HarmonEPS developments

Inger-Lise Frogner, MET Norway
and many colleagues from the Hirlam EPS team

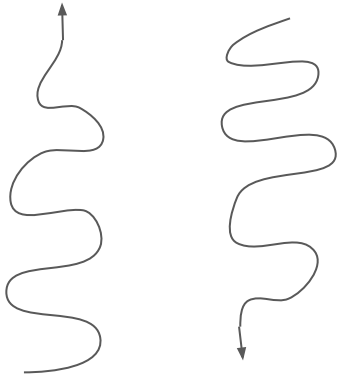
EWGLAM September 2023

Topics:

- Improvements to the Stochastically Perturbed Parameterizations (SPP) scheme
  - SPP show good potential, and introduce variability in the ensemble that the other perturbations do not, but so far we have only perturbed the physics and upper air
- Utilizing the URANIE platform for sensitivity analysis and optimization

SPP - perturbing uncertain parameters

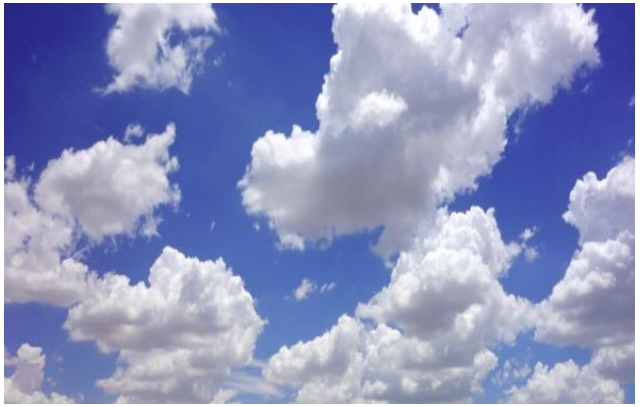
Clouds and microphysic



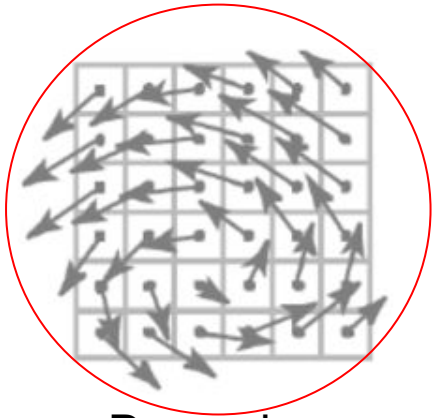
Radiation

Turbulence

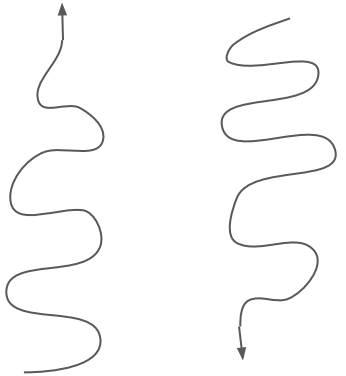
SPP - perturbing uncertain parameters



Clouds and microphysic

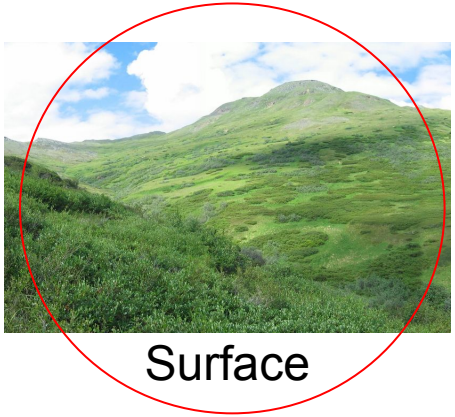


Dynamics



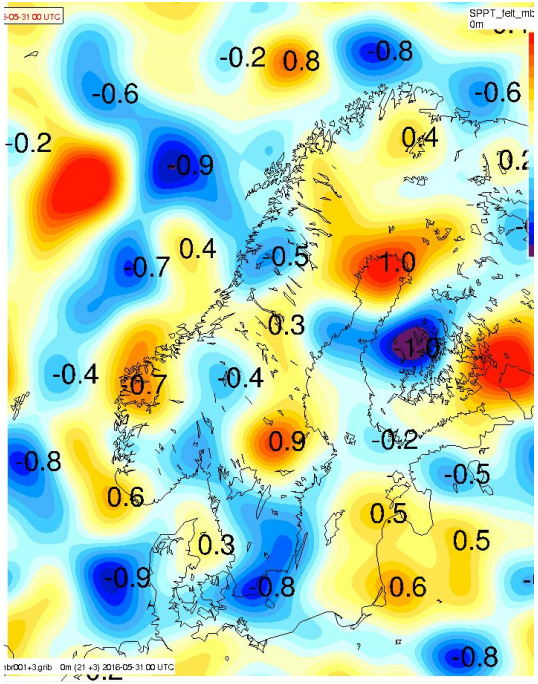
Radiation

Turbulence

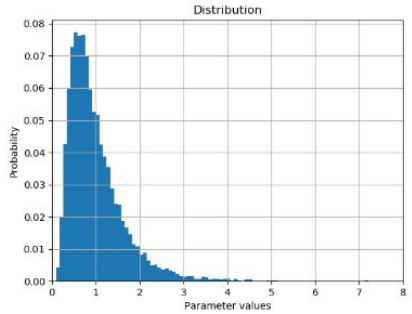


Surface

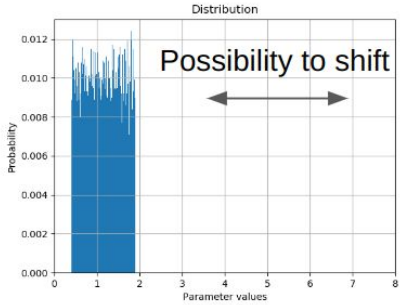
SPP basics



200 km / 12 h used



lognormal distribution



Uniform distribution

Stochastically Perturbed Parameterizations (SPP) - Upper air

Status:

- A 5 parameter version operational in MetCoOp (cooperation between Finland, Sweden, Norway and Estonia) since 30 August 2022 with a mix of lognormal and uniform distributions, two with correlated perturbations
- The same 5 parameter SPP will be part of the join operations also in UWC West (Denmark, Ireland, Iceland and Netherlands) when it goes into production next year
- A total of 19 parameters in the scheme at present - work will continue to add more parameters to the operational setups
- 5 SPP improves the probabilistic scores, as seen in the next slides

Model Uncertainty Representation in a Convection-Permitting Ensemble—SPP and SPPT in HarmonEPS

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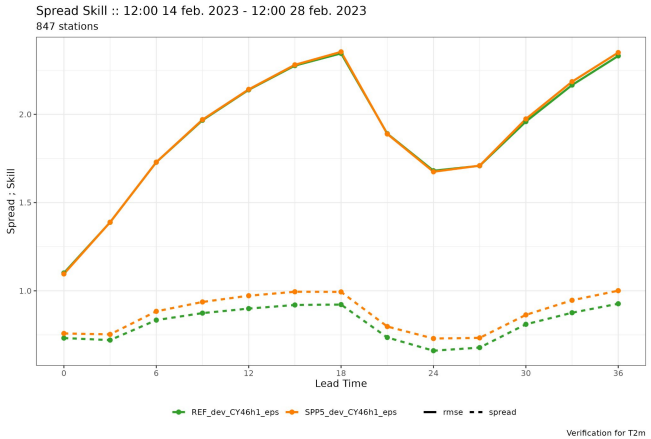
(Manuscript received 30 April 2021, in final form 15 December 2021)

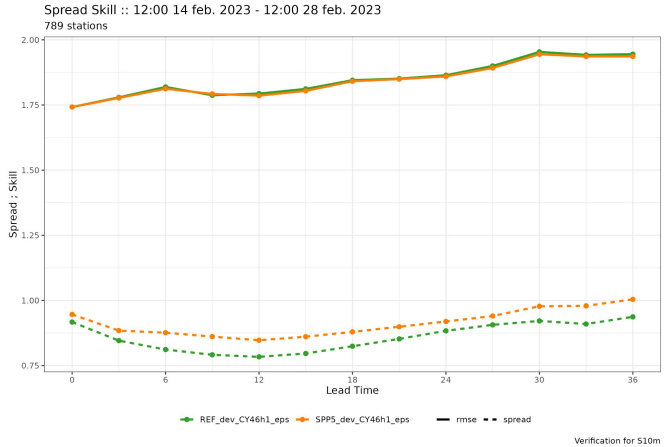
T2m

S10m

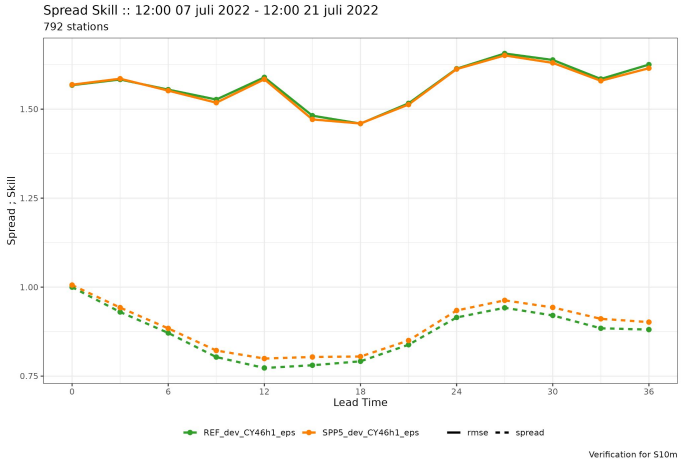
REF
+5 SPP

Winter





Summer



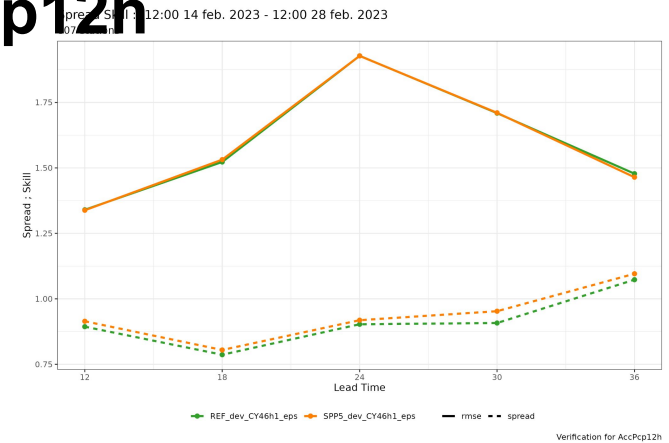
spread (---) Skill (——)

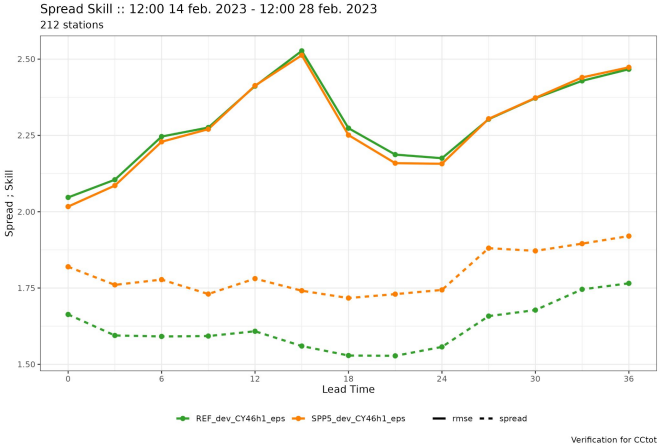
AccPcp12h

CCtot

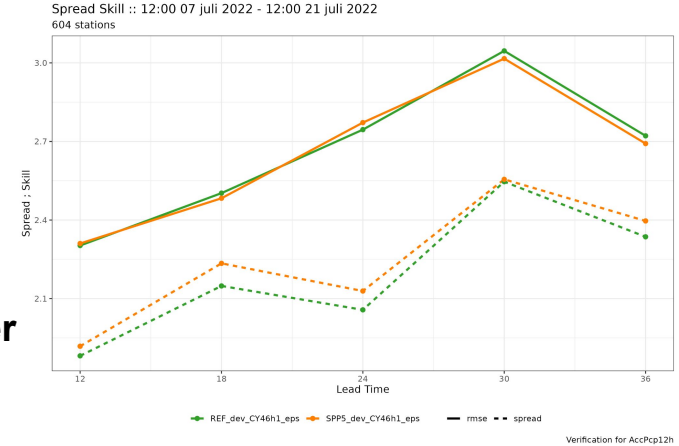
REF
+5 SPP

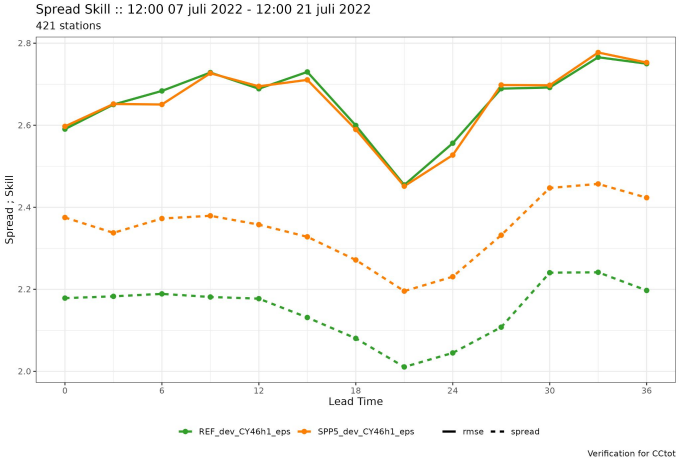
Winter





Summer





spread (---) Skill (——)

New developments - perturbing the dynamics

- First dynamics perturbation in SPP
- Perturbing V(M) in the semi-Lagrangian advection scheme
- Used to compute a refined position for the origin point of the trajectory (only for the Coriolis term)

- Formula for the wind used:
  V = 0.5*RW2TLFF*(V(F)+V(O)) + (1-RW2TLFF)*V(M)

  where F is final, O is origin and M is midpoint along trajectory

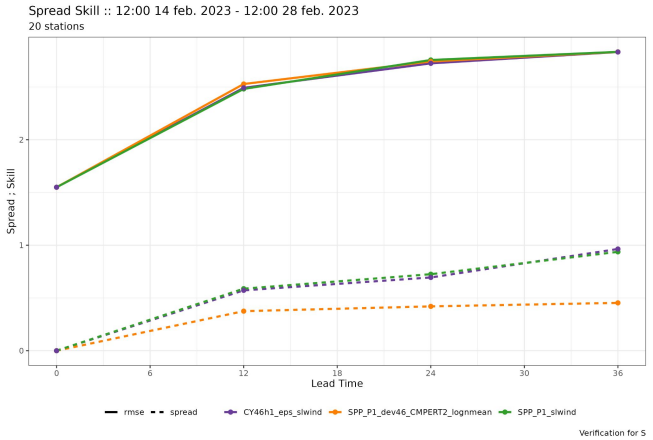
- The option sets RW2TLFF=0.5 (is 1 in unperturbed) and adds a random rotation with uniform distribution and zero mean angle to the V(M) wind.
- Compare the effect of *only* perturbing V(M) (=SLWIND) with the most influential physics parameter perturbation: VSIGQSAT (perturbes saturation limit sensitivity)

Ole Vignes

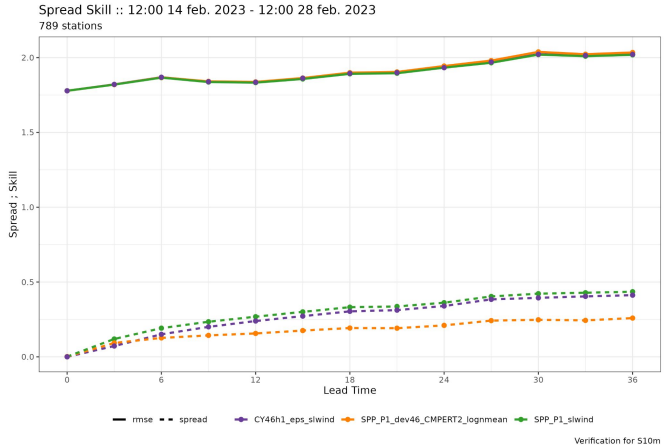
S850

VSIGQSAT
SLWIND
VSIGQSAT+
SLWIND

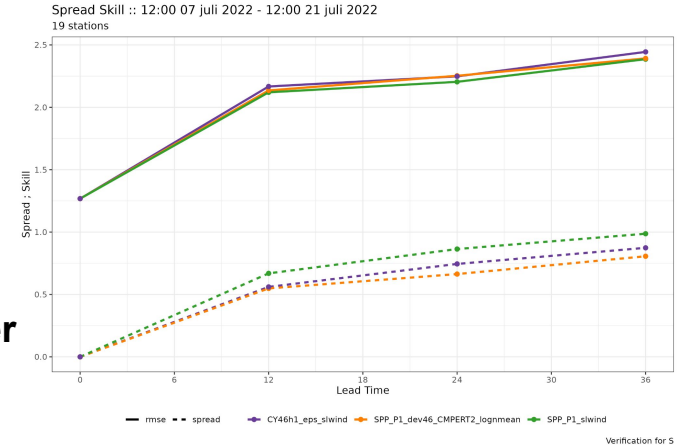
Winter

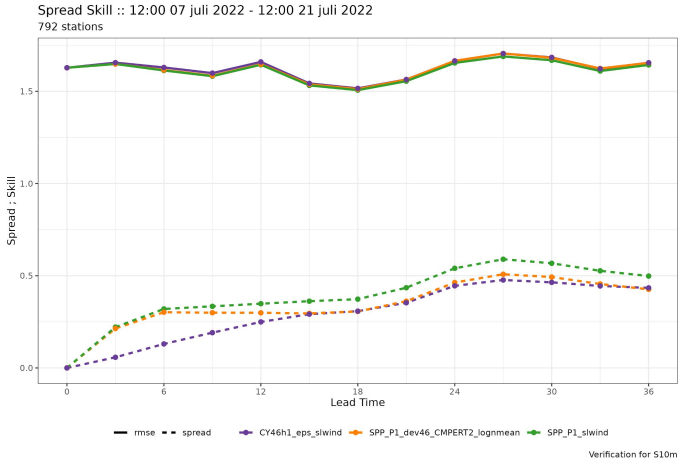


S10m



Summer



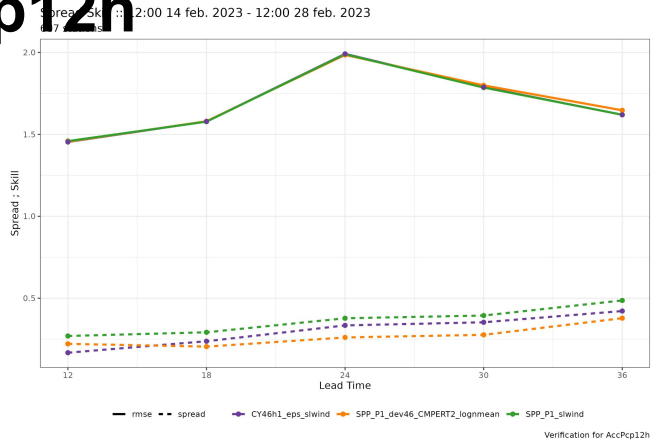


spread (---) Skill (——)

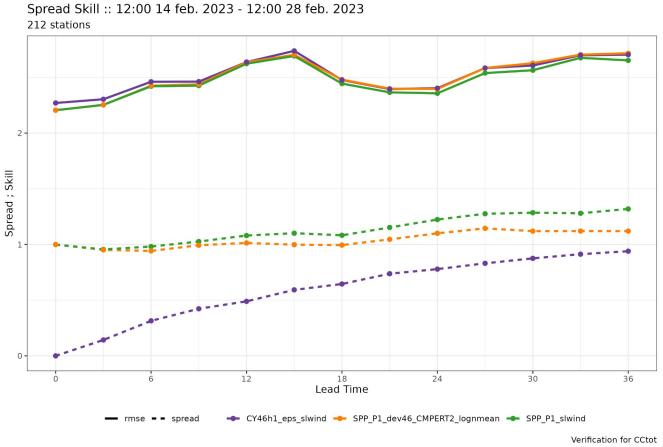
AccPcp12h

VSIGQSAT
SLWIND
VSIGQSAT+
SLWIND

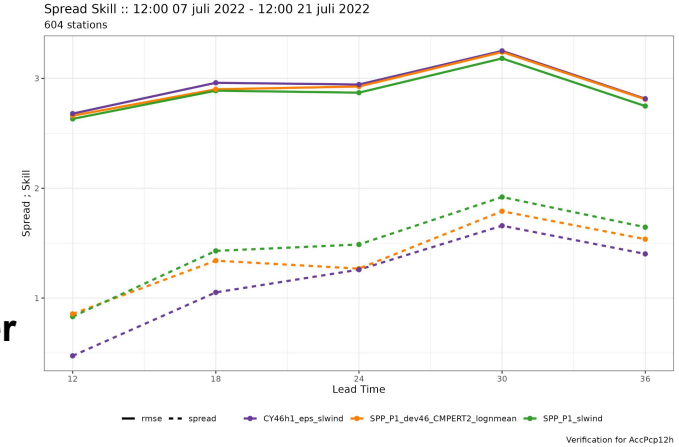
Winter

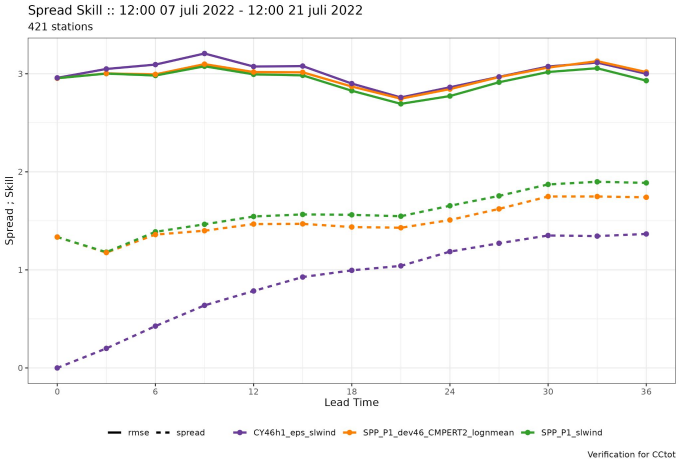


CCtot



Summer

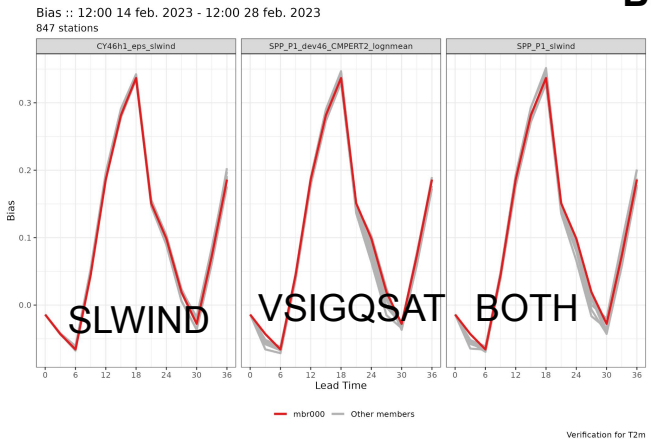




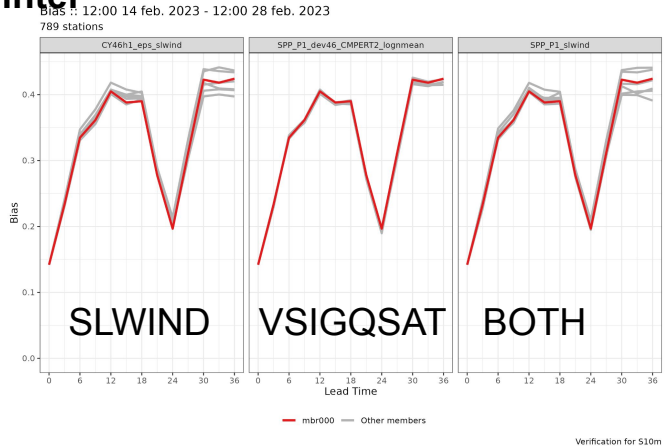
spread (---) Skill (——)

BIAS Winter

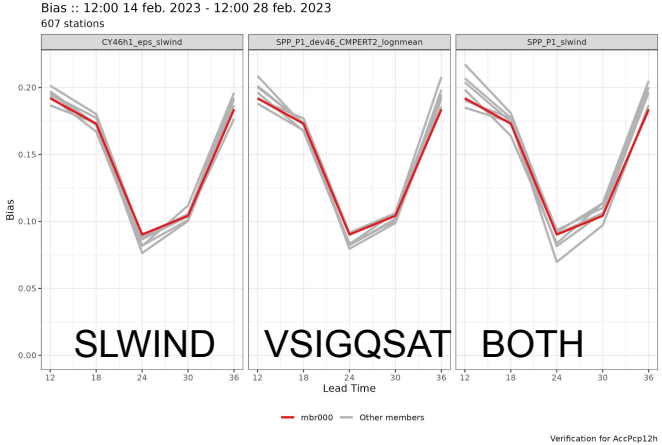
T2m



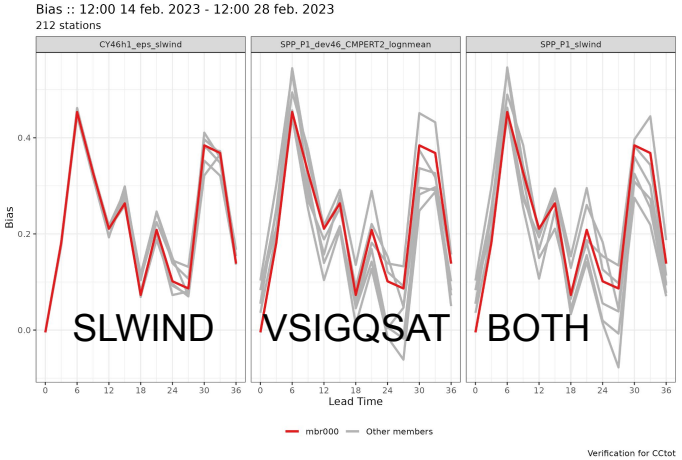
S10m



AccPcp12h



CCtot



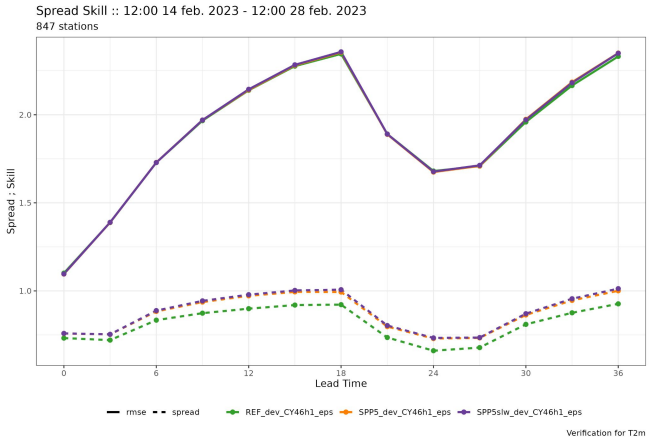
SLWIND added on top of 5 SPP and other perturbations (initial, surface, LBCs)

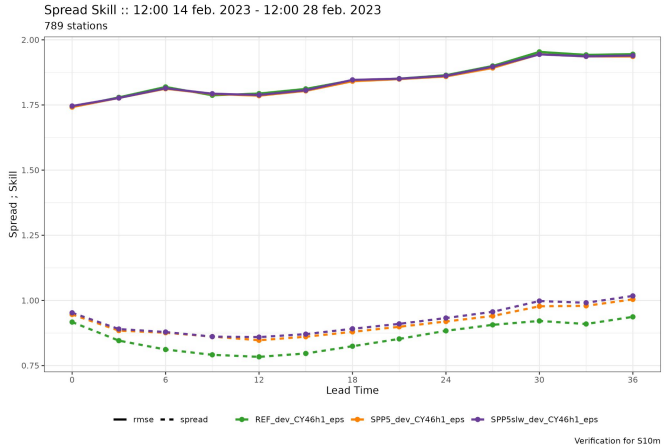
T2m

S10m

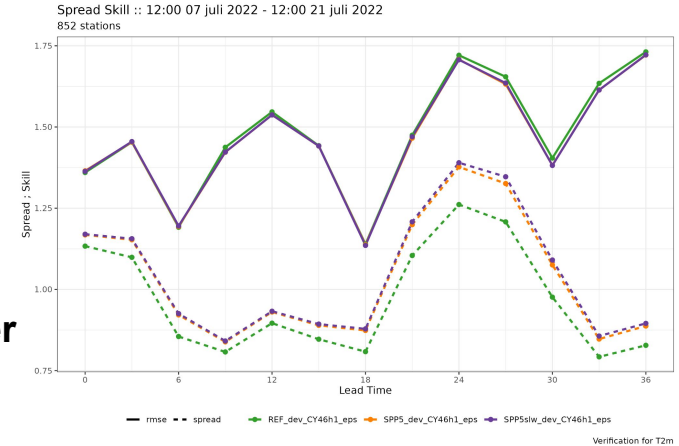
REF
+5 SPP
+SLWIND

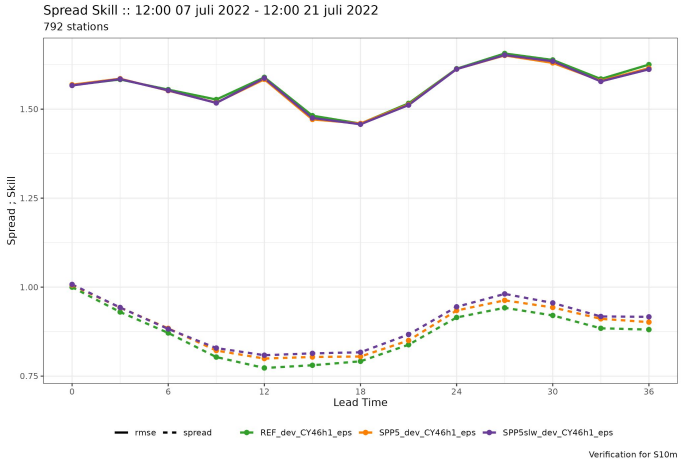
Winter





Summer





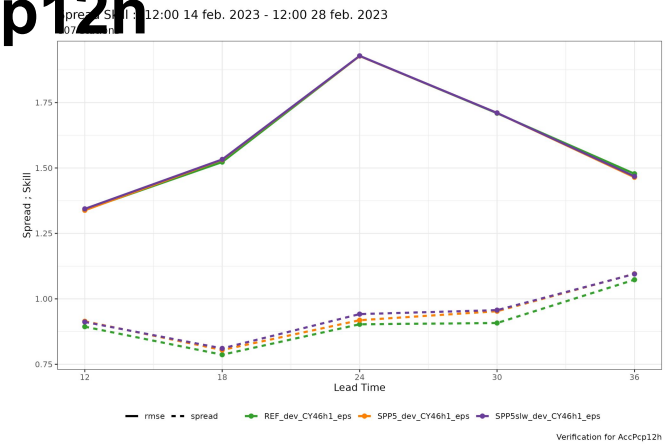
spread (---) Skill (——)

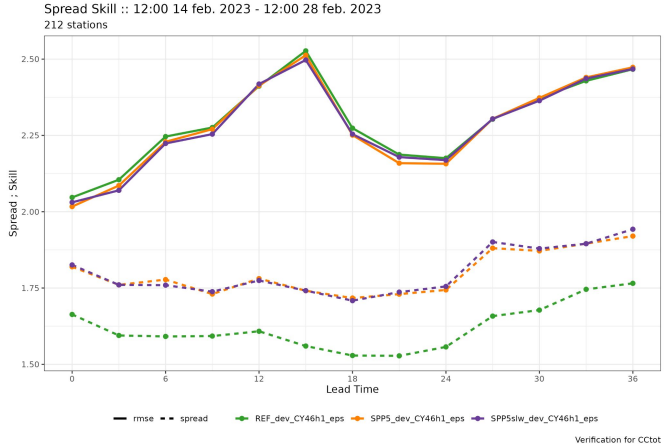
AccPcp12h

CCtot

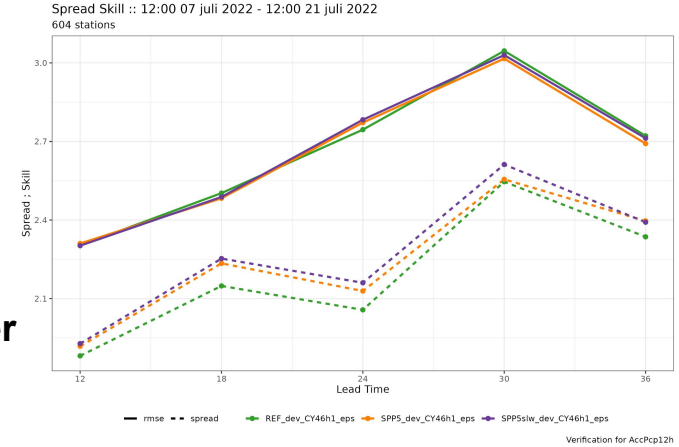
REF
+5 SPP
+SLWIND

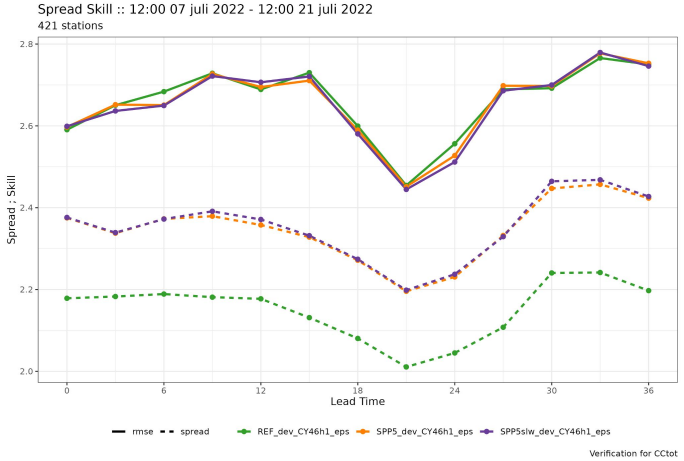
Winter





Summer





spread (---) Skill (——)

Summary - perturbing the dynamics

- Perturbing SLWIND is ~comparable to VSIGQSAT (most influential physics perturbation) except for cloud related weather parameters and T2m in summer
- SLWIND gives more spread than VSIGQSAT for S10m for winter and for both season for upper level winds
- Perturbing SLWIND does not create bias problems
- Combining VSIGQSAT and SLWIND gives better scores than each individually

- When adding SLWIND to experiments with “all other” perturbations on, the effect is more modest
  - important to include uncertainties where we know they exist
  - will study in more detail which other perturbations act on the same processes (look at tendencies)
  - play with the size of the perturbation

New developments - SPP for surface

Motivation:

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

Plan:

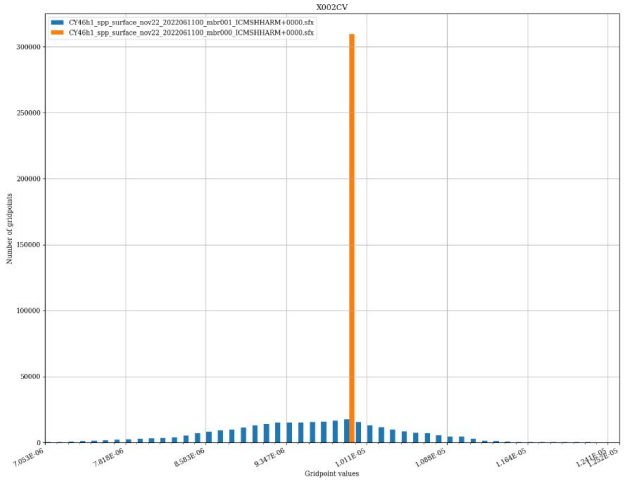
- So far CV (vegetation thermal inertia coefficient) and RSMIN (minimum stomatal resistance) are implemented
- To be compared with the current implementation in PertSFC
- Explore new parameters
- More advanced LAI perturbations

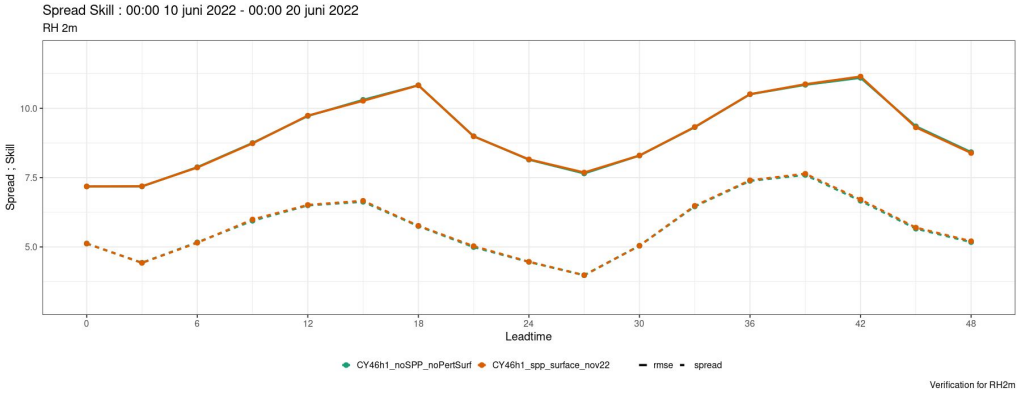
Ulf Andrae, Patrick Samuelsson, Daniel Yazgi, Harold McInnes

SSP for surface - perturbing CV

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

- Experiment with SPP perturbations of 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 on spread is far not very impressive!
  - -> Increase magnitude of perturbations.
- The impact of PertSurf and SPP on surface parameters will be compared in further experiments.



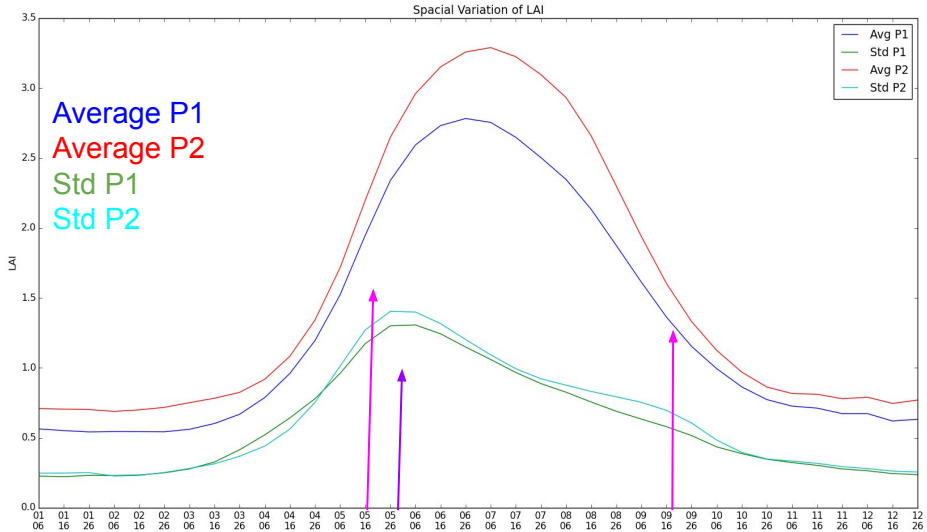


Harold McInnes

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

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?

An Update to the Stochastically Perturbed Parametrizations Scheme of HarmonEPS

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ABSTRACT: High-resolution, limited-area forecasting is strongly affected by errors in the initial atmospheric state, lateral boundary conditions (LBC), and physical parametrizations used by numerical weather prediction (NWP) models. These errors need to be accounted for through the introduction of uncertainty in an ensemble prediction system (EPS). One approach to account for model error is to use a Stochastically Perturbed Parametrizations (SPP) scheme. A first version of the SPP scheme of HarmonEPS has been tested, with promising improvements in ensemble spread. However, it introduced systematic biases and deteriorated skill scores for some variables. Here, we investigate the performance of an updated version of the HarmonEPS SPP scheme, which includes: a) the use of uniform distributions, b) the correlation of stochastic patterns between key SPP parameters and c) the introduction of four additional parameters, in the microphysics and mass-flux schemes. Two 5 parameter SPP-based setups are compared against initial and LBC perturbations setups for five forecast periods: a) 22-28 March 2019, b) 6-12 July 2020, c) 20-26 February 2021, d) 11-26 January 2021 and e) 20 May - 2 June 2021. We find that SPP-based experiments show better probabilistic metrics for near-surface and cloud-related variables than the non-SPP experiments. The SPP-based ensembles show increased spatial spread (as indicated by dFSS), while maintaining similar spatial skill (as indicated by eFSS) with the non-SPP experiment. In addition, the systematic bias in the ensemble members of the previous SPP iteration, has been alleviated with the use of uniform distributions. Finally, the use of microphysical and mass flux perturbations improves the ensemble scores for cloud-related variables, precipitation and visibility.

New SPP paper recently submitted to MWR

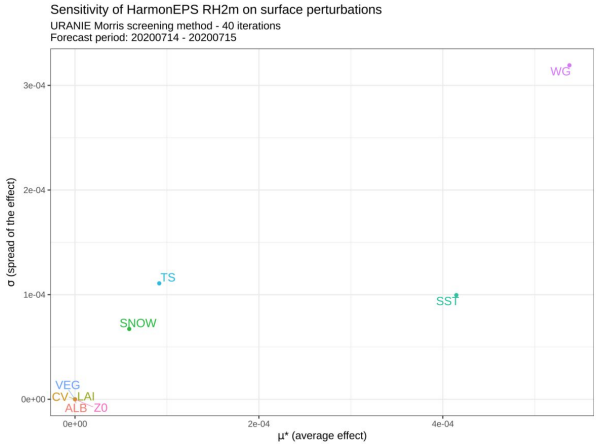
The URANIE framework in HarmonEPS

- 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

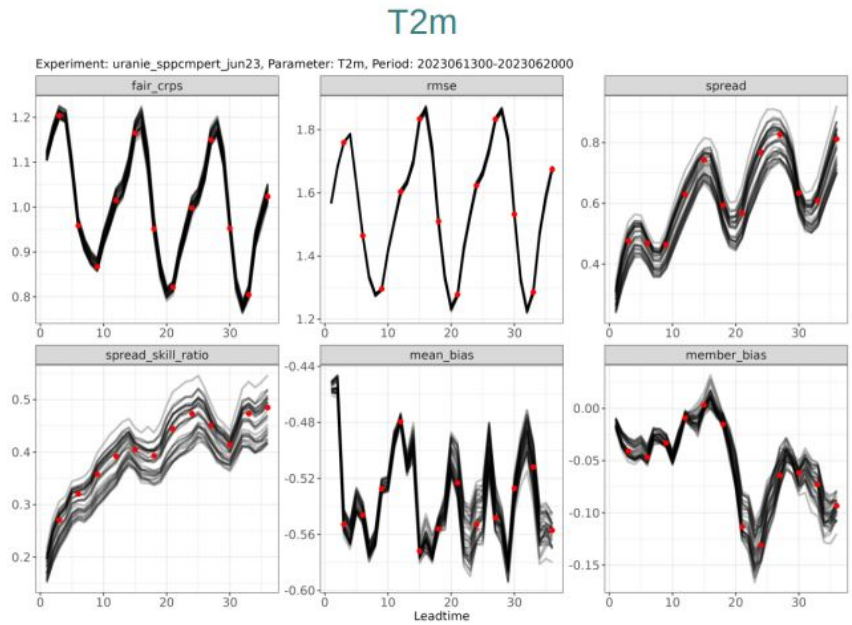
- URANIE applied to several HarmonEPS experiments:
  Impact of individual surface perturbations on RH2m bias and
  SPP perturbation length-scale optimization

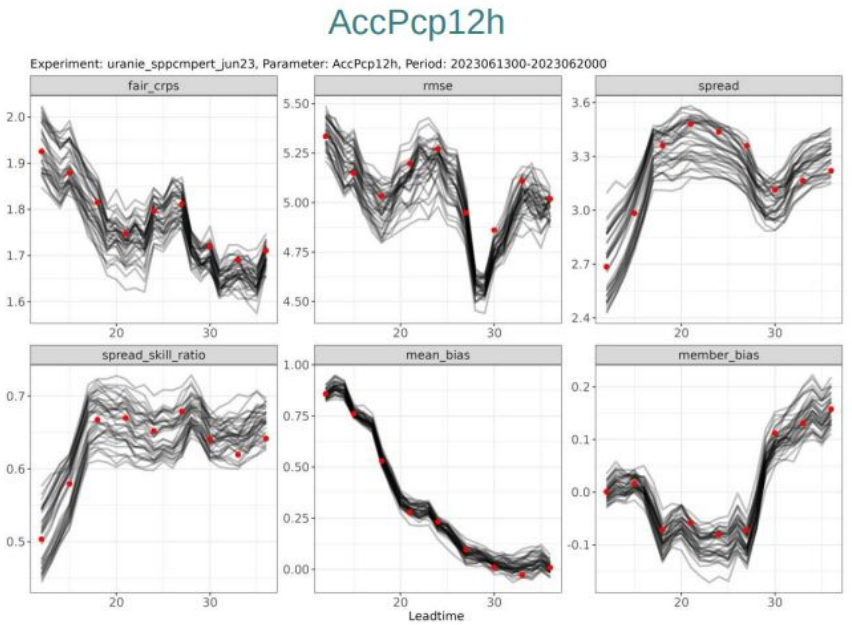
- New topics: SPP sensitivity analysis and SPP optimisation tests



URANIE SPP sensitivity analysis

5 parameter SPP configuration, CMPERT (sdev of perturbation) in range [0.75*default, 1.25*default]





Summary scores for all URANIE iterations (r*(n+1), where r=4 (trajectories) and n=5 (# of params))
Impact on RMSE and CRPS for T2m is little from SPP, impact on spread is clear.

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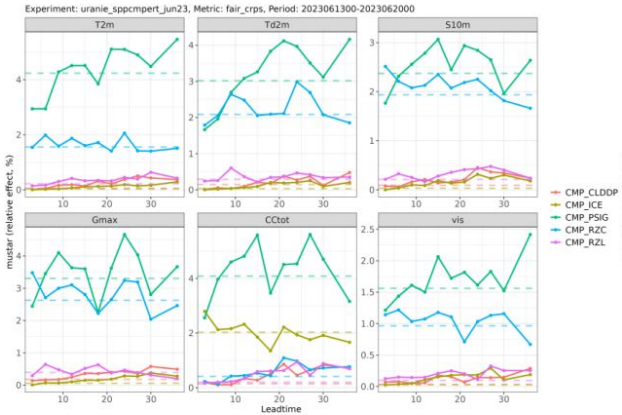
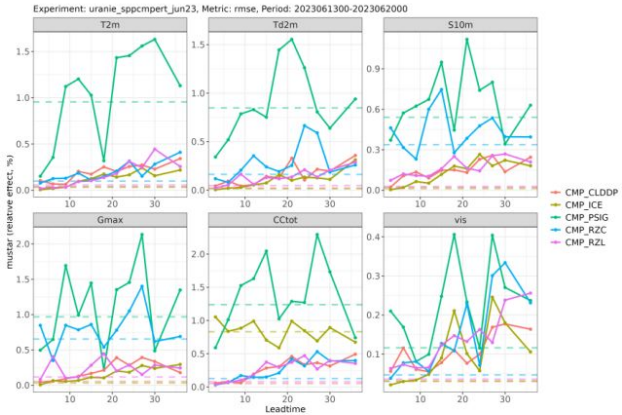
URANIE SPP sensitivity analysis - relative impact

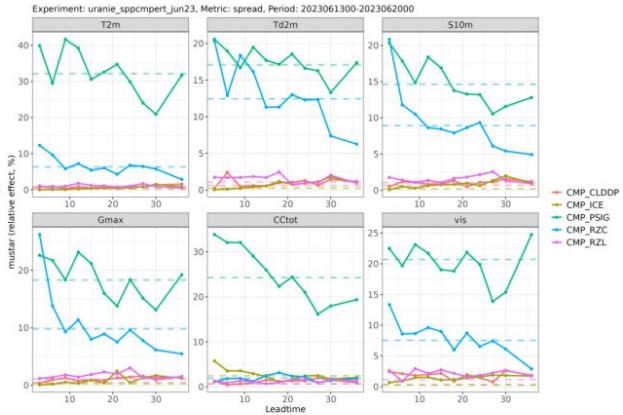
CRPS



RMSE



Spread



- Verification over ~160 SYNOP stations
- VSIGQSAT (saturation limit sensitivity) and RZC_H (stable conditions length scale) highlighted as important for all parameters. Other variables have similar contributions

James Fannon

URANIE: Summary and next steps

- Sensitivity analysis experiments appear to be working sensibly
- However, such tests are expensive to run
  - Morris screening used possibly overkill?
  - However, it is a more consistent method, automated and non-linearities can be assessed, which cannot be done when parameters are optimized one at a time as done manually
- We will look into utilizing URANIE in the one column model MUSC
- Next look at SPP optimisation. Need to define a sensible choice for the cost function

Thank you for your attention