United Weather Centres

An overview of ensemble developments at UWC

Aristofanis Tsiringakis
on behalf of the UWC-EPS team

UWC-EPS group team composition

- KNMI: Aristofanis Tsiringakis
- MET Norway: Inger-Lise Frogner, Ole Vignes, Harold McInnes
- SMHI: Ulf Andrae
- FMI: Pirkka Ollinaho, Karoliina Hämäläinen
- AEMET: Alfons Callado, Juan Gomez Navarro
- DMI: Henrik Feddersen
- IMO Iceland: Xiaohui Zhao

Content

Part 1: New SPP configuration

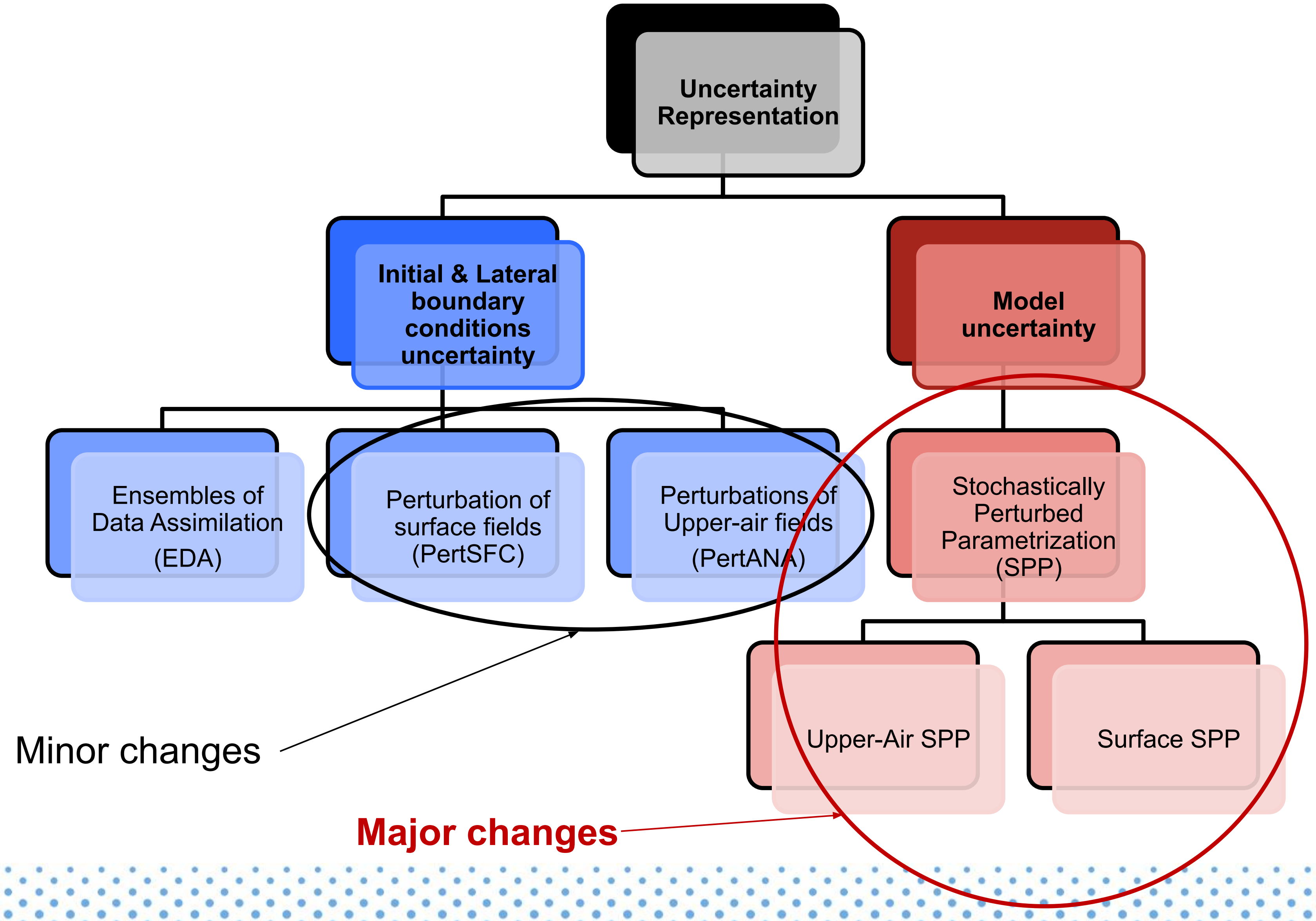
Part 2: Ensemble comparison CY43 vs CY46 setup

New Canonical Configuration for HarmonieEPS in CY46

What we currently include in our EPS configuration:

Initial and Lateral Boundary conditions Uncertainty (e.g. EDA)

Model Uncertainty (e.g., SPP)



Part 1

New SPP configuration

United Weather Centres

The Stochastically Perturbed Parametrizations (SPP) Scheme

SPP is a scheme that represent model uncertainty (i.e. uncertainty associated with model errors – not initial condition uncertainty)

SPP injects stochastic, spatially and temporally coherent perturbations in uncertain parts (parameters and tendencies) inside physical parametrization schemes

Perturbations are done “in-physics”, which ensures internal consistency with physics routines and avoids mass balance issues (e.g., no moisture/precipitation leaks)

Relevant documentation:

Ollinaho et al. (2017) - https://doi.org/10.1002/qj.2931 , Lang et al. (2021) - https://doi.org/10.1002/qj.3978 , Frogner et al. (2022) - https://doi.org/10.1175/MWR-D-21-0099.1, Tsiringakis et al. (2024) -https://doi.org/10.1175/MWR-D-23-0212.1

United Weather Centres

The Stochastically Perturbed Parametrizations (SPP) Scheme

SPP uses a stochastic pattern generator (SPG) to create spatial (2D) fields of white Gaussian noise $\Phi_j \sim N(\mu_j, \sigma_j^2)$ for each parameter j, which is spatially and temporally correlated based on spatial correlation length scale – λ and temporal decorrelation time – τ.

The perturbed parameters are created based on the distribution chosen as :

a) log-normal

$\mathbf{X_j = X_{ref} * \exp(mu_j + xmag_j * \Phi_j)}$ with $\mathbf{mu_j = 0.5 * (xmag_j * \sigma_j)^2}$ (reference value is the mean of the log-normal distribution) or $\mathbf{mu_j}$ = 0 (reference value is the median) and $\mathbf{xmag_j}$ an amplification factor for each parameter j

b) normal

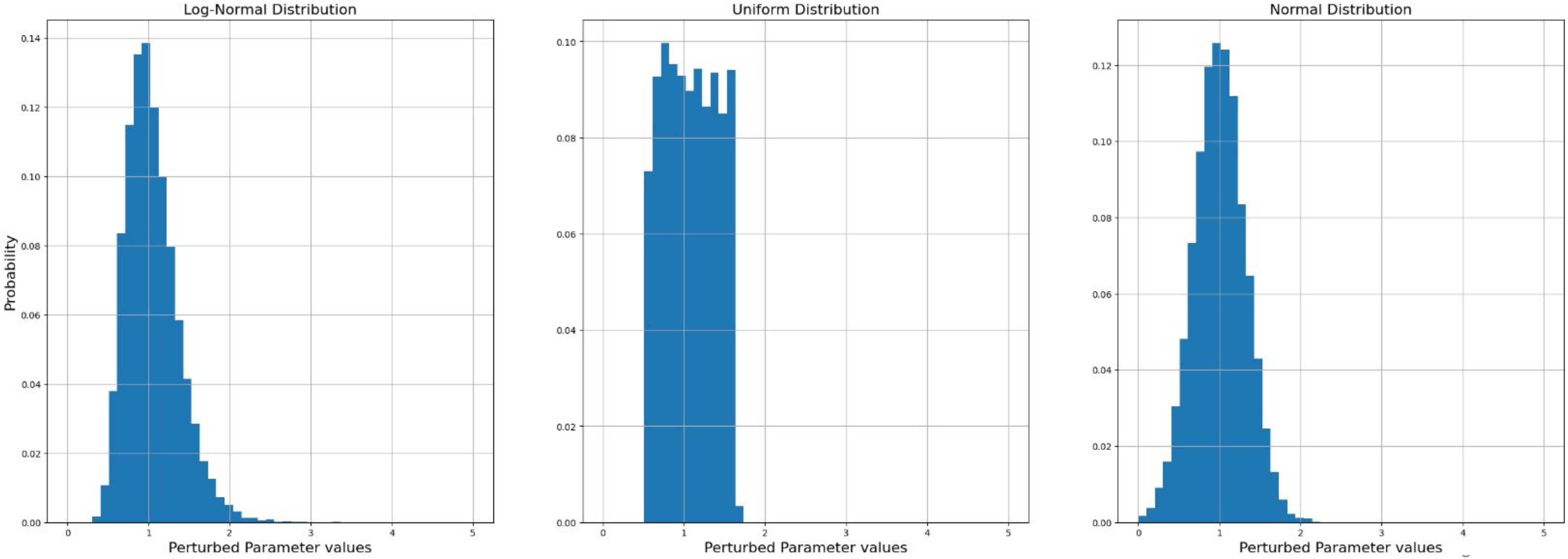
$\mathbf{X_j = X_{ref} * (1 + xmag_j * \Phi_j)}$

c) uniform

$\mathbf{X_j = X_{ref} * (1 + U_j)}$ with **Uj** being a transformation of $\mathbf{\Phi_j}$ to a uniform distribution.

The Stochastically Perturbed Parametrizations (SPP) Scheme

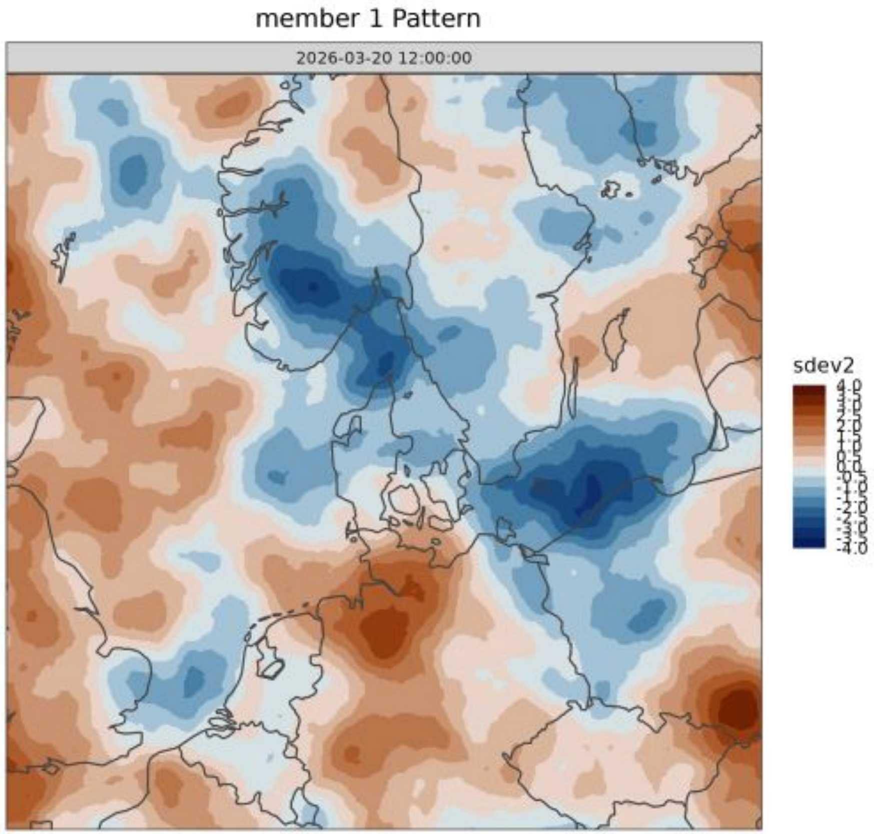
Distribution Examples

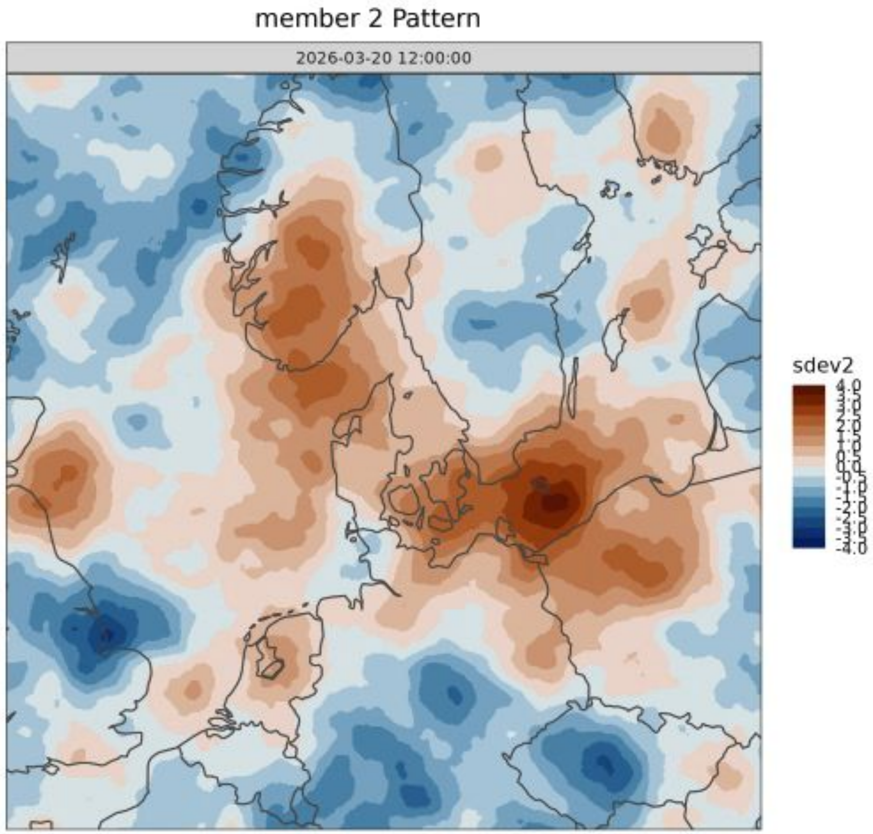


The Stochastically Perturbed Parametrizations (SPP) Scheme

λ = 200 km τ = 12 hours

Spatial Patterns Examples (HarmonEPS)





$\Phi_1 \sim N(\mu_1, \sigma_1^2)$

SPP in Harmonie CY43

1) Perturb saturation limit sensitivity VSIGQSAT
2) Perturb threshold cloud thickness used in shallow/deep convection decision RFRMIN(20)
3) Perturb cloud ice content impact on cloud thickness RFRMIN(21)
4) Perturb ice nuclei RFRMIN(9)
5) Perturb Kogan autoconversion speed RFRMIN(10)
6) Perturb Kogan subgrid scale (cloud fraction) sensitivity RFRMIN(11)
7) Perturb graupel impact on radiation RADGR
8) Perturb snow impact on radiation RADSN
9) Perturb top entrainment RFAC_TWO_COEF
10) Perturb stable conditions length scale RZC_H
11) Asymptotic free atmospheric length scale RZL_INF
12) Cloud droplet gamma distribution parameters alpha (over sea) ALPHA
13) Cloud droplet gamma distribution parameters nu (over land) RZNUC
14) Parameter for dry mass flux RZMFDRY
15) Closure parameter for moist mass flux RZMBCLOSURE
16) Perturbing V(M) in the semi-Lagrangian advection scheme, when computing the refined position of the origin point for the Coriolis term V(M)
17) Perturbing parameter in fall velocities of rain, snow and graupel XCR, XCS, XCG
18) Perturbing thermal inertia coefficient CV
19) Perturbing minimum stomatal resistance RSMIN

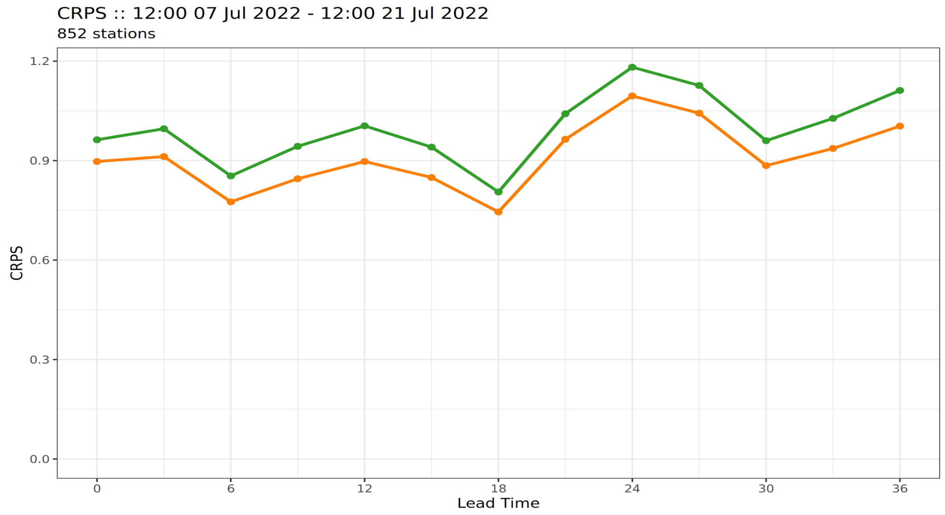
SPP in Harmonie CY46

1) Perturb saturation limit sensitivity VSIGQSAT
2) Perturb threshold cloud thickness used in shallow/deep convection decision RFRMIN(20)
3) Perturb cloud ice content impact on cloud thickness RFRMIN(21)
4) Perturb ice nuclei RFRMIN(9)
5) Perturb Kogan autoconversion speed RFRMIN(10)
6) Perturb Kogan subgrid scale (cloud fraction) sensitivity RFRMIN(11)
7) Perturb graupel impact on radiation RADGR
8) Perturb snow impact on radiation RADSN
9) Perturb top entrainment RFAC_TWO_COEF
10) Perturb stable conditions length scale RZC_H
11) Asymptotic free atmospheric length scale RZL_INF
12) Cloud droplet gamma distribution parameters alpha (over sea) ALPHA
13) Cloud droplet gamma distribution parameters nu (over land) RZNUC
14) Parameter for dry mass flux RZMFDRY
15) Closure parameter for moist mass flux RZMBCLOSURE
16) Perturbing V(M) in the semi-Lagrangian advection scheme, when computing the refined position of the origin point for the Coriolis term V(M)
17) Perturbing parameter in fall velocities of rain, snow and graupel XCR, XCS, XCG
18) Perturbing thermal inertia coefficient CV
19) Perturbing minimum stomatal resistance RSMIN

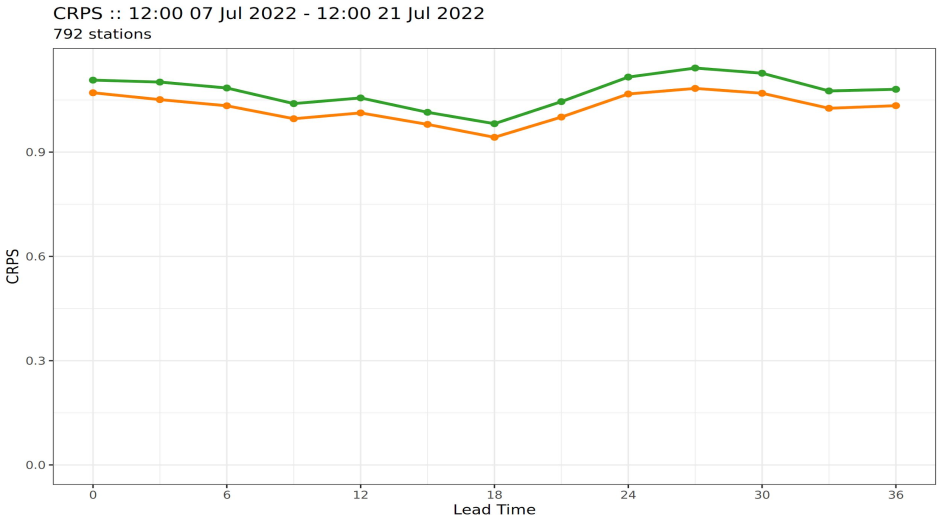
“old” SPP vs “new” SPP configurations

Summer

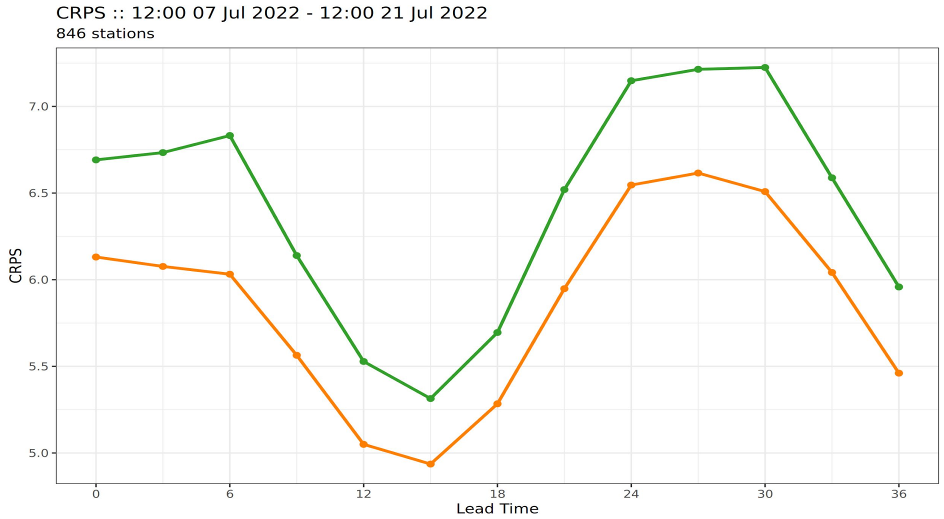
T2m



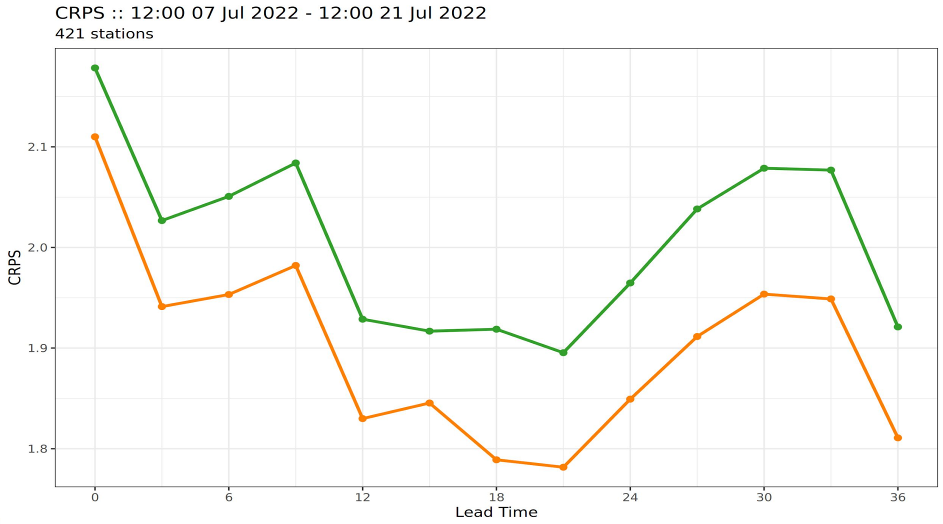
S10m



Q2m



Total cloud cover



Period:
07-21 July 2022

Configurations:
SPP_5P - old

SPP_19P - new

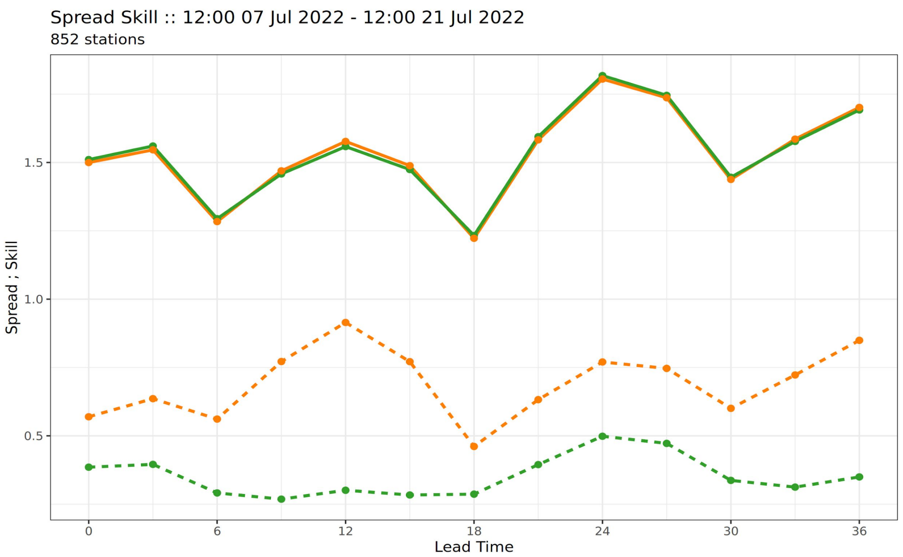
Results:

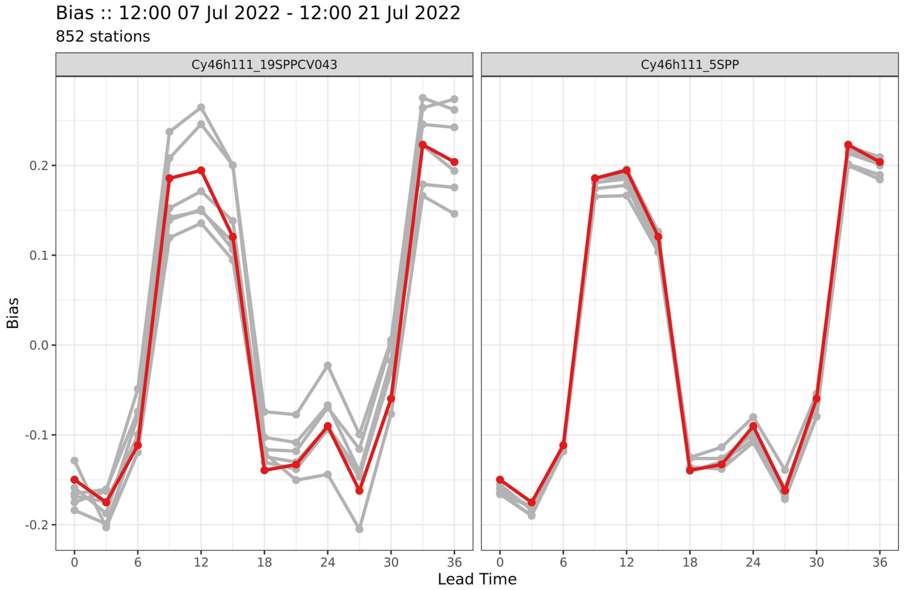
Reduced CRPS scores for new 19 parameter configuration

“old” SPP vs “new” SPP configurations

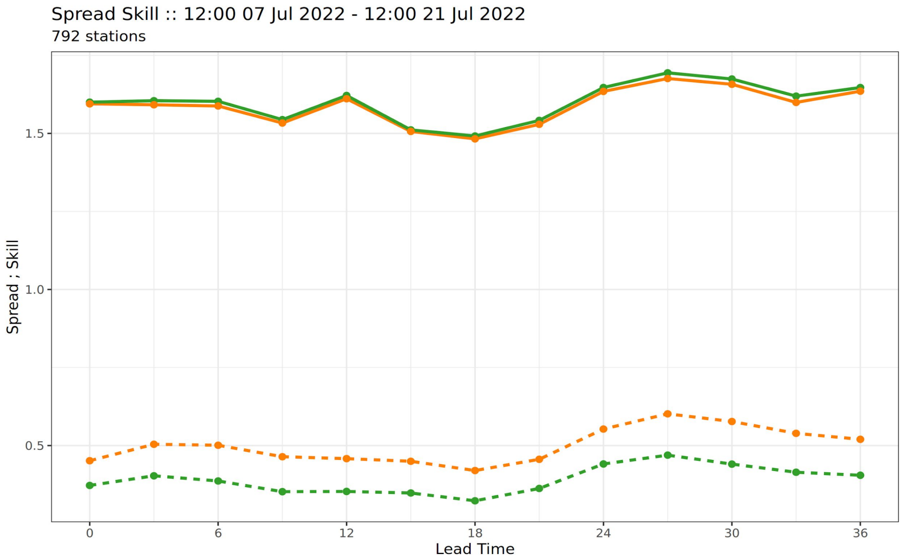
Summer

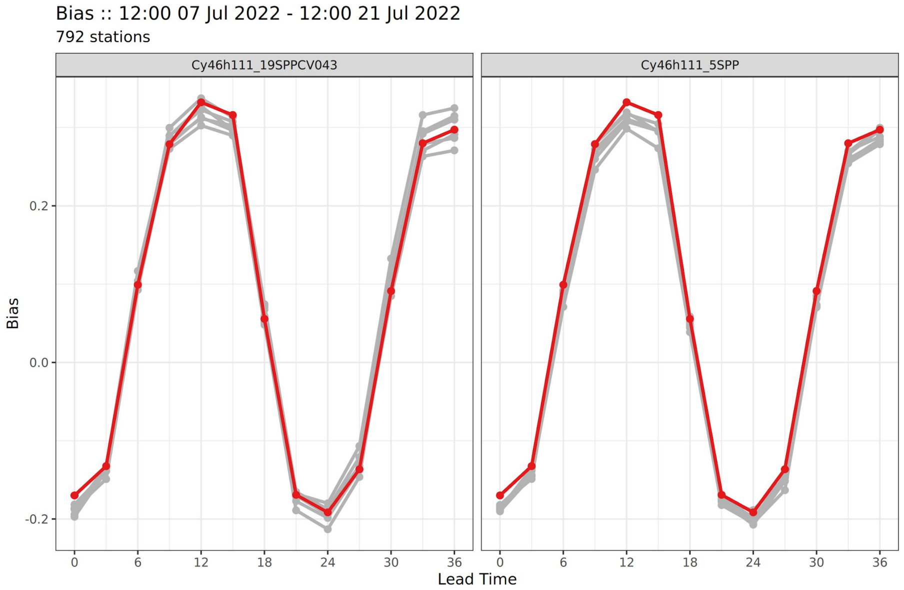
T2m





S10m





Configurations:

SPP_5P - old

SPP_19P - new

Control member

Perturbed members

Results:

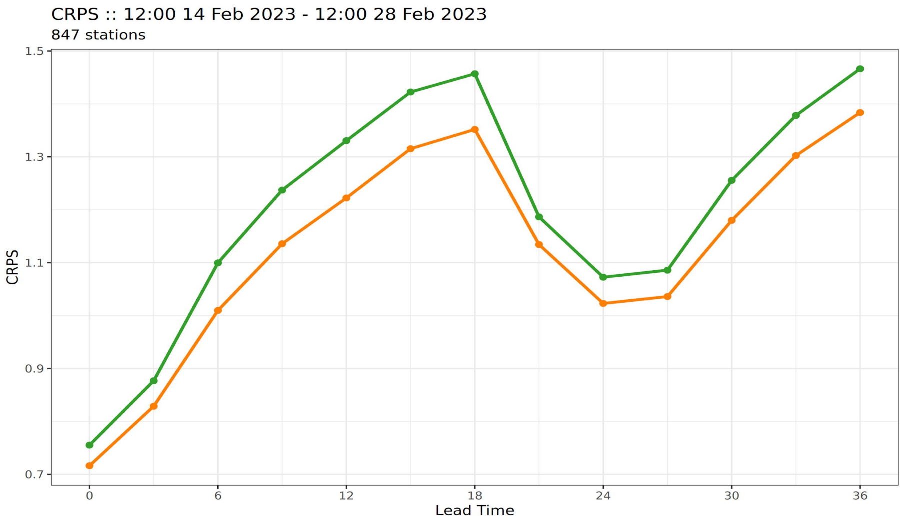
- Similar RMSE
- Increased ensemble spread
- No signs of systematic bias

“old” SPP vs “new” SPP configurations

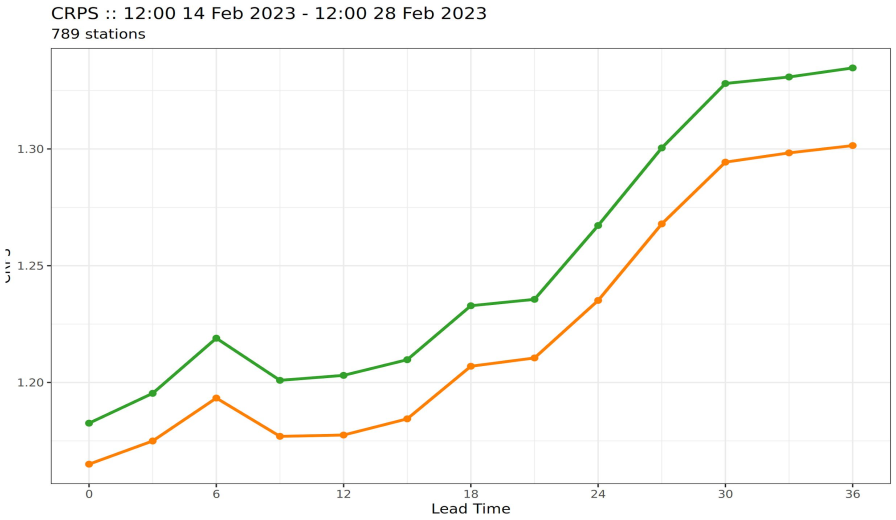
United Weather Centres

Winter

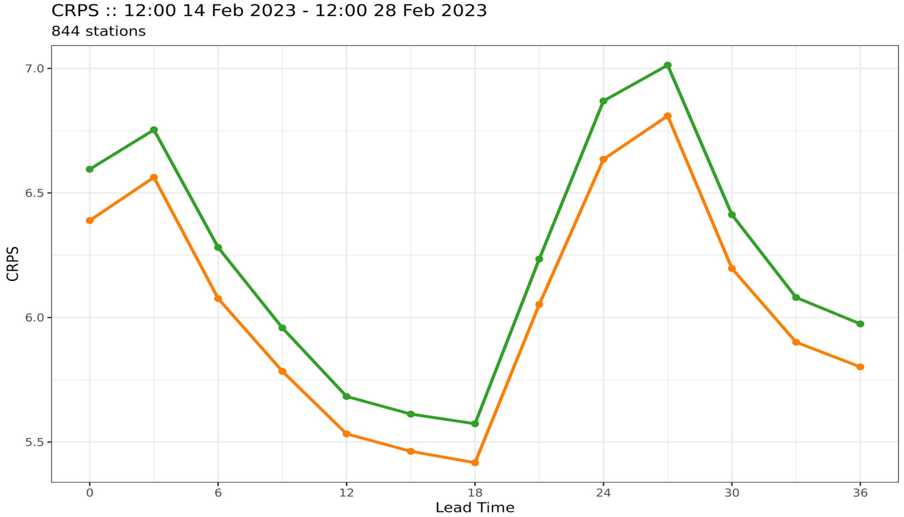
T2m



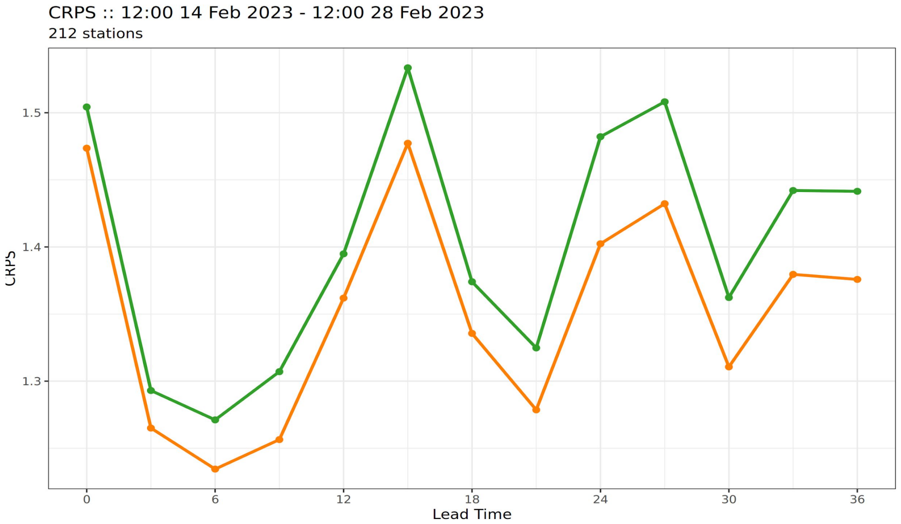
S10m



Q2m



Total cloud cover



Period:
14-28 February 2023

Configurations:
SPP_5P - old

SPP_19P - new

Results:

Reduced CRPS scores for new 19 parameter configuration

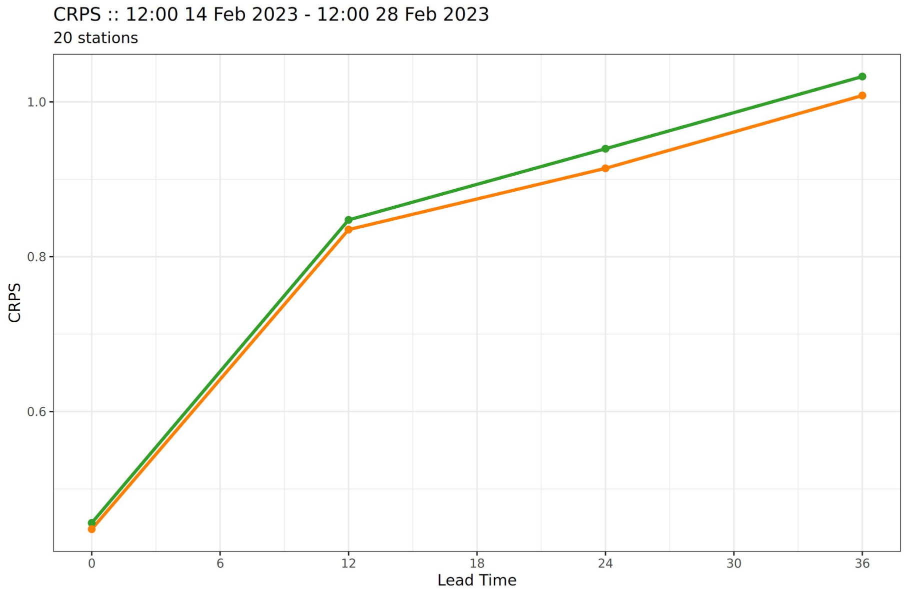
“old” SPP vs “new” SPP configurations

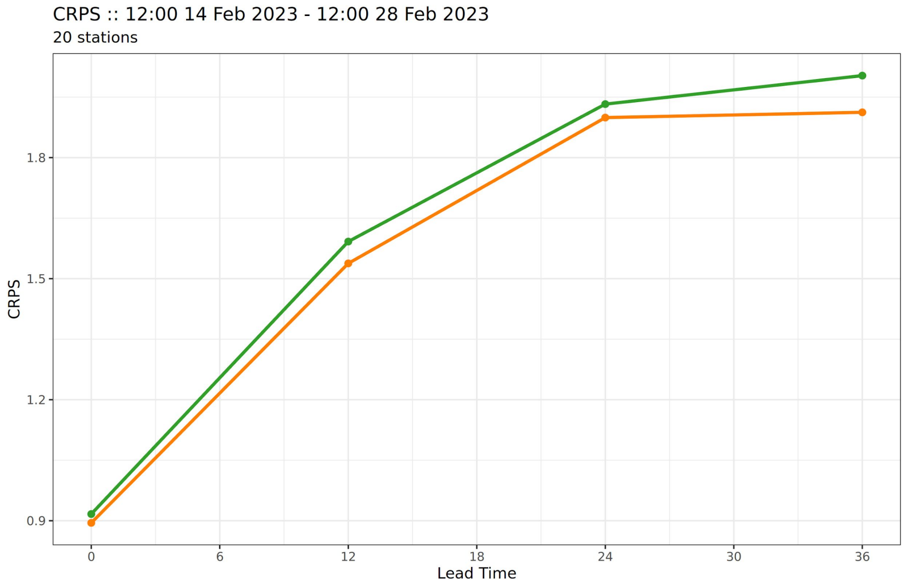
United Weather Centres

T850 hPa

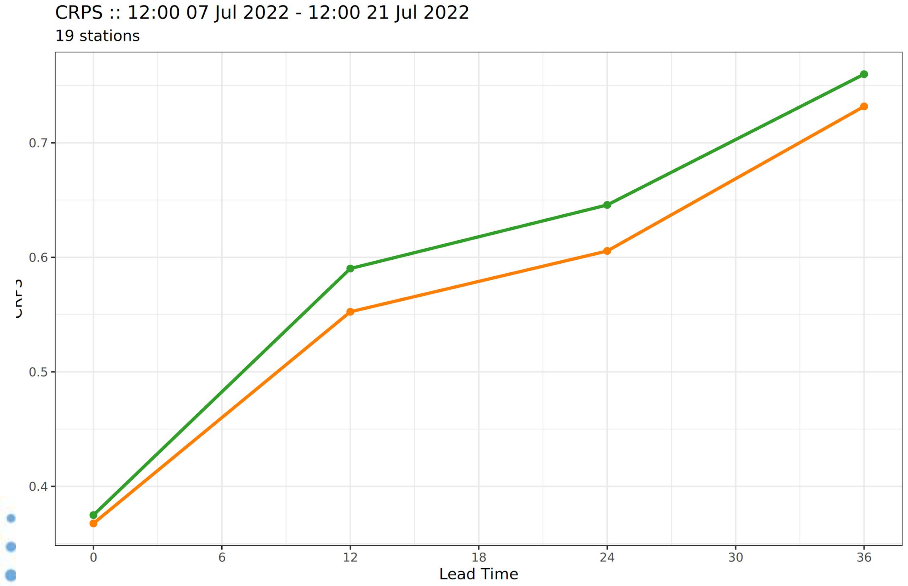
S850 hPa

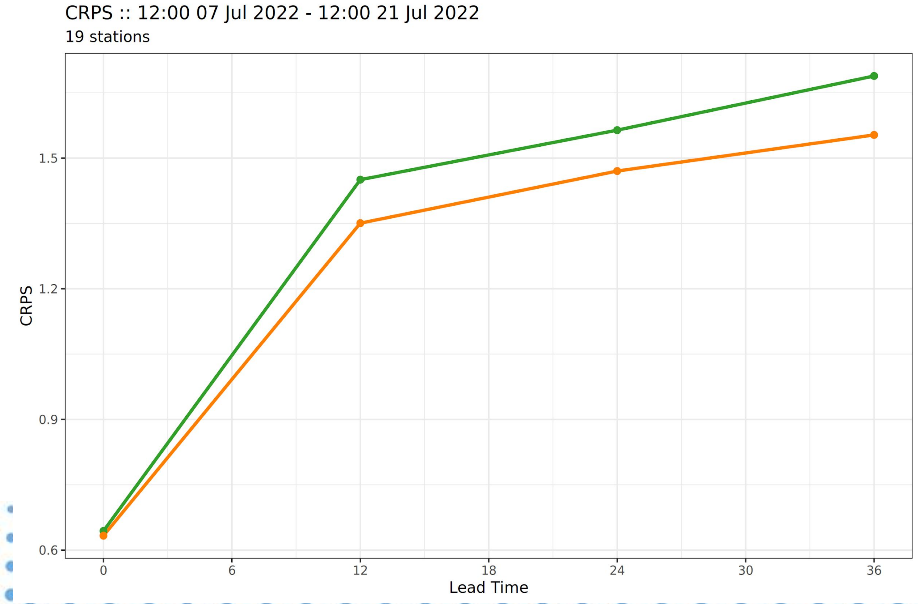
Winter





Summer





Configurations:

SPP_5P - old

SPP_19P - new

Results:

Reduced CRPS scores for new 19 parameter configuration

Larger imporvment in summer, less during winter

Part 2

Ensemble comparison CY43 vs CY46 setup

Harmonie Cycle 43 vs Cycle 46 Setup

United Weather Centres

EPS Configuraton details

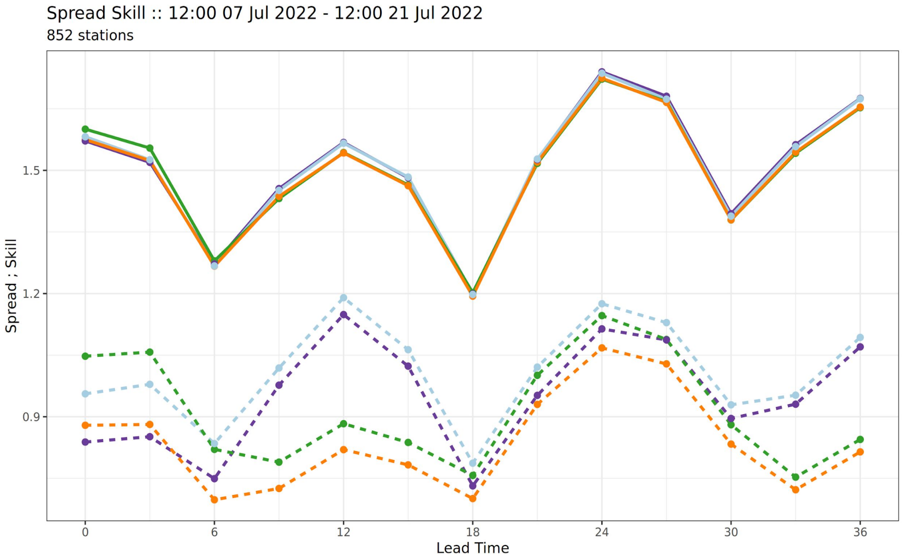
Cycle	SPP_5P_PertANA	SPP_5P_PertANA_half	SPP_19P	SPP_19P_PertANA_half
EDA	Yes	Yes	Yes	Yes
Boundaries	ECMWF-IFS-ENS (coarsened at 18 km)	ECMWF-IFS-ENS (coarsened at 18 km)	ECMWF-IFS-ENS (coarsened at 18 km)	ECMWF-IFS-ENS (coarsened at 18 km)
PertSFC	Yes - (SST, Soil temperature, soil moisture, albedo, roughness)	Yes - (SST, Soil temperature, soil moisture, albedo and roughness)	Yes - (SST, Soil temperature, soil moisture, albedo and roughness)	Yes - (SST, Soil temperature, soil moisture, albedo and roughness)
SPP	5 Parameters	5 Parameter	19 Parameter	19 Parameter
PertAna	Yes (standard magnitude)	Yes (magnitude halved)	No	Yes (magnitude halved)

Harmonie Cycle 43 vs Cycle 46 Setup

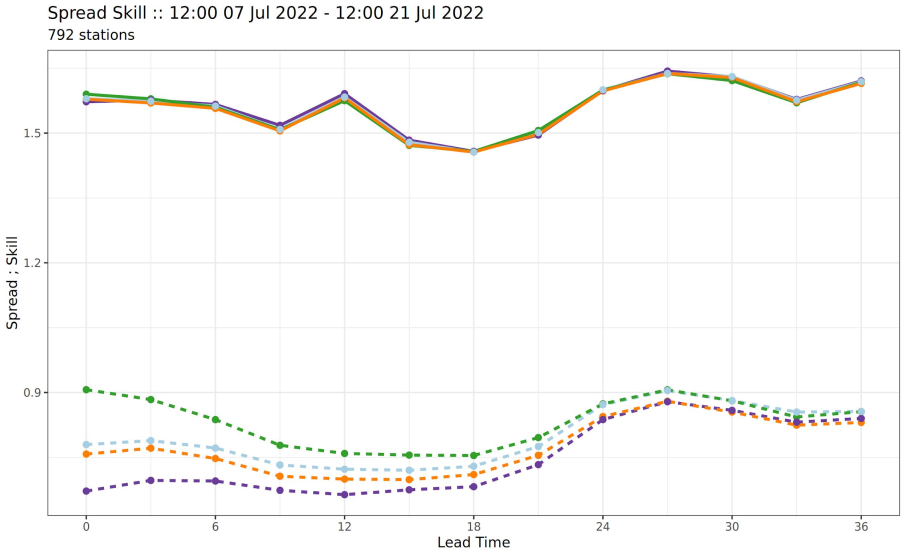
United Weather Centres

Summer

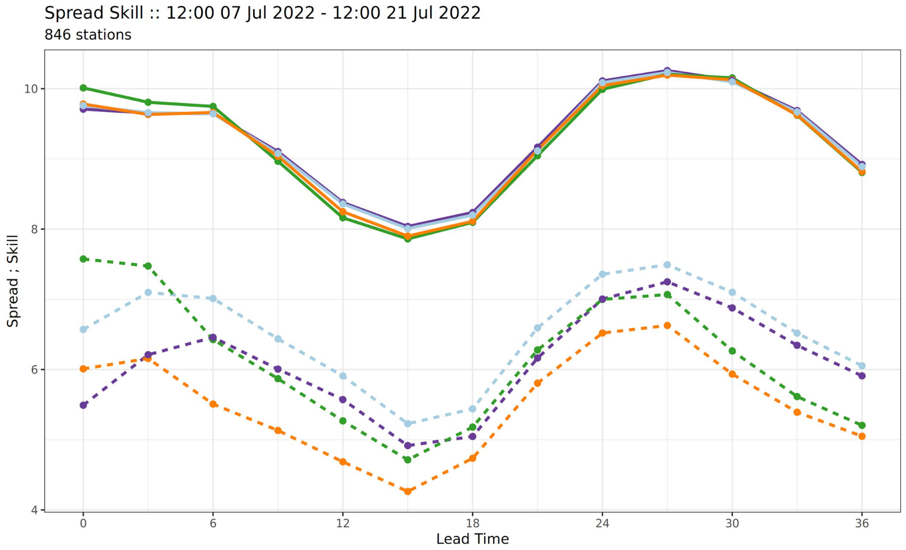
T2m



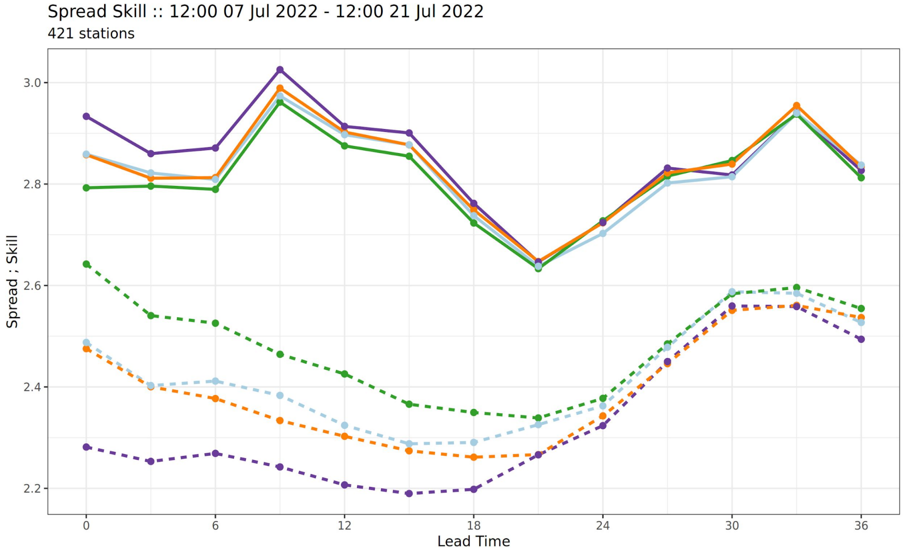
S10m



Q2m



Total cloud cover



Period:
07-21 July 2022

Configurations:

SPP_5P_PertANA

SPP_5P_PertANA_half

SPP_19P

SPP_19P_PertANA_half

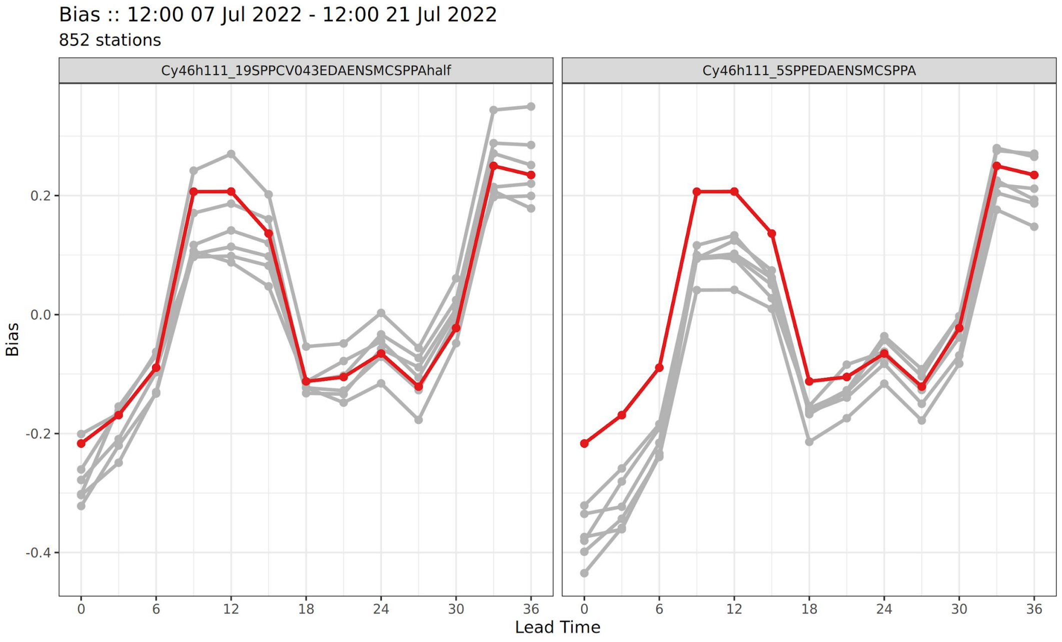
Results:

Reducing PertANA substantially reduced spread

19SPP still provides more spread/lower crps compared to 5SPP with same PertANA magnitude

Harmonie Cycle 43 vs Cycle 46 Setup

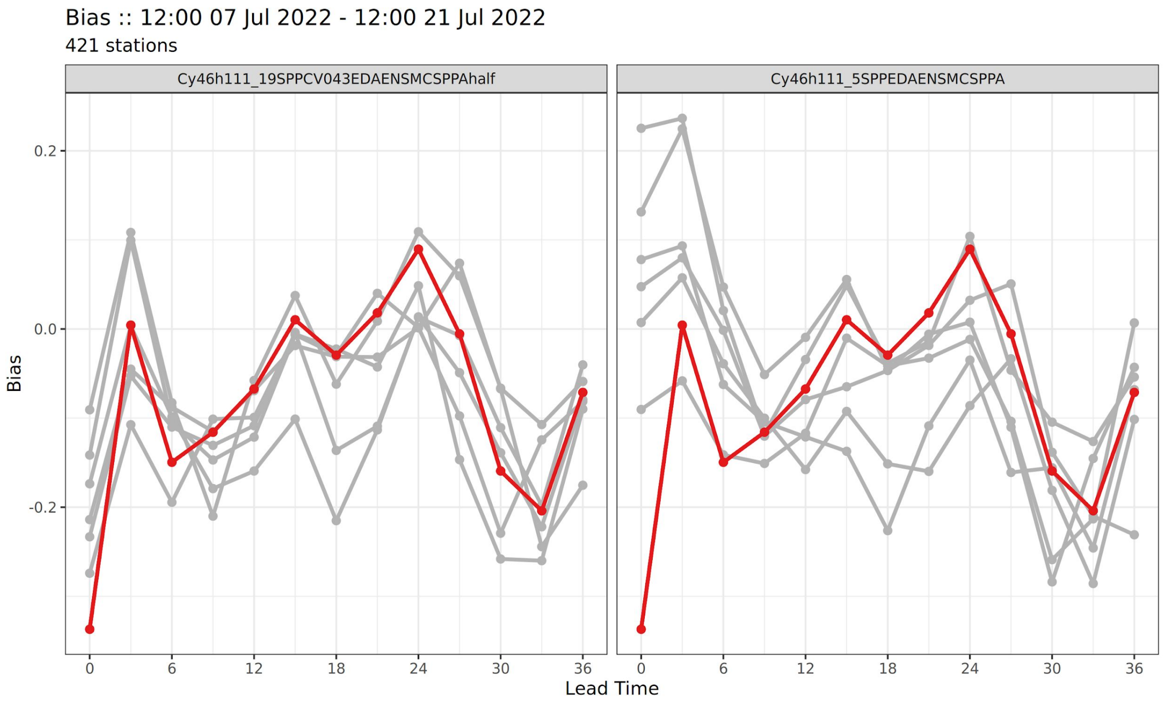
T2m



Results:

Standard magnitude perturbations with PertANA result in substantial systematic bias in perturbed members

S10m



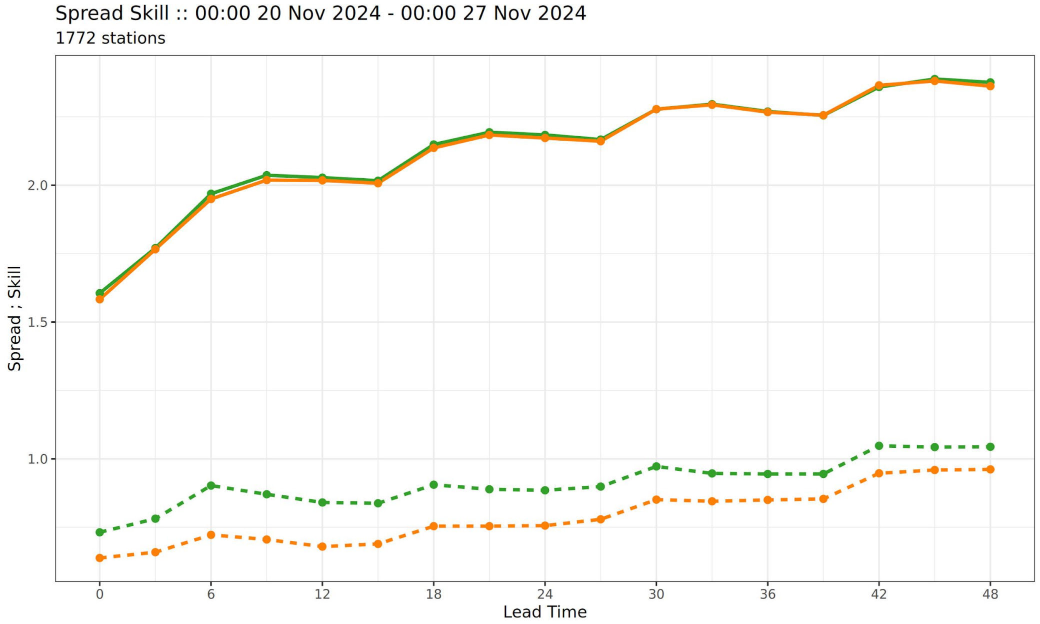
Control member

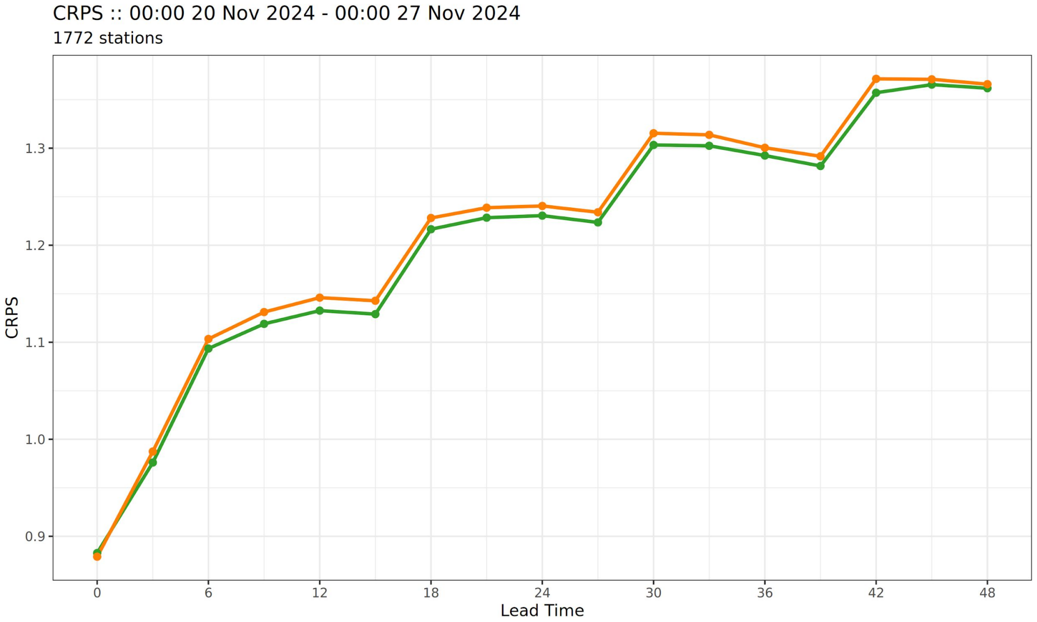
Perturbed members

Harmonie Cycle 43 vs Cycle 46 Setup

November 20th - 27th DINI domain

United Weather Centres



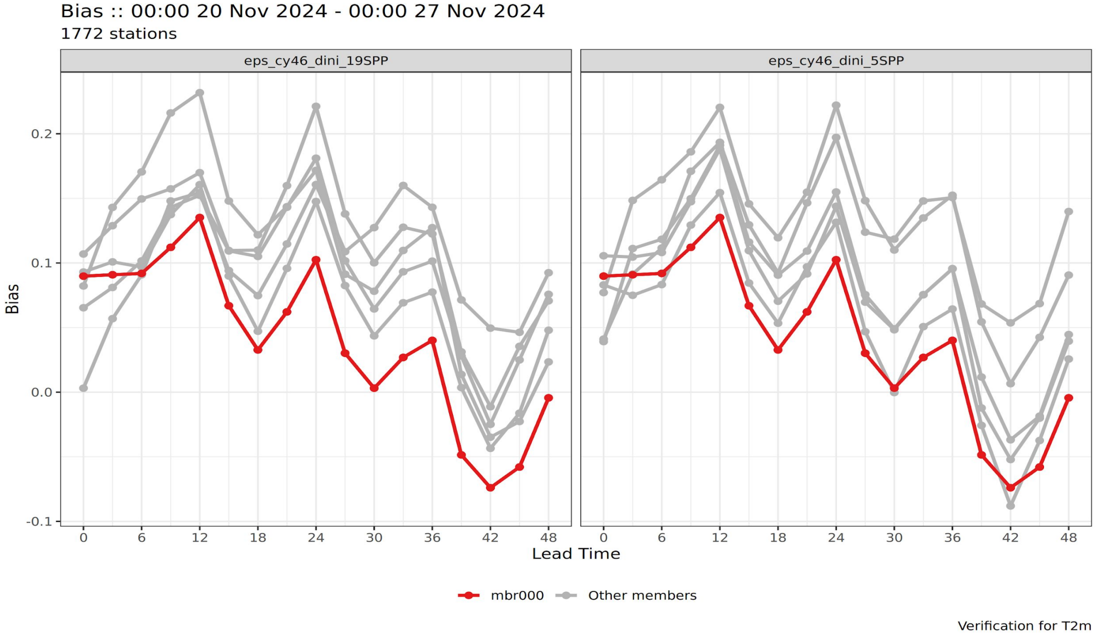


T2m

Configurations:

SPP_5P_PertANA_half

SPP_19P_PertANA_half



Case studies - Check how CY46 fares against CY43 (oper MEPS)

United Weather Centres

- Run Harmonie CY46
- Cold start
  - Surface probably not in total balance
- Run with perturbations in
  - Initial state
  - Boundary
  - Model
  - Surface conditions

Case studies - Check how CY46 fares against CY43 (oper MEPS)

- Run Harmonie CY46
- Cold start
  - Surface probably not in total balance
- Run with perturbations in
  - Initial state
  - Boundary
  - Model – SPP with 5 and 17 parameters
  - Surface conditions

Case studies - Check how CY46 fares against CY43 (oper MEPS)

- Run Harmoi
- Cold start
  - Surface
- Run with pe
  - Initial sta
  - Boundary
  - Model – SPP with 5 and 17 parameters
  - Surface conditions

NOT EXACTLY COMPARING APPLES WITH APPLES, BUT GOOD ENOUGH

Case studies - Check how CY46 fares against CY43 (oper MEPS)

- Run Harmo
- Cold start
  - Surface
- Run with pe
  - Initial sta
  - Boundary
  - Model – SPP with 5 and 17 parameters
  - Surface conditions

NOT EXACTLY COMPARING APPLES WITH APPLES, BUT GOOD ENOUGH

A proxy for the current operational ensemble, ”old”

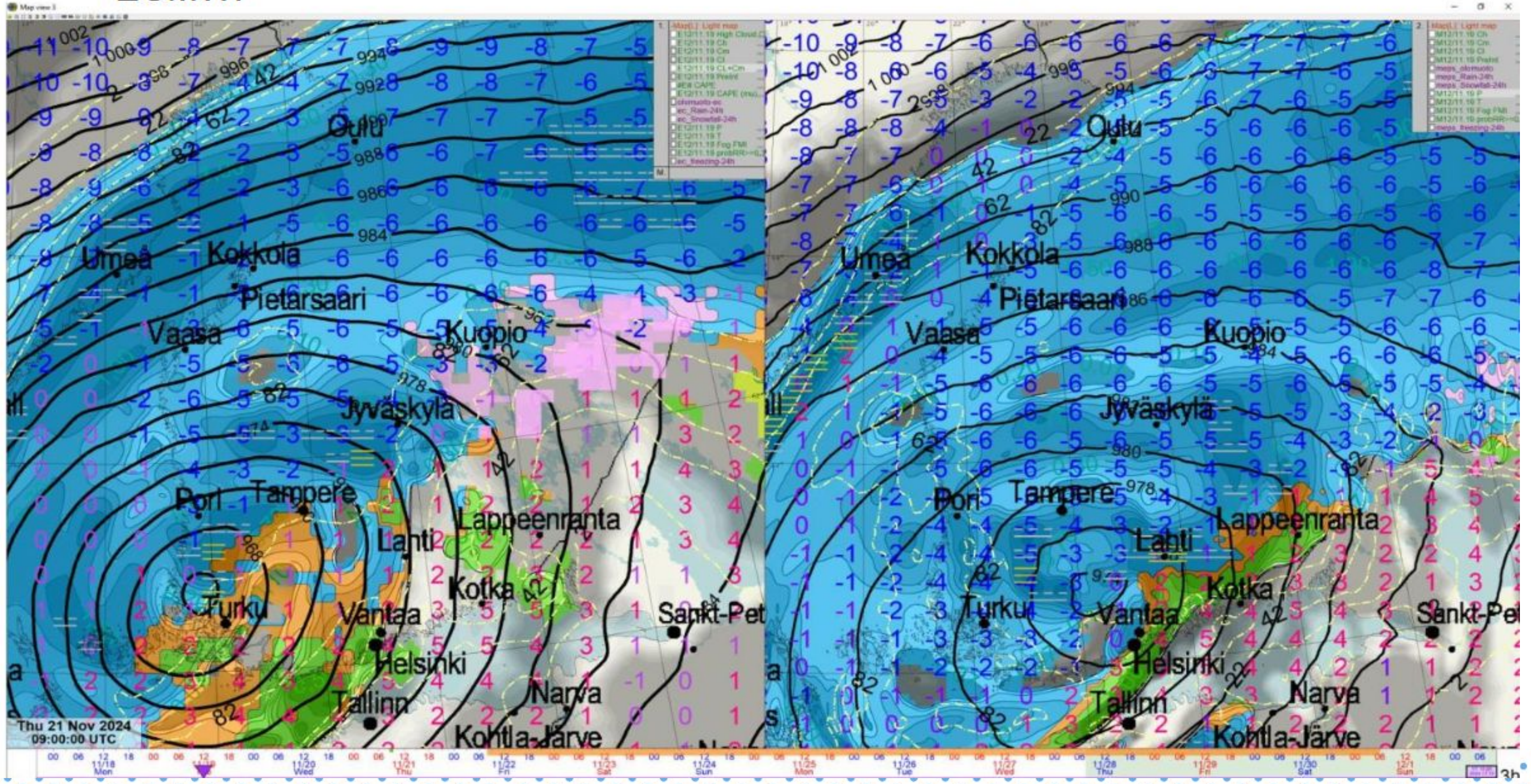
Close to the upcoming ensemble, ”new”

Jari storm 21st Nov

- Incorrect mslp forecast in MEPS affecting all parameters -> fortunately we fell back to ECMWF

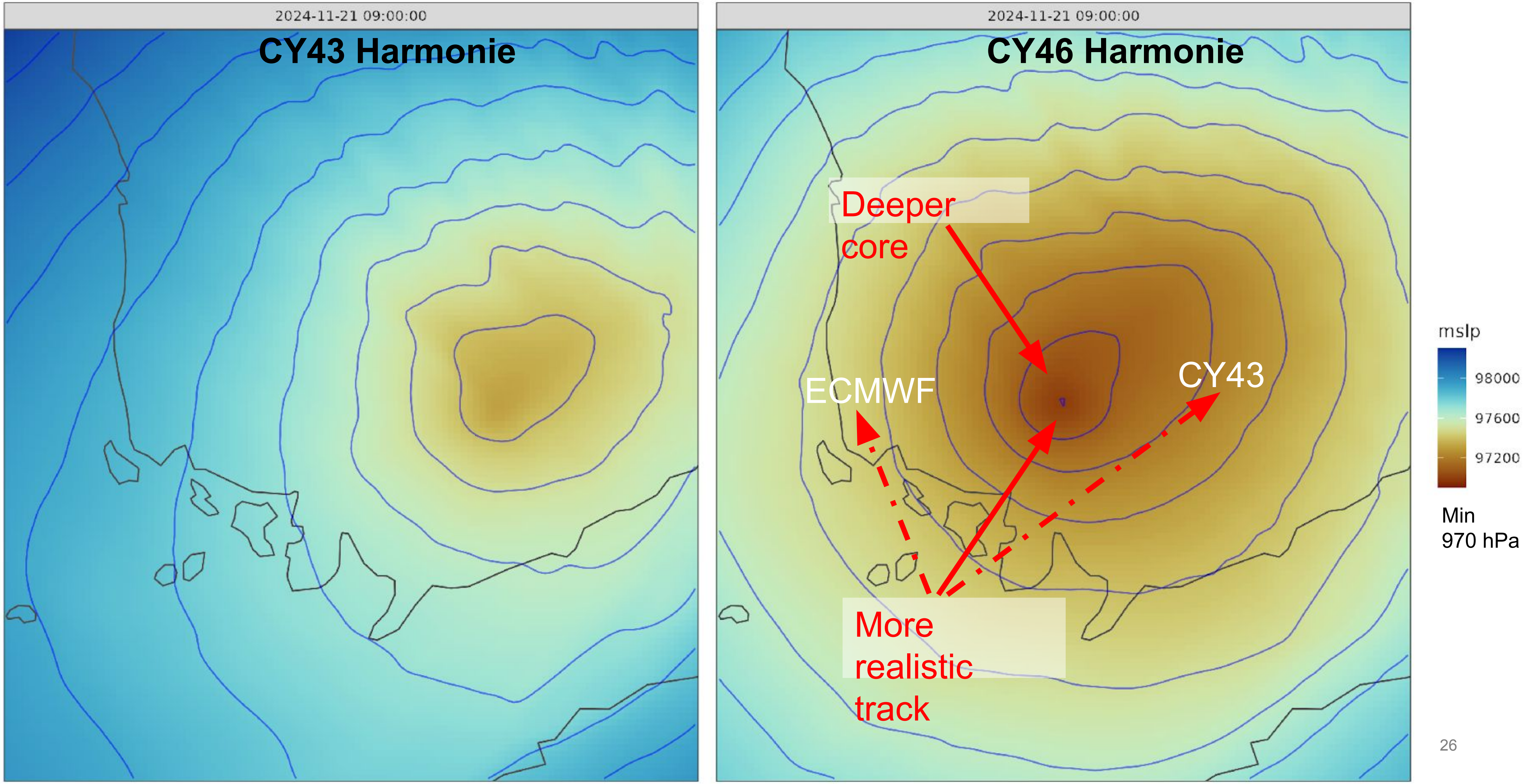
ECMWF

MEPS

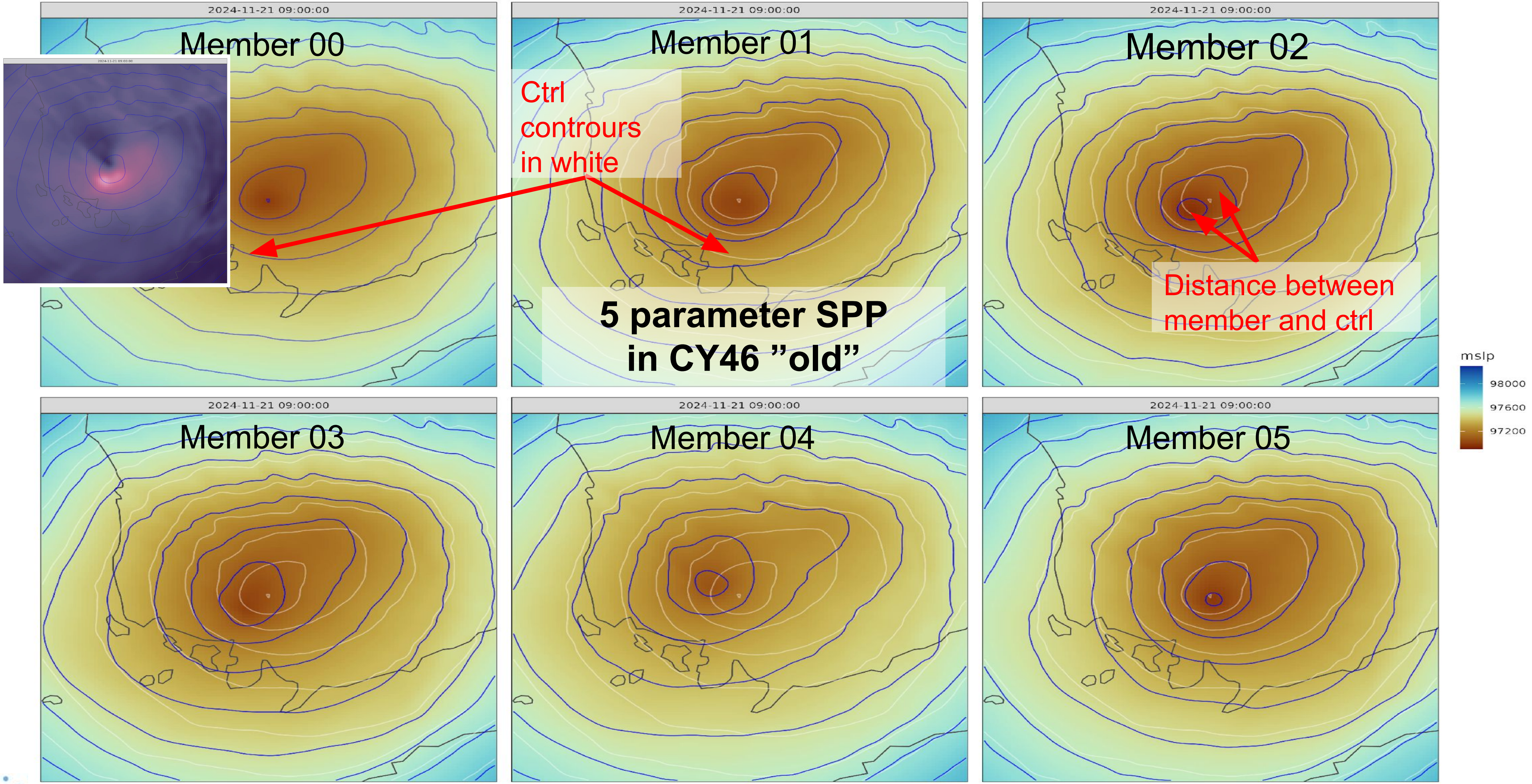


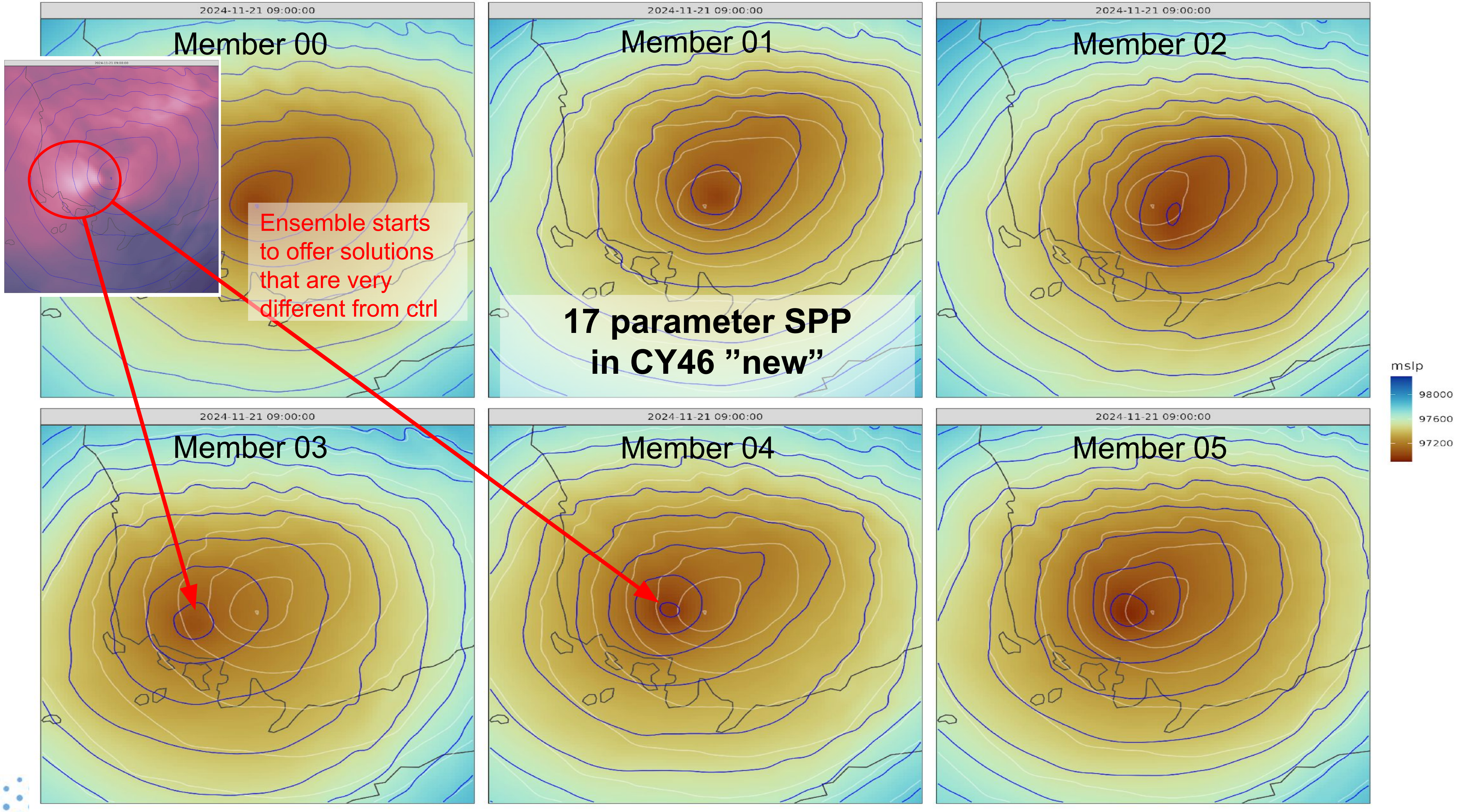
ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

United Weather Centres

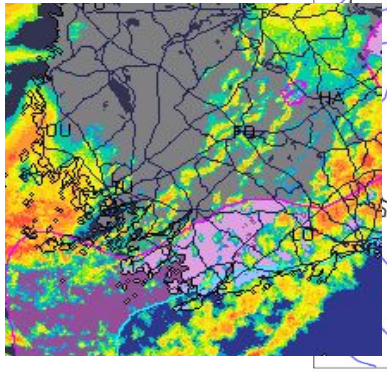


Min 970 hPa

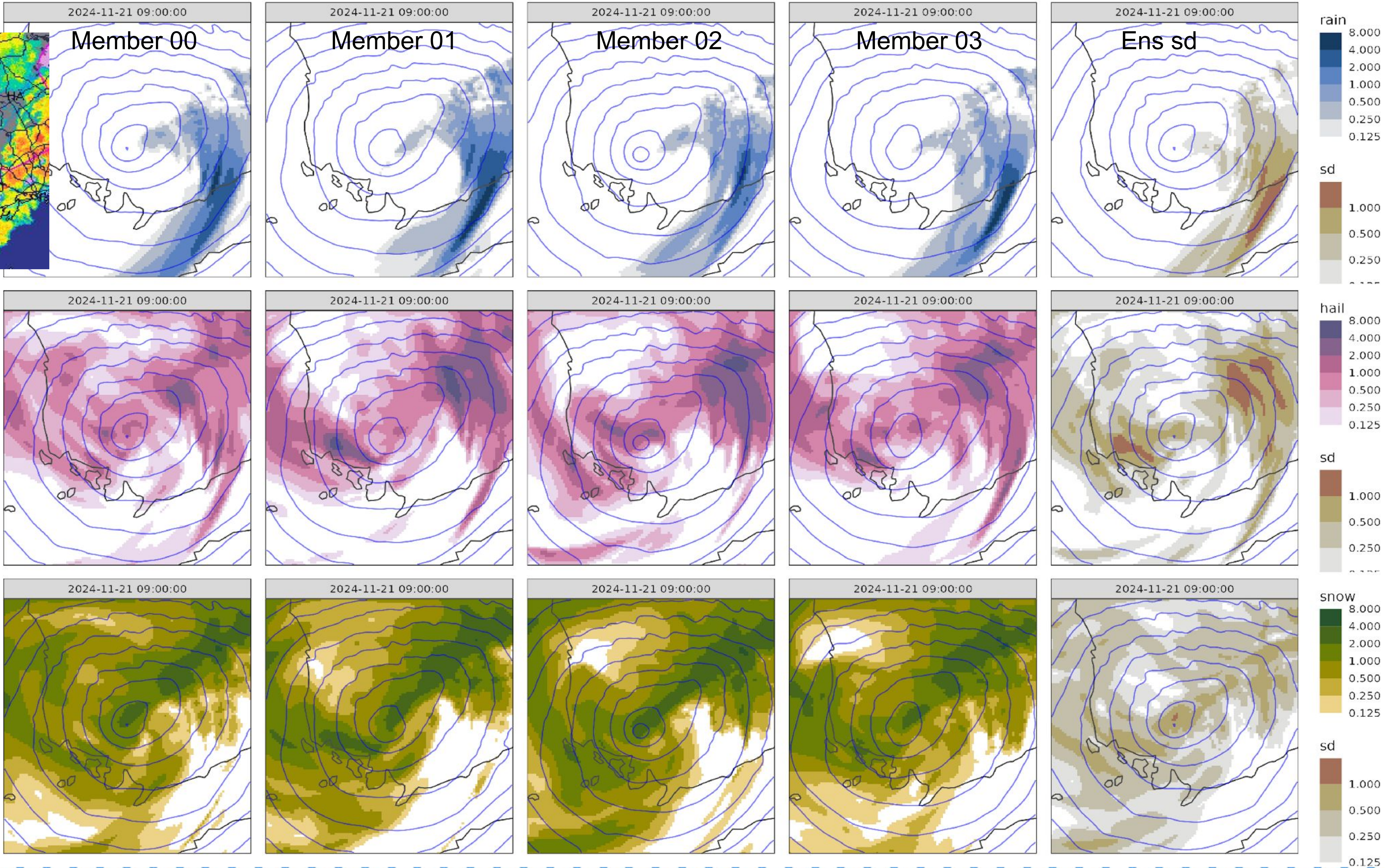

2024-11-21 09:00:00
Member 00
Member 01
Ctrl
contours
in white
5 parameter SPP
in CY46 ”old”
Member 02
Distance between
member and ctrl
mslp
98000
97600
97200
Member 03
Member 04
Member 05

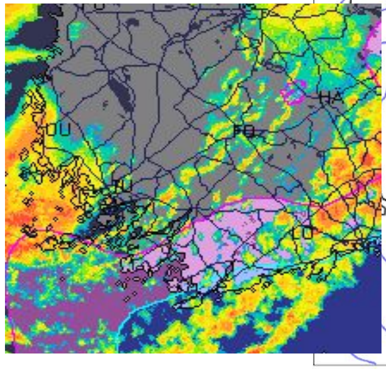

2024-11-21 09:00:00
Member 00
Ensemble starts to offer solutions that are very different from ctrl
Member 01
17 parameter SPP in CY46 "new"
Member 02
Member 03
Member 04
Member 05
mslp
98000
97600
97200

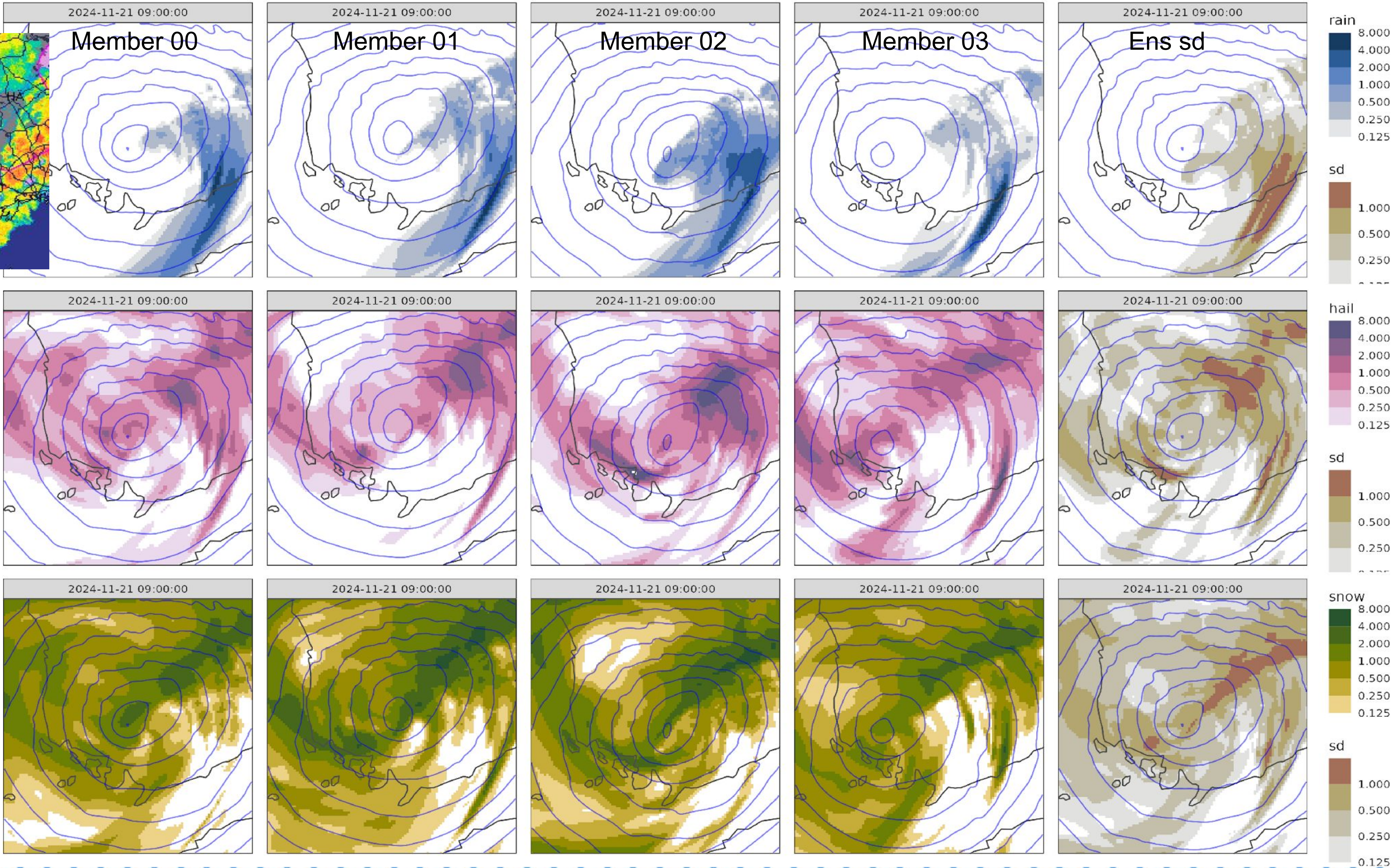
United Weather



”Old”






2024-11-21 09:00:00
Member 00
Member 01
Member 02
Member 03
Ens sd
rain
8.000
4.000
2.000
1.000
0.500
0.250
0.125
sd
1.000
0.500
0.250
hail
8.000
4.000
2.000
1.000
0.500
0.250
0.125
sd
1.000
0.500
0.250
snow
8.000
4.000
2.000
1.000
0.500
0.250
0.125
sd
1.000
0.500
0.250
0.125

”New”

Summary

New SPP configuration with 19 perturbed parameters:

- Substantial increase in ensemble spread
- Reduction in CRPS scores for near surface and upper-air variables

New EPS configuration (includes modification in PertSFC & PertANA initial state perturbations):

- Reduction in PertANA magnitude (halved) – less ensemble spread but reduced systematic biases
- Change in PertSFC parameters – RSMIN & CV move to SPP - SNOW, VEG perturbations deactivated

Outlook

- Continue the work on extending SPP to surface (e.g., move constant fields from PertSFC to SPP)
- Adding & testing flow dependence in line with what is done in Arome/Lace
- Investigate further the use of initial state perturbations (e.g., EDA, PertANA)
- Adapt to new physics in upcoming operational cycles (CY49 & CY50)
- Maintenance, refinement and future proofing (e.g., Uranie, Tactus)

Extra Slides

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.

SPP status

Operations:

- A 5 parameter version operational in MetCoOp (since August 2022) and in UWC-W - in cy43
- SPP update to be ready before the operational versions switching to cy46

AUGUST 2024 TSIRINGAKIS ET AL. 1923

An Update to the Stochastically Perturbed Parameterization Scheme of HarmonEPS

ARISTOFANIS TSIRINGAKIS,[a] INGER-LISE FROGNER,[b] WIM DE ROOY,[a] ULF ANDRAE,[c] ALAN HALLY,[d] SEBASTIÁN CONTRERAS OSORIO,[a] SIBBO VAN DER VEEN,[a] AND JAN BARKMEIJER[a]

[a] *Royal Netherlands Meteorological Institute (KNMI), De Bilt, Netherlands*
[b] *Norwegian Meteorological Institute (Met Norway), Oslo, Norway*
[c] *Swedish Meteorological and Hydrological Institute, Norrköping, Sweden*
[d] *Irish Meteorological Service (Met Éireann), Dublin, Ireland*

APRIL 2022 FROGNER ET AL. 775

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

INGER-LISE FROGNER,[a] ULF ANDRAE,[b] PIRKKA OLLINAHO,[c] ALAN HALLY,[d] KAROLIINA HÄMÄLÄINEN,[c] JANNE KAUHANEN,[c] KARL-IVAR IVARSSON,[b] AND DANIEL YAZGI[b]

[a] *Norwegian Meteorological Institute (Met Norway), Oslo, Norway*
[b] *Swedish Meteorological and Hydrological Institute, Norrköping, Sweden*
[c] *Finnish Meteorological Institute, Helsinki, Finland*
[d] *Irish Meteorological Service (Met Éireann), Dublin, Ireland*

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

Status on SPP and PertSurf

- PertSurf
  - our working horse for surface uncertainty
  - Important for the ensemble spread and good probabilistic scores
  - In operations for many years, in MetCoOp with a sub-sample of available perturbations:
    - Perturbing surface fields SST, soil temperature and soil moisture
    - Perturbing static surface fields: albedo, roughness
  - Aim: to replace the latter with SPP for surface
- SPP for surface
  - currently under development
  - 4 parameters implemented: RSMIN, CV, CD, CH
  - RSMIN and CV are to enter the SPP update for cy46 aimed for operations early next year
  - CD and CH needs more work
  - We would like to extend SPP for surface