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COSMO-E experiments with SPPT on the convection-permitting scale

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MeteoSwiss

COSMO User Seminar
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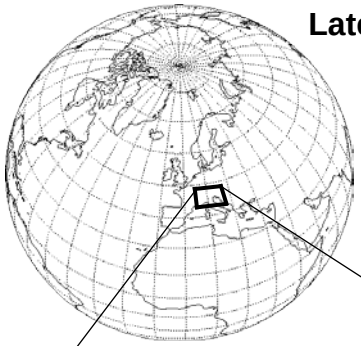
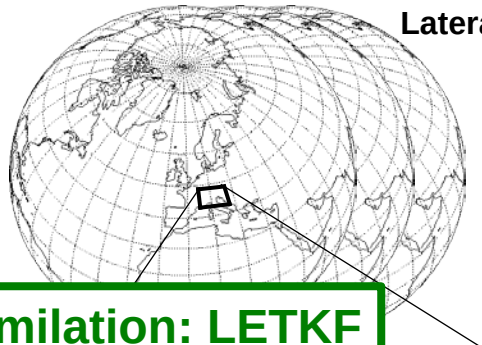
Project COSMO-NExT



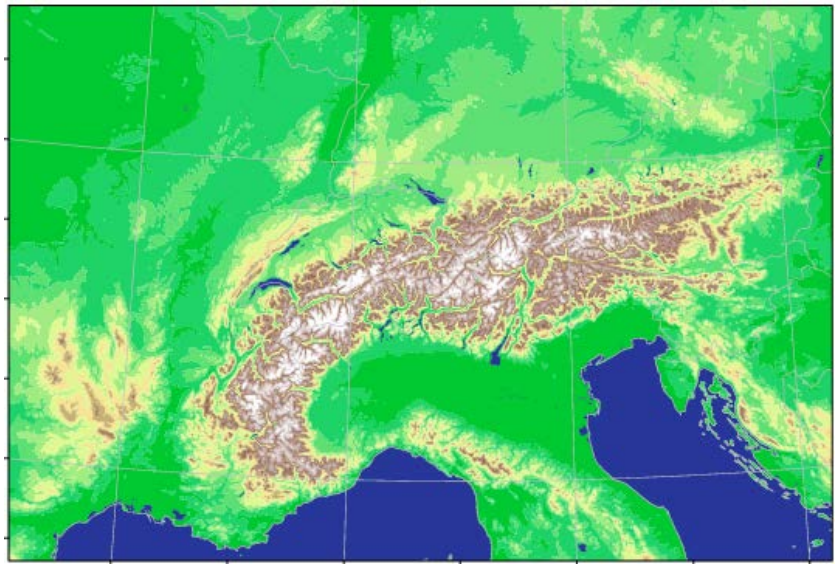
Lateral boundary conditions:
IFS-HRES
10km
4x daily



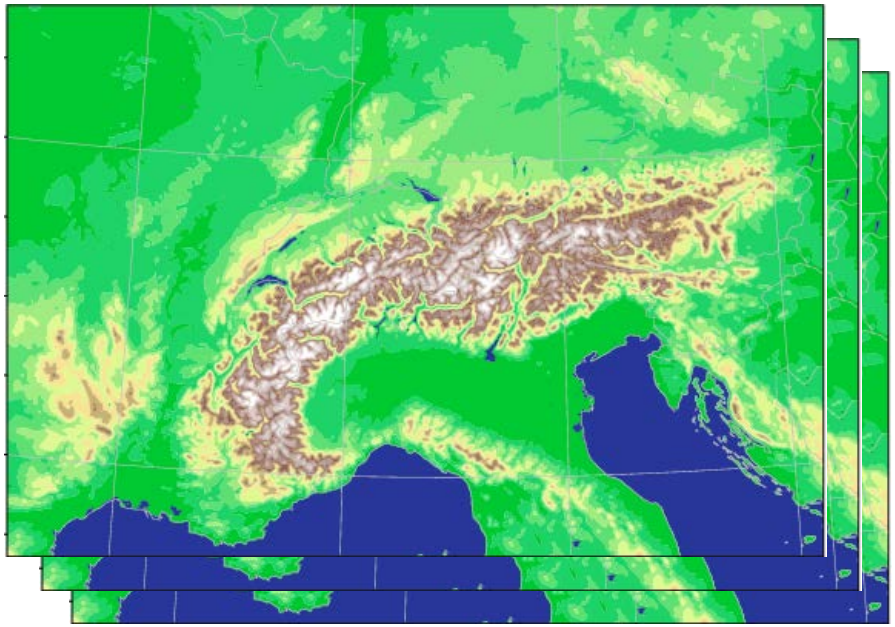
Lateral boundary conditions:
IFS-ENS
20km
2x daily

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 (experimental) setup

- Ensemble forecasts with **convection-permitting resolution** (2.2 km mesh-size, 60 vertical levels)
- **21 members, forecasts up to +120h, Alpine area**
- ICs:
  perturbations: **KENDA/LETKF analysis**
  no perturbations: operational COSMO-2 analysis
- LBCs:
  perturbations: **IFS-ENS members 0-20**
  no perturbations: IFS-ENS member 0
- COSMO version 5.0 with single precision: reduction of elapsed time to 60% with same forecast quality!

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

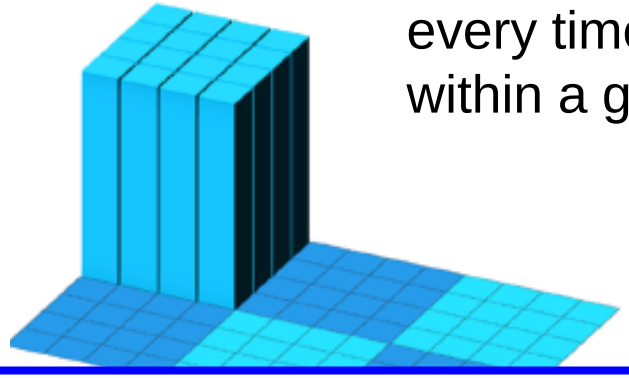
local tendency | horizontal diffusion | physics

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

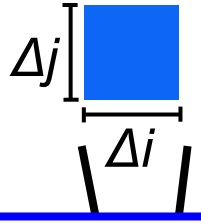
${P_i}^X$ physical parameterisation scheme *i*
(turbulence, radiation, microphysics, shallow convection, …)

copied and adapted from Shutts

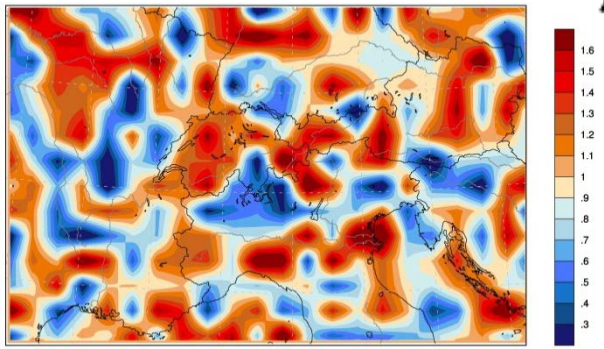
SPPT: Generation of random pattern



every timestep Δt draw N(0,σ) random numbers within a given *range* on coarse grid Δi, Δj

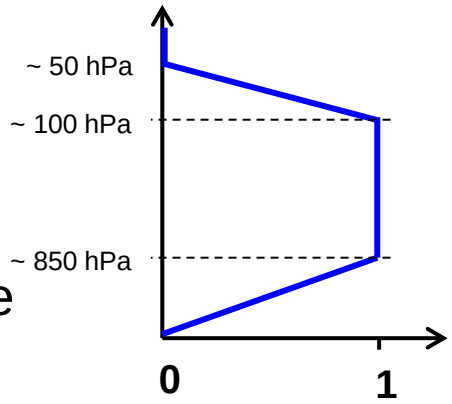


will (probably) be available with COSMO 5.1



random pattern (1+*rand*)

if required:
vertical tapering at model top and close to the surface



copied and adapted from Torrisi

Outline: COSMO-E with SPPT

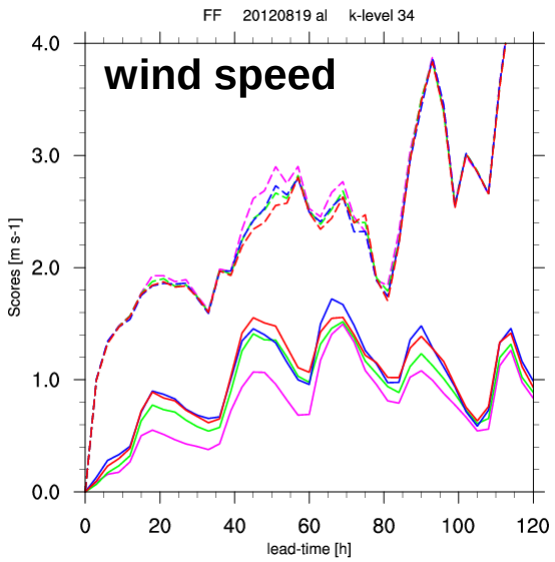
- Sensitivity
  check sensitivity of ensemble spread to different SPPT parameter settings
- Validation
  make sure chosen SPPT parameter settings do not degrade deterministic model runs (model climatology)
- Verification
  run system for extended period and assess quality
- Conclusions and outlook

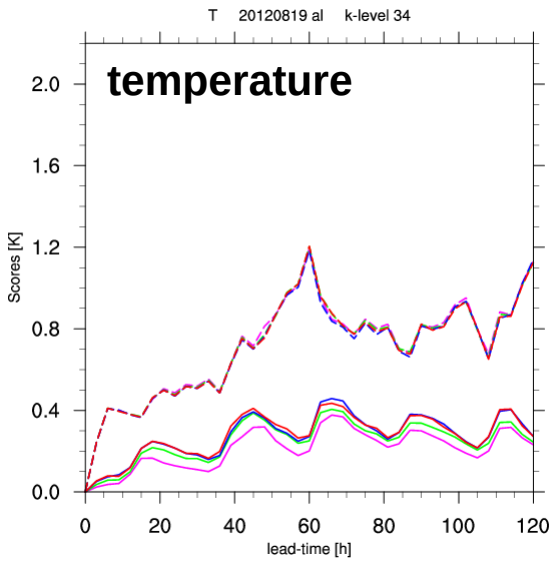
Sensitivity: SPPT perturbations only

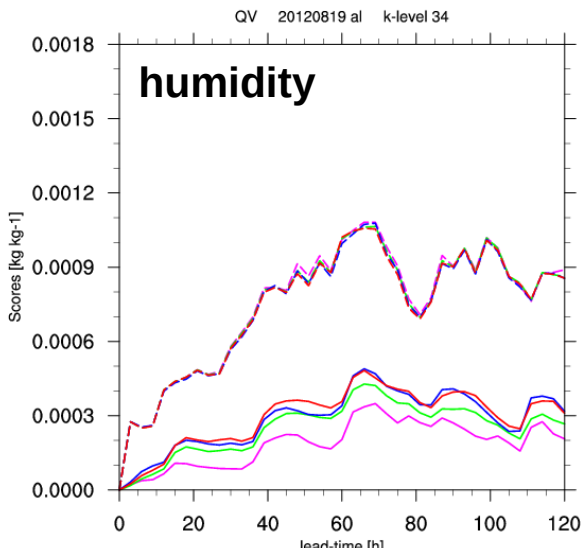
name	*Δt*	*Δi=Δj*	*σ*	*range*
12	**1h**	**0.5°**	**0.5**	**1.0**
14	6h	5.0°	0.5	1.0
19	**6h**	**5.0°**	**1.0**	**0.9**
20	6h	2.5°	1.0	0.9

- **no tapering in lower troposphere**
  - main motivation to taper SPPT in PBL are **stability** issues; **COSMO-E runs did not show any stability problems**
  - turning tapering off has significant (positive) impact on spread in PBL
- **no humidity limiter**
- **no IC and LBC perturbations**
  - ICs: COSMO-2 analysis, LBCs: IFS-ENS control

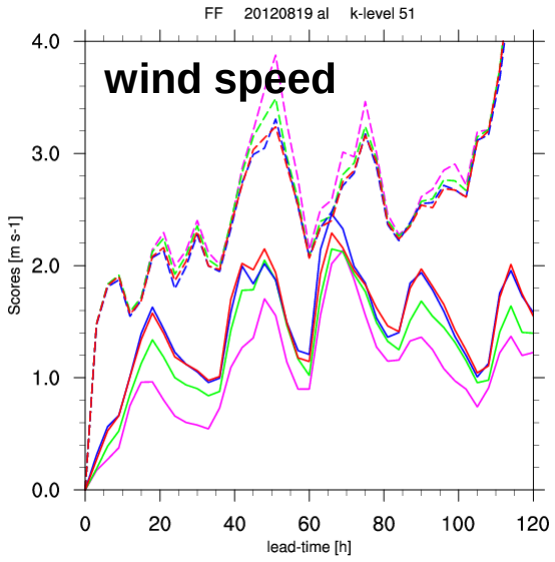
Sensitivity: 19.08.2012

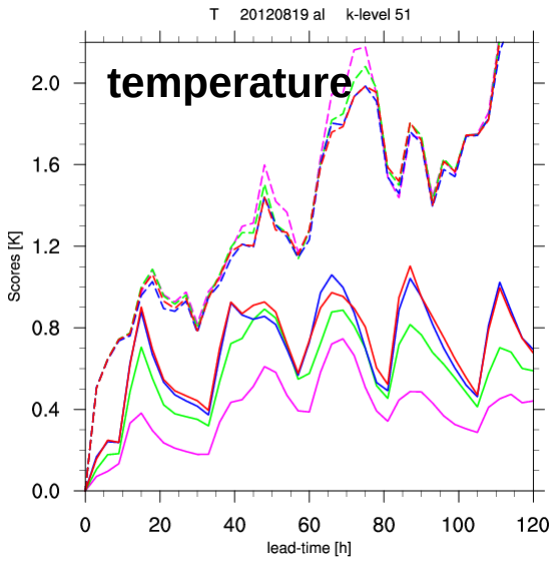


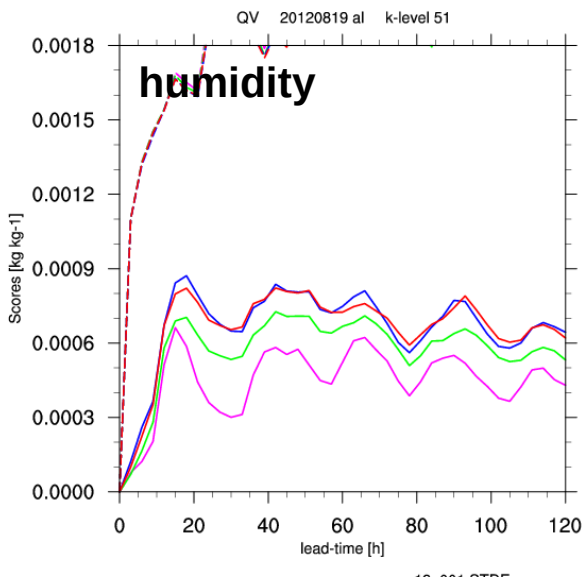




k=34 / ~500 hPa / ~5000 m







k=51 / ~925 hPa / ~600 m

spread / error

lead-time [h]

Sensitivity: results

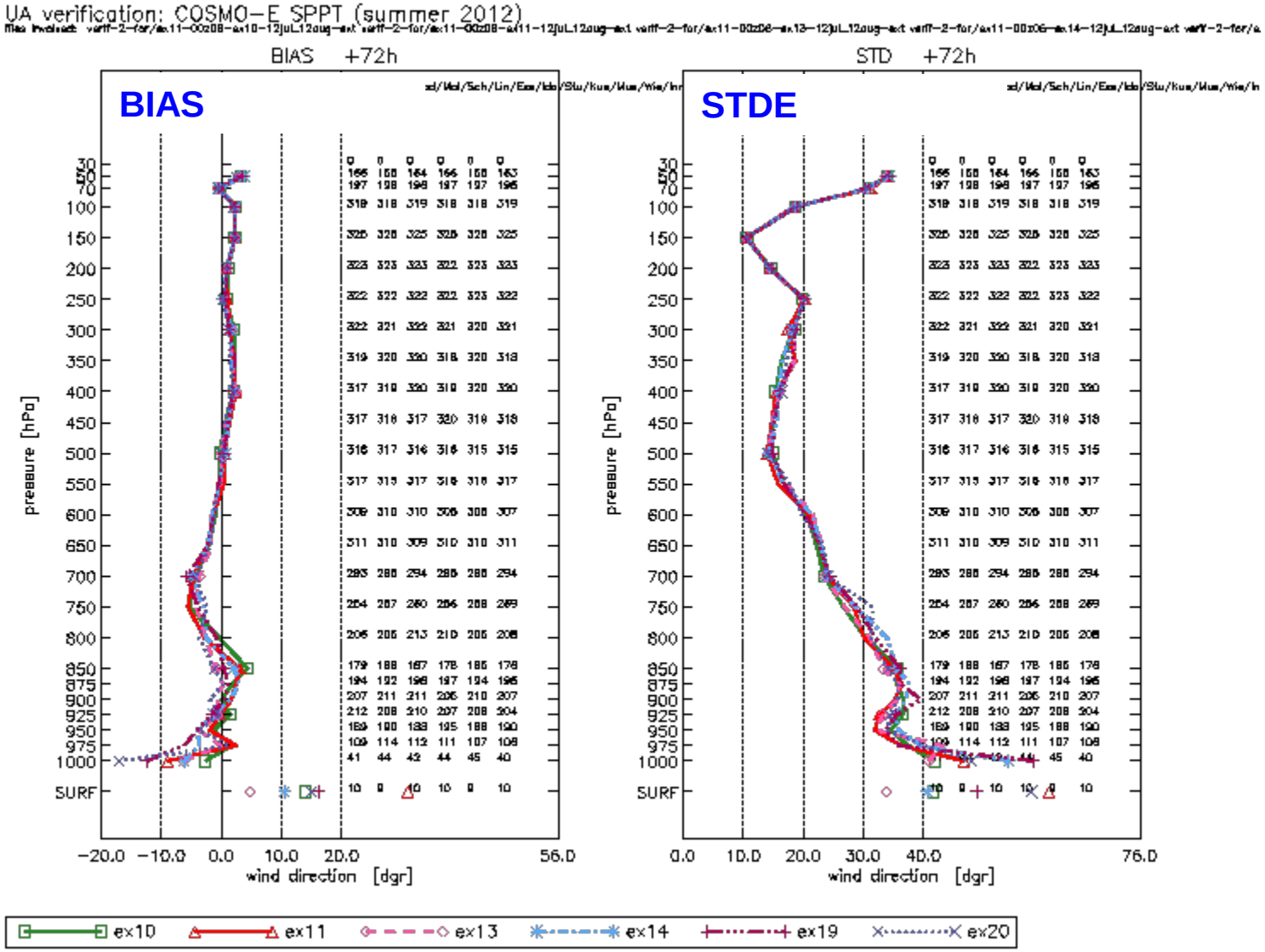
- spread decreases with increasing height above surface
  - tapering in lower troposphere reduces spread substantially
- larger random numbers produce larger spread and faster spread growth
- smaller correlation-lengths in space and time lead to (substantially!) smaller spread
- spread growth saturates at about the same lead-time for all height levels

Validation: deterministic runs

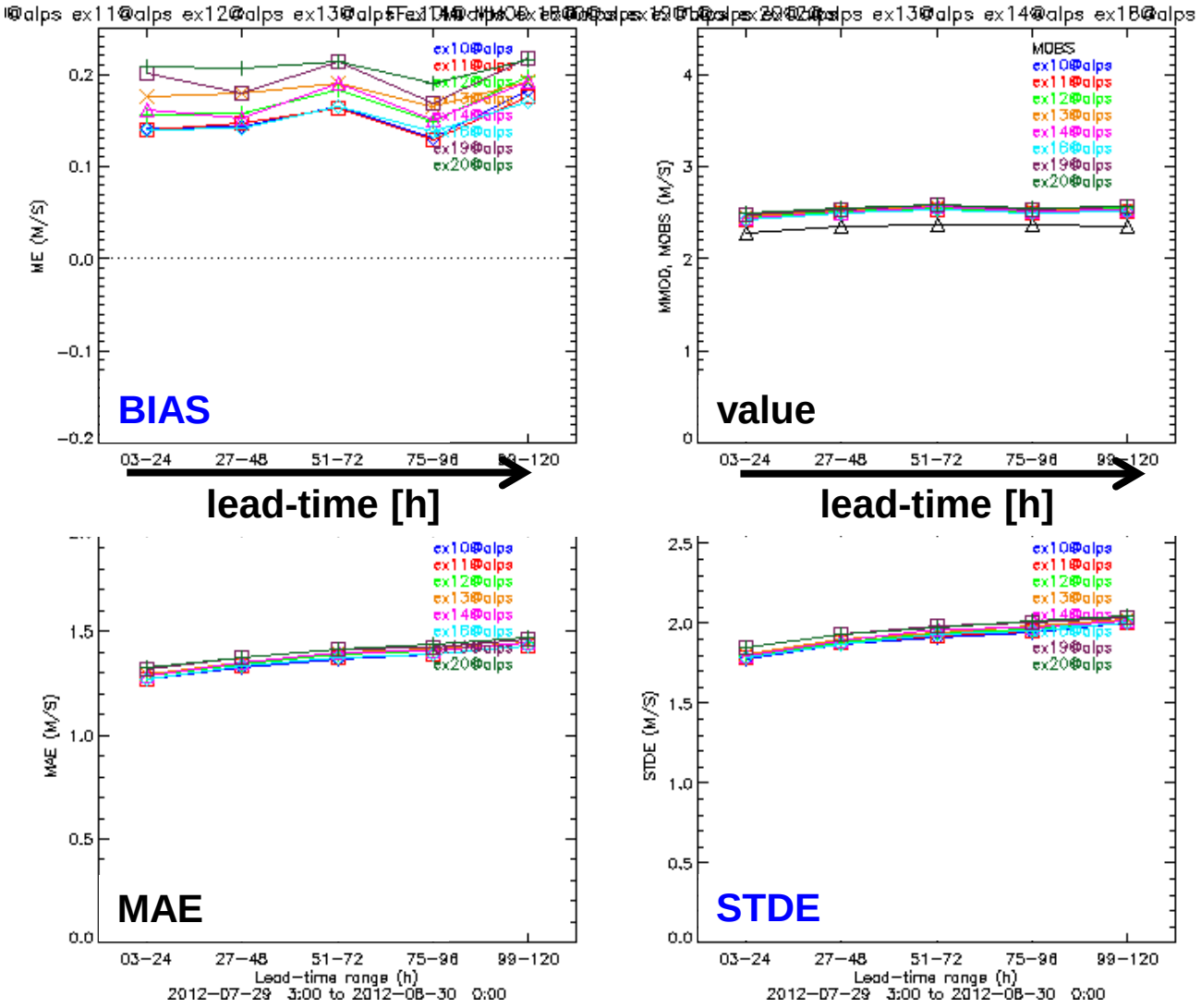
- SPPT **must not** degrade (deterministic) quality of ensemble members
- **deterministic runs (1 month each in summer and winter 2012)** for different SPPT parameter settings

→ deterministic verification, upper-air and surface;
the following slides show the largest differences between the different SPPT parameter settings

Upper-air: wind direction
+72h, all stations, 26.07-25.08.2012



Surface: wind speed
all stations, 26.07-25.08.2012



Validation: results

- **generally (very) small differences between different tested SPPT parameter settings**
- larger differences found for summer
- no differences seen for humidity; no drying observed!
- no significant quality degradation observed with SPPT, even for very strong stochastic perturbations of physical tendencies
- choose (aggressive) SPPT parameter settings “19” for subsequent tests

Verification: COSMO-E test suite

- 1 month period **(26.07.-25.08.2012),** one run at 00 UTC every second day **(results in 16 runs per setup)**
- experiments:

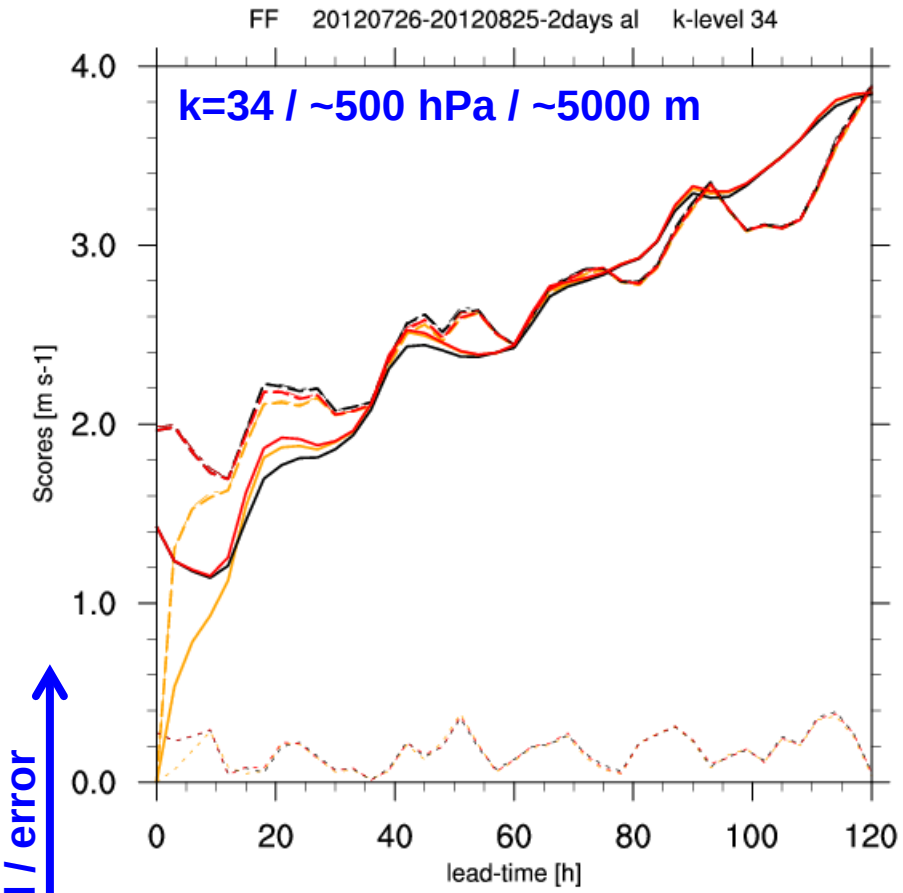
name	***ICs***	***LBCs***	***Δt***	***Δi=Δj***	***σ***	***range***
19e111	**LETKF**	**ENS**	**6h**	**5.0°**	**1.0**	**0.9**
19e110	**LETKF**	**ENS**	**---**	**---**	**---**	**---**
19e011	**COSMO-2**	**ENS**	**6h**	**5.0°**	**1.0**	**0.9**
	COSMO-LEPS (ICs & LBCs: IFS-ENS)					

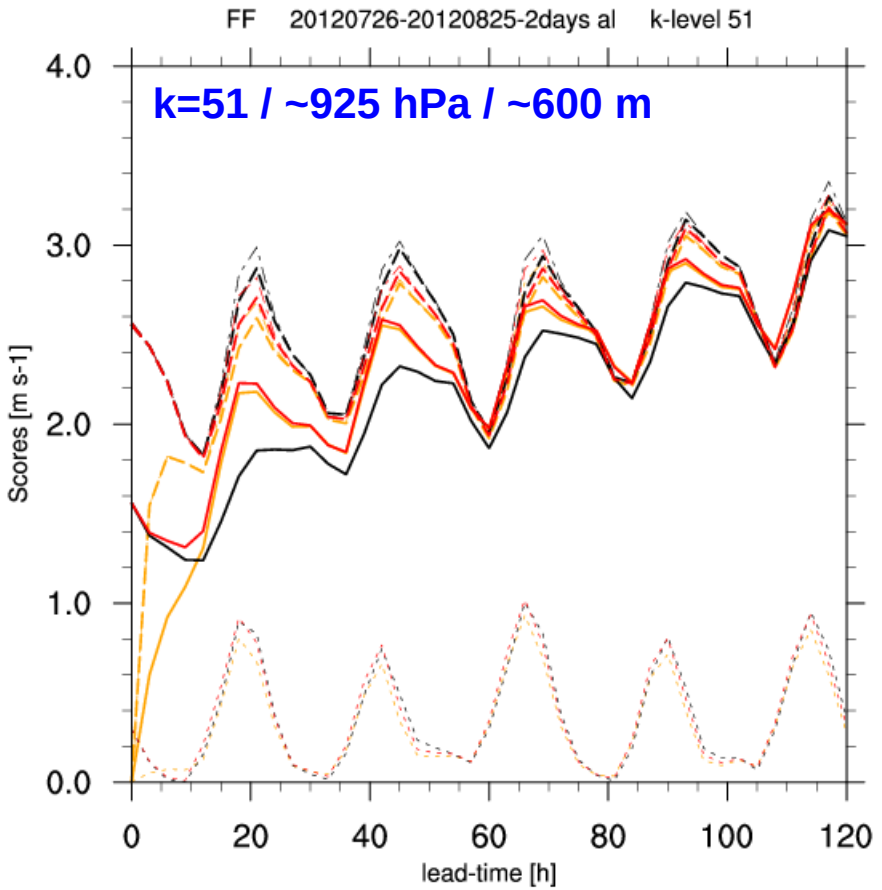
for SPPT: no tapering near the surface, no humidity limiter

→ spread / error relation against COSMO-2 analysis

→ BS and BSS against surface observations

spread / error: wind speed





spread / error

lead-time [h]

ICs plus LBCs plus SPPT

ICs plus LBCs

LBCs plus SPPT

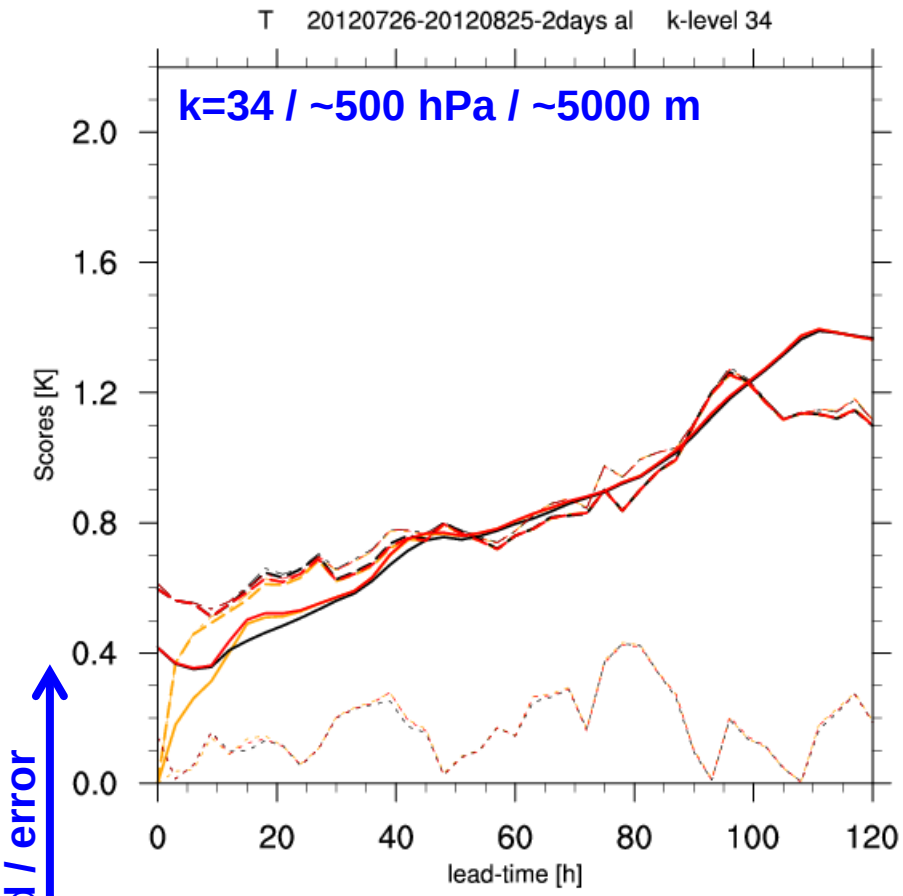
RMEV

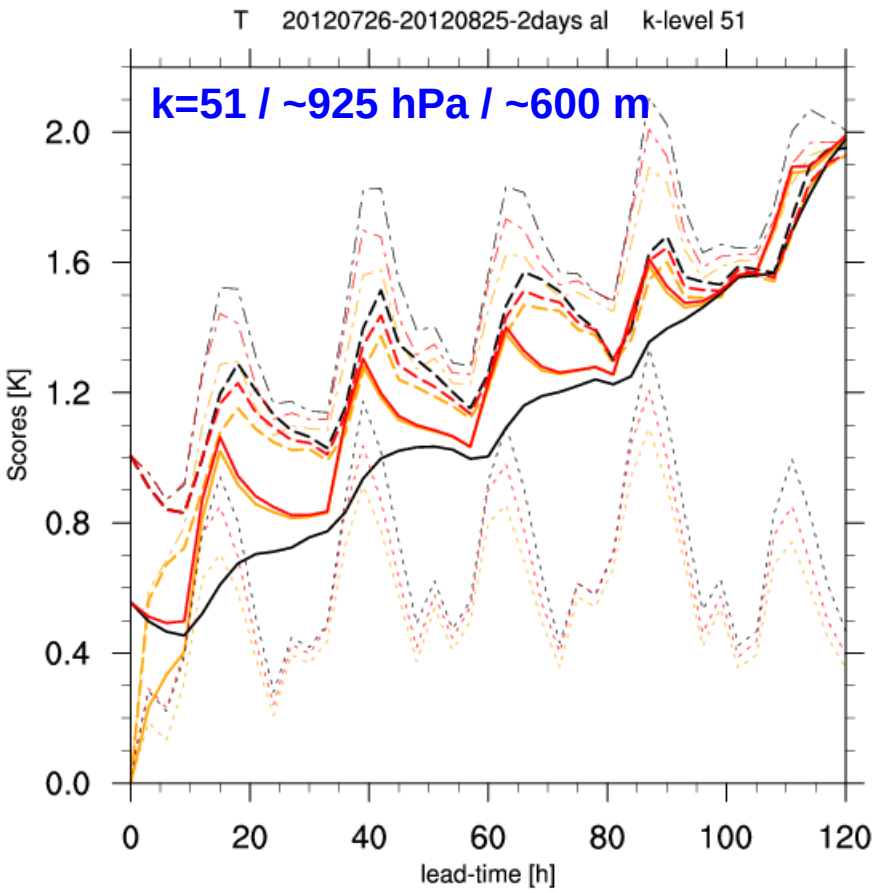
STDE

RMSE

abs(BIAS)

spread / error: temperature





spread / error

lead-time [h]

ICs plus LBCs plus SPPT

ICs plus LBCs

LBCs plus SPPT

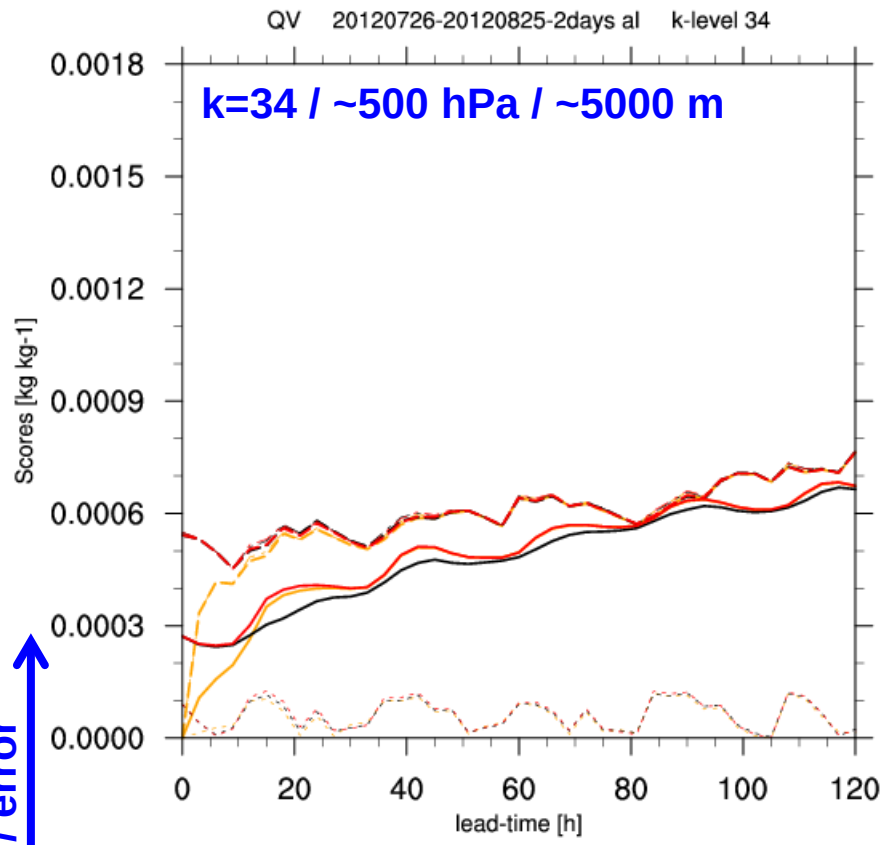
RMEV

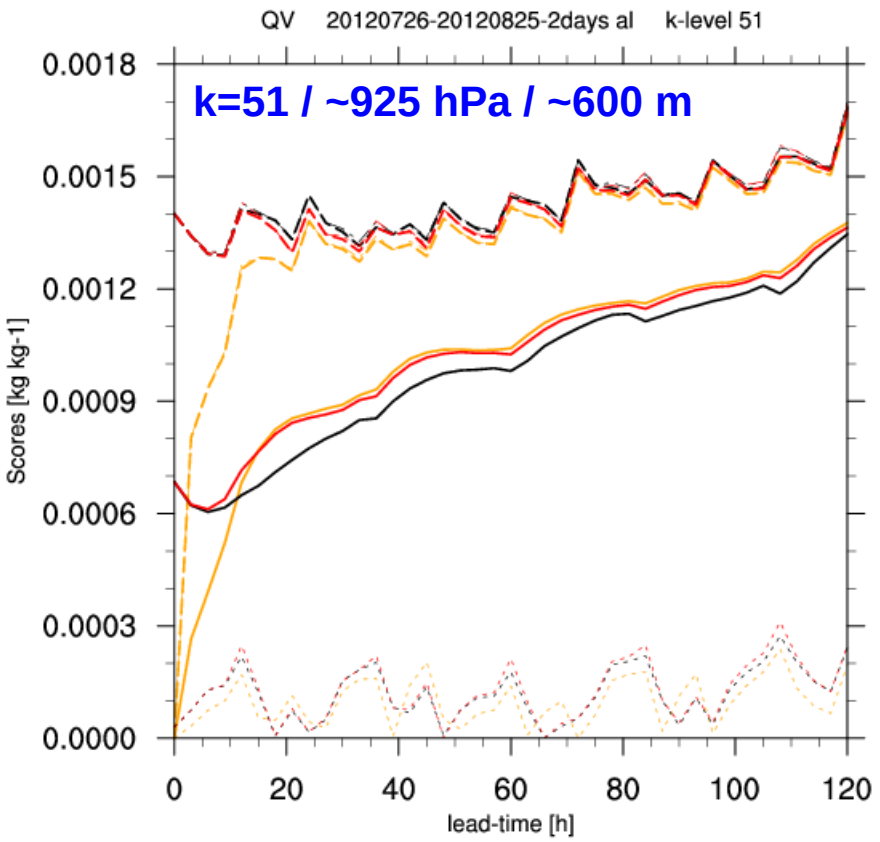
STDE

RMSE

abs(BIAS)

spread / error: humidity





spread / error

lead-time [h]

ICs plus LBCs plus SPPT

ICs plus LBCs

LBCs plus SPPT

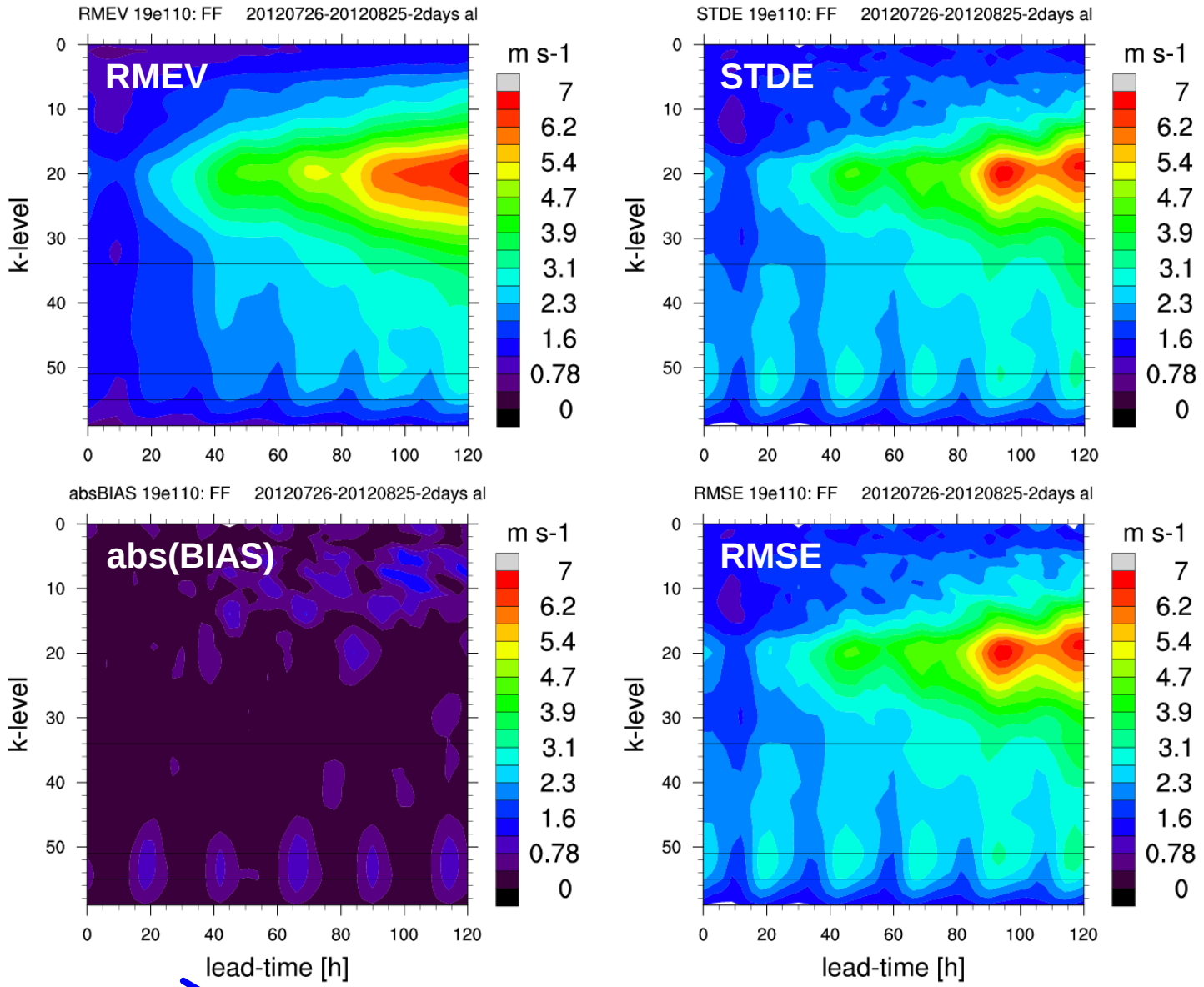
RMEV

STDE

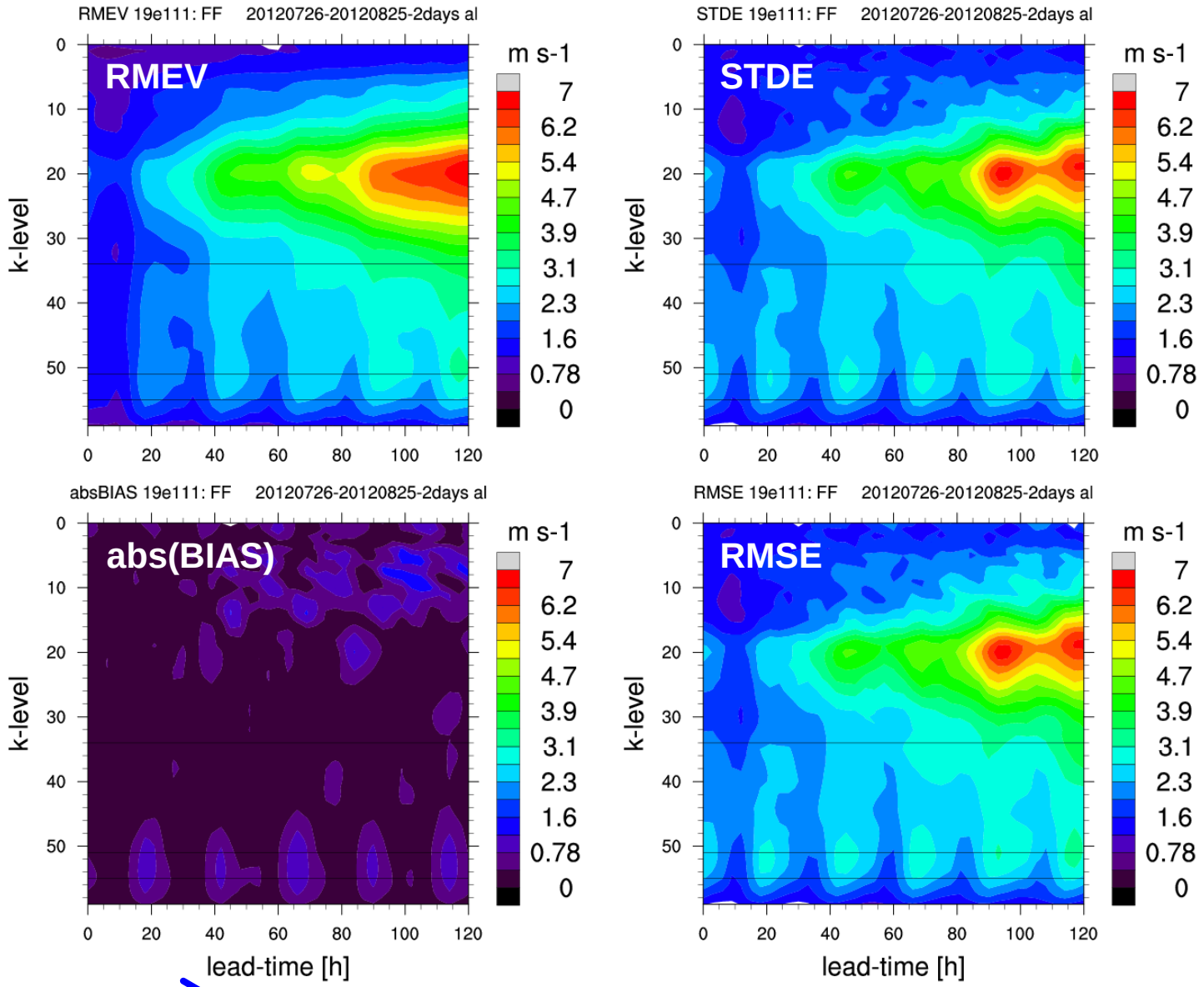
RMSE

abs(BIAS)

spread / error: wind speed, 19e110



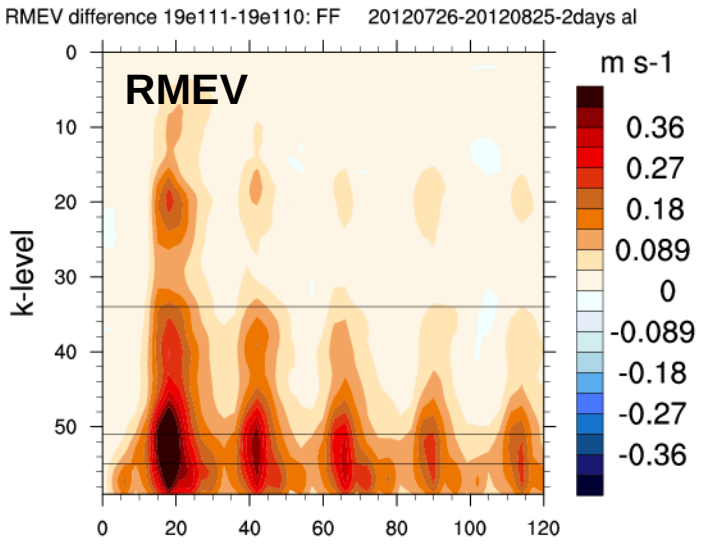
spread / error: wind speed, 19e111

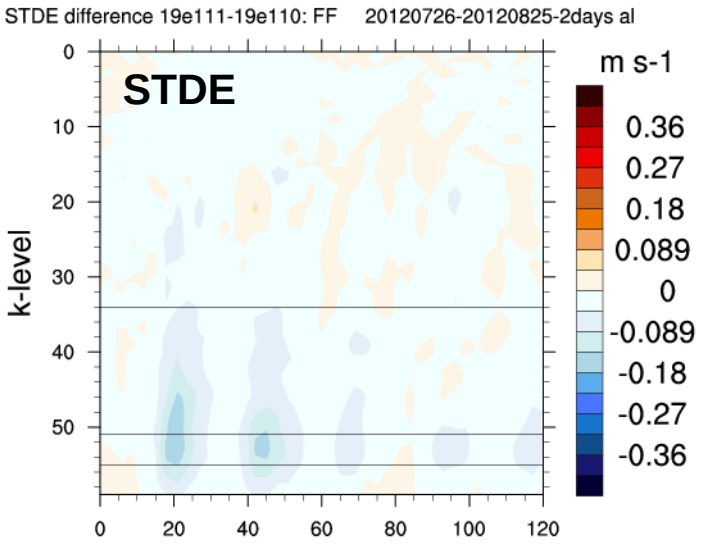


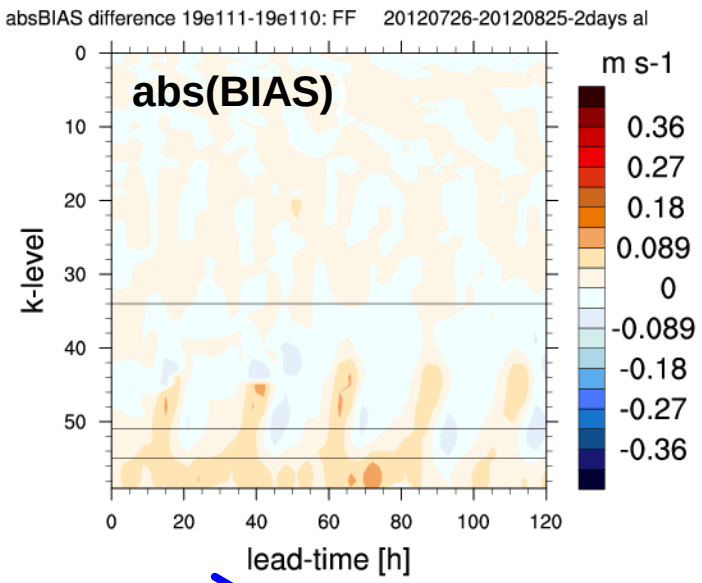
k-level

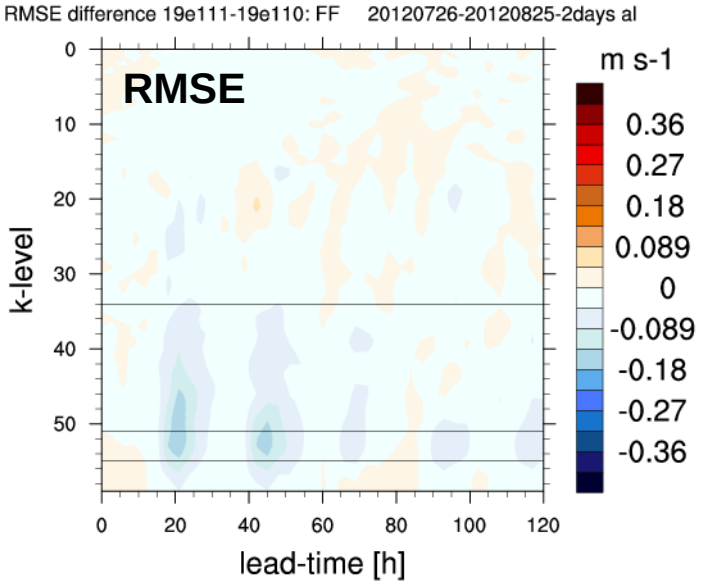
lead-time [h]

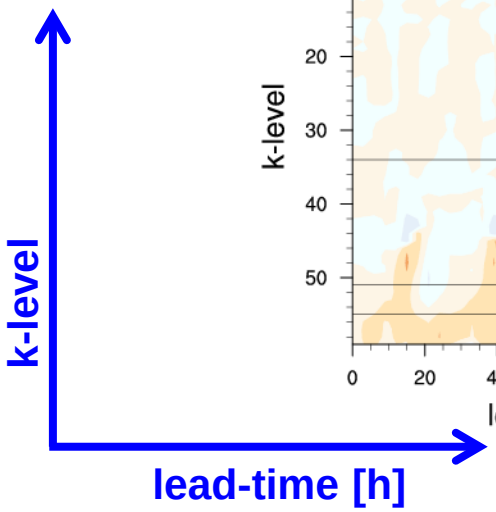
spread / error: FF, 19e111-19e110



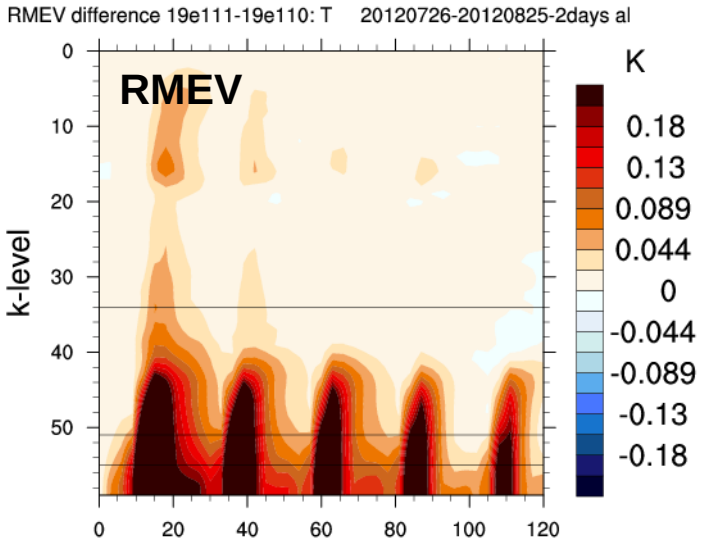


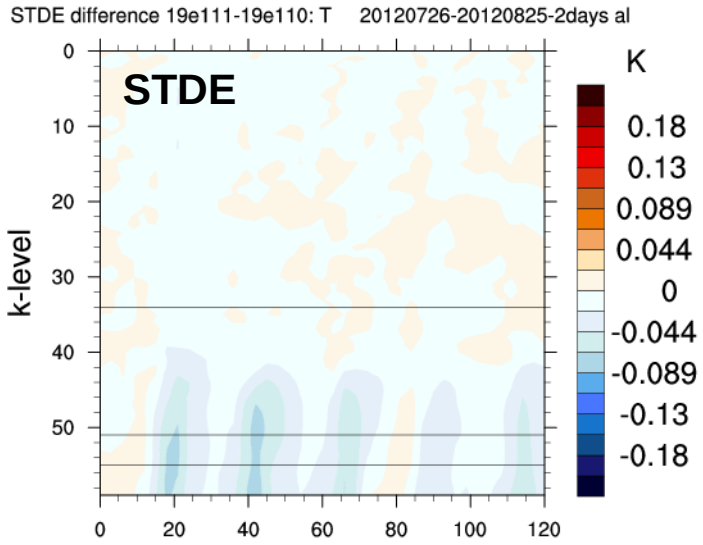


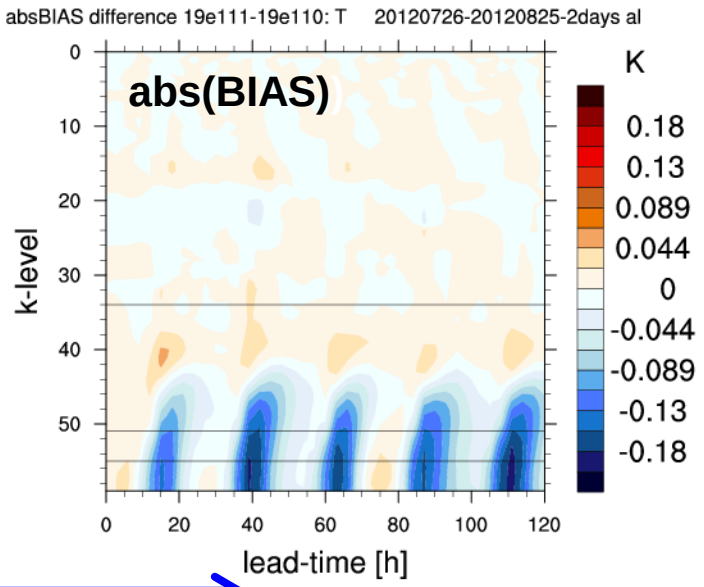


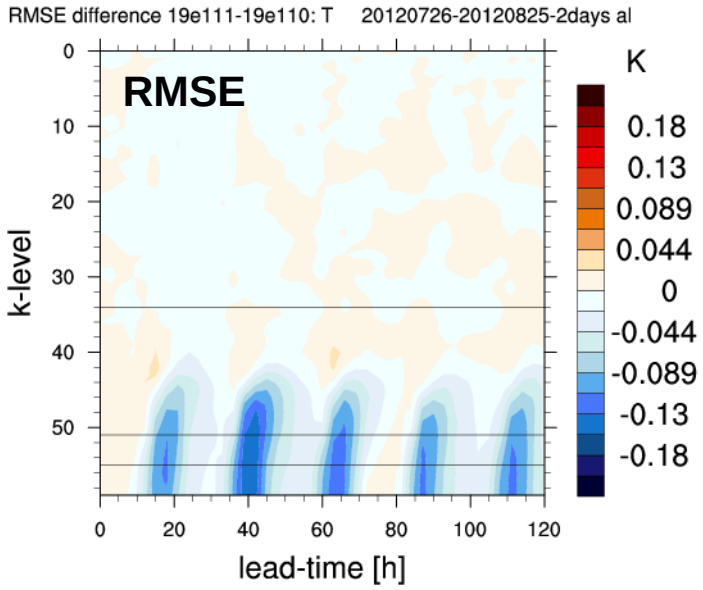


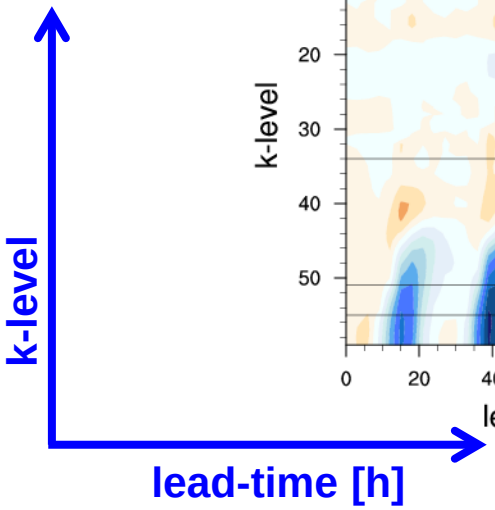
spread / error: T, 19e111-19e110



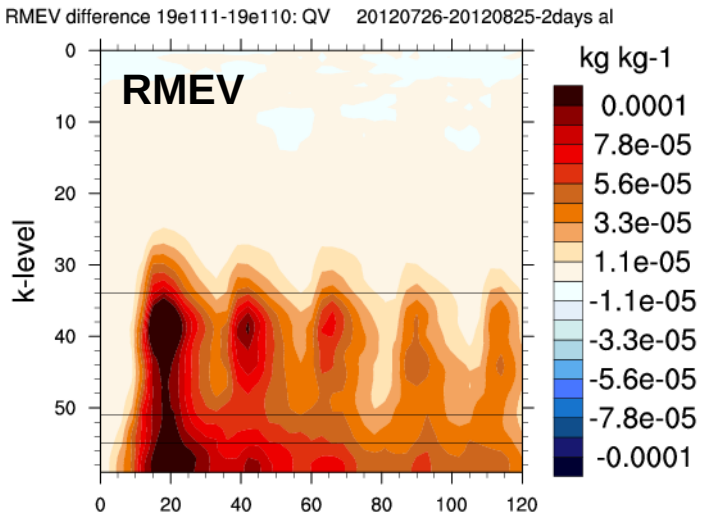


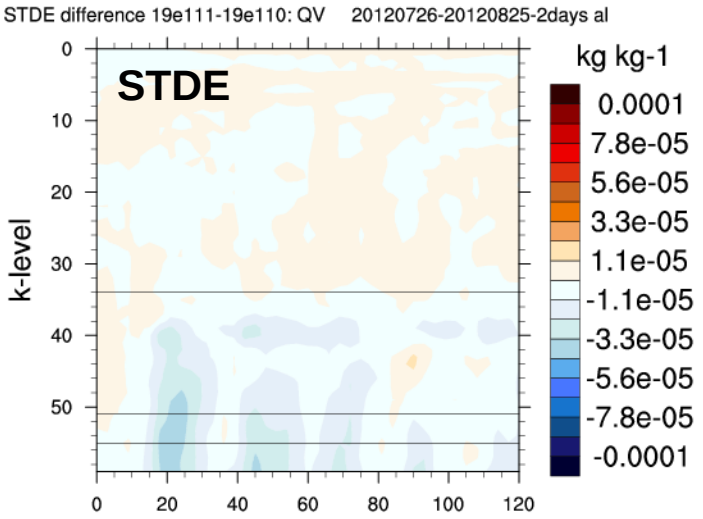


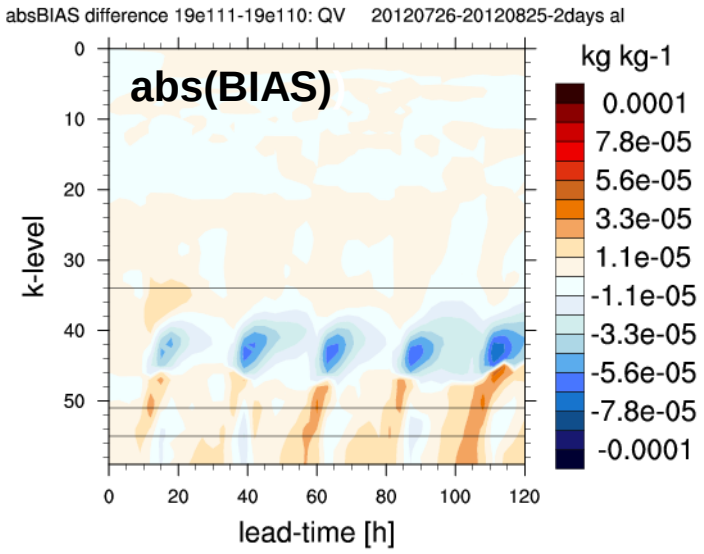


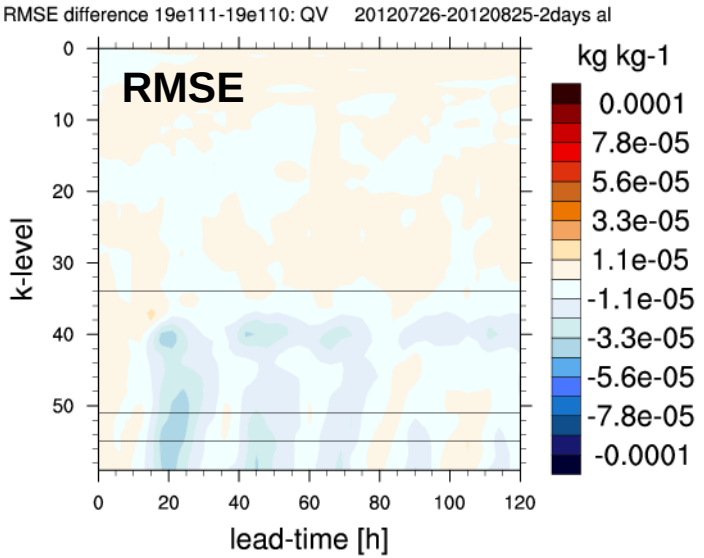


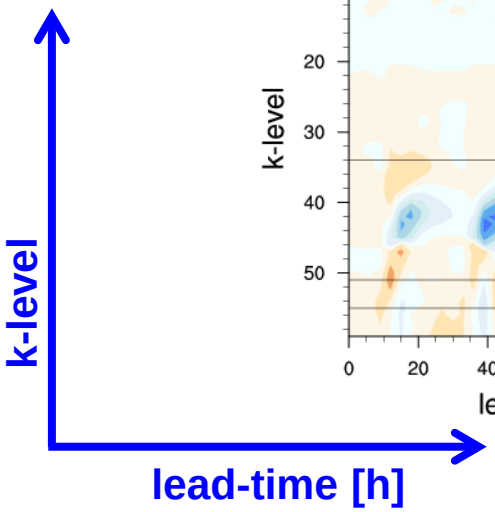
spread / error: QV, 19e111-19e110







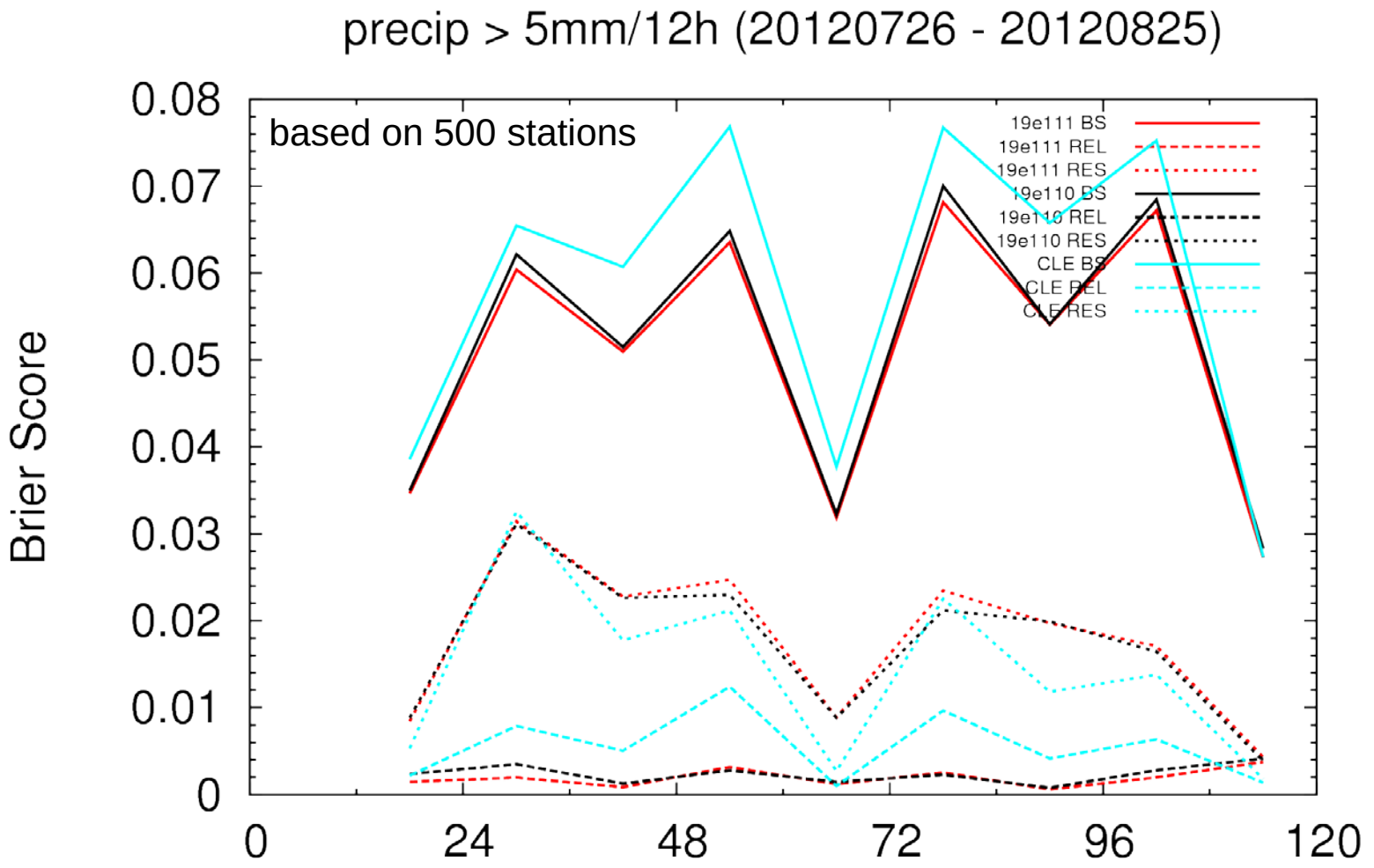




Verification against COSMO-2 analysis: conclusions

- **generally satisfactory** spread-error relation in **middle and upper troposphere**
  - too little spread for first 36hrs and due to IC perturbations
  - beyond day 2 spread only determined by LBC perturbations
  - almost too much spread for day 5
- **significant improvement** of RMEV, STDE, and BIAS **due to SPPT** in **lower troposphere**
  - still lacking spread in first 3 days and due to IC perturbations
  - positive effect of SPPT for entire forecast range
- poorest effect / results for **humidity** (still too little spread)

Brier Score: precip, > 5mm/12h



ICs plus LBCs plus SPPT

ICs plus LBCs

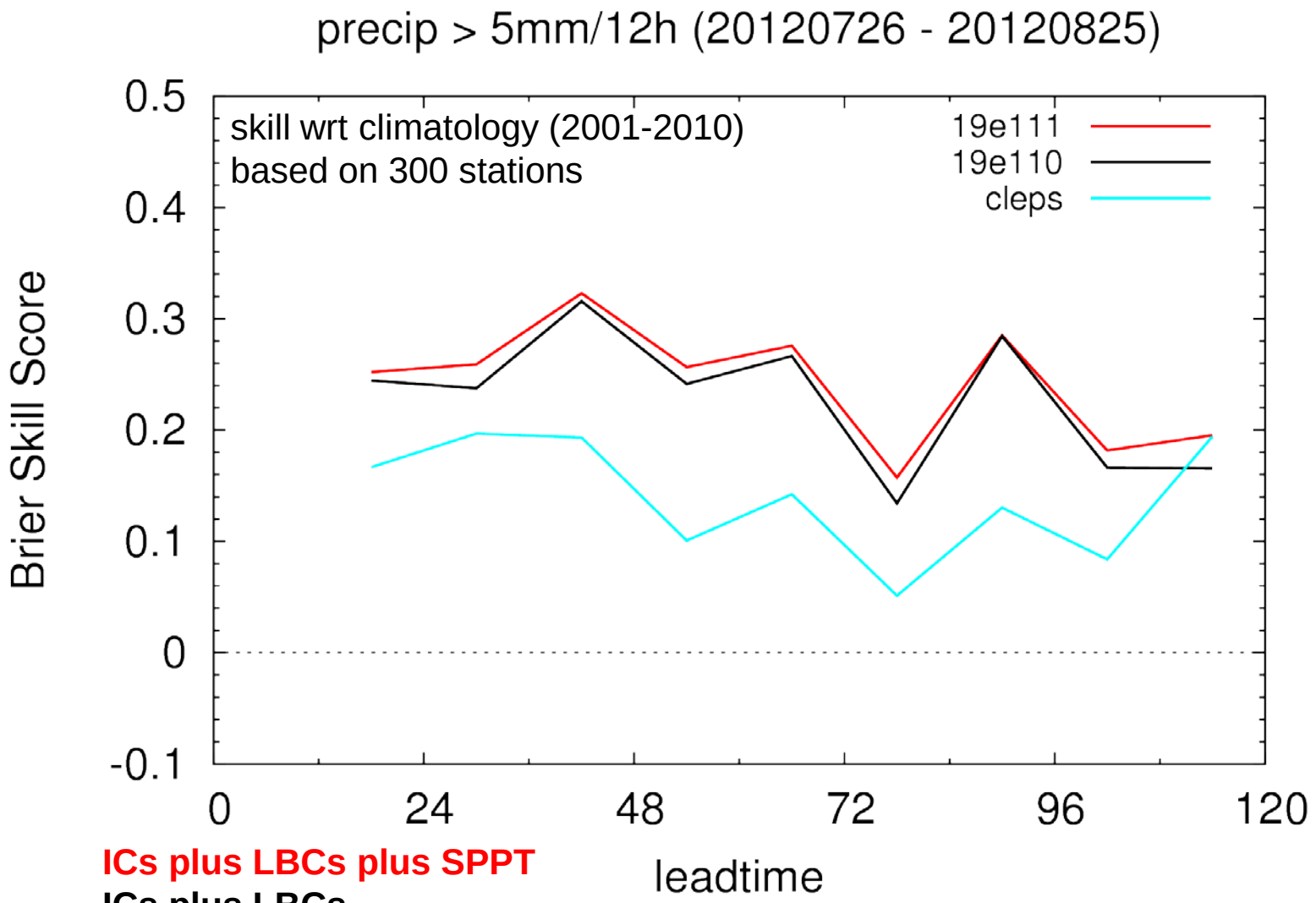
COSMO-LEPS

Brier Score

reliability

resolution

Brier Skill Score: precip, > 5mm/12h

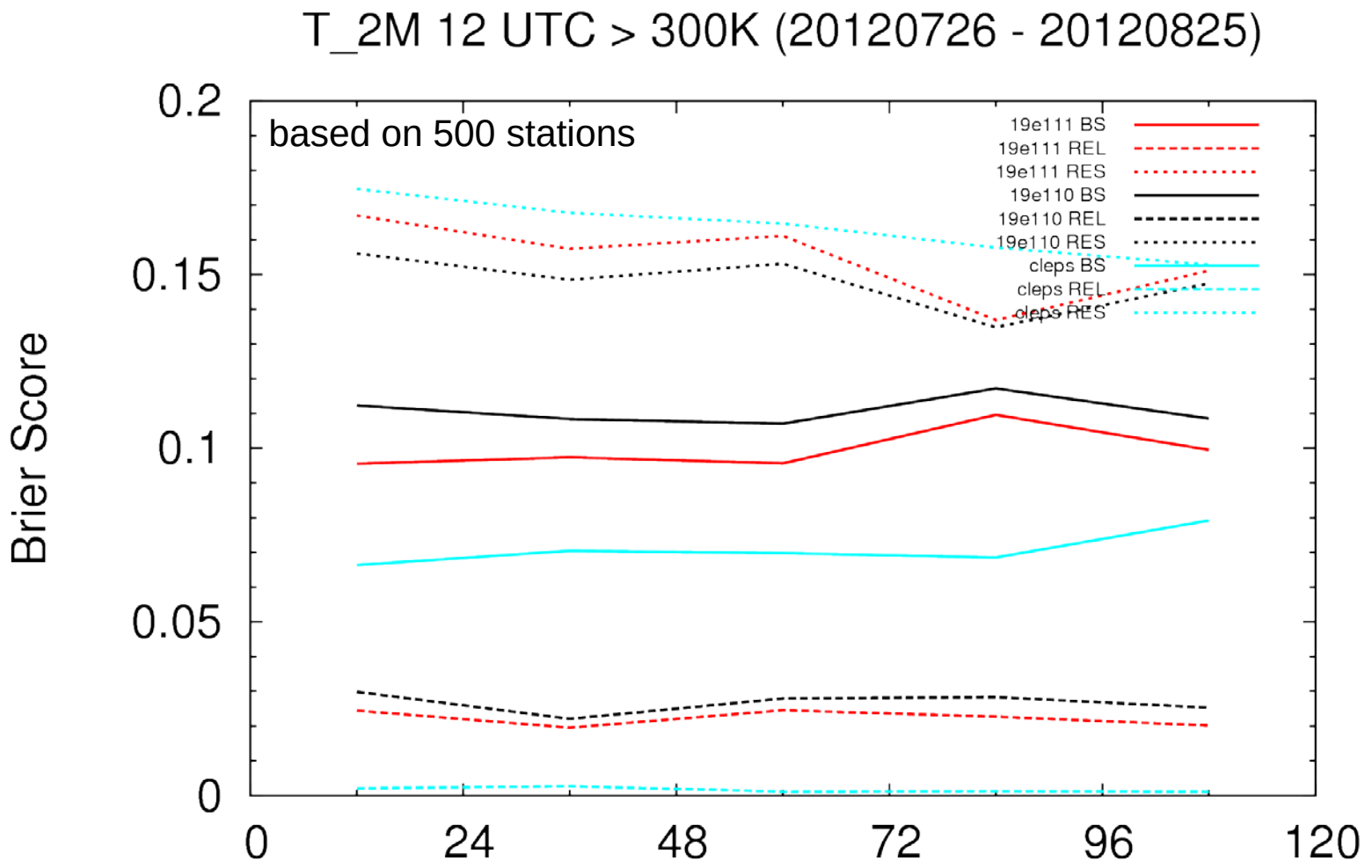


ICs plus LBCs plus SPPT

ICs plus LBCs

COSMO-LEPS

Brier Score: T2m, 12 UTC, > 300K



ICs plus LBCs plus SPPT

ICs plus LBCs

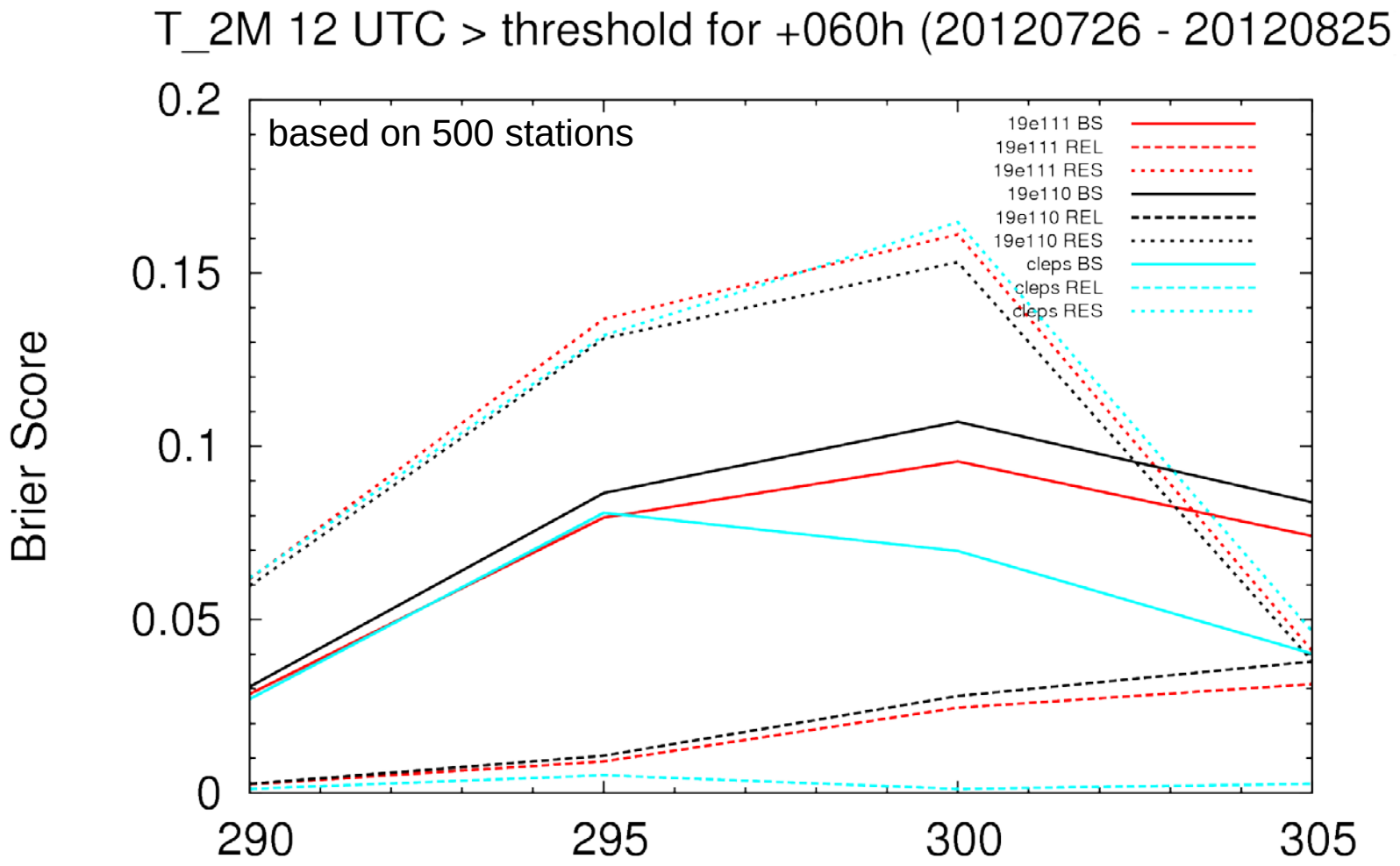
COSMO-LEPS

Brier Score

reliability

resolution

Brier Score: T2m, 12 UTC, +60h



ICs plus LBCs plus SPPT

ICs plus LBCs

COSMO-LEPS

Brier Score

reliability

resolution

Verification against observations: conclusions

- 12h precipitation
  - surprisingly good reliability for all lead-times; slightly decreasing resolution with increasing lead-time
  - **small (!) improvement due to SPPT**
  - skillful (wrt climatology); outperforms COSMO-LEPS
- 2m temperature
  - fair reliability for all lead-times; slightly decreasing resolution with increasing lead-time
  - **moderate improvement due to SPPT**
  - poorer than COSMO-LEPS for T2m > 300/305K (reliability!)

General conclusions

- **significant and positive impact** of SPPT on **ensemble spread (and STDE, BIAS)** in **troposphere**;
  impact of SPPT much larger than of parameter perturbations (not shown)
- **moderate impact** of SPPT on **Brier Score** for **surface parameters**
- **still lack some spread in first 2-3 days**
- skilful perturbation of **humidity** most difficult

Outlook

- increase statistics (e.g., winter); **start regular runs**
- improve ICs and IC perturbations (KENDA/LETKF)
- add "additional" perturbations at/in the surface (e.g., soil moisture; LETKF already allows for a free evolving soil, but time-scales involved are large …)?

- look into Stochastic Kinetic Energy Backscattering Scheme (SKEBS) and/or Stochastic Pattern Generator (→ poster)?

- last but not least: get a versatile and powerful verification tool