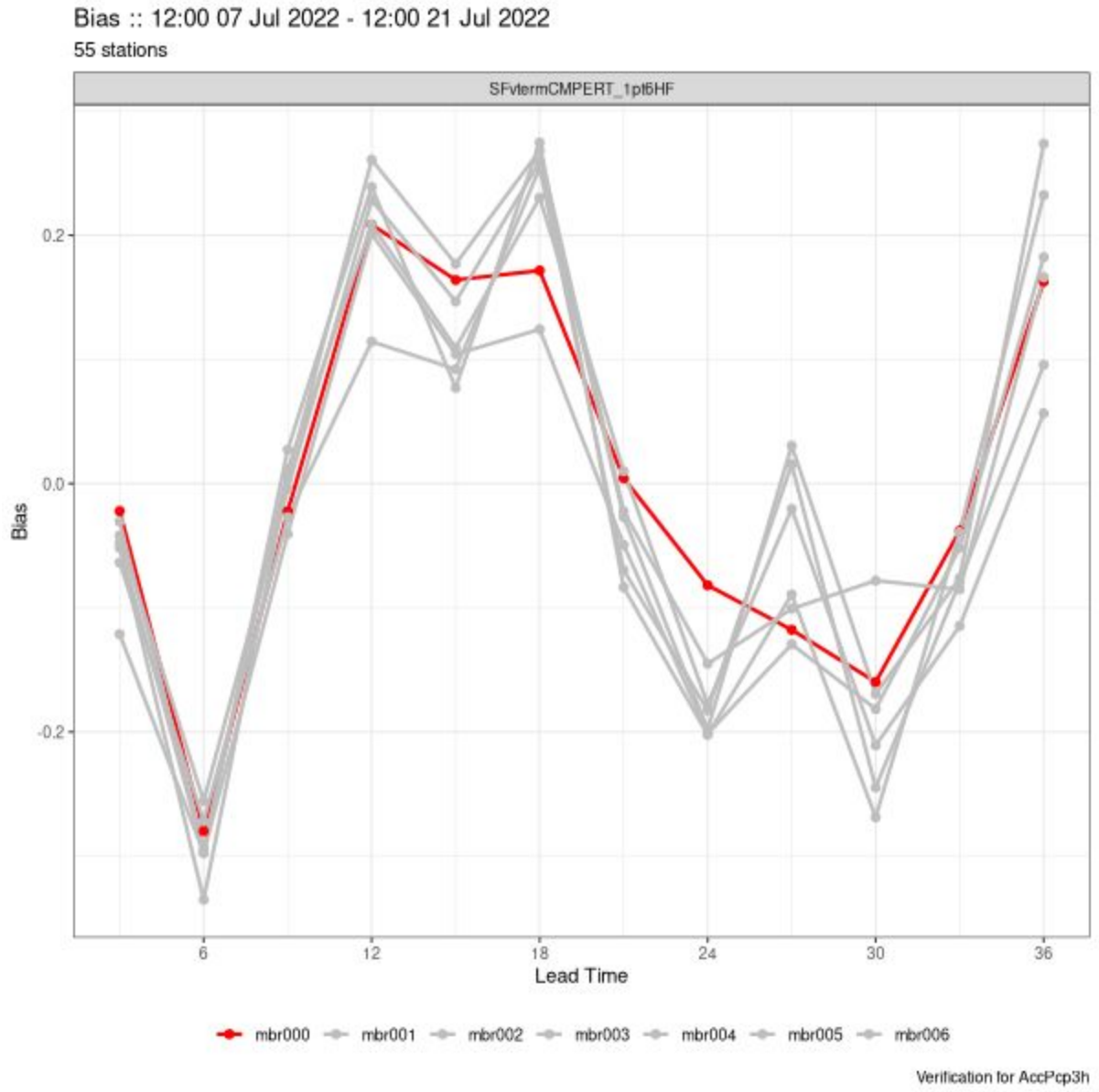
CMPERT=1.6 RH2m



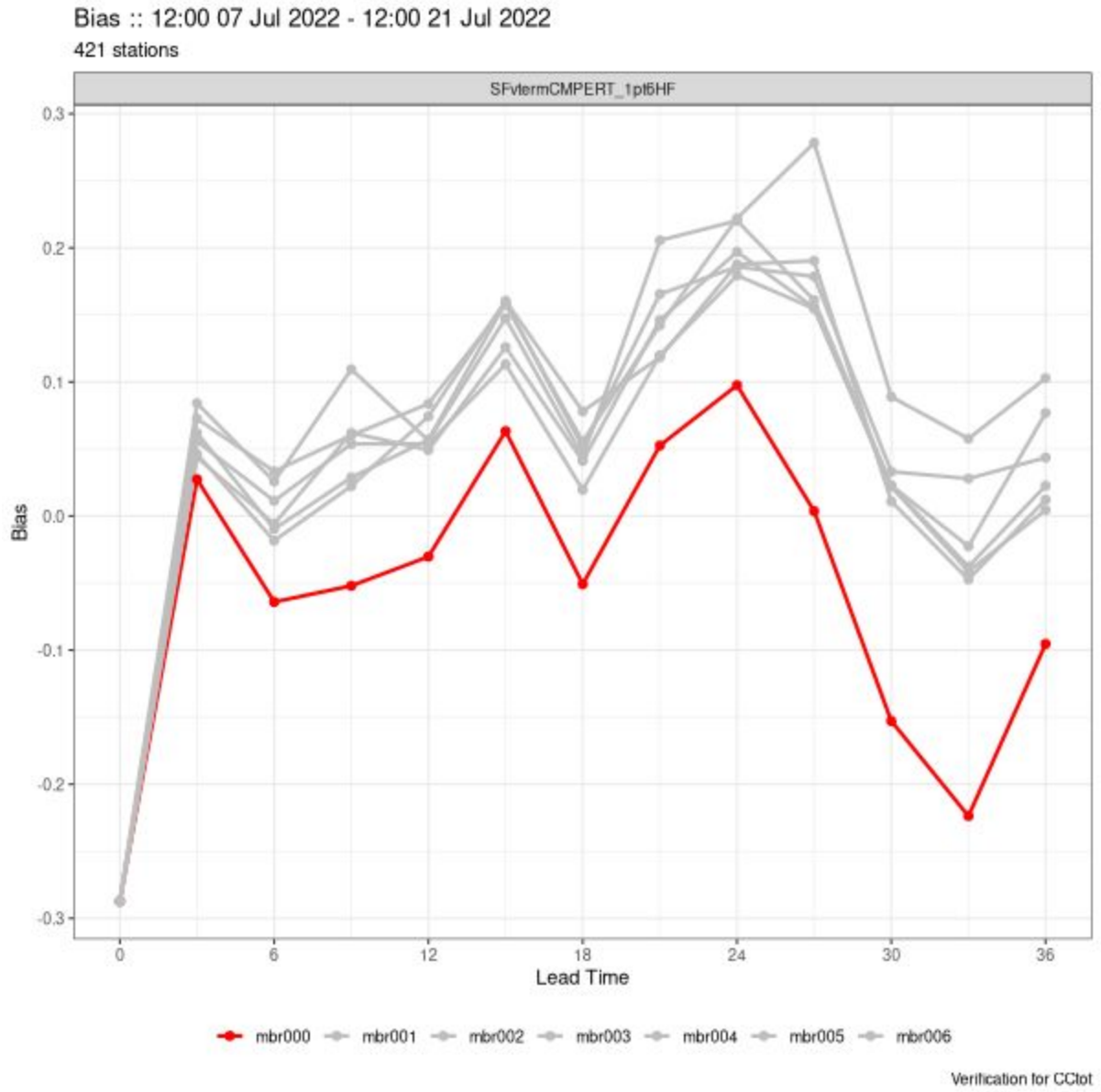
CMPERT=1.6 T2m



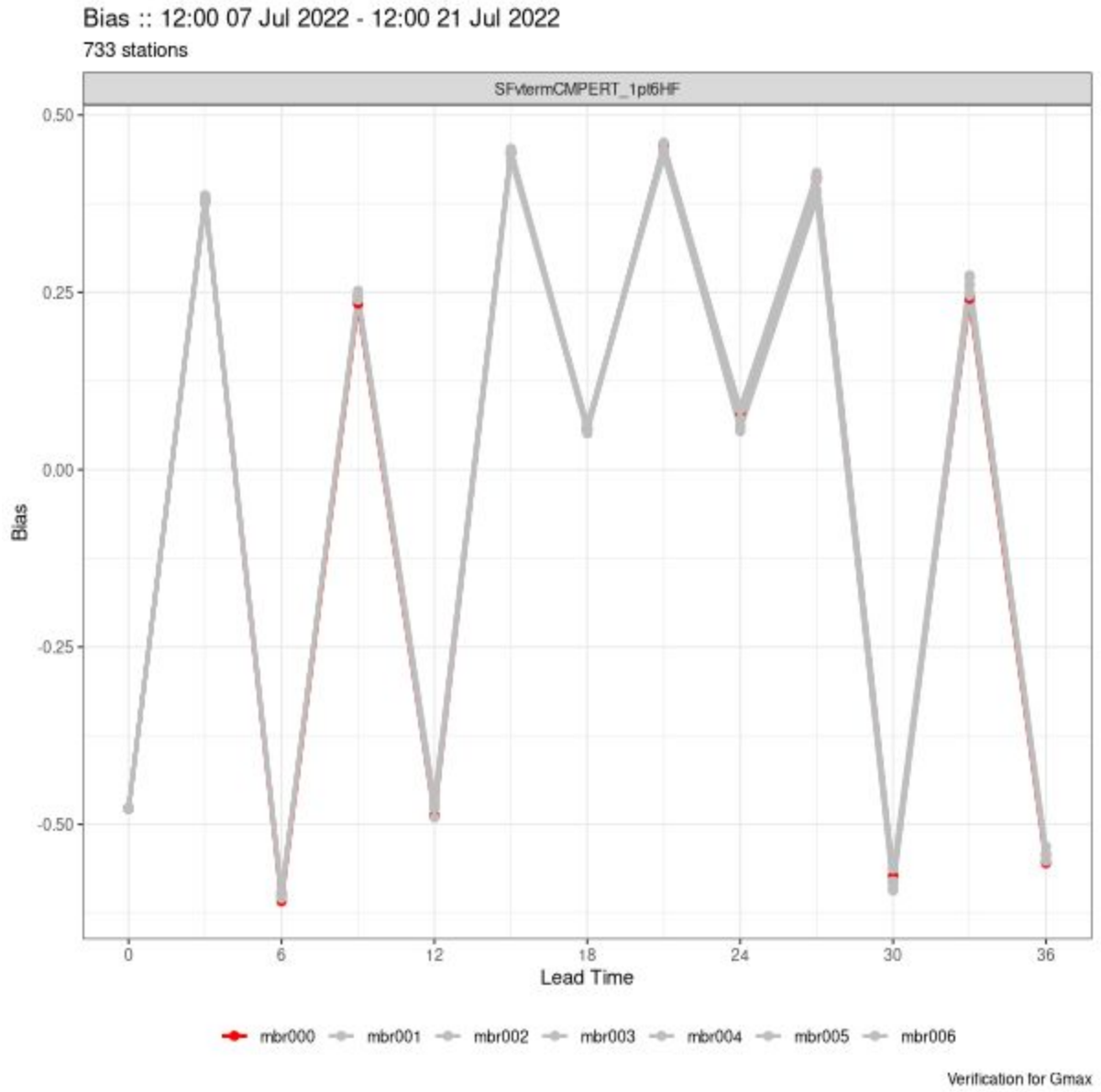
CMPERT=1.6 AccPcp3h



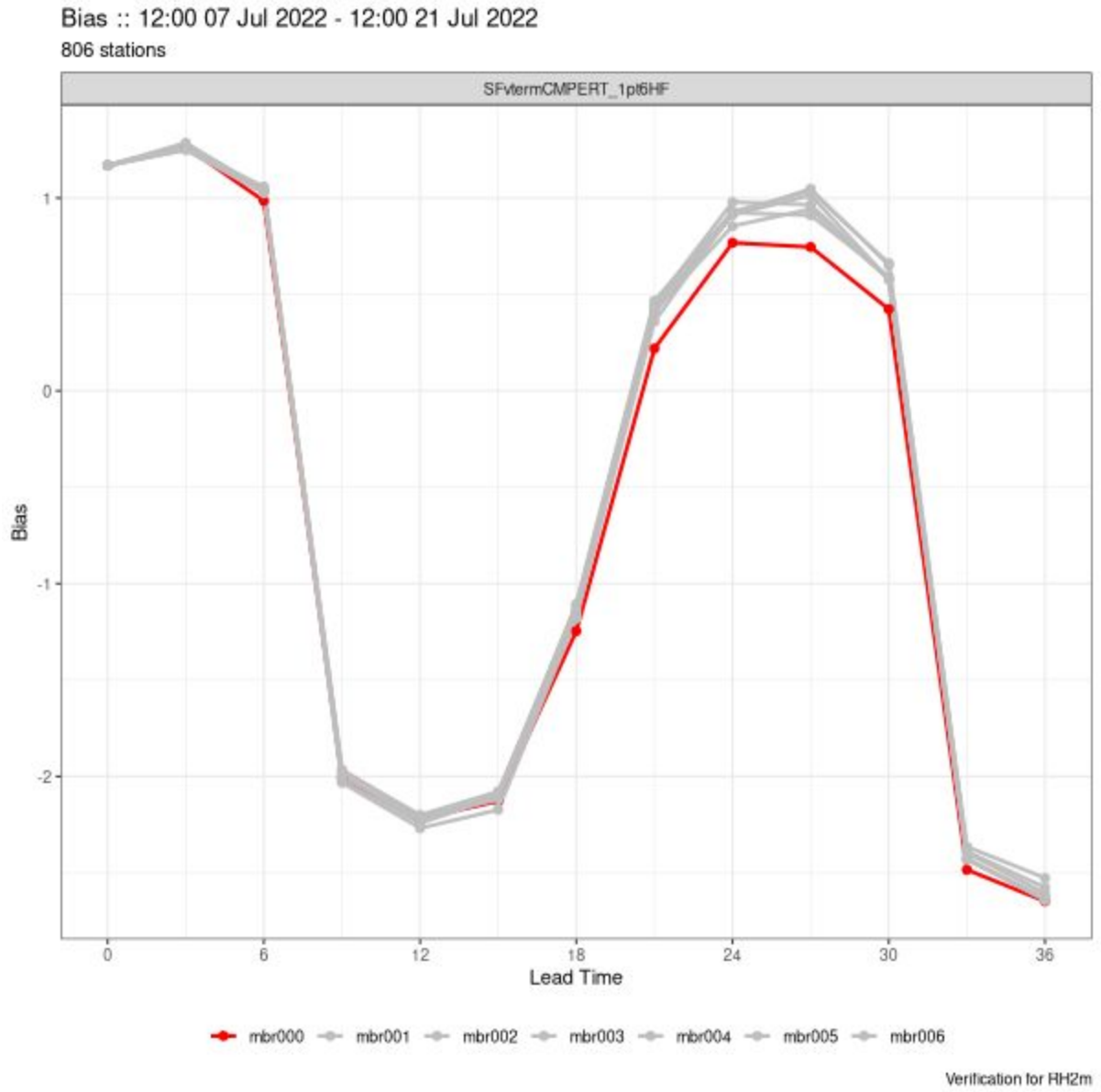
CMPERT=1.6 CCtot



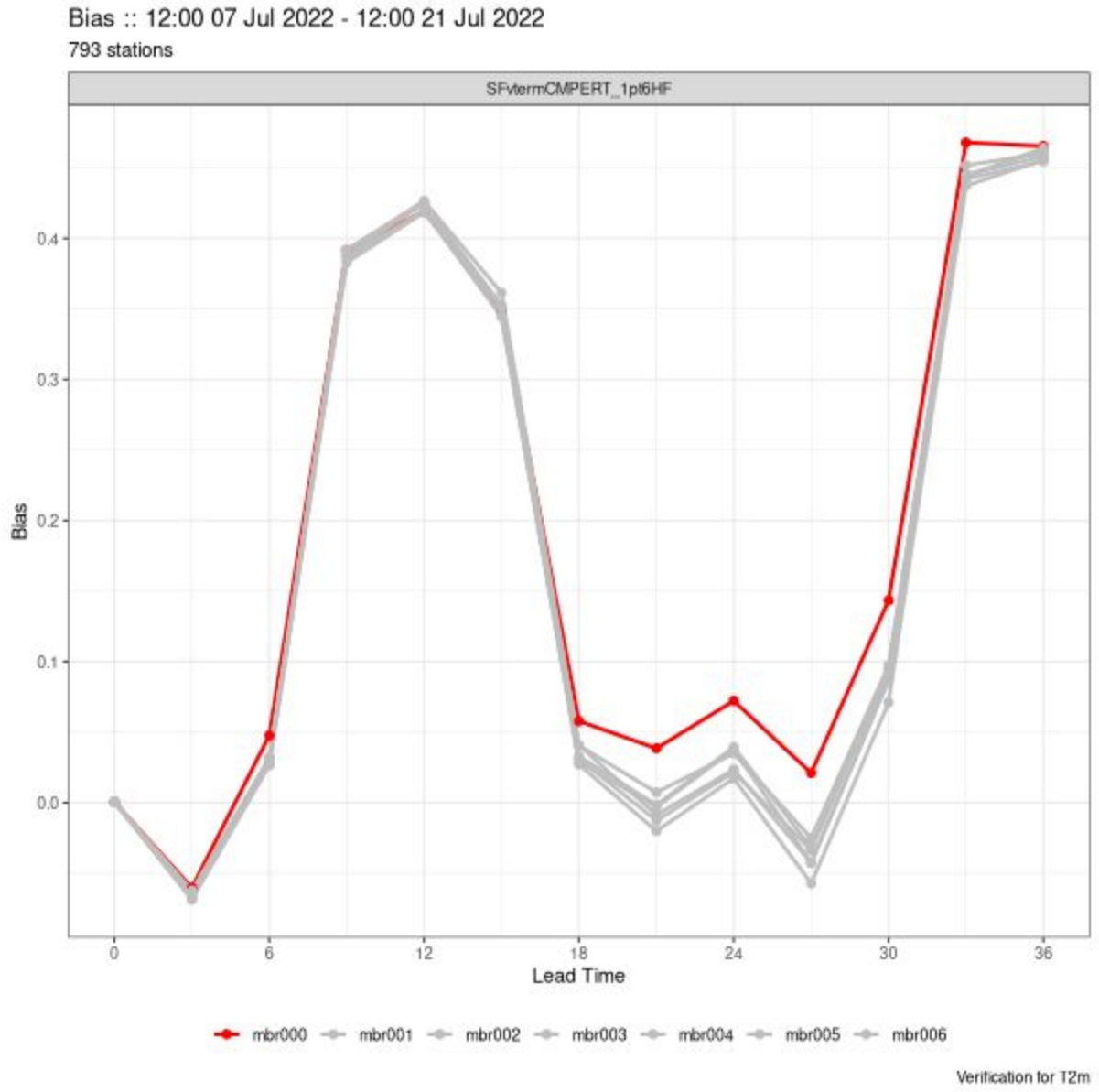
CMPERT=1.6 Gmax



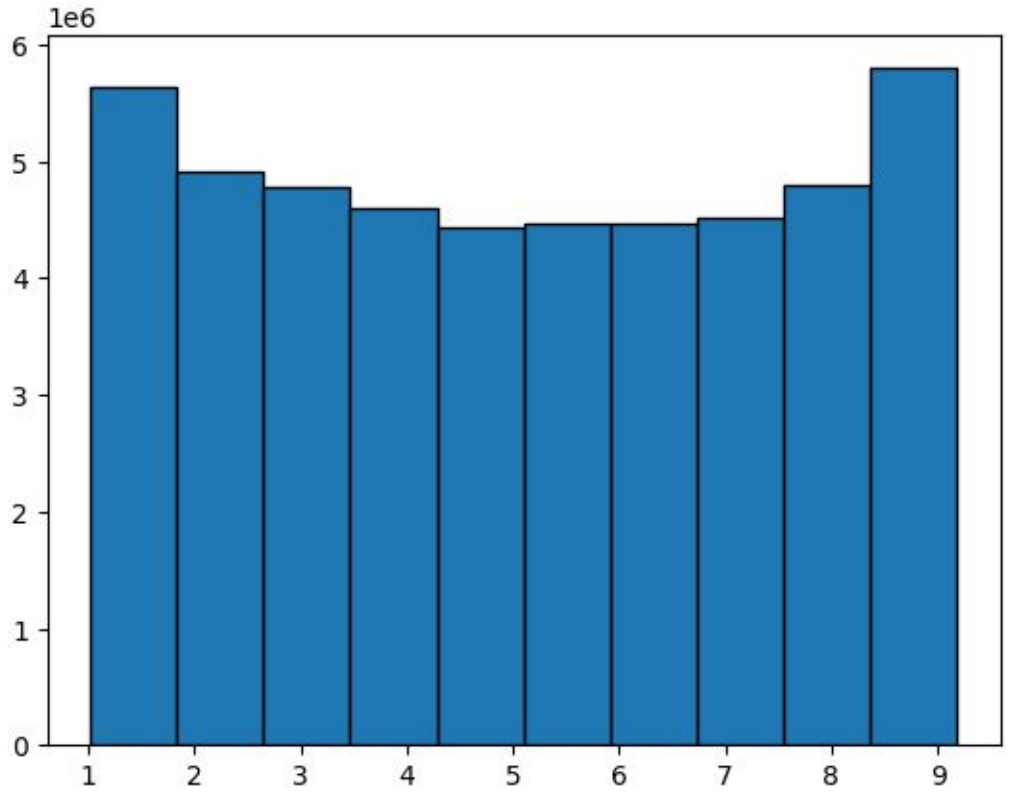
CMPERT=1.6 RH2m



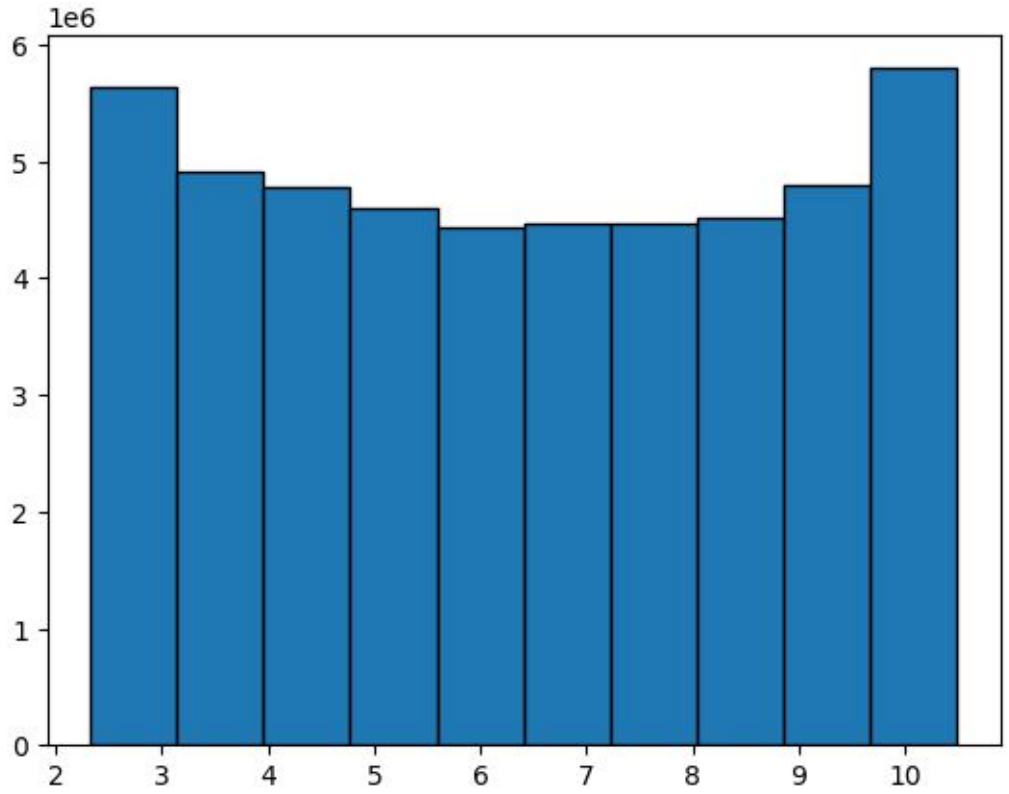
CMPERT=1.6 T2m



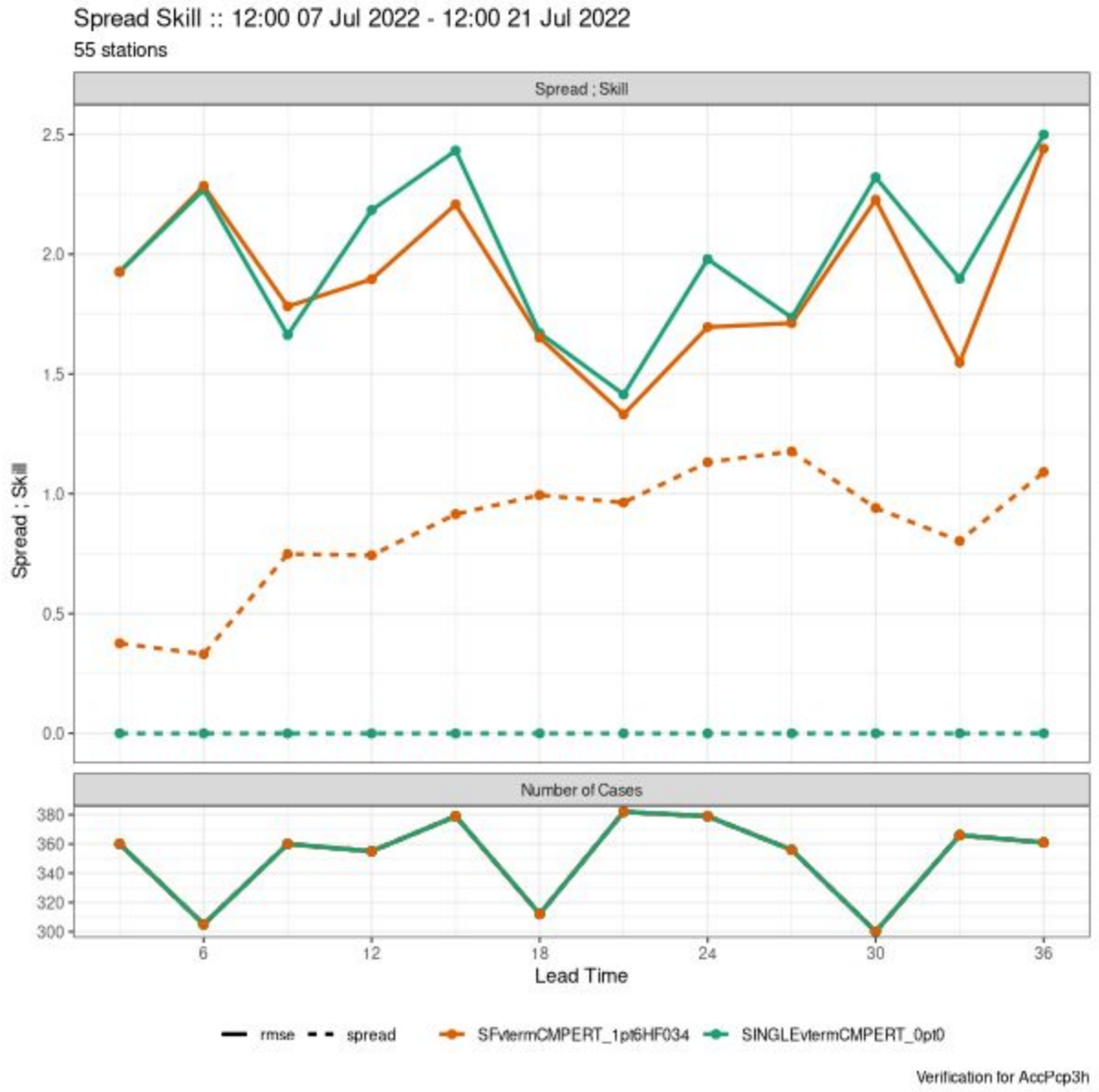
original



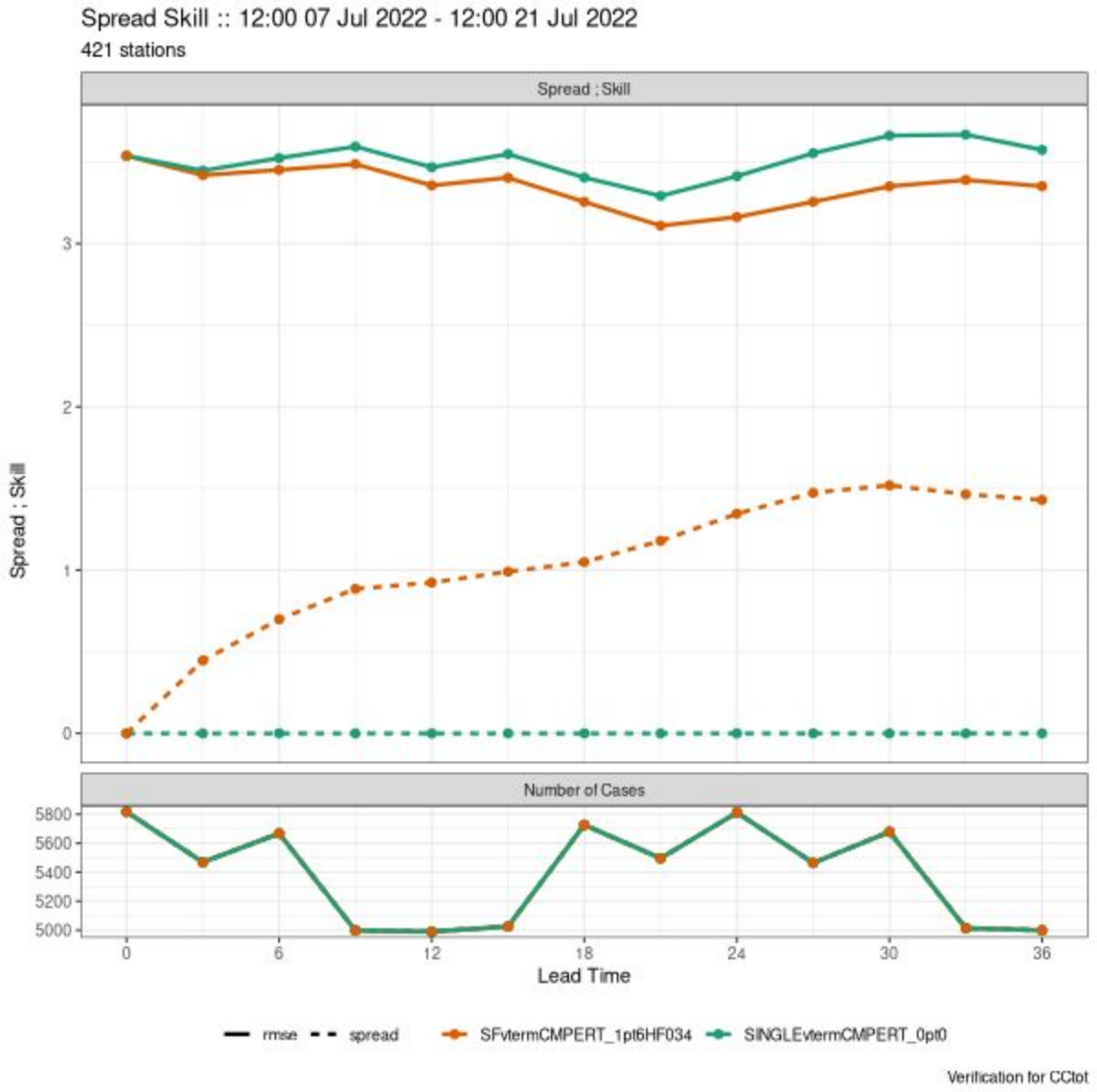
shifted



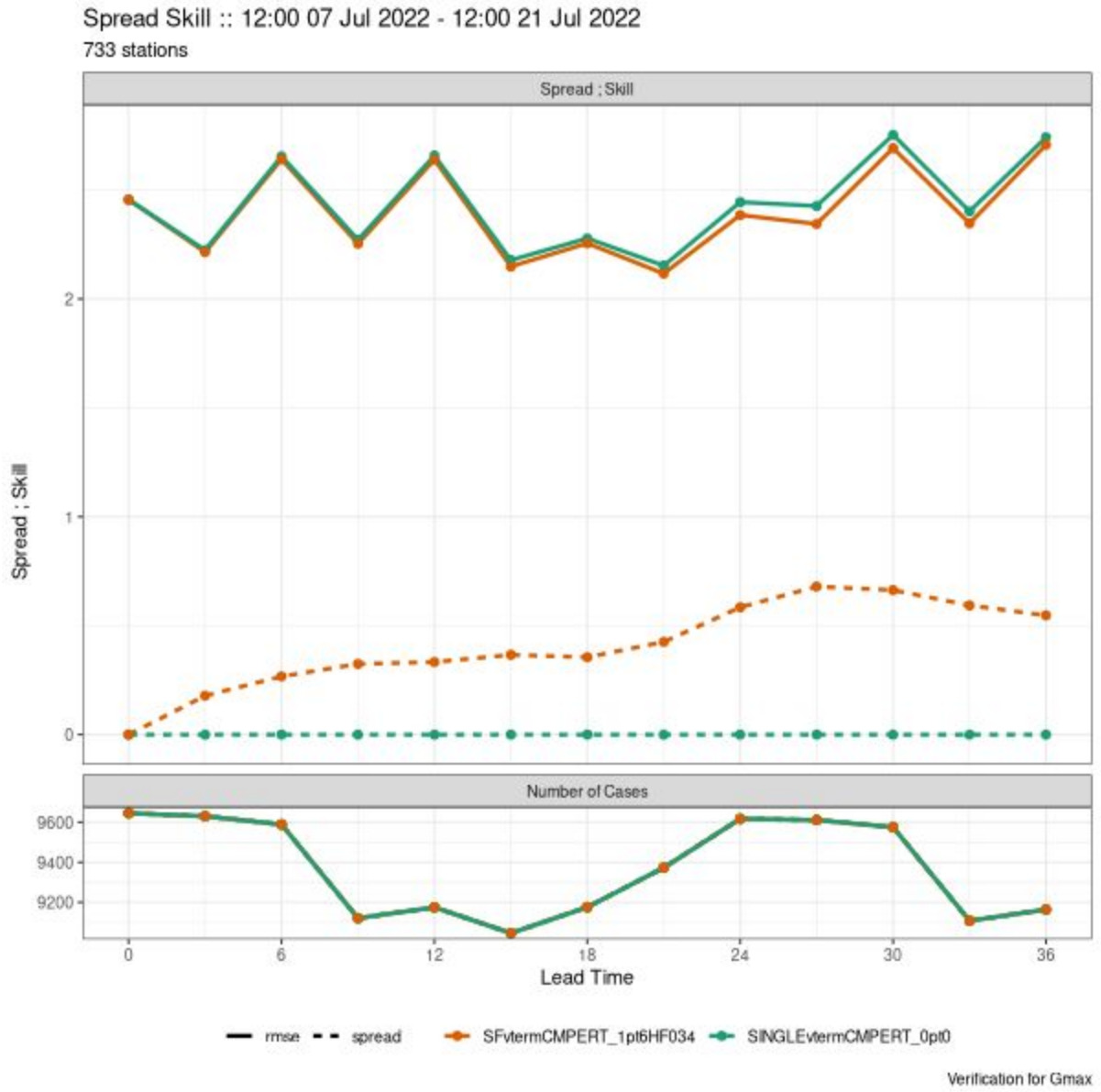
CMPERT=1.6 AccPcp3h shift



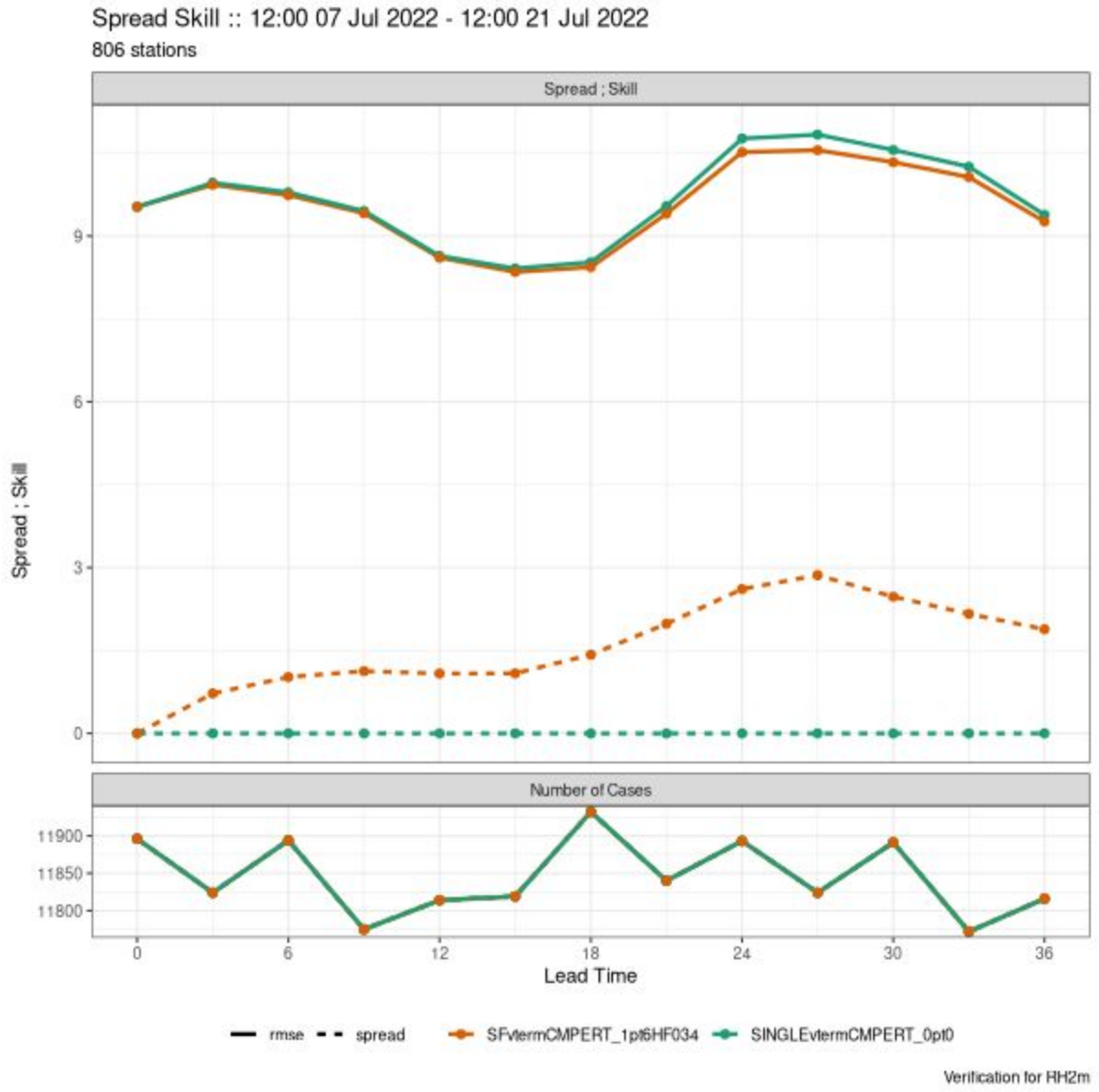
CMPERT=1.6 Cctot shift



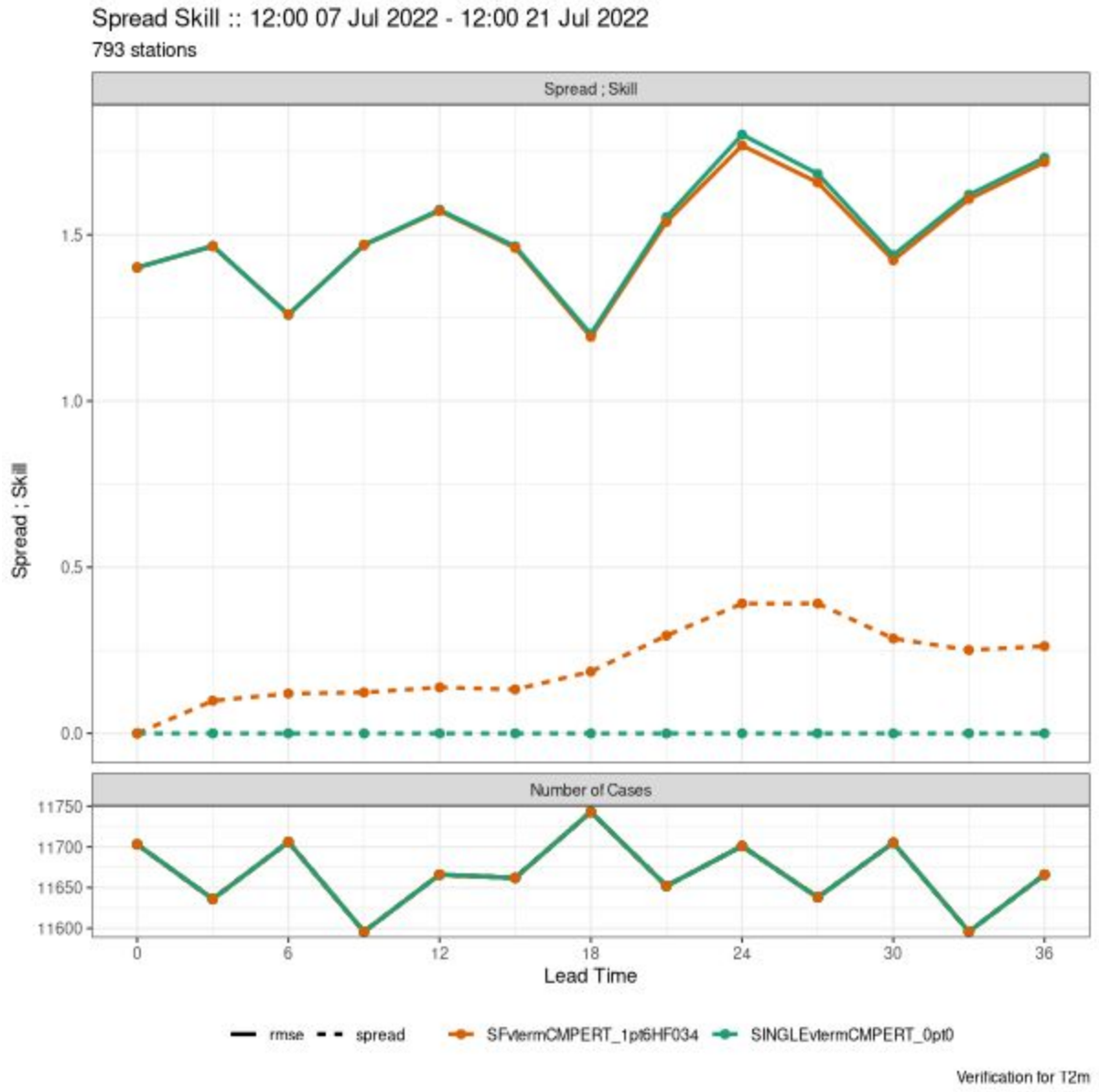
CMPERT=1.6 Gmax shift



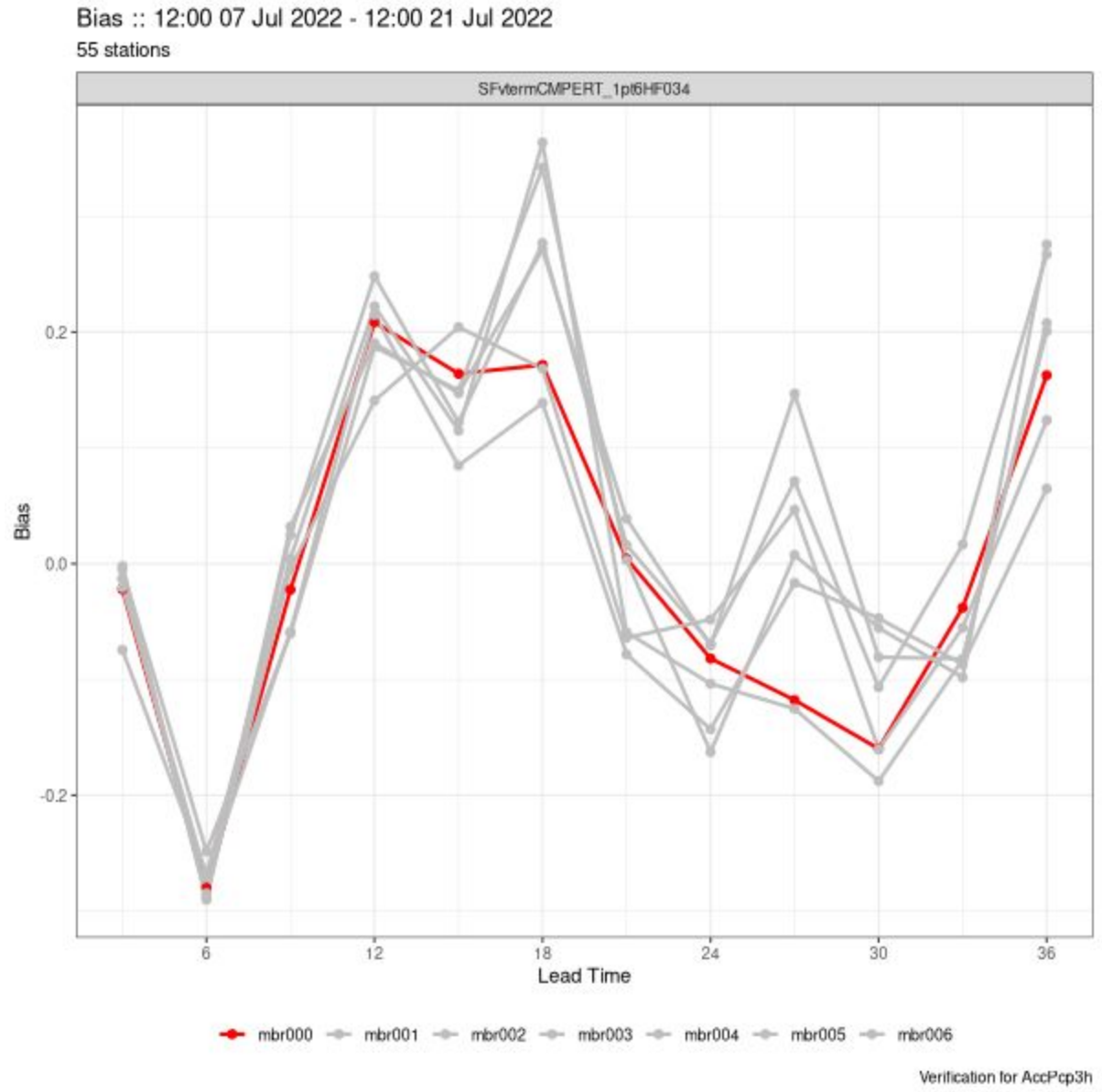
CMPERT=1.6 RH2m shift



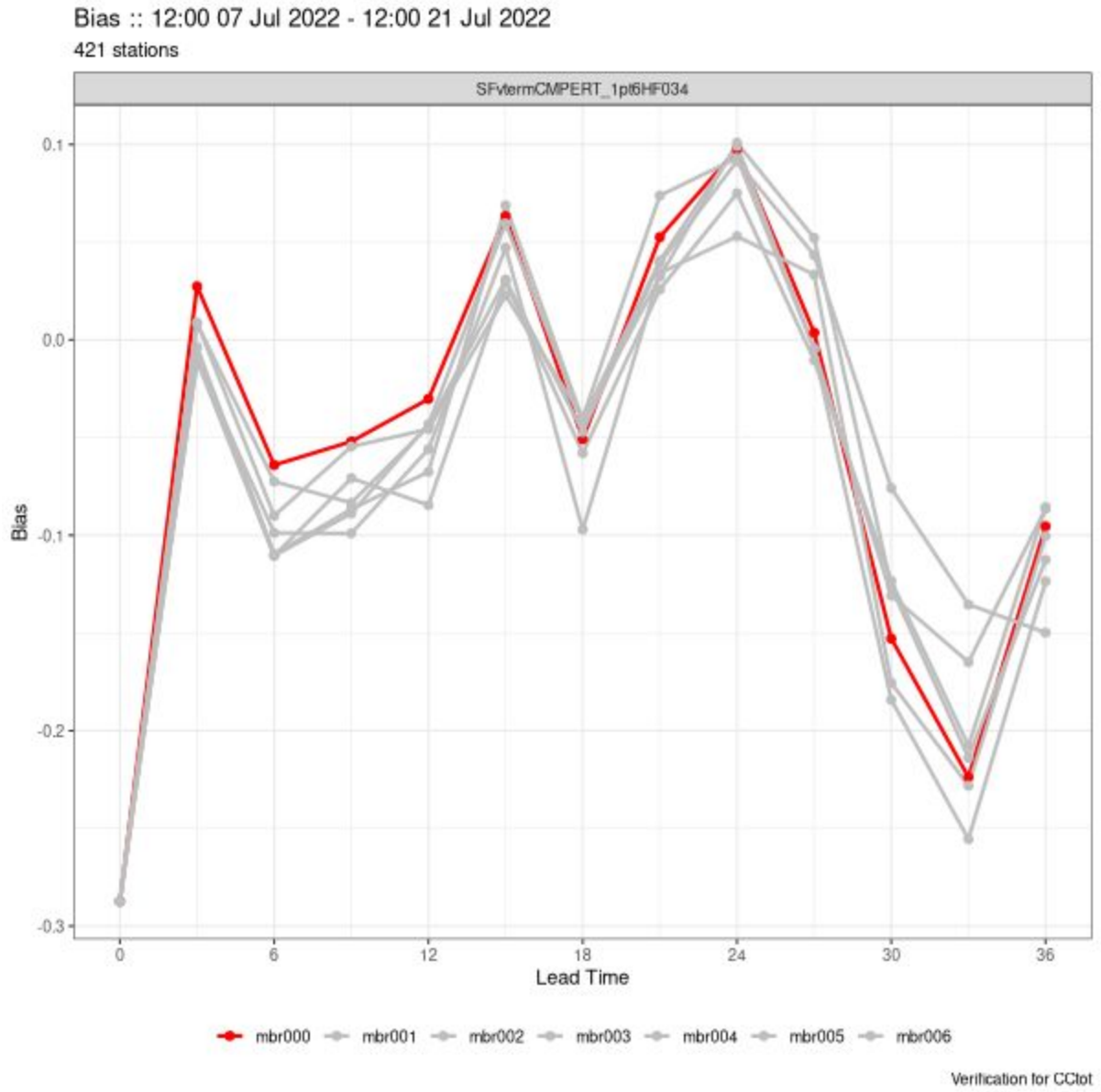
CMPERT=1.6 T2m shift



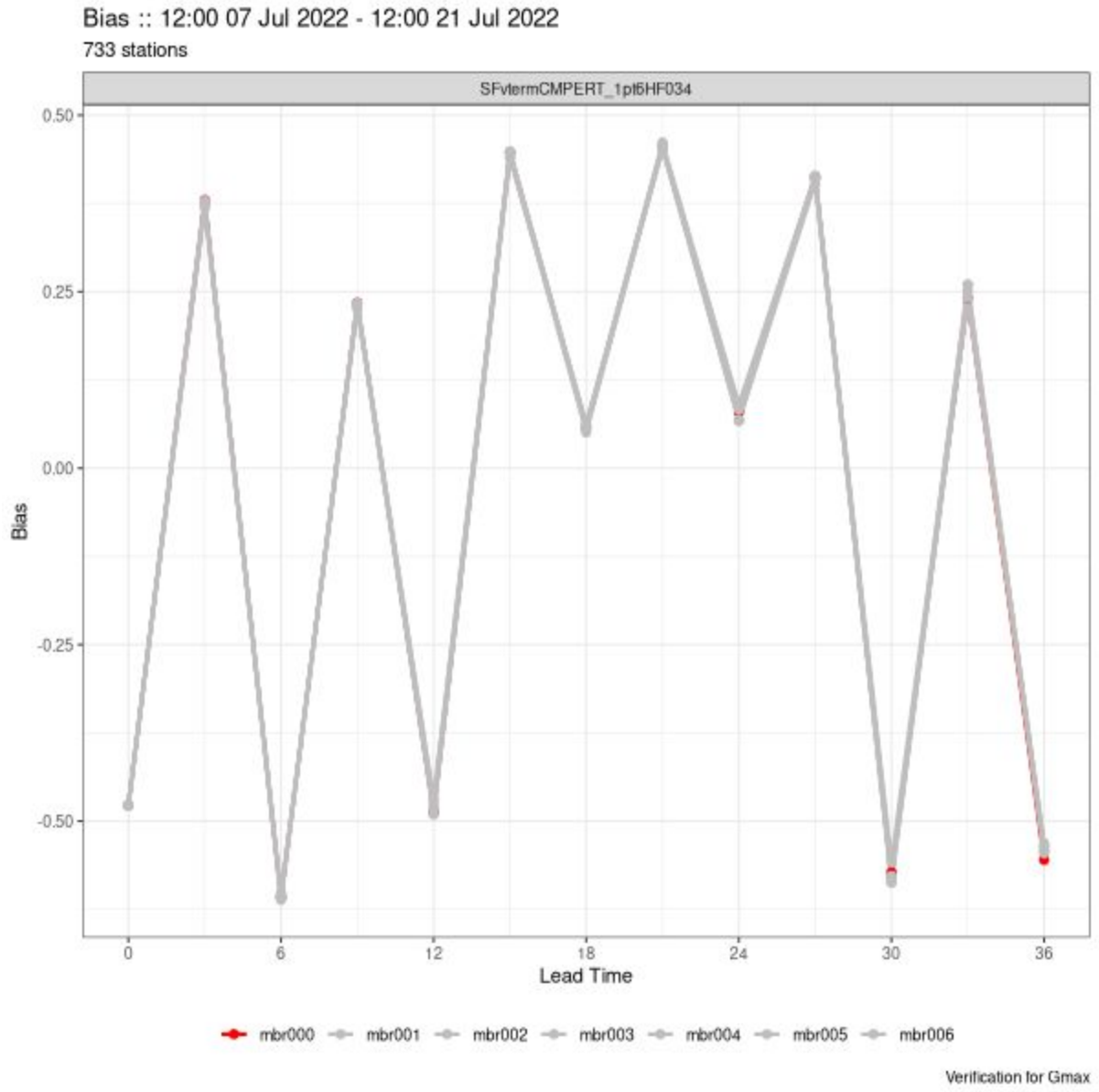
CMPERT=1.6 AccPcp3h shift



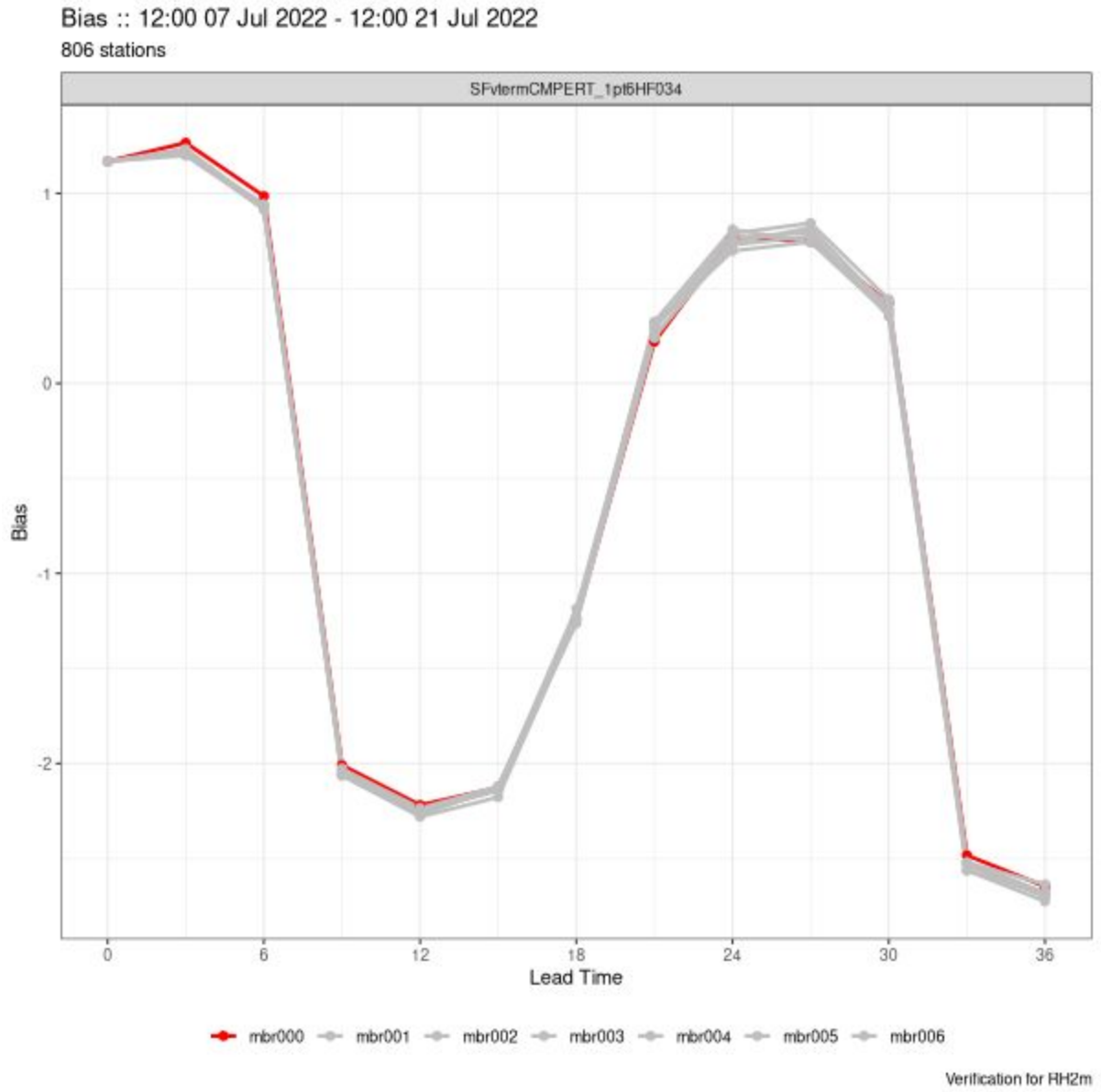
CMPERT=1.6 Cctot shift



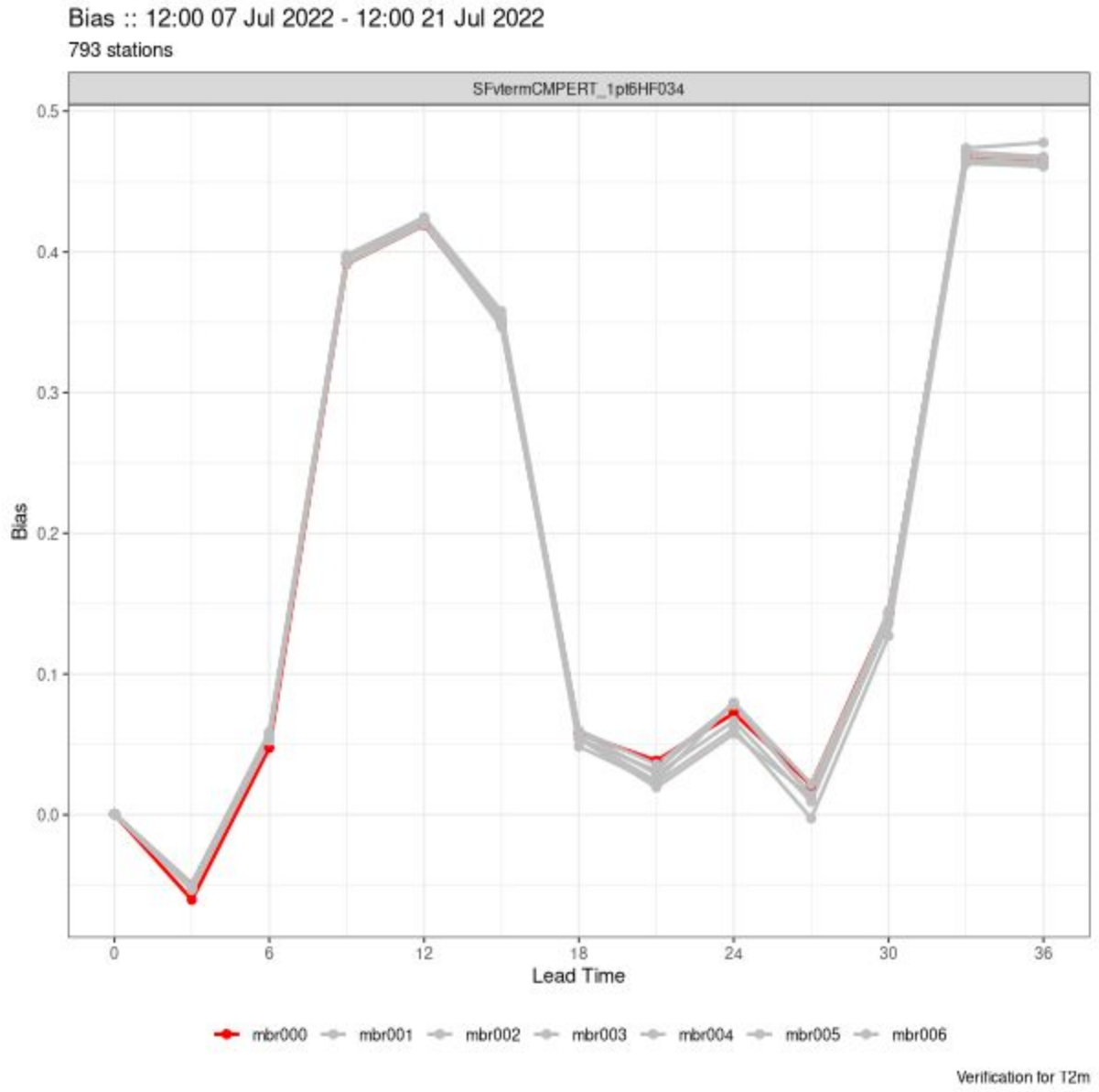
CMPERT=1.6 Gmax shift



CMPERT=1.6 RH2m shift



CMPERT=1.6 T2m shift



Conclusions

- Verification shows considerable spread and neutral or better (for larger CMPERT) skill for AccPcp3h, Cctot, Gmax, T2m and RH2m
- Spread increases with lead time (until ~24h)
- Spread only weakly decreases with decreasing CMPERT
- Large CMPERT: bias of individual members can be removed by shifting the pseudo-uniform distribution
- Very small values of CMPERT still cause considerable spread (more in SP than in DP)

(except when CMPERT=0)

- Exact location of convection very sensitive to small changes in fall velocities in deterministic run (*not shown)*

Outlook

Combine VTERM with:

- P1: LPERT_PSIGQSAT – lognormal, cmpert 0.25 *(saturation limit sensitivity)*
- P3: LPERT_CLDDPTHDP – uniform, offset 0.5, cmpert 1.4 *(cloud thickness used in shallow/deep convection)*
- P4: LPERT_ICE_CLD_WGT – uniform, offset 0.475, cmpert 1.0 *(ice cloud content impact on cloud thickness)*
- P11:LPERT_RZC_H - uniform, offset 0.5, cmpert 0.8 *(stable conditions length scale)*
- P12:LPERT_RZL_INF – lognormal, cmpert 0.35 *(asymptotic free atmospheric length scale)*