HarmonEPS developments

Inger-Lise Frogner - Hirlam project leader for EPS and predictability
with contributions from the Hirlam EPS team

ACCORD All Staff Workshop 2023 - Tallinn

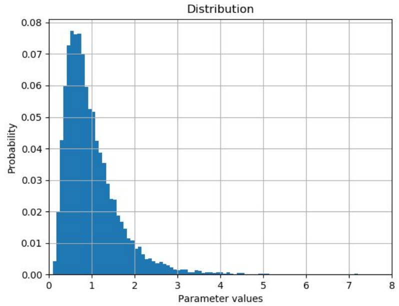
Topics:

- SPP for upper air; status, new developments and plans
- SPP for surface, first try and plans
- Status and plans for utilizing the URANIE platform
- EDA with 4DVar, first results

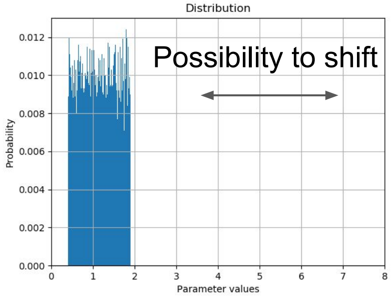
Stochastically Perturbed Parameterizations (SPP)
Upper air

Status:

- Operational in MetCoOp since 30 August 2022
- 5P SPP in MetCoOp - with a mix of lognormal and uniform distributions
- SPP aimed for operations also in UWC West
- A total of 18 parameters in the scheme at present



lognormal distribution



Uniform distribution

Parameters that can be perturbed by SPP

Perturbation	Description	Perturbs
P1: LPERT_PSIGQSAT	Perturb saturation limit sensitivity	VSIGQSAT
P3: LPERT_CLDDPTHDP	Perturb threshold cloud thickness used in shallow/deep convection decision	RFRMIN(20)
P4: LPERT_ICE_CLD_WGT	Perturb cloud ice content impact on cloud thickness	RFRMIN(21)
P5: LPERT_ICENU	Perturb ice nuclei	RFRMIN(9)
P6: LPERT_KGN_ACON	Perturb Kogan autoconversion speed	RFRMIN(10)
P7: LPERT_KGN_SBGR	Perturb Kogan subgrid scale (cloud fraction) sensitivity	RFRMIN(11)
P8: LPERT_RADGR	Perturb graupel impact on radiation	RADGR
P9: LPERT_RADSN	Perturb snow impact on radiation	RADSN
P10:LPERT_RFAC_TWOC	Perturb top entrainment	RFAC_TWO_COEF
P11:LPERT_RZC_H	Perturb stable conditions length scale	RZC_H
P12:LPERT_RZL_INF	Asymptotic free atmospheric length scale	RZL_INF
P13:LPERT_RLWINHF	Long wave inhomogeneity factor	RLWINHF
P14:LPERT_RSWINHF	Short wave inhomogeneity factor	RSWINHF
P15:LPERT_ALPHA	Cloud droplet gamma distribution parameters alpha (over sea)	ALPHA
P16:LPERT_RZNUC	Cloud droplet gamma distribution parameters nu (over land)	RZNUC
P17:LPERT_RZMFDRY	Parameter for dry mass flux	RZMFDRY
P18:LPERT_RZMBCLOSURE	Closure parameter for moist mass flux	RZMBCLOSURE

Parameters that can be perturbed by SPP

Used operationally by MetCoOp

Correlated

Perturbation	Description	Perturbs
P1: LPERT_PSIGQSAT	Perturb saturation limit sensitivity	VSIGQSAT
P3: LPERT_CLDDPTHDP	Perturb threshold cloud thickness used in shallow/deep convection decision	RFRMIN(20)
P4: LPERT_ICE_CLD_WGT	Perturb cloud ice content impact on cloud thickness	RFRMIN(21)
P5: LPERT_ICENU	Perturb ice nuclei	RFRMIN(9)
P6: LPERT_KGN_ACON	Perturb Kogan autoconversion speed	RFRMIN(10)
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P8: LPERT_RADGR	Perturb graupel impact on radiation	RADGR
P9: LPERT_RADSN	Perturb snow impact on radiation	RADSN
P10:LPERT_RFAC_TWOC	Perturb top entrainment	RFAC_TWO_COEF
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P13:LPERT_RLWINHF	Long wave inhomogeneity factor	RLWINHF
P14:LPERT_RSWINHF	Short wave inhomogeneity factor	RSWINHF
P15:LPERT_ALPHA	Cloud droplet gamma distribution parameters alpha (over sea)	ALPHA
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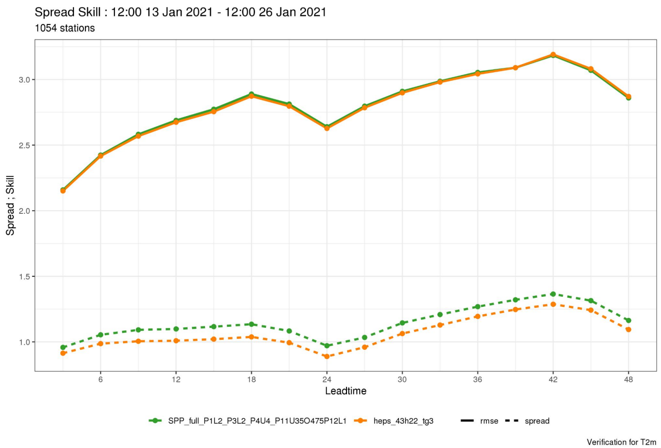
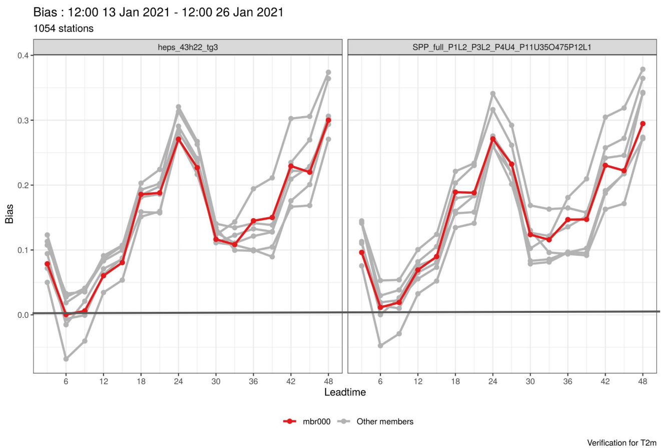
P17:LPERT_RZMFDRY	Parameter for dry mass flux	RZMFDRY
P18:LPERT_RZMBCLOSURE	Closure parameter for moist mass flux	RZMBCLOSURE

T2m

REF
SPP

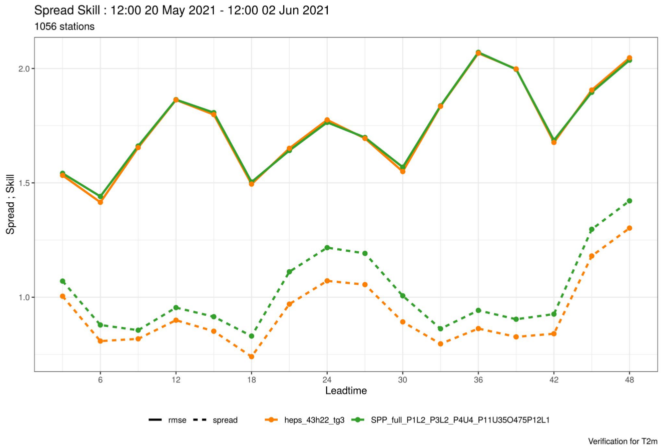
Winter

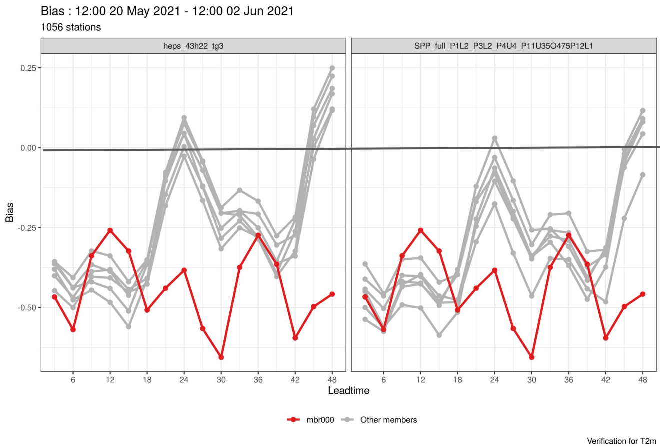




REF SPP

Summer





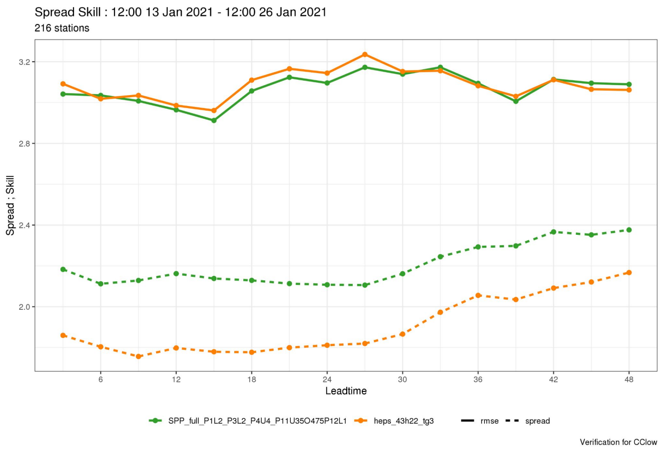
spread (---) Skill (——)

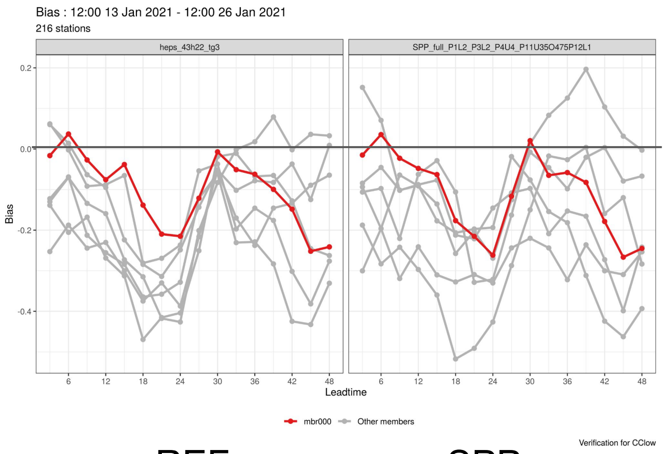
Bias members control

CClow

REF
SPP

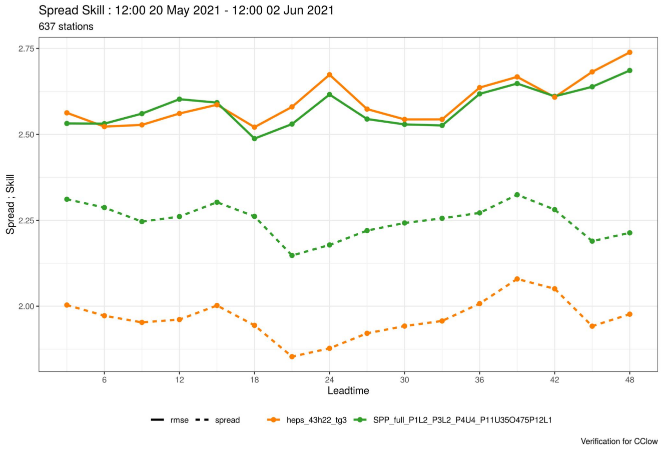
Winter

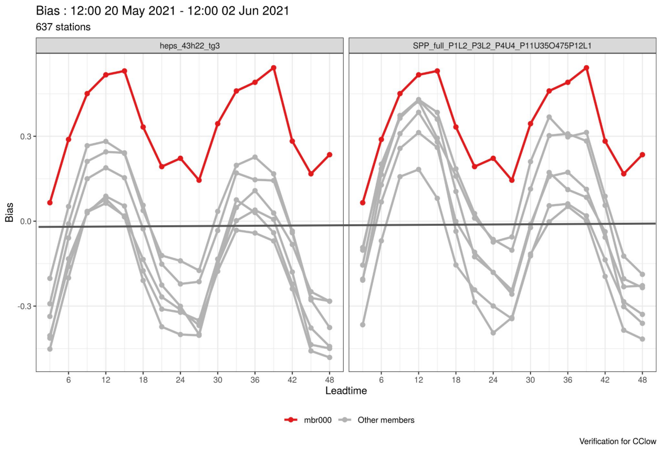




REF SPP

Summer





spread (---) Skill (——)

Bias members control

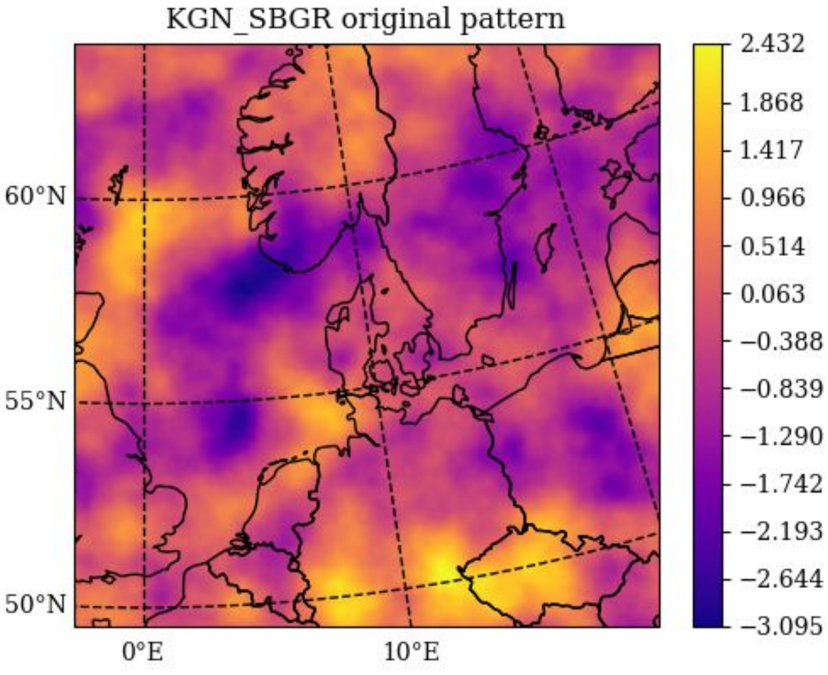
Stochastically Perturbed Parameterizations (SPP) Upper air

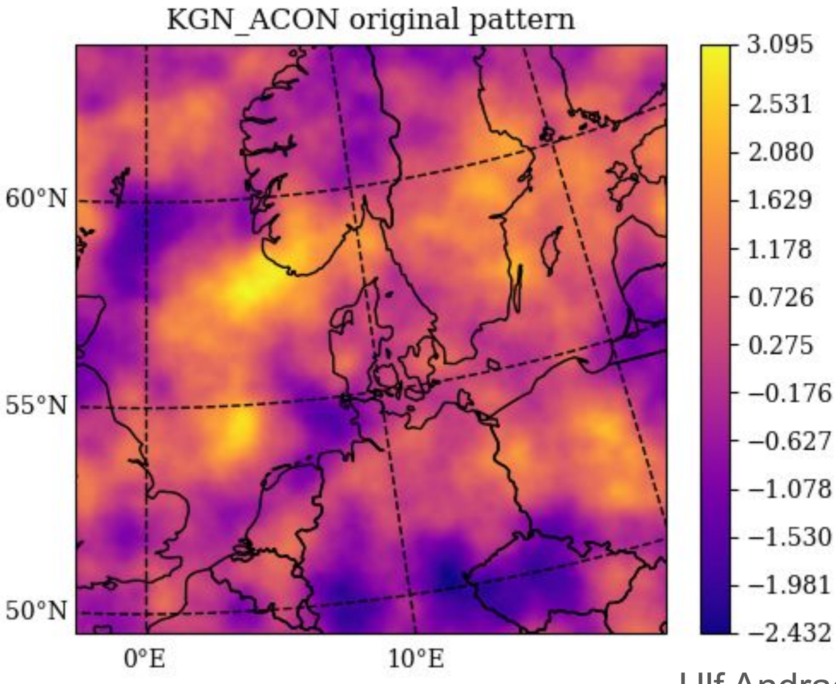
<u>New developments:</u> Easy way to correlate/anti-correlate perturbation patterns - namelist driven

- Before this the correlation patterns were fixed to certain parameters in the code and introducing more correlations required extra coding.
- In addition a full set of patterns were still initialized and evolved, i.e. an extra cost for nothing.
- Now (dev-CY46h1), for each parameter a new namelist key MP_X is introduced where MP_X tells which parameters to give the same pattern.
- To force more parameters to use the same pattern just set MP_X1 = MP_X2 … = MP_XN
- If MP_X is not given the parameter will have its own pattern
- Different parameters using the same pattern can be anticorrelated by setting IC_X = -1 in the namelist

Ulf Andrae

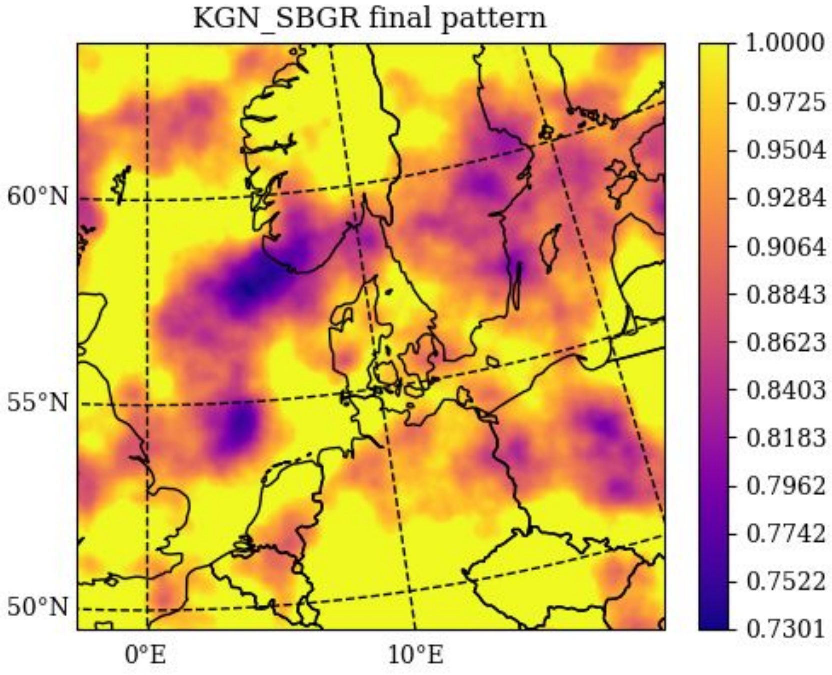
Original, anticorrelated, patterns

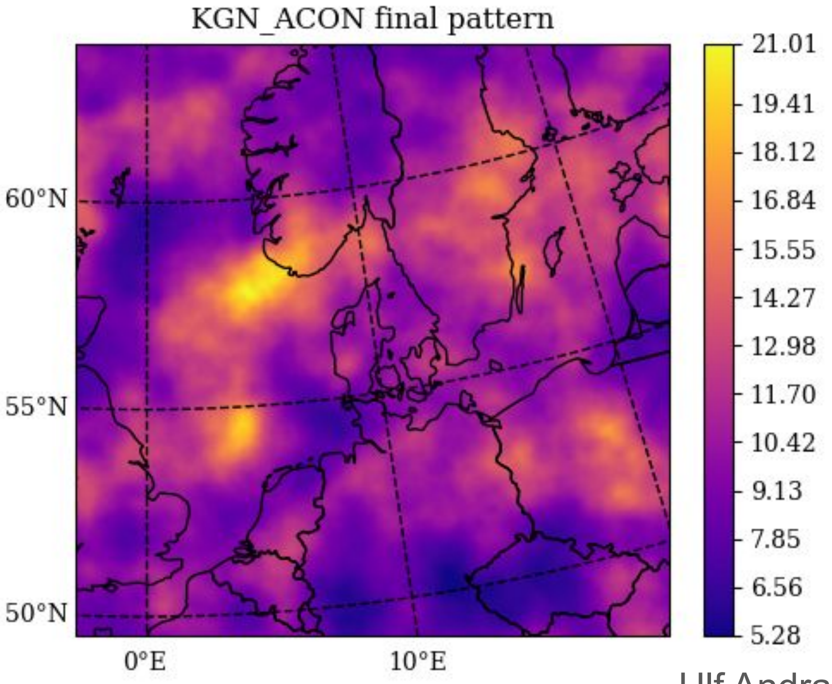




Ulf Andrae

Perturbed parameters





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Stochastically Perturbed Parameterizations (SPP) Upper air

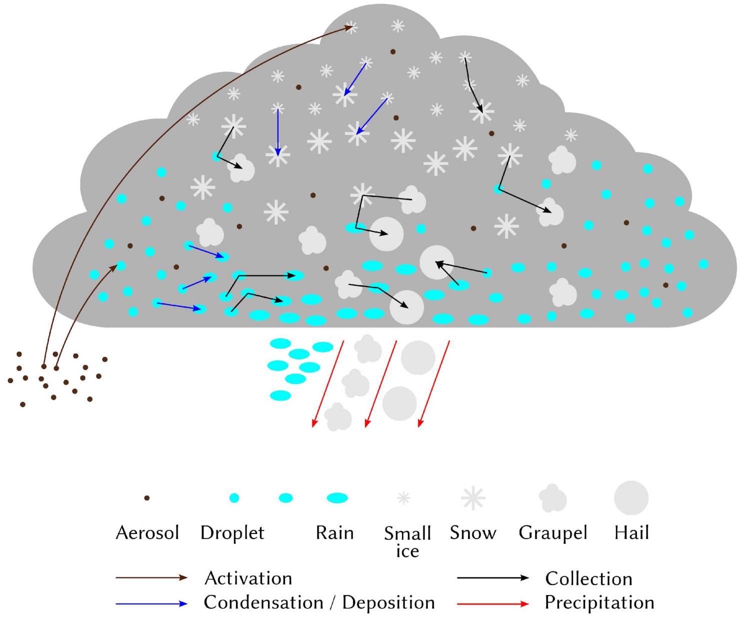
<u>New developments -</u> Accounting for uncertainties in new parameters/processes.

- The size distributions of different (solid) water species
- Hydrometeor terminal fall velocities

Being technically implemented at the moment

Motivation for perturbing presented here

Perturbations in the ICE4 scheme



https://www.encyclopedie-environnement.org/app/uploads/2020/09/microphysical-processes-evolution-cloud.png

- Large uncertainties in describing the size distributions of different (solid) water species
- This leads to uncertainties in the calculated number concentrations and how the different species interact with each other (growth/decay)
  - Growth/decay processes influence latent heating inside the cloud
- The distribution of different water species within the cloud affects cloud dynamics and radiation calculations
- The distribution also directly links to forecasted precipitation type

Pirkka Ollinaho, Karl-Ivar Ivarsson

Perturbations of hydrometeor terminal fall velocities

Motivation for perturbing hydrometeor fall velocities:

- The parameterization of particle size spectra of rain, snow and graupel in Harmonie implies a certain amount of spread in fall velocities, but only bulk fall velocities are computed (that depend on the mixing ratios of the different hydrometeors)
- Changed fall velocities will have impact on convection dynamics
- Changed humidity fields (due to changed evaporation because of changed fall velocities) will influence forecasts of clouds, radiation, precipitation, T2m, etc.

Sibbo van der Veen

Further work and prospects for SPP

- Add more parameters to the scheme - including getting more parameters ready for operations
- Continue the work on the parameter pdfs and correlations
- Test more distributions - if needed
- Play with the temporal and spatial scales - different for different parameters?
- Extend to 3D?

<u>In addition we are working on:</u>

- Extending SPP to surface
- More automatic tuning - utilize the URANIE framework

SPP for surface

Motivation:

- We are currently perturbing surface parameters and fields by PertSurf (Bouttier et al. 2016)
- We want to unify (simplify) perturbation methodology by gathering all under the SPP umbrella, with SPP we also get time varying perturbations

Plan:

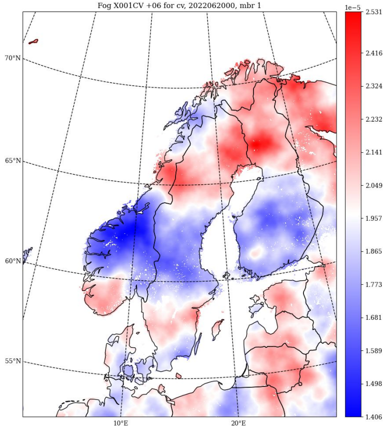
- So far CV and RSMIN are implemented
- To be compared with the current implementation in PertSFC
- Explore new parameters
- More advanced LAI perturbations

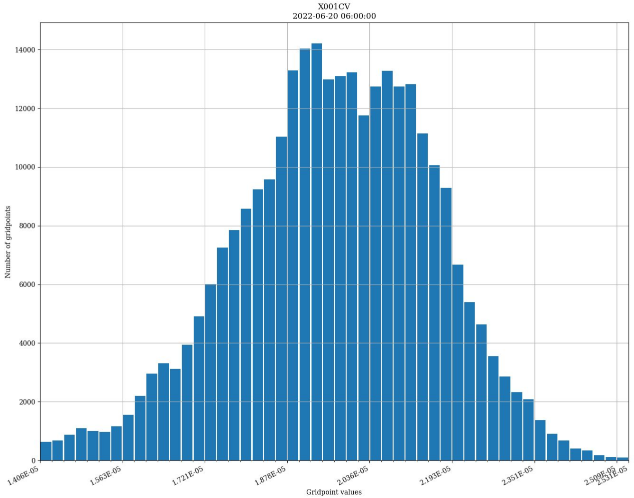
Ulf Andrae, Patrick Samuelsson, Daniel Yazgi, Harold McInnes

SSP for surface - perturbing CV

First test to see if SPP on surface works technically (dev-CY46h1)

- Experiment with SPP perturbations of vegetation thermal inertia coefficient (CV) and reference experiment without, currently running perturbing CV with PertSurf for comparison
- Tested for 10 to 20 June 2022 with seven ensemble members including control. PertSurf turned off.
- The impact of SPP on CV seems to be limited on spread and RMSE (not shown)
  - Increase magnitude of perturbations.
- The impact of PertSurf and SPP on surface parameters will be compared in further experiments.



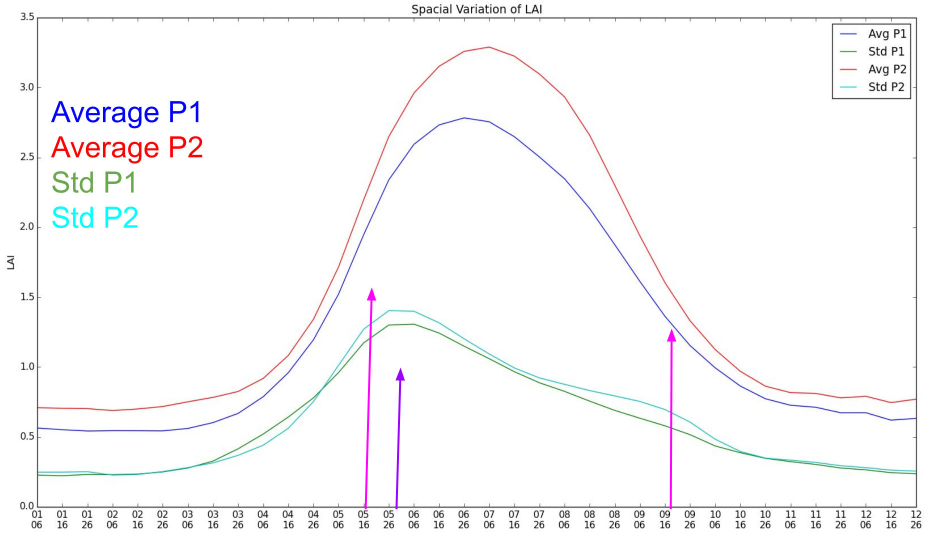


Harold McInnes

Perturbing LAI using the seasonal variability as a scaling factor

Motivation:

- Current perturbations of LAI in PertSurf has shown to have some problems, like removing all vegetation in forest areas or adding vegetation in completely bare areas.
- LAI has high change rates in some periods of the year (see figure), the uncertainty is highest when the temporal change rate is high
- To have robust perturbations and not to generate spurious LAI, LAI is perturbed based on statistical information at each grid point (next slide)



The figure shows the spatial averages and standard deviations of LAI over the MetCoOp domain for patches 1 and 2. The largest change rates in the averages is in May and September. The spatial variability is maximum in the end of May.

Daniel Yazgi

Perturbing LAI using the seasonal variability as a scaling factor

Method:

- The model recalculates LAI during the integration when using ECOCLIMAP SG.
- LAI has three different values each month on 1st, 11th and 21th.
- It is convenient to perturb such values when recalculated by the model.

- At time t and grid point i, l_i^t refers to LAI. t changes from 1 to 36
- The change rate c_i^t is normalized on the maximum slope value for all times:

$$c_i^t = \frac{l_i^{t+1} - l_i^{t-1}}{\max_j |c_i^j|}$$

- If r_i is uniformaly distributed number between $[-0.5, 0.5]$ thn the perturbed LAI p_i^t can be calulated from

$$p_i^t = l_i^t \left(1 + r_i \frac{1 + c_i^t}{2}\right)$$

- In this way at most half of the value of LAI will be added or subtracted, and regions with zero LAI will not be changed, so will not create completely bare areas where there is vegetation and will not produce vegetation in bare areas.

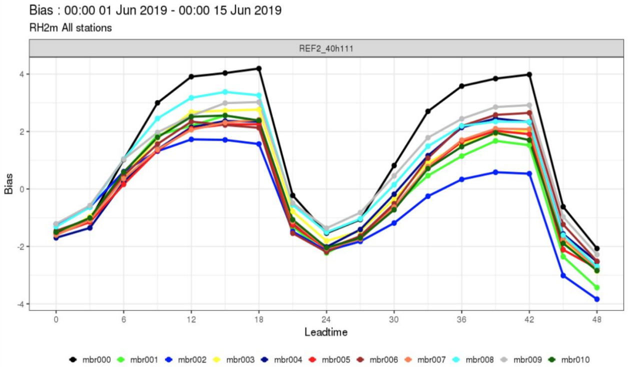
Daniel Yazgi

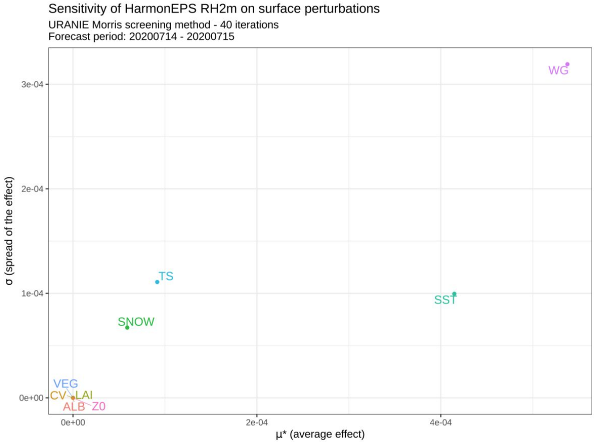
RWP task E9.9: "Test parameter sensitivity in 1D-model using the URANIE framework"

- URANIE: a sensitivity and uncertainty analysis platform
  - [Uranie download | SourceForge.net]

- Previous work by Michiel Van Ginderachter (RMI) on using URANIE with HarmonEPS
  - Part of ESCAPE-2 project
  - Presentation at ACCORD ASW 2022:
    [HarmonEPS VVUQ using the URANIE platform]

- URANIE applied to several HarmonEPS experiments:
  - Impact of individual surface perturbations on RH2m bias in cycle 40
  - SPP perturbation length-scale optimization





RWP task E9.9: Plans for 2023

- Our aim is to apply URANIE to additional HarmonEPS test cases and assess the feasibility of its wider use within the community.

- Tasks:

1) Implement URANIE in cycle 46 (porting to Atos already carried out by Michiel).

2) Documentation and soil moisture experiment template (Michiel).

3) Investigate URANIE capabilities for SPP optimization/tuning.
   E.g. which pert parameters have the greatest impact?

4) Investigate URANIE capabilities for more rigorous single precision testing.
   E.g. changes induced by single precision < typical ensemble spread?

5) Further exploration of individual surface perturbations.
   E.g. for high-impact weather, as set out in RWP task E11.6.

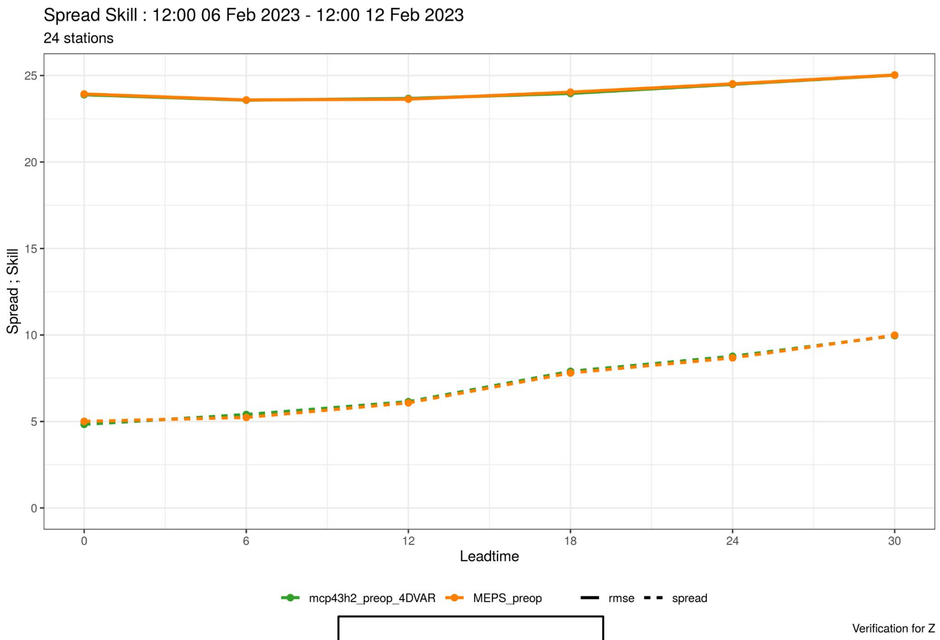
EDA in 4DVar

- One of the initial perturbation methods is perturbation of observations within the range of the observation errors (EDA). This is done after the screening in PERT_ccma.
- The impact and performance of EDA under 4DVAR has not been tested earlier
- The work aims at documenting the performance and possible shortcomings w.r.t to DA and EPS scores.
- Short period (so far): 2023020612 - 2023021212

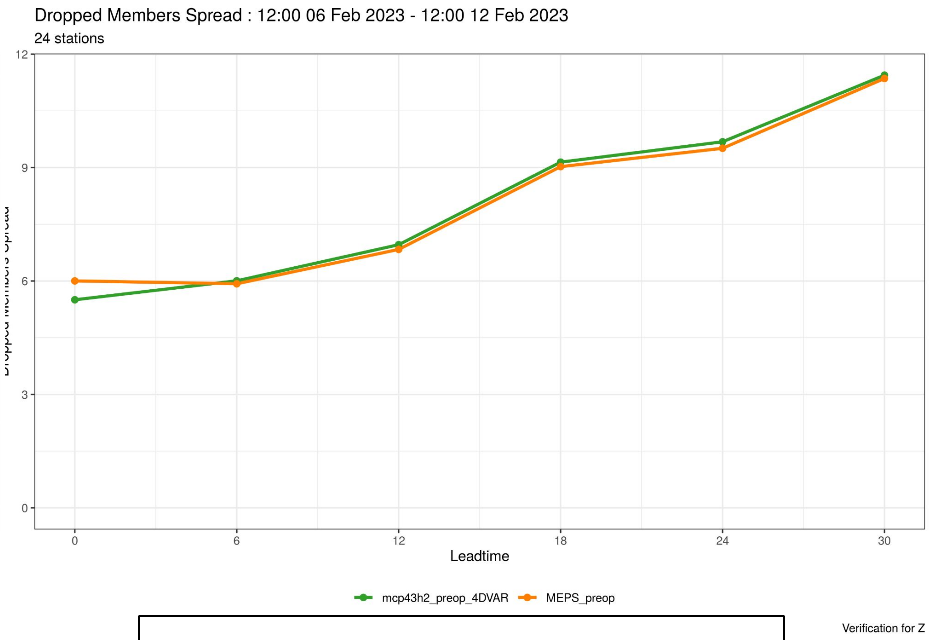
Ulf Andrae (MetCoOp work)

Z 850

MEPS 3DVar
MEPS 4DVar



spread - skill



spread, control excluded

MEPS 4DVar worst for the first few hours, slightly better after +6h (seen mainly from the spread plott)

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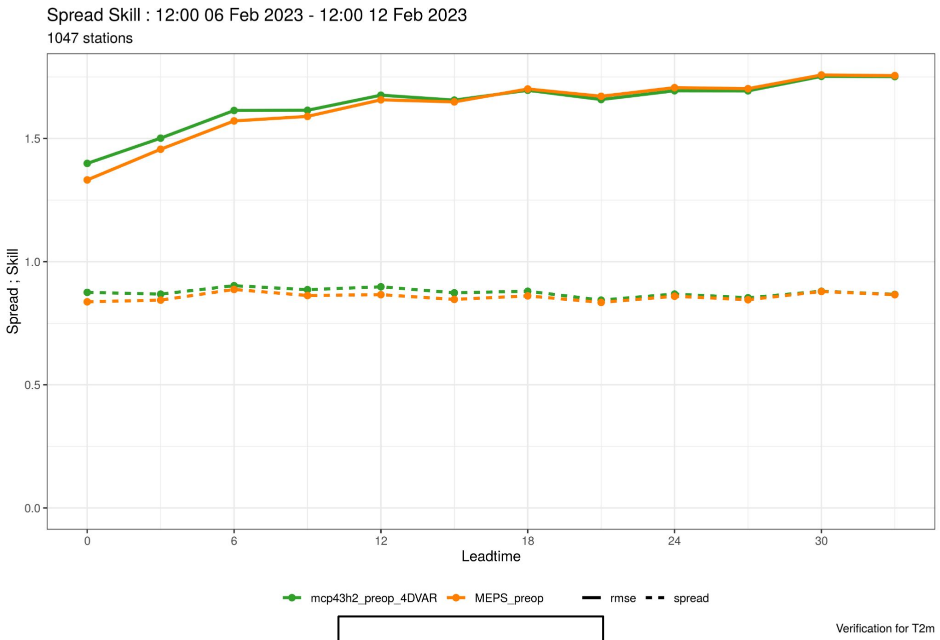
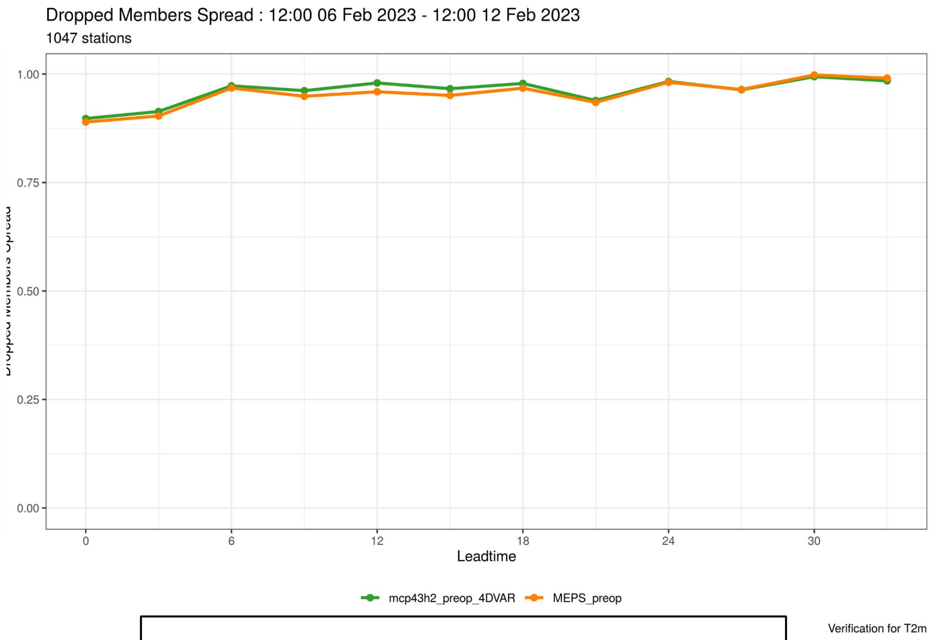
T2m

MEPS 3DVar
MEPS 4DVar



spread - skill



spread, control excluded

MEPS 4DVar better than MEPS 3DVar for spread, but RMSE worse.

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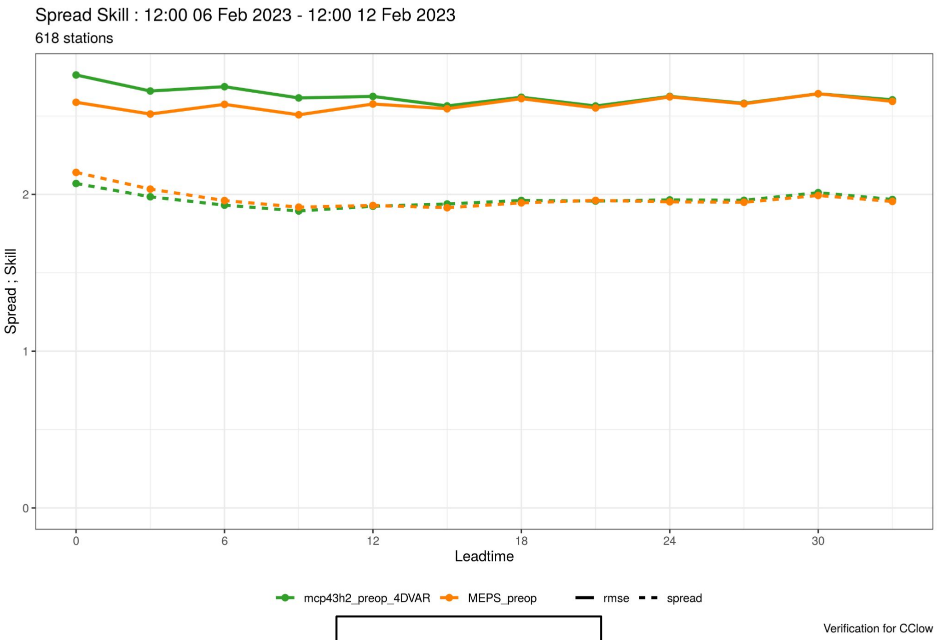
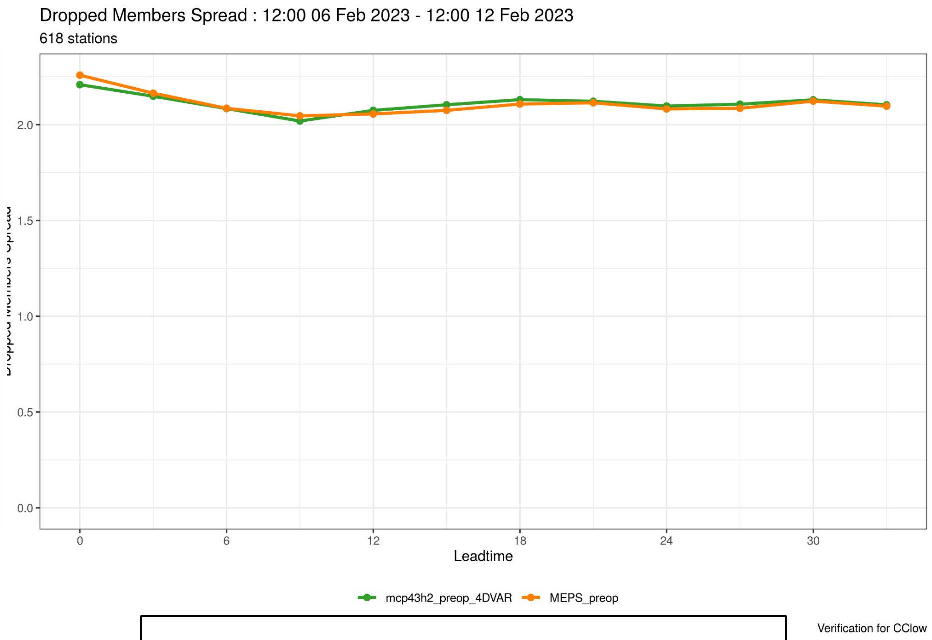
CClow MEPS 3DVar MEPS 4DVar



spread - skill



spread, control excluded

MEPS 4DVar worse than MEPS 3DVar both regarding spread and skill first part of the forecast

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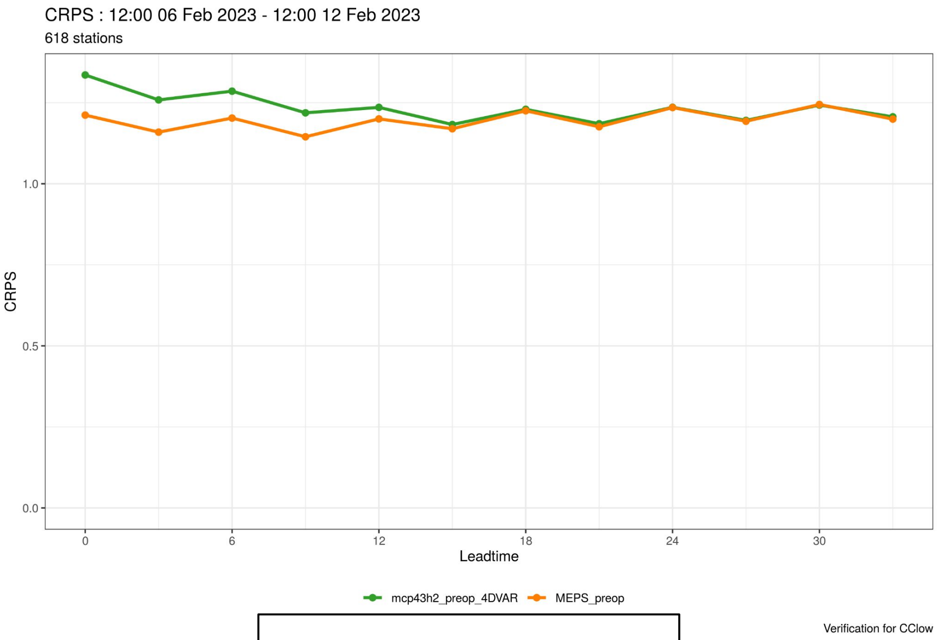
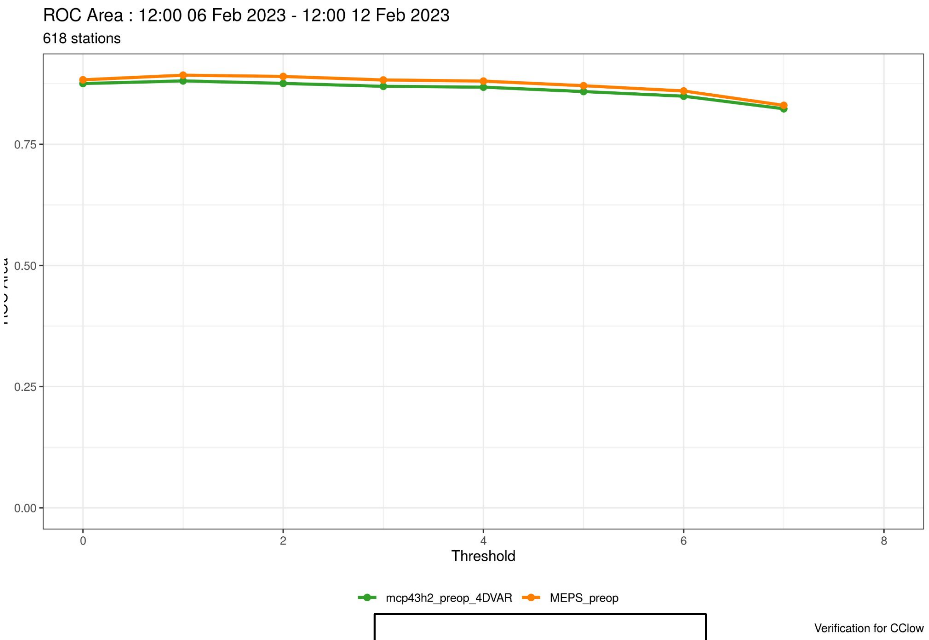
CClow

MEPS 3DVar
MEPS 4DVar



CRPS (lower is better)



ROC area +9h

MEPS 3DVar better CRPS especially for first fc hours. ROC Area is better for MEPS 3DVar than MEPS 4DVar

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EDA in 4DVar

- EDA is now working with 4DVar
- The probabilistic scores in the experiment are within the expected range, no obvious errors
- No clear benefit of 4DVAR vs 3DVAR seen (for this short period)
- Experiment will continue to get more solid statistics

Thank you for your attention

Extra

SPP - 11 parameter setup

SPP gives statistically indistinguishable ensemble members
The conservation properties and internal consistency are preserved

No.	Description	PAR.	Det.	STD#1	STD#2	95 perc.	Type
1)	Threshold for cloud thickness used in shallow/deep convection decision	CLDDPTHDP	4000	0.1	0.4	2.21	CONV
2)	Cloud ice content impact on cloud thickness	ICE_CLD_WGT	1	0.1	0.4	2.23	IM
3)	Ice nuclei concentration	ICENU	1	0.35	0.7	13.48	IM
4)	Saturation limit sensitivity for condensation	VSIGQSAT	0.03	0.1	0.4	2.17	LM
5)	Kogan autoconverltsion speed	KGN_ACON	10	0.25	0.5	2.06	LM
6)	Kogan subgrid scale (cloud fraction) sensitivity	KGN_SBGR	0.5	0.1	0.2	1.77	LM
7)	Graupel impact on radiation	RADGR	0.5	0.15	0.3	1.99	RAD
8)	Snow impact on radiation	RADSN	0.5	0.15	0.3	2.03	RAD
9)	Top entrainment efficiency	RFAC_TWO_COEF	2	0.1	0.4	2.07	TURB
10)	Stable conditions length scale	RZC_H	0.15	0.1	0.4	2.38	TURB
11)	Asymptotic free atmospheric length scale	RZL_INF	100	0.15	0.6	1.87	TURB

- Det. is the deterministic value of the parameter
- STD#1 is the original standard deviation
- STD#2 is the standard deviation we ended up with
- 95 perc. is the 95 percentile of the resulting pdf for STD#2, scaled by the deterministic value
- LM = liquid micro-physics
- IM = ice micro-physics
- RAD = radiation
- CONV = convection
- TURB = turbulence

the threshold for cloud thickness for stratocumulus/cumulus transition not in use

The following parameters are perturbed in MEPS:

Description	Parameter	Type
Threshold for cloud thickness used in shallow/deep convection decision	CLDDPTHDP	convection
Saturation limit sensitivity for condensation	VSIGQSAT	liquid microphysics
Cloud ice content impact on cloud thickness	ICE_CLD_WGT	ice microphysics
Stable conditions length scale	RZC_H	turbulence
Asymptotic free atmospheric length scale	RZL_INF	turbulence

SPG

Stochastic pattern generator (SPG; Tsyrulnikov and Gayfulin 2017) is employed for the generation of the random perturbation fields.

This pattern generator has the advantage of accounting for ‘proportionality of scales’, meaning it takes into account the fact that longer spatial scales live longer than shorter spatial scales, which die out quicker, a widespread feature in geophysics.

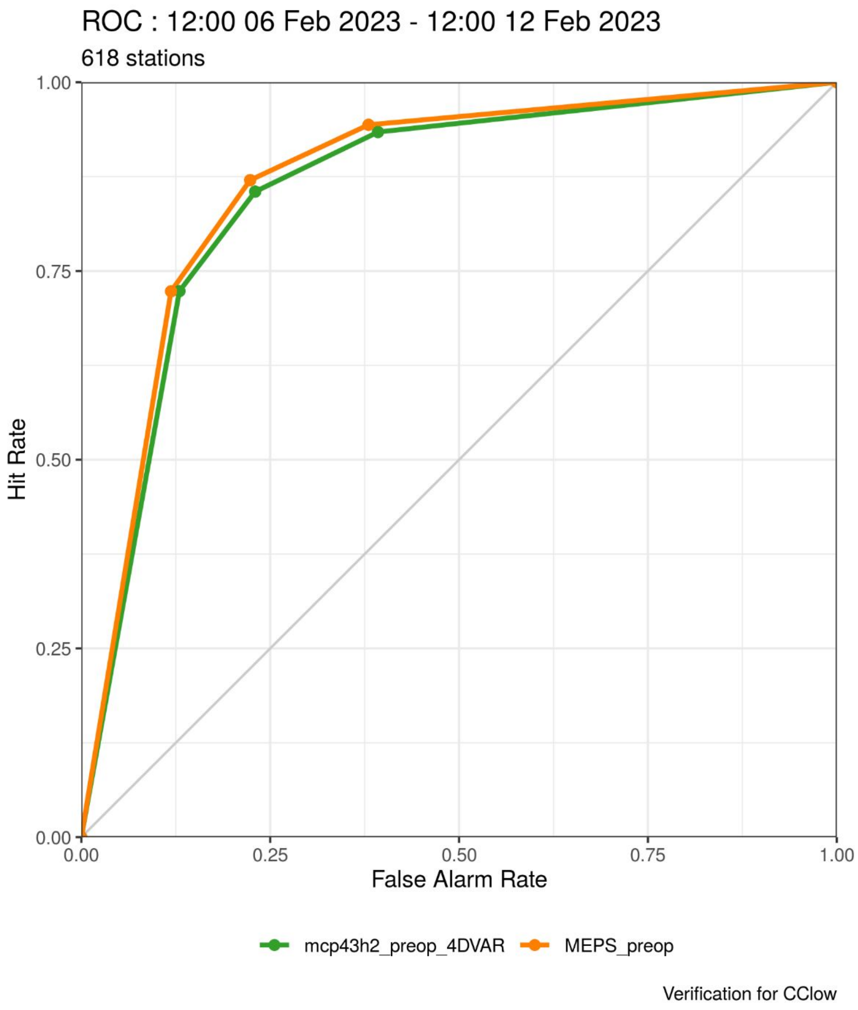
In SPG, the perturbations vary spatially and temporally, and are correlated through a third-order in time stochastic differential equation with a pseudo-differential spatial operator defined on a limited area.

The implementation in HarmonEPS interfaces the code provided by Tsyrulnikov and Gayfulin (2017) and is solely defined by the spatial (XLCOR) and temporal (TAU) correlation length scales, and the standard deviation, SDEV

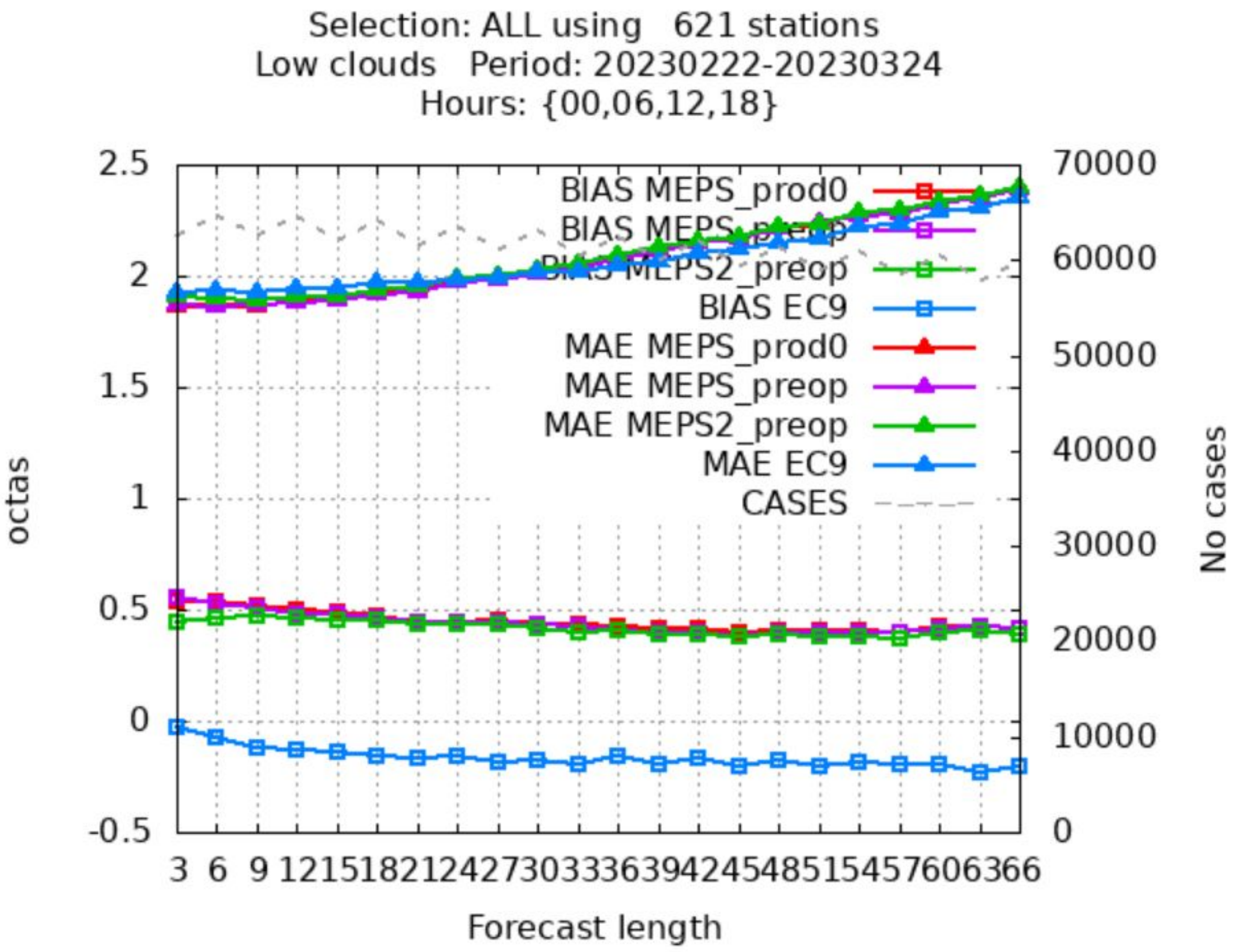
Surface perturbations

Surface perturbations are applied to account for uncertainties in the turbulent fluxes emanating from interactions between the surface and the atmosphere. These uncertainties may come from both the specification of static physiographic fields and the analysis of prognostic surface parameters in the initial conditions. The method used to apply the surface perturbations is taken from Bouttier et al. (2016). The perturbations are applied to parameters in the SURFEX analysis after the surface data assimilation is completed and remain fixed throughout the forecast for static parameters. For prognostic parameters (i.e., soil temperature and soil moistures), the forecasts begin from the perturbed state and are then allowed to adjust dynamically to the model atmospheric forcing.

Parameter	Standard deviation	Type
Vegetation fraction	0.1	×
Leaf area index	0.1	×
Thermal coefficient of vegetation	0.1	×
Surface roughness length over land	0.2	×
Albedo	0.1	×
Sea surface temperature	0.25	+
Soil temperature	1.5	+
Soil moisture	0.1	×
Snow depth	0.5	×
Surface fluxes over sea	0.2	×



FAR and HR
Divided into probability bins



Selection: ALL using 621 stations
Low clouds Period: 20230222-20230324
Hours: {00,06,12,18}
BIAS MEPS_prod0
BIAS MEPS_preop
BIAS MEPS2_preop
BIAS EC9
MAE MEPS_prod0
MAE MEPS_preop
MAE MEPS2_preop
MAE EC9
CASES
octas
No cases
Forecast length

CRPS is a quadratic measure of the difference between the forecast cumulative distribution function (CDF) and the empirical CDF of the observation.

Let the parameter of interest be denoted by x. For instance, x could be the 2-m temperature or 10-m wind speed. PDF forecast by an ensemble system is given by $\rho(x)$ and that x_a is the value that actually occurred. Then the co probability score (Brown 1974; Matheson and Winkler 1976;Unger 1985; Bouttier 1994), expressing some kind between the probabilistic forecast ρ and truth x_a, is defined as

$$\mathrm{CRPS} = \mathrm{CRPS}(P, x_a) = \int_{-\infty}^{\infty} [P(x) - P_a(x)]^2 \, dx. \quad (1)$$

View Expanded

Here, P and P_a are cumulative distributions:

$$P(x) = \int_{-\infty}^{x} \rho(y) \, dy \quad \text{and} \quad (2)$$

$$P_a(x) = H(x - x_a), \quad (3)$$

View Expanded

where

$$H(x) = \begin{cases} 0 & \text{for } x < 0 \\ 1 & \text{for } x \geq 0 \end{cases} \quad (4)$$