CONSORTIUM FOR SMALL SCALE MODELING COSMO

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Steps forward in the COSMO ensembles

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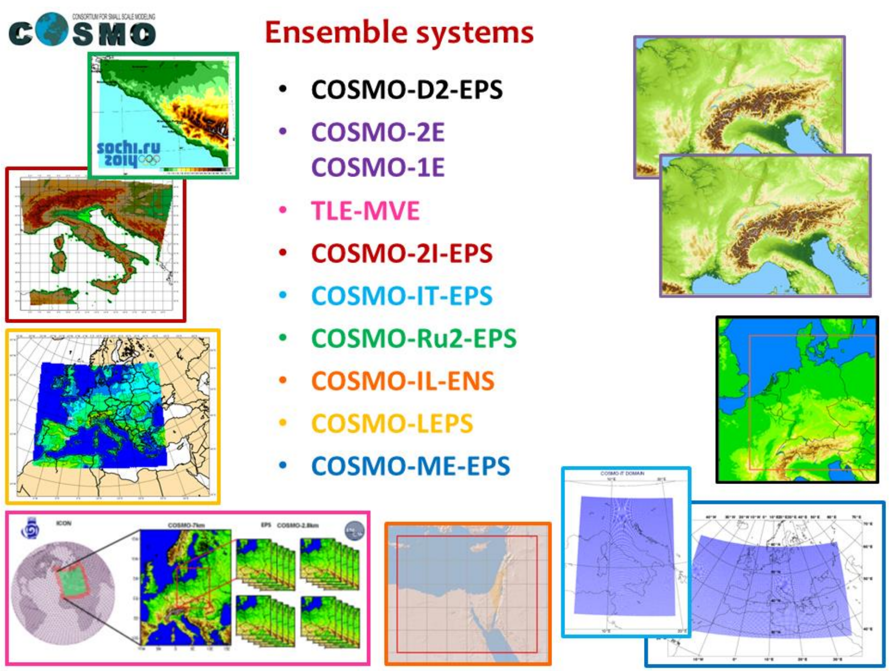
Deutscher Wetterdienst

With the contribution of the WG7 (Predictability and Ensemble Methods) colleagues

Outline

- The COSMO ensembles
- What is more relevant: Increasing the model resolution or increasing the number of ensemble members?
- Recent developments
  - Model perturbation
  - Boundary condition perturbation
- Conclusions and future plans



The performance of an ensemble
(or: again trying to get a good coffee …)

- Are we sure that among 20 different coffees we will find the one satisfying our taste?
  - Add milk
  - Add sugar
  - Change the brewing time
  - Stir very fast!

- If the basis is not good, nothing can help!

COSMO-2E & COSMO-1E

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Higher resolution versus higher number of ensemble members – can the smaller COSMO-1E ensemble with 11 members beat the bigger COSMO-2E ensemble with 22 members?

with COSMO 5.07 (single precision) -> **model improvement!** Based on:

Jan-Peter Schulz and Gerd Vogel, 2020: Improving the Processes in the Land Surface Scheme TERRA: Bare Soil Evaporation and Skin Temperature, *Atmosphere*, **11**, 513

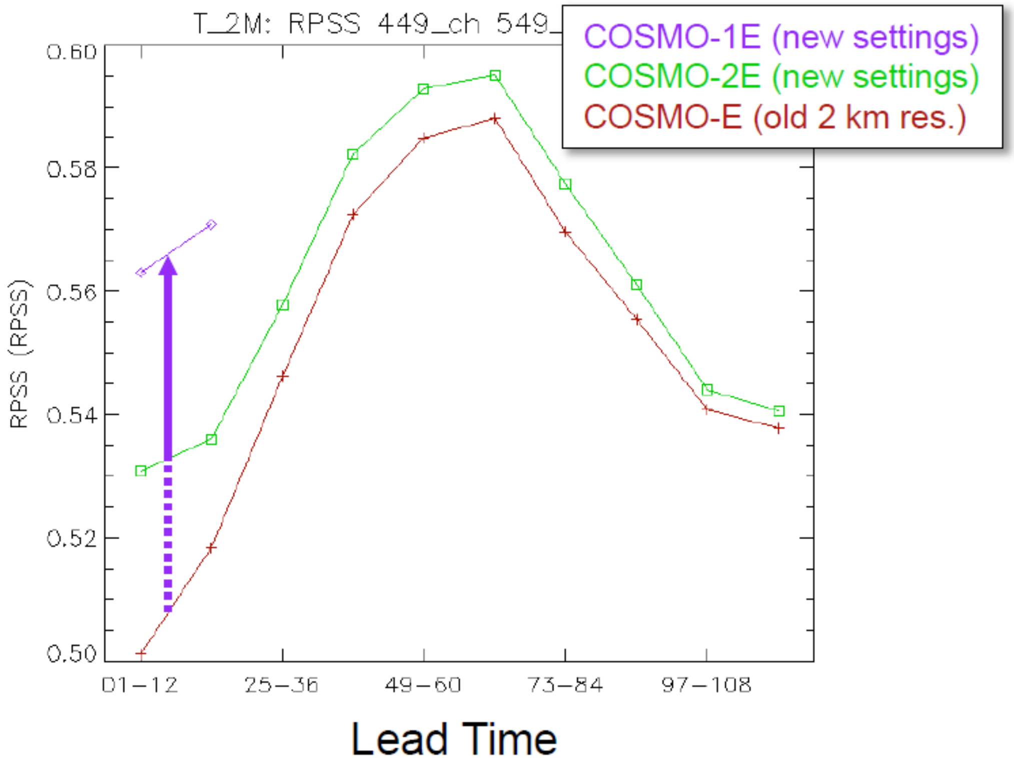
A. Walser, M. Arpagaus - MCH

COSMO-1E vs COSMO-2E

Ranked Probability Skill Score (RPSS)

The RPSS of COSMO-1E is better for most parameters and most seasons

Example: RPSS T2m, Autumn 2019



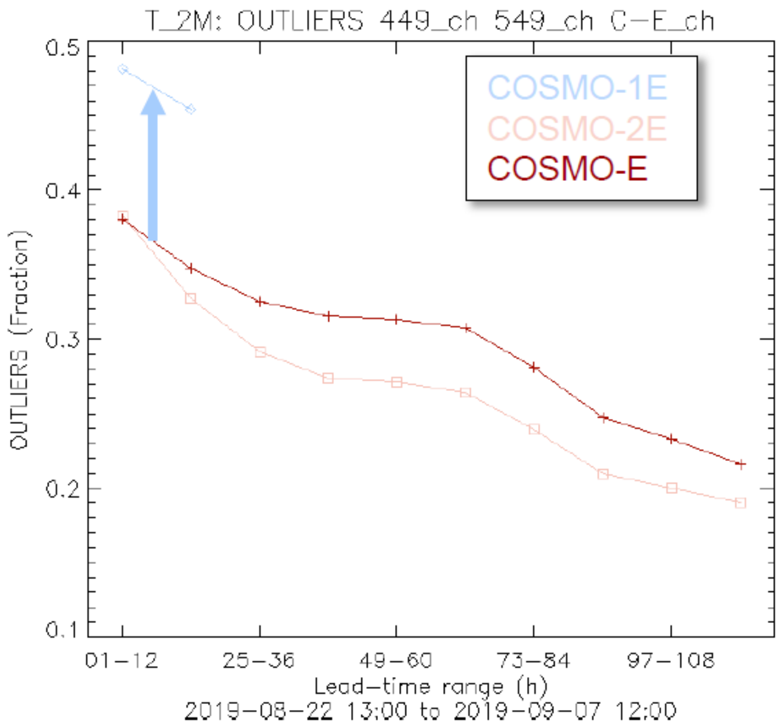
P. Kaufmann - MCH

COSMO-1E vs COSMO-2E

Outliers

The smaller ensemble size of COSMO-1E leads to a larger number of outliers

Example: T 2 m, summer 2019



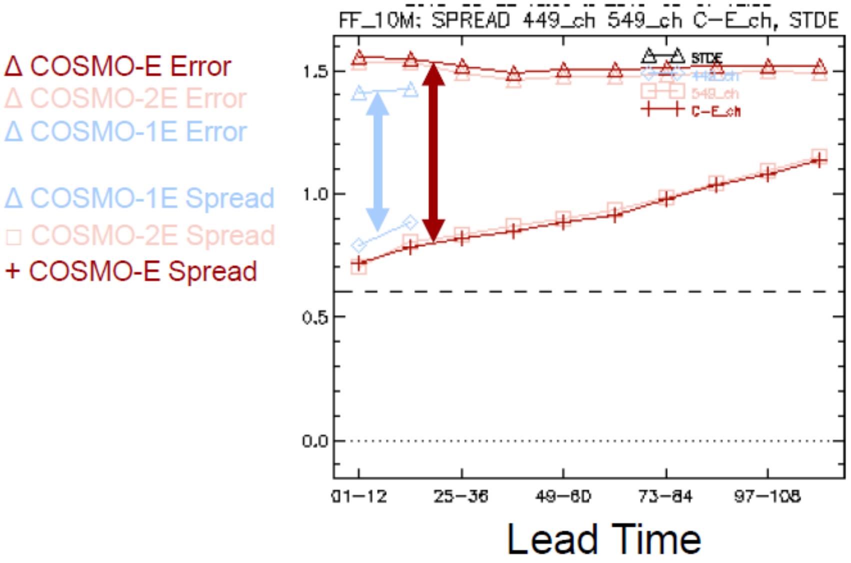
P. Kaufmann - MCH

COSMO-1E vs COSMO-2E

Spread/error relation

The spread/error relation for the 1.1 km model COSMO-1E is similar for most parameters and for some even better than for the 2.2 km models COSMO-2E and COSMO-E

Example: wind speed, summer 2019



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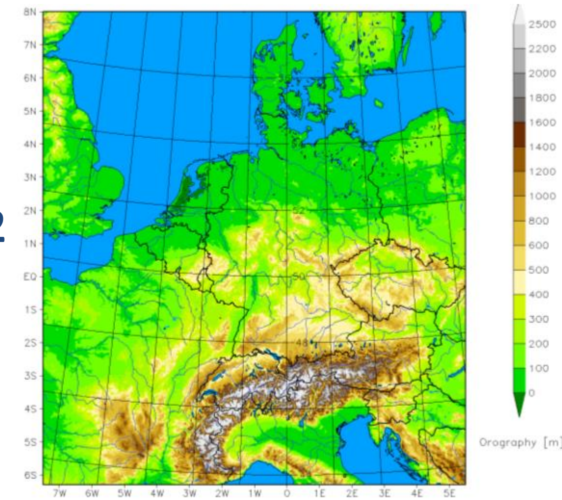
ICON-D2-EPS

ICON-D2-EPS (pre-operational)

- ~ 2.1 km icosahedral grid

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 perturbed parameters
  - IC KENDA
- operational in Q1 2021



C. Gebhardt - DWD

ICON-D2-EPS vs COSMO-D2-EPS

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DWD

00 UTC

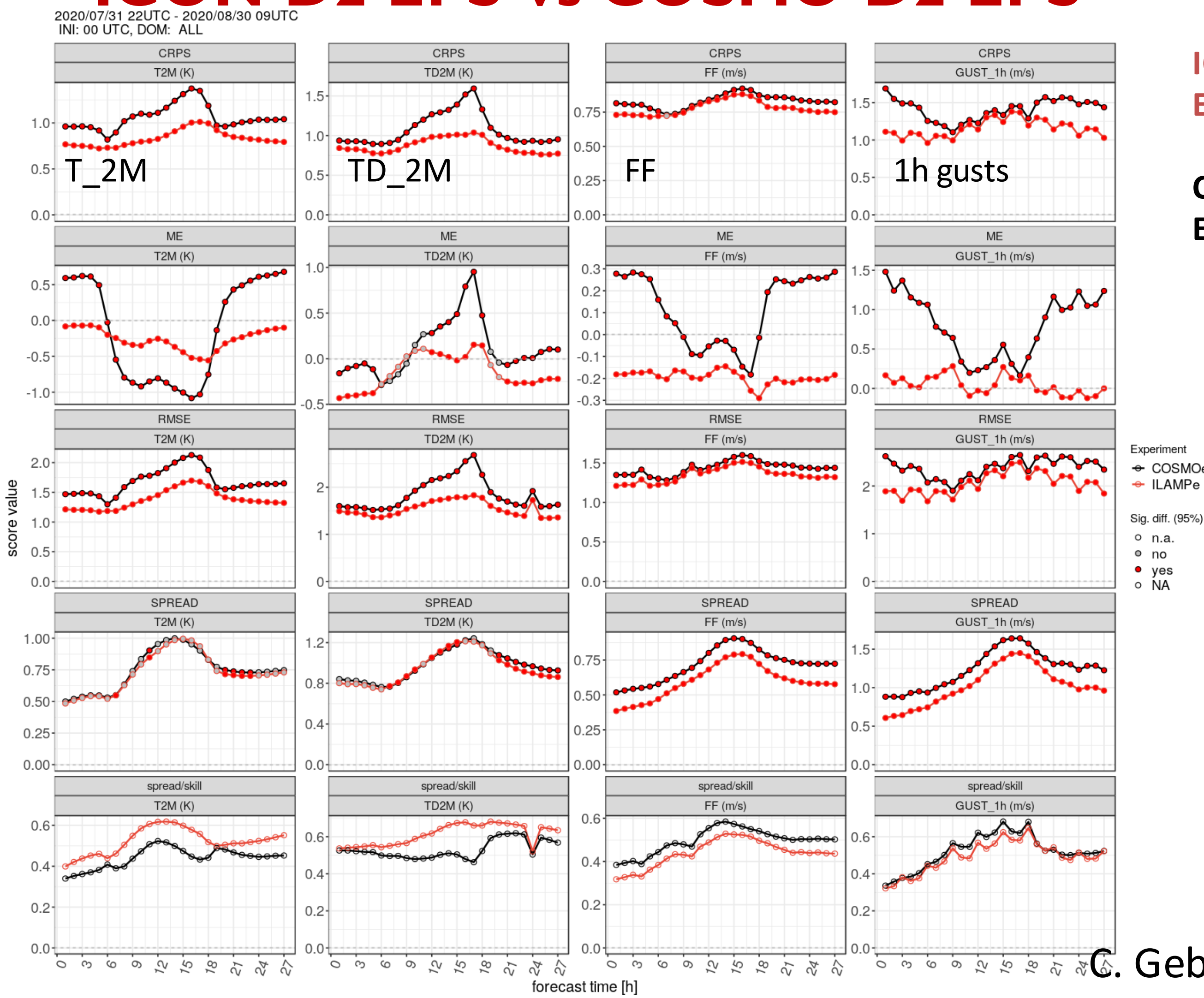
CRPS

Bias

RMSE

Spread

Spread/
Skill



ICON-D2
EPS

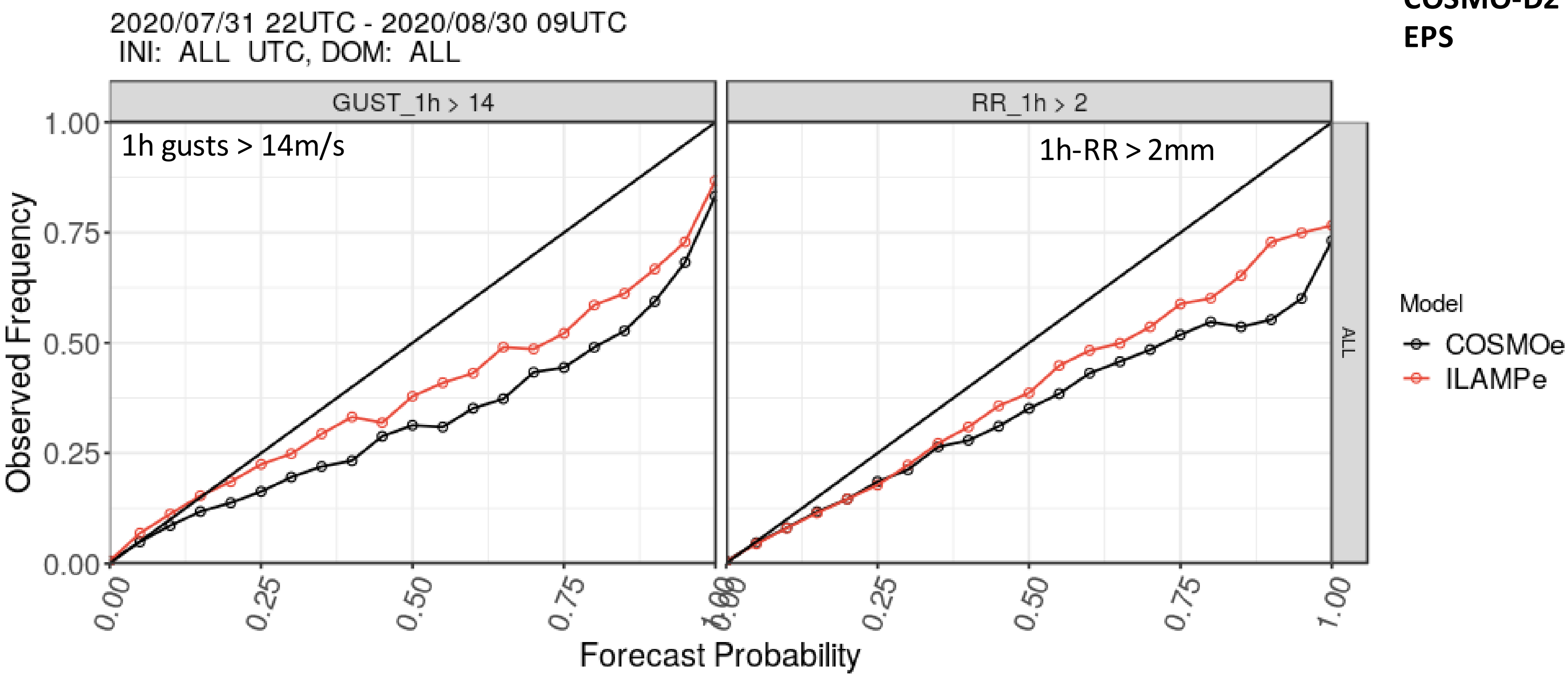
COSMO-D2
EPS

C. Gebhardt - DWD

ICON-D2-EPS vs COSMO-D2-EPS

Reliability diagram 00 & 12 UTC fc range: 1 – 27h

ICON-D2 EPS
COSMO-D2 EPS



C. Gebhardt - DWD

AMPT: Additive Model-error perturbations scaled by Physical Tendencies

The AMPT perturbations $\mathcal{P}(x,y,\mu,t)$ are spatio-temporal random fields scaled by the area averaged (in the horizontal) modulus of the phys… tendency ***P(x,y, μ, t).***

atmosphere & soil

$$\mathcal{P}(x,y,\mu,t) = \sigma \ \ldots \ t)|\}\ \xi(x,y,\mu,t)$$

where σ determines the pert… …itude,
the overbar denotes th… …eraging operator,
$\xi(x,y,\mu,t)$ is the pseud… …om field generated by the Stochastic Pattern Generator SPG (Tsyrulnikov, Gayfulin, 201…),
μ is the vertical coordinate.
Now averaging can be over the **whole** domain (for Gaussian variables) or over a **sliding subdomain** (for non-Gaussian variables).

Tsyrulnikov M. and Gayfulin D., 2017: A limited-area spatio-temporal stochastic pattern generator for simulation of uncertainties in ensemble applications. *Meteorol. Zeitschrift*, **26(5)**, 549-566

Application of AMPT to perturbation of soil characteristics

Which elements are perturbed?

Soil temperature and soil water content at all model levels are perturbed at each model time step. In addition, initial perturbations are introduced to T_soil and soil moisture index (SMI).

Does the perturbation pattern change from level to level ?

No, the same random field is used for all levels but perturbations have different magnitudes. The pseudo-random field ξ is 2D for soil.

Do the perturbations decay downward?

Yes, their magnitude is specified for the uppermost level k=1. At level k>1 the magnitude equals that at level k-1 divided by a number greater than one (from 1.5 to 3, subject for tuning).

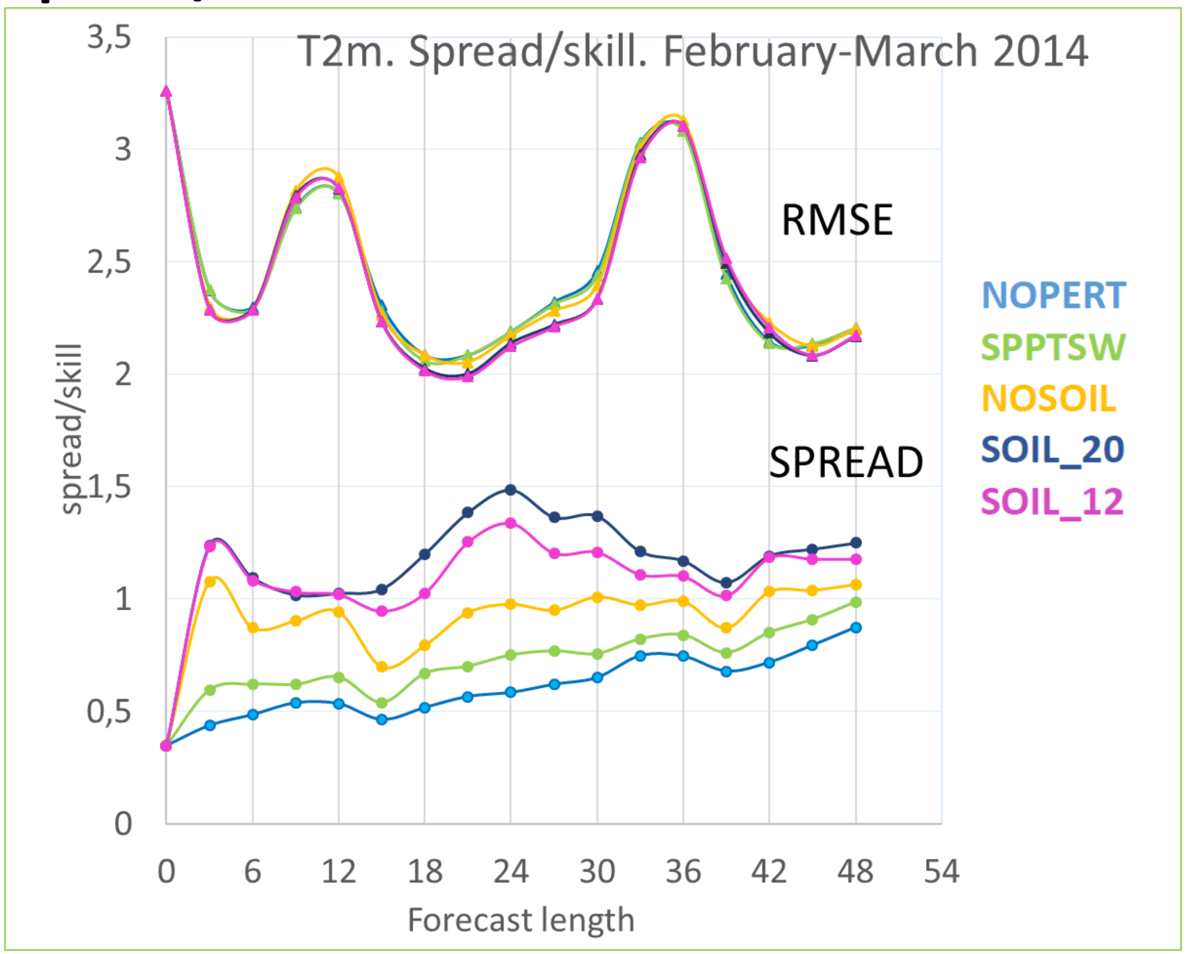
Are the temperature and moisture perturbations related to each other?

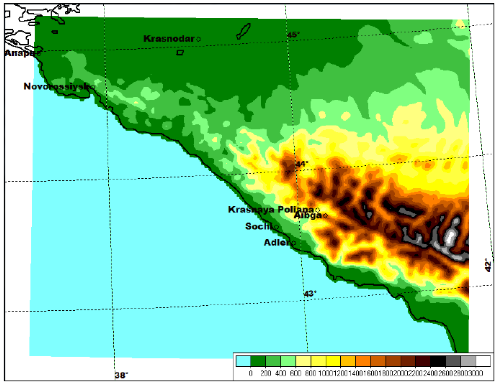
No. But the temporal scales of W and T soil perturbations are the same (and significantly greater than in the atmosphere).

E. Astakhova - RHM

COSMO-Ru2-EPS

Spread/error relation: 2m T





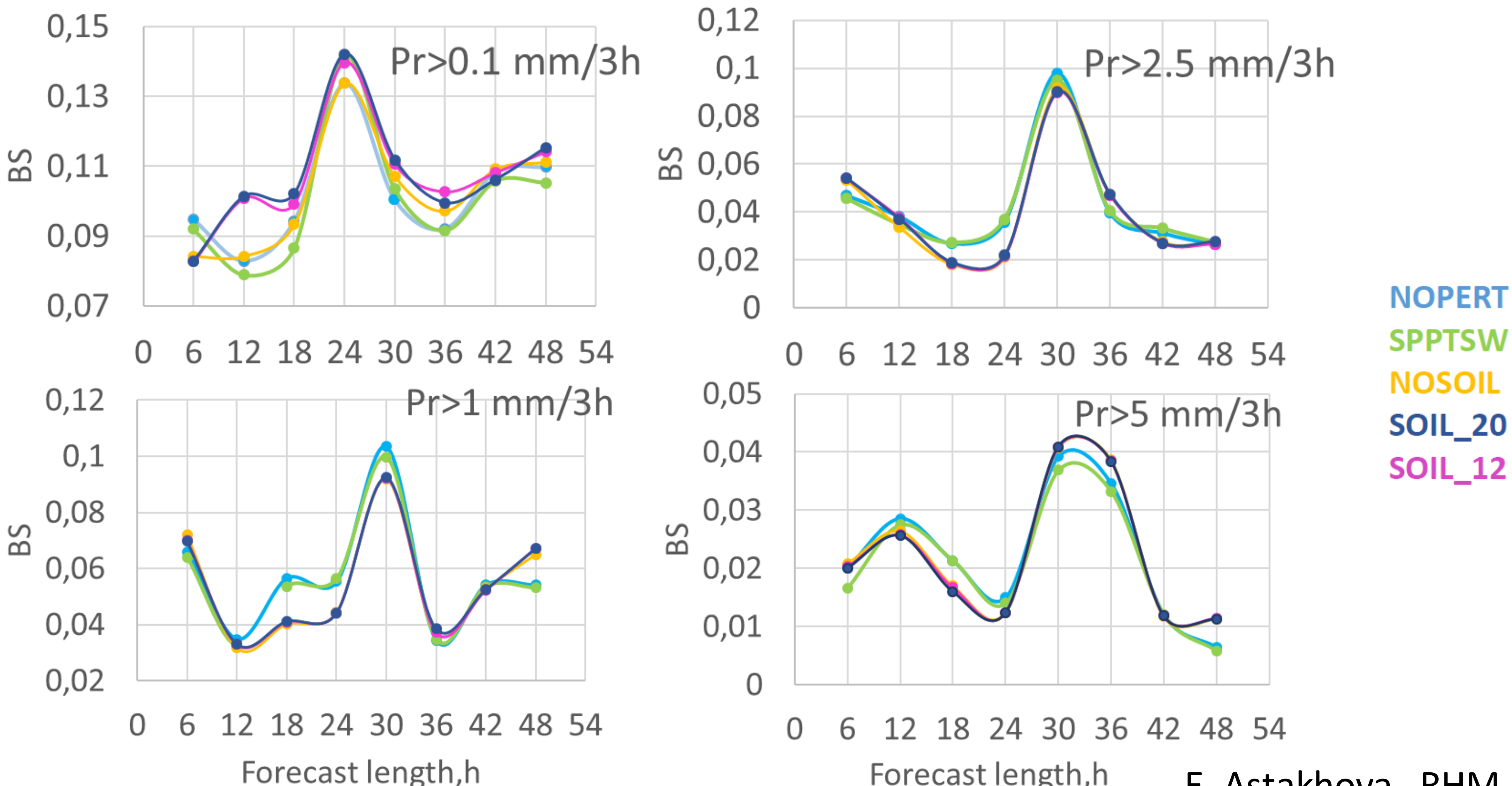
No model perturbations
SPPT with MeteoSwiss settings
AMPT only in the atmosphere
AMPT atmosphere & soil T05=20
AMPT atmosphere & soil T05=12

- *no tapering*
- *σ=0.75 (soil & atmosphere)*
- *random field atm.:*
  spatial scale 50 km
  temporal scale ~1h

E. Astakhova - RHM

COSMO-Ru2-EPS

Brier Score: TP



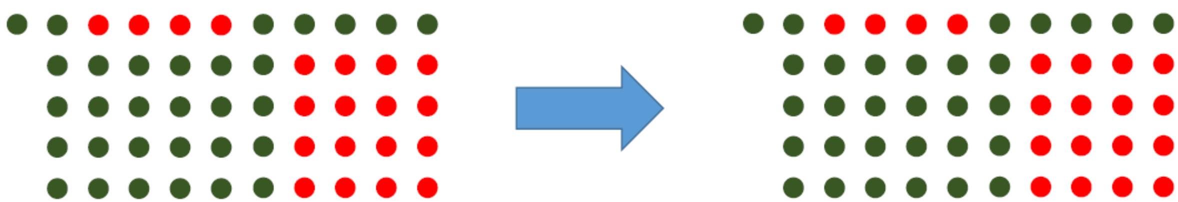
E. Astakhova - RHM

Cluster Analysis

ECMWF ensemble

COSMO ensemble

B. Try method 1



Verify **those** and decide if this method is good

C. Try method 2,... and so on

Molteni F. et al, 2001. and Marsigli C. et al., 2001. "A strategy for high-resolution ensemble prediction. I and II". *Quarterly Journal of the Royal Meteorol. Soc.*, **127**, 2069-2094 and 2095-2115.

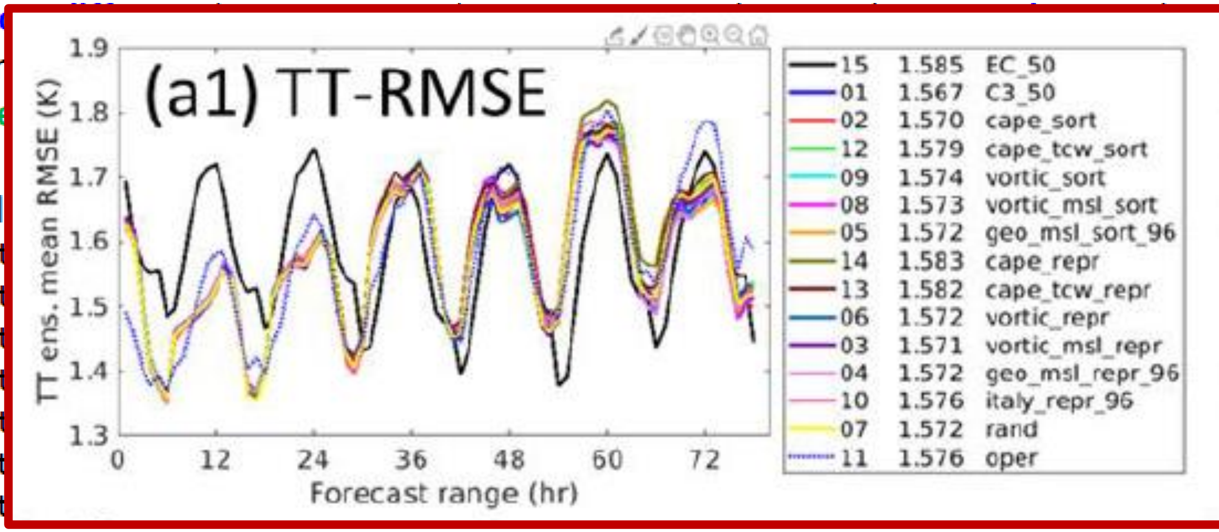
COSMO-IL-ENS

Cluster Analysis

Suggest 12 methods for selection of driving EC-ENS sub-ensemble (20 members)

Questions:

A. Choose m ... ministic IFS?
B. Which atm
C. Which fore



The suggested

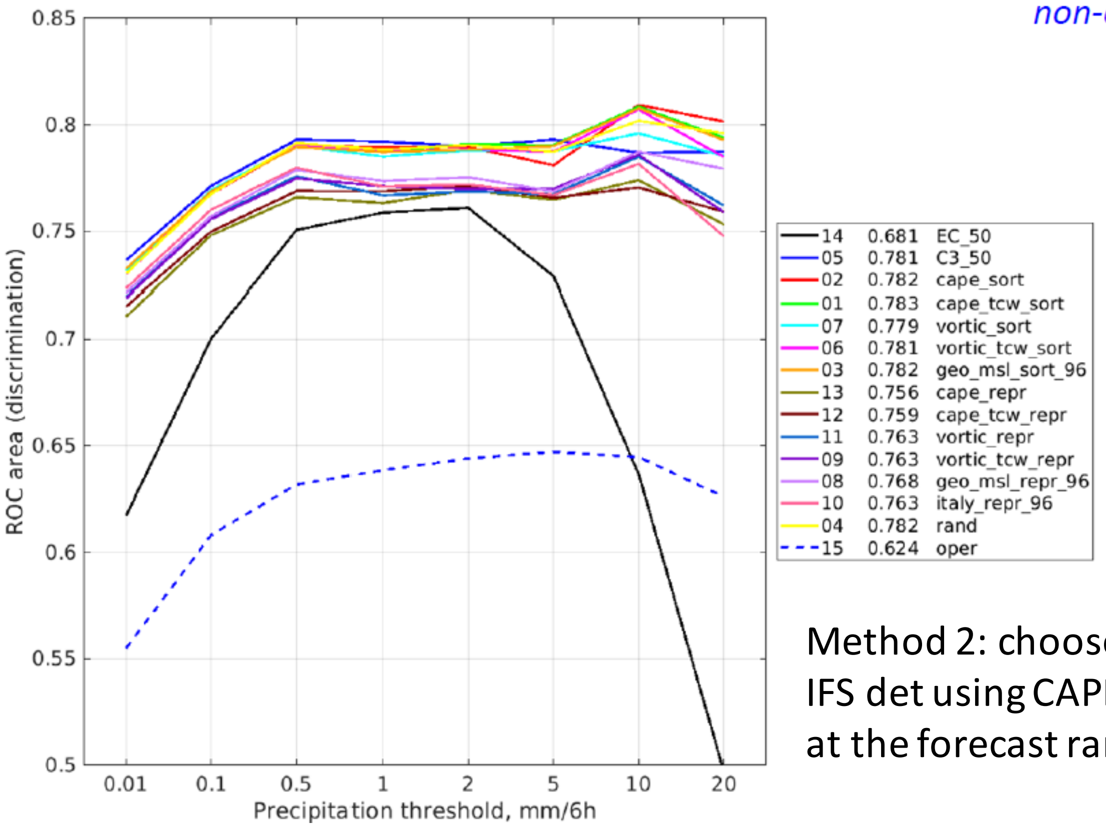
1. Most close t
2. Most close t
3. Most close t
4. Most close t ... ad
5. Most close t
6. Representat
7. Representat
8. Representative, vorticity$_{500}$, larger domain, forecast range with maximum spread
9. Representative, vorticity$_{500}$ and MSL 50%-50%, larger domain, forecast range with maximum spread
10. Representative, Z_{500} and MSL 50%-50%, larger domain, forecast range=96h
11. Representative, (*similar to LEPS*), fields: Z, QV, U, V at 500, 700, 850 hPa, larger domain, forecast range=96h
12. Random 20 members at each run

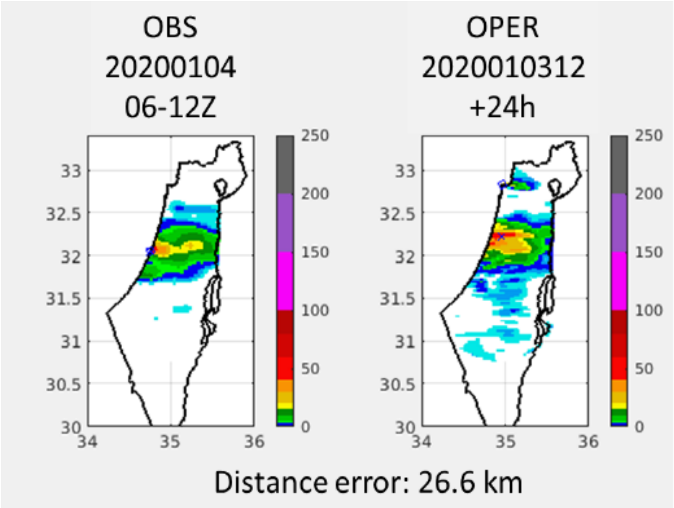
P. Khain - IMS

Verification of precipitation

ROC area

Ability to discriminate between events and non-events





Method 2: choose EC-ENS members closest to IFS det using CAPE and TCWV over small domain at the forecast range with the maximum spread

P. Khain - IMS

Keep at home message

- The first COSMO 1km ensemble is operational, with 1km KENDA data assimilation (MCH)
- The first ICON-LAM ensemble is pre-operational (DWD)
- Israel joined the ensemble development group of COSMO!
- Added value of higher resolution ensemble is (again) demonstrated
- Future plan:
  - More on model perturbation:
    - implement iSPPT, extend PP
    - model for the model error
    - AMPT with Stochastic Pattern Generator (RHM)
  - Cluster Analysis for BCs
  - Stochastic parametrization: Workshop in February/March

On-going: stochastic shallow convection (M.Ahlgrimm, DWD)