SPRED PP: summary and conclusions

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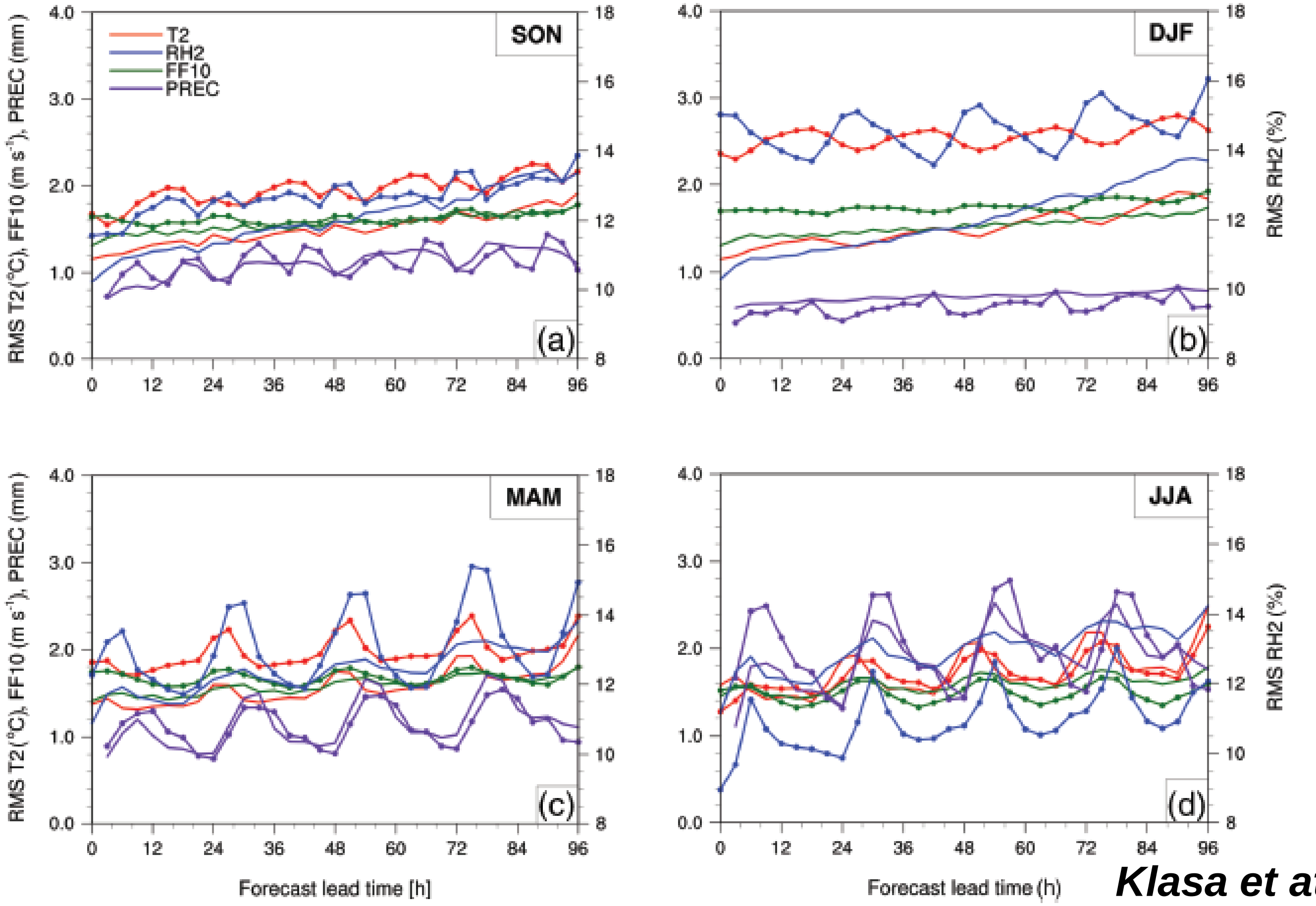
Outline

- SPRED PP lasted from Sep 2015 to Feb 2018 (with extension of 6 month)
- Participation of: ARPA Piemonte, ARPA SIMC, COMET, DWD, IMGW, MeteoSwiss, RHM
- Aim: improving the spread/skill relation of the Convection Permitting ensembles
- Five Tasks:
  - Task 1: Study of the spread/skill relation in the ensembles
  - Task 2: Model perturbation
  - Task 3: Lower boundary perturbation
  - Task 4: Post-processing and interpretation
  - Task 5: Initial Conditions for the CP ensembles

Task 1:
Study of the spread/skill relation in the ensembles

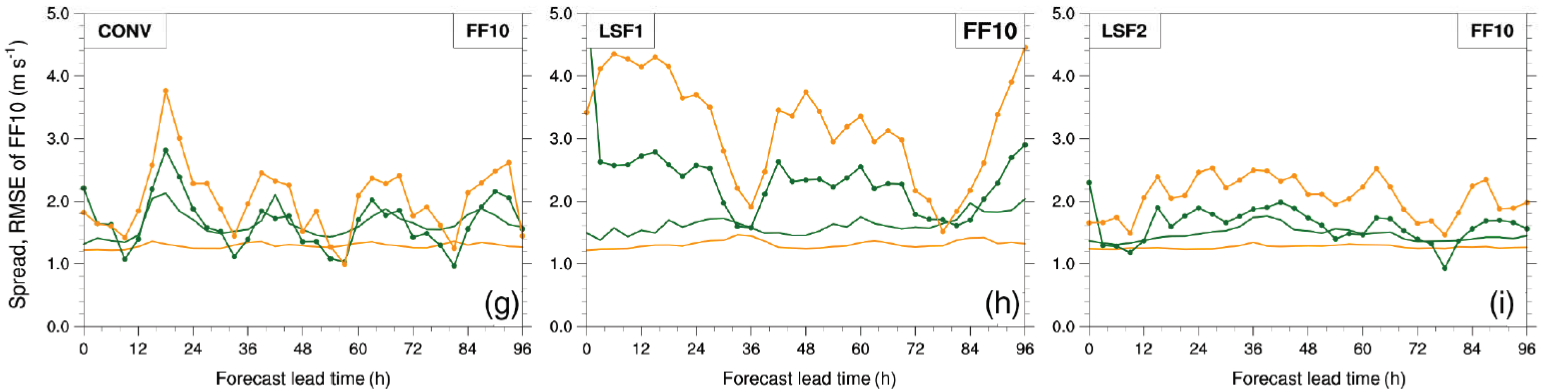
COSMO-E opr 2016/2017



Klasa et at. (2017)

- Lack of spread most of all in winter, in particular for T2m & RH2m
- Rather well dispersed in summer except for RH2m (overdispersive!)

COSMO-E vs ENS for FF@10m
Case studies



- convective (CONV) & 2 large-scale flow (LSF1/LSF2) cases
- COSMO-E shows smaller error and larger spread than ENS
- ENS misses the diurnal cycle of the spread for CONV

Klasa et at. (2017)

Accounting for observation errors

Following Saetra et al. (2004), Klasa et al. (2017) added the squared observation error estimate (Table 1) r_o^2 to the ensemble variance s^2. The total spread s_t is then derived as:

$$s_t = \sqrt{s^2 + r_o^2}$$

TABLE 1 Observation-error estimates for near-surface temperature (T2), relative humidity (RH2), wind speed (FF10), and 3 hr accumulated precipitation (PREC3), taken from Bouttier et al. (2012)

Variable	T2 (K)	RH2 (%)	FF10 (m/s)	PREC3 (mm)
Obs error	1.1	10	1.2	$0.5+0.3\text{PREC3}_{obs}$

- r_o has a large impact on spread/skill results
- available values are only rough estimates for observation and representativeness errors
- should we work towards more appropriate estimates? From our KENDA cycles as soon as we assimilate near surface obs?
- or should we all work with these/the same numbers to get comparable results?

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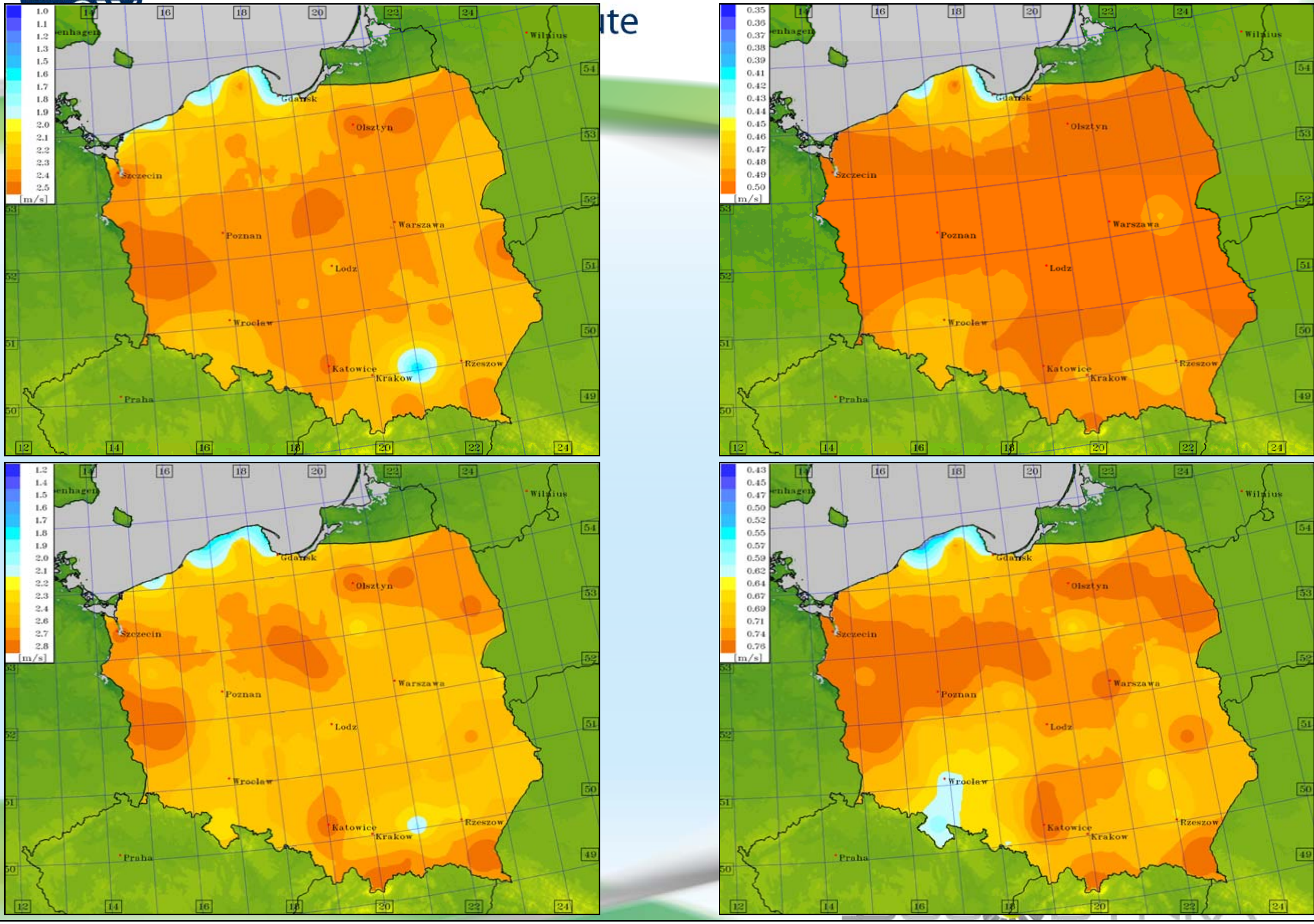


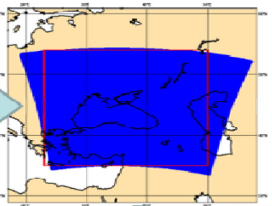
Skill (left) and spread (right) for U10M (upper – 2016; lower – 2017)

For a month period for the Sochi area the ensemble T2m spread was compared for systems

A) with different resolutions: COSMO-S14-EPS 7km, COSMO-Ru2-EPS 2.2km

ECMWF-EPS
Globe
T779L61 (Δx~30 km)
M51, fc+14d
ECMWF computer

Clustering
Nesting

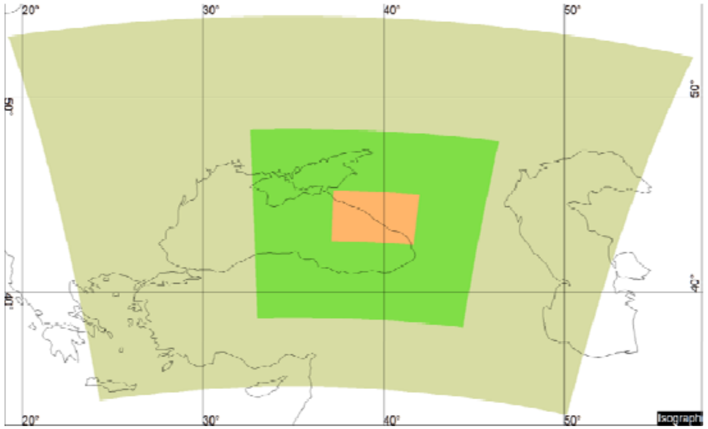


COSMO-S14-EPS
SOCHI DOMain
Δx~7km, L40
M10, fc+72h
ECMWF computer

Nesting

COSMO-Ru2-EPS
Sochi region
Δx~2.2 km, L51
M10, fc+48h
RHMC computer

B) with different domain sizes



COSMO-S14-EPS
7 km
Archive data

COSMO-Ru2-EPS
2.2 km
Rerun with v. 5.01

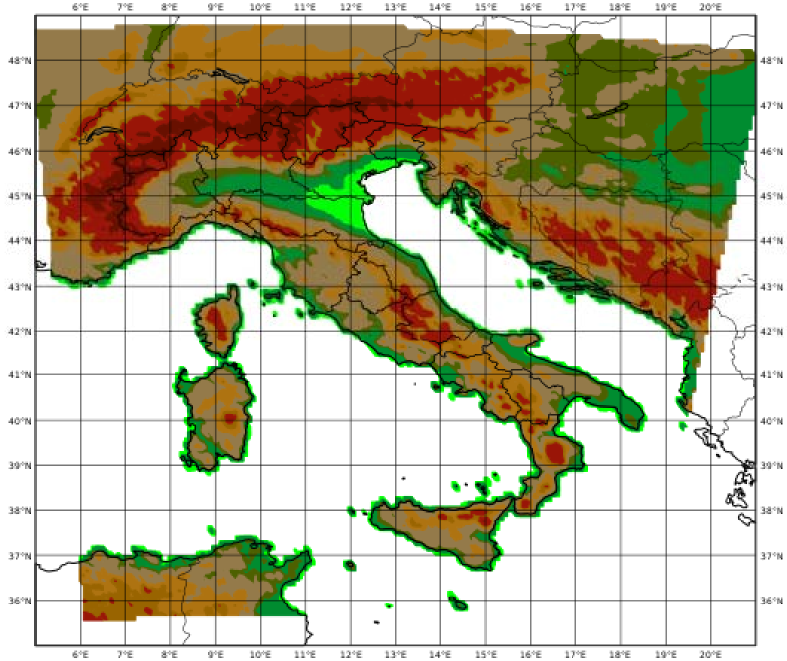
COSMO-Ru2-EPS
2.2 km
Rerun with v. 5.01

- In many cases the T2m spread was higher for the coarser-resolution EPS.
- The monthly-averaged spread was also larger for the 7-km EPS.

- The forecast results (both ensemble mean and spread patterns) depend on the size of the integration domain.
- The effect is related to weather situation and is most pronounced in lower layers, in regions with complex topography, and near the lateral boundaries.

COSMO-IT-EPS - Evaluation of ensemble spread

- 2.8 km
- 10 members
- 3 set-up:
  - no physics perturbation
  - SPPT
  - SPPT + Perturbed Parameters



- **Aim**: assess the impact of physics perturbations on precipitation: do they increase the spread?
- **Compute dFSS (FSS between all pairs of ensemble members)**
- **Compute SAL between all pairs of ensemble members**

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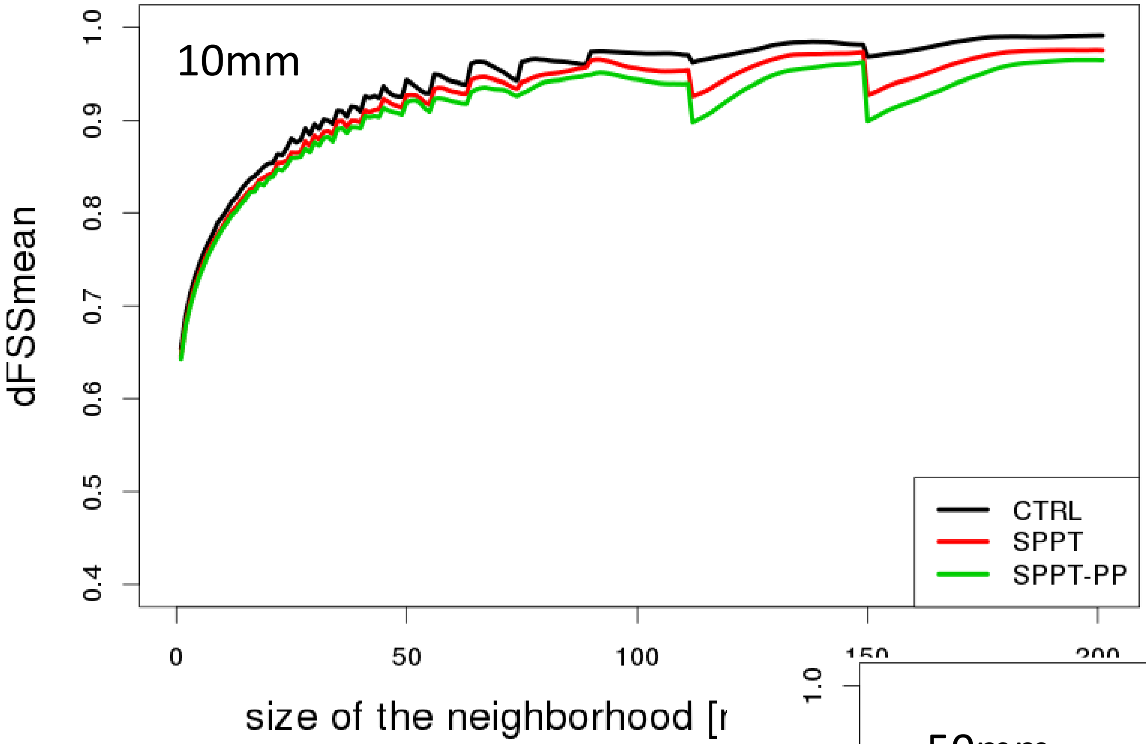
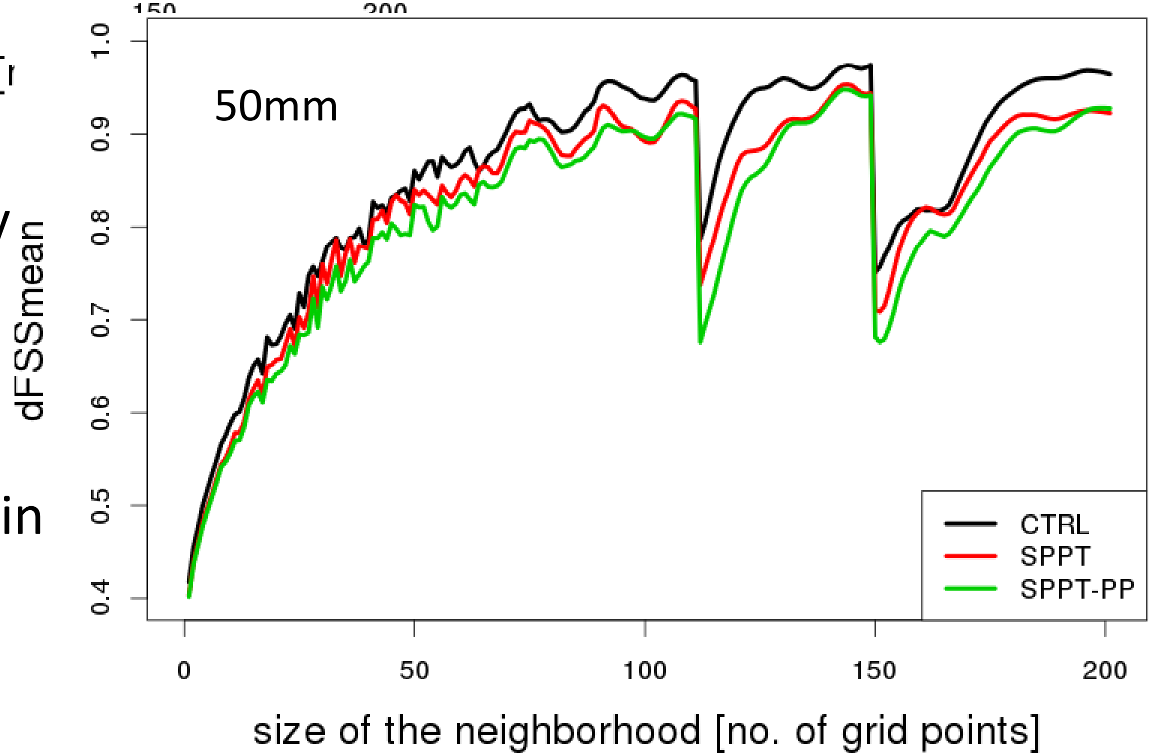
dFSS: dispersion Fraction Skill Score

31 October 2016
Calabria
24h precipitation

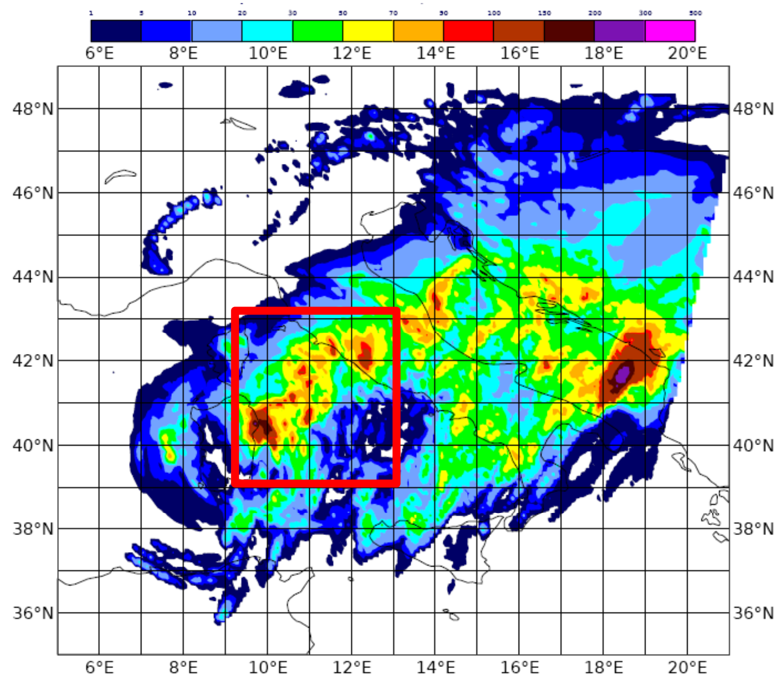


- dFSS uses the FSS to express the (dis)similarity of all the pairs of ensemble members
- dFSSmean indicates the “spatial” agreement within the ensemble for a given neighbourhood size



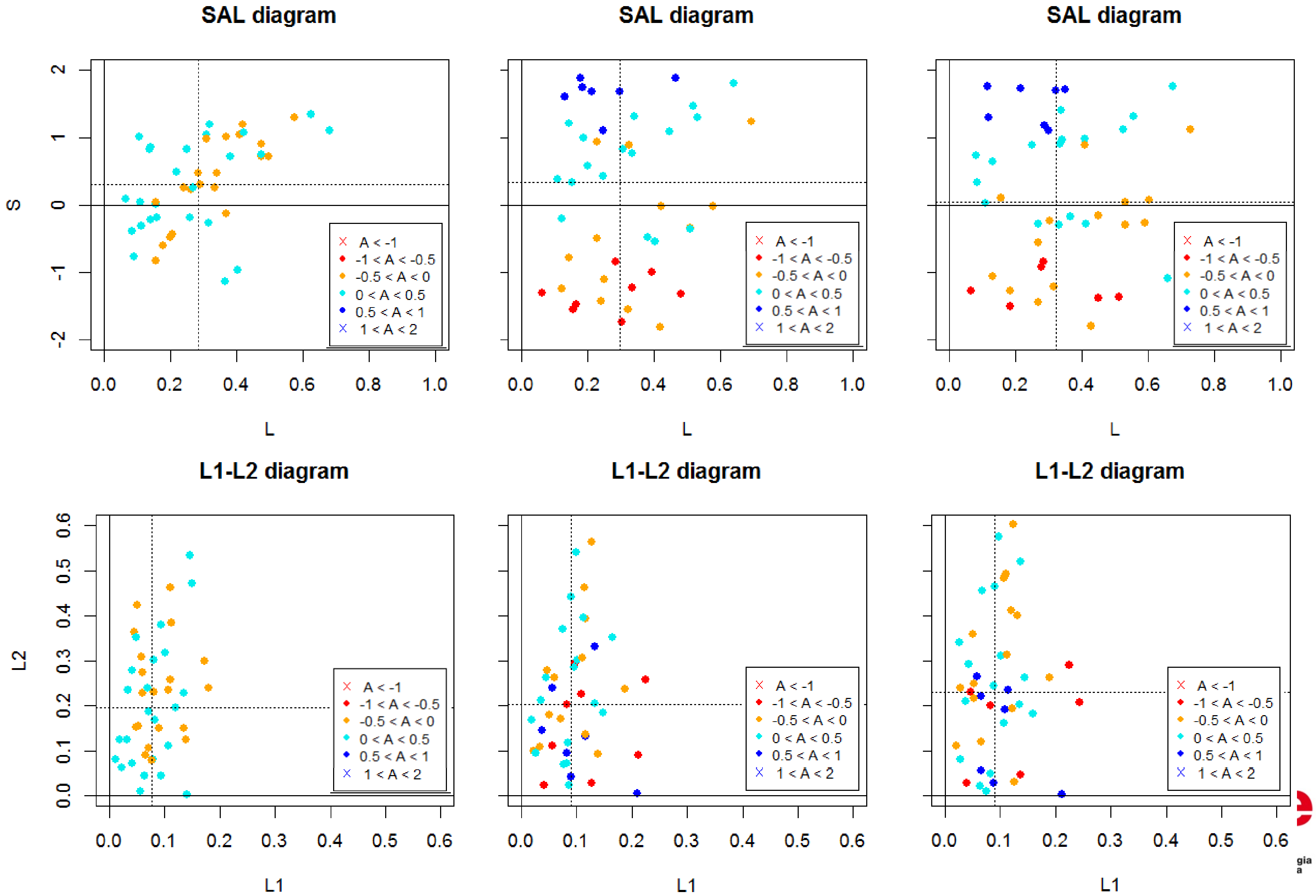
Evaluation of ensemble spread using the SAL metric

- SAL (Wernli et al 2008)
- 3 independent components:
  - **Structure**
  - **Amplitude**
  - **Location**
- Used here not for verification but for evaluating the similarity between fields, only forecasts



10/10/15 - 100mm – 125x163

no physics pert **SPPT** **SPPT + PP**



Summary of problems of the ensemble spread/skill

- in order for the ensemble to be reliable for the desired variable/phenomenon, the ensemble spread should match the forecast error
- the observational error should also be taken into account, but do we have a good estimate of it?
- the model bias hinders the estimate of the spread/skill relation, ideally should be removed (e.g. skill computed against analysis)
- what is a good measure of spread for the precipitation? Or the cloud cover, or the fog?
- how to combine spatial approach / user oriented and spread estimate?

Task 2:
Model perturbation

Model perturbations (task 2)

Learnings from model perturbations used and tested in COSMO-E:

- Stochastic Perturbation of Physical Tendencies (SPPT)
- Stochastic boundary layer perturbation scheme of Kober and Craig, 2016 (BLPERT)

Kober, K., and C. Craig, 2016: *Physically Based Stochastic Perturbations (PSP) in the Boundary Layer to Represent Uncertainty in Convective Initiation*, J. Atmos. Sci., **73**, 2893-2911.

Learnings from SPPT in COSMO-E

- Sum of parameterization tendencies for T and QV is largest in summer and dominated by those from the turbulence scheme
- Hence, SPPT is able to significantly increase spread in T/QV near surface in summer, but hardly in winter
- SPPT has only significant impact with large correlation lengths in space and time in the random pattern (we thus use 5deg and 6h)
- higher chance for unphysical temperature anomalies caused by advection scheme when physics tendencies are significantly reduced by SPPT (switched off locally in such cases)
- opr SPPT setup of COSMO-E leads to model crashes in 1.1 km runs

Thoughts about model perturbations

- model perturbations with BLPERT and SPPT have an impact on the physical processes that keep a convective system alive and they can be disruptive
- chance that perturbations are disruptive are particularly high with BLPERT with new random numbers every 10 minutes
- an issue of all our stochastic model perturbations schemes in convection-resolving ensembles (?)
- probably less an issue with parameter perturbations (?)
- process-level uncertainty representation by stochastic perturbed parameterizations (SPP) the long-term goal for our ensembles…?

Randomized physics (RP) in COSMO-DE-EPS

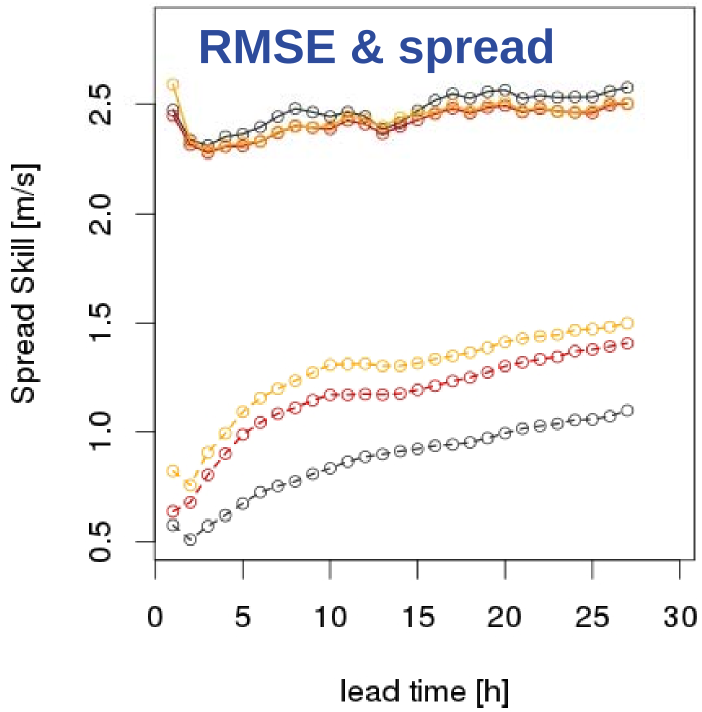
- ➔ Randomised selection of the physics parameter perturbation for COSMO-DE-EPS
- ➔ The values of the parameters are not random (2-3 different values for each of the 12 parameters) [see table]
- ➔ Each parameter gets perturbed for 50% of the members of each ensemble run and stays fixed over the forecast range

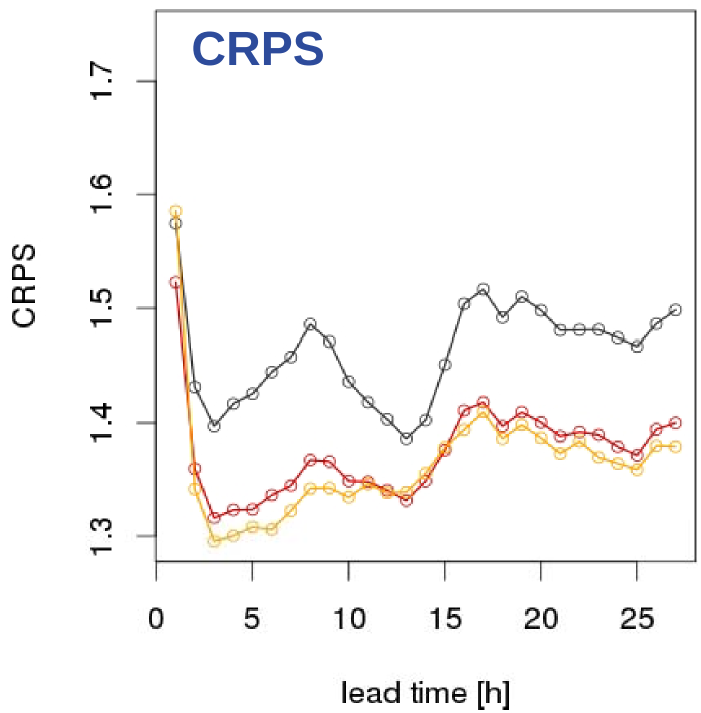
New perturbations (easier to implement with the RP)

a_stab	c_diff	radqi_fact	radqc_Fact	thick_sc	rlam_heat	entr_sc	q_crit	tur_len	tkh min	tkm min	lhn_coef
0	0.2	0.5	0.5	25000	1	0.0003	1.6	150	0.4	0.4	1
1	0.1	0.9	0.9	10000	10	0.002	4	500	0.7	0.7	0.5
	10			30000	0.1				0.2	0.2	

Results for 10m gusts, December 2014

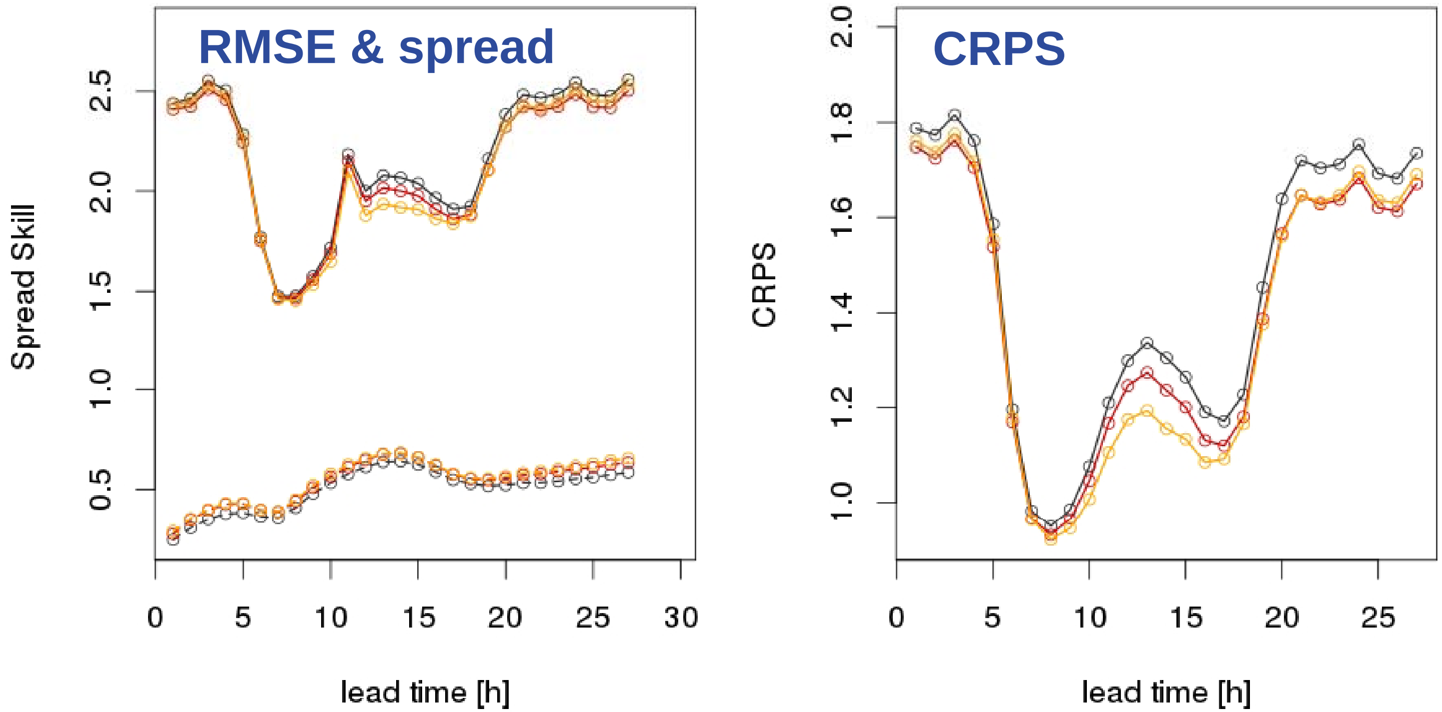
fixed (reference)
fixed with new perturbations
random with new perturbations





Results for T_2M, August 2013

fixed (reference)
fixed with new perturbations
random with new perturbations



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

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

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

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

$\xi(t)$: Gaussian noise

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

> γ, λ and σ are weather-dependent and are derived from past data.
> Potential predictors are $\left|\frac{\mathrm{d}T}{\mathrm{d}t}\right|$, $|U|$, cl.cover, $\left|\frac{\mathrm{d}q}{\mathrm{d}t}\right|$)
> for different model levels („offline“ training).

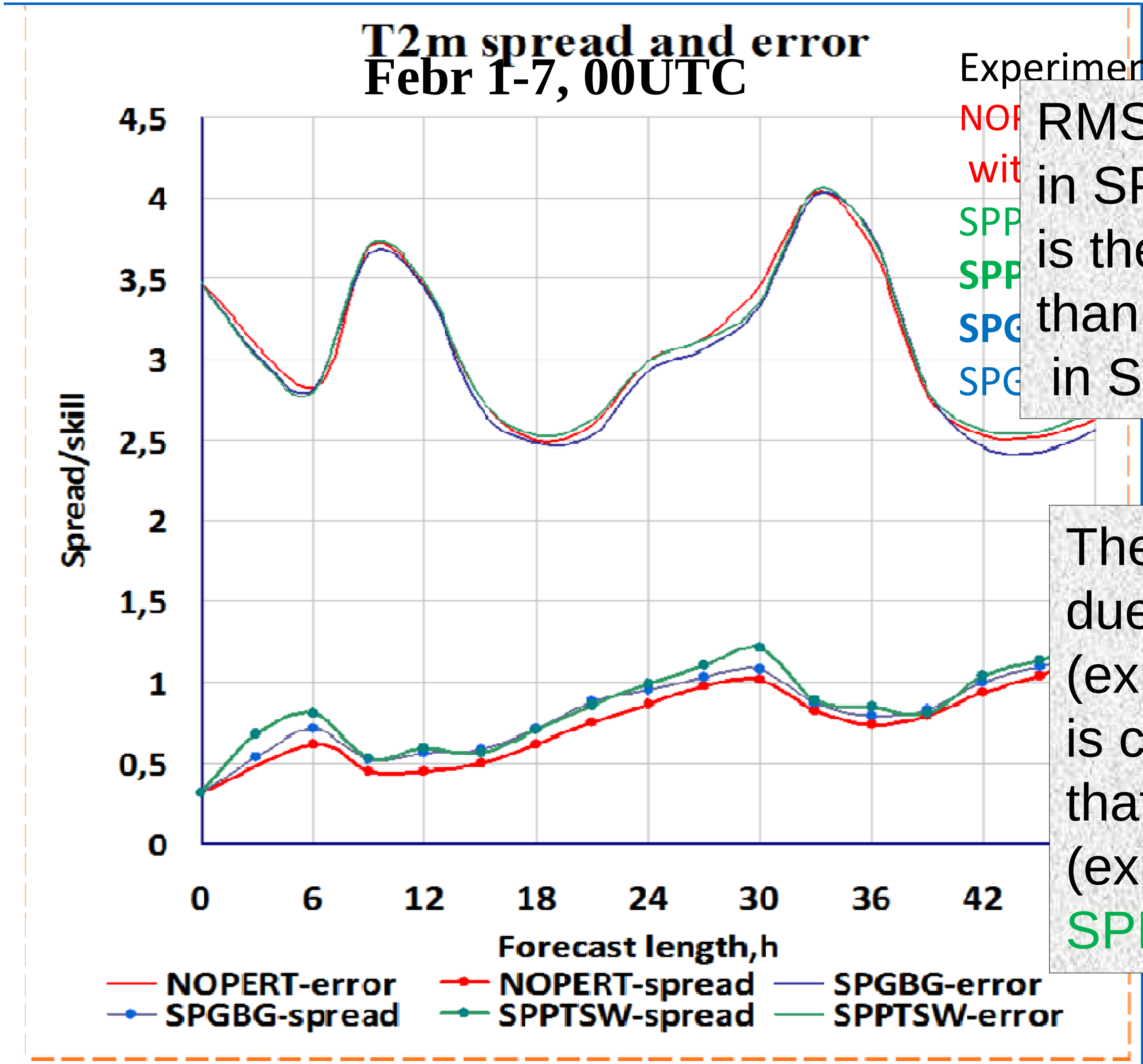
Application of stochastic pattern generator (SPG)* in COSMO-Ru2-EPS

- Experiments with COSMO-Ru2-EPS have been performed for winter period
- SPG was used in additive mode
- RMSE did not grow in SPG experiments
- The spread was comparable with that in SPPT experiments

) Tsyrulnikov M. and Gayfulin D. A limited-area spatio-temporal stochastic pattern generator for simulation of uncertainties in ensemble applications. – Meteorologische Zeitschrift, 2017, v. 26, N5, 549-566.

SPG was implemented to the COSMO code within KENDA PP

First results presented at CUS18 . The work in on-going within the APSU project



RMSE
in SPG experiments
is the same or smaller
than
in SPPT experiments

The spread increase due to SPG (experiment SPGBG) is comparable with that due to SPPT (experiment SPPTSW)

Task 3:
Lower boundary perturbation

Perturbation of other fields/parameters: soil surface temperature and collection efficiency coefficient

• Soil surface temperature (analysis – *laf*) was perturbed with additional constraints applied – an average perturbation over the entire domain is set to zero via normalization of perturbation values.

•An amplitude of perturbation was related to the soil type (clay, sand, peat etc.).

Collection efficiency coefficient E_c (*eff-coeff*) describes the efficiency with which a drop intercepts and unites with the smaller drops it overtakes.

• E_c is largely determined by the relative airflow around the falling drop.

• Smaller particles may be carried out of the path of the collector drop (E_c<1) or droplets not in the geometrical sweep-out volume may collide with the large drop due to turbulence or electric effects (E_c>0).

• In COSMO E_c is assumed constant and equal to 0.8.

• Perturbation was effective only for non-zero precipitation.

• Combinations of all perturbations were also examined.

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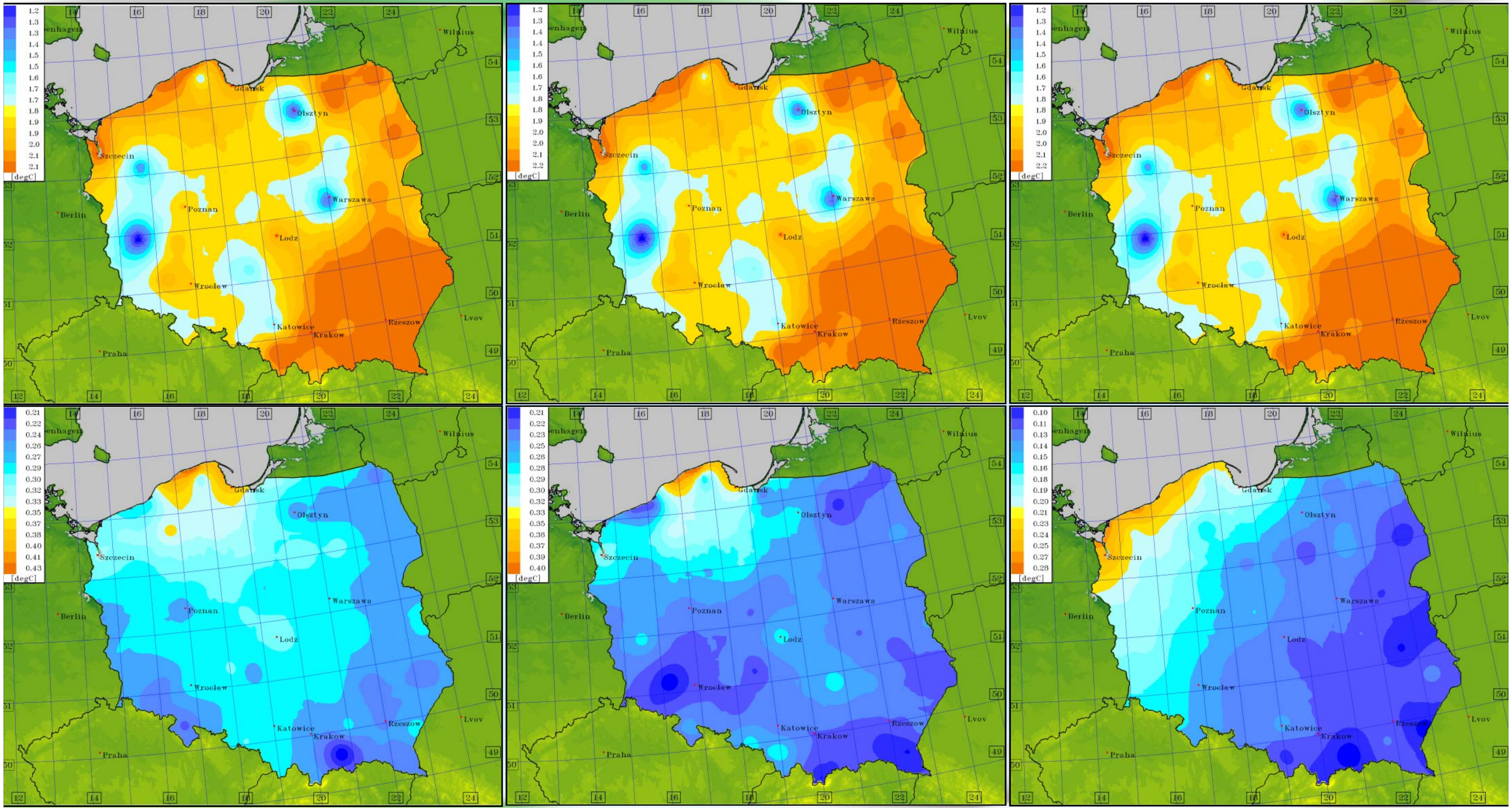


Results for TD2M EPS forecasts, June 2013. Upper – average skill, lower – average spread. Left: c_soil, middle: eps_all, right: laf_pert

Task 4:
Post-processing and interpretation

EUMETNET Project SRNWP EPS II

Fog forecasting tool *(fortran code)*

- **Input**:
  standard GRIB1/GRIB2 fcst from different models (defined by configuration namelist)

- **Output**:
  horizontal visibility [m] at surface computed with different algorithms
  + precipitation reduction (optional)

- **Methods**
  - Boudala et al., 2012 (minimum set of input parameters ... only surface fields T,Td,Ps,UV)
  - LWC (surface fields + T,Q,P,UV fields at lowest model level + qi,qc,qr,qs,qg)
  - Zhou, 2011 (surface fields + T,Q,P,UV vertical information at least in the first 500 m)
  - UPS approach (surface fields + T,Q,P,UV vertical information at least in the first 1200 m + 0-24 hours fcst of TD2m and T2m)
  - combined methods + correction for visibility reduction by precipitation

input parameters

EUMETNET

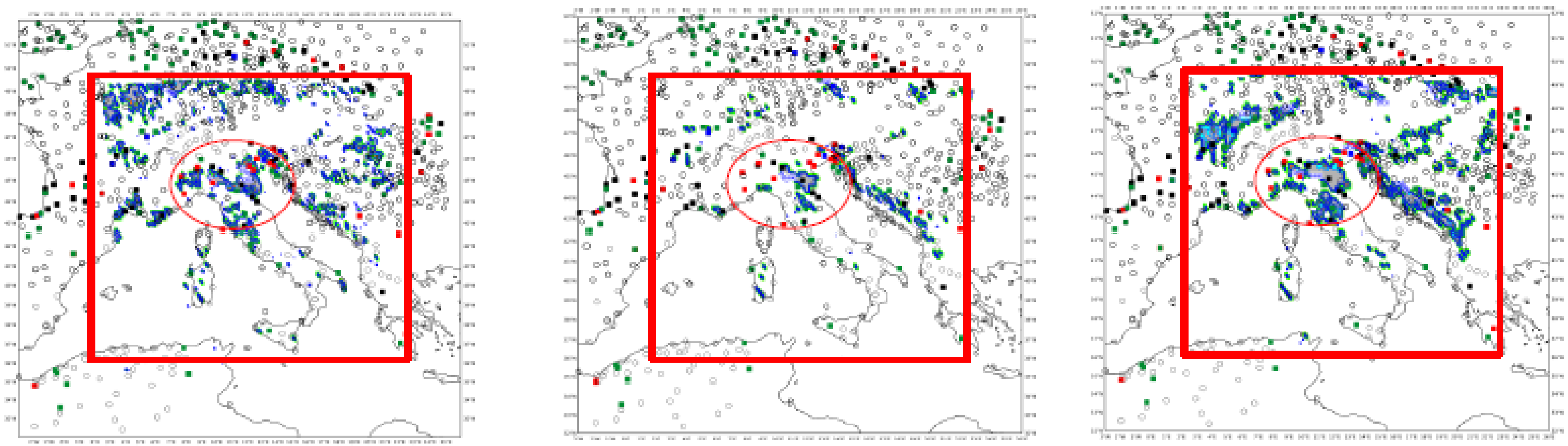
AERONAUTICA MILITARE 1923 2008 SERVIZIO METEOROLOGICO

Results with regional NWP model outputs:

COSMO-IT (2.8 km, Italian domain)

23 March 2017, 06UTC, T+30h

Zhou | **LWC** | **Boudala**



OBS	■	1-500	■	500-1000	■	1000-2000	■	2000-5000	O	> 5000
FCST	▭	1-500	▭	500-1000	▭	1000-2000	▭	2000-5000	▭	> 5000

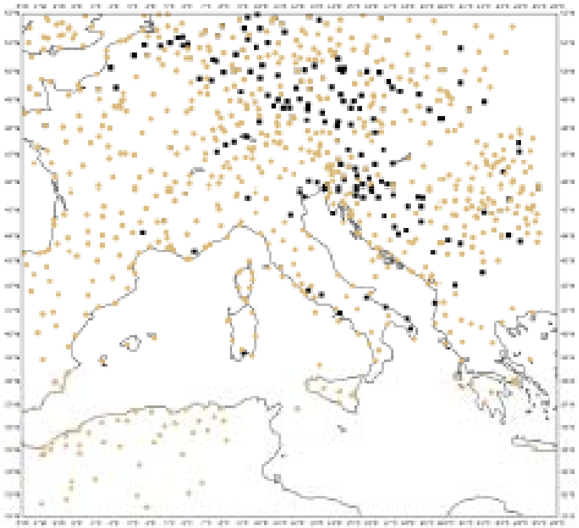
Results with regional NWP model outputs:

COSMO-ME EPS (7 km, Euromediterranean domain)

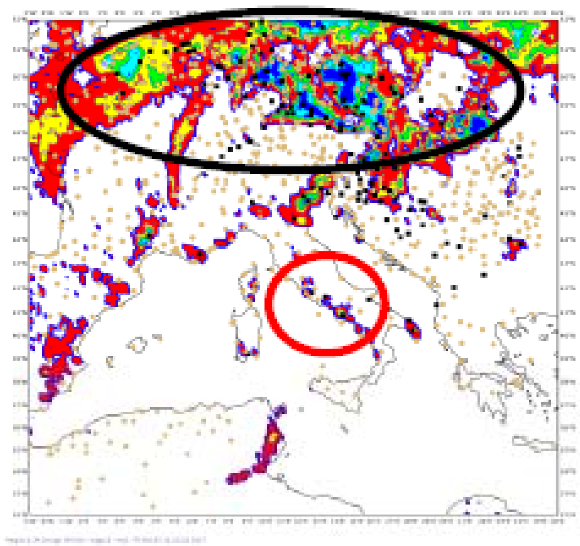
Probabilities of visibility < 1000 m

18 October 2017, 06UTC

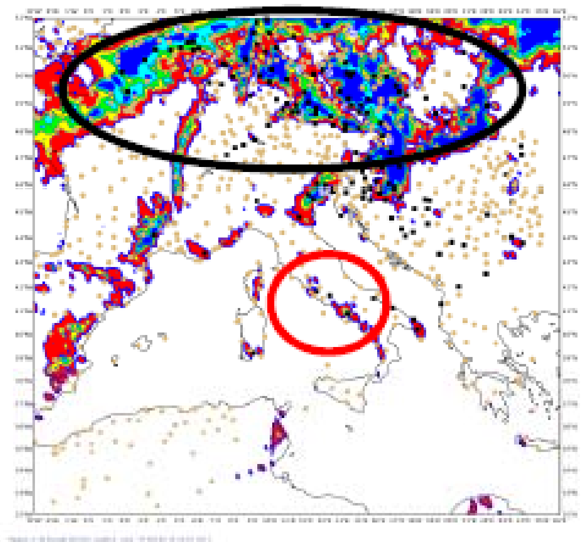
OBS



Zhou



Boudala



OBS > 1000 m < 1000 m

PROBABILITY 1-20% 20 - 40% 40 - 60% 60 - 80% 80-100%

Task 5:
Initial Conditions for the CP ensembles

Member selection for ICs and LBCs

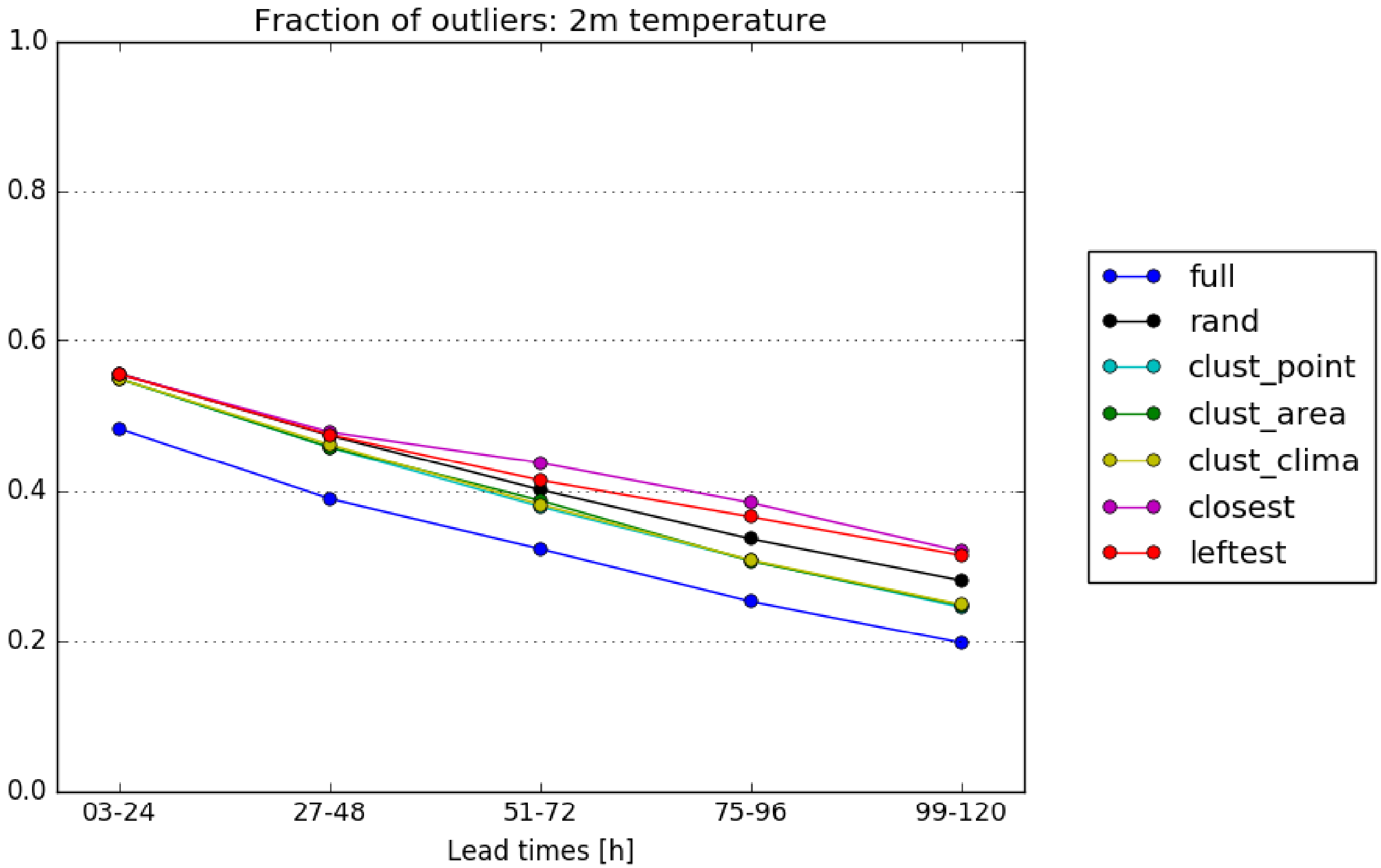
- Work by Stephanie Westerhuis (master thesis)
- Reminder operational setup: the perturbed members just use members 1-20 of KENDA and IFS-ENS

Questions:

- Is it possible to increase the COSMO-E forecast quality by using a smarter selection?
- How big is the difference in forecast quality between using the ‘best’ and the ‘worst’ set of 20 perturbed members?

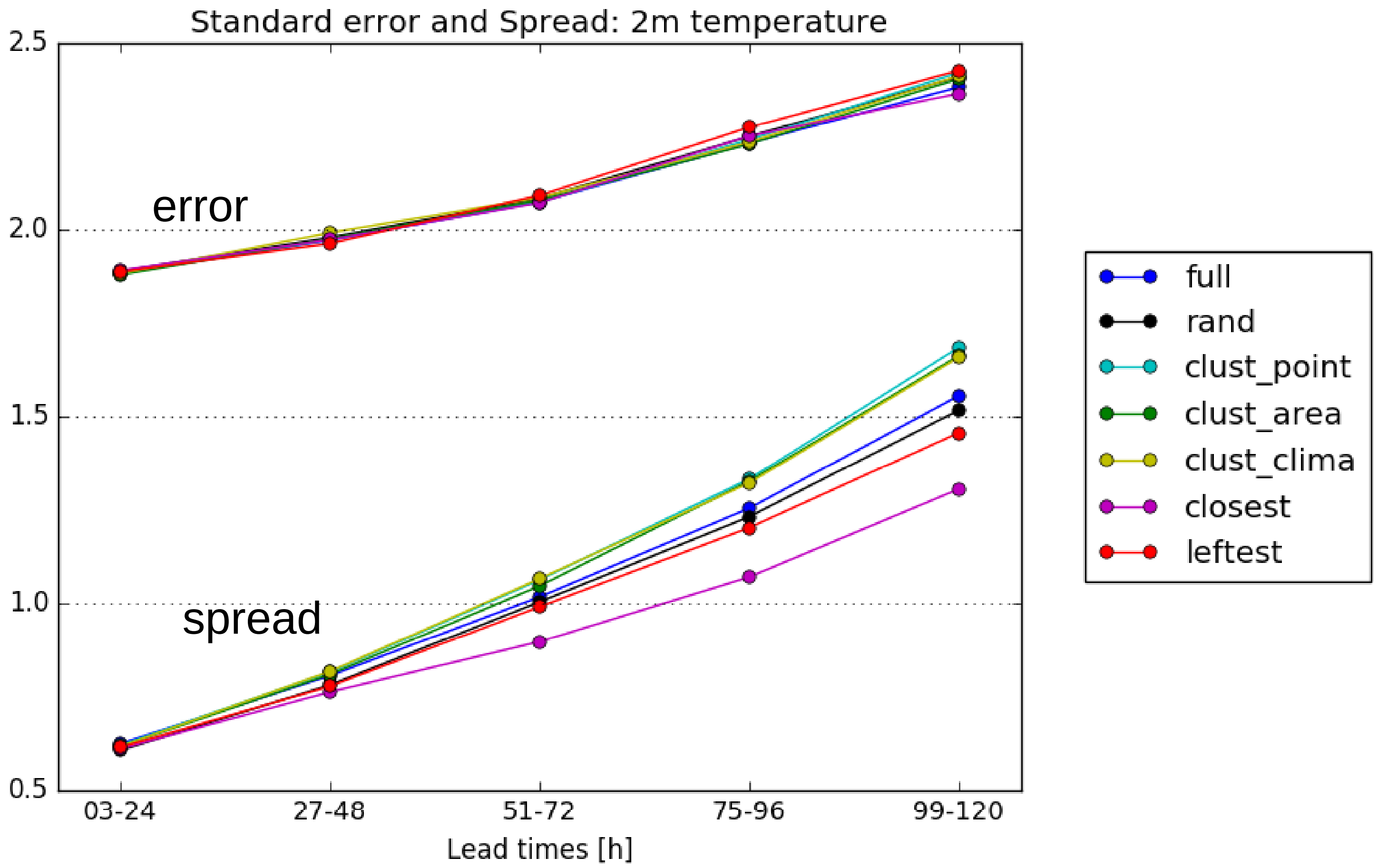
→ similar approach used as in COSMO-LEPS clustering:
3 variables: wind, temperature, humidity on 3 model levels
(~850, 700, 500 hPa)

2m temperature, outliers



‘full’ best as expected, 3 clustering setups second and almost identical, than ‘rand’, ‘leftest’, ‘closest’ is worse

2m temperature, spread/error



- 'clust' shows larger spread than 'full'! → tails 'overpopulated'
- 'rand' third, 'closest' clearly worst

Conclusions

- The spread/skill relation of the ensembles has been assessed extensively
- New methods were implemented/applied in the COSMO countries (maps of spread/error, new methods for spread computation, observational error)
- Model perturbations have been further tested or developed, also leading to reformulation of plans due to unsatisfactory performances
- Post-processing has been applied to the ensemble, probabilistic products for selected phenomena have been tested