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First experiments with SPPT for COSMO-E

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MeteoSwiss

Stochastic Physics Workshop
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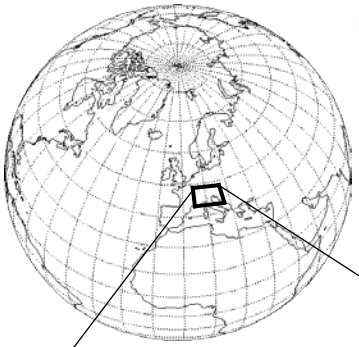
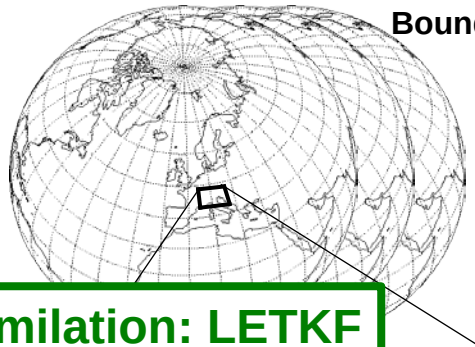
Project COSMO-NExT



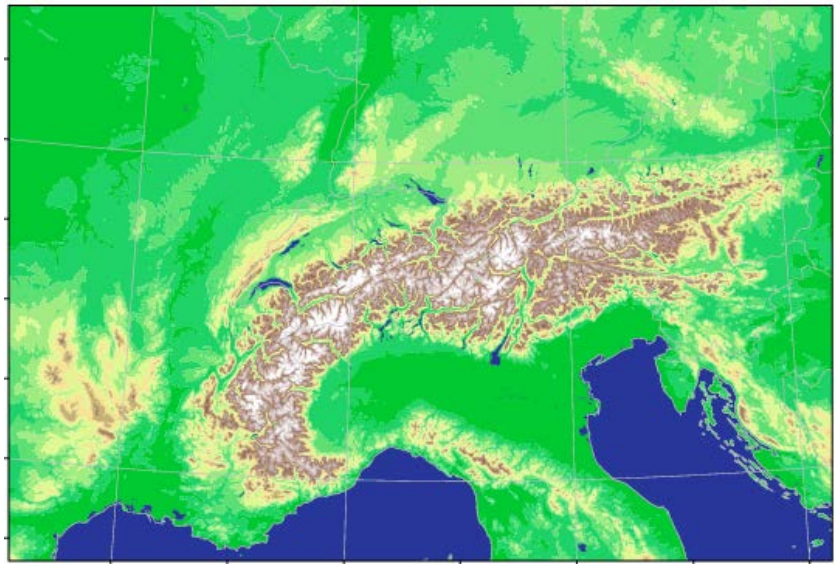
Boundary conditions: IFS
10km
4x daily



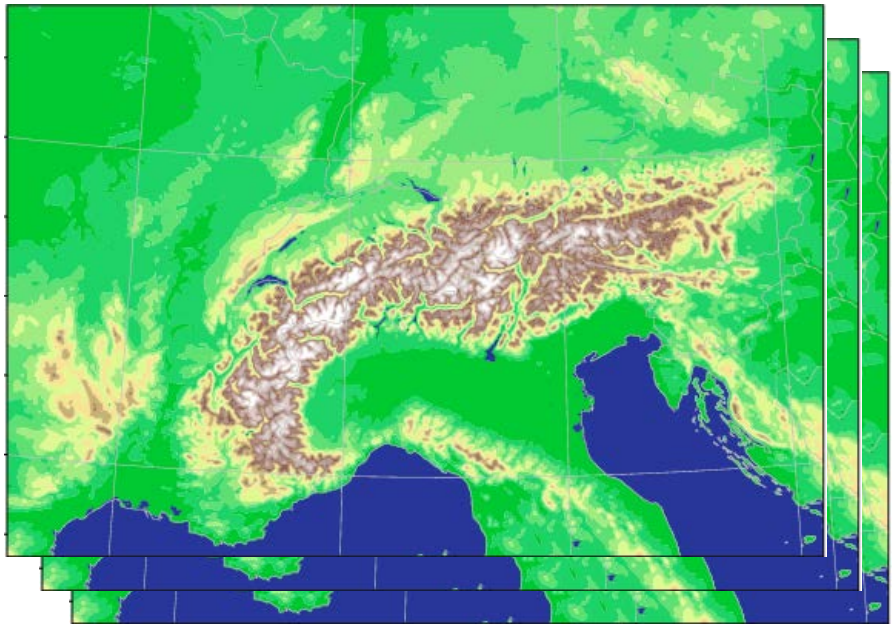
Boundary conditions: VarEPS
20km
2x daily

ensemble data assimilation: LETKF

COSMO-1: 8x daily O(24 hour) forecasts
1.1km grid size (convection permitting)

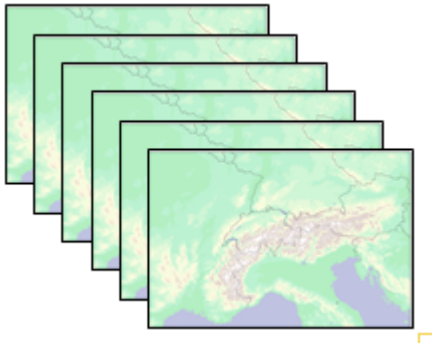


COSMO-E: 2x daily 5 day forecasts
2.2km grid size (convection permitting)
O(21) ensemble members



COSMO-E setup

- Ensemble forecasts with convection-permitting resolution (2.2 km mesh-size)
- 21 members
- Twice a day up to +120h for Alpine area (15% larger than COSMO-2 domain)



- Range of possible scenarios and “best estimate”
- COSMO version 4.26
- Single precision: reduction of elapsed time to 60% with same forecast quality!

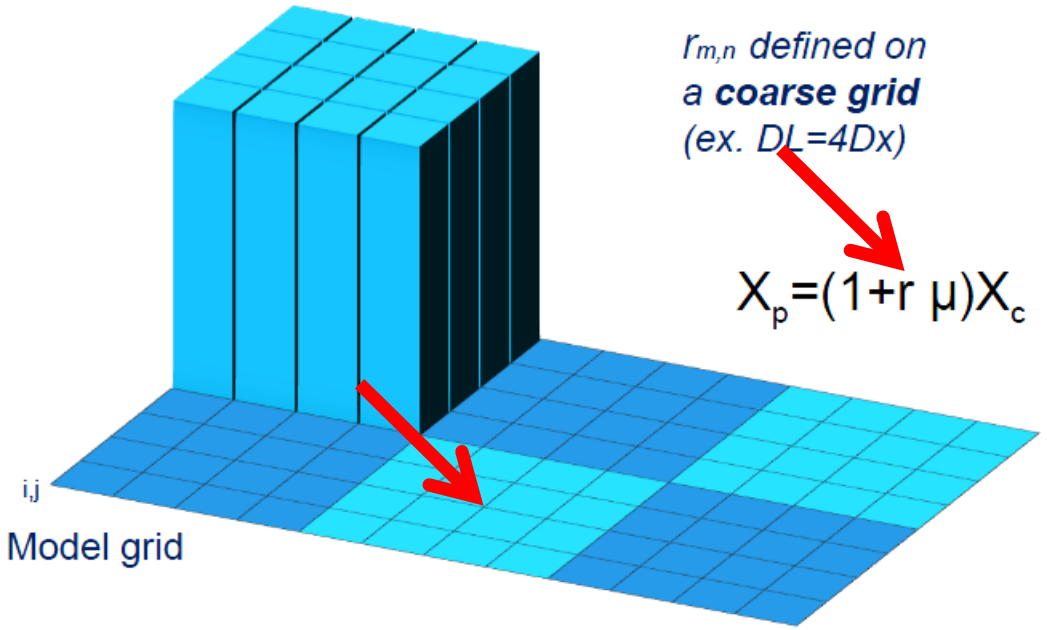
Outline

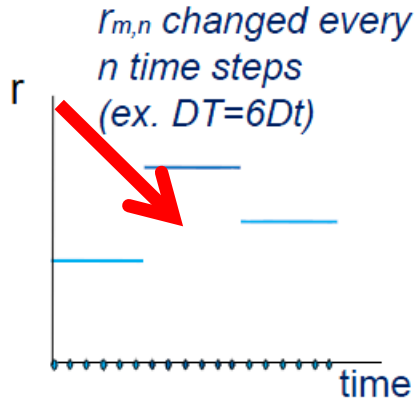
- COSMO-E physics perturbations
  - Validation of stochastic perturbation of physics tendencies (SPPT) scheme for deterministic runs
  - Impact of SPPT settings based on 4 case studies
  - Verification results from a 4 weeks test suite
  - Questions and Outlook

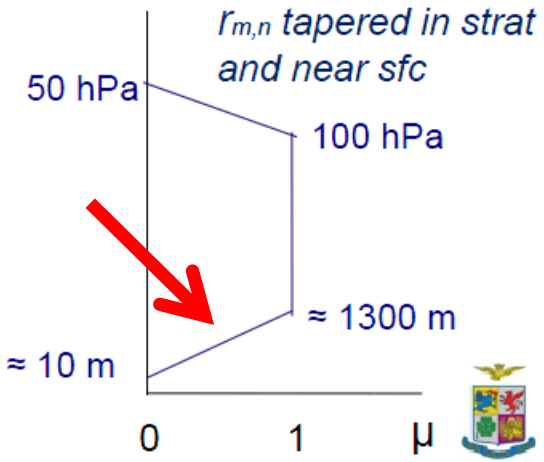
- One slide on SKEBS for COSMO …

Implementation into COSMO by L. Torrisi (CNMCA)

In Buizza et al. 1999: Spatial correlation is imposed using the same r in a whole column and drawing r for a coarse grid with spacing DL (boxes). Temporal correlation is achieved by drawing r every n time steps (DT)





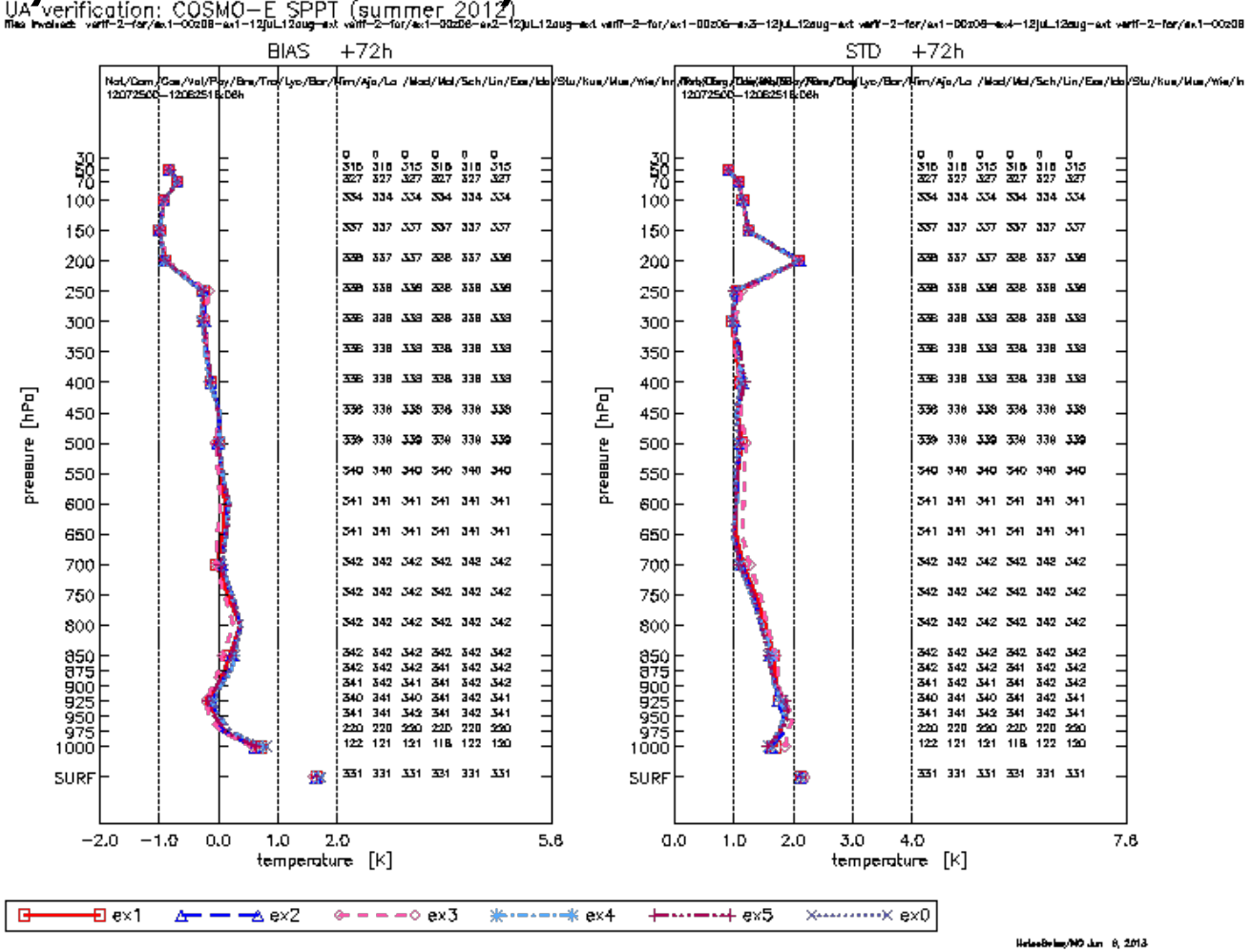


Univariate distribution with reduced perturbation close to the surface and in the stratosphere (as in Palmer et al, 1999) modified to have a smoother pattern in time and horizontally in space

Validation of SPPT

- SPPT must not degrade (deterministic) quality of members
- **deterministic runs (1 month)** for different SPPT setups:
  - for all: lgauss_rn = lhorint_rn = ltimeint_rn = .true.
  - ex0: no SPPT
  - ex1: SPPT, recommended settings by Lucio (sigma = 0.25 & random number within [-0.75, 0.75])
  - **ex2: lqv_pertlim = .true.**
  - ex3: sigma = 0.5 & random number within [-1.0, 1.0]
  - ex4: length-scale = 0.5 deg., time-scale = 30 min (default: 5 deg., 6 hrs)
  - **ex5: no tapering in lower troposphere / PBL (default: tapering below approx. 850 hPa)**

Upper-air: temperature
+72h, all stations, 25.07-25.08.2012

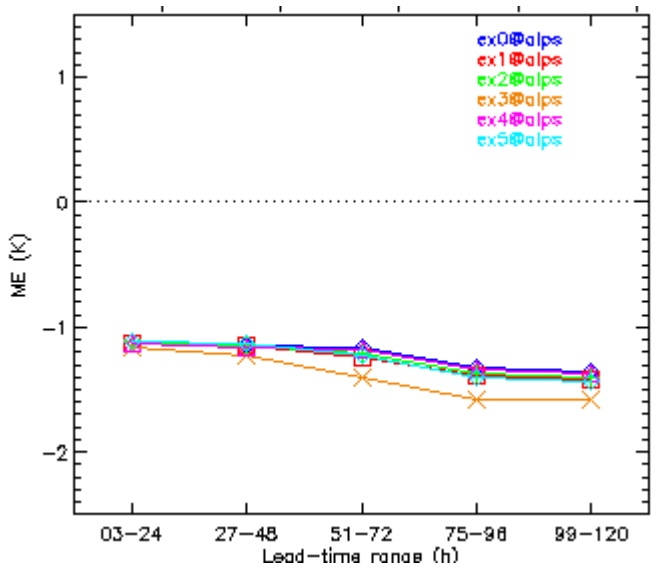


Upper-air verification: conclusions

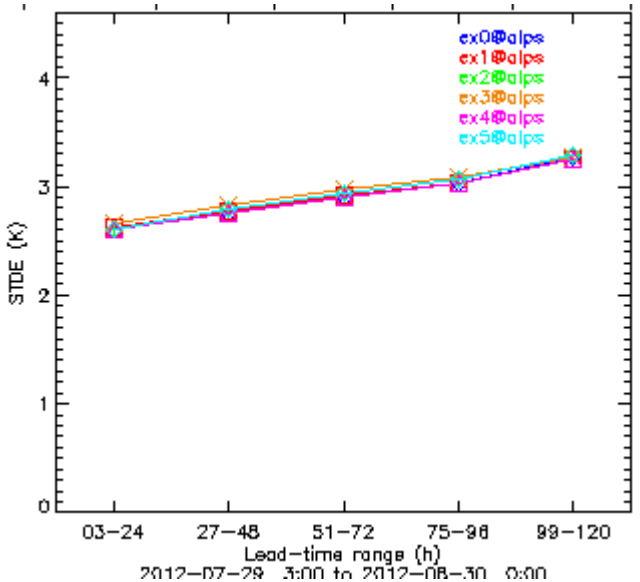
- largest differences found for wind speed and wind direction in summer:
  - ex3 shows larger STDE
  - minor negative impact for ex1
  - minor positive impact for ex4
- **marginal differences** between all experiments for T, Z, and RH
- no drying observed!

Surface: dew-point temperature all stations, 25.07-25.08.2012

bias



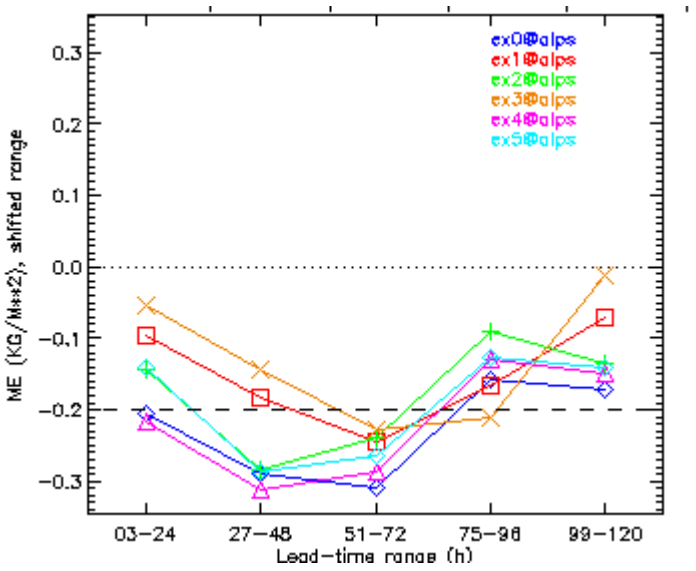
standard deviation



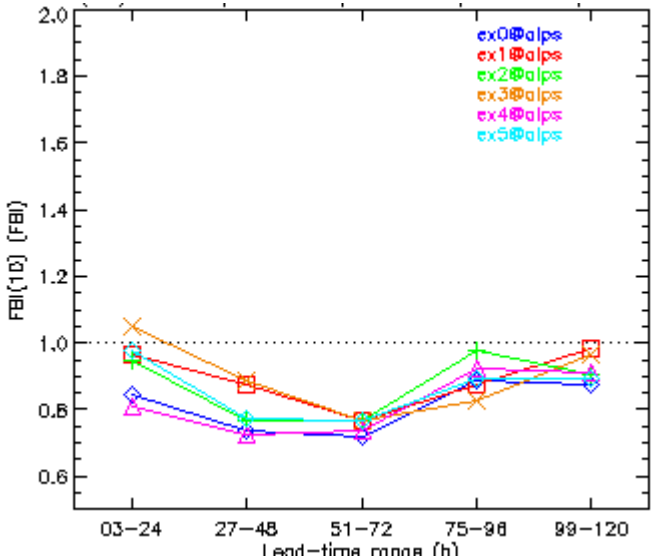
drying in ex3

Surface: precipitation, 12h sum all stations, 25.07-25.08.2012

bias



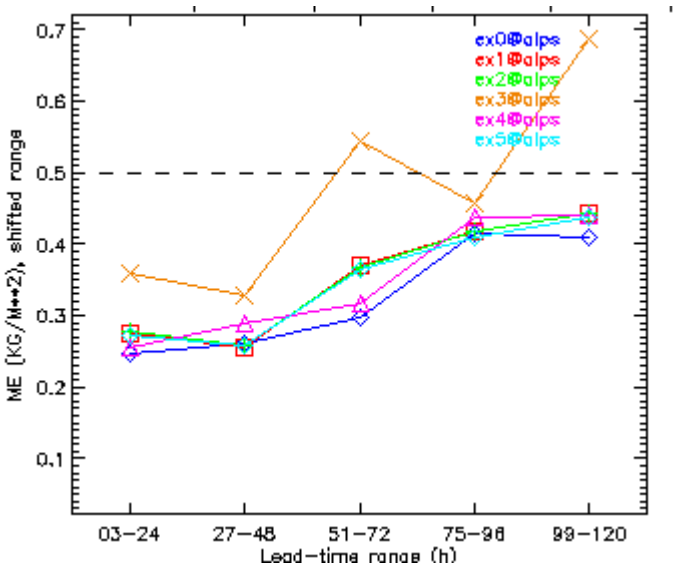
frequency bias (10mm/12h)



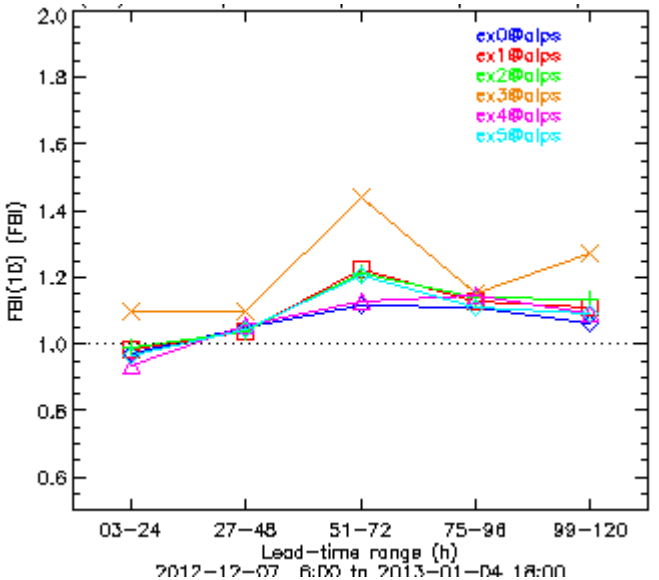
for summer precipitation ex3 belongs to the best experiments …

Surface: precipitation, 12h sum all stations, 03.12-31.12.2012

bias



frequency bias (10mm/12h)



… but for winter precipitation ex3 it is the worst one

Surface verification: conclusions

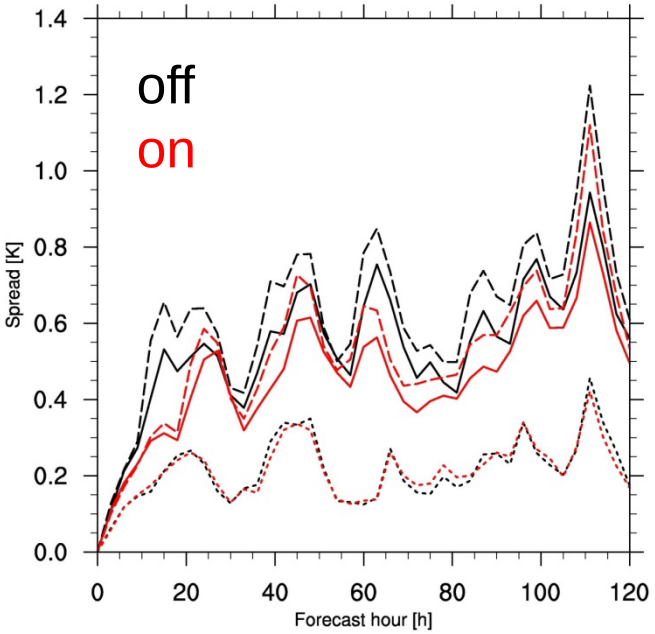
- **small differences between all experiments, except for ex3** which shows
  - larger STDE for some parameters
  - drying in summer (Td_2m)
  - higher precipitation amounts (worse in winter, better in summer)

→ No significant quality degradation seen with SPPT except for ex3 (large random numbers together with large correlation-lengths)

No tapering in lower troposphere

- Main motivation to taper SPPT in PBL are **stability** issues
- SPPT validation runs did not show any problems
- Turning it off has significant impact on spread in PBL

Temperature spread over Swiss domain



250m above ground (dashed)

700m above ground (full line)

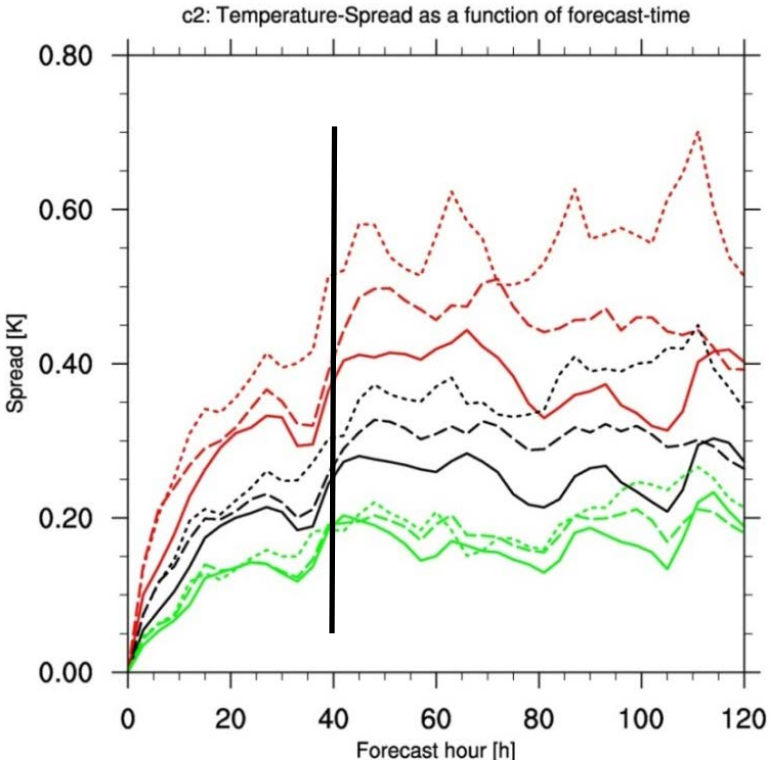
tropopause (dotted)

COSMO-E SPPT case studies

- Experiments for **2 summer and 2 autumn cases** investigated
- **SPPT perturbations only (no IC and BC perturbations)**
- COSMO-2 domain (instead of new COSMO-E domain)
- ICs: COSMO-2 analysis
- LBCs: IFS-ENS control

Impact of SPPT settings on spread

Case 2012-08-01: **T spread** COSMO-E domain (**tapering in PBL!**)



@ 500 (solid lines), 700 (dashed), 850 (dotted) hPa

large stdv_rn=0.5, range_rn=1 (ex3)

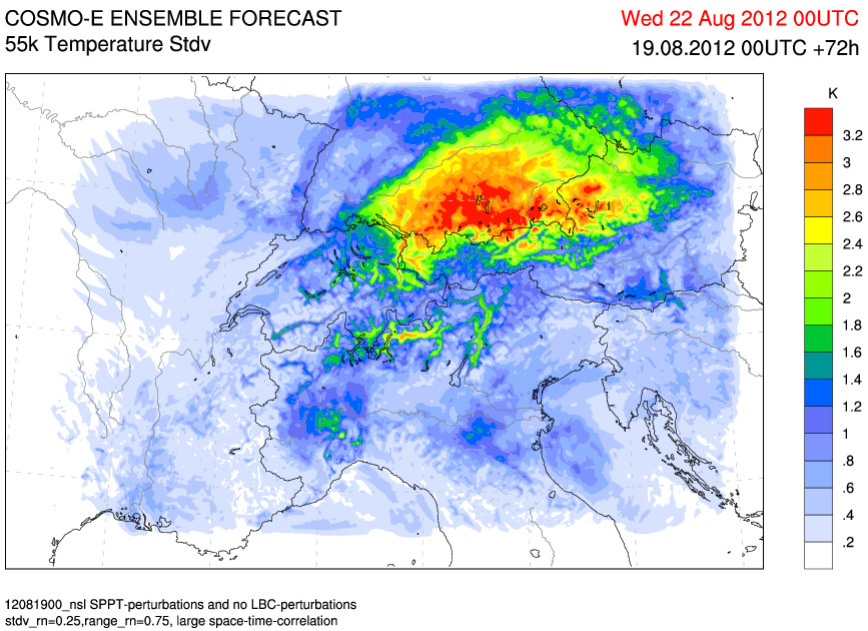
stdv_rn=0.25, range_rn=0.75 (ex1)

stdv_rn=0.25, range_rn=0.75, dlat_rn=dlon_rn=0.5°, ninc_rn=90 (ex4)

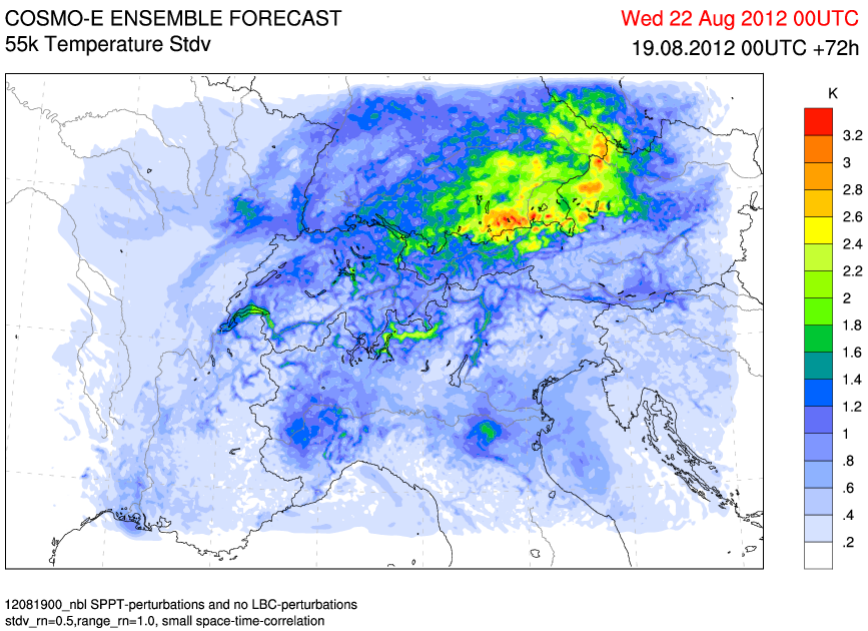
- spread largest at 850 hPa, lowest at 500 hPa
- smaller correlation-lengths in space and time lead to smaller spread
- larger random numbers produce larger spread and faster spread growth
- spread saturation is reached at all height levels at about same lead-time

Impact of SPPT settings on spread

Case 2012-08-19: **T spread** ~250 m above ground for +72h



small sigma/range (0.25/0.75)
large space/time correlation (5.0/1080)
(ex1)



large sigma/range (0.5/1.0)
small space/time correlation (0.5/90)

First COSMO-E test suite

- **4 weeks period (25.07. -25.08.2012)**
- 00 UTC forecast only
- Experiments with 3 setups:
  - **LBC + SPPT**
    - lqv_pertlim=.false. (default: .true.)
    - dlat_rn=dlon_rn=0.5 (5.0)
    - ninc_rn=180 (1080)

    } scale of convective systems
    - stdv_rn=0.5 (0.5)
    - range_rn=1.0 (1.0)
    - no tapering near surface
    - setup validated as well (not shown before)
  - **LBC + COSMO-DE-EPS parameter perturbation (PP)**
  - **LBC only**

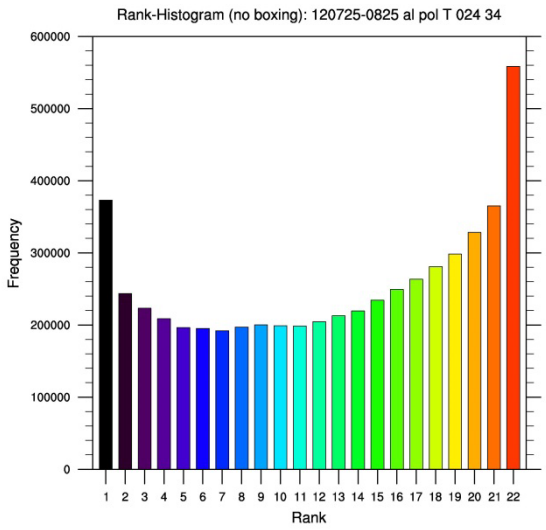
Verification COSMO-E test suite

- reminder: focus on lead-times beyond 24 hours due to lack of IC perturbations
- first step: against COSMO-2 analysis

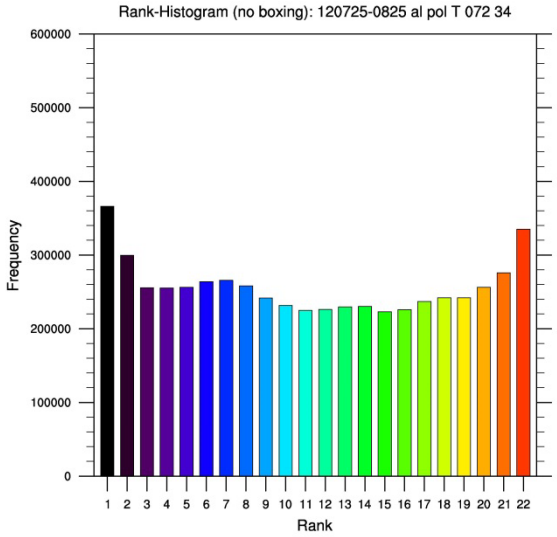
Rank histogram LBC+SPPT

temperature ~5500m above ground

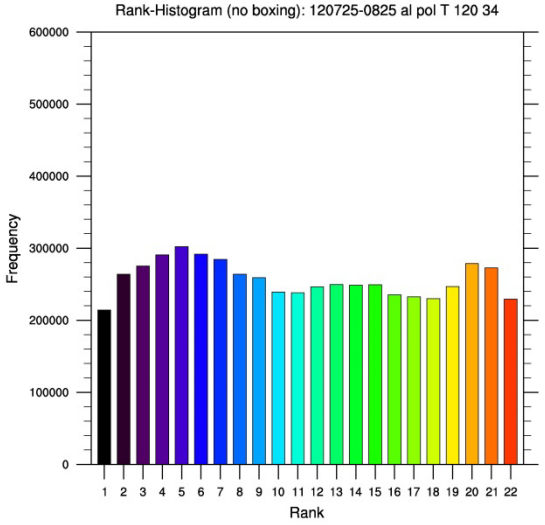
+24h



+72h



+120h



- too small spread up to +72h
- but rather too large spread for end of forecast range
- no difference between setups at the end of the forecast

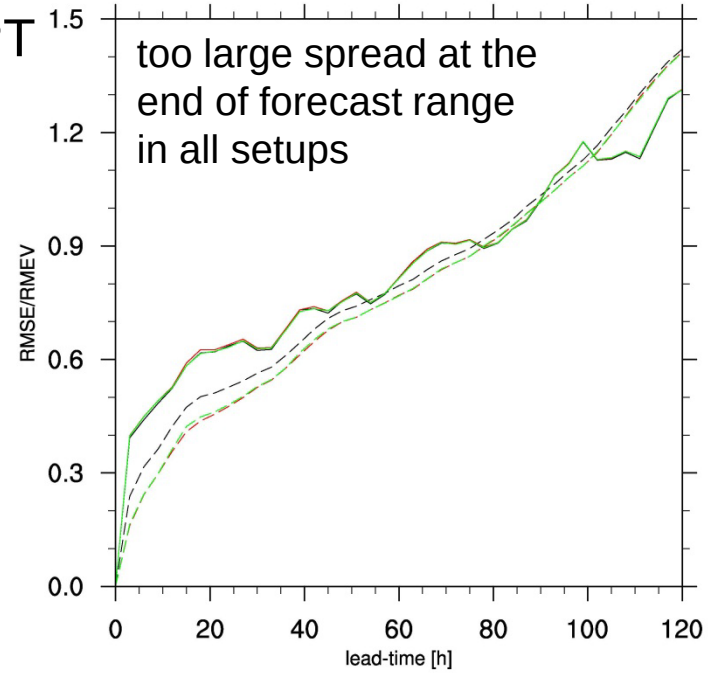
Spread & error temperature

—— mean squared **error**

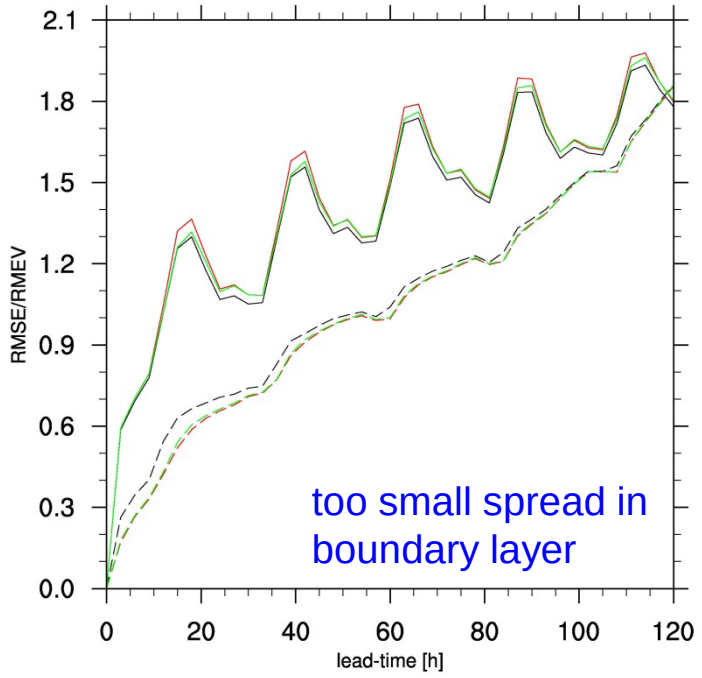
– – – mean ensemble **variance**

LBC+SPPT
LBC+PP
LBC

~5500m



~700m

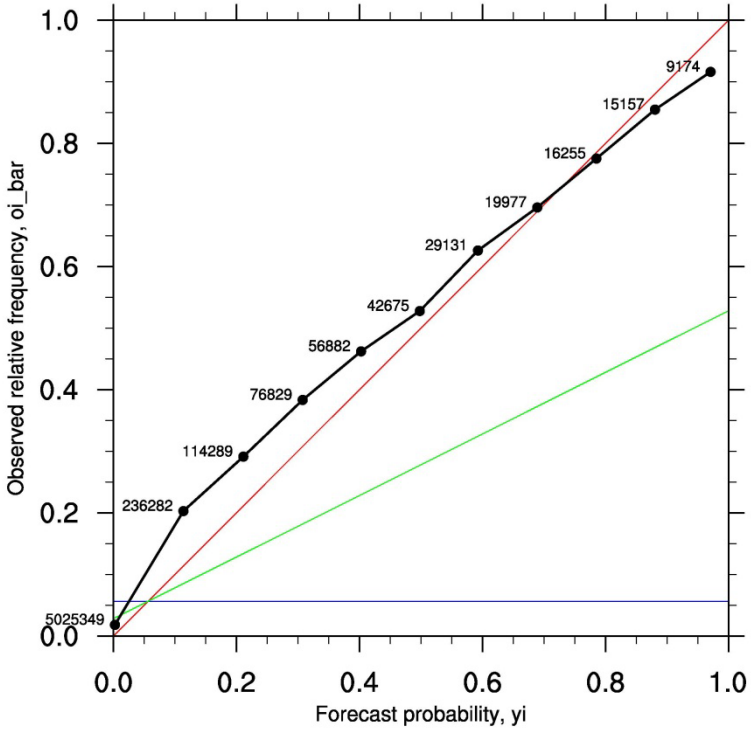


- LBC+PP and LBC slightly smaller spread
- LBC show largest error
- LBC+SPPT best, but differences small

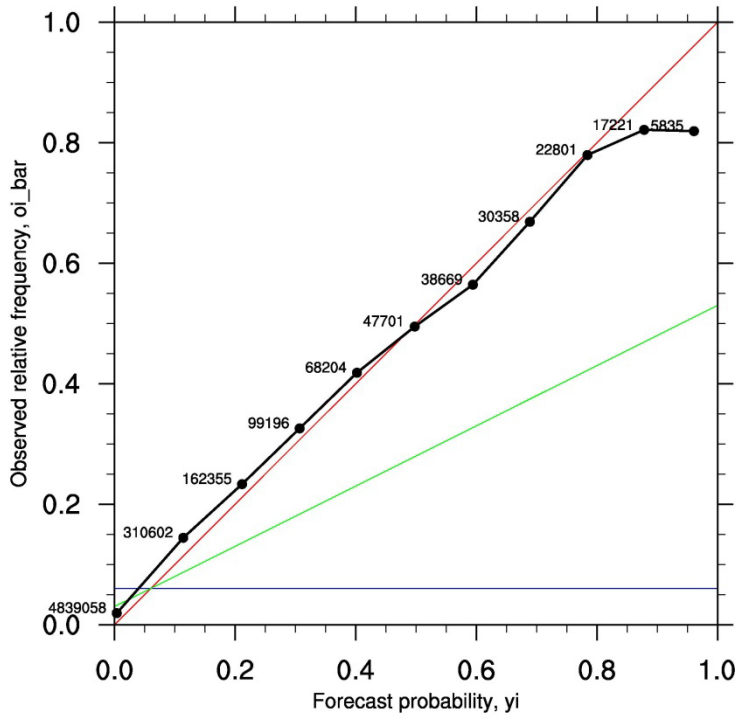
Reliability diagram LBC-SPPT

precipitation > 5mm/12h (verif vs analysis!)

+48h



+96h

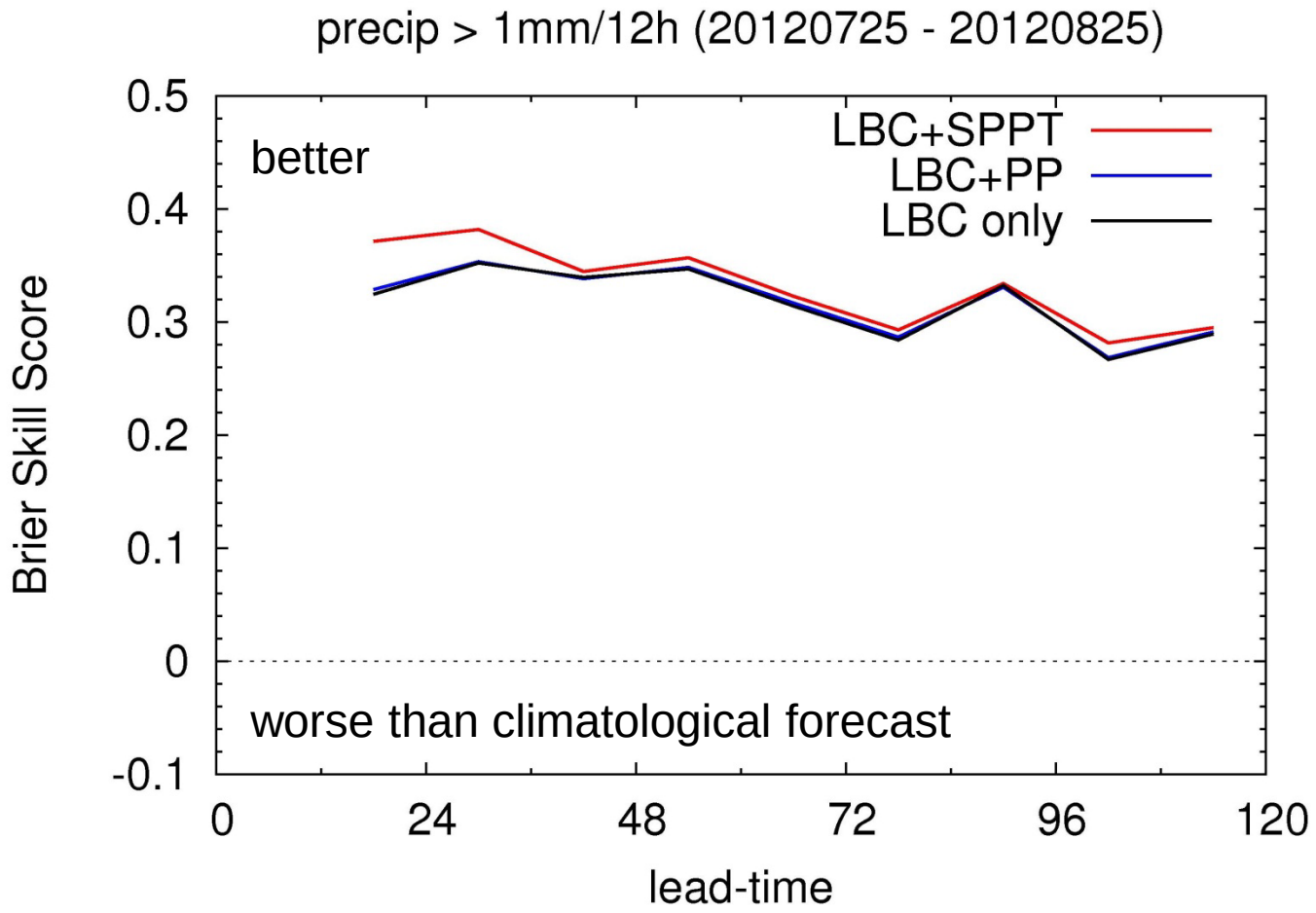


- high reliability in particular for longer lead-times
- good resolution even for longer lead-times

Verification COSMO-E test suite

- reminder: focus on lead-times beyond 24 hours due to lack of IC perturbations
- first step: against COSMO-2 analysis
- second step: against SYNOP observations

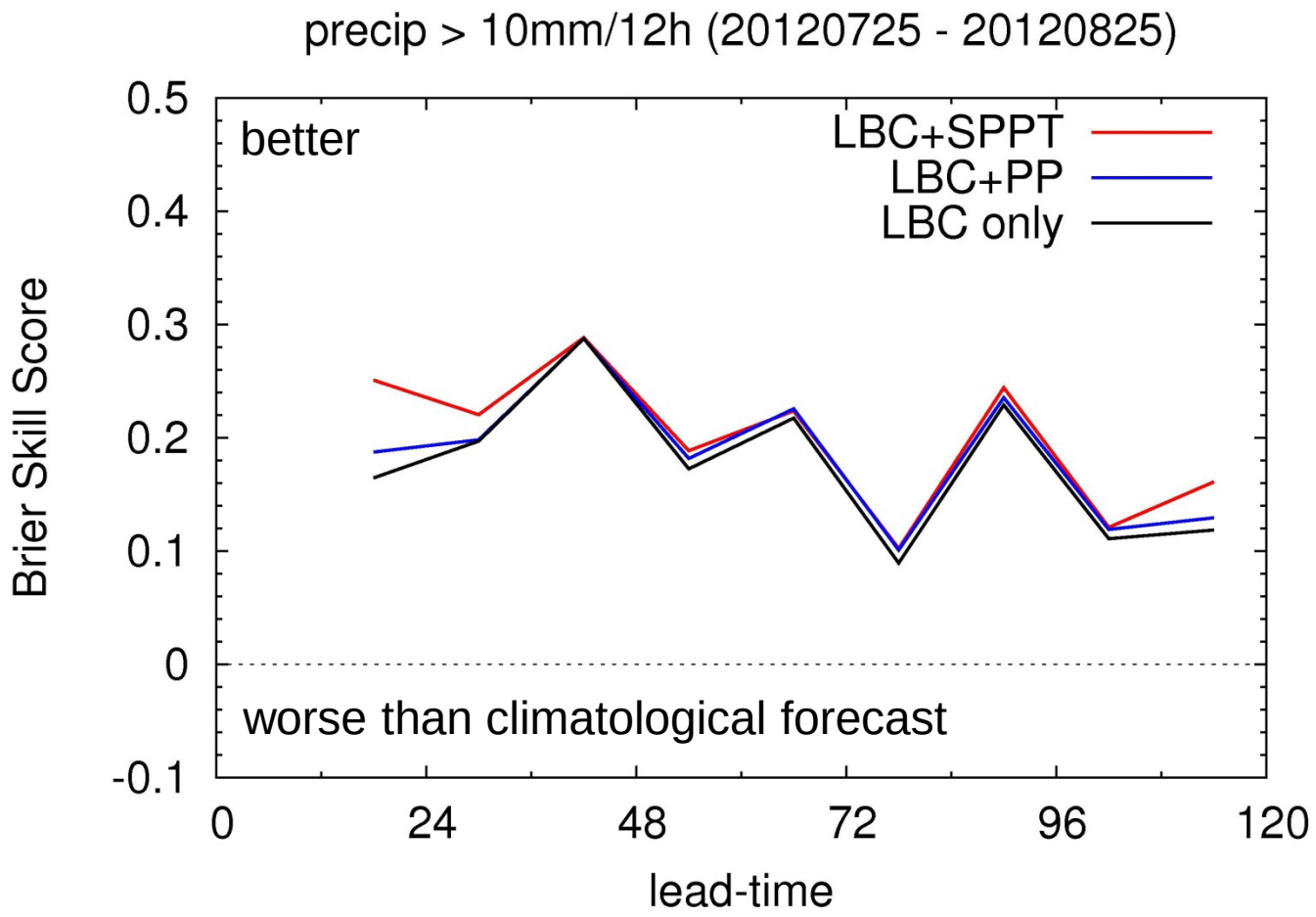
Brier Skill Score (ref=climatology)



Reference: forecast based on station climatology 2001-2010 (300 stations)

- all experiments clearly better than clim. forecast for all lead-times
- LBC+SPPT best until +30h, thereafter differences very small

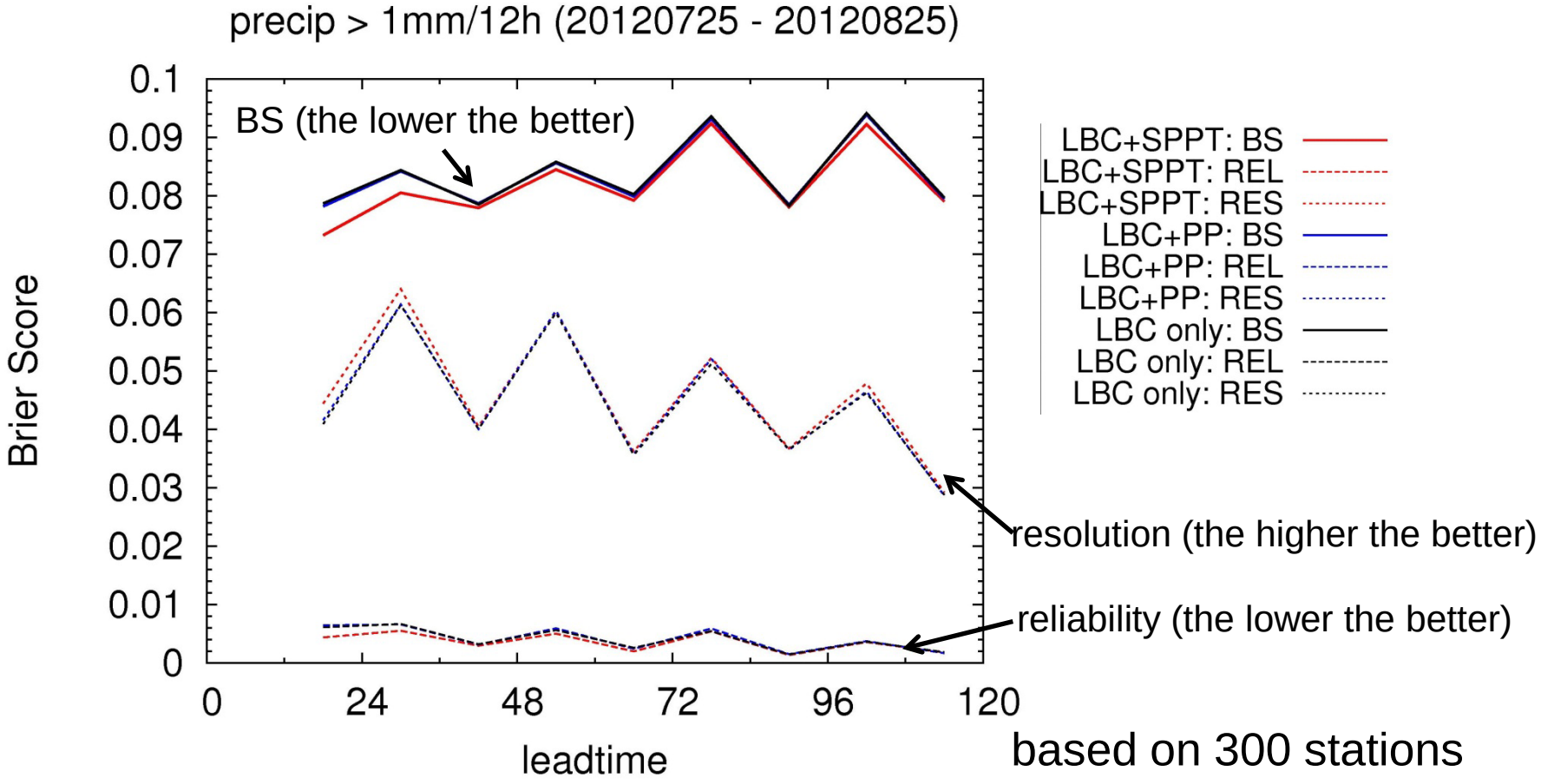
Brier Skill Score (ref=climatology)



Reference: forecast based on station climatology 2001-2010 (300 stations)

- still better than clim. forecast, but gain is smaller
- LBC+SPPT best until +30h, thereafter differences very small

Brier Score decomposition



All experiments very similar:

- very good reliability
- resolution only slightly decreasing with increasing lead-times

Conclusions COSMO-E experiments

- Surprisingly large reduction in spread with smaller correlation lengths for random numbers
- **SPPT produces only small additional spread for runs with LBC perturbations**
- **3 setups LBC+SPPT, LBC+PP and LBC show similar results; impact of SPPT larger than of PP**
- spread clearly too small in PBL …
- … but rather too large in upper-air for +120h
- **only slightly better scores (up to +30h) with SPPT so far**
- experiments show surprisingly high reliability for precipitation probabilities (enough statistics?)

Questions …

- Should we increase the perturbation amplitude again (after having removed the Coriolis tendencies from the SPPT)?
- What about the spatial and temporal correlation scales?
- Individual perturbation of each parameterization scheme?
  - If yes, which ones are most uncertain, and should hence be perturbed the most?
  - Should some of the parameterization schemes not be perturbed at all?
  - What about perturbing the soil / lower boundary condition (i.e., TERRA, FLake, …)?
- Why are qc, qi, qr, qs, and qg tendencies not perturbed?
- Do we need to re-visit the physics-dynamics coupling?

… and Outlook

- continue work with SPPT (internship of Daliah Maurer)
  - analyse characteristics of SPPT term in model equations
  - try to generate more spread near the surface without increasing upper-air spread

- include IC perturbation from KENDA
- look into Stochastic Kinetic Energy Backscattering Scheme (SKEBS)

One slide on SKEBS for COSMO …

- Latest WRF version ported to COSMO (André Walser with Judith Berner); does not include link to dissipation rates
- Clean-up and minimal performance improvements (e.g., optimized libraries) still to be done
- Single run (technically) successful, but (meteorological) experiments still to be done; first step is to run same four cases as run for SPPT and compare the two schemes
- Later, and only if meteorological tests successful: more rigorous performance improvements (FFTs …)