Schweizerische Eidgenossenschaft
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Swiss Confederation

Federal Department of Home Affairs FDHA
**Federal Office of Meteorology and Climatology MeteoSwiss**

# COSMO-E

## Status and new Developments

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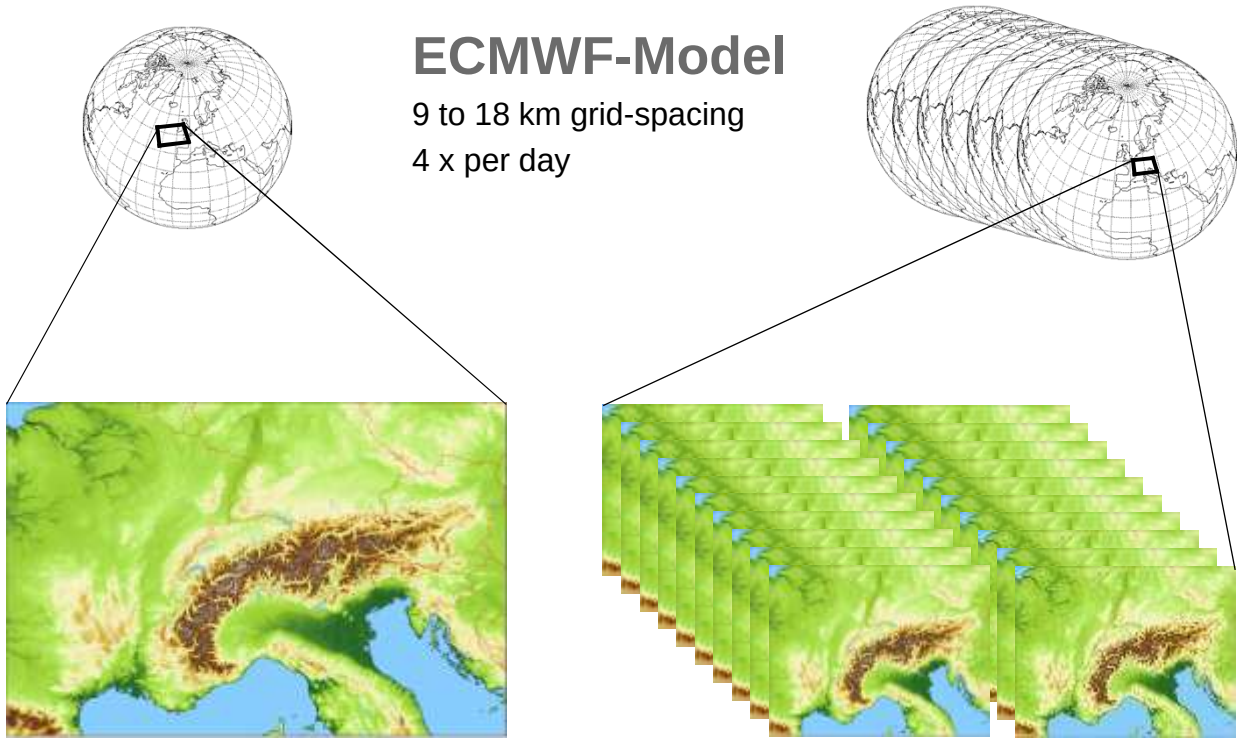
COSMO General Meeting, 5.– 8. September 2016

# COSMO-NExT

## ECMWF-Model

9 to 18 km grid-spacing
4 x per day



## COSMO-1

1.1 km grid-spacing
8 x per day
1 to 2 d forecast
**opr since March 31**

## COSMO-E

2.2 km grid-spacing
2 x per day
5 d forecast
21 members
**opr since May 19**

planned

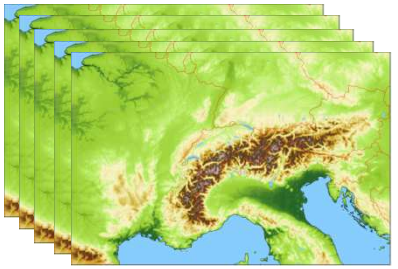
## KENDA

2.2 km grid-spacing
24 x per day
40 members
**opr since May 19**

# Outline

- Setup & implementation
- Recent work on SPPT
- Forecast quality
- Member selection for ICs and LBCs

# COSMO-E operational setup

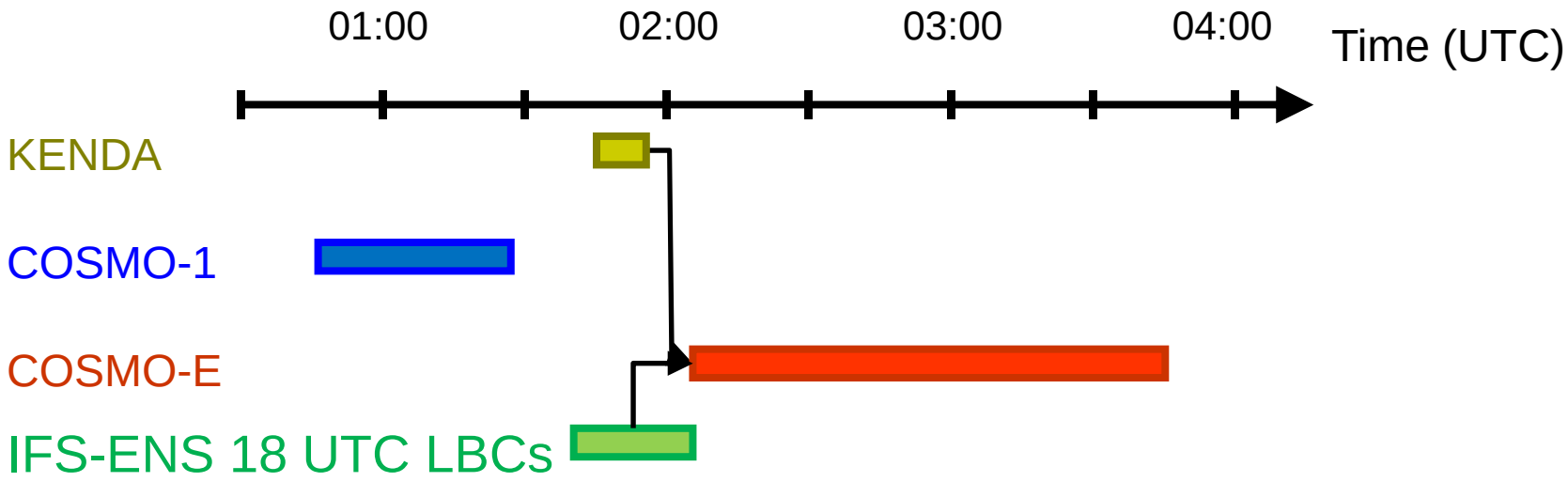


- 21 members (control and 20 perturbed runs)
- 2.2 km mesh-size, 60 levels
- two forecasts per day (00 and 12 UTC) up to +120h
- initial condition (perturbations): KENDA assimilation cycle
  - KENDA ensemble mean for control
  - KENDA members 1-20 (out of 40)
- lateral boundary condition (perturbations): IFS-ENS 18 & 06 UTC (i.e. 6h older LBCs):
  - IFS-ENS control for control
  - IFS-ENS members 1-20 (out of 50)
- model uncertainty: SPPT
- COSMO version 5.0+/GPU, single precision

# Implementation & performance on Piz Kesch


- System: 12 computational nodes per rack (using 50% of rack space) with:
  - 8 dual GPU cards (NVIDIA Tesla K80)
  - 2 Intel Haswell (2.6GHZ, 12-core) CPUs
- COSMO-E Setup:
  - 21 members in parallel
  - 2 members per node (i.e. 1 member has 1 CPU and 8 GPUs)
- Performance: 97 min for +120h forecast

# Schedule 00 UTC forecasts




- COSMO-E can only run after COSMO-1
- wait additional 30 minutes for new IFS-ENS LBCs

→ (currently) long cut-off for KENDA 00/12 UTC analyses: 105 min.

# SPPT: Stochastic Perturbation of Physical Tendencies

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

dynamics — random pattern

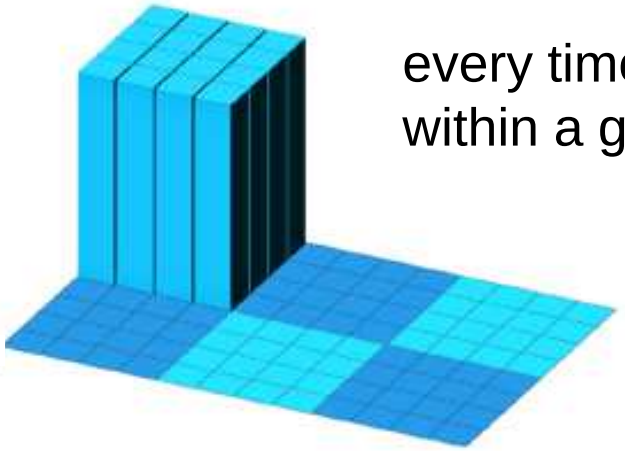
local tendency | horizontal diffusion | physics

$X$ prognostic variable (u, v, T, $q_v$, $q_c$, $q_i$, $q_r$, $q_s$, $q_g$)

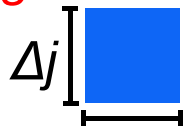
${P_i}^X$ physical parameterisation scheme *i*
(turbulence, radiation, microphysics, shallow convection, …)

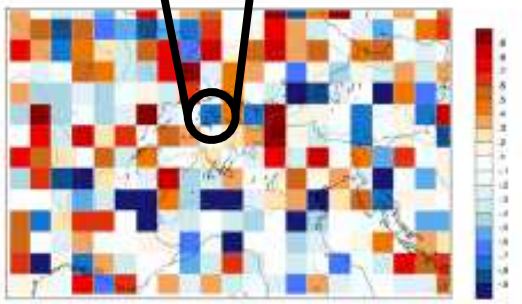
*copied and adapted from Shutts*

# SPPT: Generation of random pattern

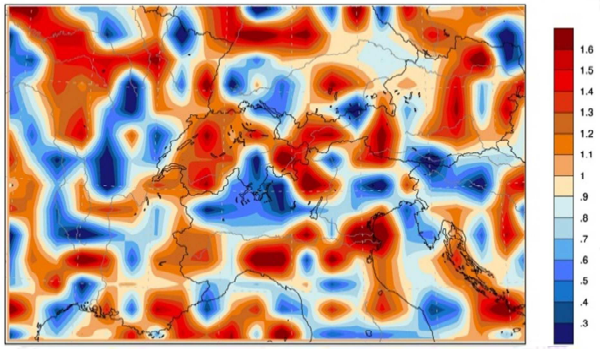


every timestep $\Delta t$ draw N(0,$\sigma$) random numbers within a given *range* on coarse grid $\Delta i$, $\Delta j$



generate smooth pattern on COSMO grid by interpolating in time and horizontally in space

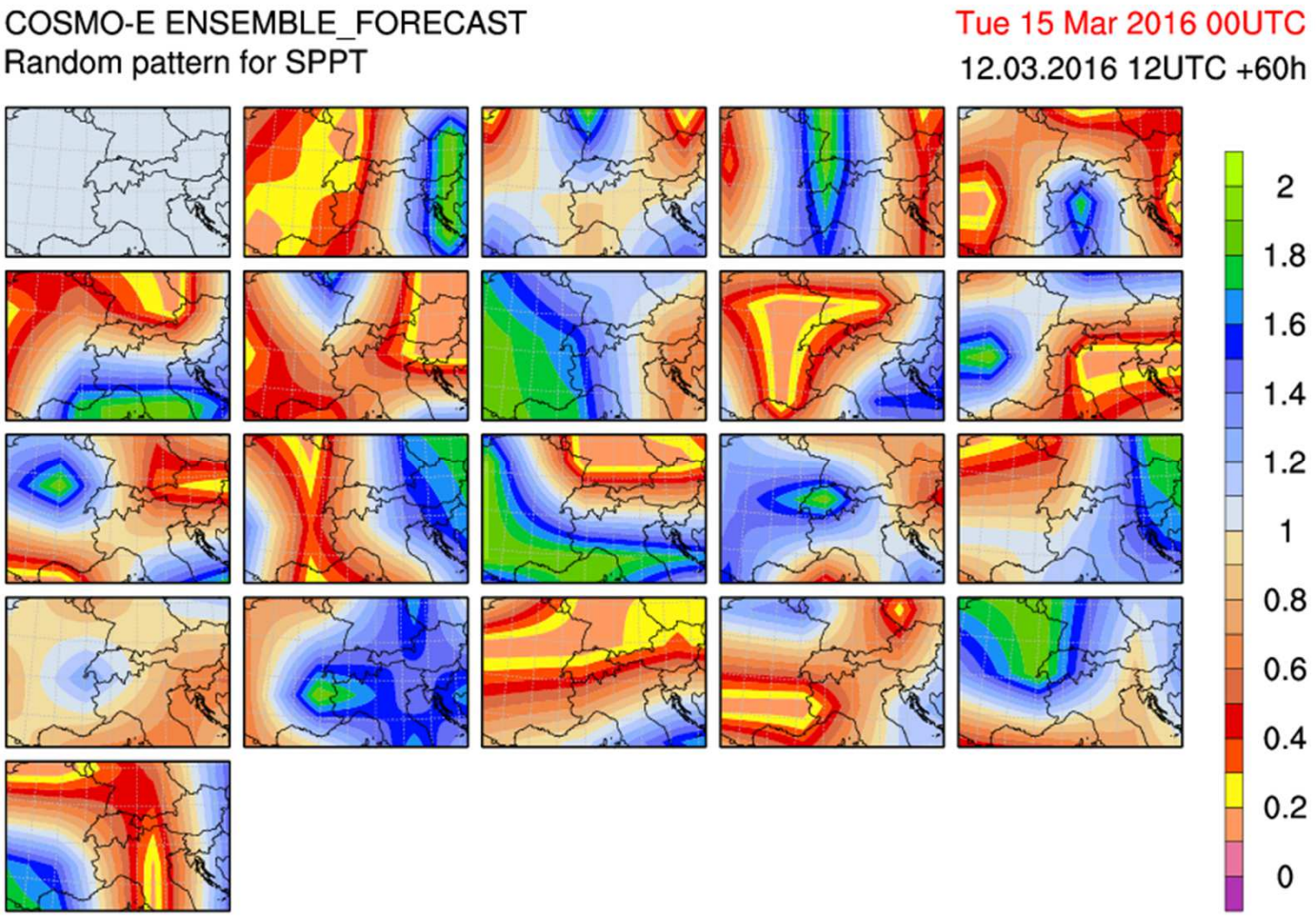



random pattern (1+*rand*) "RAPA"



*copied and adapted from Torrisi*

# Random pattern (RAPA)

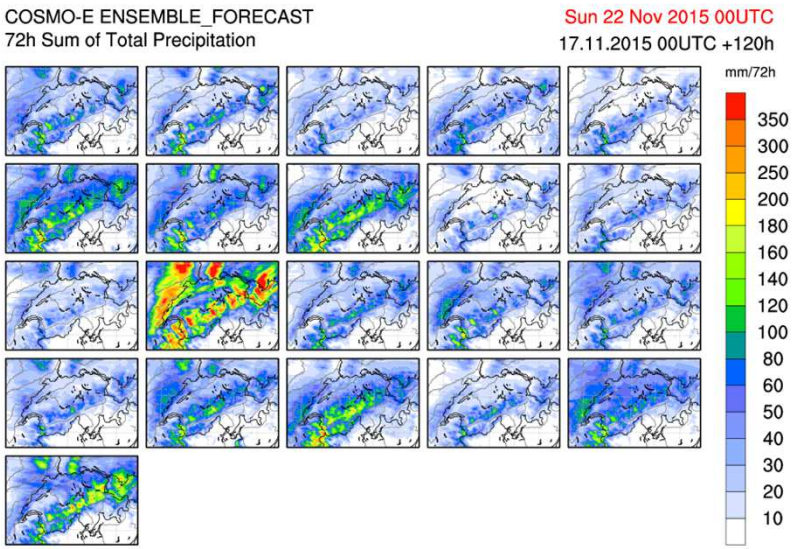


# Work on SPPT since last COSMO GM and findings

- investigated excessive precipitation amounts in some members
- solution for temperature anomaly problem

# Excessive precipitation due to SPPT setup

- itype_qxpert_rn != 2 can lead to unrealistically high precipitation amounts if the random pattern has a small value during a precipitation event
- all available qx tendencies must be perturbed with the same random pattern to be physically consistent
  → use itype_qxpert_rn=2! (if using qr, qs, qg)




*members with up to 1000 mm/120h*

# Temperature anomaly problem

- 5$^{th}$ order advection scheme can produce temperature anomalies
- usually mitigated by physics and targeted diffusion
- however, if physics tendencies are significantly reduced by SPPT, temperature anomalies can become significant: cold/warm pools and even model crashes
- new switch *ltargetdiff_mask* to switch off SPPT (for the next time step) where targeted diffusion is active
- allows to use SPPT again down to the lowest model level

# Temperature anomaly problem

- Main code changes:

**hori_diffusion.f90:**

```
DO l=1, nmbr_points
   i = i_liste(l)
   j = j_liste(l)        } grid-point at which targeted diffusion is active
   k = k_liste(l)
   Tp(i,j,k) = T_new(l)
   IF (ltargetdiff_mask) THEN
     pertstoph_mask(i,j,k) = 0.0_wp
   ENDIF
ENDO
```

**src_stoch_physics.f90:**

```
IF (ltargetdiff_mask) THEN
  pertstoph(i,j,k) = pertstoph(i,j,k) * pertstoph_mask(i,j,k) + 1.0_wp
  ! reset mask
  pertstoph_mask(i,j,k) = 1.0_wp
ELSE
```

*done by O. Fuhrer and P. Spörri*

# Current SPPT setup

SPPT namelist switches for COSMO-E, changes since last COSMO GM in red:

```
&EPSCTL
  itype_vtaper_rn=2,
  itype_qxpert_rn=2,
  itype_qxlim_rn=0,
  npattern_rn=1,
  hinc_rn=6,
  dlat_rn=5.0,
  dlon_rn=5.0,
  stdv_rn=1.0,
  range_rn=0.9,
  lgauss_rn=.TRUE.,
  lhorint_rn=.TRUE.,
  ltimeint_rn=.TRUE.,
  ltargetdiff_mask=.TRUE.
```

# COSMO-E forecast quality

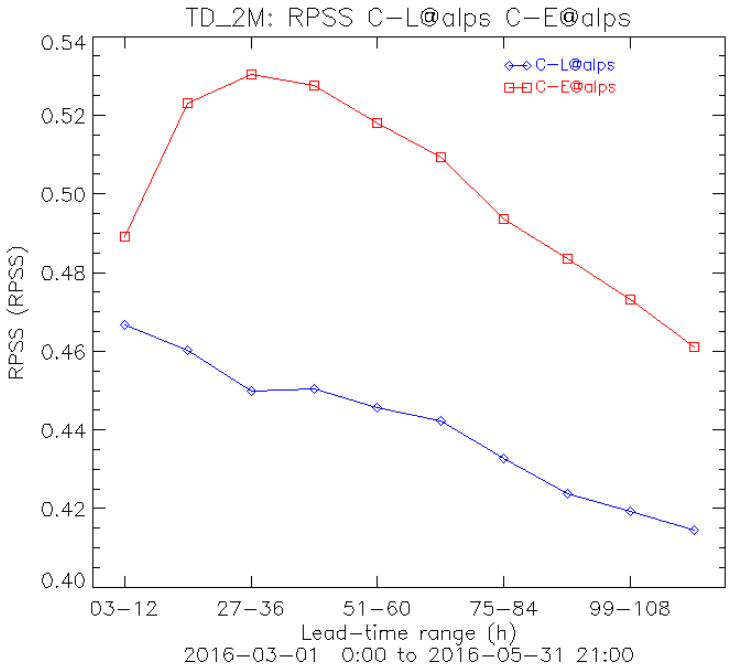
- ensemble verification for March – May 2016 for SYNOP stations
- comparison against COSMO-LEPS

# COSMO-E vs. COSMO-LEPS

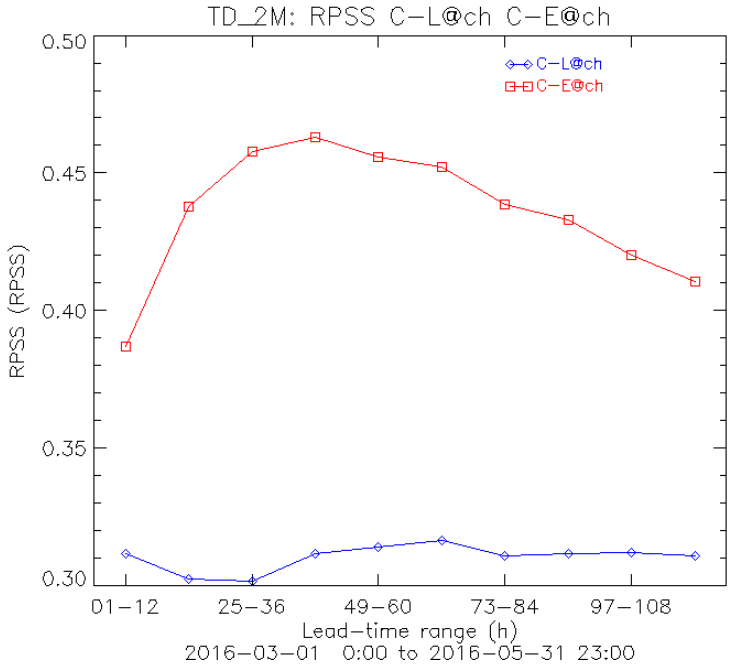
| | COSMO-E | COSMO-LEPS |
|---|---|---|
| grid-spacing | 2.2 km (0.02°) | 7.0 km (0.0625°) |
| domain | Alps | Europe |
| forecast range | +120h | +132h |
| deep convection | explicit | Tiedtke convection scheme |
| subgrid-scale orographic drag | roughness length | SSO scheme & roughness length |
| initial conditions | KENDA | IFS-ENS + COSMO-EU soil |
| boundary conditions | IFS-ENS -6h | IFS-ENS 0 & -12h ('super-ensemble') |
| physics perturbations | SPPT | Parameter perturbations |
| availability (last product) | 4h after analysis time (3:30h as soon as ECMWF provides LBCs earlier) | ~10:15h after analysis time |

# TD2m, RPSS, MAM 2016

Alps



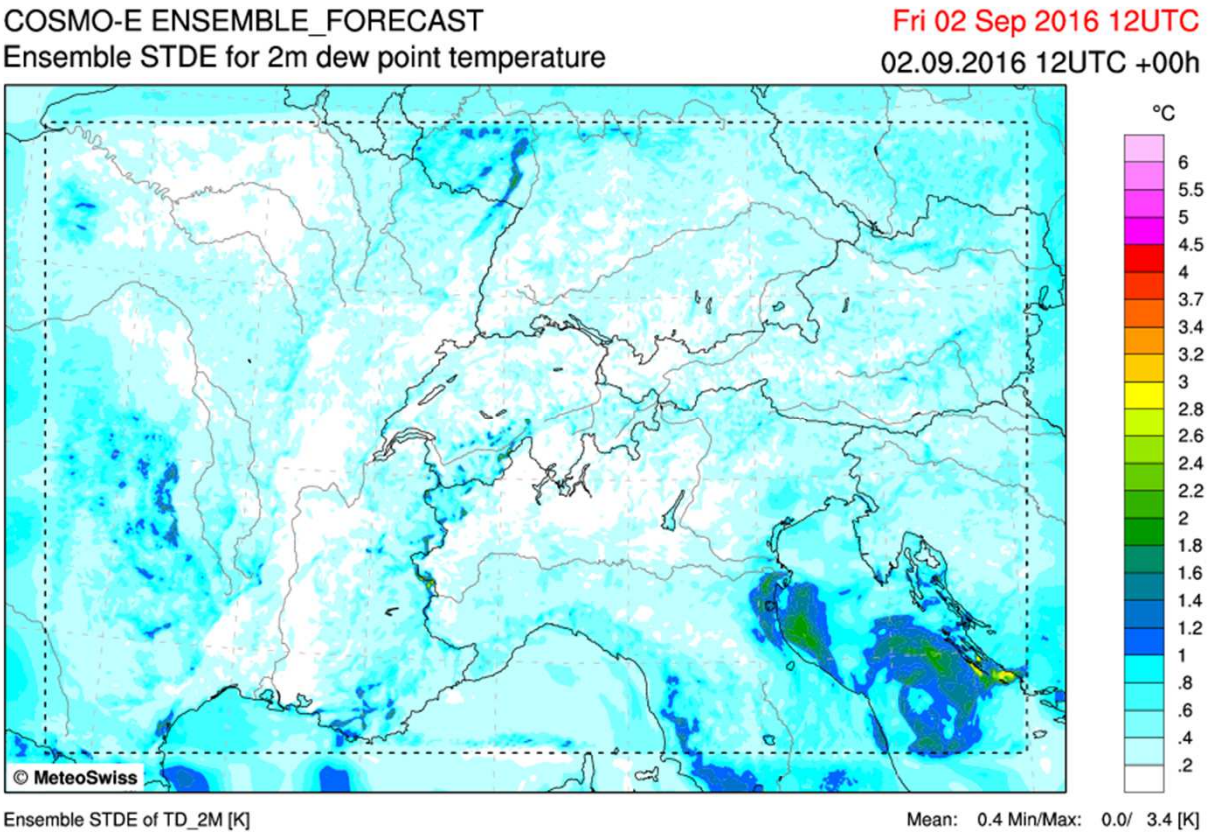

COSMO-E
Switzerland
COSMO-LEPS




Thresholds: -15,-10,-5,0,5,10,15,20,25 degrees Celsius

- COSMO-E clearly better than COSMO-LEPS
- but COSMO-E shows strange score in the short-range since we use KENDA Ics (T2m behaves similar but less pronounce)

# Spread TD2m (example opr suite)

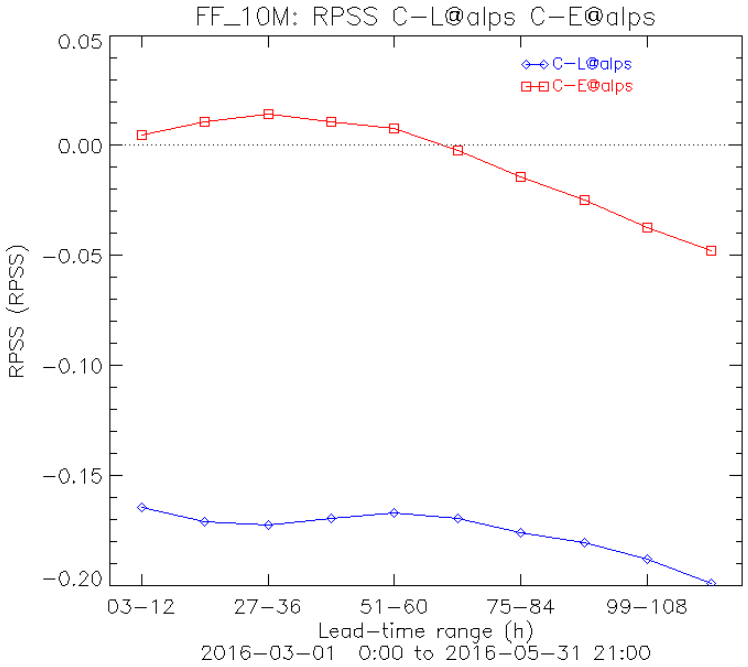



- spread in ICs smaller than 0.2 K in larger parts of Switzerland (!)
- uncertainty definitely much larger
- eager to get ICs from new KENDA setup (SPPT, soil moisture perturbations → see talk by Daniel)

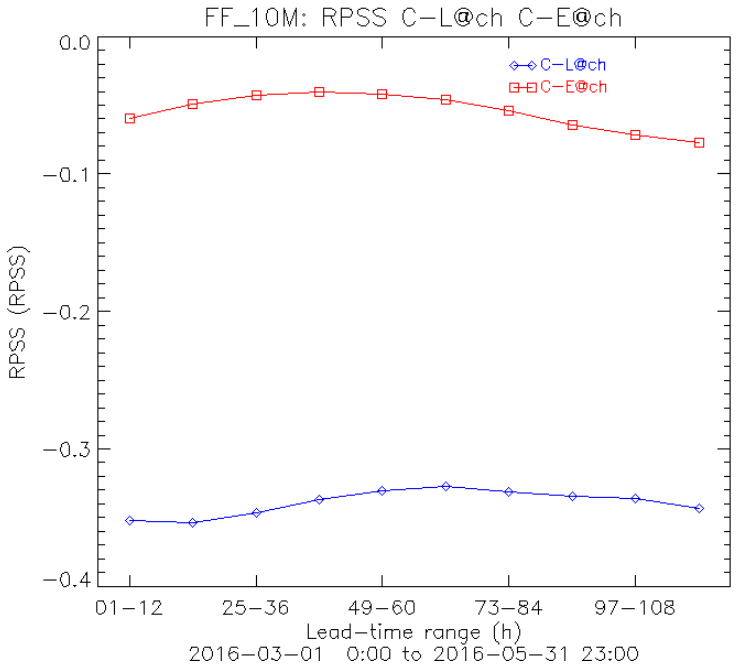
# Wind speed 10m, RPSS, MAM 2016

COSMO-E
COSMO-LEPS

Alps




Switzerland



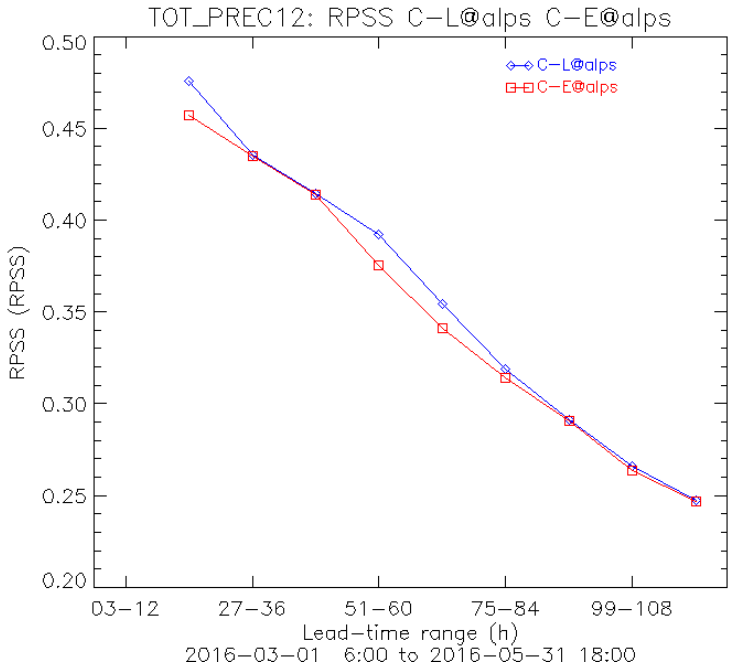

Thresholds: 2.5,5.0,7.5,10,15,20 m/s

- very bad, worse than climatological forecast (!)
- COSMO-E at least better than COSMO-LEPS

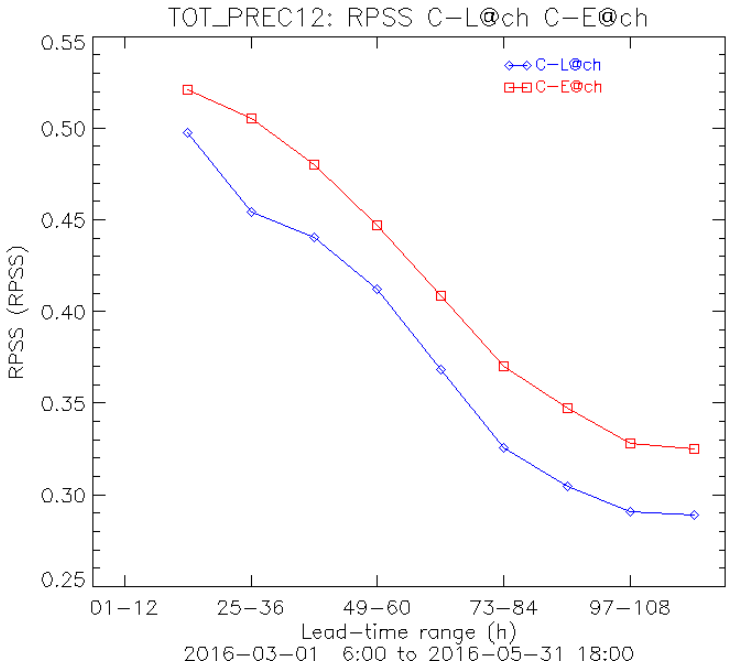
# 12h precipitation, RPSS, MAM 2016

COSMO-E
COSMO-LEPS

Alps




Switzerland



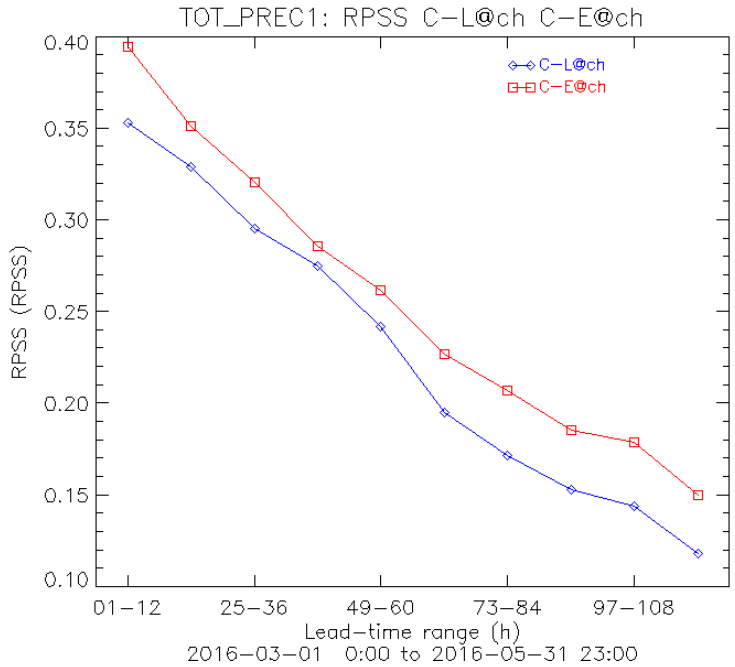

Thresholds: 0.1,0.2,0.5,1,2,5,10,20,30,50mm

- skill until end of forecast range
- COSMO-E outperforms COSMO-LEPS for Swiss domain only

# RPSS, 1h precipitation, MAM 2016

COSMO-E
COSMO-LEPS

Switzerland



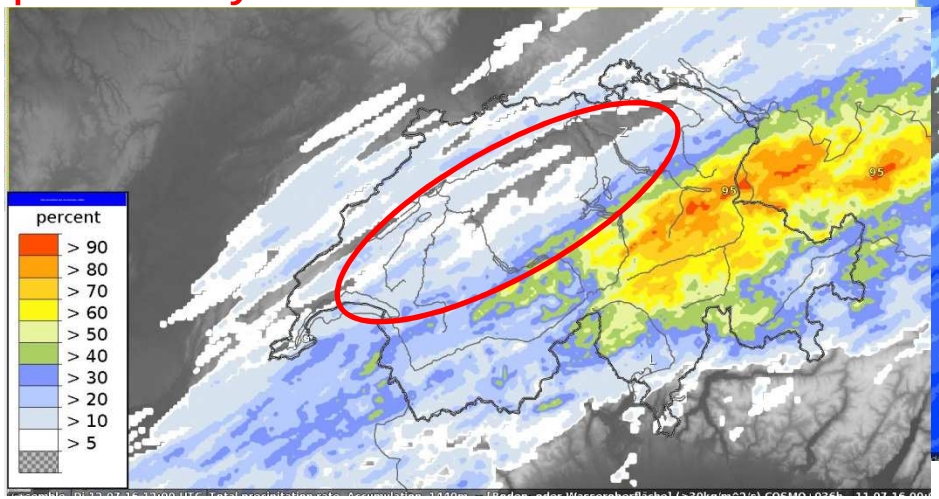

Thresholds: 0.1,0.2,0.5,1,2,5,10 mm

- COSMO-E shows skill until end of forecast range
- COSMO-E clearly outperforms COSMO-LEPS

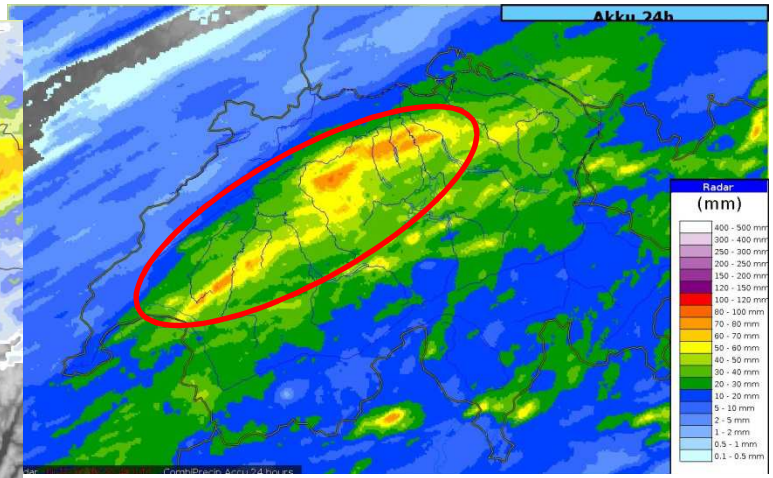
# Main feedbacks from forecasters

- COSMO-E often triggers convection over the Alps only and misses it over the Swiss plateau:
  → lack of convective precipitation
  → missed warnings for thunderstorms
  → in particular with weak synoptic forcing
- Example:

probability TP > 30mm/24h:




TP sum, up to 70mm/24h:



# Forecast quality summary

- COSMO-E outperforms COSMO-LEPS in most variables despite the 6h older LBCs
- benefit more pronounced over Switzerland
- still underdispersive in the PBL, most severe in the short-range: too small spread in the initial conditions
- very bad scores for wind speed (and gusts)
- problems in convection triggering without orographic forcing

# 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

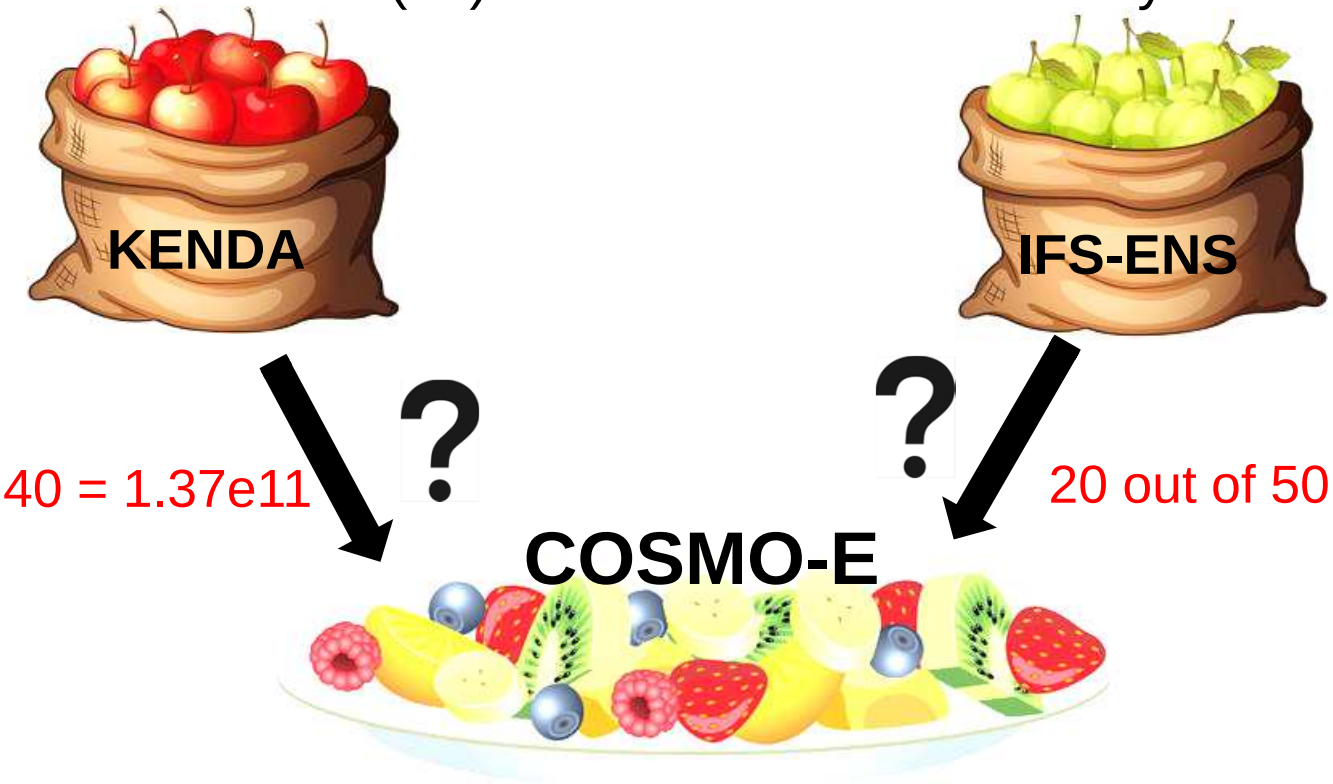
Questions:

- 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?

# Many possible selections…

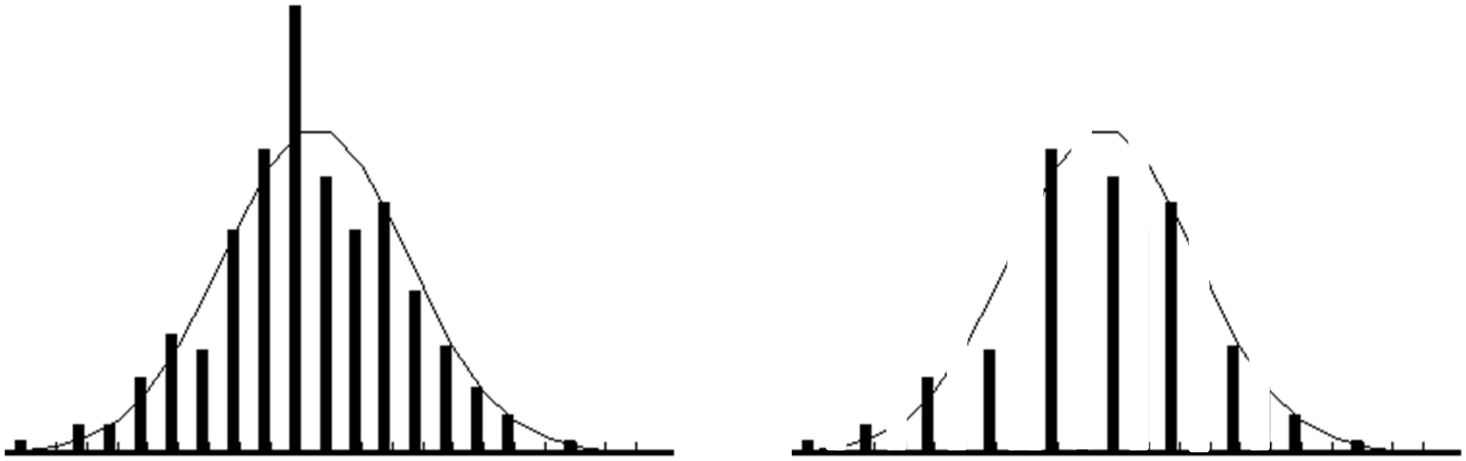
Initial conditions (40)

Lateral boundary conditions (50)




Pragmatic way out: take full ensemble as a proxy for the best possible selection (worst see later).

# Goal: Keep the “shape of the PDF”

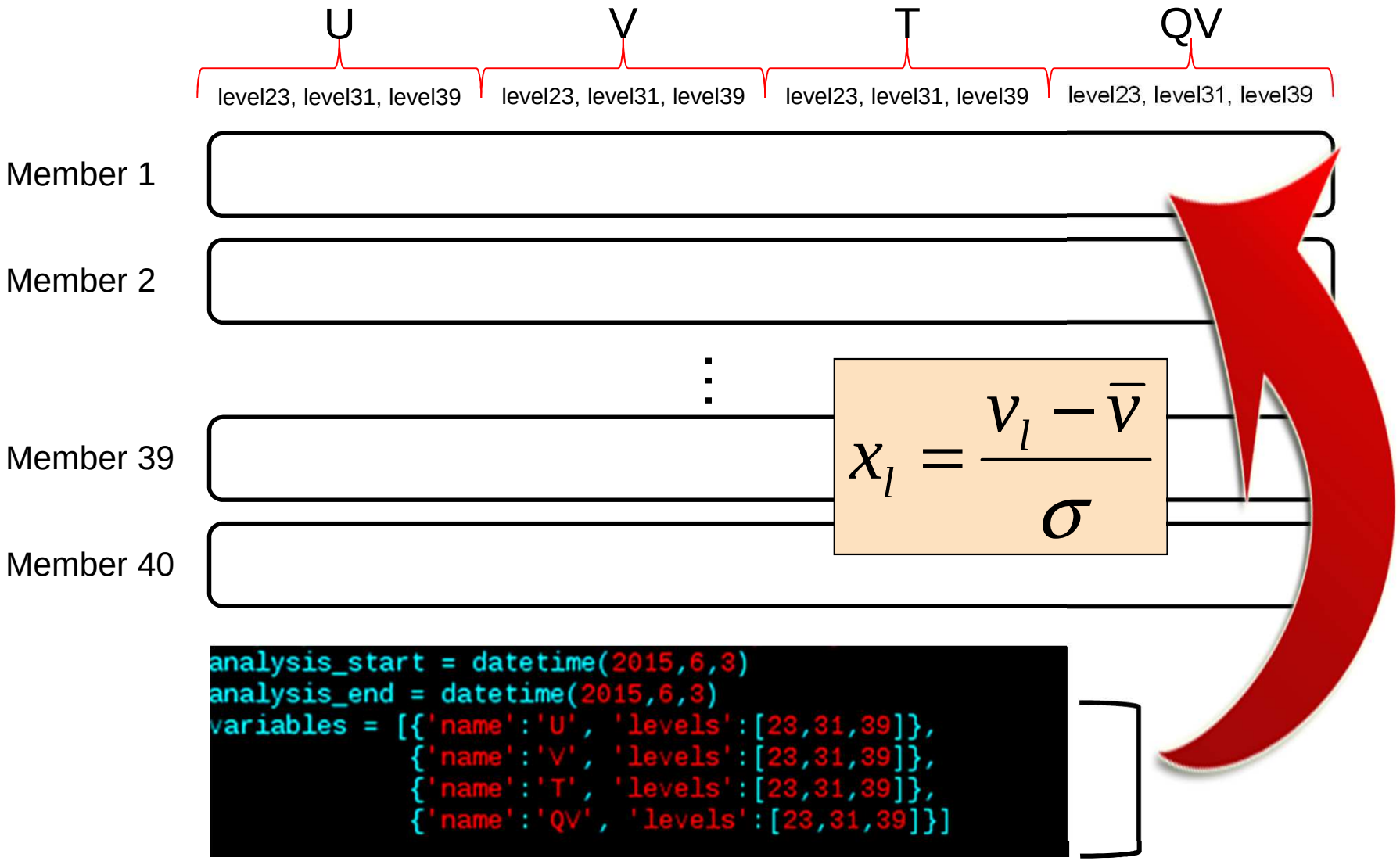


Problem: Multidimensionality (grid-points, variables)

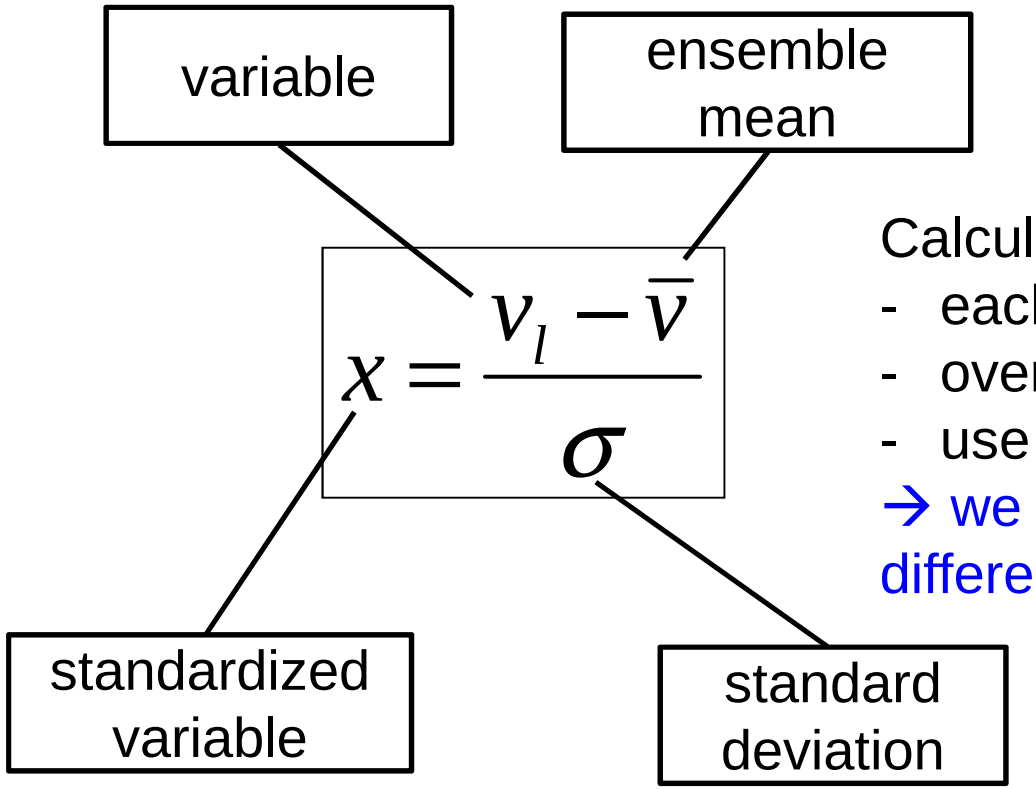
→ reduce phase space and «make» it one-dimensional

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

# Tranformation to 1- dim. & standardisation



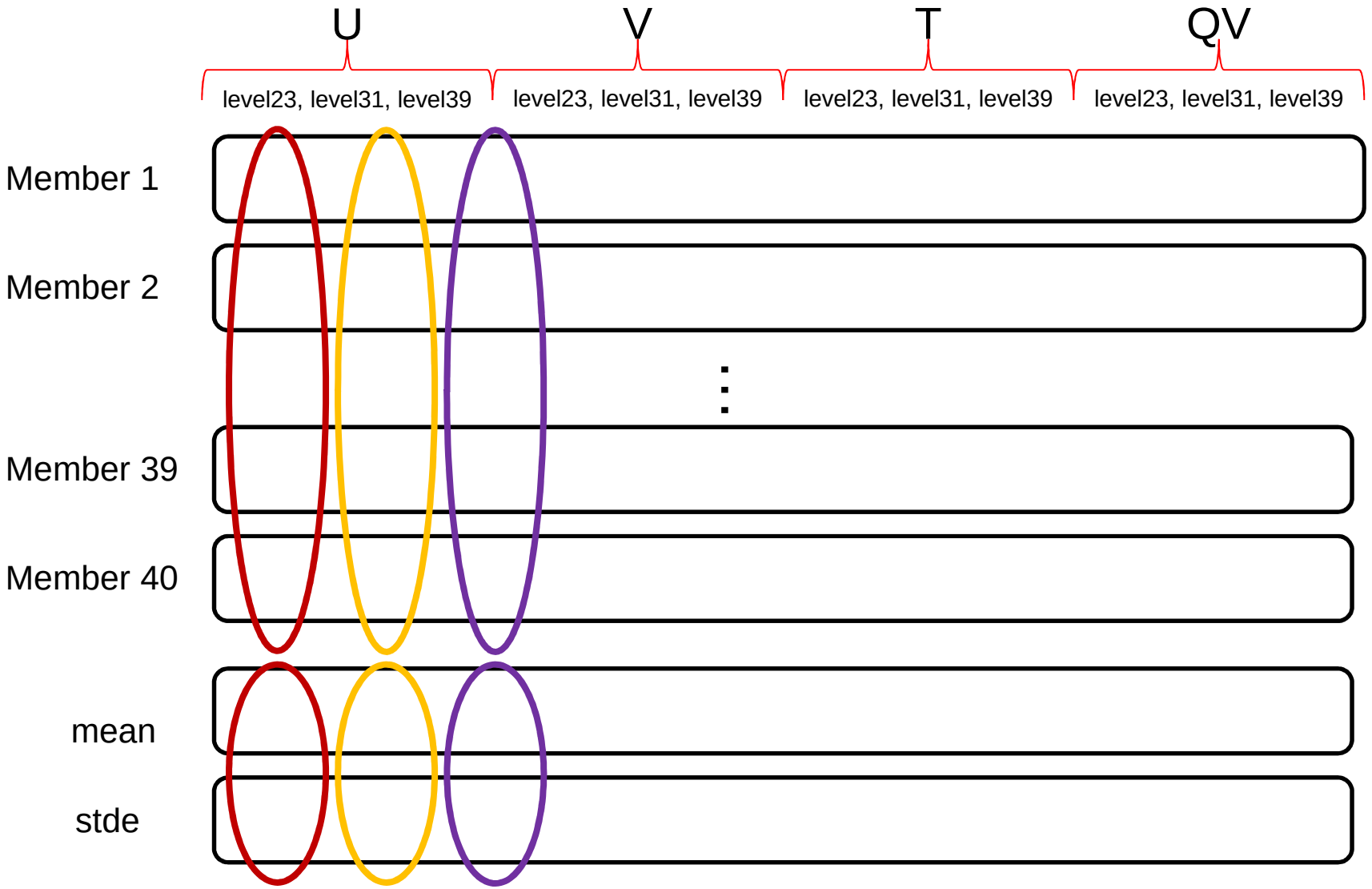
# Standardisation




Calculate mean and std. dev. for
- each point?
- over area (domain)?
- use ‘climatology’?

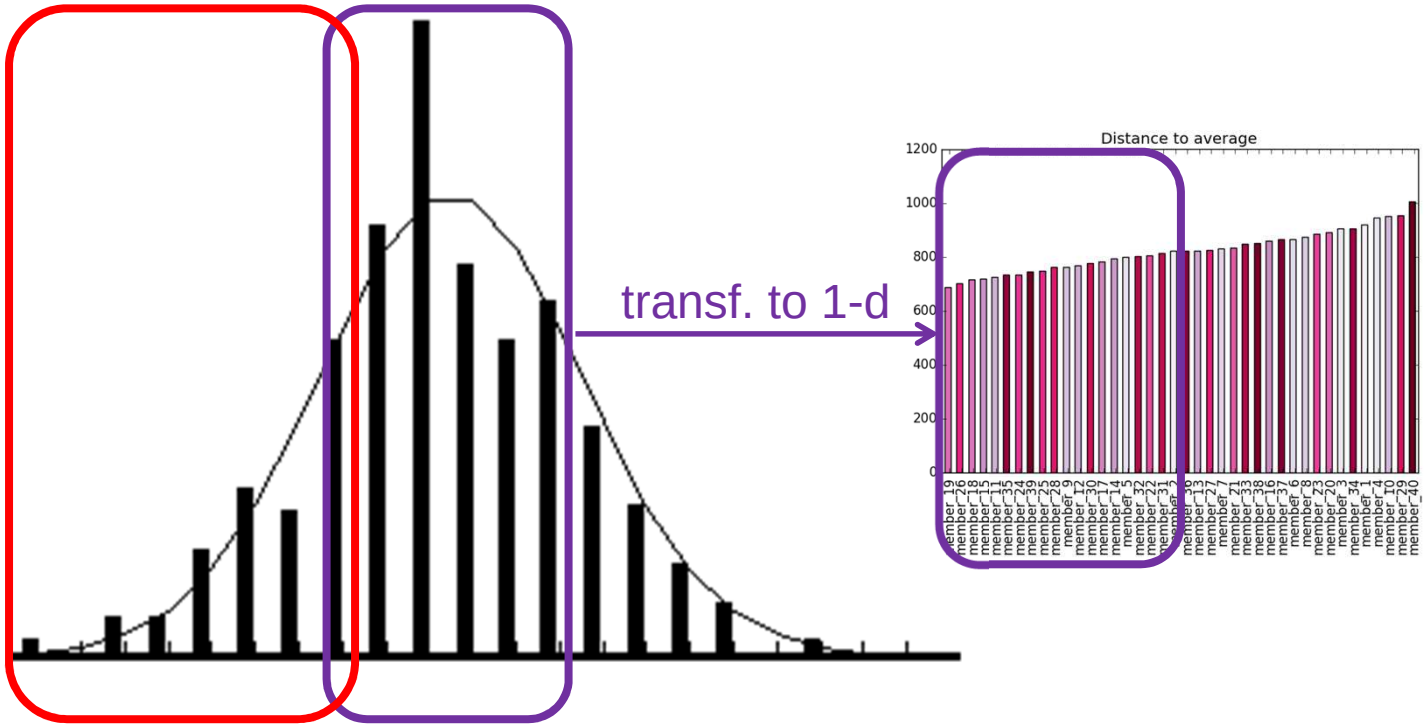
→ we tested all 3 options, but differences small in most cases

# Point-wise standardisation cheapest



# 2 proxies for worst possible selection

- ‘leftmost’: left tail of PDF for QV (20 driest members)
- ‘closest’: closest to ensemble mean for U,V,T,QV



# Sophisticated selection: clustering

complete-linkage hierarchical clustering, similar as in COSMO-LEPS:

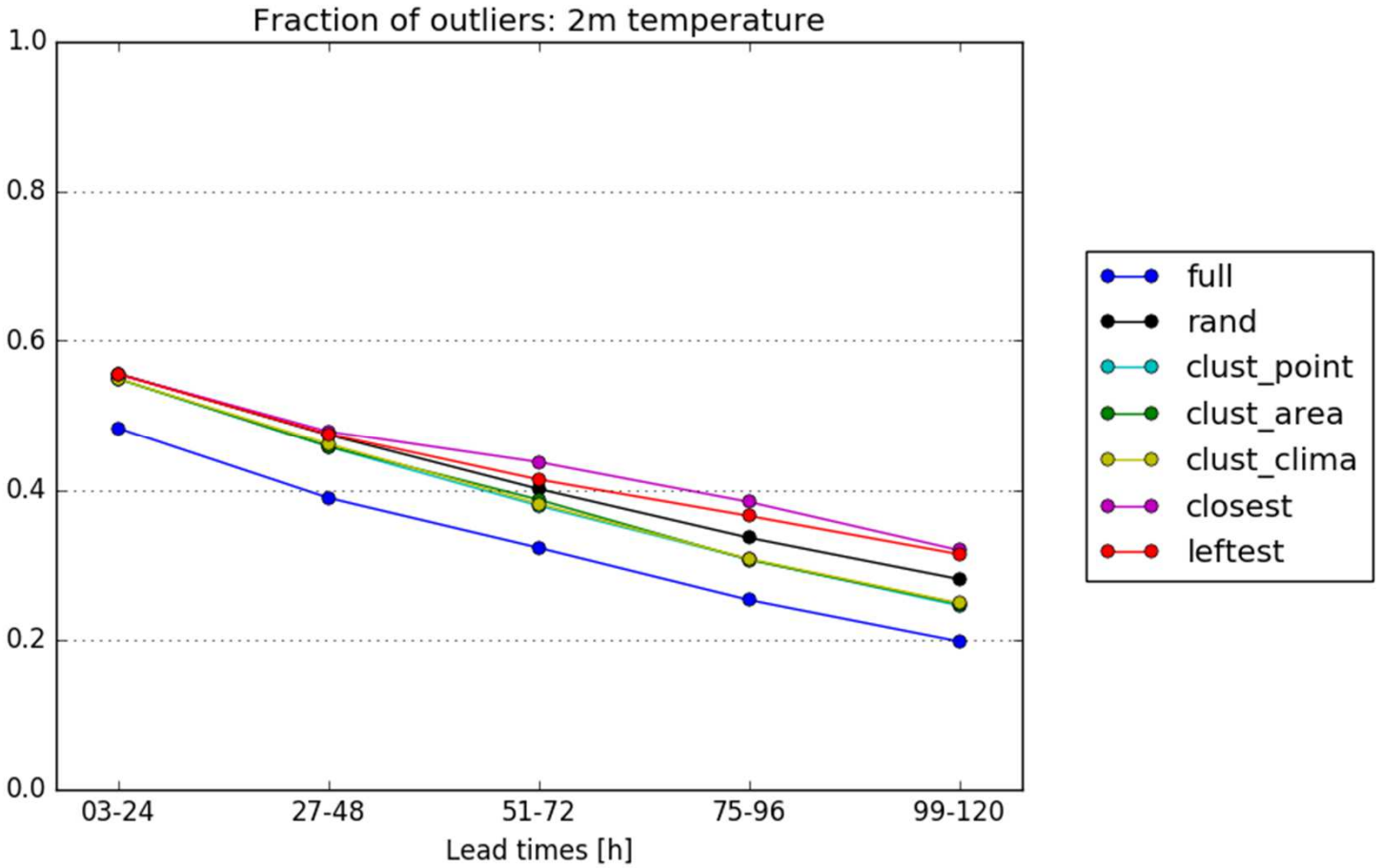
- on COSMO-E model domain
- U,V,T,QV on 3 model levels (~500, 700, 850 hPa)
- lead-times +48h & +96h
- representative members (RMs)

# Experiments for LBCs

- 19 forecasts (00 UTC) with strong synoptic forcing (21 March – 8 April 2015) for +120h
- Control + 50 perturbed members driven by IFS-ENS
- Analysis from KENDA members 1-40 (+1-10 for members 41-50)
- Ensemble verification against SYNOP stations for entire COSMO-E domain for 7 selection configurations for LBCs:
  - full: all 50 members
  - rand: first 20 IFS-ENS
  - clust_point: 20 RMs, point-wise standardisation
  - clust_area: 20 RMs, area-mean standardisation
  - clust_clima: 20 RMs, point-wise stand. using 30d
  - closest: 20 members with smallest distance to mean
  - leftest: 20 driest members

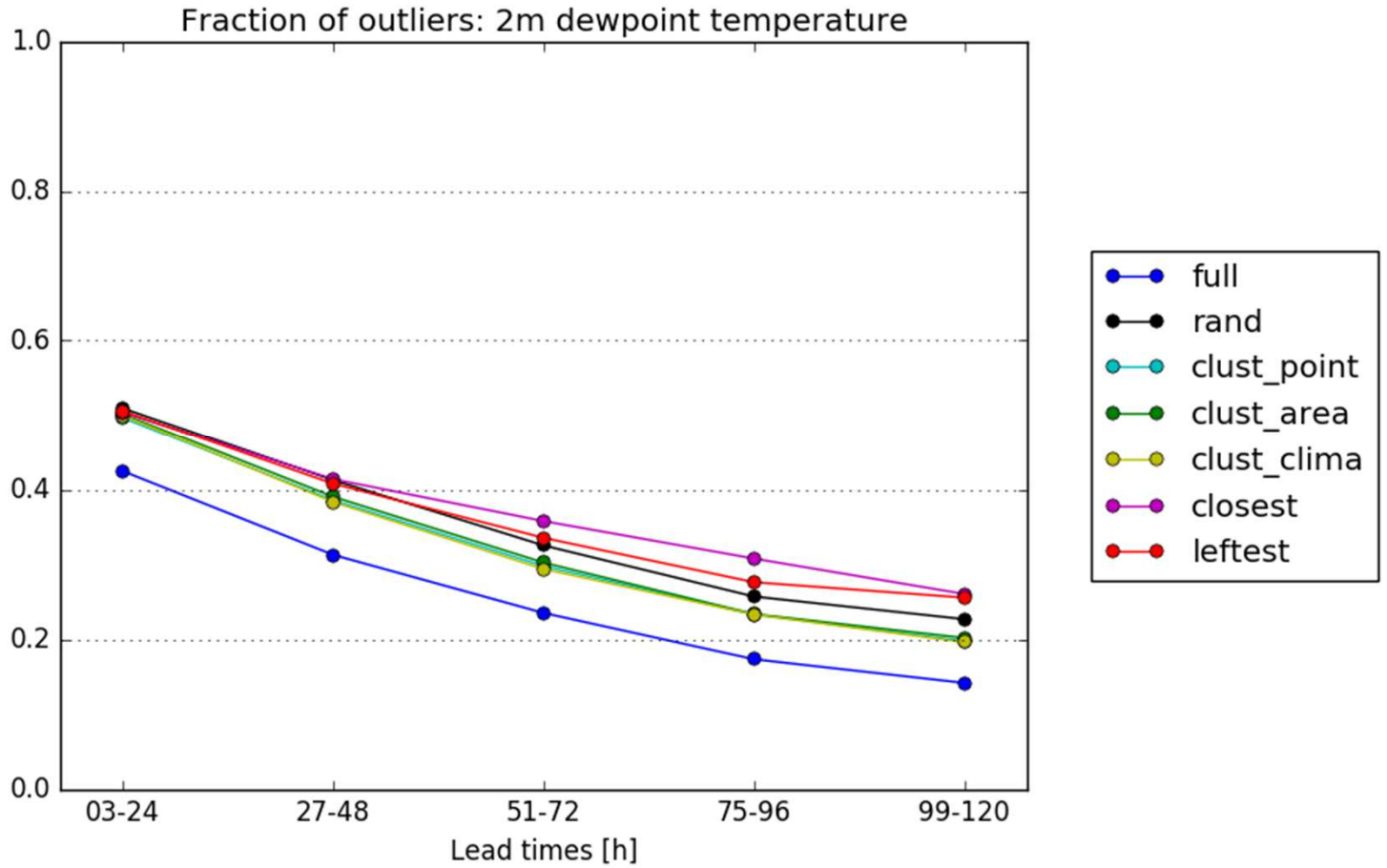
+ control

# 2m temperature, outliers



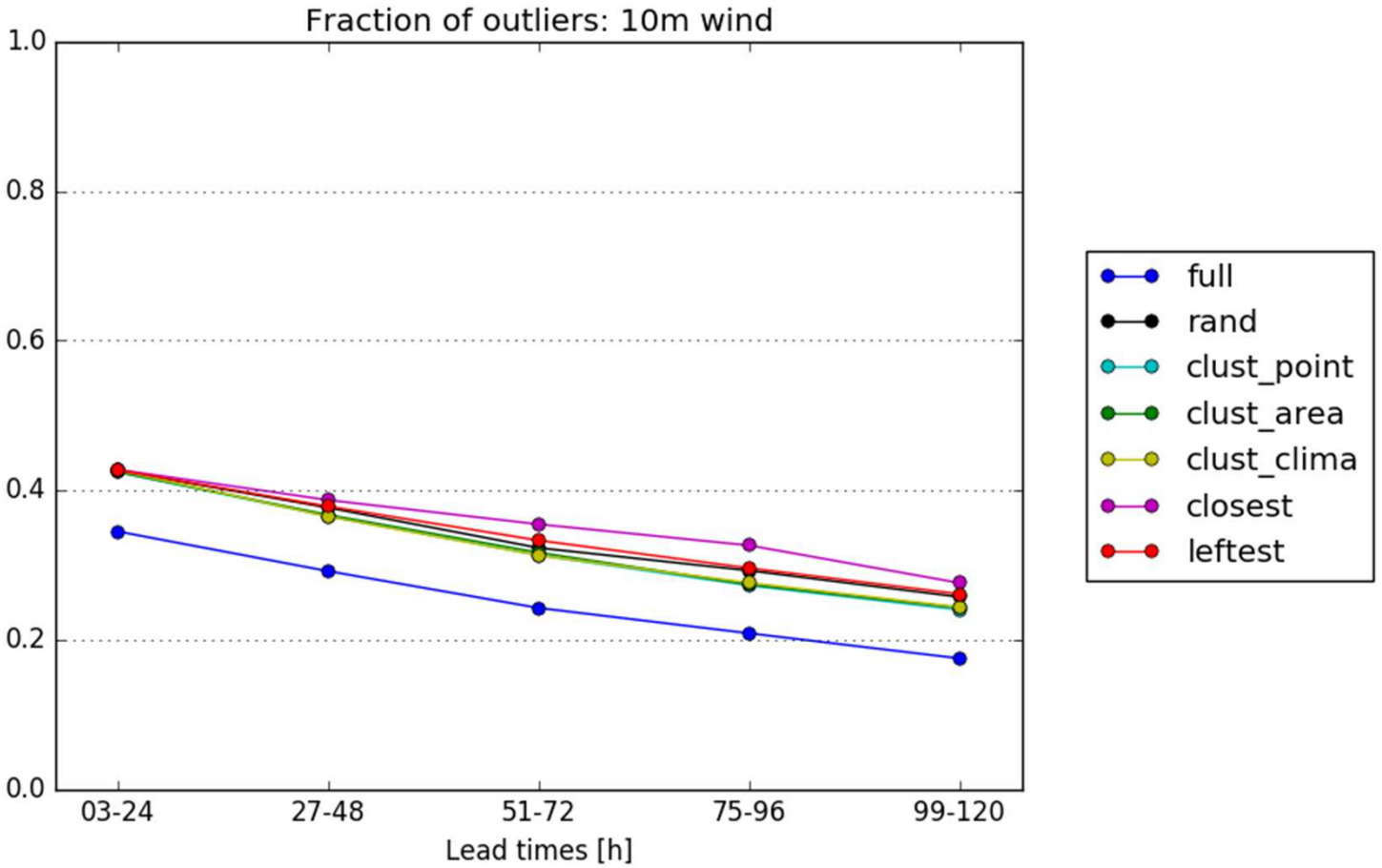

‘full’ best as expected, 3 clustering setups second and almost identical, than ‘rand’, ‘leftest’, ‘closest’ is worse

# 2m dew point temperature, outliers



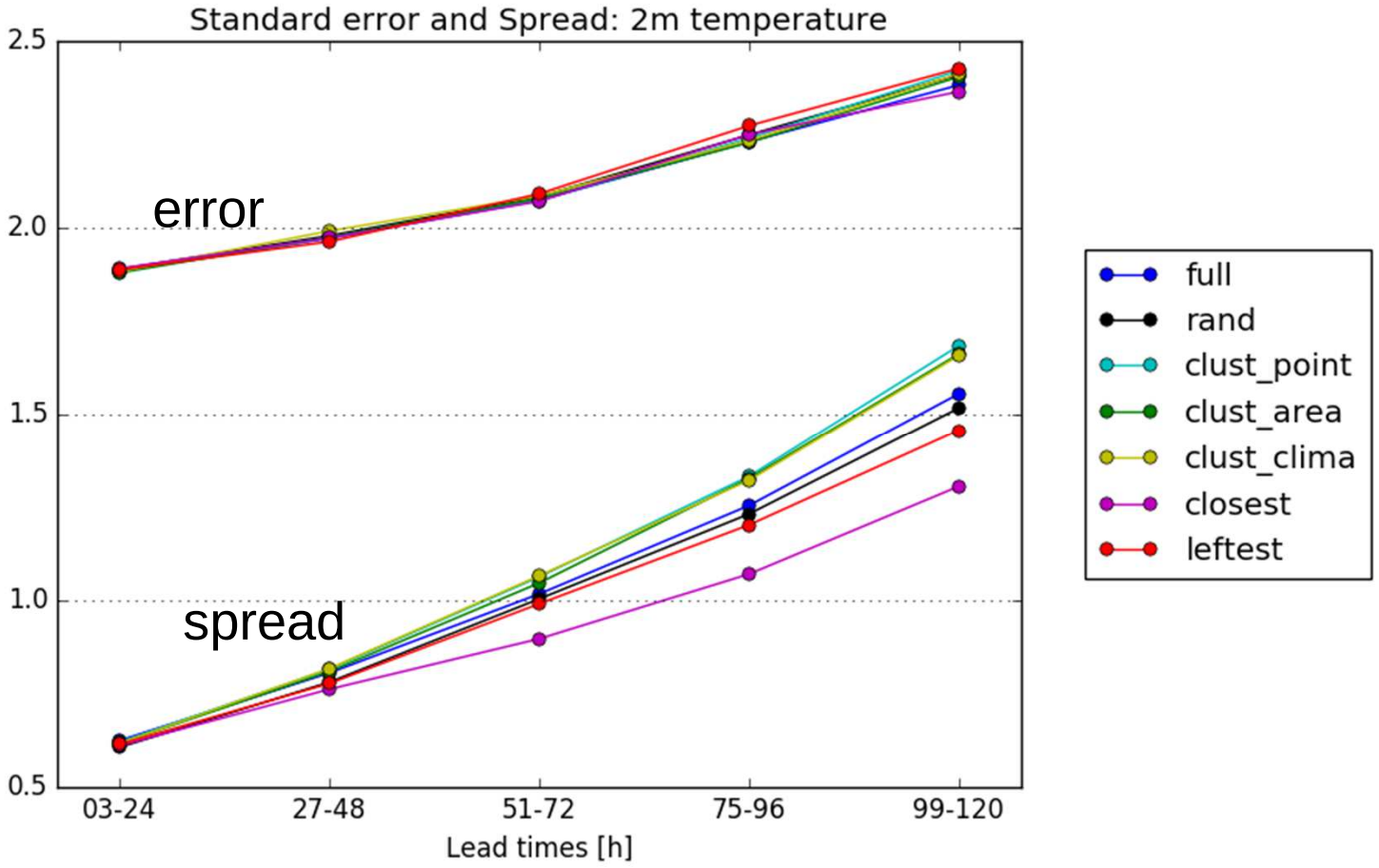

same results

# 10m wind speed, outliers



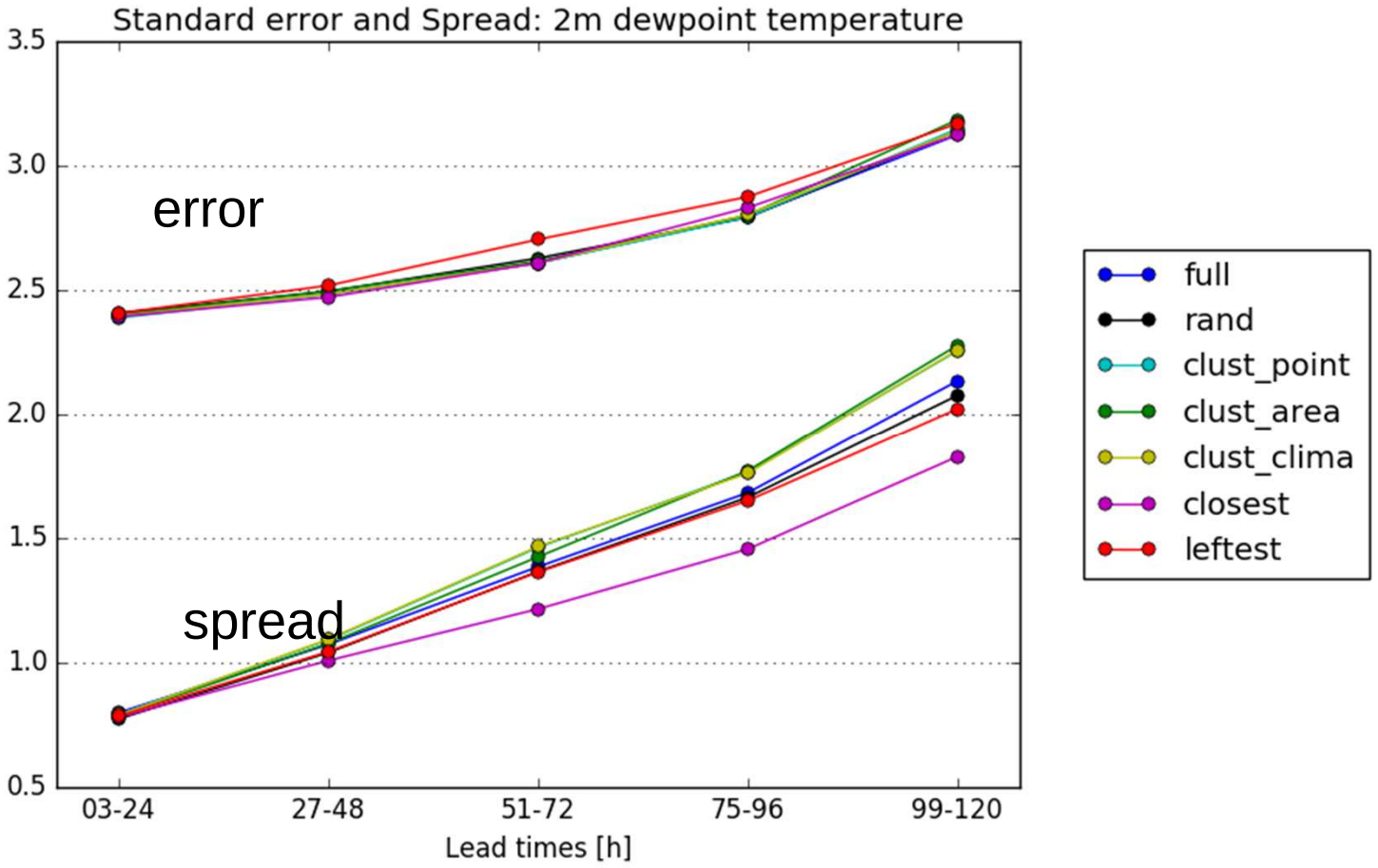

similar results, but differences smaller except ‘full’ and ‘rand’ hardly better than ‘leftest'

# 2m temperature, spread/error



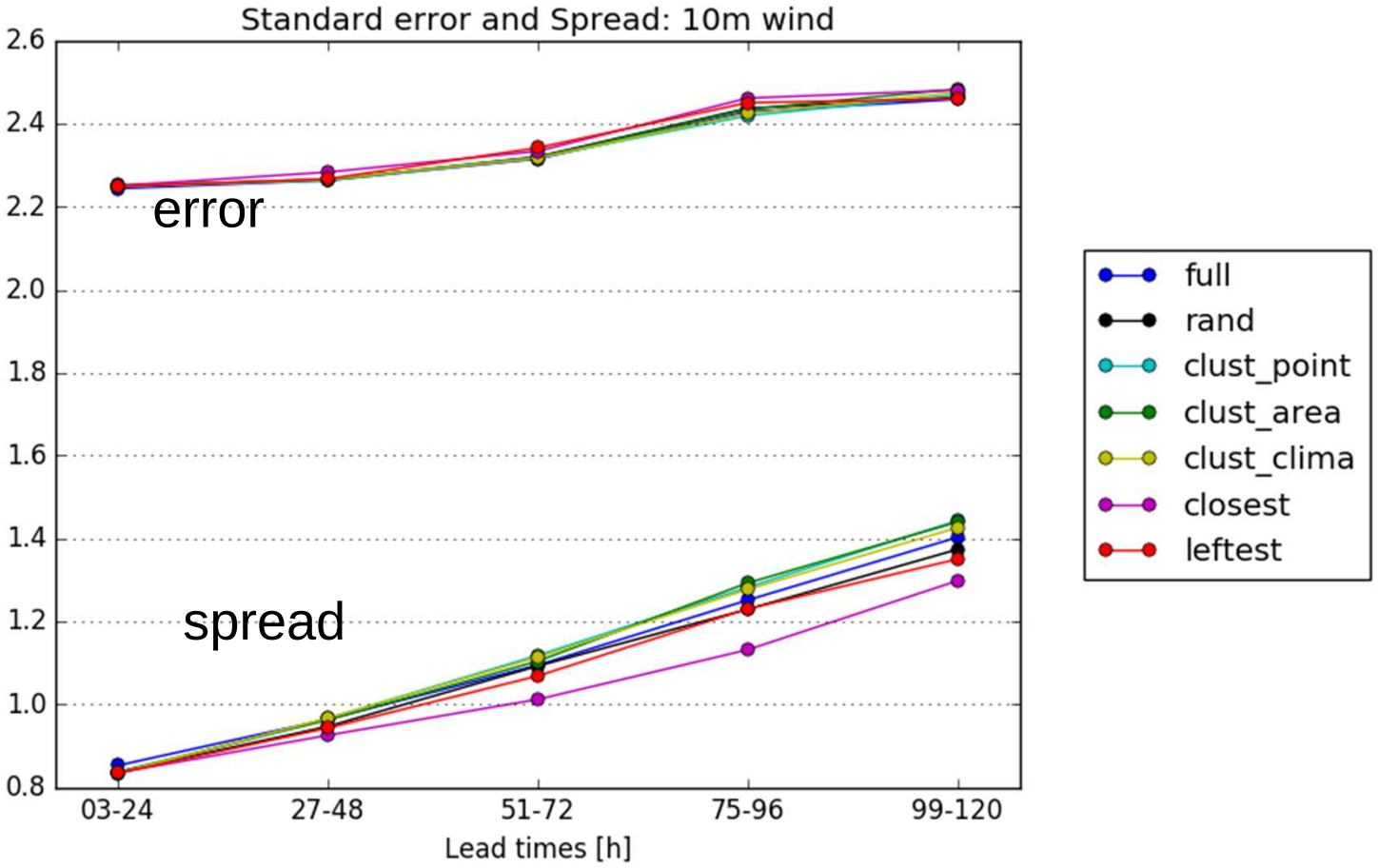

- ‘clust’ shows larger spread than ‘full’! → tails ‘overpopulated’
- ‘rand’ third, ‘closest’ clearly worst

# 2m dew point temp., spread/error



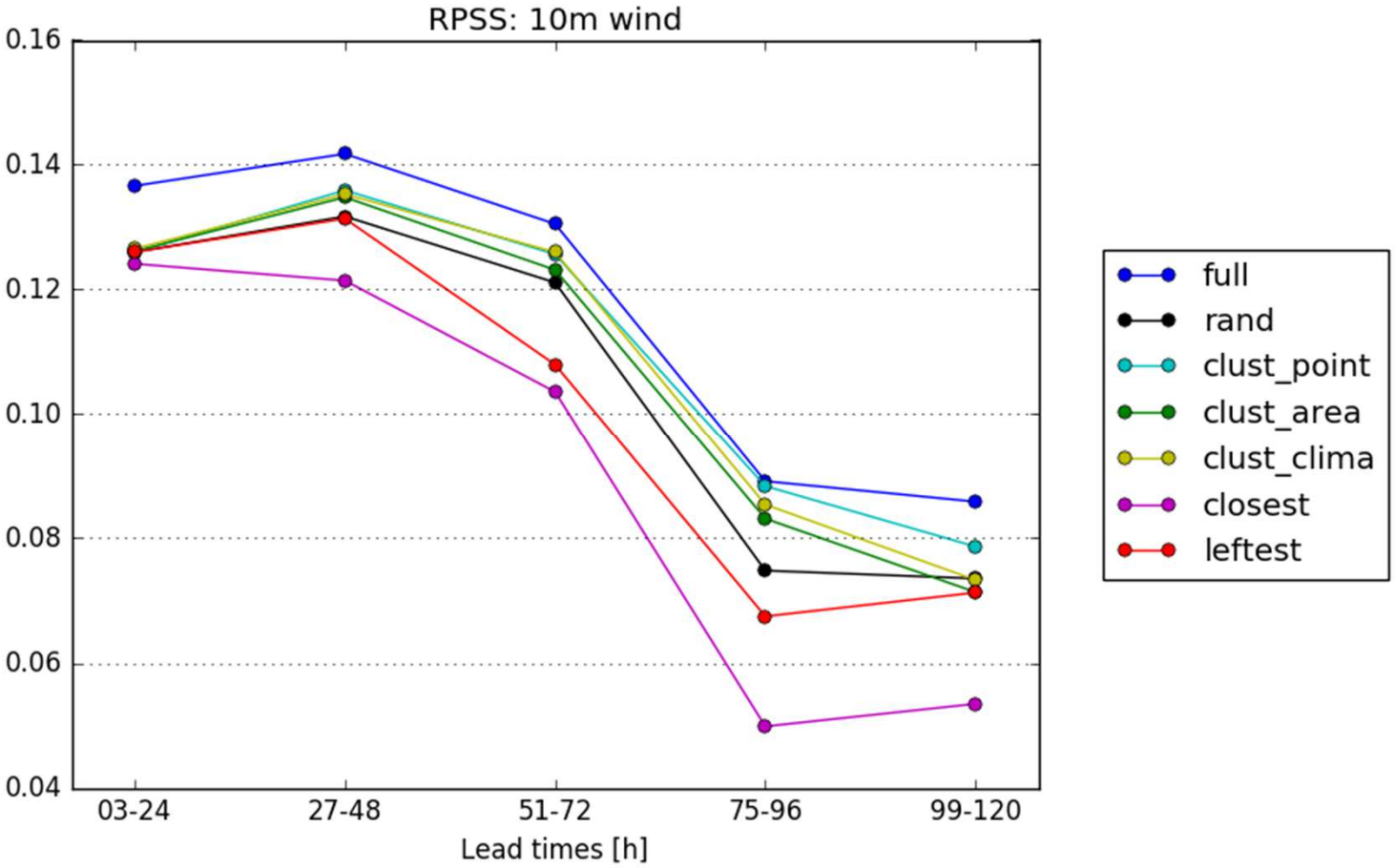

same results

# 10m wind speed, spread/error



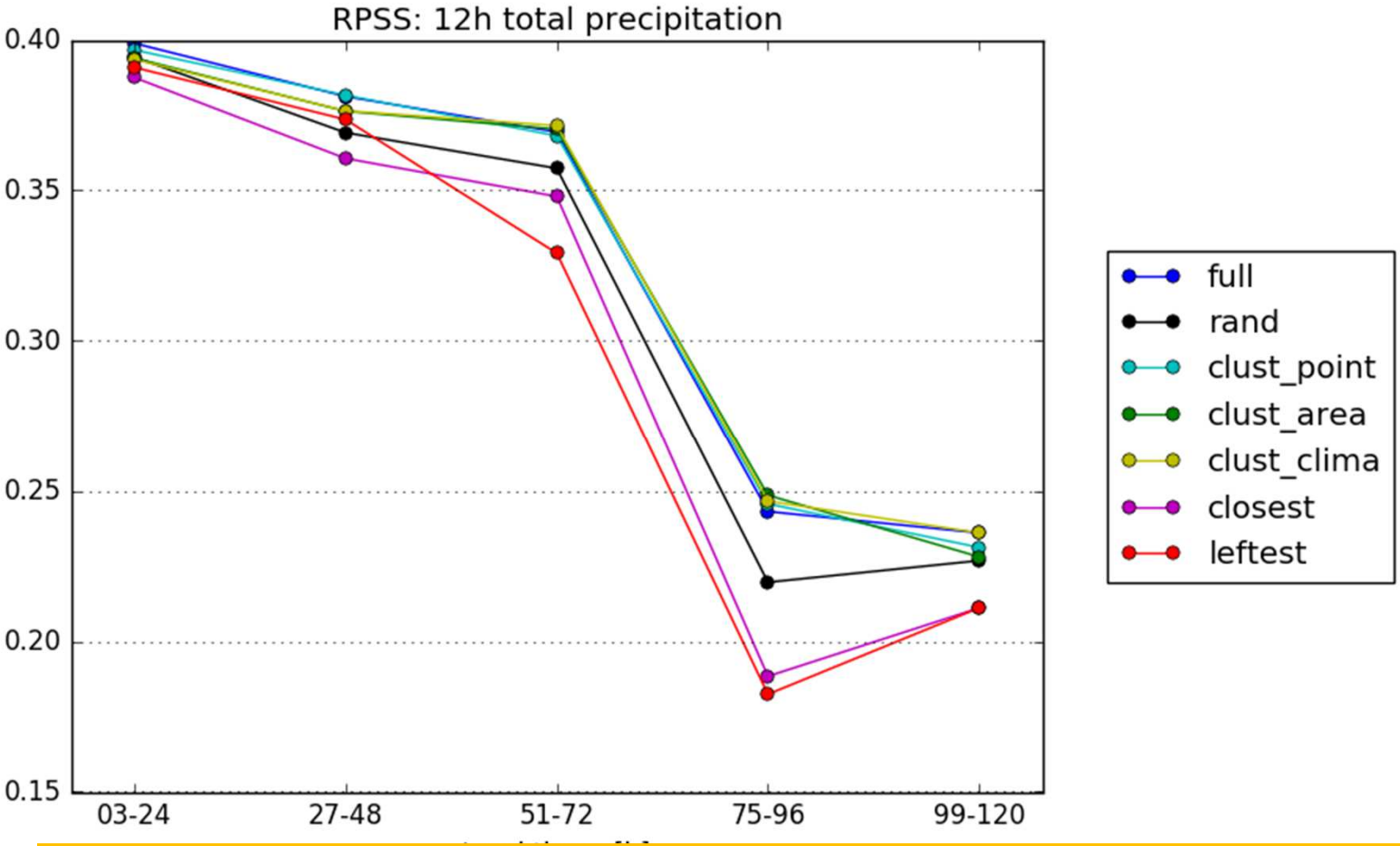

similar results, but differences smaller

# 10m wind speed, RPSS



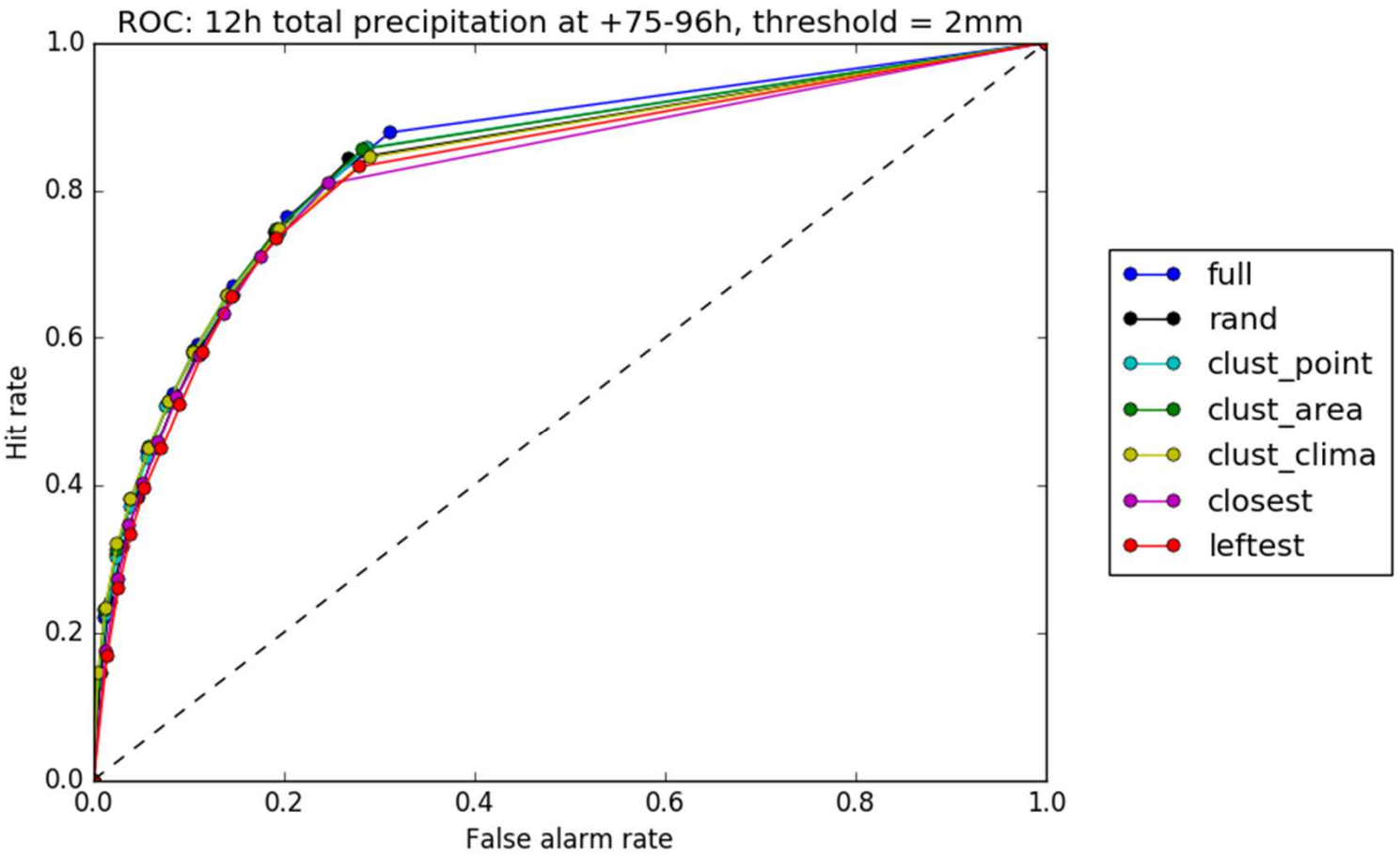

‘full’ best as expected, 3 clustering setups, than ‘rand’, ‘closest’ clearly worse

# 12h total precipitation, RPSS




similar results, but clustering as good as ‘full’ an ‘leftest’ worst

# 12h total precipitation, ROC curve




results confirmed by ROC, but differences small

# Experiments for ICs

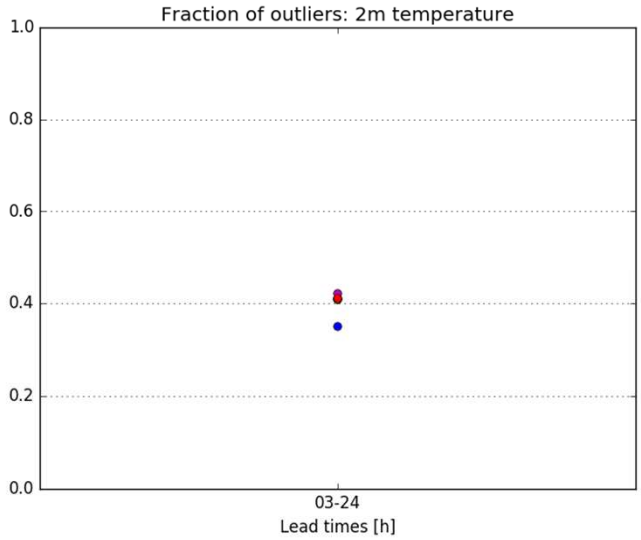
- 16 forecasts (00 UTC) weak synoptic forcing (3 – 18 June 2015) for +24h
- Control (KENDA analysis mean) + 40 perturbed members driven by IFS-ENS (1-40)
- Selections based on analyses
- Ensemble verification against SYNOP stations for entire COSMO-E domain for 7 selection configurations:
  - full: all 40 members
  - rand: first 20 KENDA members
  - clust_point: 20 RMs, point-wise standardisation
  - clust_area: 20 RMs, area-mean standardisation
  - clust_clima: 20 RMs, point-wise stand. using 30d
  - closest: 20 members with smallest distance to mean
  - leftest: 20 driest members

+ control

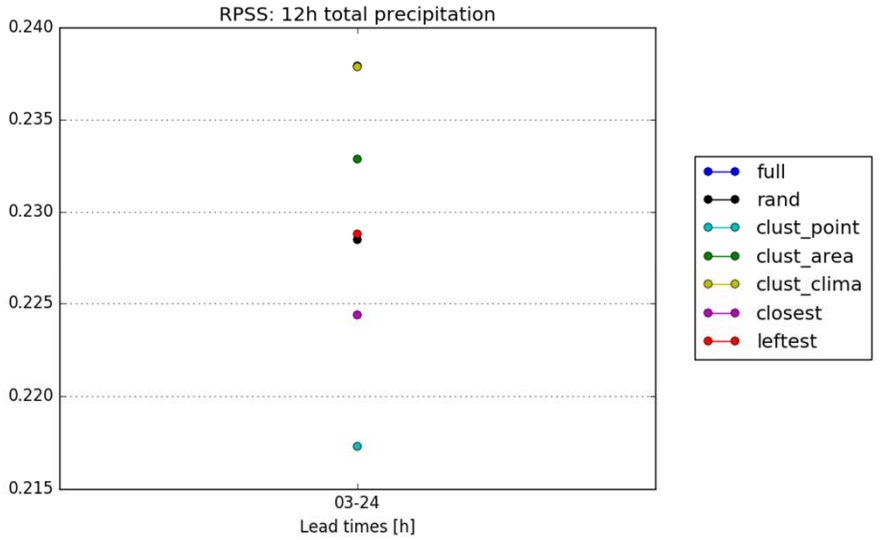
# Results

- Differences between selection methods much smaller and most of them insignificant
- Probably limited potential due to small (lack of) spread
- Largest impact seen for precipitation, but results ambiguous

2m temperature, outliers




12h total precipitation, RPSS



# Summary for member selection

- sophisticated member selection like clustering for LBCs can improve COSMO-E forecasts significantly
- clustering is able to increase the spread for near-surface variables (most welcome!) → probably main reason for better scores
- random member choice can result in significantly worse forecasts with bad luck, can be at least as worse than ‘closest’ in specific case
- benefit of better IC selection limited, at least for scores averaged over day 1 (may be different for the very short range)
- elapsed time for LBC selection might be an issue, in particular since we wait for the LBCs to start COSMO-E

# Outlook

- Investigate impact of new KENDA setup (→ talk by Daniel) on COSMO-E forecast quality
- Impact of member selection methods on upper-level spread?
- Investigate problem in convection triggering and underestimation of strong winds
- continue work on model perturbations → see talk by Christina Klasa

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