HarmonEPS developments

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

ACCORD All Staff Workshop 2024 - Norrköping

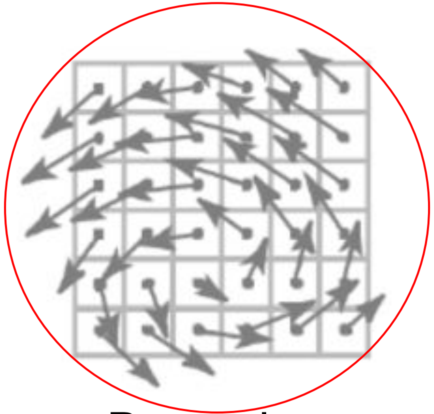
Topics:

- New features in SPP
  - Upper air: adding perturbations to the dynamics, diagnosing precipitation phase
  - Surface: first results and new developments

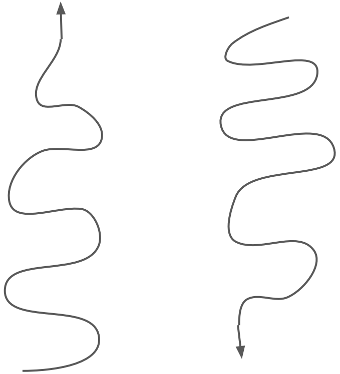
- Short about EPS@DEODE phase 2

SPP - perturbing uncertain parameters

Clouds and microphysic



Dynamics



Radiation

Turbulence

Surface

Stochastically Perturbed Parameterizations (SPP) - Upper air

Status:

- A 5 parameter version operational in MetCoOp since 30 August 2022
- A total of 19 parameters in the scheme at present + more in technical development state - work ongoing to add more parameters to the operational setups

APRIL 2022 FROGNER ET AL. 775

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)

An Update to the Stochastically Perturbed Parametrizations Scheme of the HarmonEPS

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Ole Vignes

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

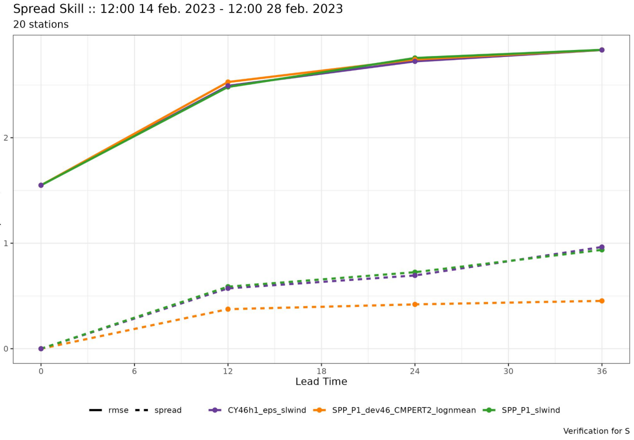
- The option sets RW2TLFF=0.5 (is 1 in unperturbed) and adds a random rotation with uniform distribution and zero mean angle to the V(M) wind.
- Compare the effect of *only* perturbing V(M) (=SLWIND) with the most influential physics parameter perturbation: VSIGQSAT (perturbes saturation limit sensitivity)

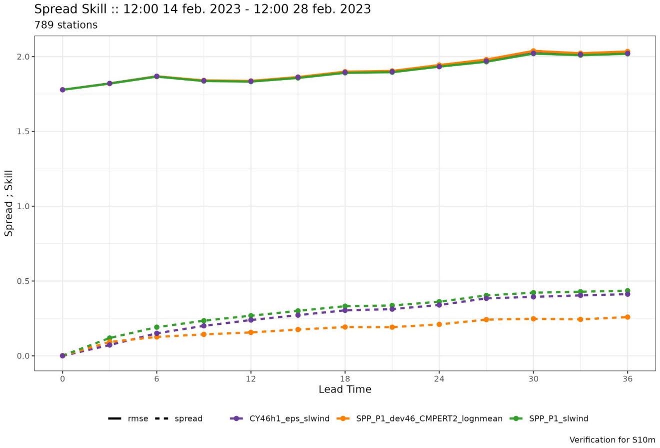
S850

S10m

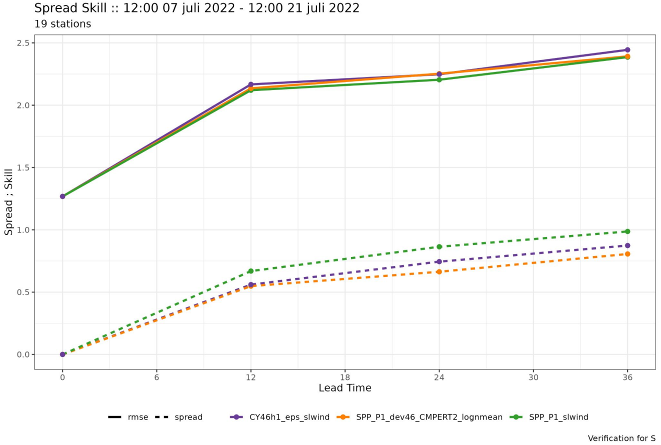
VSIGQSAT
SLWIND
VSIGQSAT+
SLWIND

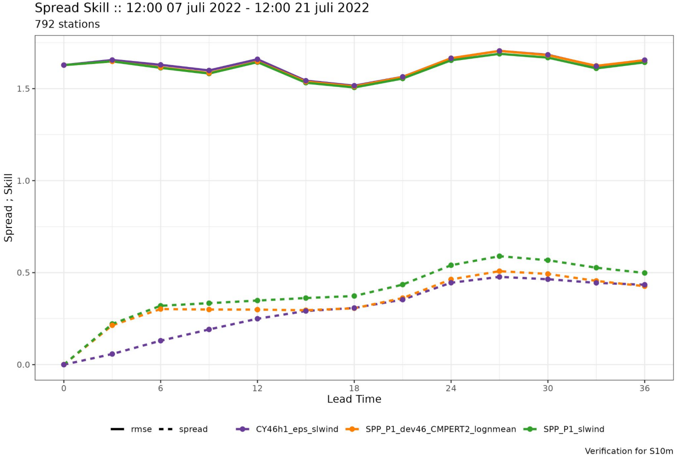
Winter





Summer





spread (---) Skill (——)

AccPcp12h

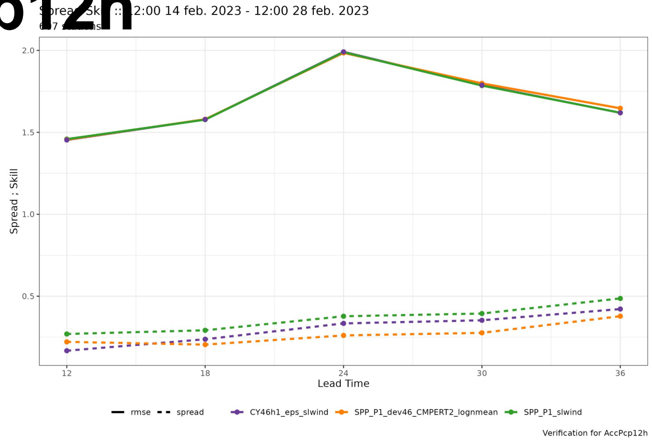
CCtot

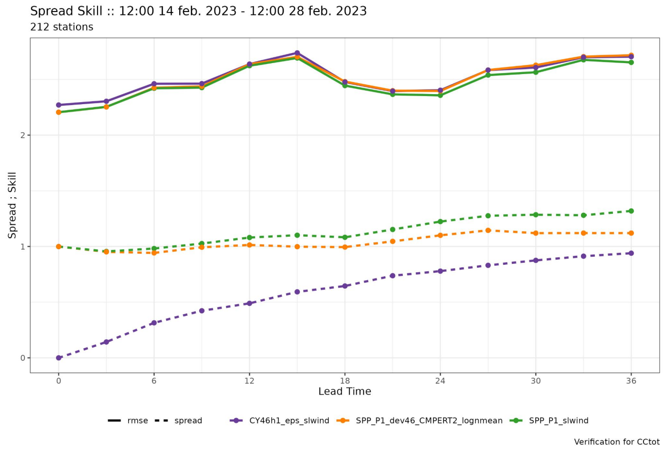
VSIGQSAT

SLWIND

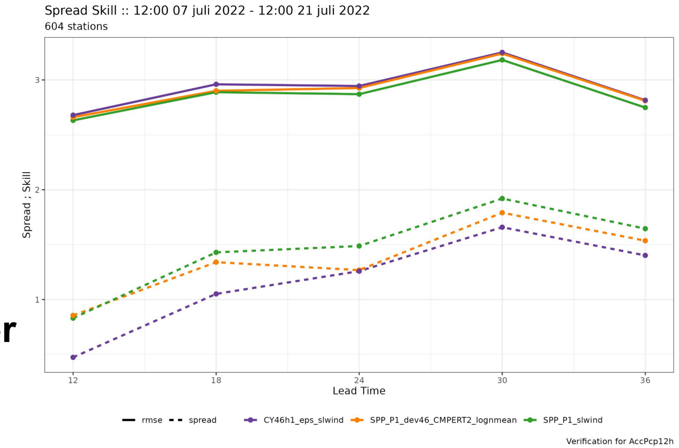
VSIGQSAT+ SLWIND

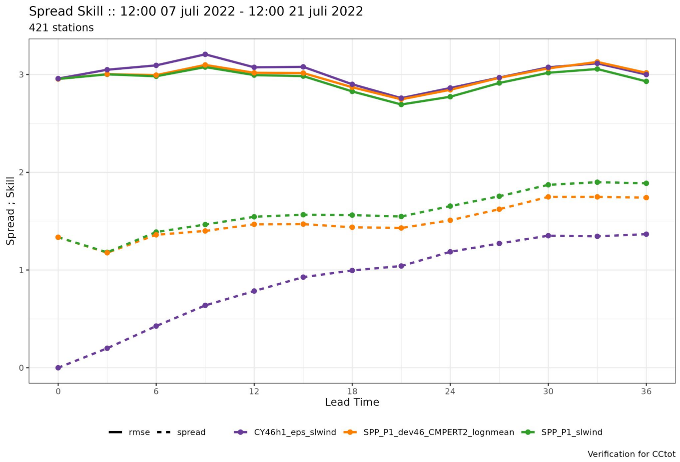
Winter





Summer





spread (---) Skill (——)

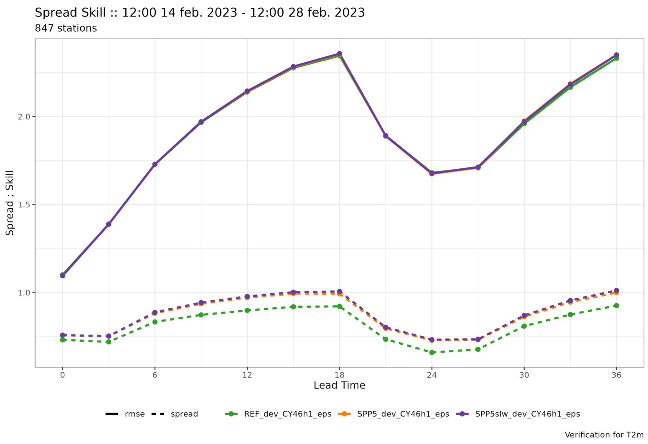
SLWIND added on top of 5 SPP and other perturbations (initial, surface, LBCs)

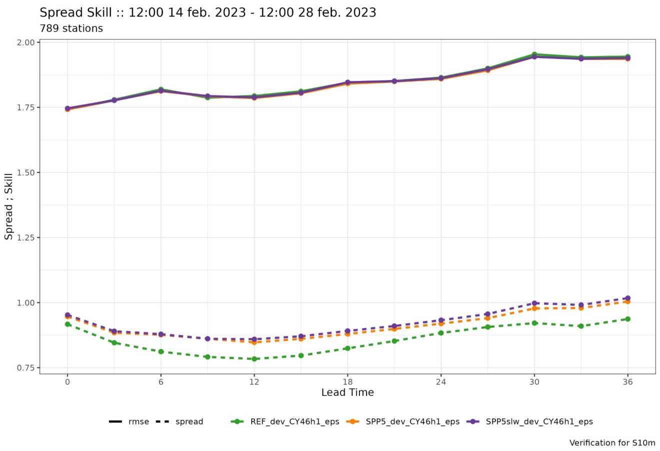
T2m

S10m

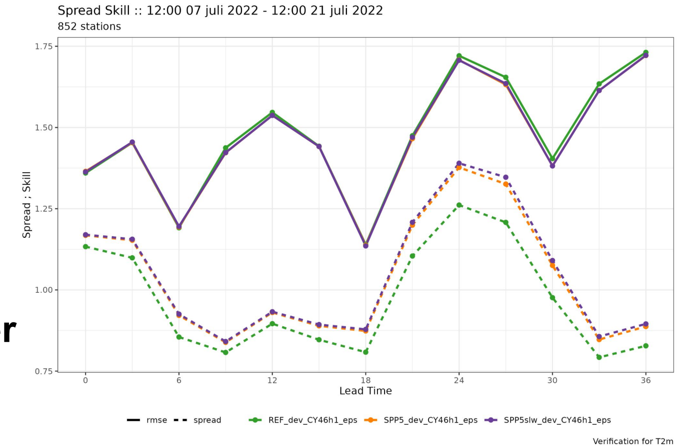
REF
+5 SPP
+SLWIND

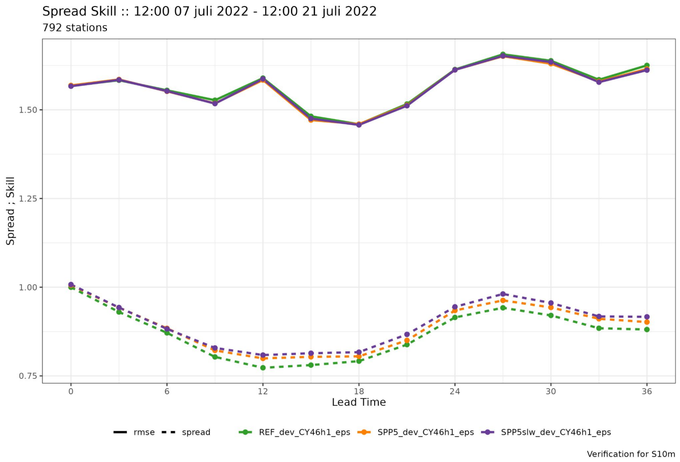
Winter





Summer





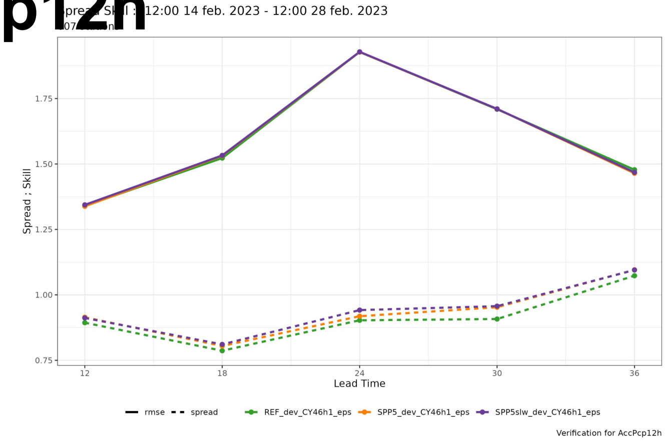
spread (---) Skill (——)

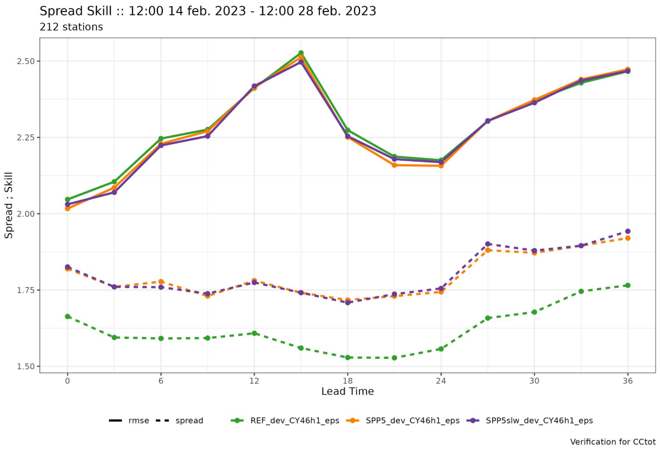
AccPcp12h

CCtot

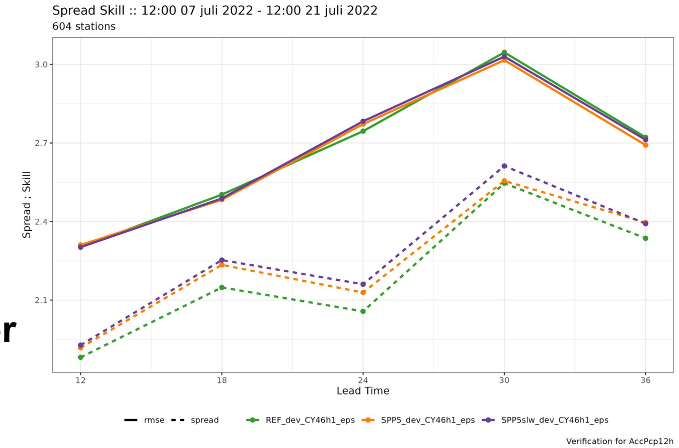
REF
+5 SPP
+SLWIND

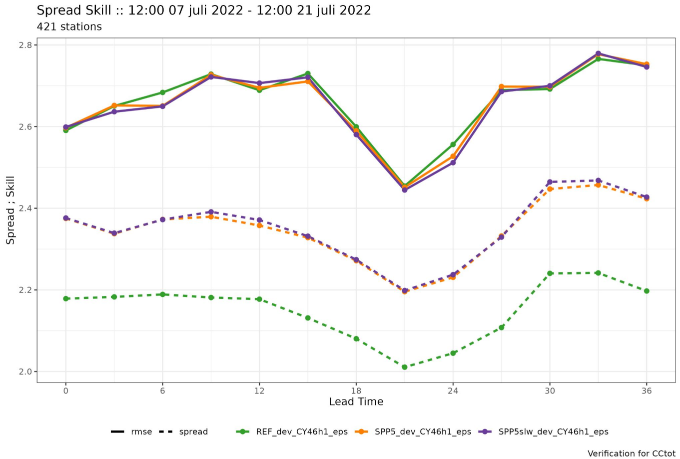
Winter





Summer





spread (---) Skill (——)

Summary - perturbing the dynamics

- Perturbing SLWIND is ~comparable to VSIGQSAT (most influential physics perturbation) except for cloud related weather parameters
- 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 (not shown)
- 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

Pirkka Ollinaho

SPP and diagnosing precipitation phase

Motivation

Parameters investigated when originally implementing SPP for HarmonEPS

No.	Description	PAR.
1	Threshold for cloud thickness used in shallow/deep convection decision	CLDDPTHDP
2	Cloud ice content impact on cloud thickness	ICE_CLD_WGT
3	Ice nuclei concentration	ICENU
4	Saturation limit sensitivity for condensation	VSIGQSAT
5	Kogan autoconversion speed	KGN_ACON
6	Kogan subgrid-scale (cloud fraction) sensitivity	KGN_SBGR
7	Graupel impact on radiation	RADGR
8	Snow impact on radiation	RADSN
9	Top entrainment efficiency	RFAC_TWO_COEF
10	Stable conditions length scale	RZC_H
11	Asymptotic free atmospheric length scale	RZL_INF

Motivation

Little impact on generating differences (i.e. spread) to the ensembe

Large impact on generating differences to the ensemble

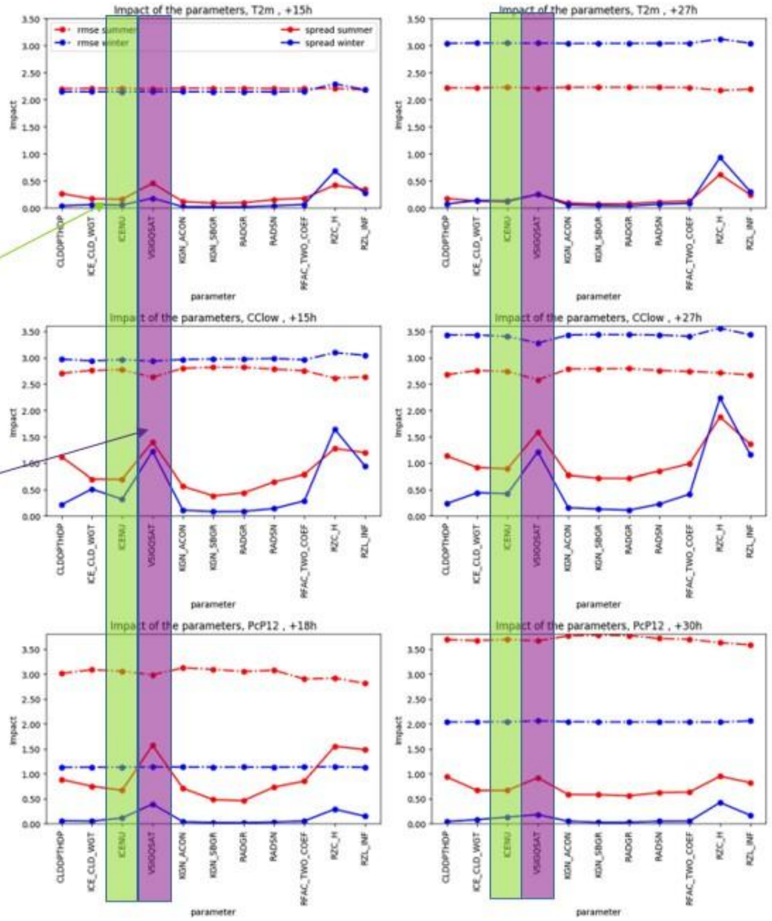


FIG. 6. Spread (solid line) and RMSE of the ensemble mean (dashed line), for summer (red) and winter (blue). The parameters on the x axis correspond to those in Table 2. (top) 2-m temperature (T2m), (middle) fraction of low cloud cover (CClow), and (bottom) 12-h accumulated precipitation (PcP12h). Forecast length is +15 and +27 h for T2m and CClow, and +18 and +30 h for PcP12h.

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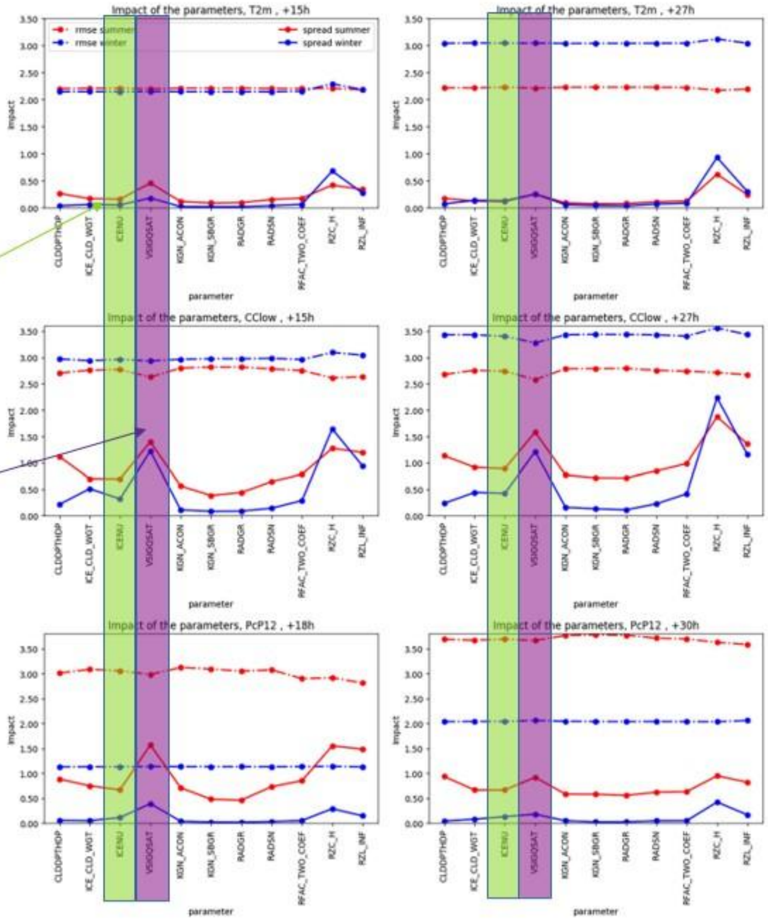
Motivation

Little impact on generating differences (i.e. spread) to the ensembe

Large impact on generating differences to the ensemble



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Could there still be value in
adding ICENU to the SPP scheme?

Case study 20-02-2023

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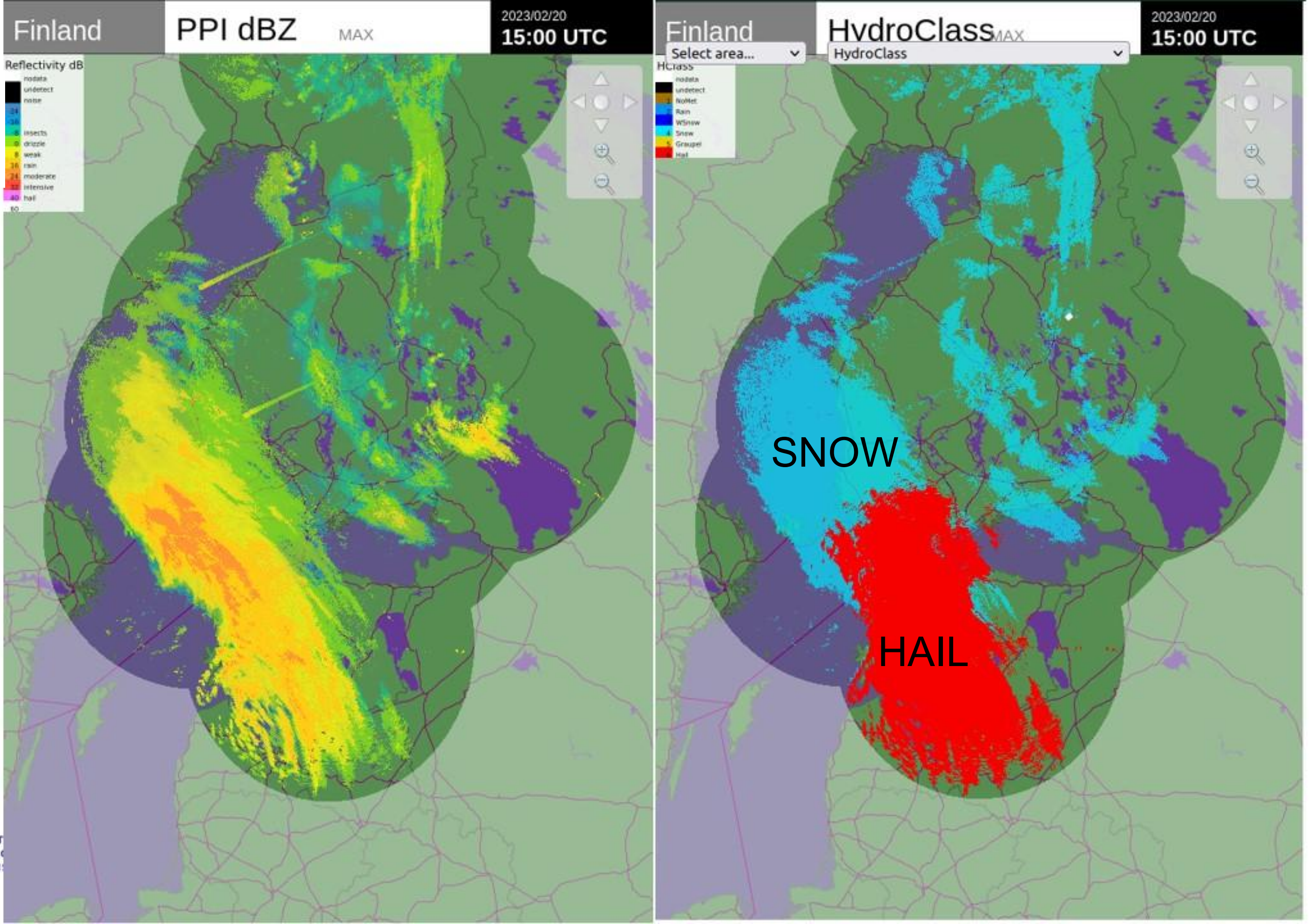

Finland
PPI dBZ
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15:00 UTC
Reflectivity dB
nodata
undetect
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insects
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weak
rain
moderate
intensive
hail
Finland
HydroClass
MAX
Select area...
HydroClass
2023/02/20
15:00 UTC
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nodata
undetect
NoMet
Rain
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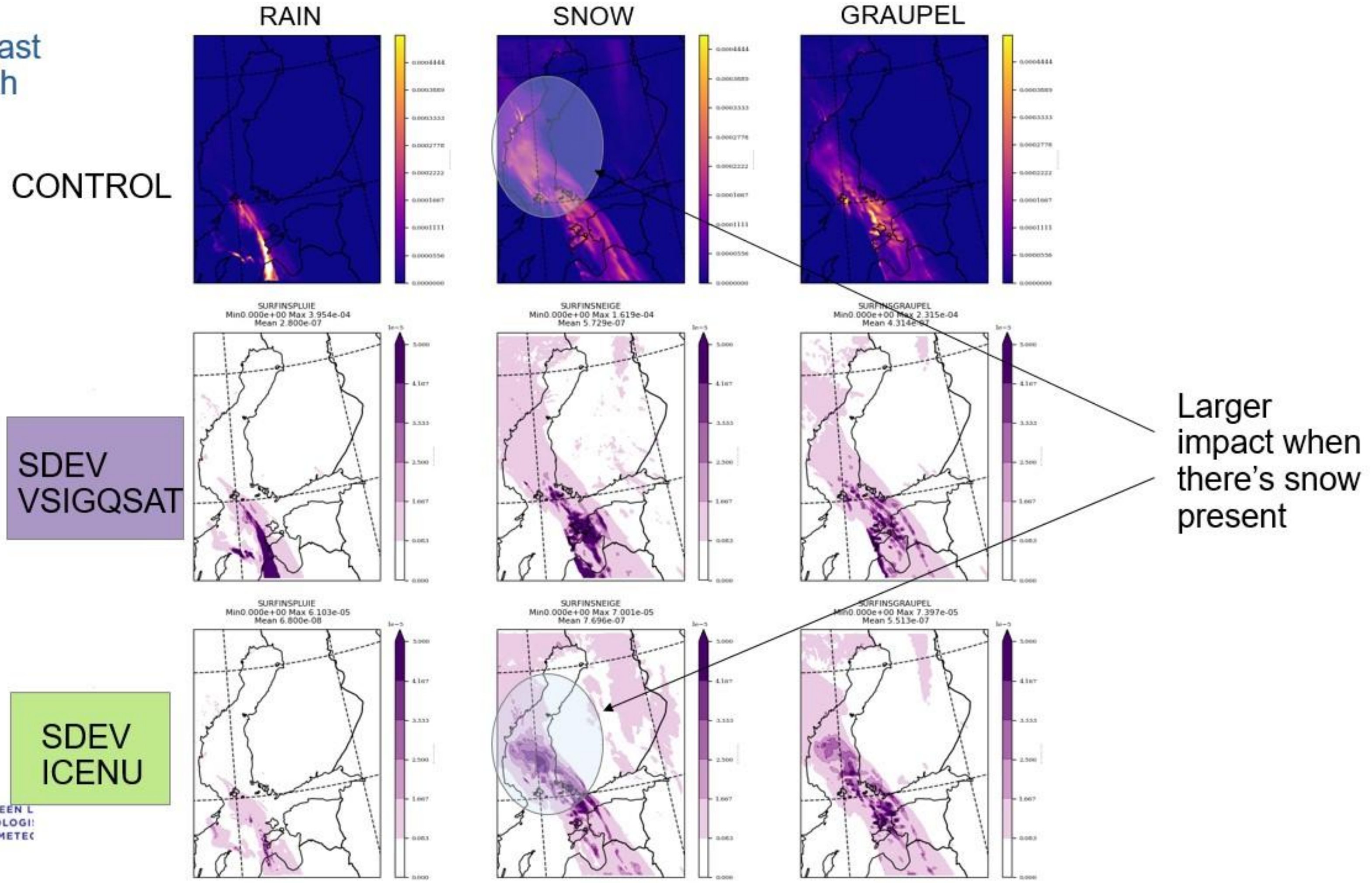
Snow
Graupel
Hail
SNOW
HAIL

+03h forecast valid at 20th 15UTC



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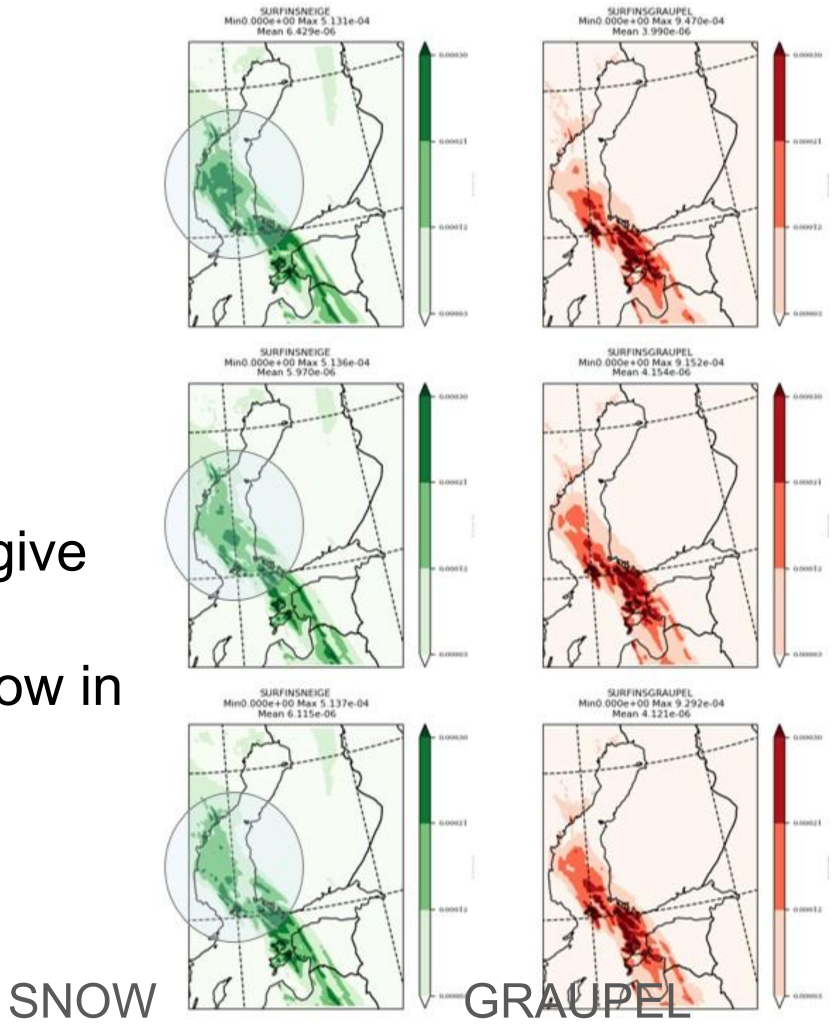
+03h forecast
valid at 20th
15UTC

- Individual ensemble member forecasts for snow and graupel

- ICENU perturbations are adding spread for snow forecast -> can give useful information to the forecast even if it does not necessarily show in the overall verification statistics



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Harold Mc Innes, Ulf Andrae

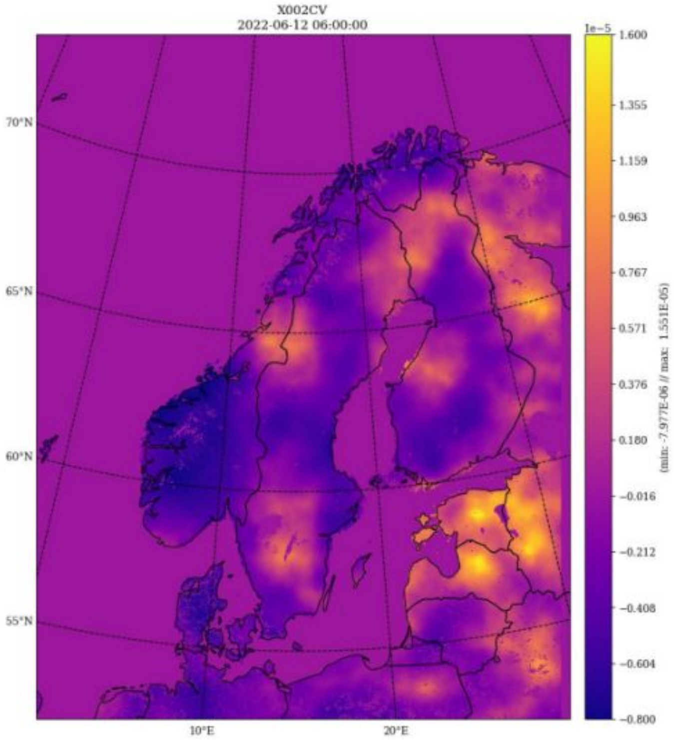
SPP for surface

Motivation:

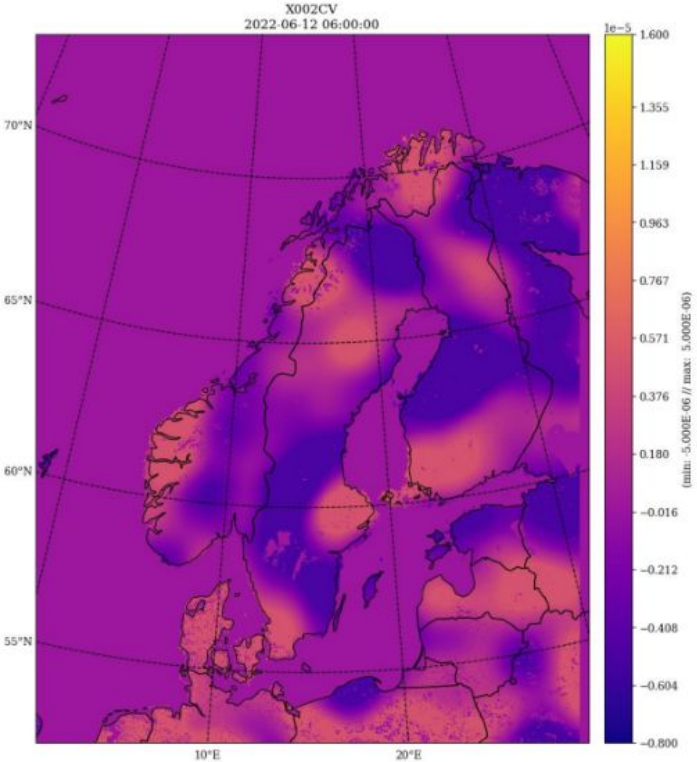
- We are currently perturbing surface parameters and fields by PertSurf (Bouttier et al. 2016)
- We want to unify (simplify) perturbation methodology by gathering all under the SPP umbrella, with SPP we also get time varying perturbations

- So far CV and RSMIN are implemented and tested
- Work ongoing for heat and drag coefficient perturbations

Difference: Perturbed field - control

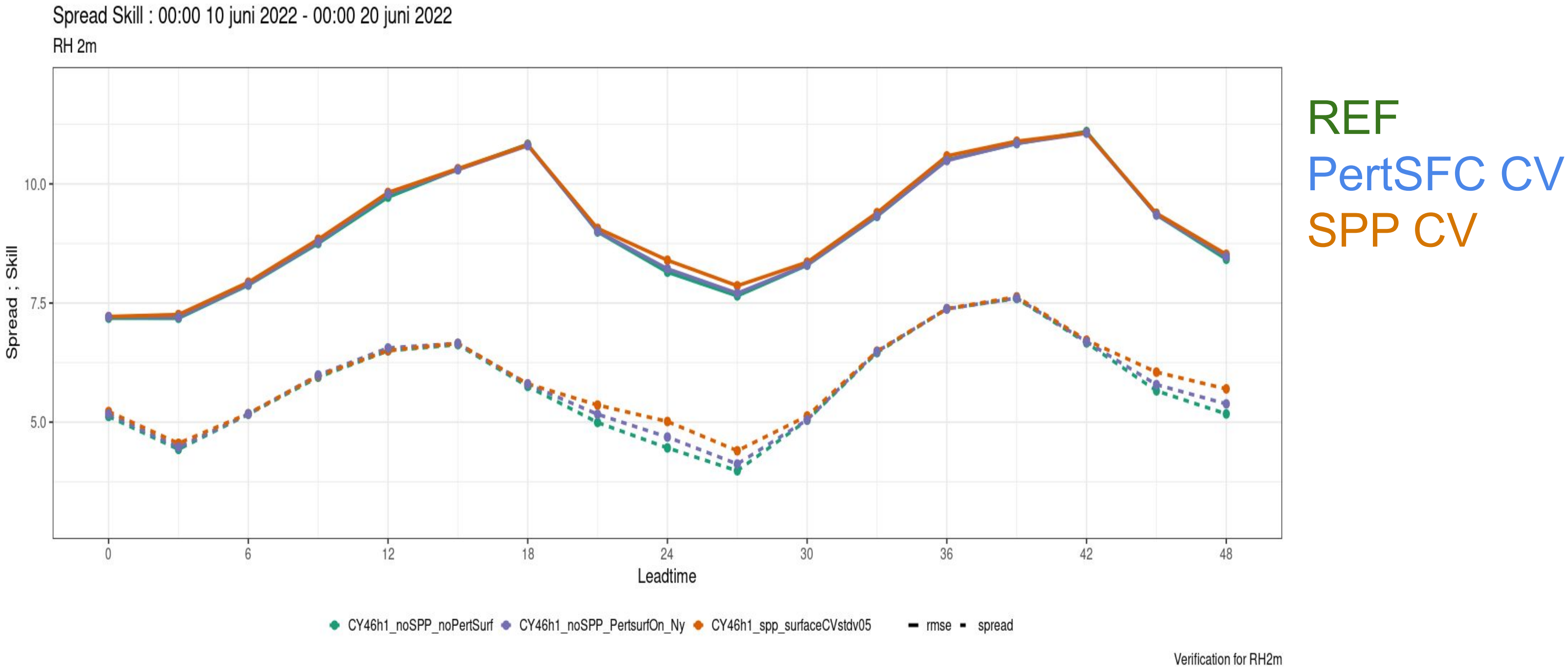


SPP CV (mbr1 - control)



Pertsurf CV (mbr1 - control)

RH2m



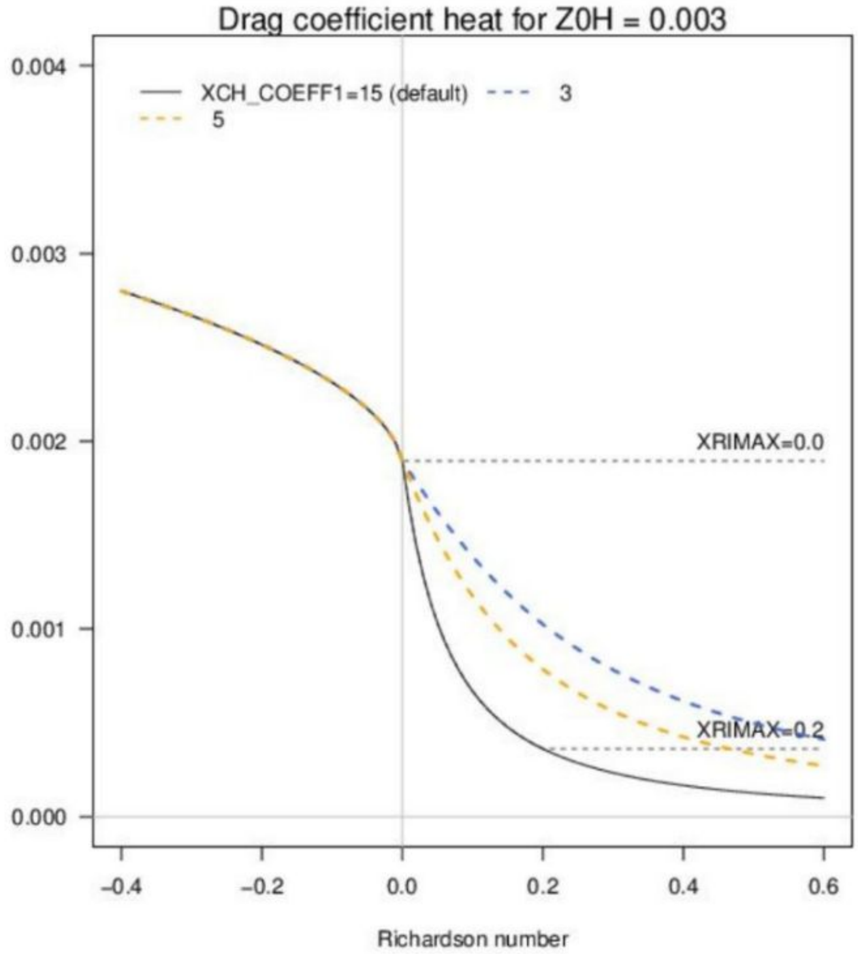
spread (---) Skill (——)

Impact on spread is comparable to PertSFC, more optimization to be done (amplitude and distribution for SPP perturbations)

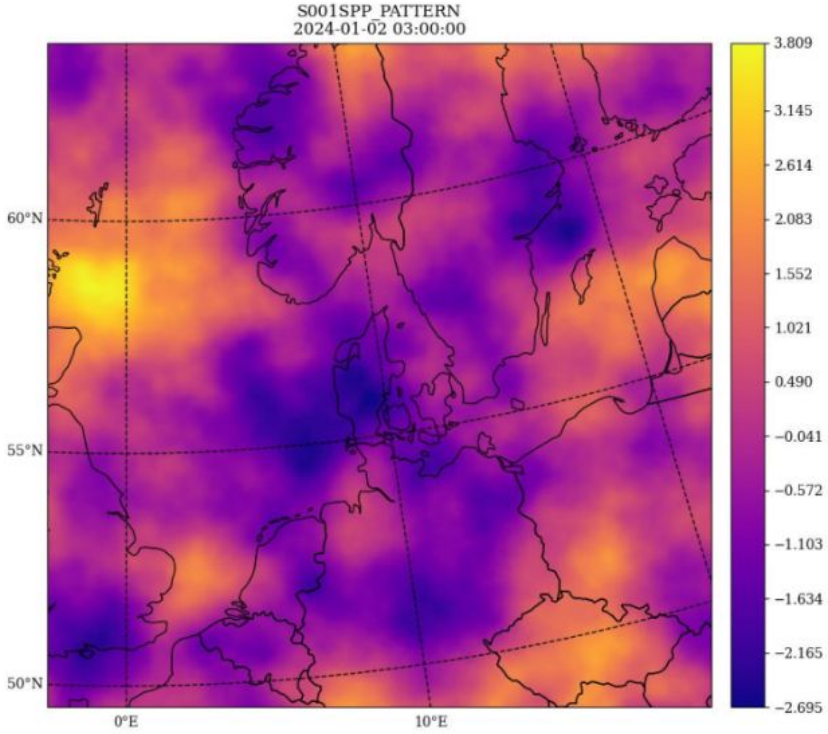
Background

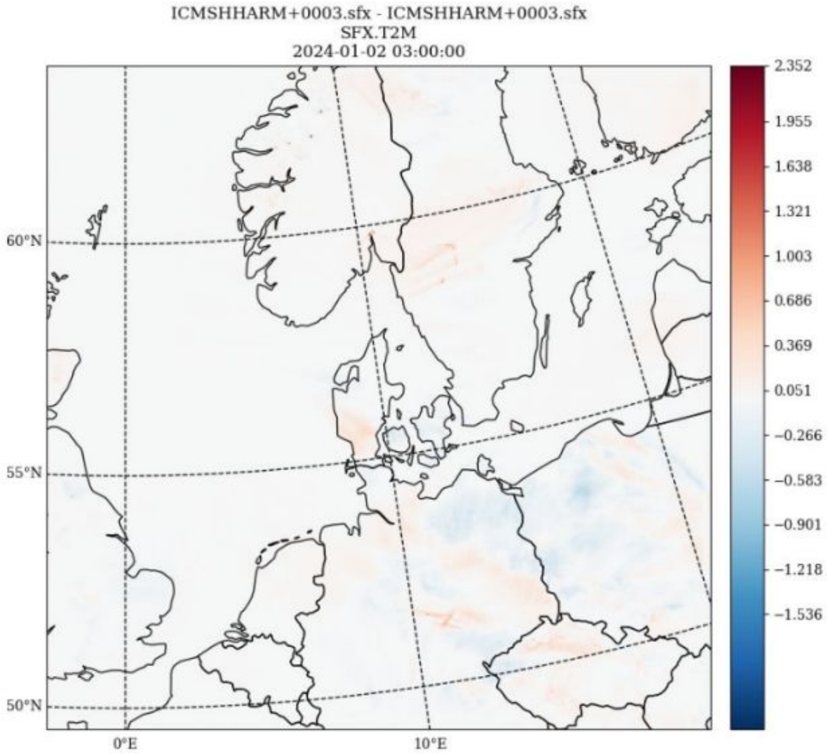
- The surface heat and momentum exchange for stable conditions is controlled by an exchange curve, XRIMAX and XRISHIFT
- XRIMAX applied in HARMONIE varies between 0 and ~ 0.4 depending on the usage and geographical area
- XRIMAX has a large impact on T2M as well as the lower SBL stability.
- XCH_COEFF1 and XCD_COEFF1 has been chosen as suitable for perturbations to represent the uncertainty when RI > 0

Figure from Mariken Holmleid Met Norway



First result where perturbation of CH_COEFF1 is the only perturbation applied





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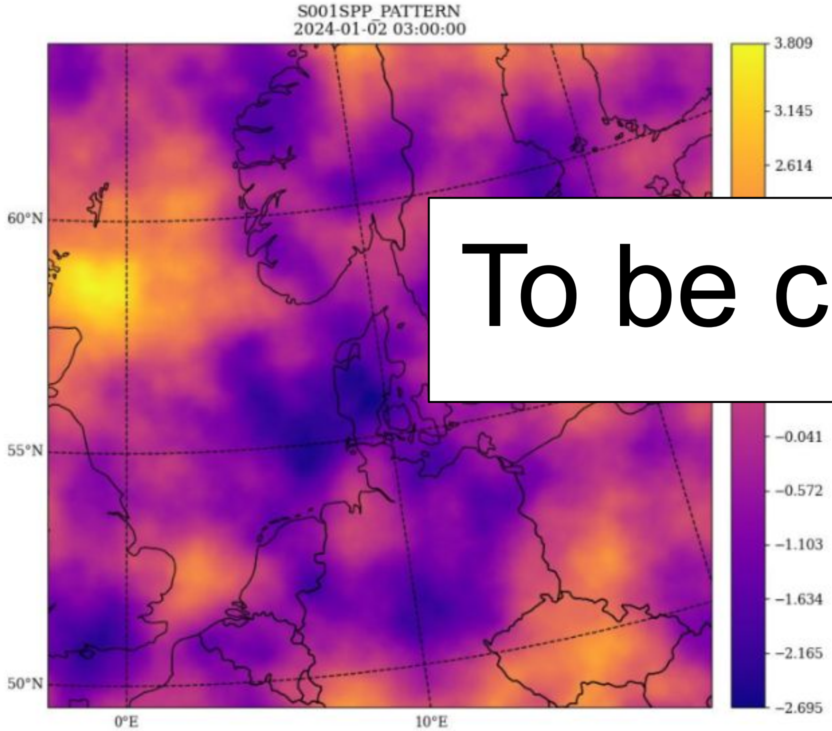
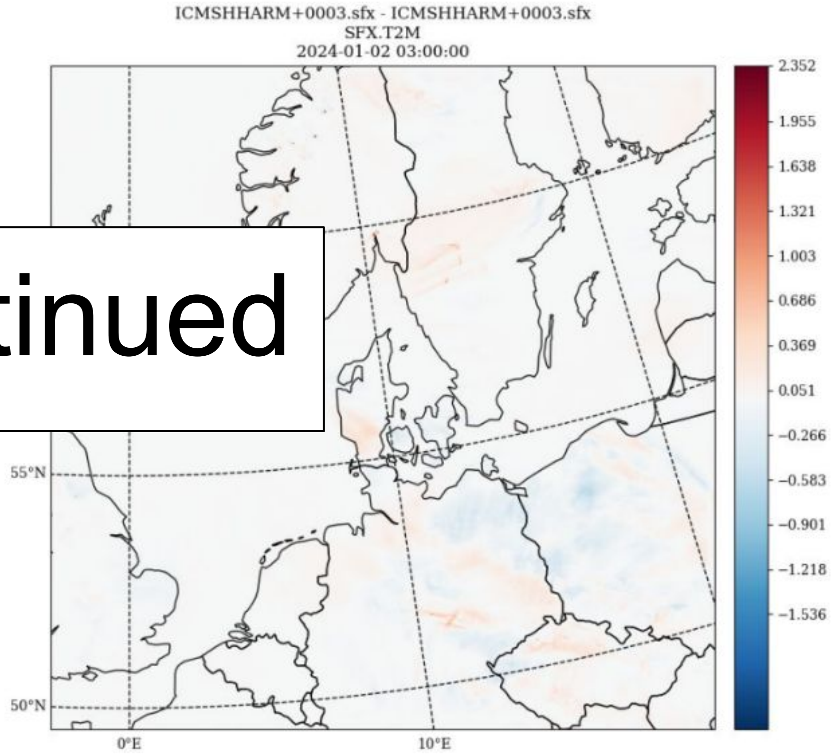




To be continued

EPS@DEODE

- EPS is new in Phase 2 (starting May 1st)
- Develop our ACCORD EPS systems to hectometric resolution
- Focus on model uncertainty and LBCs (as no DA in DEODE)
- Participants in the EPS task:
    - Pirkka Ollinaho, Clemens Wastl, Martin Bellus, Harold Mc Innes, James Fannon, Simona Tascu, Ole Vignes and Inger-Lise Frogner

Thank you for your attention

Extra

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)
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

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.

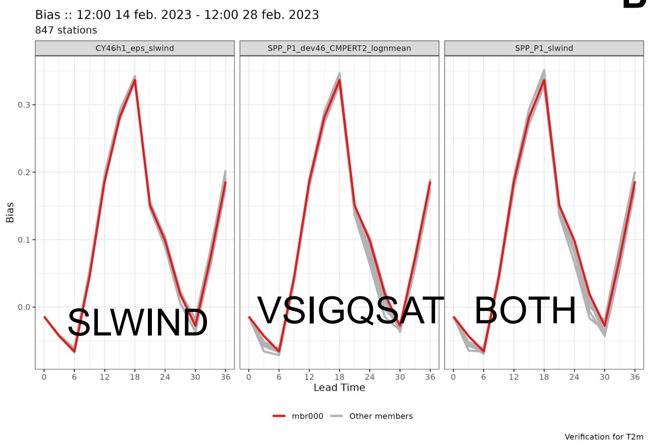
This pattern generator has the advantage of accounting for ‘proportionality of scales’, meaning it takes into account the fact that longer spatial scales live longer than shorter spatial scales, which die out quicker, a widespread feature in geophysics.

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.

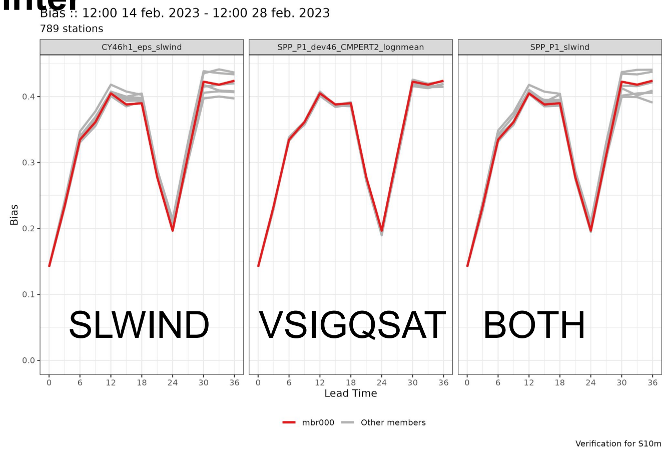
The implementation in HarmonEPS interfaces the code provided by Tsyrulnikov and Gayfulin (2017) and is solely defined by the spatial (XLCOR) and temporal (TAU) correlation length scales, and the standard deviation, SDEV

BIAS Winter

T2m



S10m



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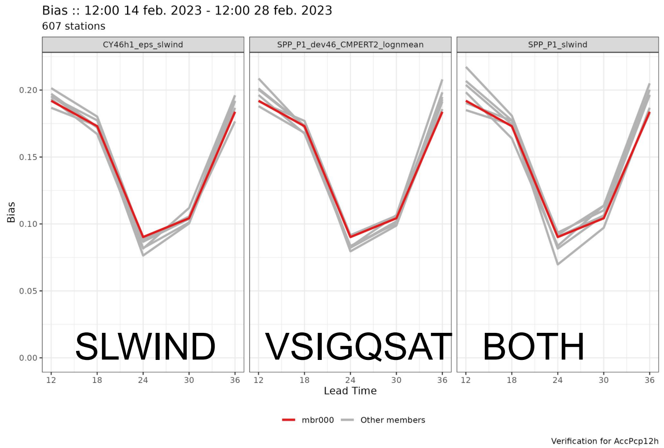

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