APSU Priority Project

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Deutscher Wetterdienst

Outline

- APSU Priority Project running from March 2018 to August 2020
- Participants:
  - Arpae
  - COMET (Marcucci)
  - DWD (Gebhardt, Machulskaya)
  - IMGW (Duniec, Interewicz, Mazur)
  - MeteoSwiss (Arpagaus, Füzer, Walser)
  - RHM (Alferov, Astakhova, Gayfulin, Tsyrulnikov)
- CP ensemble developments, focus on: representation of model uncertainty, calibration and post-processing for ensemble, transition to ICON-LAM for ensembles

WG7 - Priority Project APSU

- development of **model perturbation** methodologies (**Task 1, 2, 3**):
  - At DWD:
    - test of the **EM-scheme** (also: implementation in ICON-EPS)
    - run of **ICON-D2-EPS** experiments with parameter perturbation (Task 6)
  - At MCH:
    - evaluation of **KENDA analysis increments** to be used as model perturbations
    - Implementation of **iSPPT** in COSMO-E: results not satisfactory (work stopped)
  - At RHM:
    - **AMPT scheme** (Additive Model error perturbations scaled by Physical Tendencies), using the SPG. Verification comparing with SPPT scheme
  - At IMGW:
    - evaluation of the perturbation of soil surface temperature, and of the combination of **perturbations of few soil and upper air parameters**

WG7 - Priority Project APSU

- **post-processing** methods for the CP ensembles (severe weather) (**Task 4**)
  - Calibration at IMGW
  - Product generation at COMET (SRNWP-EPS of EUMETNET)
- improvement of **Initial and Boundary Conditions** for the CP ensembles (**Task 5**):
  - MCH: compare COSMO-E with IFS-ENS vs. ICON-EPS BCs, primarily for short-range forecasts (start in autumn by an internship)
  - DWD: test selection of KENDA analyses for initialising the ensemble forecast (when resources will be available)
- transition to **ICON-LAM** for the ensembles (**Task 6**): planning to be refined/defined
  - discussion in WG7 on Monday

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

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

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

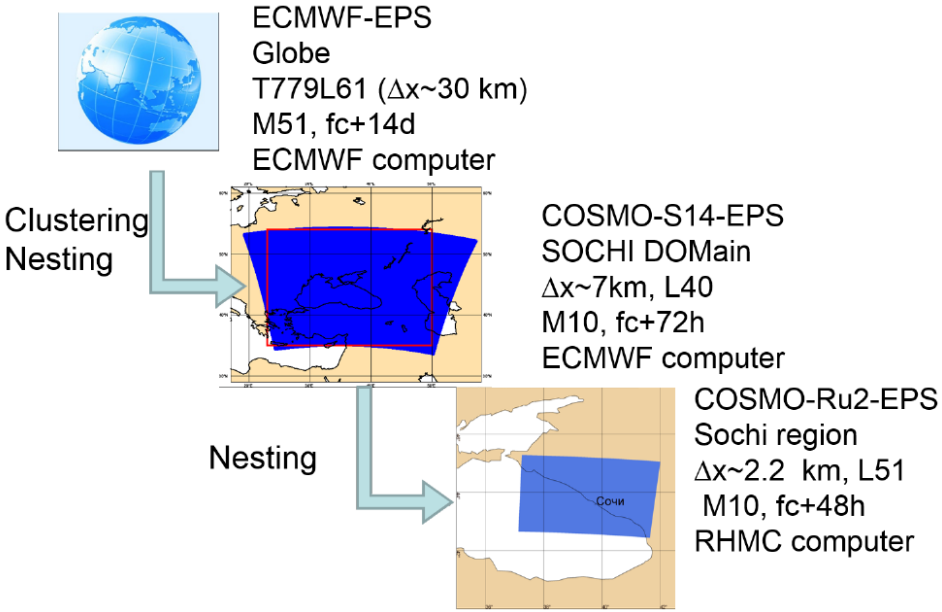
AMPT model perturbation scheme

- A tool for model-error simulation in LAM EPS/EDA, based on SPG
- The SPG works on 2-D and 3-D limited area spatial domains with meaningful and tunable spatio-temporal structure
- AMPT implements the SPG in the additive mode with an automatically selected magnitude
- AMPT works in COSMO and perturbs T, p, u, v, qv, qc, qi
- The AMPT model error perturbations are the mutually uncorrelated spatio-temporal (SPG-generated) random fields scaled by the area averaged (in the horizontal) physics tendency $|\mathcal{P}|$
- $|\mathcal{P}|$ is updated every hour at every level for every field.

M. Tsyrulnikov
E. Astakhova
RHM

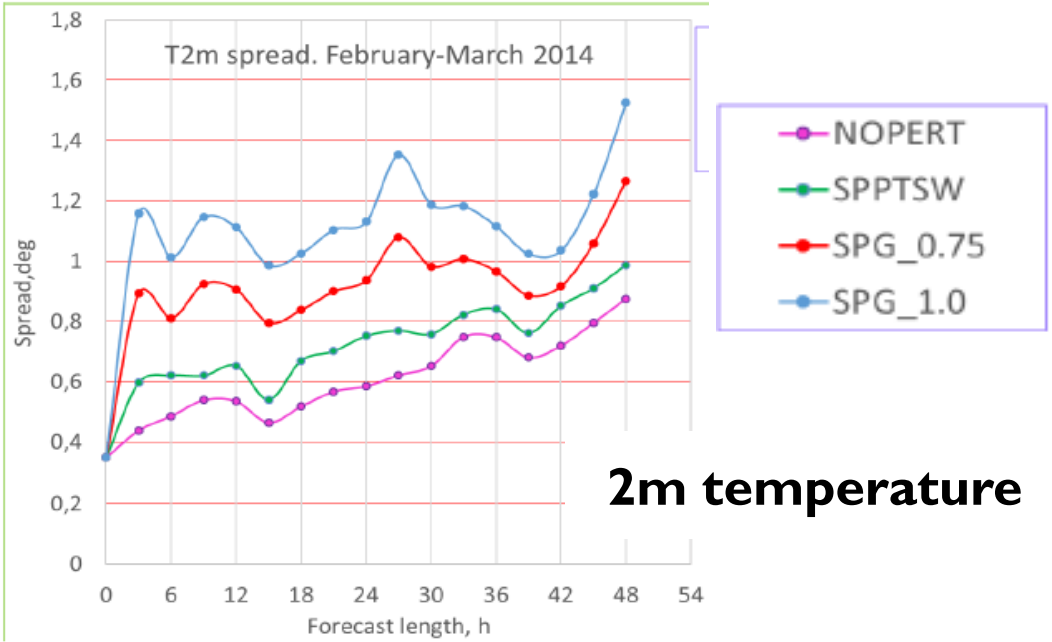
AMPT model perturbation scheme

- 300*400 km area centered at Sochi (latitude 44N). Half of the domain is Black sea, another half is land with mountains.
- Resolution: 2.2 km, 50 levels
- Ensemble size 10
- Initial and lateral boundary conditions for ensemble members are taken from COSMO-LEPS adapted for a larger Sochi region (resolution 7 km), made by the Italian colleagues.
- Time period: February - March 2014

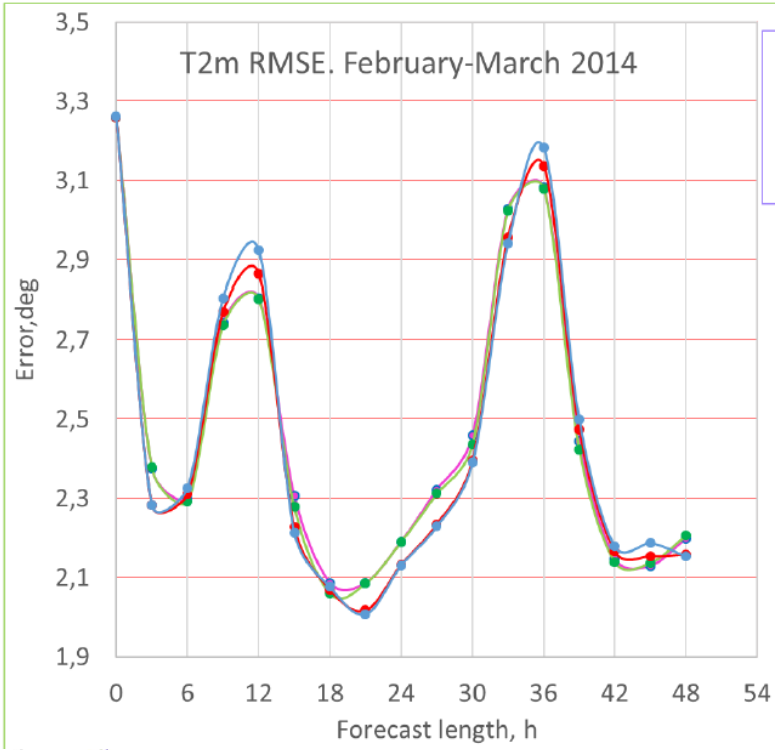


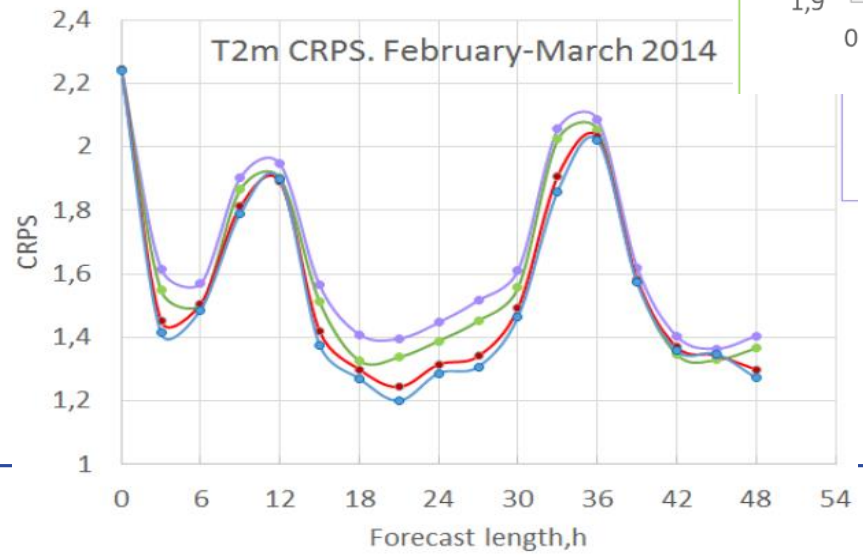
M. Tsyrulnikov
E. Astakhova
RHM

AMPT model perturbation scheme



2m temperature





M. Tsyrulnikov
E. Astakhova
RHM

AMPT model perturbation scheme: plans

- 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:
  - transfer testing from COSMO to ICON
  - 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

iSPPT (independent SPPT)

- independent stochastically perturbed physical tendencies:

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

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

L. Füzer, A. Walser, MCH

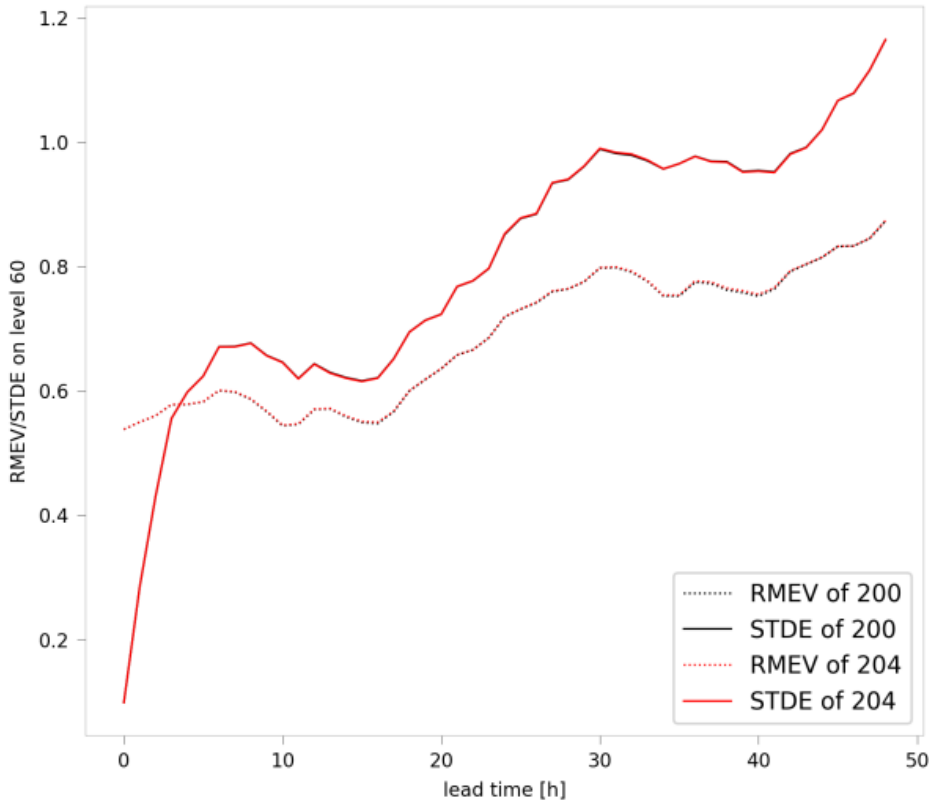
iSPPT: experiment setup

- Model: COSMO 5.0+
- iSPPT not ported to GPU
- only limited CPU resources available
- 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 2nd day)

L. Füzer, A. Walser, MCH

Temp RMEV vs. STDE, k=60, winter



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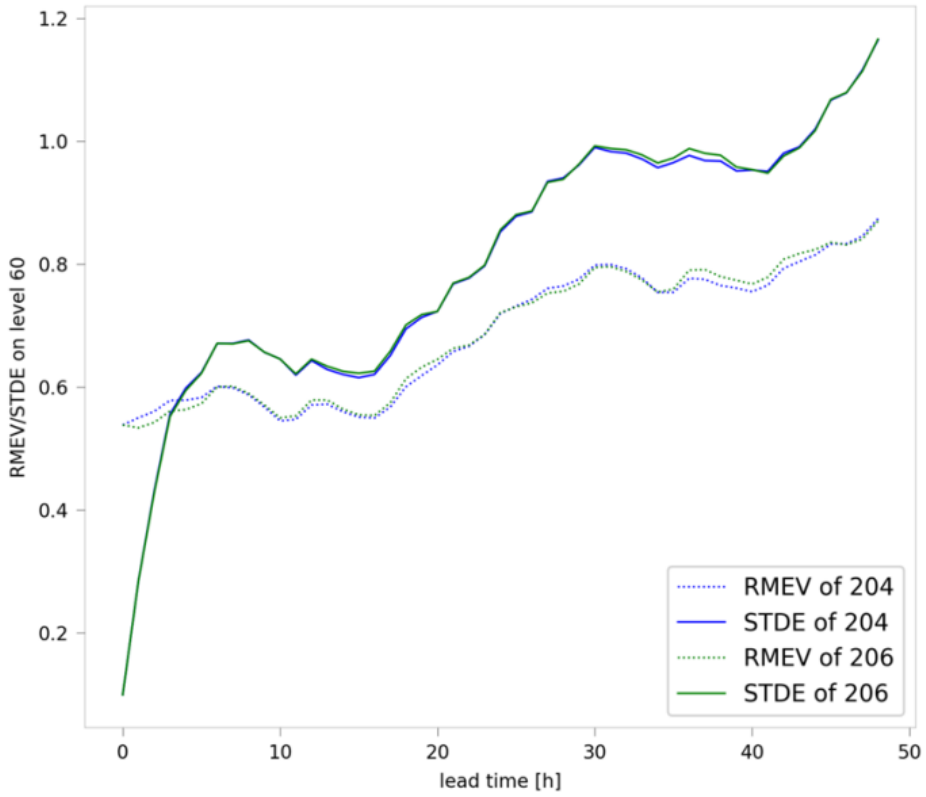
dlat/dlon_rn_rad	5.0	5.0	5.0
dlat/dlon_rn_shc		5.0	5.0
dlat/dlon_rn_mic		5.0	5.0
dlat/dlon_rn_tur		5.0	5.0
stdv_rn_tur	1.0	1.0	1.0
stdv_rn_rad		1.0	1.0
stdv_rn_shc		1.0	1.0
stdv_rn_mic		1.0	1.0
range_tur	0.8	0.8	0.8
range_rad		0.8	0.8
range_shc		0.8	0.8
range_mic		0.8	0.8

→ SPPT and iSPPT identical

KENDA ensemble mean analysis used as truth

L. Füzer, A. Walser, MCH

Temp RMEV vs. STDE, k=60, winter



Exp ID	200 Ref	204 Dec	206 Dec
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**

→ Spread and error almost identical

KENDA ensemble mean analysis used as truth

L. Füzer, A. Walser, MCH

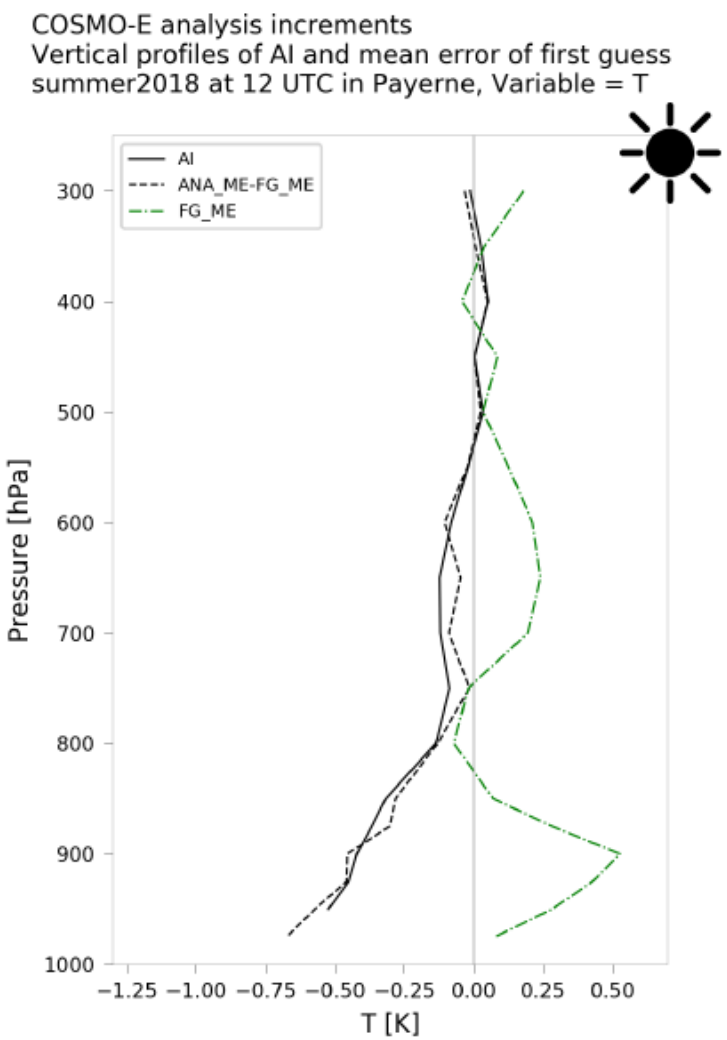
Summary of iSPPT experiment results

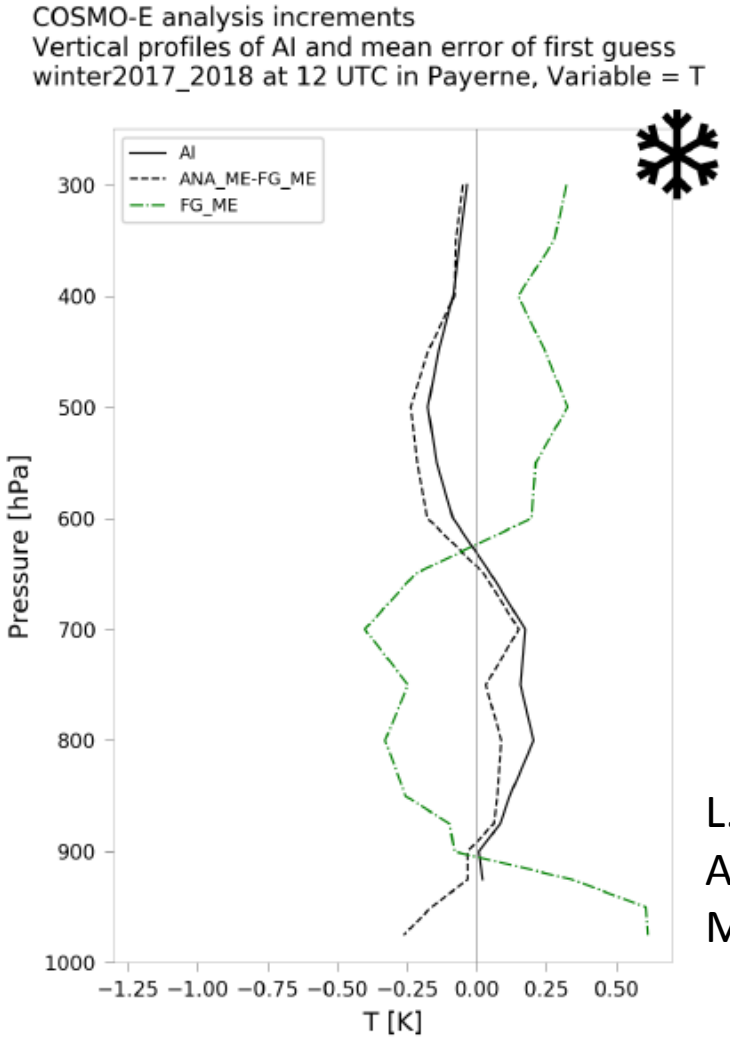
- iSPPT does not improve spread-error relationship in COSMO-E per se
- in contrast to Christensen et al. (2017) no tendencies from deep convection
- risk for unphysical values and stability issues (CFL) with larger ranges than +/- 0.9 for the random numbers
- model crashes with range > 1, i.e. switch 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
- best way to increase spread with (i)SPPT is to increase stdv_rn

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)

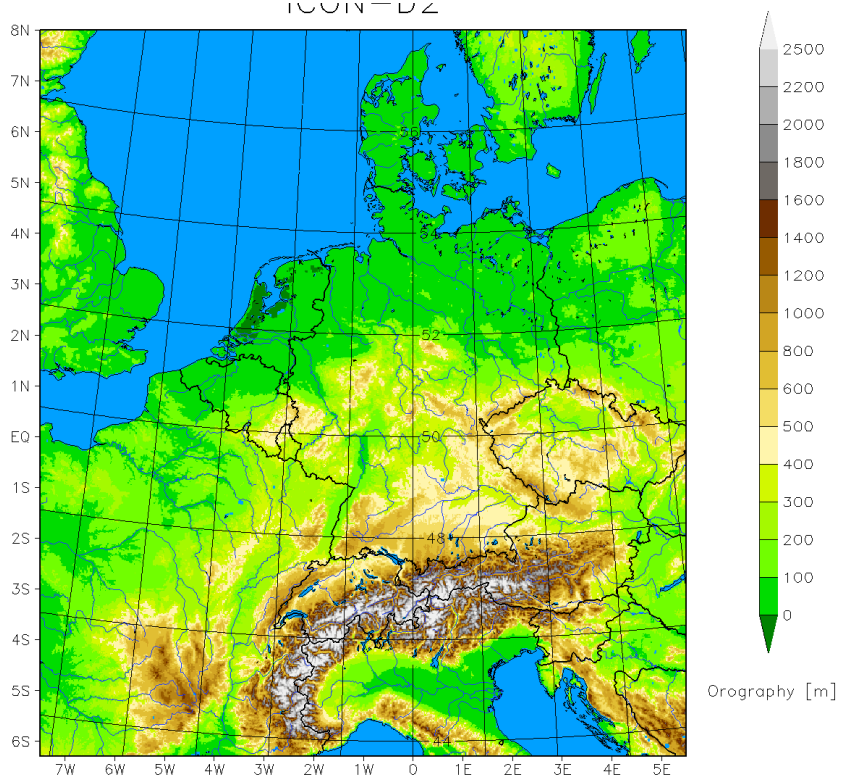




L. Füzer
A. Walser
MCH

ICON-D2-EPS

- ~ 2.1 km icosahedral grid, 65 vertical levels
- can be interpolated to the rotated lat-lon grid of COSMO-D2
- 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.)
  - IC (KENDA)
- pre-operational: October 2019
- operational in Q4 2020

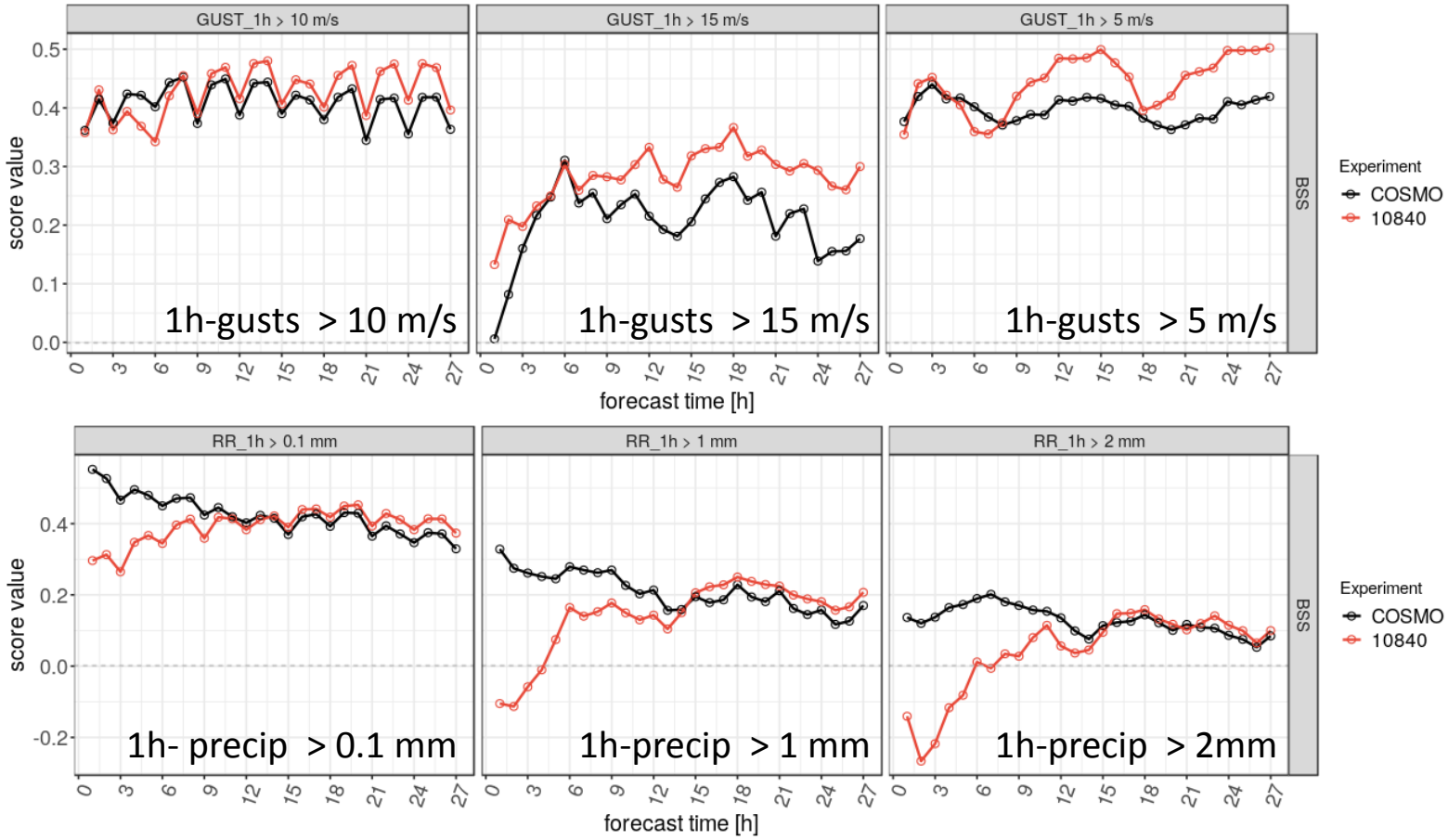


C. Gebhardt, DWD

Partial ICON-D2-EPS – first experiments

- boundary conditions: forecasts of ICON-EU-EPS
- perturbed physics (randomized parameter selection)
  - 2-3 different values for each of 17 parameters
  - for each parameter separately: random selection of members which are perturbed
- NO perturbation of initial conditions
  (all members start from interpolated operational ICON-EU 3-hourly forecast which implies 'no assimiliation')
- 22nd April – 23rd May 2019
- 00 and 12 UTC runs to 27 hours
- 20 members

BSS 00 and 12 UTC



ICON-D2-EPS

COSMO-D2-EPS

ICON-D2-EPS – next steps

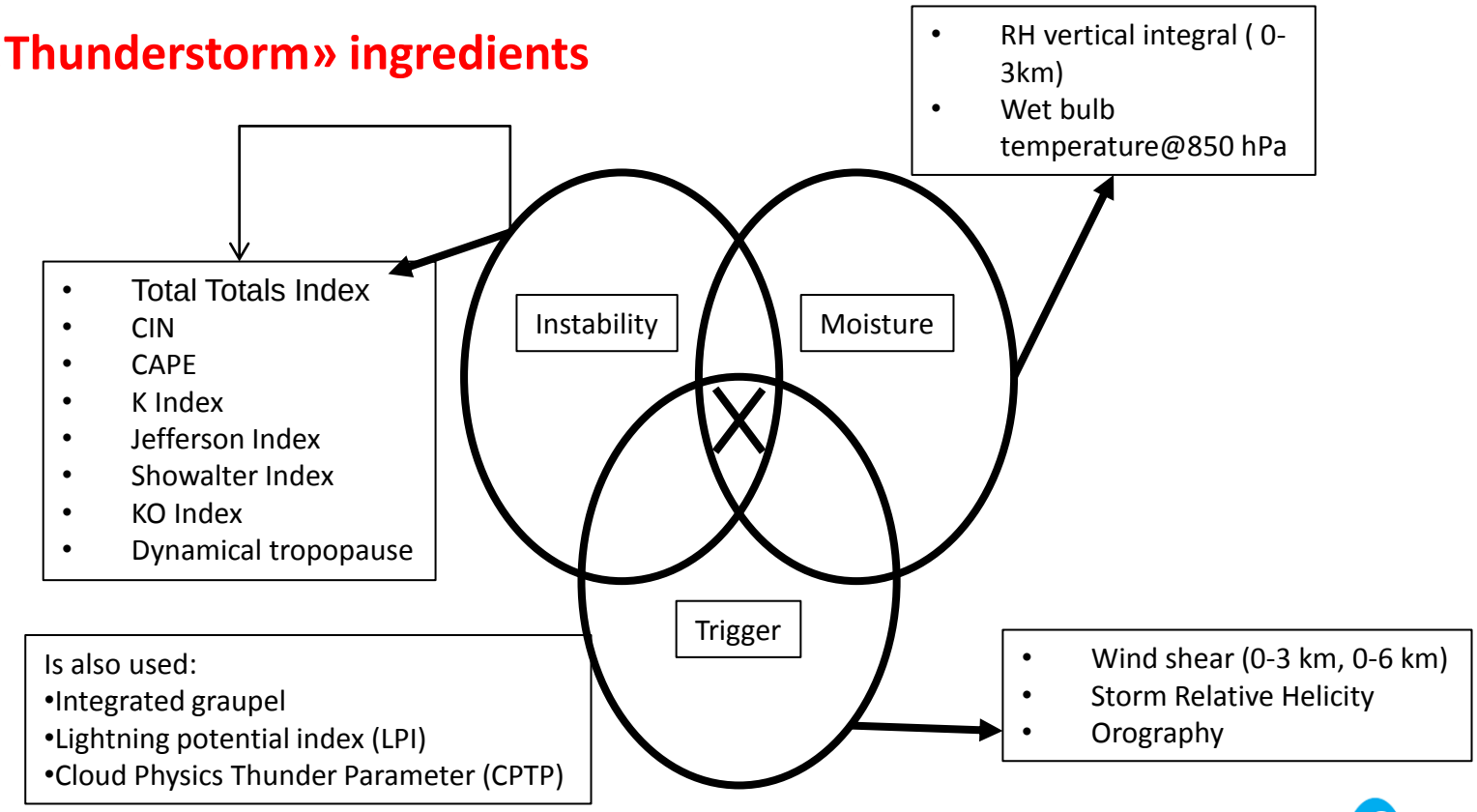
- Combine BC and physics perturbations with KENDA for ICON-D2
- Q4 2019 : pre-operational suite
- Q4 2020 : operational start of ICON-LAM-EPS

- alternative/complementary:
  model for the model error ("EM-scheme")
- alternative/complementary:
  stochastic representation of shallow convection (physics group)

C. Gebhardt, DWD

Generation of ensemble products for thunderstorms

«Thunderstorm» ingredients

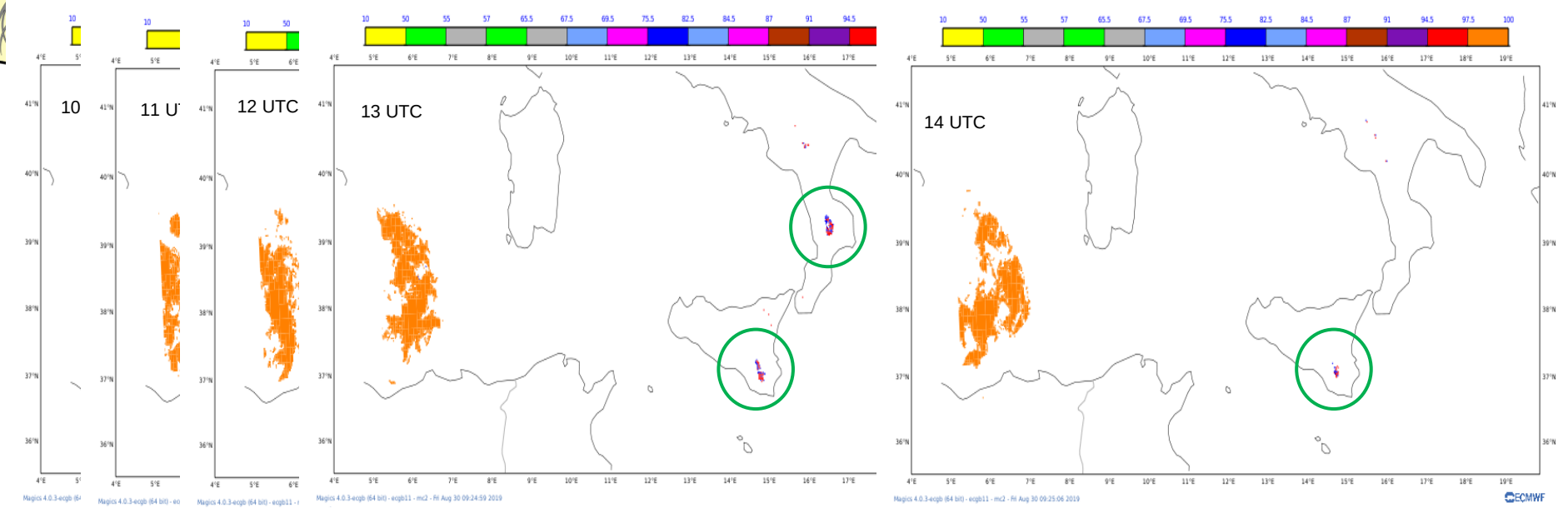


SRNWP-EPS

EUMETNET
EUROPEAN METEOROLOGICAL SERVICES NETWORK

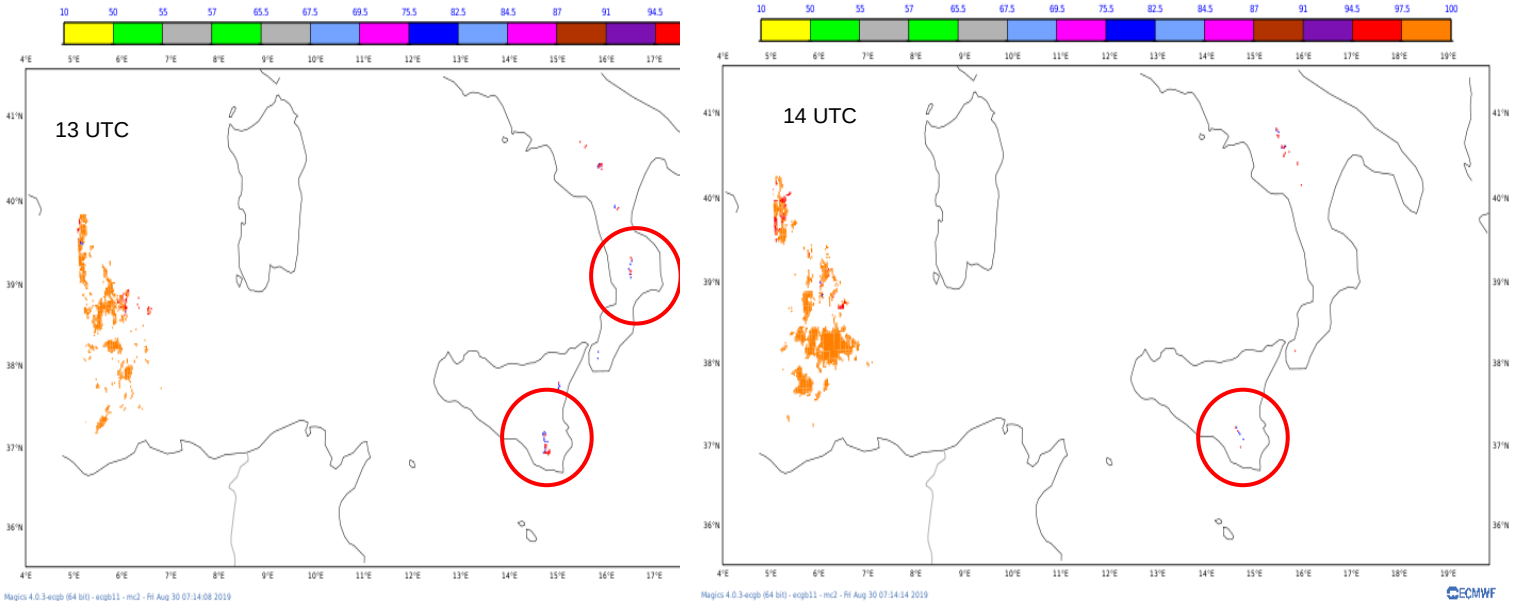
F. Marcucci, M. Alemanno, COMET

Outputs from COSMO-IT EPS (bechtold)



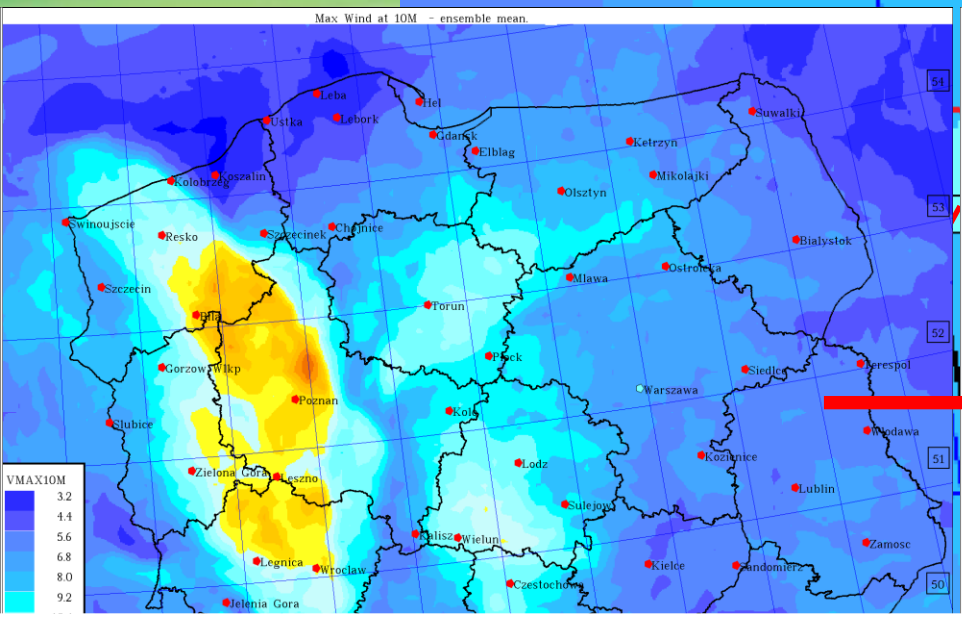
Outputs from COSMO-IT EPS (tiedtke)

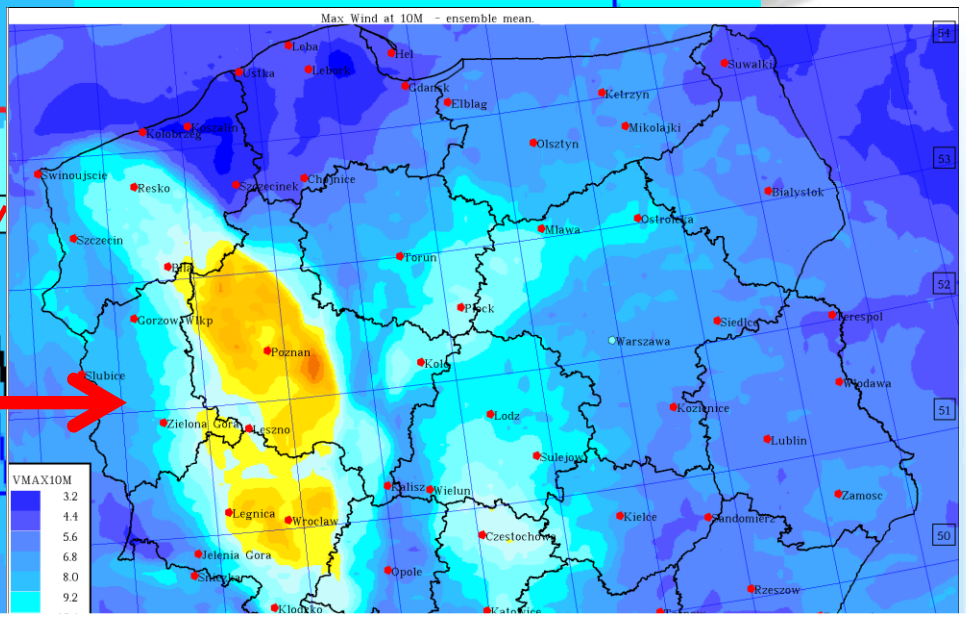
significant changes in the «most probable» phenomenon



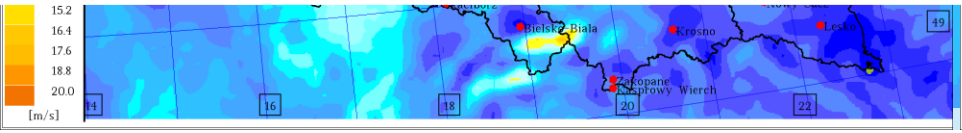
F. Marcucci
M. Alemanno
COMET

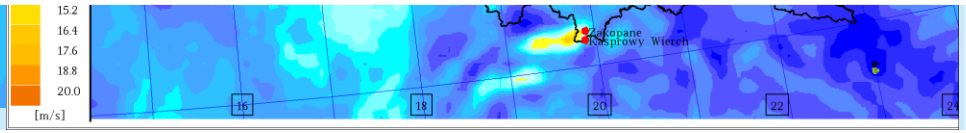
Vector Of Displacement for ‘regular’ fields





Some sixty SYNOP stations… not enough…





1. At all SYNOP stations: in defined vicinity (red circle), find the grid *(x,y*, horiz. arrow*)* with the forecast’ value closest to the one measured at station *(x_s,y_s*, vert. arrow).
2. Calculate the displacement vector for single station as *(x-x_s,y-y_s*, red arrow).
3. Calculate an overall VOD as mean for all the stations
4. Displace every value of fcst by the vector of displacement

Transition to ICON-LAM for ensembles

- At DWD: pre-operational ICON-D2 EPS in Q4 2019, operational in Q4 2020 (with KENDA ICs)
- At MCH: transition to ICON LAM in 2022. In Q1 2020 new operational system, COSMO-E 1 km, then start experiments with ICON-LAM for the ensemble
- At RHM: COSMO-Ru2-EPS is only available for the Sochi Olympics period (due to availability of BCs), too limited for extensive experiments with AMPT. Therefore, it is planned to first (starting in Q4 2019) implement the scheme in ICON(LAM) and continue there the testing of the model perturbation
- At IMGW: planning of transition to ICON-LAM in ensemble will come after the transition for the deterministic and the experience gained there
- At COMET: transition for ensemble depends on the possibility to run ICON-LAM on GPUs

Ensemble products for ICON-D2-EPS

- Provide an example of post-processing of the ICON-LAM fields by using the COSMO SW Fieldextra
- Fieldextra can manage the unstructured ICON grid, by using the icontools package
- The ICON-LAM fields are transformed to a regular grid before further post-processing: **regular latlon** or **rotated latlon**
- Interpolation is made with the radial basis function method. The nearest neighbour interpolation method does not work for ICON-LAM
- It is planned to provide in Fieldextra full support of the ICON grid
- Quantities:
  - Ensemble mean, minimum, maximum
  - Spread / interquartile range
  - Exceedance probabilities
  - Percentiles
  - Future: upscaled probabilities (10x10 grid points)

C. Marsigli, DWD

Fieldextra namelist – Tmin 6h

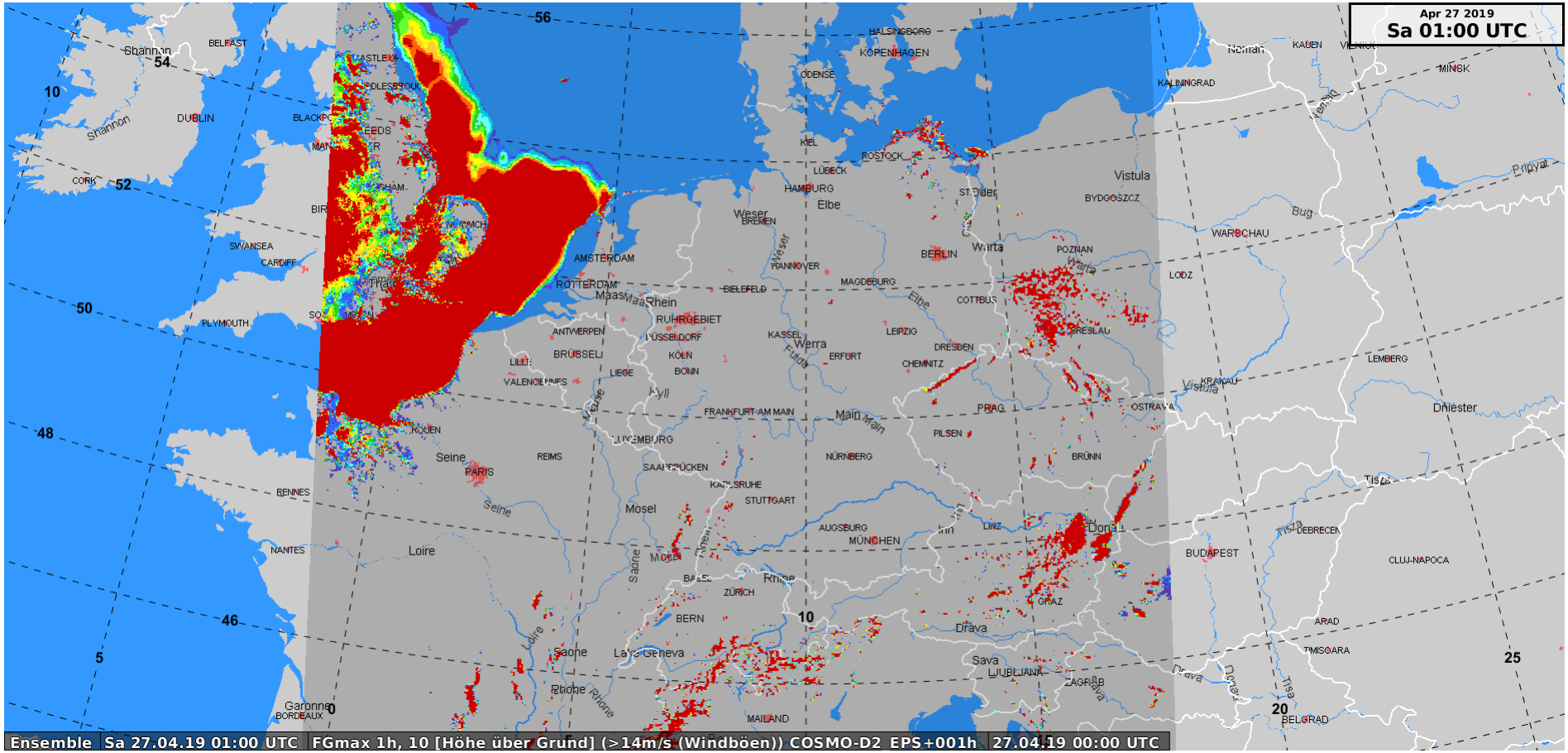

```
&GlobalResource
dictionary                = "%extradir%/dictionary_icon.txt"
icon_grid_description = "%icongrid%„
/
&GlobalSettings
default_dictionary                = "icon"
default_model_name             = "icon"
/
&ModelSpecification
model_name       = "icon"
regrid_method     = "from_unstructured_grid,rbf"
/
&Process
in_file="%infile_TMM%"
in_regrid_target = "rotlatlon,%minlon%,%minlat%,%maxlon%,%maxlat%,%reslon%,%reslat%,%pollon%,%pollat%",
in_regrid_method = "default",
out_type="GRIB2"
out_file= "%outfile%_TMM„
/
&Process in_field="TMIN_2M",toper="min,-5,0,hour"
/
&Process  out_field="TMIN_2M", product_category='eps_mean' /
&Process  out_field="TMIN_2M", product_category='eps_standard_deviation'/
&Process  out_field="TMIN_2M", product_category='eps_quantile', quantile=90 /
&Process  out_field="TMIN_2M", product_category='eps_probability',prob_thigh=273.15,tag="T_MIN273.15"/
```

Here: COSMO-D2-EPS domain

minimum over last 6 hours

ensemble mean
ensemble spread

Wind gusts – probability of excedance 14m/s



C. Marsigli, DWD

Final remarks

- work on model perturbation; coordination between DWD and RHM on the development of models for the model error
- some planned activities are on hold, due to human resources not available: parameter perturbation at Arpae, analysis-increment based perturbation at MCH
- link with WG5 and WG4 about verification of high-impact weather product (AWARE PP, joint session on Tuesday)
- transition to ICON-LAM: perform tests of ensemble perturbation in COSMO or in ICON?

- **SPRED P**riority **P**roject: COSMO Technical Report published, DOI: 10.5676/DWDpub/nwv/cosmo-tr39