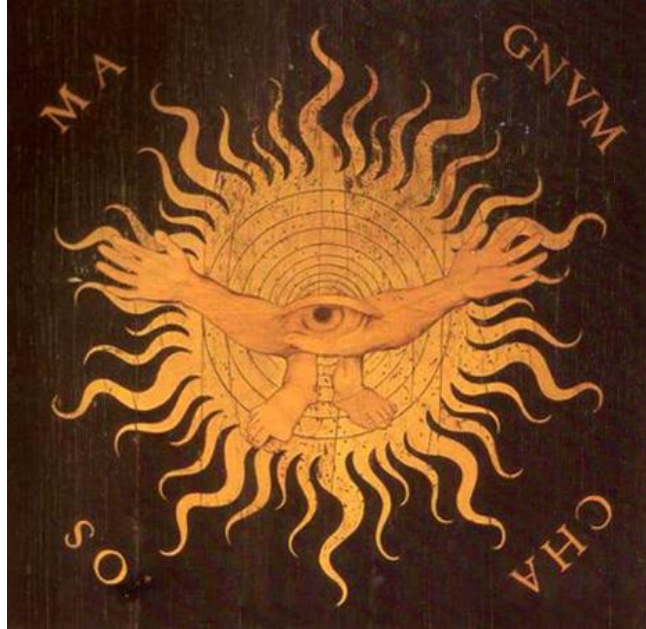
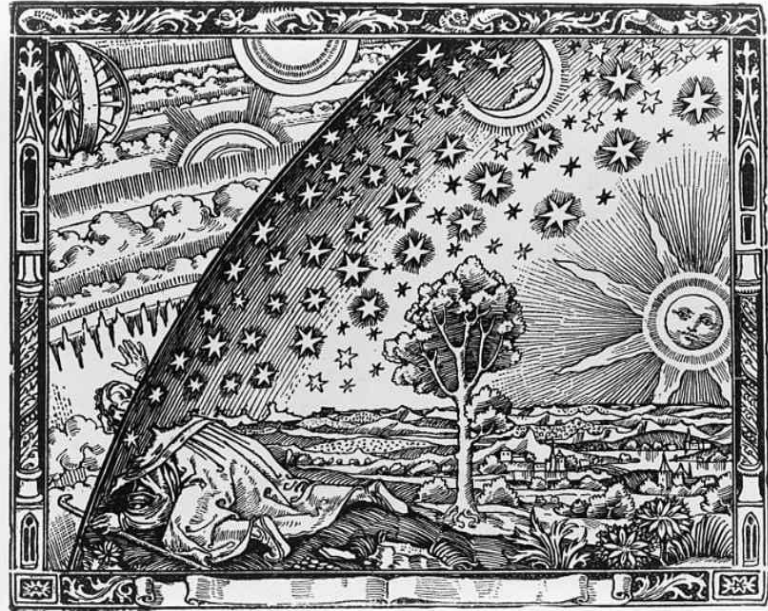
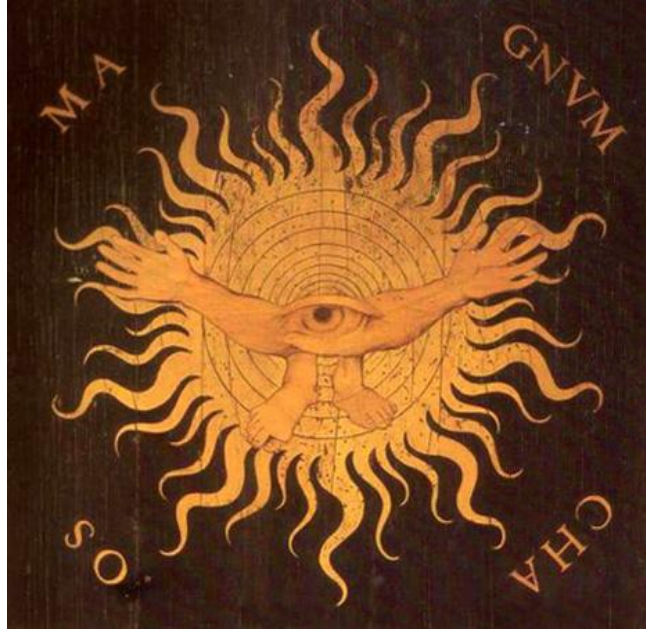


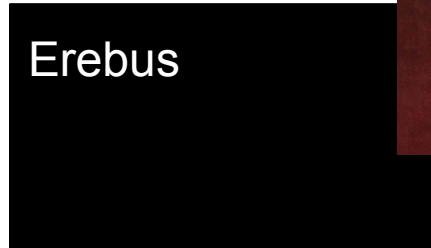
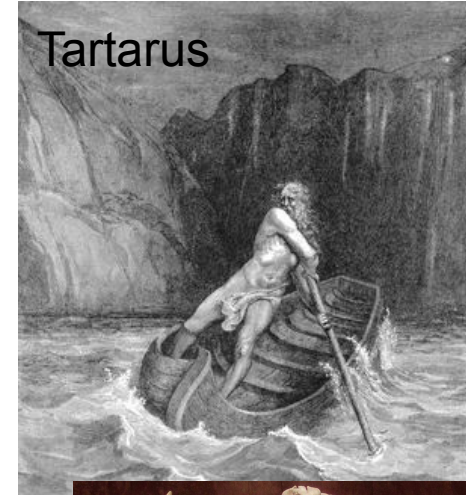
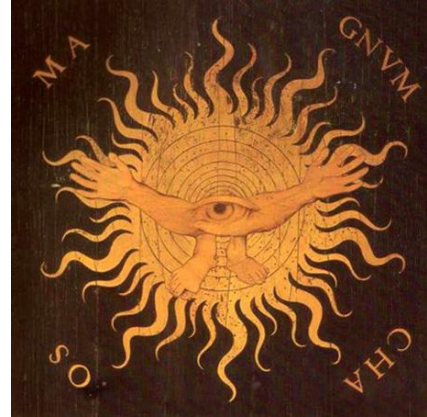
WG EPS and Predictability

Chiara Marsigli and Enrico Minguzzi
Arpae-SIMC

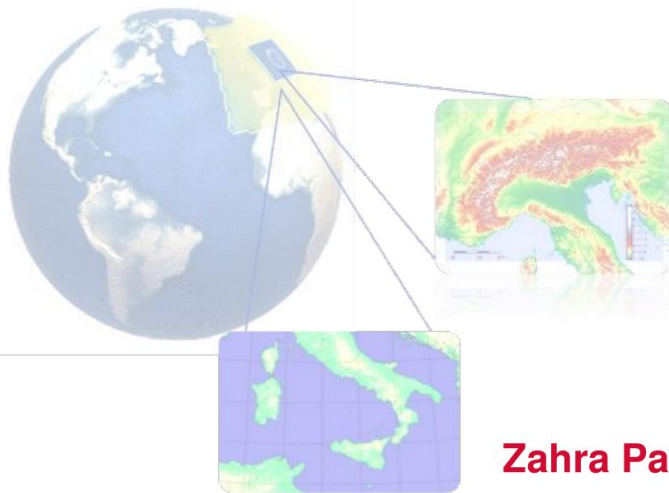
- KAOS Priority Project
 - implementation, tuning and testing of SPP in ICON (DWD + IMGW and Arpae)
 - perturbation of soil temperature at IMGW
 - usage of ensemble for Nowcasting: best member selection (IMS)
 - spatial verification and diagnostics of ensembles (all)
 - ensemble combination: super(TL)ensemble at IMGW
- transition to ICON-LEPS
 - verification (Arpae + HNMS + Arpa Piemonte)
 - test of model perturbation (Arpae)







SPP development in ICON



28th COSMO General Meeting

14 September 2026 | Rome, Italy

Zahra Parsakhoo, Christoph Gebhardt, Chiara Marsigli



CPP vs. SPP: Key Differences

Classical parameter perturbation (CPP)



Each uncertain parameter is set to

- default or
- boundary value of the range



The value is kept **fix** during the run



~18 parameters

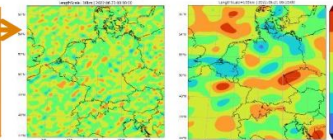
Stochastic parameter perturbation(SPP):



Each uncertain parameter is perturbed by
Stochastic Pattern

- Temporally evolving via spectral space
- Spatial and temporal correlations
- Some certain properties

Length scale
Time scale
Variance
Mode



Seed different for each:

- parameter
- ensemble member
- initialization date
- initialization time



Introducing SPP in ICON

SPG implementation in ICON

**Stochastic Pattern Generator
(SPG)**

By Axel Seifert and Maleen Hanst

Deterministic forecast
Coupled with microphysics
To perturb **sedimentation velocity of graupel**

Merged into
ICON master
(June 2025)

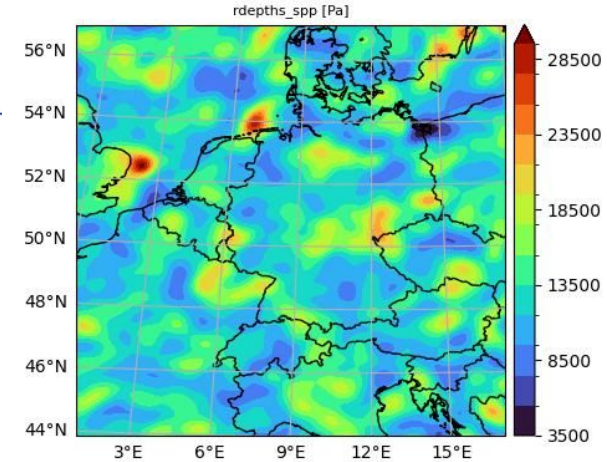
$\text{perturbed} = \text{unperturbed} \times \exp(\text{SPG})$

ICON-LAM

SPP

EPS

- Coupled to convection → **rdepths**
- **Maximum allowed shallow convection depth**
- Coupled to land → **r_bsmin**
- **Minimum bare soil evapotranspiration resistance**



SPP in ICON : Technical & Theoretical Evaluation

To evaluate

- role of SPG namelist parameters
- parameter behavior before and after SPP (both from a technical and theoretical perspective).

SPG properties (namelist):

```
spg_fourier_modes = .true.  
spg_length_scale = 50e3  
spg_time_scale = 36  
spg_spec_modes = 50  
spg_variance = 0.2
```

The realized variance and structure of the SPG field depend on the interaction between the prescribed length scale and the spectral truncation and domain size. If the spectrum is not adequately resolved, the model produces biased variance



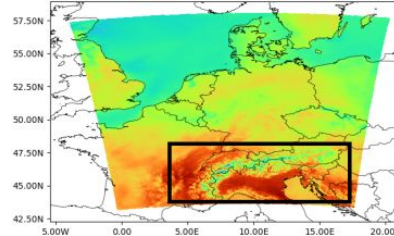
Test Setup “clean” Experiments

LAT-BC → **no** Perturbation
Initial Conditions → **no** Perturbation

CPPclean

~18 physical parameter
perturbation fixed during
forecast run time
▪ Operational perturbation

ICON-D2 2km



period:
08-16.05.2023

SPPclean

SPP activated for perturbing

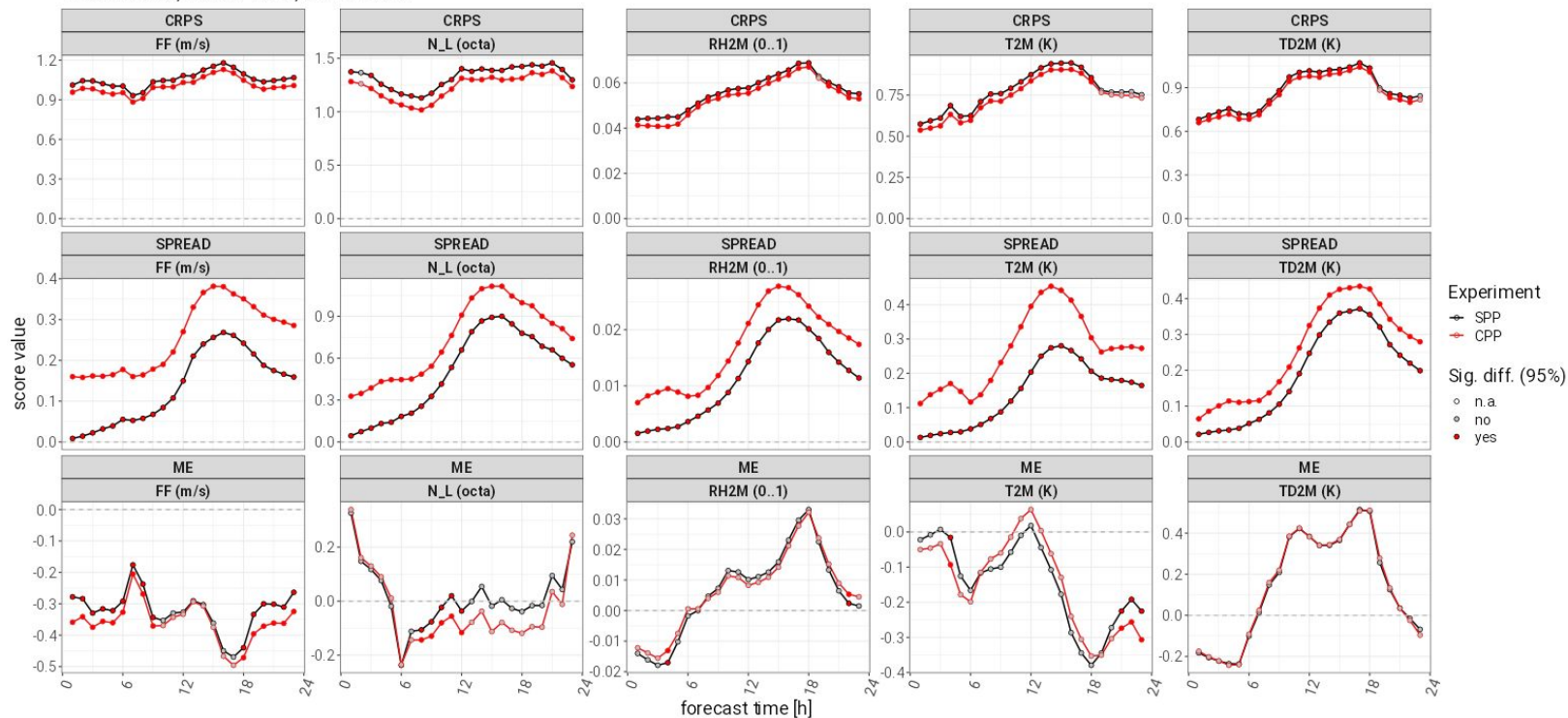
- ✓ Sed. Vel. Graupel
- ✓ rdepths
- ✓ r_bsmin



Introducing SPP in ICON

2023/05/08 01UTC - 2023/05/15 23UTC

INI: 00 UTC, DOM: ALL, STAT: ALL



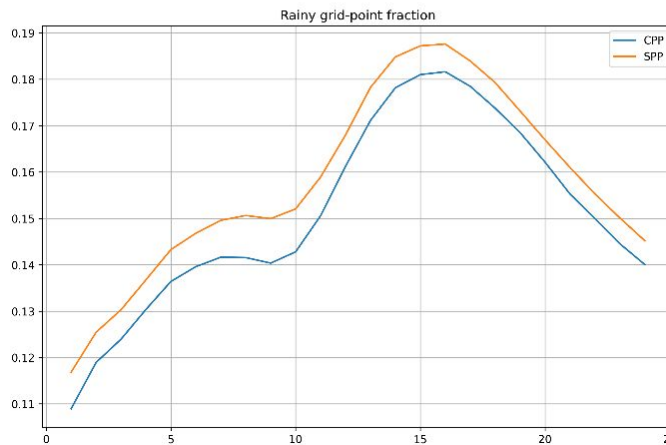
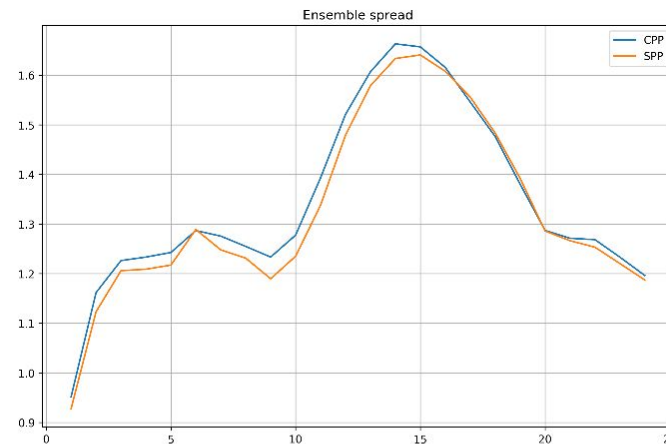
Zahra.Parsakhoo@dwd.de

Introducing SPP in ICON

SPP and CPP show small differences in domain-averaged ensemble spread for hourly precipitation.

Domain-averaged spread masks local ensemble sensitivity

SPP slightly increases rainy-grid fraction



SPP in ICON | Outlook

- **Implementation:**
 - Add spg_call_interval in spg namelist
 - Test other physical uncertain parameters (Any suggestion!?)
 - Combine with Adaptive Parameter Tuning (by Günther Zängl)
- More case studies
- Refining SPP for Higher Resolution: Focus on 1 km resolution for the GLORI Alpine region.
- Nest: First test uncoupled at 500 m resolution, then fully coupled with SPP.

1.4. Perturbation of the soil variables

1.1. SPP in ICON: cloud microphysics parameters in single- and double-moment schemes

Grzegorz Zakrzewski, Jakub Lewandowski, Tatiana Tabalchuk, Andrzej Mazur, Andrzej Wyszogrodzki

14th September 2026, COSMO General Meeting, Rome



Introducing SPP (Stochastic Parameter Perturbation) in ICON

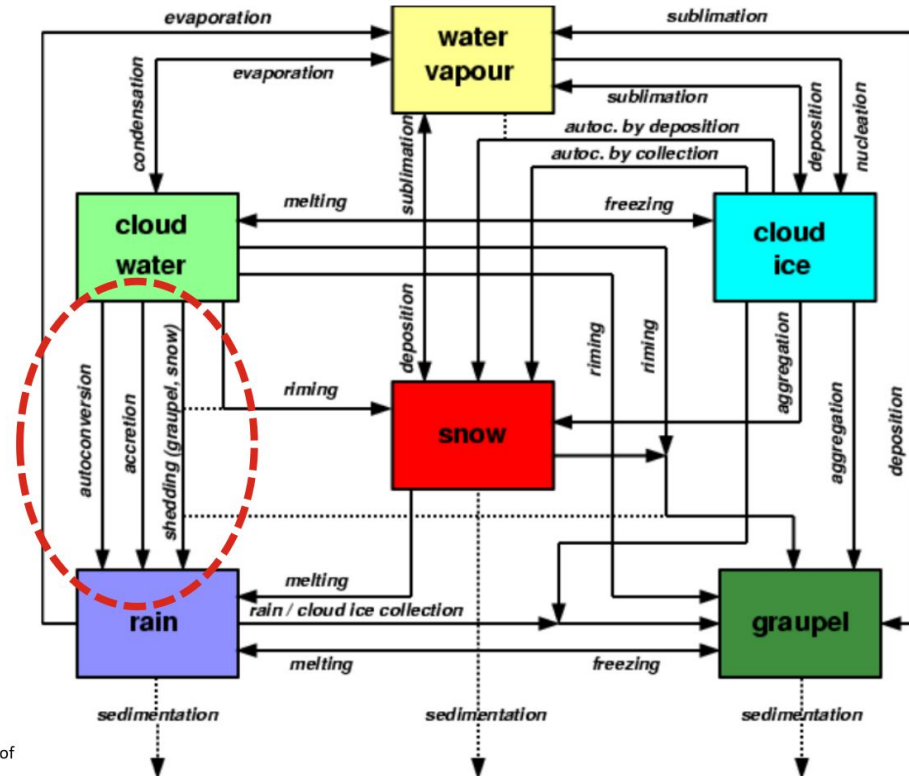
Cloud microphysics perturbations: what is going on there?



Instytut Meteorologii i Gospodarki Wodnej
Państwowy Instytut Badawczy

Parametrized warm-rain processes:

- accretion
- autoconversion
- selfcollection
- breakup



Doms, G., Förstner, J., Heise, E., Herzog, H.-J., Mironov, D., Raschendorfer, M., Reinhardt, T., Ritter, B., Schrodin, R., Schulz, J.-P., Vogel, G., 2021. A Description of the Nonhydrostatic Regional COSMO-Model: Part II Physical Parametrizations.

Cloud microphysics perturbations: what is going on there?



Instytut Meteorologii i Gospodarki Wodnej
Państwowy Instytut Badawczy

	cloud droplets	raindrops
cloud droplets	selfcollection: $c + c \rightarrow c$ (Eq. 9) autoconversion: $c + c \rightarrow r$ (Eqs. 4–6)	
raindrops	accretion: $r + c \rightarrow r$ (Eqs. 7–8)	selfcollection: $r + r \rightarrow r$ (Eqs. 10–11) breakup: $r + r \rightarrow r$ (Eqs. 13–15)

Seifert, A., Beheng, K.D., 2006. A two-moment cloud microphysics parameterization for mixed-phase clouds. Part 1: Model description. Meteorol. Atmos. Phys. 92, 45–66.

	single-moment	double-moment
autoconversion	$k_{cc} = 9.44 \text{ m}^3 \text{ kg}^{-2} \text{ s}^{-1}$	Onishi & Seifert (2016)
accretion	$k_{cr} = 5.25 \text{ m}^3 \text{ kg}^{-1} \text{ s}^{-1}$	$k_{cr} = 5.78 \text{ m}^3 \text{ kg}^{-1} \text{ s}^{-1}$
selfcollection	N/A	$k_{rr} = 4.33 \text{ m}^3 \text{ kg}^{-1} \text{ s}^{-1}$ $D_{br} = 1.1 \text{ mm}$
breakup	N/A	$k_{br} = 1 \text{ mm}^{-1}$

Introducing SPP (Stochastic Parameter Perturbation) in ICON

Cloud microphysics perturbations: Niquet et al. to derive ranges for k_{rr} , k_{br} and D_{br}



Instytut Meteorologii i Gospodarki Wodnej
Państwowy Instytut Badawczy

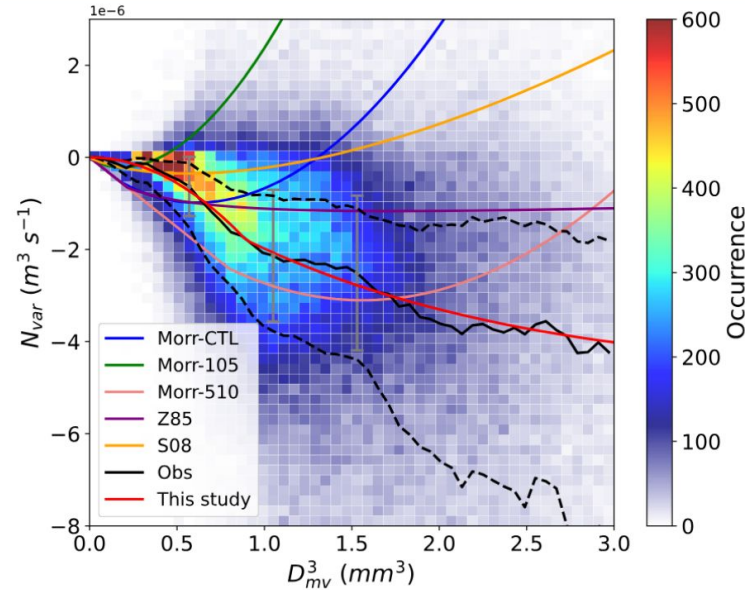


Figure 10. Probability density function of $N_{var} = (1/N_r^2)(dN_r/dt)$ as a function of D_{mv}^3 with observation points corresponding to the combination of the Finland and Oklahoma cases shown as a density plot in color.

Niquet, L., Tridon, F., Grzegorzcyk, P., Causse, A., Bordet, B., Wobrock, W., Planche, C., 2024. Evaluation of the Representation of Raindrop Self-Collection and Breakup in Two-Moment Bulk Models Using a Multifrequency Radar Retrieval. Journal of Geophysical Research: Atmospheres 129, e2024JD041269.

Cloud microphysics perturbations: Niquet et al. to derive ranges for k_{rr} , k_{br} and D_{br}



Instytut Meteorologii i Gospodarki Wodnej
Państwowy Instytut Badawczy

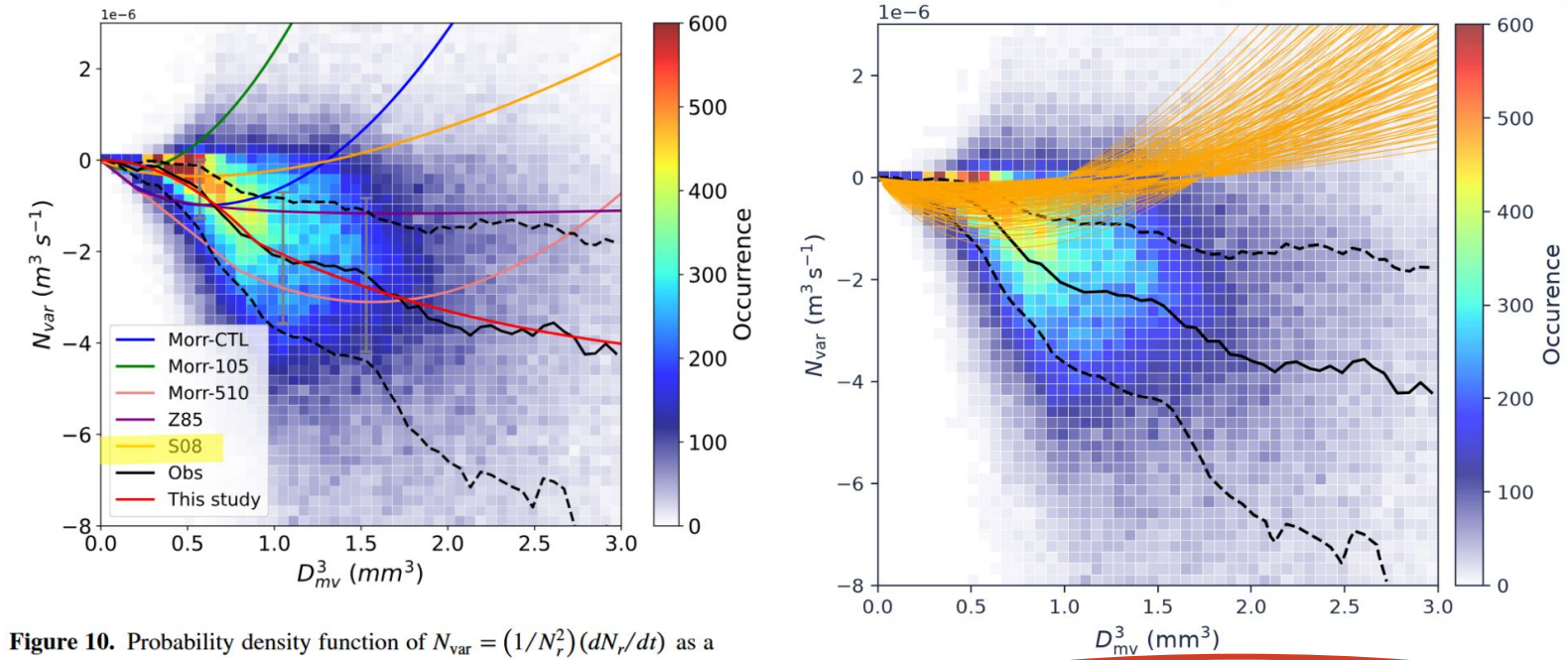


Figure 10. Probability density function of $N_{var} = (1/N_r^2)(dN_r/dt)$ as a function of D_{mv}^3 with observation points corresponding to the combination of the Finland and Oklahoma cases shown as a density plot in color.

Niquet, L., Tridon, F., Grzegorzczak, P., Causse, A., Bordet, B., Wobrock, W., Planche, C., 2024. Evaluation of the Representation of Raindrop Self-Collection and Breakup in Two-Moment Bulk Models Using a Multifrequency Radar Retrieval. Journal of Geophysical Research: Atmospheres 129, e2024JD041269.

- Selected perturbation ranges:**
- $k_{rr} \in [3.0, 6.0] \text{ m}^3 \text{ kg}^{-1} \text{ s}^{-1}$
 - $k_{br} \in [0.5, 2.0] \text{ mm}^{-1}$
 - $D_{br} \in [1.0, 1.2] \text{ mm}$

Introducing SPP (Stochastic Parameter Perturbation) in ICON

Towards physically perturbed ensemble at IMGW-PIB

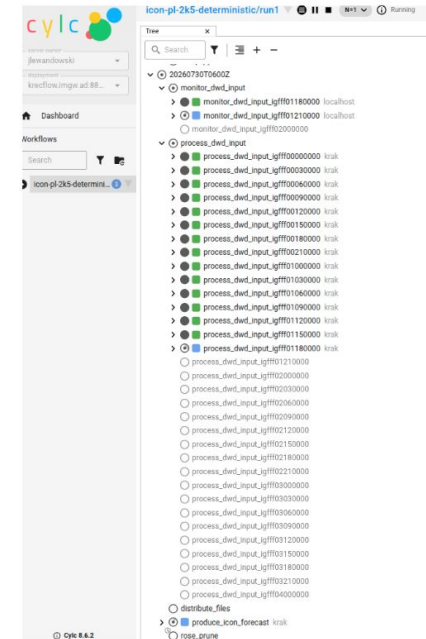


Instytut Meteorologii i Gospodarki Wodnej
Państwowy Instytut Badawczy

Lots of progress, but nothing shiny

- Deployed new scheduler - cylc
- Acquired IFS-ENS data for boundary conditions
- Created converter of in-situ observations (SYNOP, TEMP, SHIP, BUOY, AMDAR)
- Sorted out conversion of volumetric radar reflectivity data
- Updated EMVORADO metadata for the upgraded Polish radar network (merge to upstream after more testing)

next: SPP implementation for
the new parameters and test

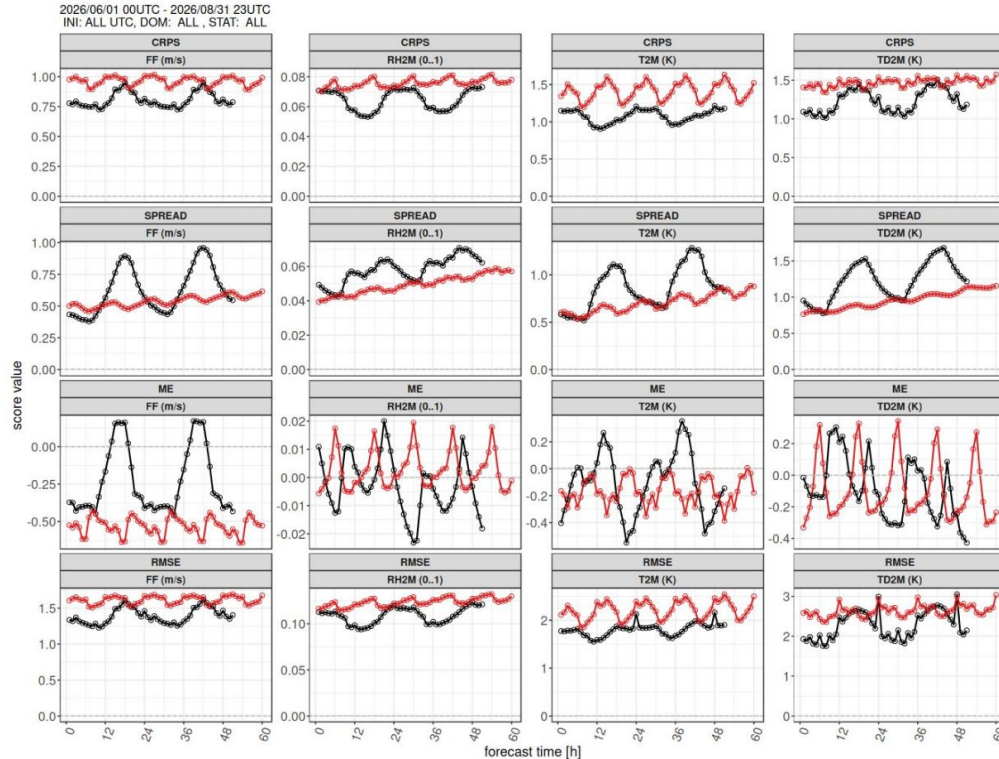


ICON-2I ensemble system at Arpae:

Summer verification against IFS
Introducing SPP, a first case study

Alessandro Frigato, Davide Cesari, Thomas Gastaldo, Chiara Marsigli

Verification 2026 JJA - FFV2 - Lead time



IniTimes:
ICON-2I: 21
IFS: 00, 12

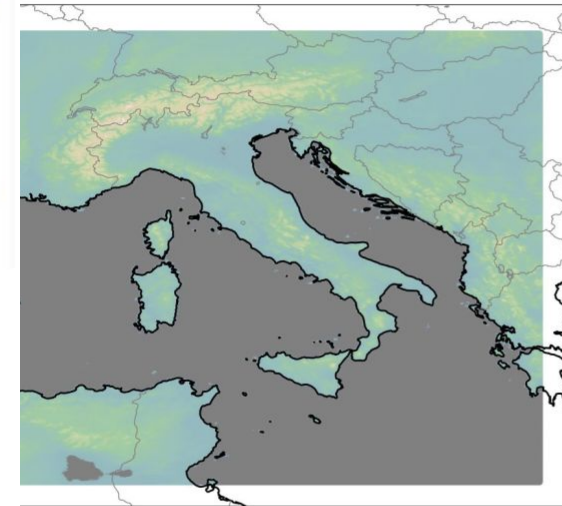
Sig. diff. (95%)

○ n.a.
no
yes

Experiment

○ ICON-2I
○ IFS

ICON-2I EPS



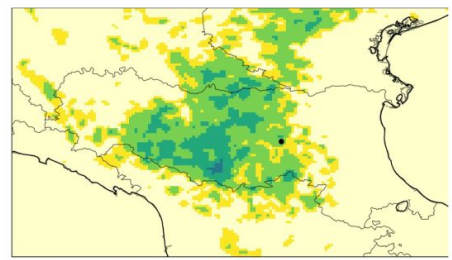
SPP case study: storm in Bologna, 2026 june 29-30th

ICON-2I	Experiments
Common Setup	Differences
• Grid : 2.2 km • v.l : 65 • Perturbed ICs : Kenda analysis • Initial Time : 202606282100 • BCs : from IFS-ENS first 20 members • Fc range : 51h • forecastTimes : 24, 27, 30 • Microphysics: 1-mom • parameter : tp 3h	- control [ctrl]: no model pert. - operational [ope] : phy. parameter pert. - SPP : from master ICON config. SPP_multi (rdepth, r_bsmin)

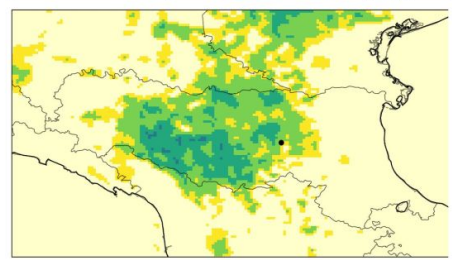
Introducing SPP (Stochastic Parameter Perturbation) in ICON

ENS mean 3h tp +24
18 - 21 UTC
IT : 2026-06-28
21:00

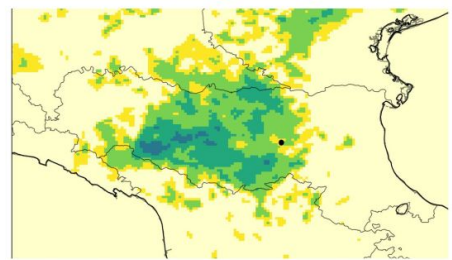
ope



SPP

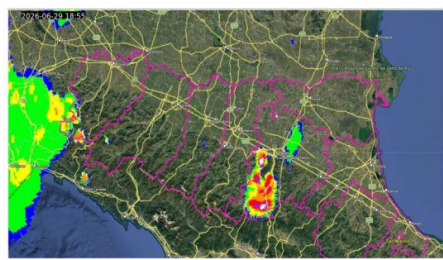


ctrl



Radar reflectivity
29/06/2026

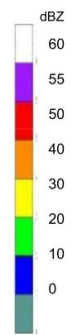
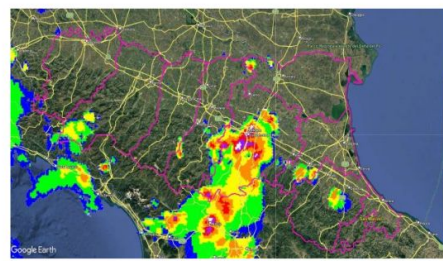
18:55 UTC



19:55 UTC

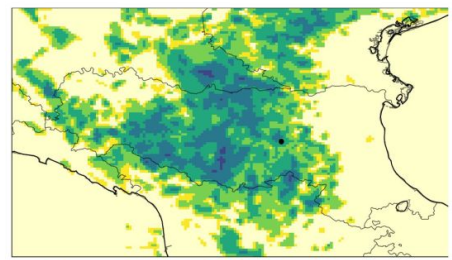


20:15 UTC

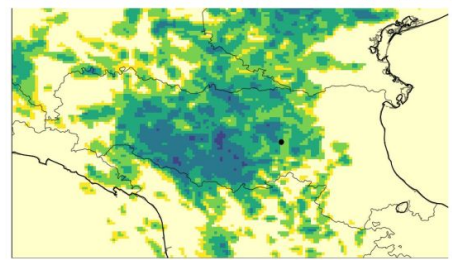


ENS spread 3h tp +24 IT : 2026-06-28
18 - 21 UTC 21:00

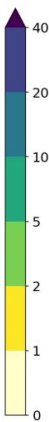
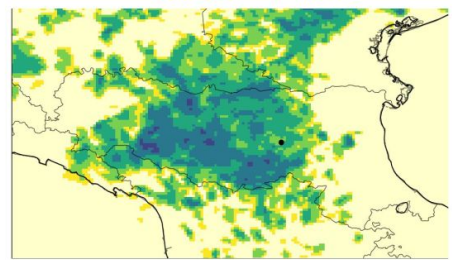
ope



SPP



ctrl



next: SPP evaluation for other cases;
implementation for new parameters

Recent updates on the Best-Member approach using satellite data

Pavel Khain, Amir Givati, Elyakom Vadislavsky, Yoav Levi
Israel Meteorological Service

Ensemble WG, GM 2026

Methodology

- During rainy days, ICON-EPS is running twice daily with 50 members, driven by EC-ENS for 30 hours
- Every hour, all 50 ICON-EPS members are automatically verified versus the radar, satellite and lightning data available during the last hour, and the best member for the current hour is defined
- This member is rerun till that hour with radar-data assimilation (LHN) and then continued as free run for additional 12 hours

Best member selection

A set of different scores is evaluated for every ensemble member:

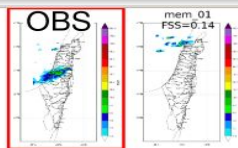
- S_R: precipitation score, vs radar (RMSE over upscaled data)
- S_M: max precip. score, vs radar (absolute error of max values)
- S_L: lightning score, vs ground measurements+MTG (FSS)
- S_T: cloud top temperature score, vs MTG (FSS)

All scores are normalized over worst member

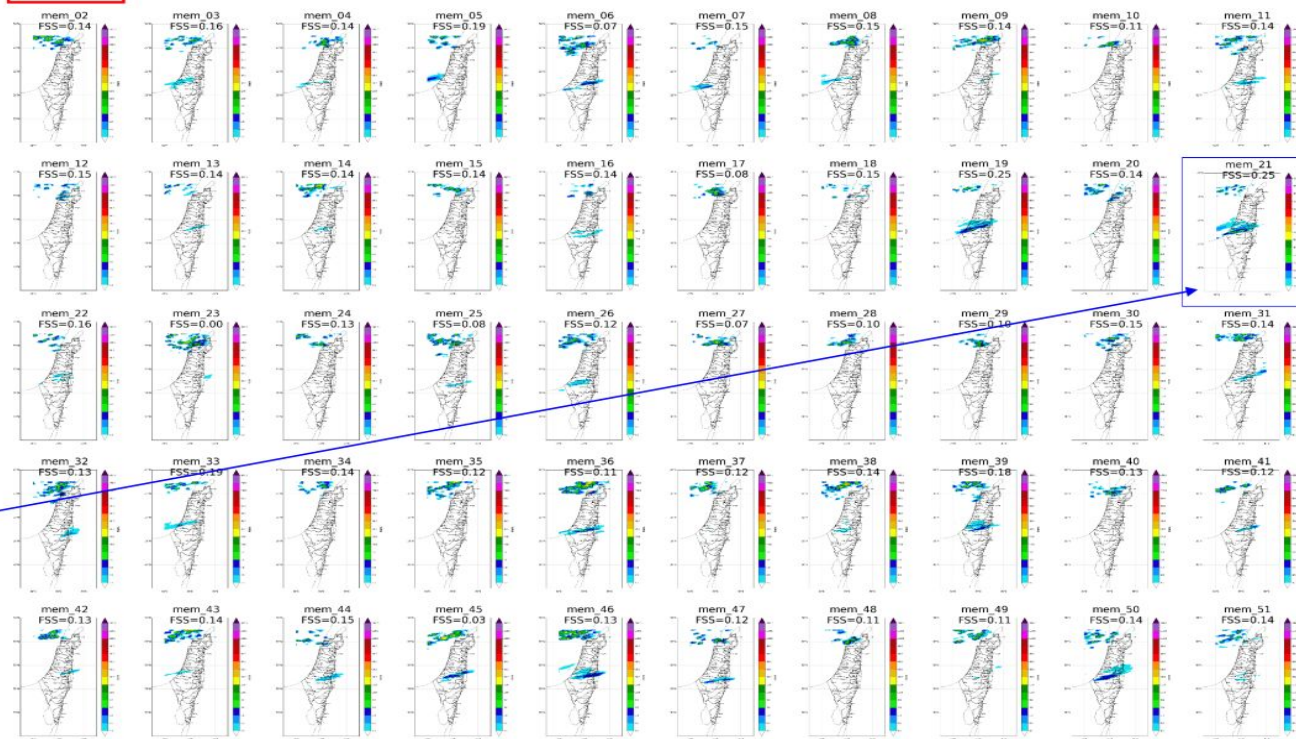
The final score is an empirically-chosen weighted average

Score	Meaning	weight
S_R	Precip. score	1
S_M	Max rain score	0.5
S_L	Lightning score	3
S_D	Max DBZ score	0
S_T	Cloud top temp	0.5

OBS
during the
last hour



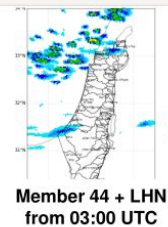
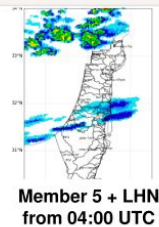
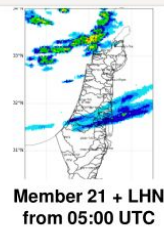
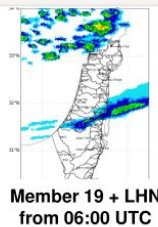
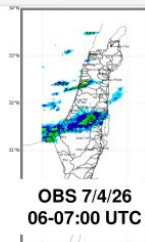
Example: 7/4/2026 05Z: member 21 is selected



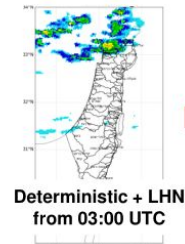
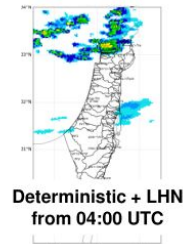
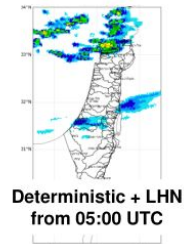
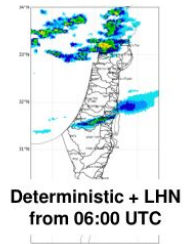
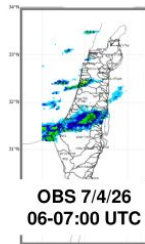
Best
ensemble
member
during the
last hour

How was the
forecast
2 hours
later?

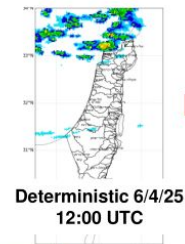
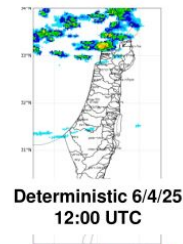
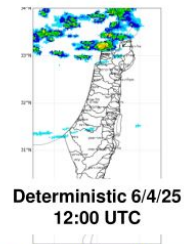
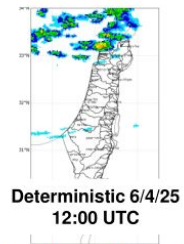
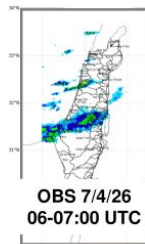
(on 7/4/2026 07Z)



Best member



Deterministic
+ LHN



Deterministic

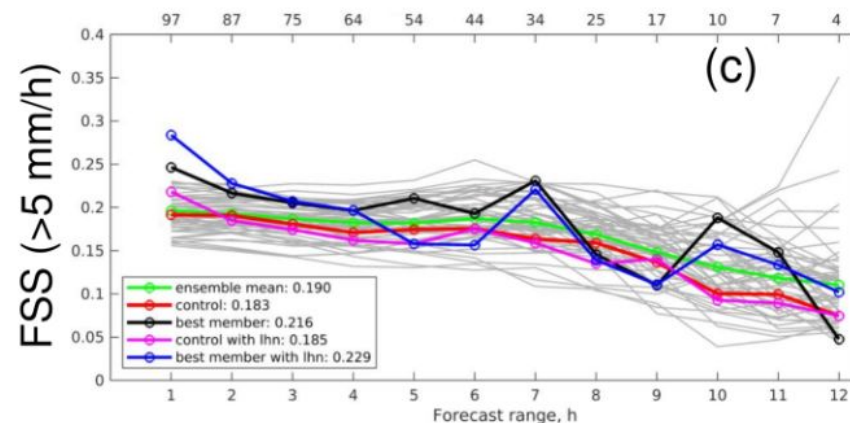
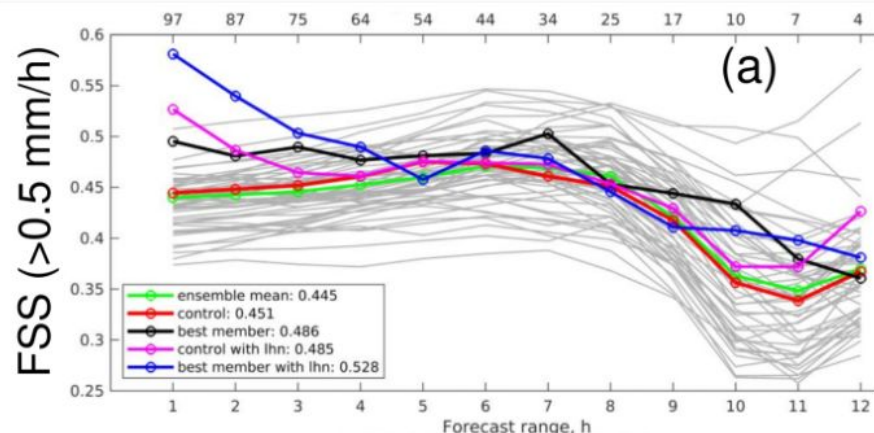


Results (verification over many events)

- ICON “best member” is better than any other option for the first 4 hours
- LHN on the “best member” is very beneficial in the first hours; at longer lead time its impact is variable

A lot of open questions related to the choice of the current best ensemble member:

- Metric?
- Focus on entire area or strongest cells?
- Time span to define the best member?
- Met. Fields to define the best member?
- New idea: run not only the best member, but an ensemble of several winners!





Operational development of EPS at IMGW



Operational development of EPS at IMGW

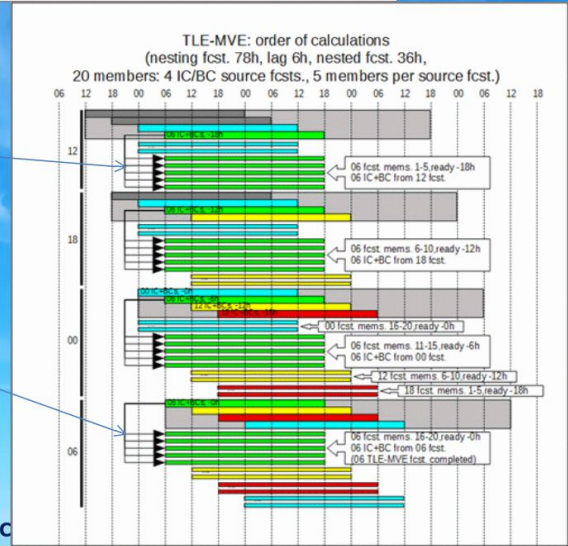
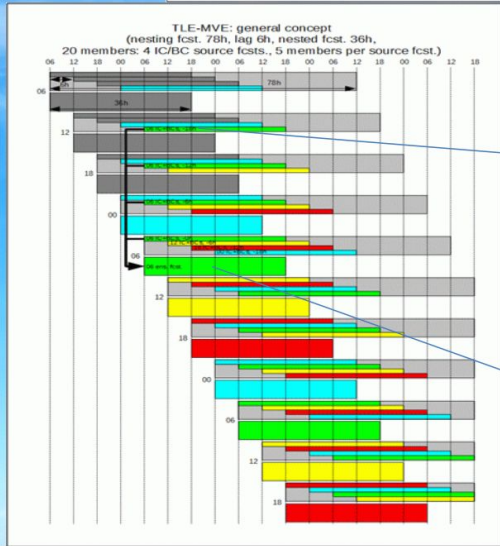
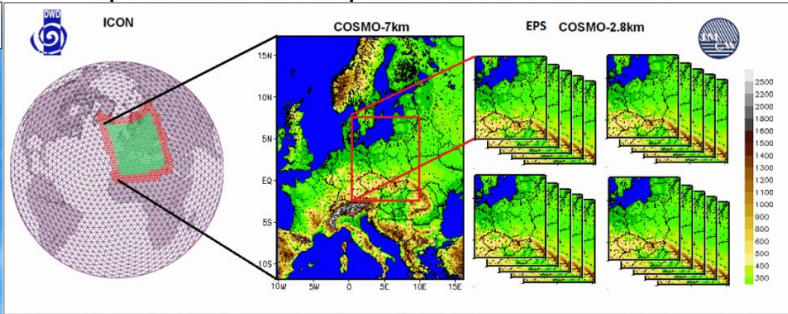
Andrzej Mazur, Tatiana Tabalchuk

LMM ZPN-COSMO IMGW-PIB



Concept and
implementation

Operational development of EPS at IMGW

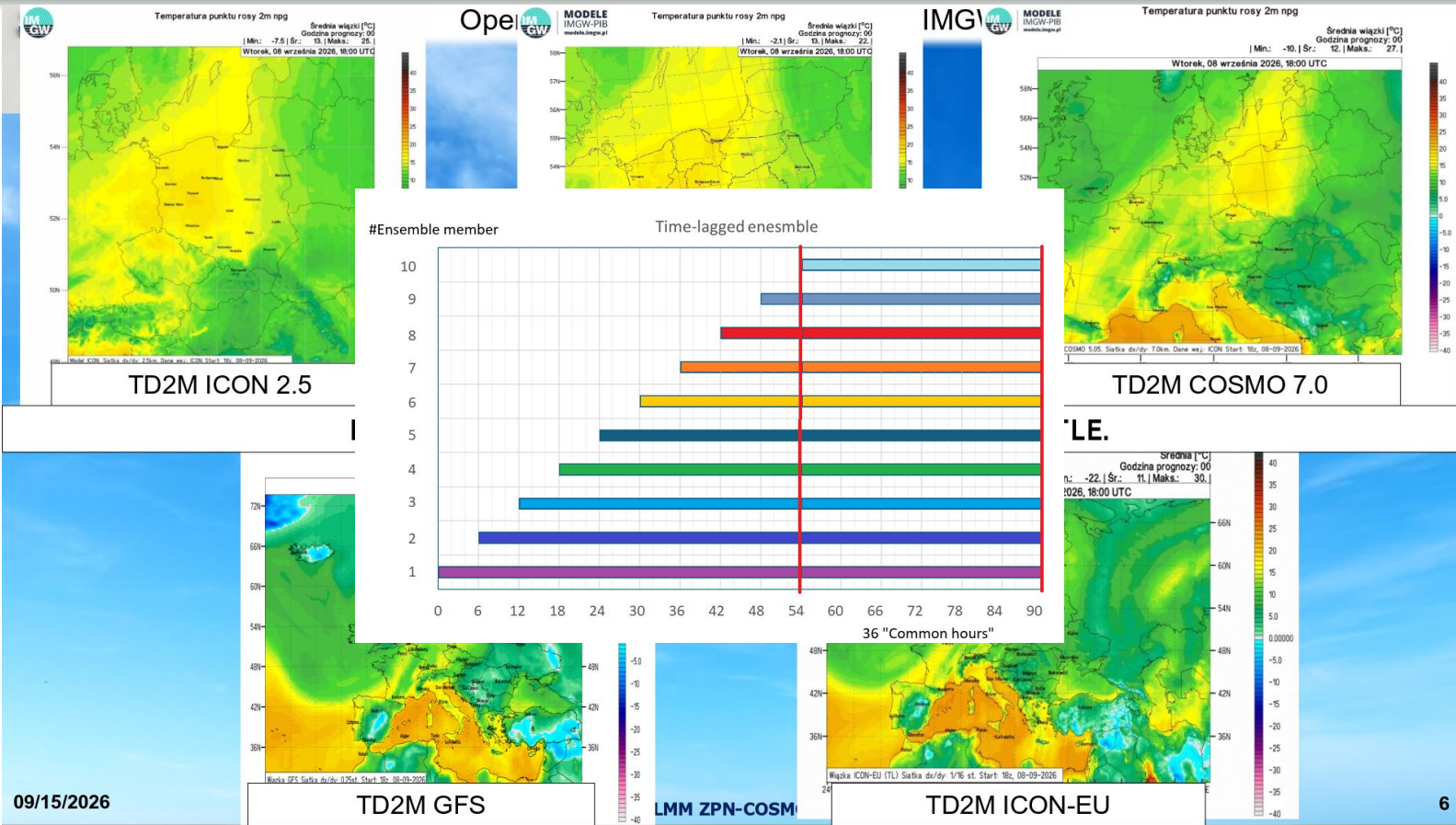


09/15/2026

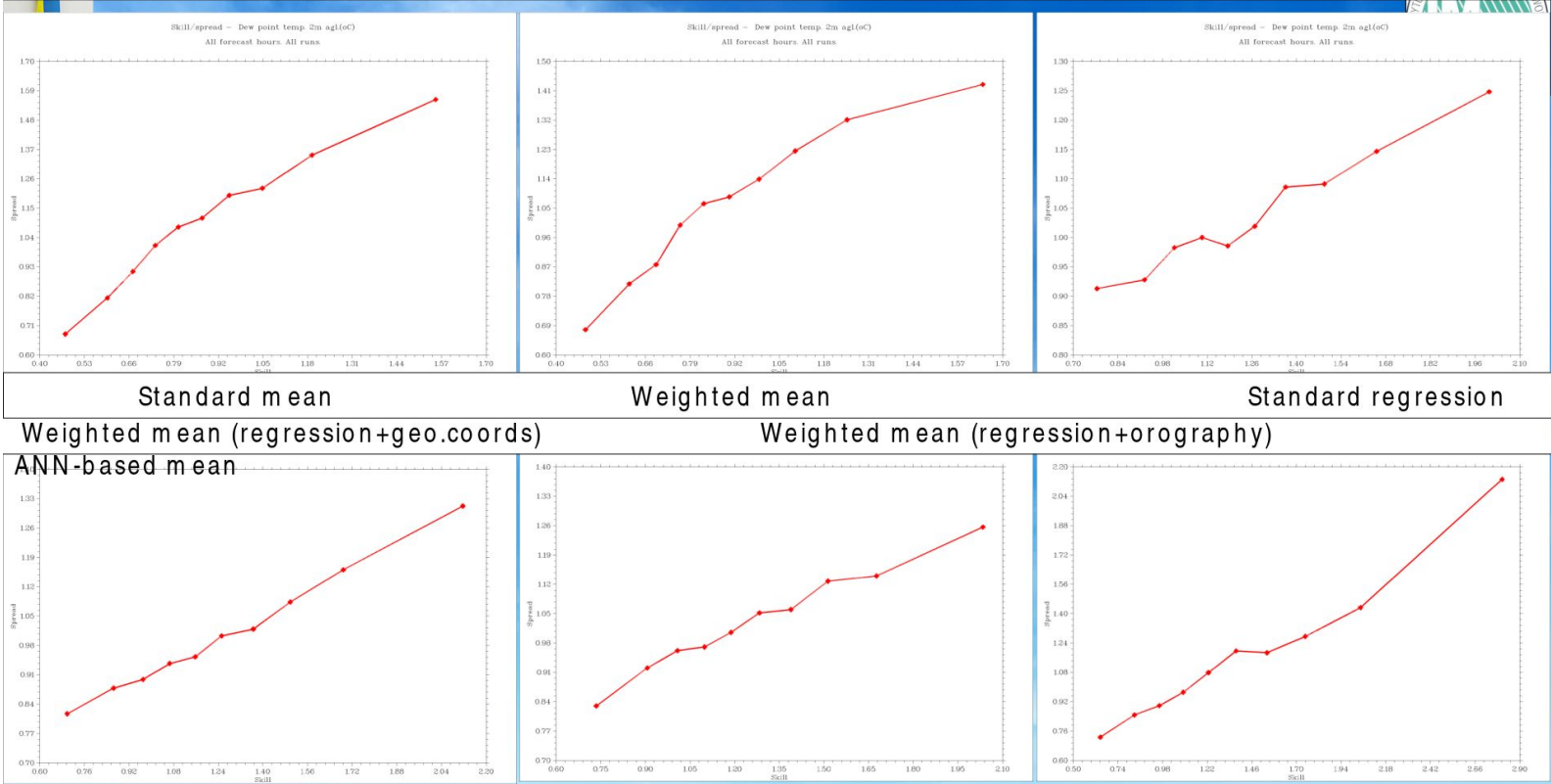
ZPN-C

3

Time lagged ensemble and superensemble



Spread-Skill charts; TD2M , "Superensemble", 60 members



09/15/2026

LMM ZPN-COSMO IMGW-PIB

26

Verification activities proposed:

- 1) Common verification (Dimitra, HNMS): all members, 3 hours frequency, subdomain, up to +48h; delivered every 3 months. *CARMA observations (Amalia); LEPS FF upladed to NMA ftp server*
- 2) Deterministic verification (Flora and Keloniki, HNMS): only “control” run, 3 hours frequency, full domain, up to +120h. *CARMA observations (Amalia); LEPS grib output made available on ATOS*
- 3) Scientific verification on subdomains
 - ARPAE: comparison with IFS-ENS and ARPAE-ENS on Italy. *Spatial verification of precipitation. Overlap with PP KAOS*
 - ARPA Piemonte (Naima): *fuzzy verification of precipitation, for ensemble mean and percentiles*
 - Greece, Poland (PP Kaos, task 3.1)
- 4) Comparison with IFS-ENS
Include ICON-LEPS in the operational ENS verification at DWD? Contact person: Harald Anlauf
- 5) *Alternative software by Michael Hoff, for spatial verification etc.*
- 6) *Production of “light” FF (hourly resolution, only surface) for comparison high res. observations (?)*

WG EPS

Thank you for your attention!