Ensemble developments in COSMO

Chiara Marsigli
Deutscher Wetterdienst

COSMO Working Group on Predictability and Ensemble Methods
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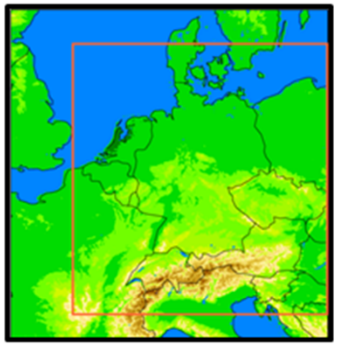
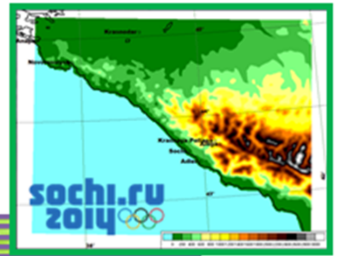
The COSMO ensembles

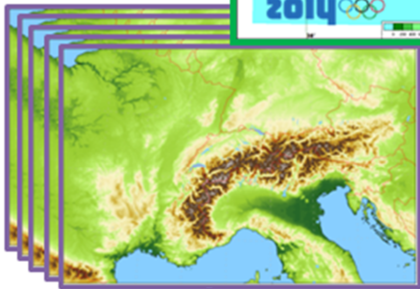
CONSORTIUM FOR SMALL SCALE MODELING COSMO

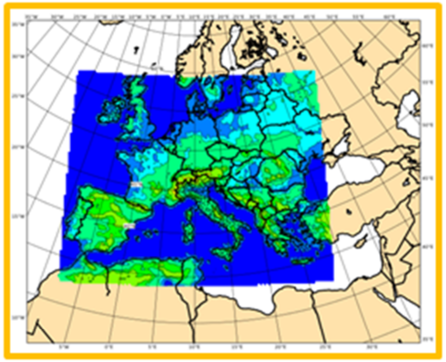
Ensemble systems

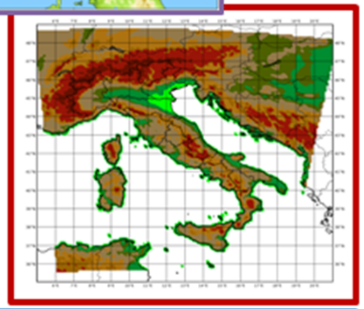
- COSMO-D2-EPS
- COSMO-E
- TLE-MVE
- COSMO-2I-EPS
- COSMO-IT-EPS
- COSMO-Ru2-EPS
- COSMO-LEPS
- COSMO-ME-EPS

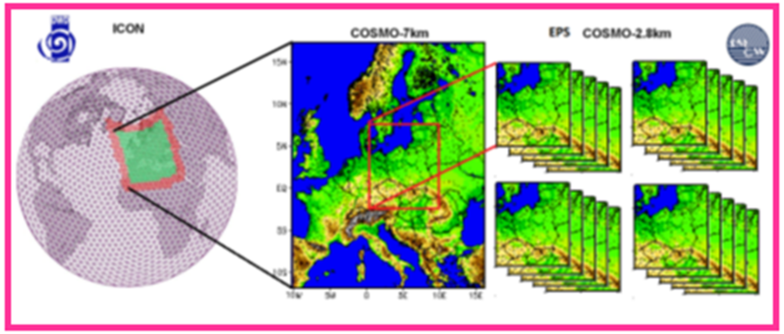


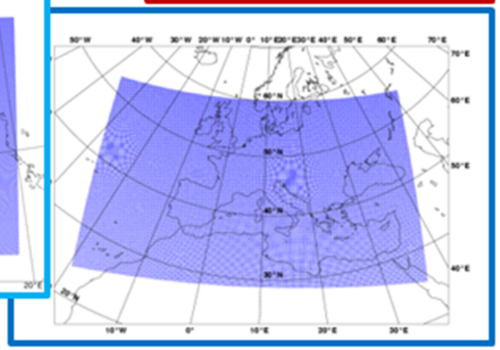












http://www.cosmo-model.org/content/tasks/workGroups/wg7

The COSMO ensembles

- the COSMO members develop and maintain several ensemble systems at the convection-permitting scale:
  - COSMO-D2-EPS, by DWD, operational, 2.2 km
  - COSMO-E, by MCH, operational, 2.2 km
  - TLE-MVE, by IMGW, operational, 2.8 km
  - COSMO-2I-EPS, by Arpae, pre-operational, 2.2 km
  - COSMO-IT-EPS, by COMET, pre-operational, 2.2 km
  - COSMO-Ru2-EPS, by RHM, for research, 2.8 km

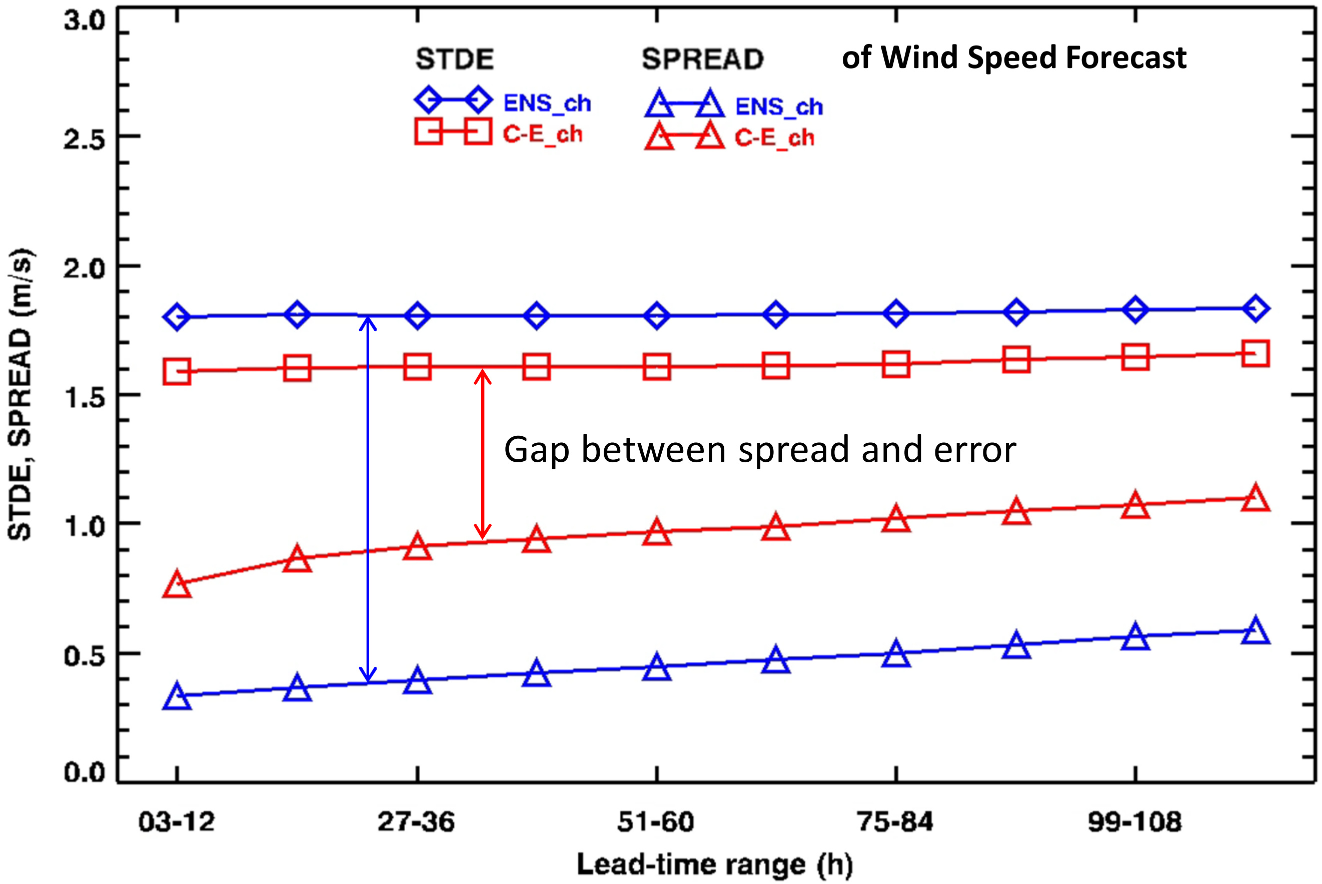
- COMET operates an ensemble at 7 km, COSMO-ME-EPS

- COSMO-LEPS is the Consortium ensemble, running since 2002, 7 km

Spread/skill relation

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

COSMO-E vs IFS-ENS over Switzerland for summer (JJA) 2018



P. Kaufmann, A. Walser - MCH

Model perturbation

- Developing a **model for the model error** (additive perturbation)
  - at DWD
  - at RHM
- Test of new model perturbations at MCH
  - Implementation of **iSPPT** in COSMO-E
  - evaluation of **KENDA analysis increments** to be used as model perturbations
- **Parameter perturbation**:
  - DWD: Transfer to ICON run at Limited-area (ICON-D2-EPS)
  - IMGW: combination of perturbations of few soil and upper air parameters

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EM-scheme: model for the model error (E. Machulskaya)

$$\frac{\partial\psi}{\partial t} = \left[\frac{\partial\psi}{\partial t}\right]_{\mathrm{det}} + \eta(t) \qquad \frac{\partial\eta}{\partial t} = -\gamma\eta + \gamma\nabla(\lambda^2\nabla\eta) + \sigma\xi(t)$$

ψ : prognostic variables (T, QV, U, V)

$\eta(t)$: noise field / model error, correlated in time and space

$\xi(t)$: Gaussian noise

σ, γ, λ: standard deviation and spatial and temporal correlation

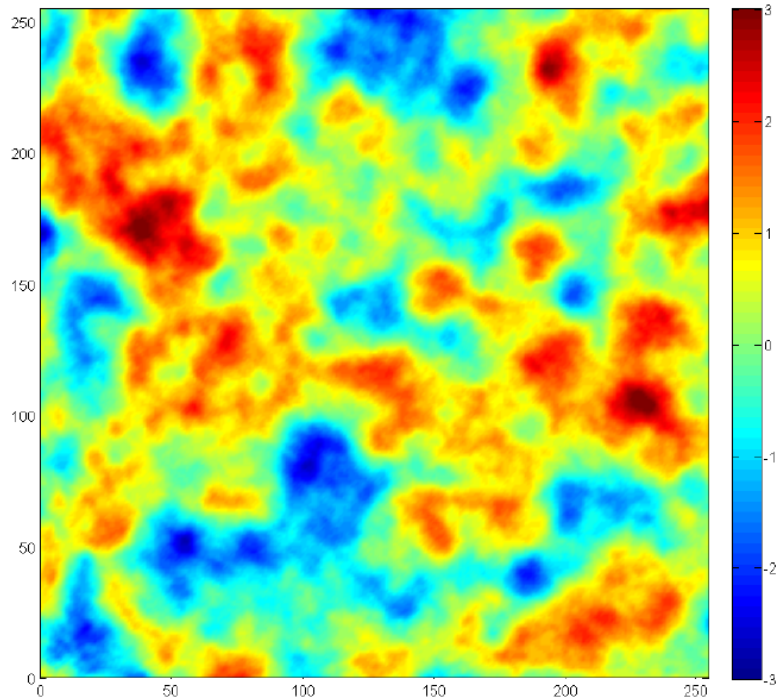
γ, λ and σ are weather-dependent and are derived from past data

- First extensive experiment of the scheme used in ensemble forecast started

C. Gebhardt, DWD

AMPT model perturbation scheme

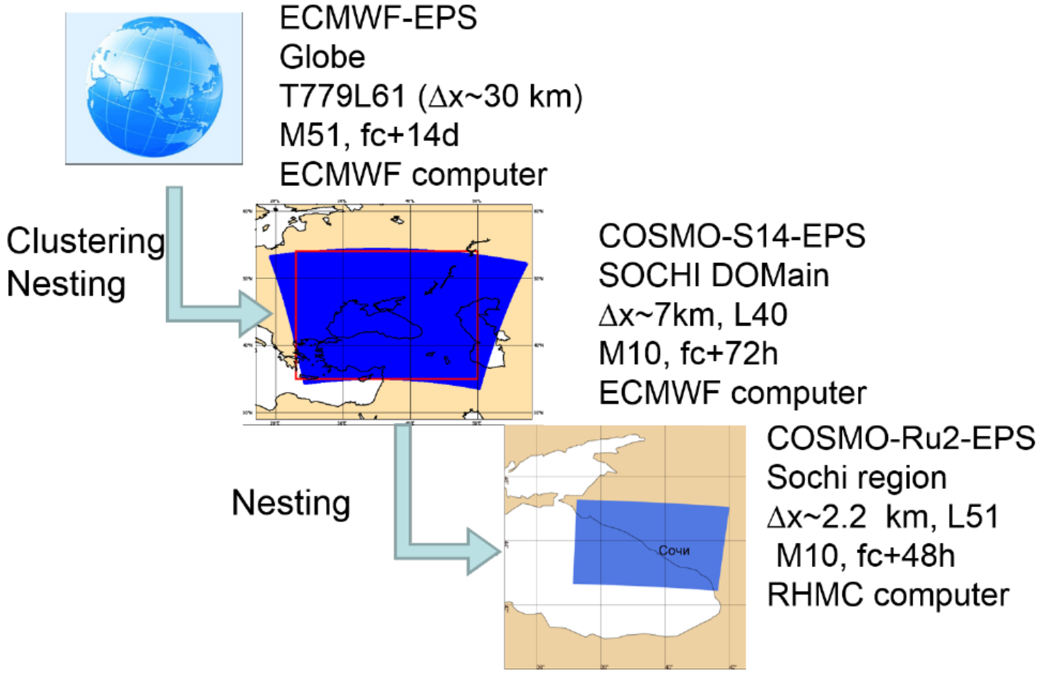
- Additive Model-error perturbations scaled by Physical Tendencies
- Based on the Stochastic Pattern Generator (SPG, Tsyrulnikov and Gayfulin 2017)
- The SPG works on 2-D and 3-D limited area spatial domains with meaningful and tunable spatio-temporal structure
- The perturbations are the mutually uncorrelated spatio-temporal (SPG-generated) random fields scaled by the area averaged physics tendency $|\mathcal{P}|$
- $|\mathcal{P}|$ is updated every hour at every level and for every field



M. Tsyrulnikov, E. Astakhova - RHM

AMPT model perturbation scheme

- Domain centered at Sochi. Half of the domain is Black sea, half is land with mountains.
- Resolution: 2.2 km, 50 levels
- Ensemble size 10
- Initial and lateral boundary conditions from COSMO-LEPS adapted for a larger Sochi region (resolution 7 km), made by the Italian colleagues.
- Time period: February - March 2014



M. Tsyrulnikov, E. Astakhova - RHM

AMPT model perturbation scheme

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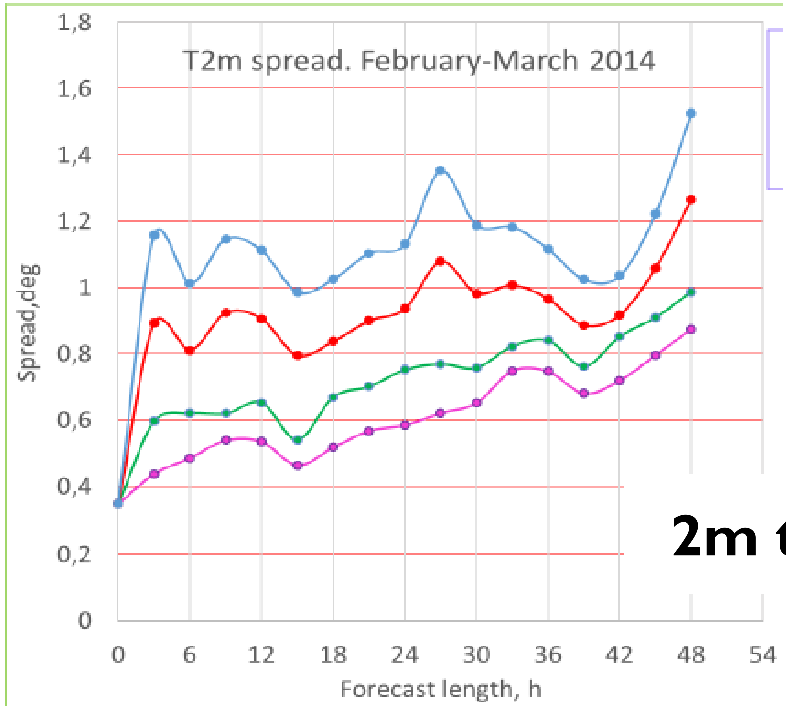
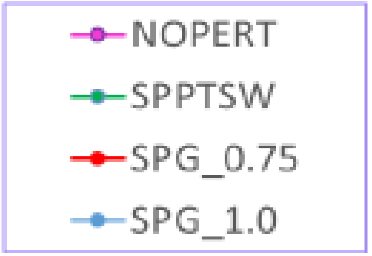
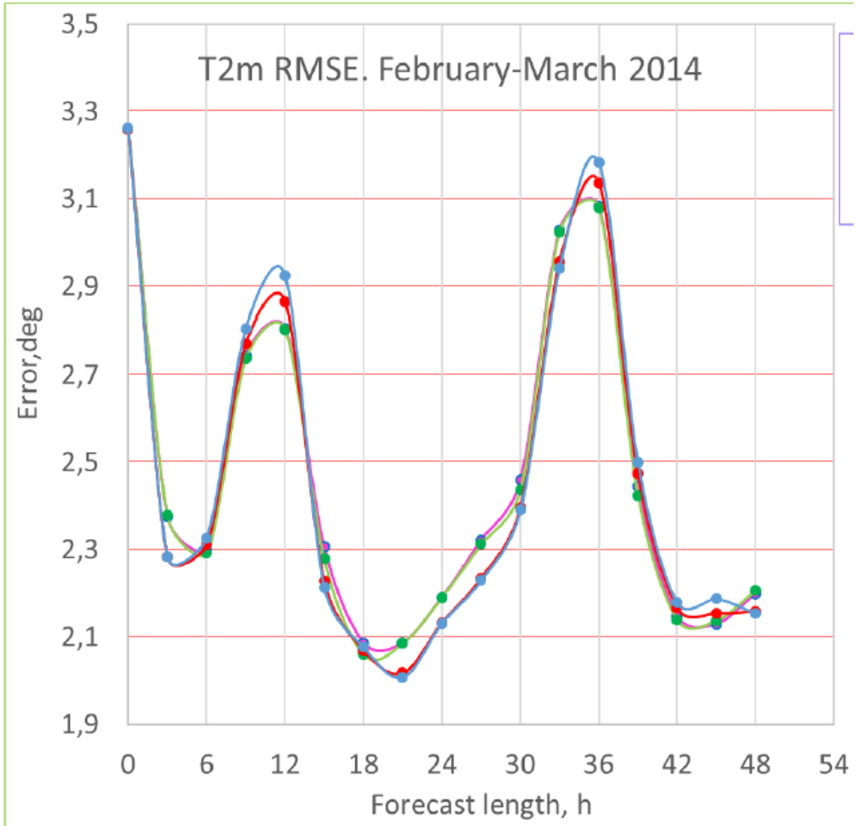
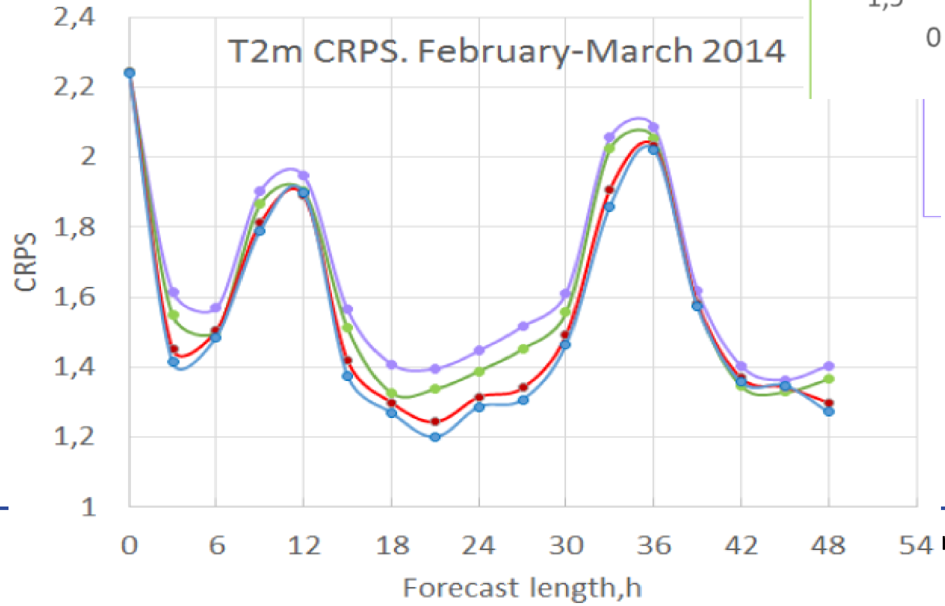




2m temperature





M. Tsyrulnikov
E. Astakhova
RHM

AMPT model perturbation scheme

- Status:
  - Tapering in the lower troposphere is switched off
  - An upper-level humidity tapering is introduced
  - Hydrometeors: only at grid points with non-zero concentrations the perturbations are added
- Outlook:
  - Implementation of SPG/AMPT in ICON (in the LAM setup).
  - Setting up a new LAM-EPS in central Russia
  - Improvement in the generation of AMPT wind perturbations (switching from u, v to stream function and velocity potential)
  - Further investigation of the role of humidity and hydrometeor perturbations

M. Tsyrulnikov, E. Astakhova - RHM

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iSPPT (independent SPPT)

- independent stochastically perturbed physical tendencies (Christensen et al., 2017):

$$\frac{\partial X}{\partial t} = D^X + K^X \sum_{i=1}^{N} (1 + rand_i)\, P_i^X$$

X = meteorological variable (e.g. T, U, V etc.)
D = dynamics
K = horizontal diffusion
i = radiation, turbulence, microphysics, shallow convection
P = physical parametrization tendency

Turbulence

Radiation

Microphysics

Shallow convection

L. Füzer, A. Walser, MCH

iSPPT: experiment setup

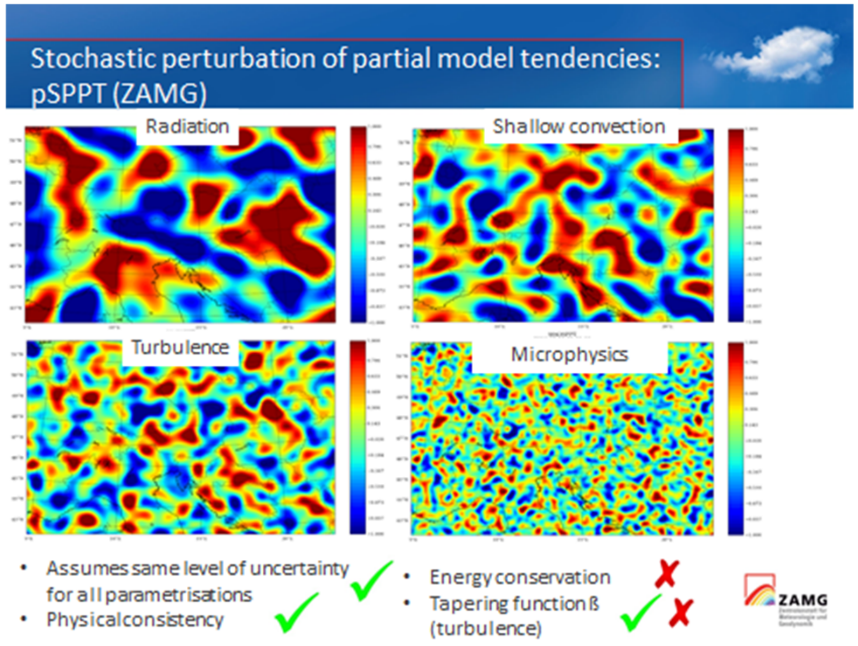
- ~ COSMO-E
- Members: 16
- Lead time: 48 hours
- Analysis: KENDA
- LBCs: IFS-ENS

- Time period summer: 06-06-2018 to 26-06-2018
- Time period winter: 08-12-2017 to 28-12-2017
- Number of runs per exp: 10 (initialized every 2^{nd} day)

L. Füzer, A. Walser, MCH

iSPPT: experiment

Exp ID	200 Ref (SPPT)	204 Dec (iSPPT)	206 Dec (iSPPT)
dlat/dlon_rn_rad	5.0	5.0	**5.0**
dlat/dlon_rn_shc		5.0	**2.0**
dlat/dlon_rn_mic		5.0	**0.5**
dlat/dlon_rn_tur		5.0	**1.0**
stdv_rn_tur	1.0	1.0	1.0
stdv_rn_rad		1.0	1.0
stdv_rn_shc		1.0	1.0
stdv_rn_mic		1.0	1.0
range_tur	0.8	0.8	**0.99**
range_rad		0.8	**0.99**
range_shc		0.8	**0.99**
range_mic		0.8	**0.99**



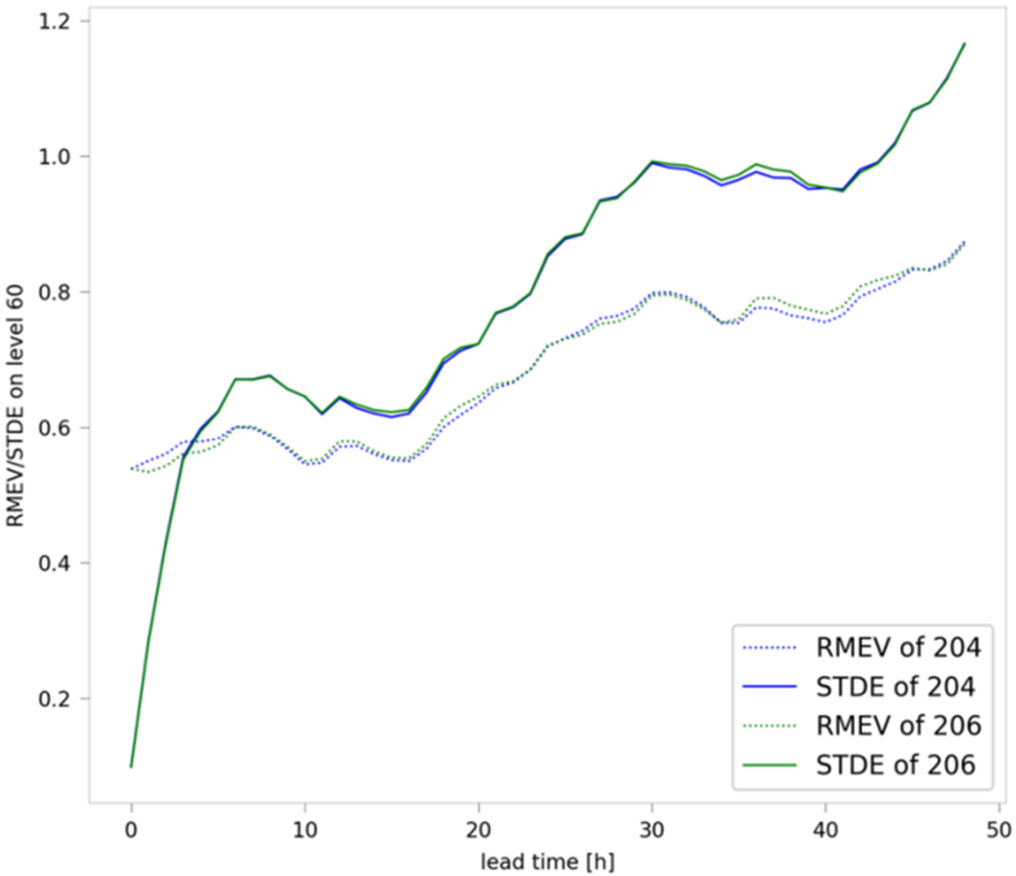
Courtesy Clemens Wastl, ZAMG

- spread loss due to smaller correlation length counteracted with larger range for random numbers
- range > 1.0 change sign of tendency → model crashes

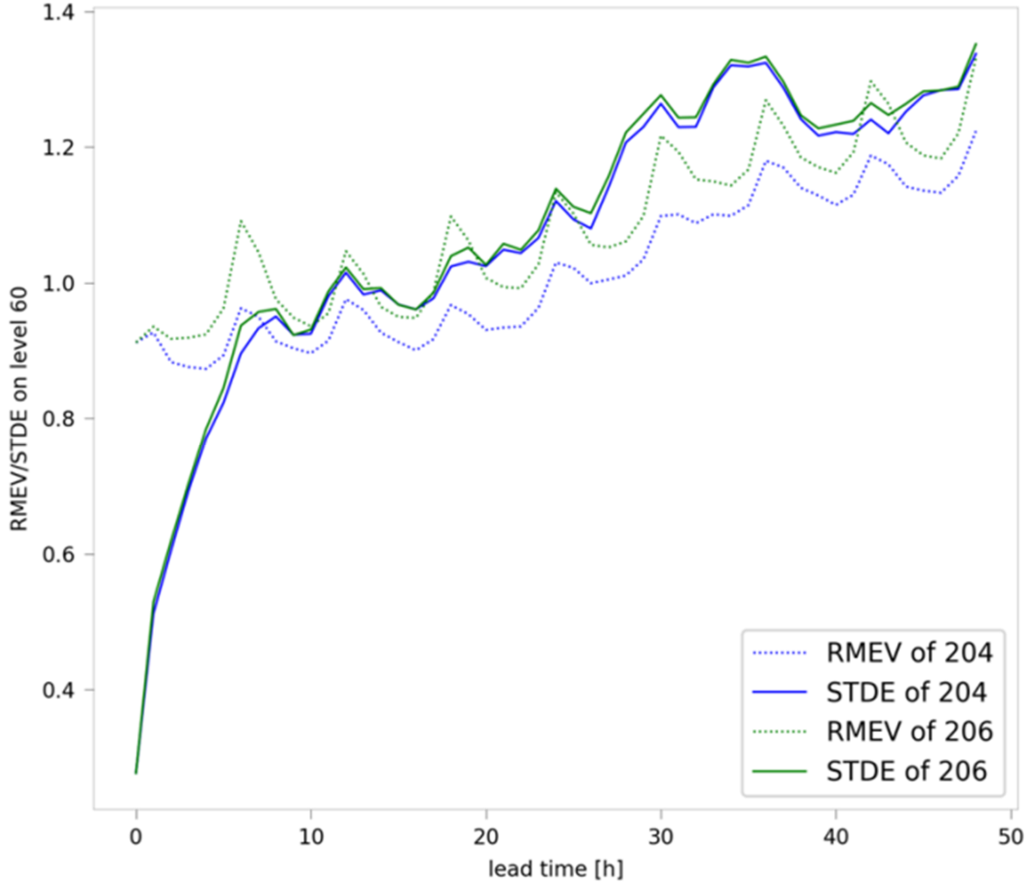
L. Füzer, A. Walser, MCH

RMEV (spread) vs. STDE (error), winter

Temperature, lowest model level



Wind speed, lowest model level

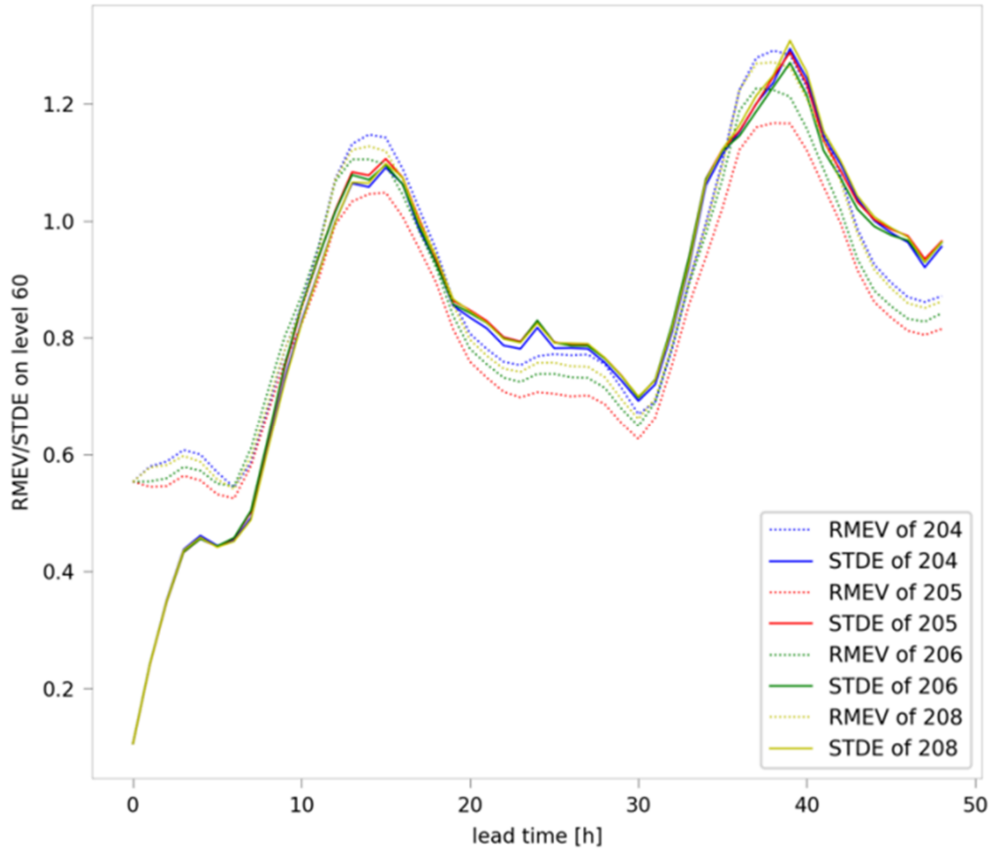


L. Füzer, A. Walser, MCH

KENDA ensemble mean analysis used as truth

RMEV (spread) vs. STDE (error), summer

Temperature, lowest model level



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KENDA ensemble mean analysis used as truth

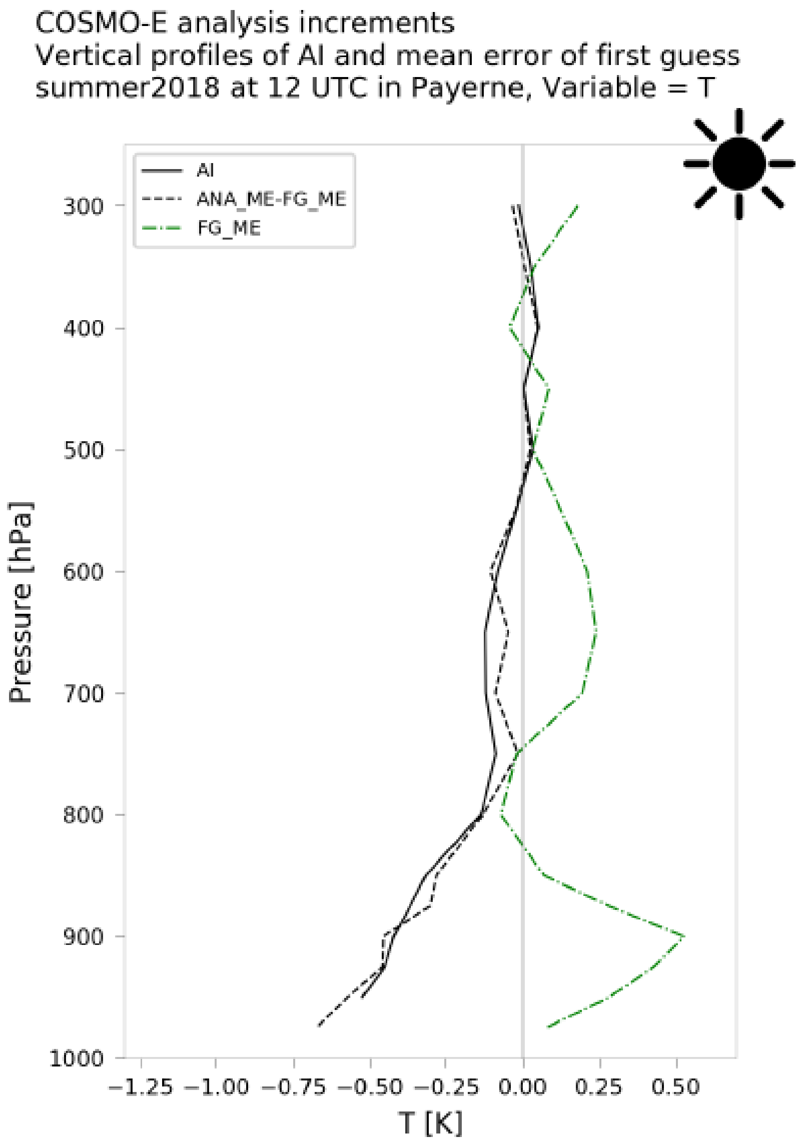
Summary of iSPPT experiment results

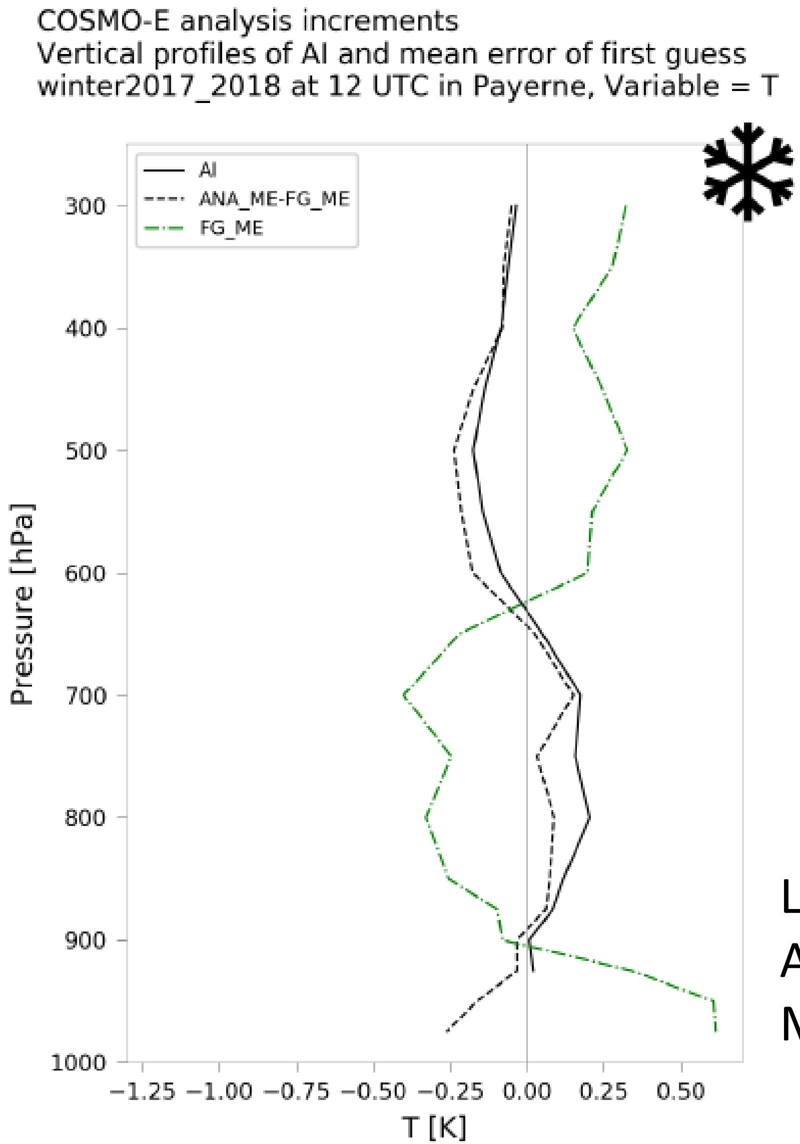
- iSPPT does not improve spread-error relationship in COSMO-E per se
- in contrast to Christensen et al. (2017) no tendencies from deep convection
- risk for unphysical values and stability issues (CFL) with larger ranges than +/- 0.9 for the random numbers
- model crashes with range > 1, i.e. switch sign of tendency
- since we push the perturbations to the limits the additional flexibility provided by iSPPT is hardly of any use in COSMO-E

L. Füzer, A. Walser, MCH

KENDA analysis increments as model perturbations

- estimate to what extent the Analysis Increments can be considered as a proxy for model error to generate ensemble perturbations (Piccolo et al., 2017)





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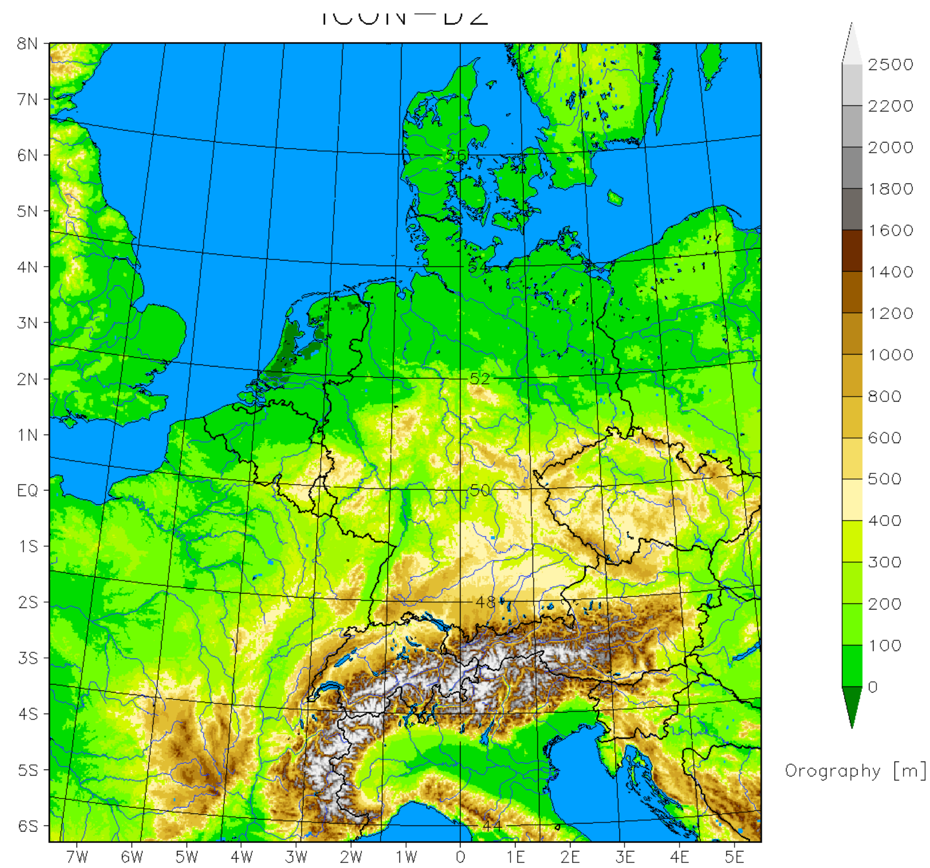
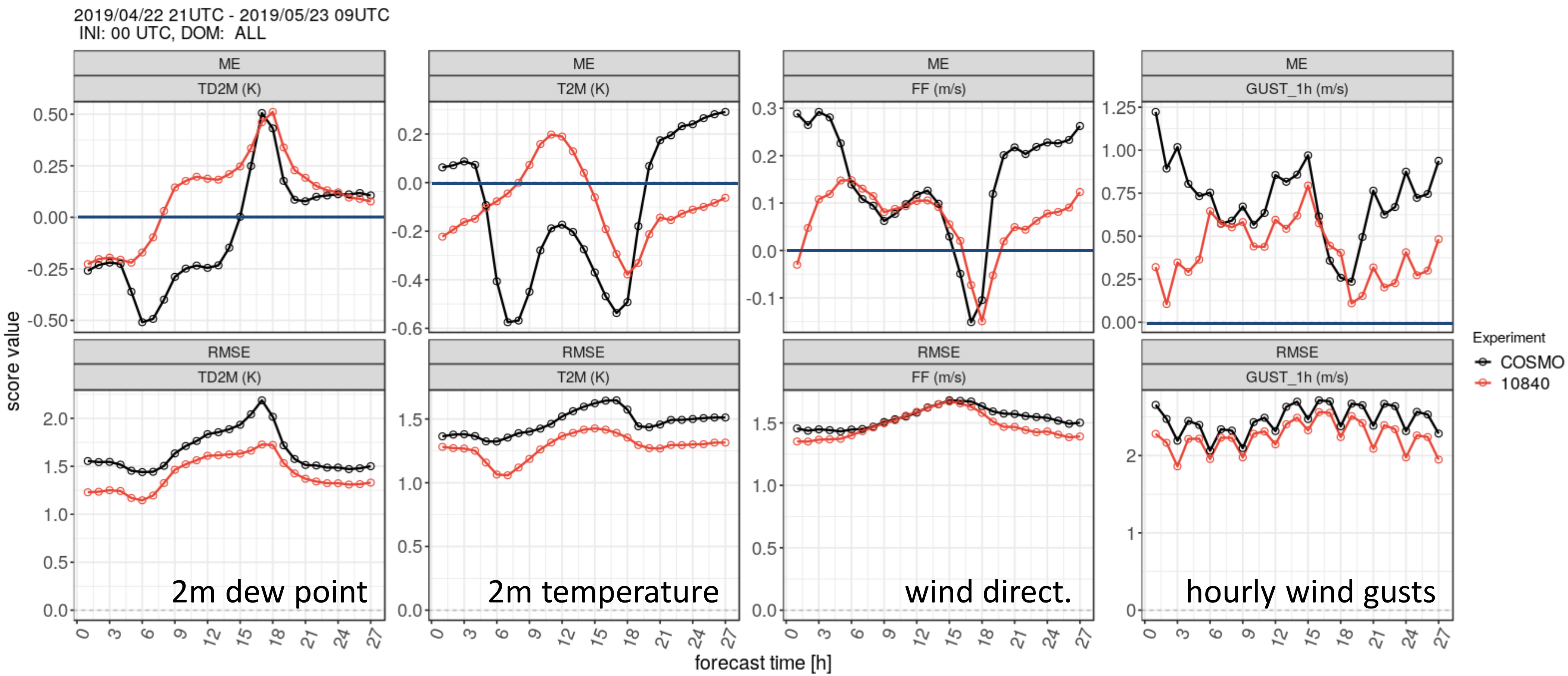
ICON-D2-EPS

- ~ 2.1 km icosahedral grid, 65 vertical levels
- 20 members
- 00, 03, 06, 09, 12, 15, 18, 21 UTC
- 27 hours (45 hours for 03 UTC)
  (planned: 48 hours)
- perturbation of
  - BC: ICON-EU-EPS
  - physics (randomized pert. 2-3 different values for each of 17 parameters)
  - IC: KENDA
- pre-operational: October 2019
- operational in Q4 2020



C. Gebhardt, DWD

Bias and RMSE for 00 UTC runs (EPS mean)



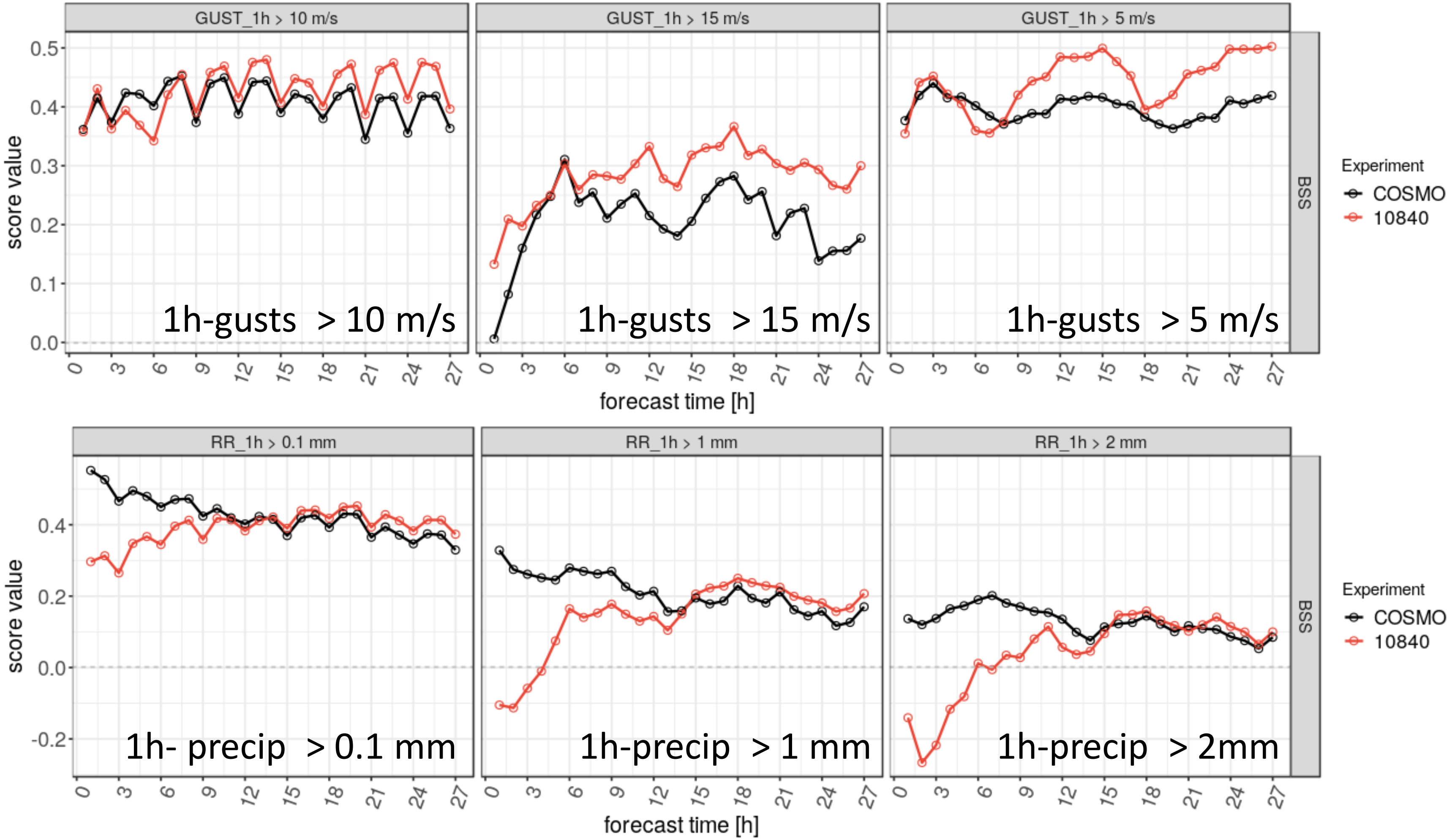
ICON-D2-EPS

COSMO-D2-EPS

Very similar to score differences between deterministic ICON-D2 and COSMO-D2

BSS 00 and 12 UTC

22nd April – 23rd May 2019



ICON-D2-EPS

COSMO-D2-EPS

No perturbed Initial Conditions

Other ensemble developments

- **post-processing** methods for the CP ensembles (severe weather)
  - Calibration at IMGW
  - Product generation at COMET (SRNWP-EPS of EUMETNET)
- improvement of **Initial and Boundary Conditions** for the CP ensembles
  - MCH: compare COSMO-E with IFS-ENS vs. ICON-EPS BCs, primarily for short-range forecasts
  - DWD: test selection of KENDA analyses for initialising the ensemble forecast
- transition to **ICON-LAM** for the ensembles

TLE-MVE for an High Impact Weather event

CONSORTIUM FOR SMALL SCALE MODELING COSMO

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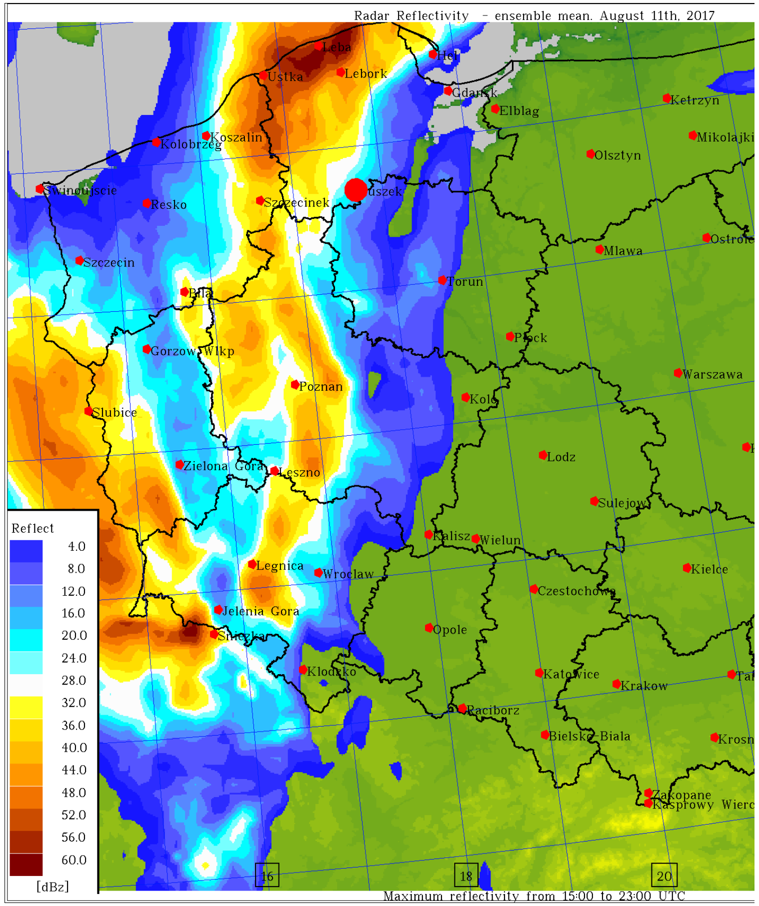
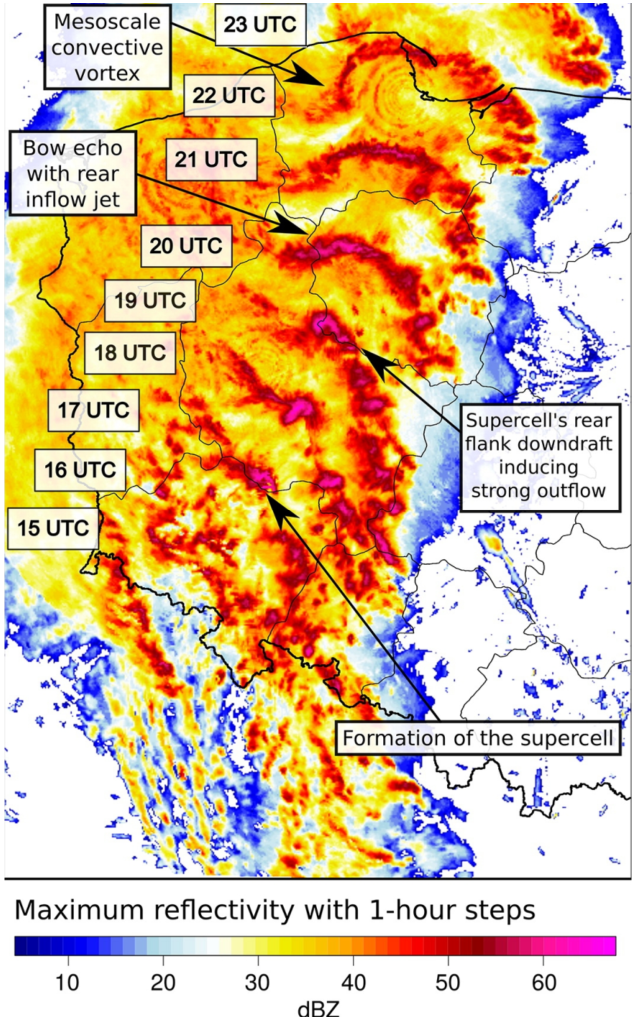
DWD

radar reflectivity forecast
ensemble mean

observed reflectivity
Polish radar network





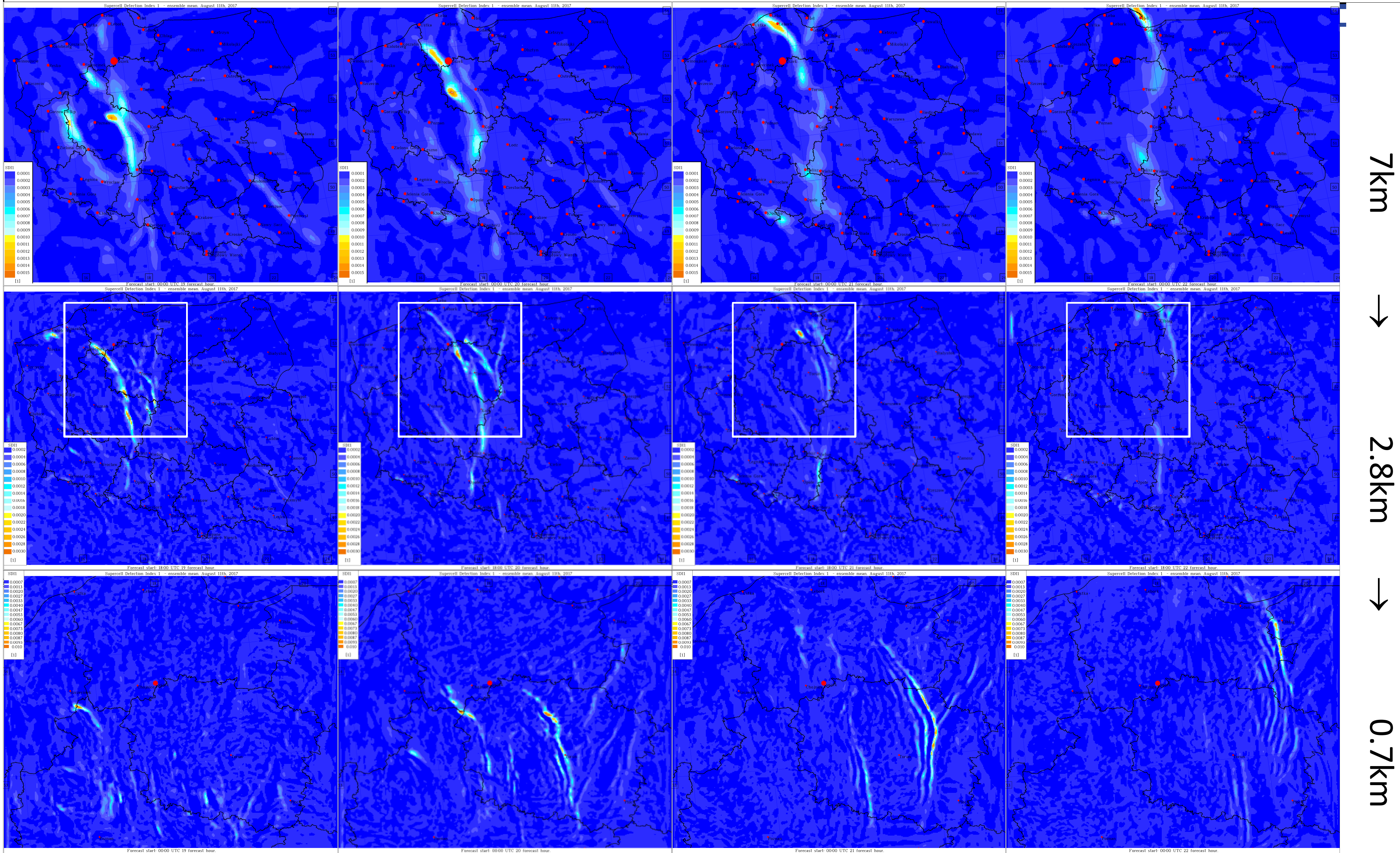
A. Mazur, G. Duniec, IMGW

from Taszarek *et al.* (2019): Derecho Evolving from a Mesocyclone

Single case – HIW event from 7 to 0.7km

DWD

Supercell Detection Index (SDI), ensemble mean



19:00 20:00 21:00 22:00

Suszek, August 11th, 2017

Concluding remarks

- It is difficult to perturb the model!

- Development of a model for the model error is promising
- To be combined with studying the predictability and uncertainties in the processes, to go towards stochastic parametrizations
- Perturbed parameters still provide a valuable and “safe” approach
- No positive impact of using iSPPT with respect to SPPT in Switzerland
- How to use and interpret the ensemble forecast? Work (with the forecasters) on ensemble interpretation, products, upscale, neighbourhood …