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Testing SPPT for COSMO-E: Summary

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COSMO General Meeting
10 September 2014, Eretria

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 1-20**
  - no perturbations: IFS-ENS member 0
- COSMO version 5.0; **single precision**

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 — physics

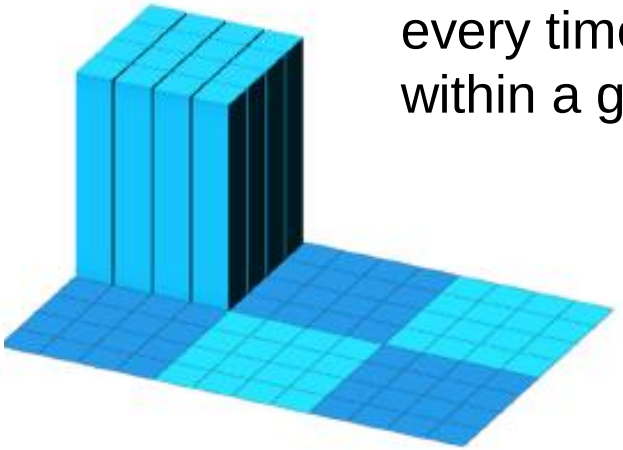
local tendency — horizontal diffusion

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

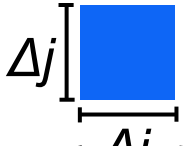
${P_i}^X$ physical parameterisation scheme *i*
(turbulence, radiation, microphysics, shallow convection, …)

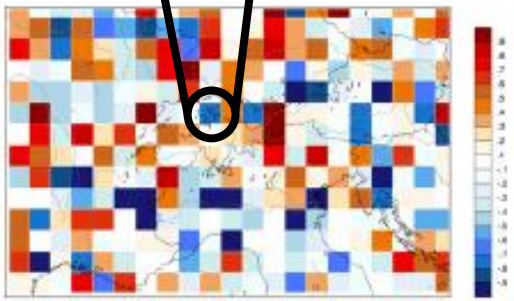
copied and adapted from Shutts

SPPT: Generation of random pattern

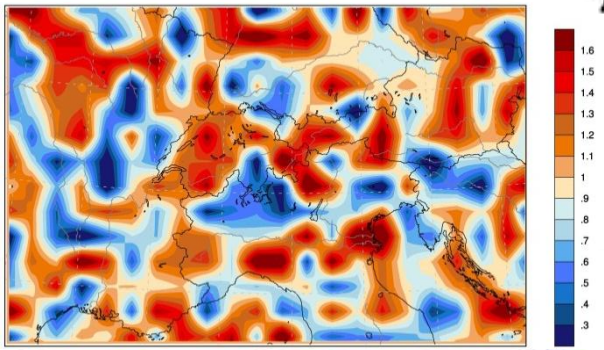


every timestep Δt draw N(0,σ) random numbers within a given *range* on coarse grid Δi, Δj



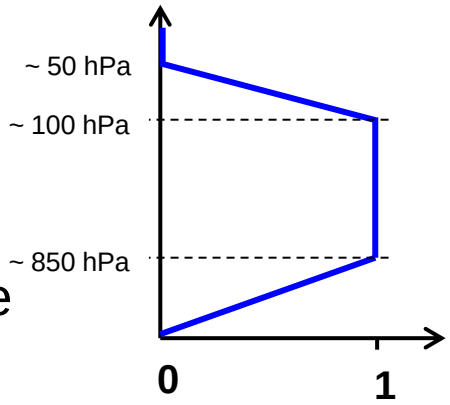


generate smooth pattern on COSMO grid by interpolating in time and horizontally in space



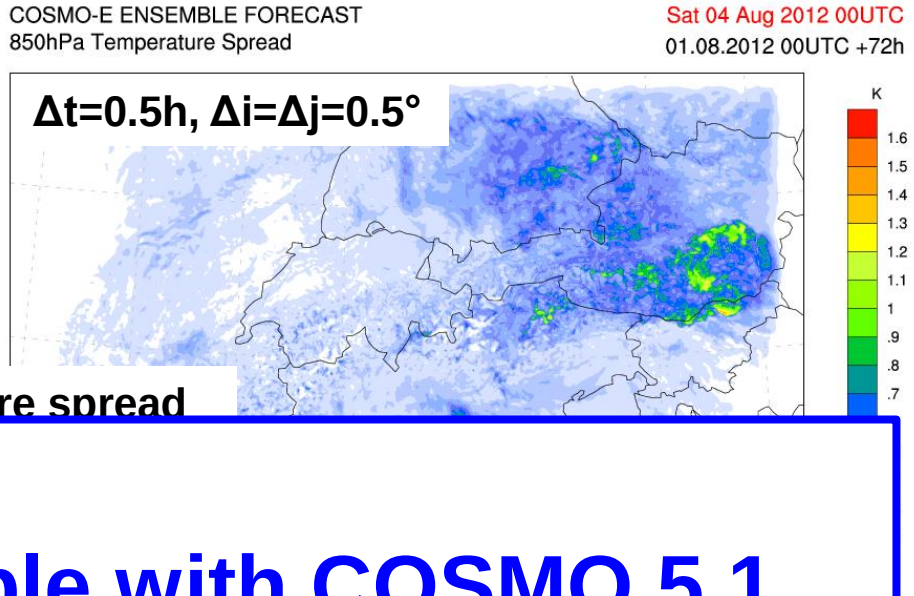
random pattern (1+*rand*)

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



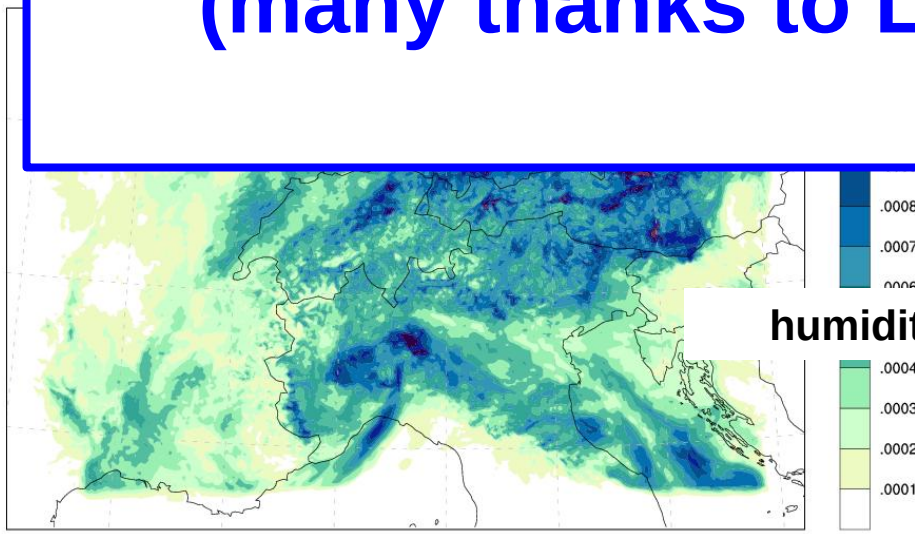
copied and adapted from Torrisi

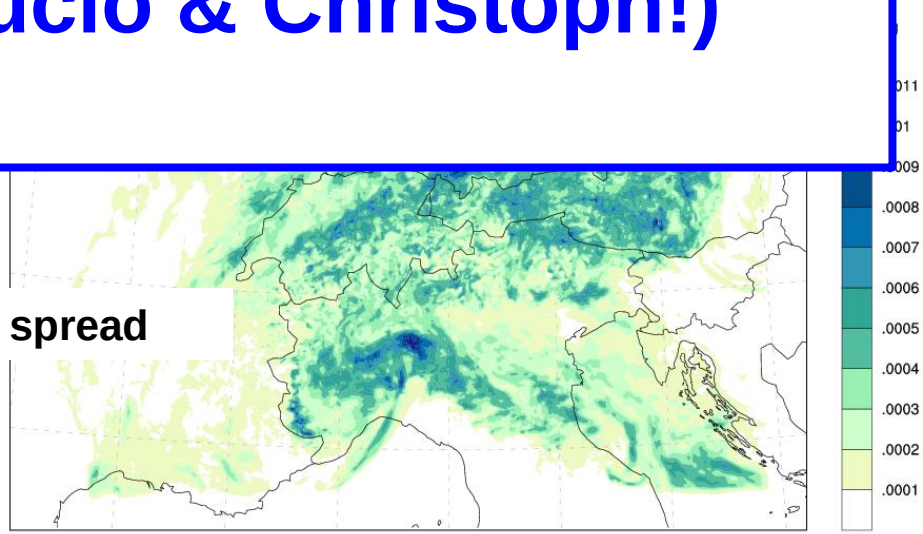
Sensitivity: 01.08.2012



temperature spread

SPPT will be available with COSMO 5.1 (many thanks to Lucio & Christoph!)





humidity spread

COSMO-E with SPPT: “work plan”

- 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)
- Impact
  run system for extended period and assess benefit of SPPT

→ Note: New setups with larger Δt, Δi, Δj and σ tested as compared to results presented last year.

Verification: COSMO-E for Aug 2012

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

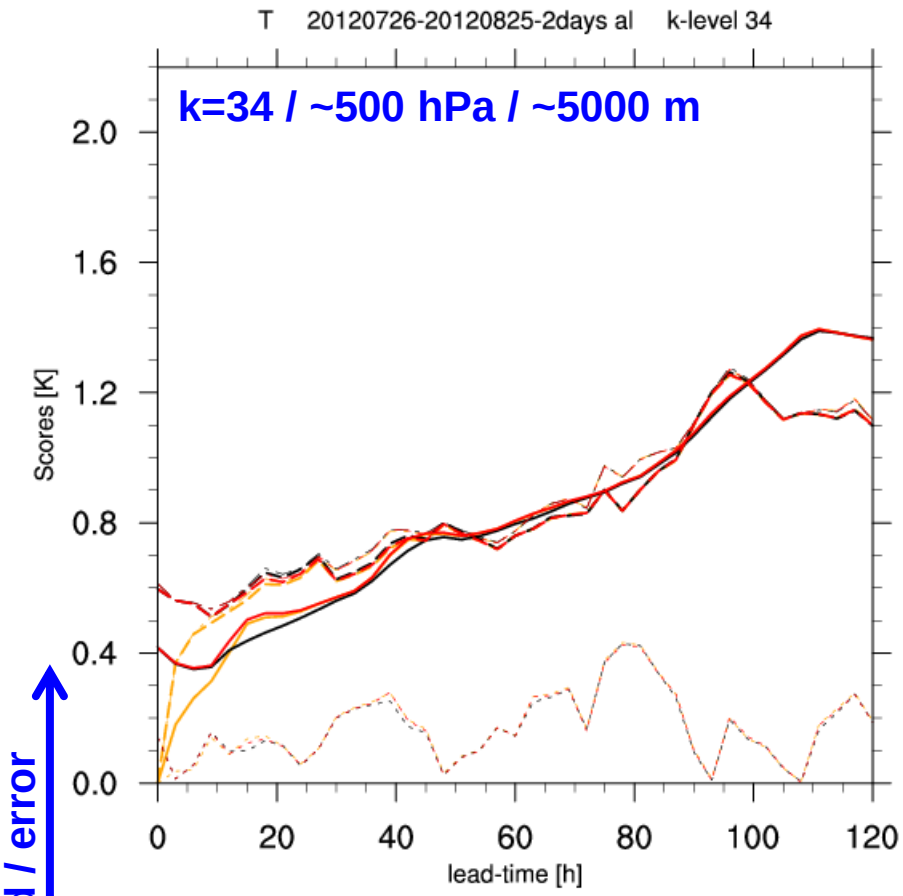
name	*ICs*	*LBCs*	*Δt*	*Δi=Δj*	*σ*	*range*
19e111	**LETKF**	**ENS**	**6h**	**5.0°**	**1.0**	**0.9**
19e110	**LETKF**	**ENS**	**---**	**---**	**---**	**---**
19e011	**COSMO-2**	**ENS**	**6h**	**5.0°**	**1.0**	**0.9**
	COSMO-LEPS (ICs & LBCs: IFS-ENS)					

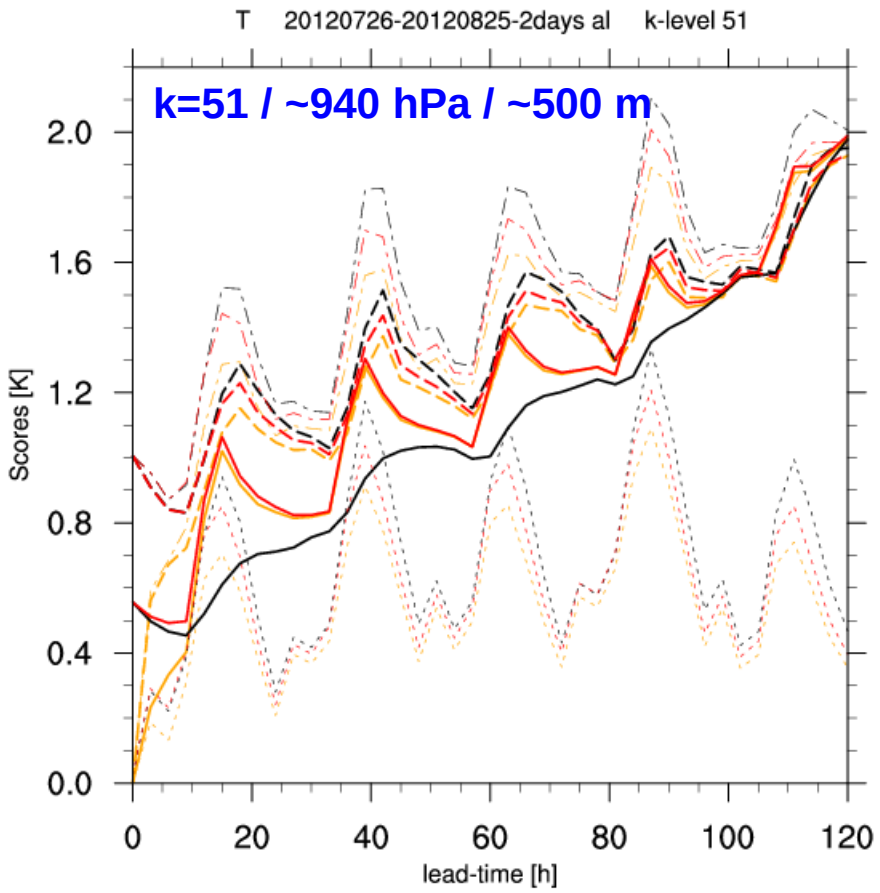
for SPPT: no tapering near the surface, no humidity limiter

→ spread / error relation against COSMO-2 analysis

→ BS and BSS against surface observations

spread / error: temperature





spread / error

lead-time [h]

ICs plus LBCs plus SPPT

ICs plus LBCs

LBCs plus SPPT

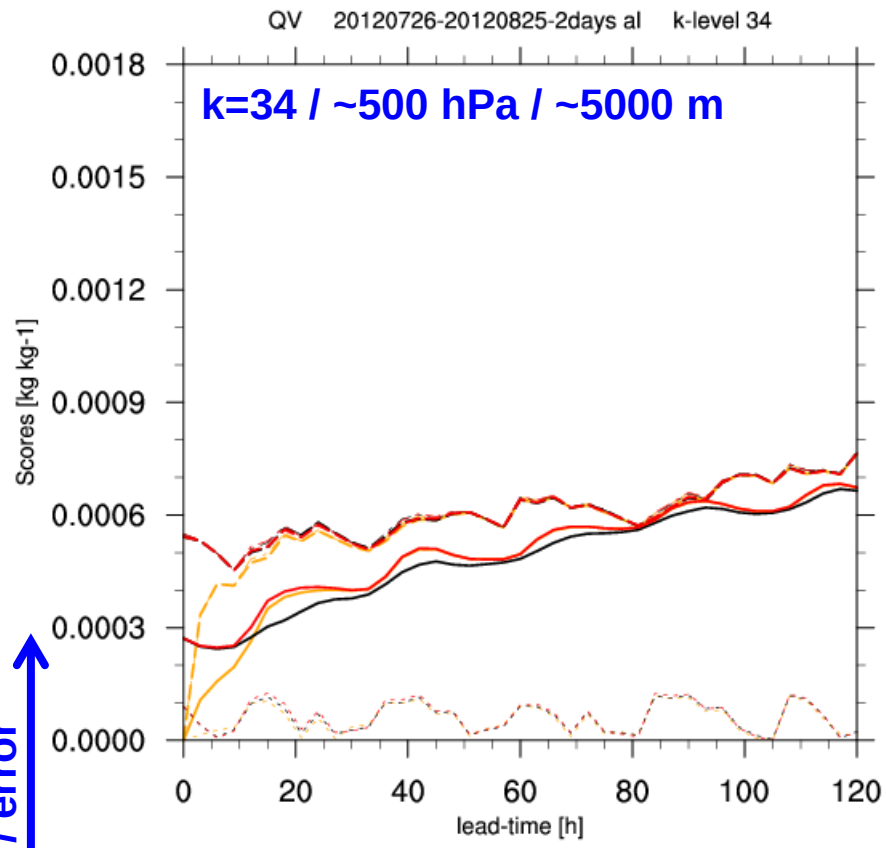
RMEV

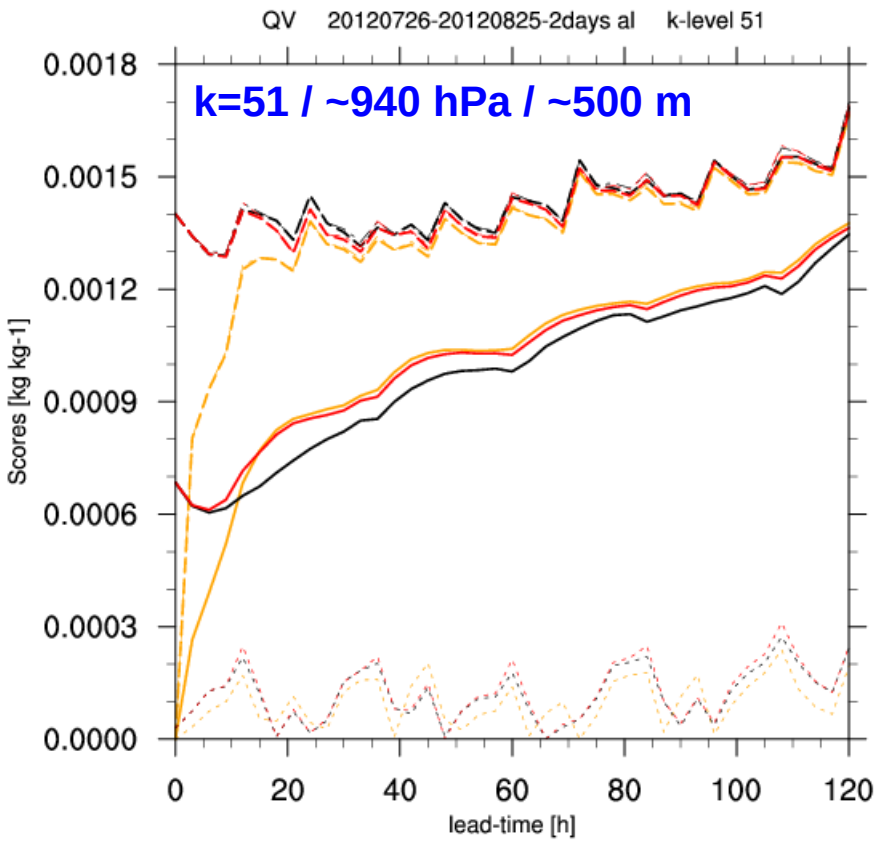
STDE

RMSE

abs(BIAS)

spread / error: humidity





spread / error

lead-time [h]

ICs plus LBCs plus SPPT

ICs plus LBCs

LBCs plus SPPT

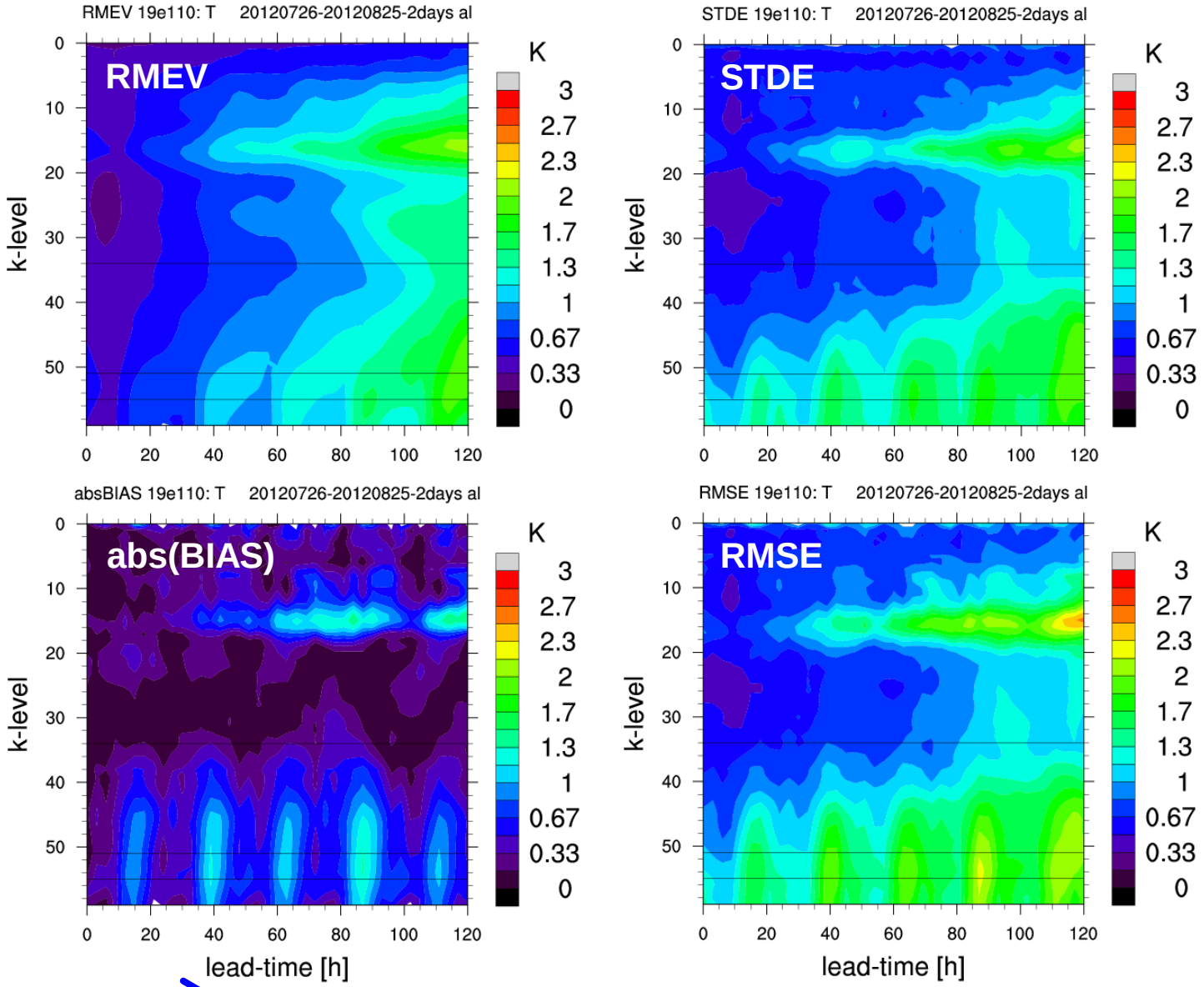
RMEV

STDE

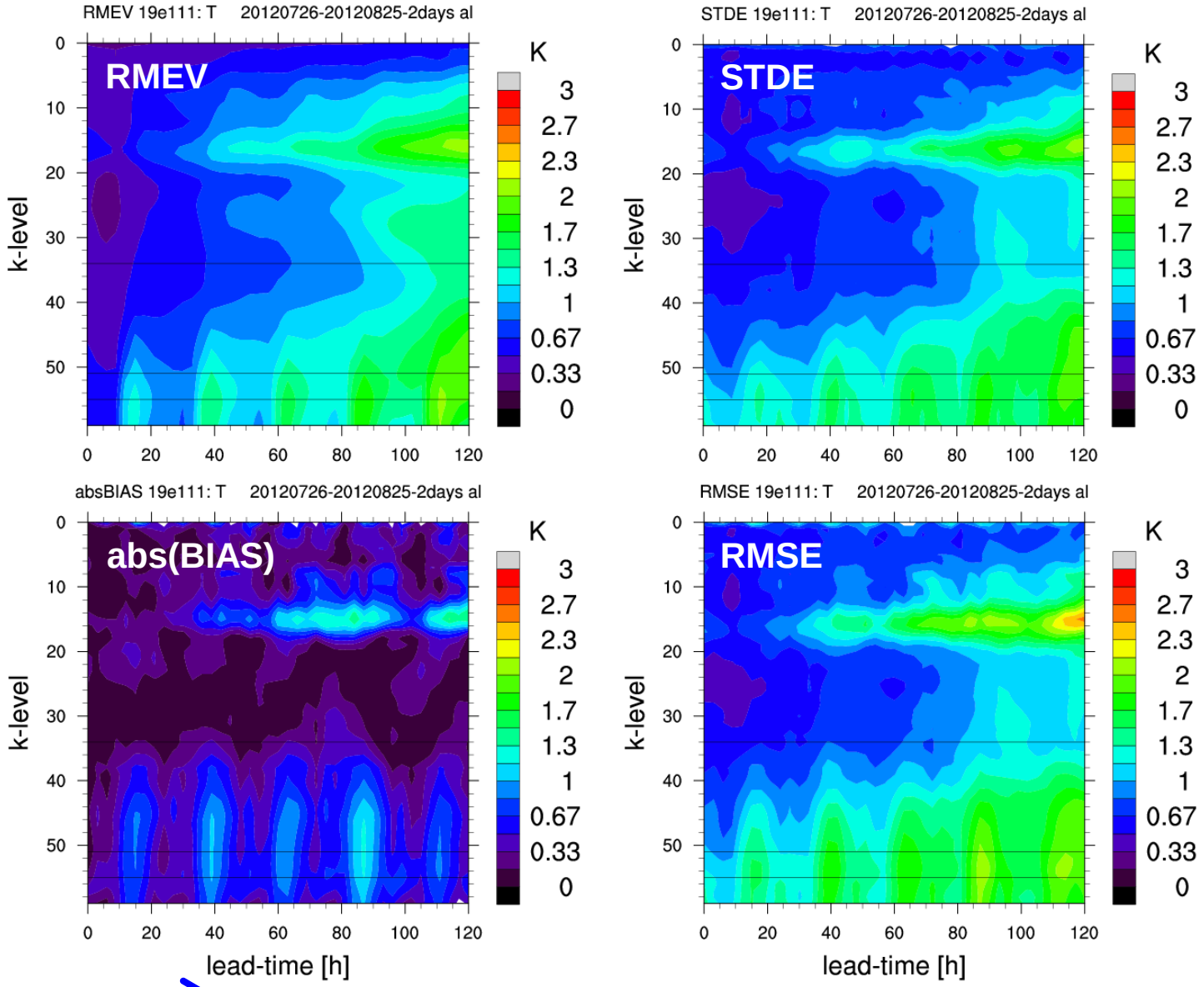
RMSE

abs(BIAS)

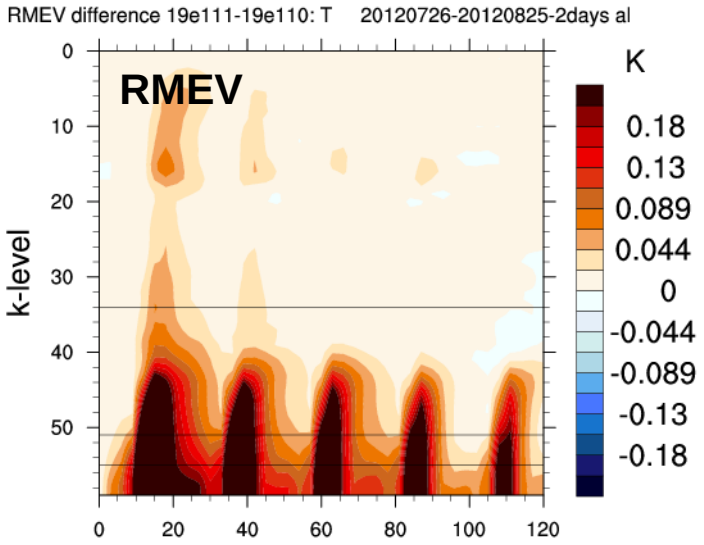
spread / error: temperature, 19e110

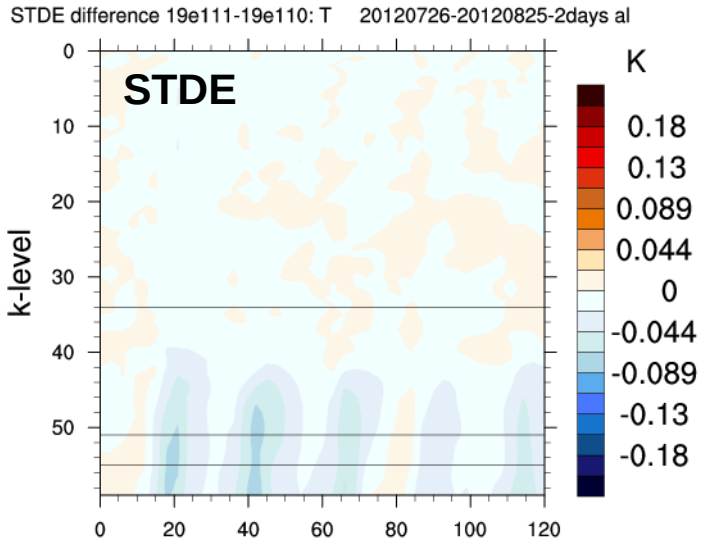


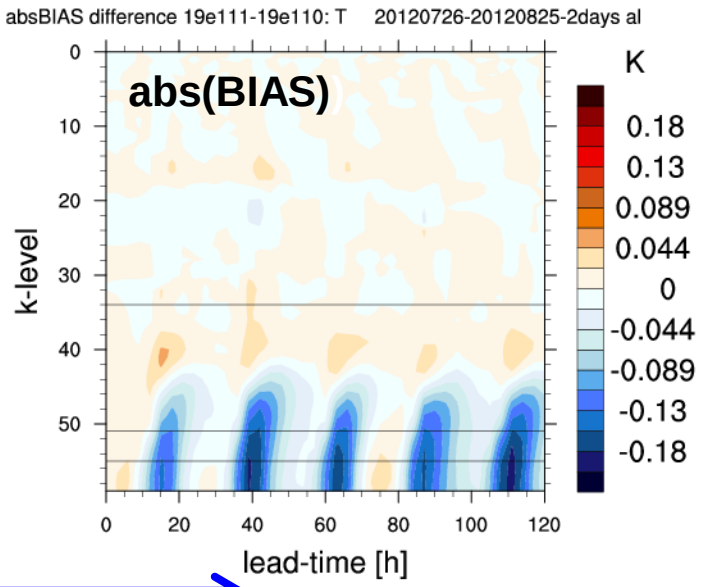
spread / error: temperature, 19e111

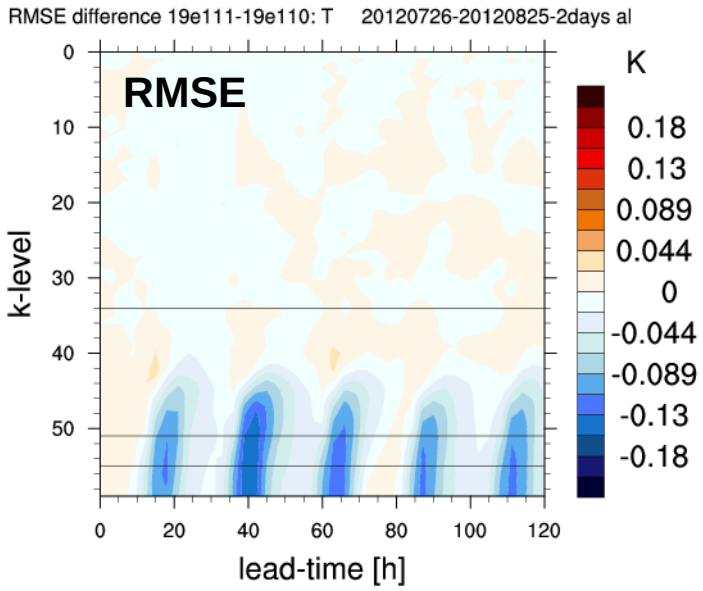


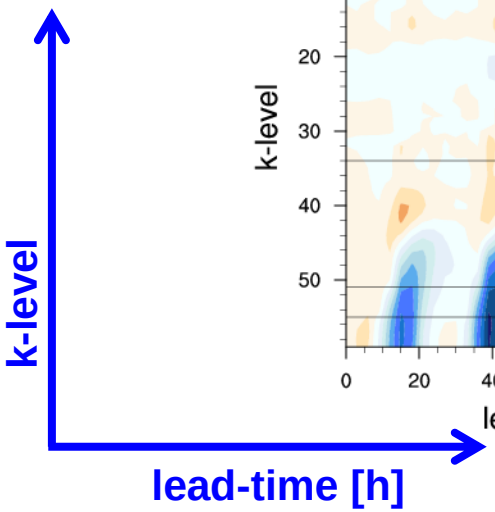
spread / error: T, 19e111-19e110



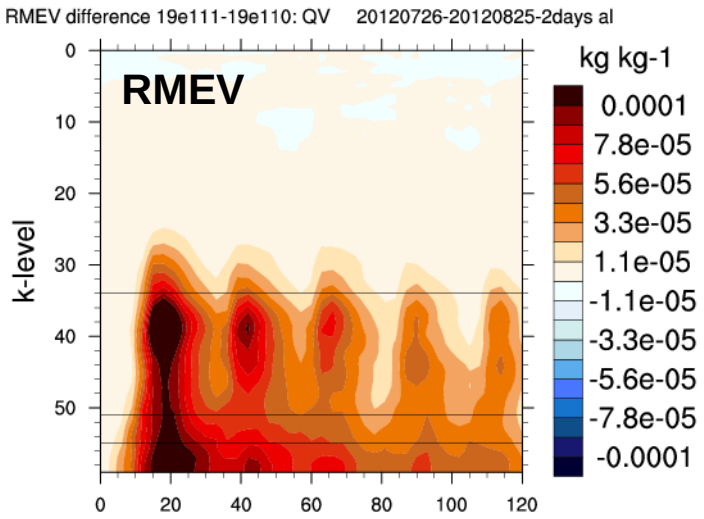


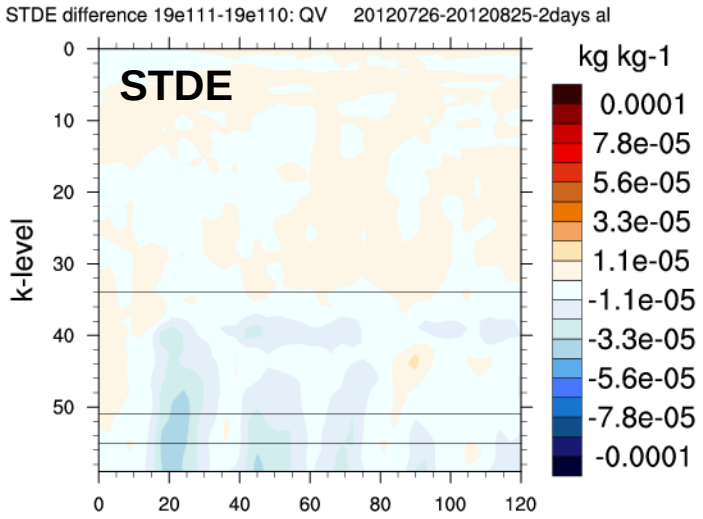


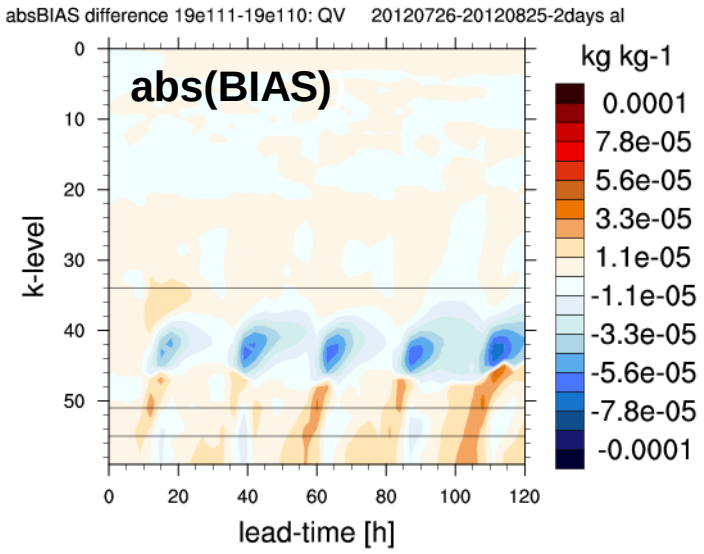


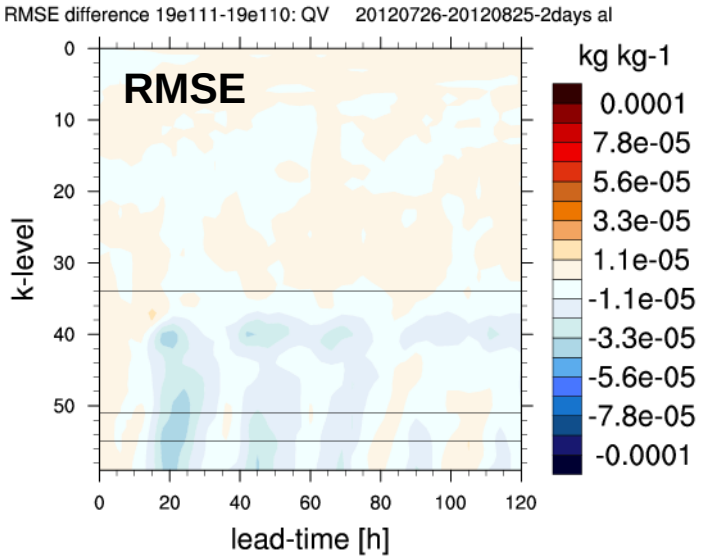


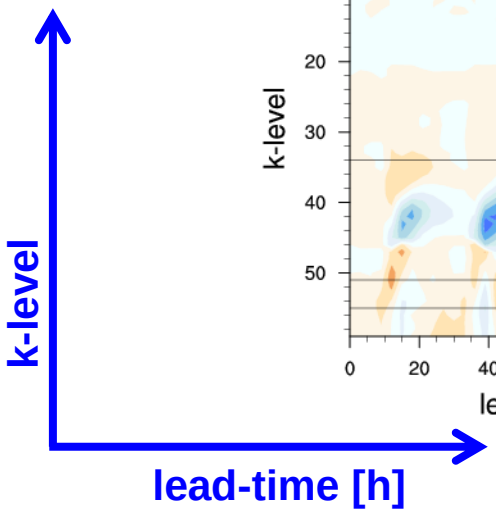
spread / error: QV, 19e111-19e110











Verification: COSMO-E for Dec 2012

- 1 month period **(03.12.-31.12.2012),** one run at 00 UTC every second day **(results in 15 runs per setup)**
- experiments:

name	*ICs*	*LBCs*	*Δt*	*Δi=Δj*	*σ*	*range*
19e011	**COSMO-2**	**ENS**	**6h**	**5.0°**	**1.0**	**0.9**
19e010	**COSMO-2**	**ENS**	**---**	**---**	**---**	**---**
	COSMO-LEPS (ICs & LBCs: IFS-ENS)					

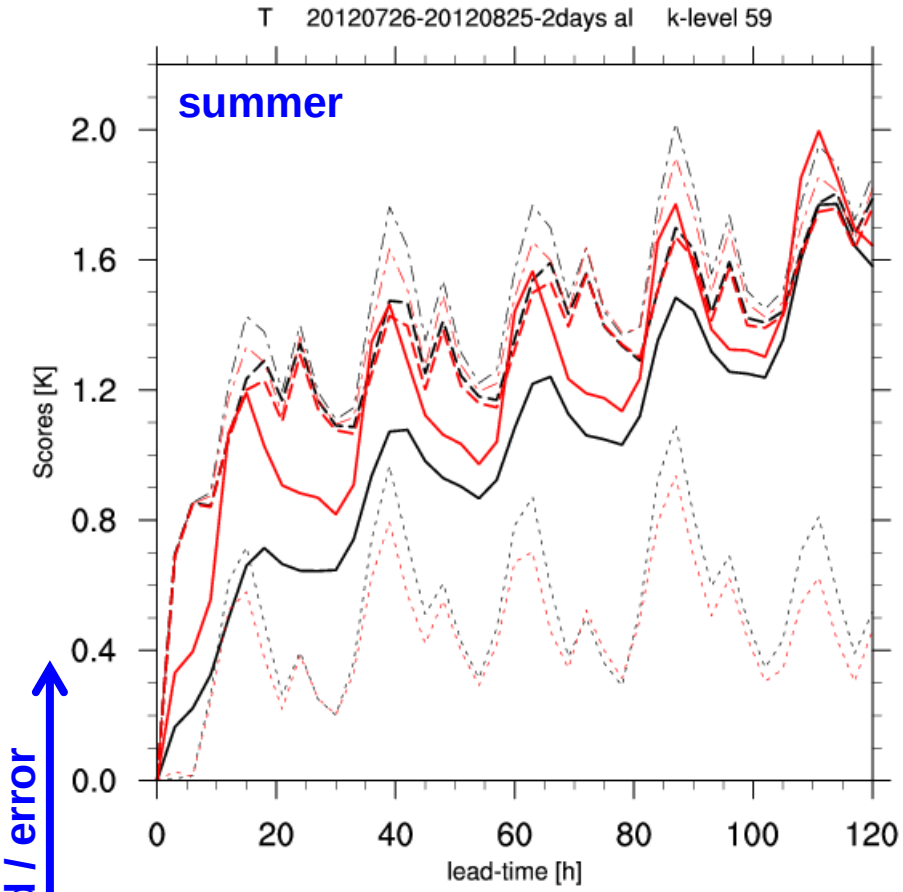
for SPPT: no tapering near the surface, no humidity limiter

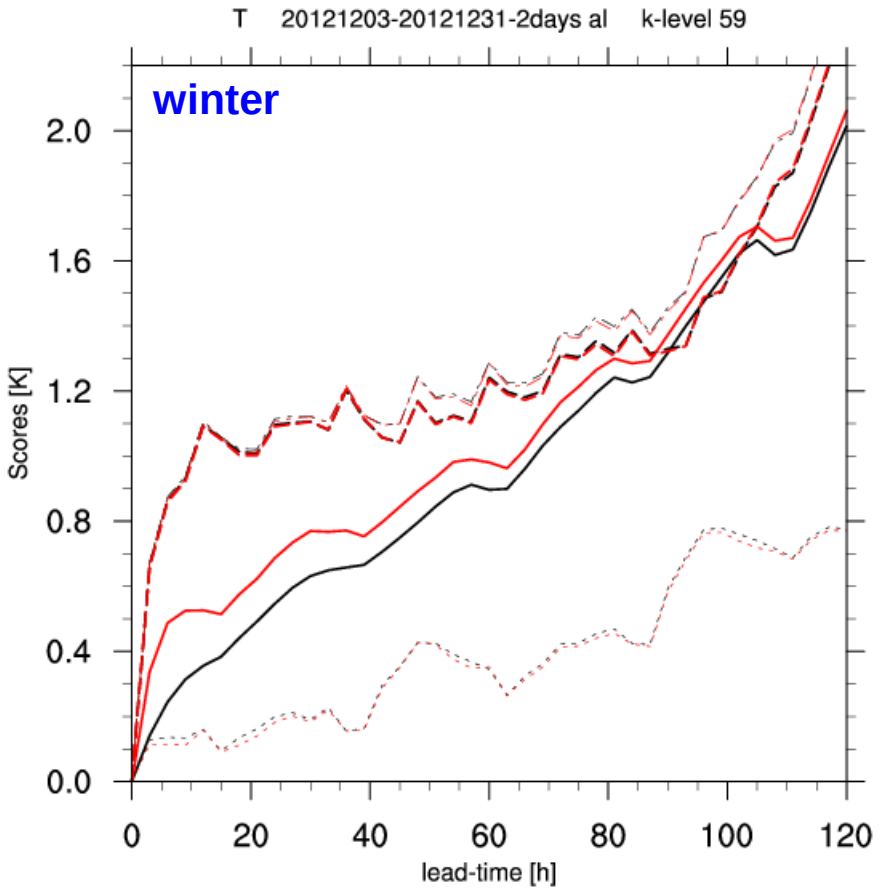
→ spread / error relation against COSMO-2 analysis

→ BS and BSS against surface observations

spread / error: temperature

k=59 / ~10 m





spread / error

lead-time [h]

LBCs plus SPPT

LBCs

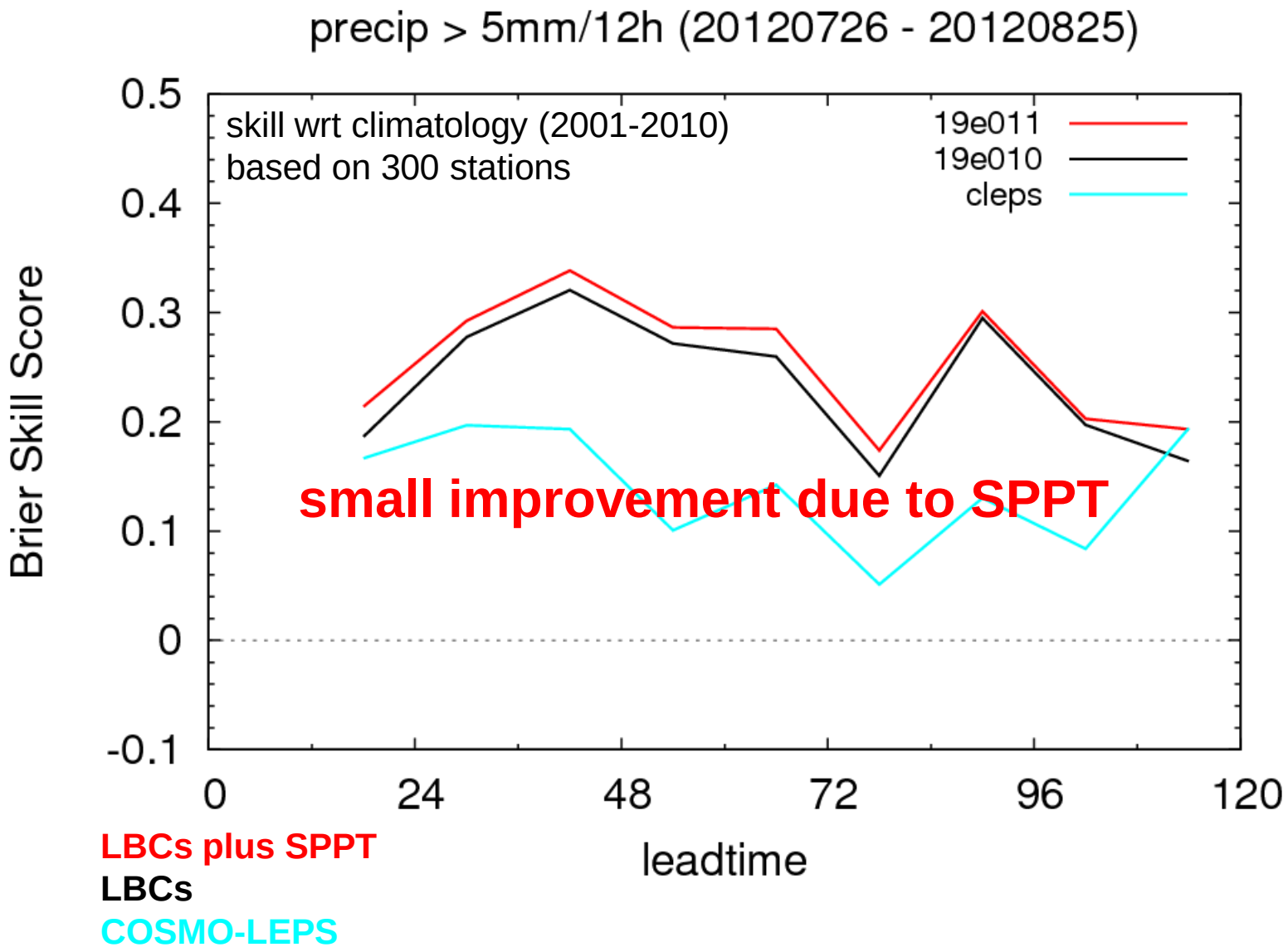
RMEV

STDE

RMSE

abs(BIAS)

Verification against observations:
BSS: precip, > 5mm/12h, Aug



LBCs plus SPPT

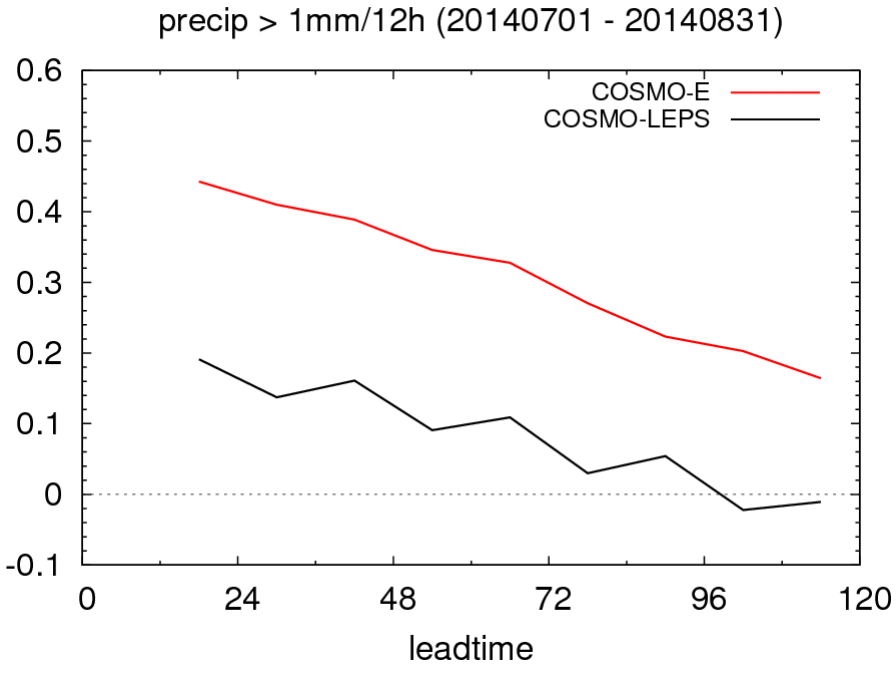
LBCs

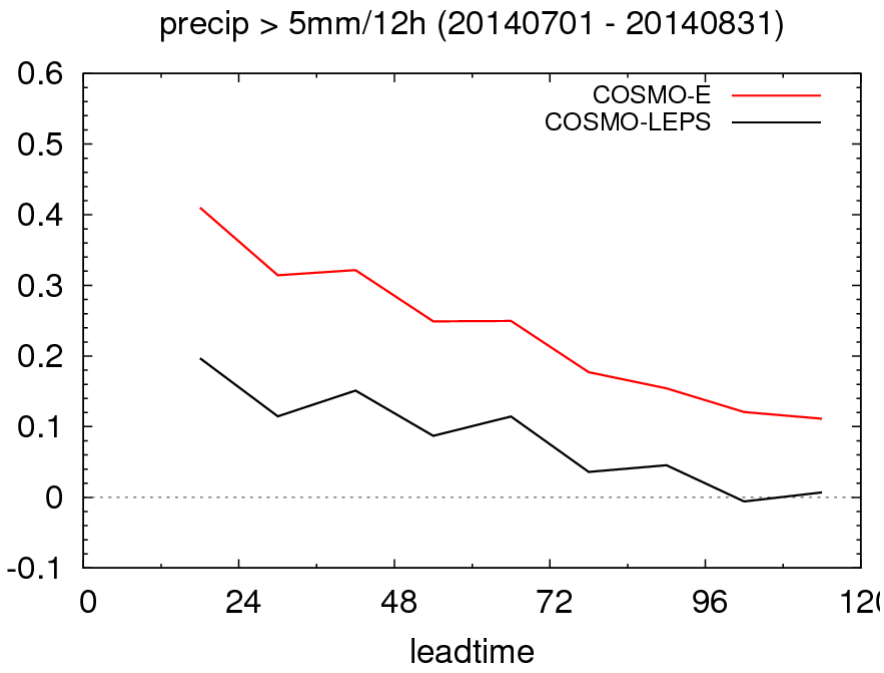
COSMO-LEPS

COSMO-E regular runs: BSS

skill wrt climatology (2001-2010) based on 300 stations

COSMO-E
COSMO-LEPS





- COSMO-E shows significant skill until end of forecast range
- clearly better than COSMO-LEPS, even though 9 grid-point averages used for both

Verification: conclusions

- **middle and upper troposphere:** spread dominated by LBC perturbations, **generally satisfactory** spread-error relation
- **lower troposphere: considerable improvement of RMEV**, STDE, and BIAS **due to SPPT**, **impact larger in summer**, but still lacking spread, in particular for humidity
- **SYNOP verification: small improvements** in probabilistic scores for precipitation and 2m temperature **due to SPPT**
- **Turbulence scheme** shows largest physics tendencies and hence contributes strongest to SPPT impact

Outlook

- Improve ICs and IC perturbations (KENDA/LETKF)

- Test **“additional” perturbations at/in the surface** consistent with LETKF (e.g., soil moisture, based on COTEKINO results)
- Look into **Stochastic Pattern Generator** (Michail, Dmitriy) and **empirical model error model** (Ekaterina)
- Test **stochastic boundary layer parameterization scheme** (Kirstin Kober, LMU)?
- Start of **PhD on improved spread / error relation** for COSMO-E in Oct 2014 (Prof Heini Wernli, IACETH)

extra slides …

Sensitivity: results

- larger correlation-lengths in space and time lead to (substantially!) larger spread
- larger random numbers produce larger spread and faster spread growth
- spread decreases with increasing height above surface
  - turning tapering off has significant (positive) impact on spread in PBL

Validation: deterministic runs

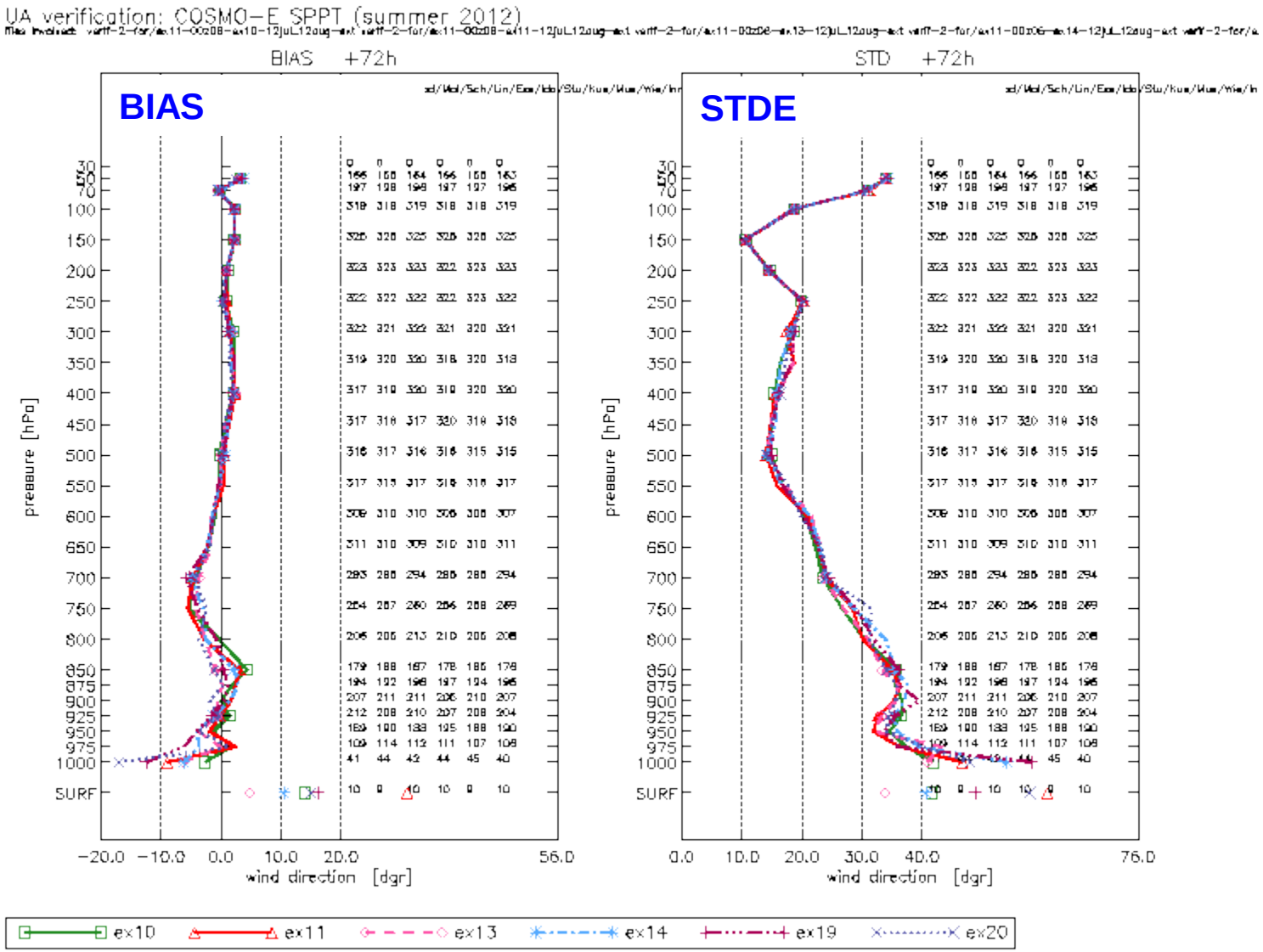
- SPPT **must not** degrade (deterministic) quality of ensemble members
- **deterministic runs (1 month each in summer and winter 2012)** for different SPPT parameter settings

➢ no significant quality degradation observed with SPPT, even for very strong stochastic perturbations of physical tendencies

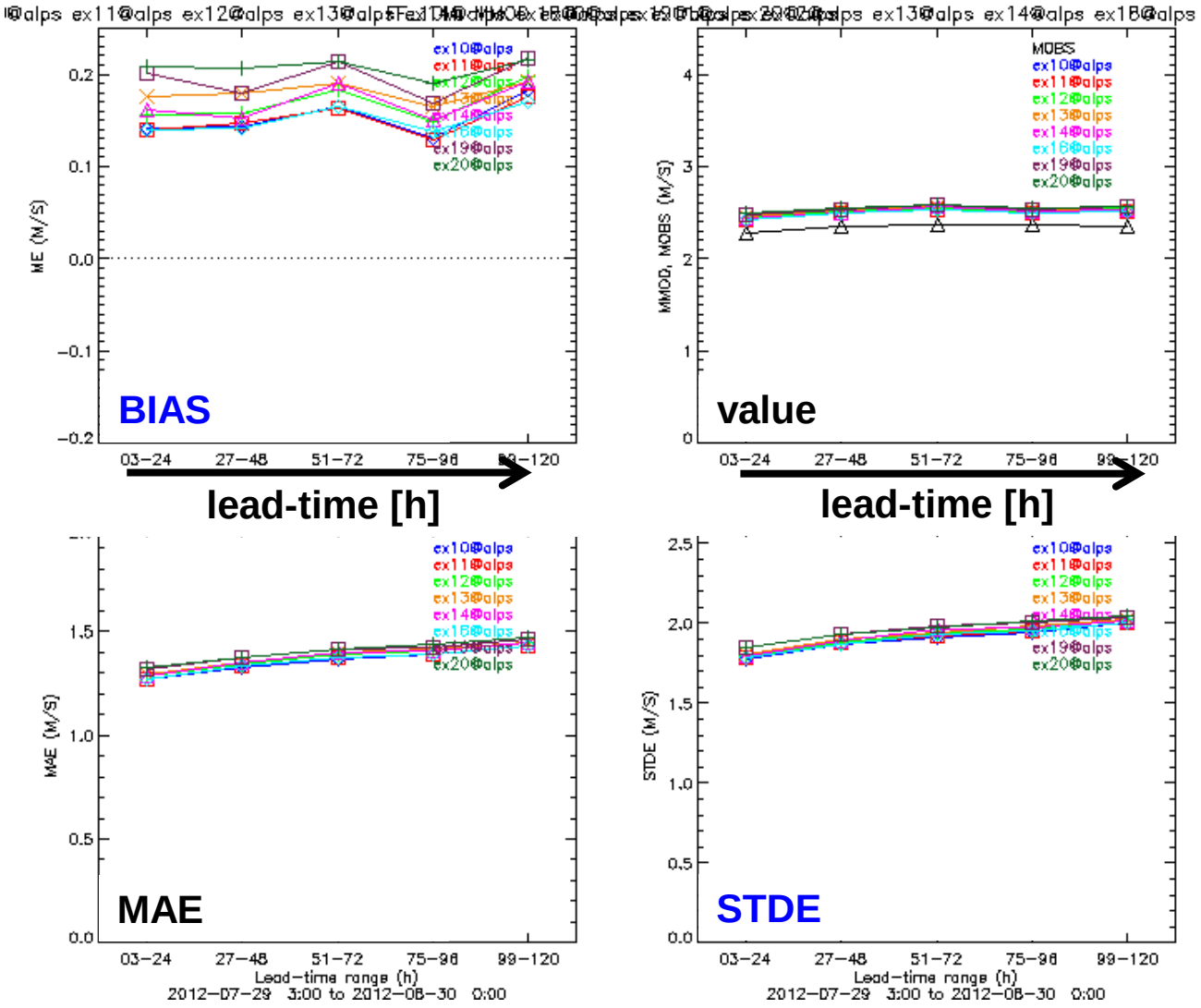
➢ choose (aggressive) SPPT parameter settings “19” for subsequent tests

name	Δt	$\Delta i=\Delta j$	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

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



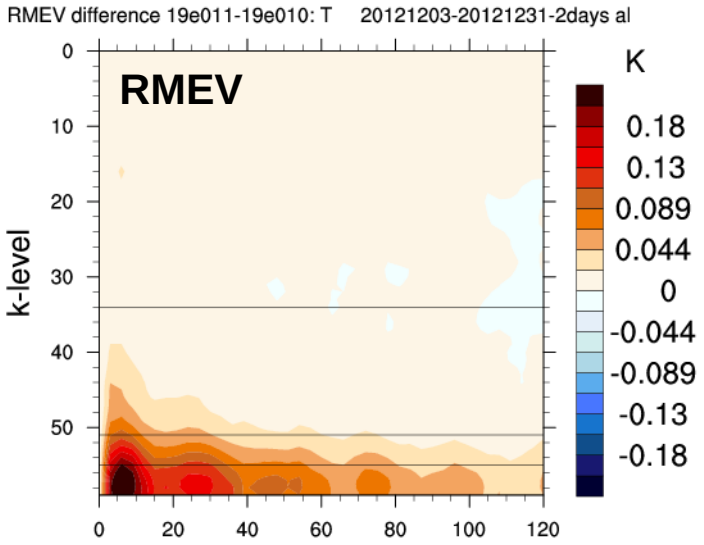
Surface: wind speed
all stations, 26.07-25.08.2012

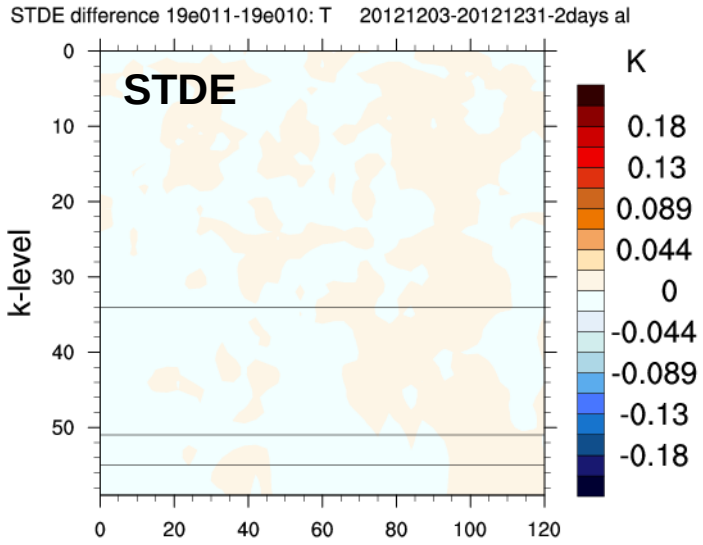


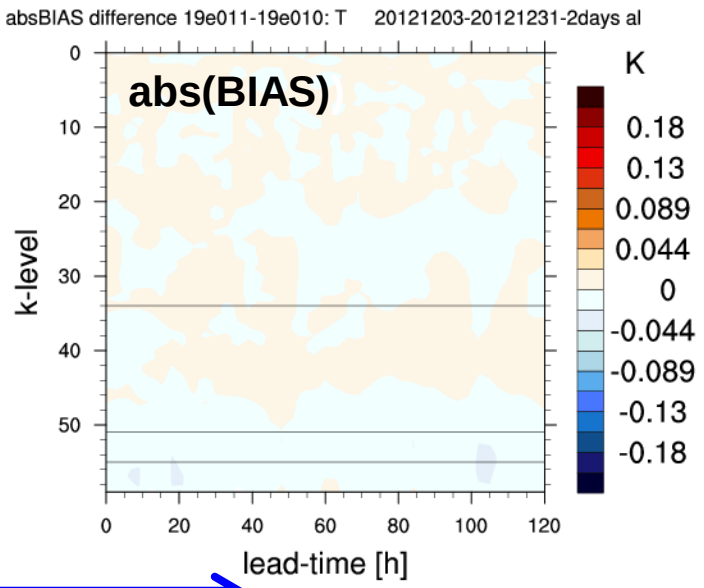
Validation: results

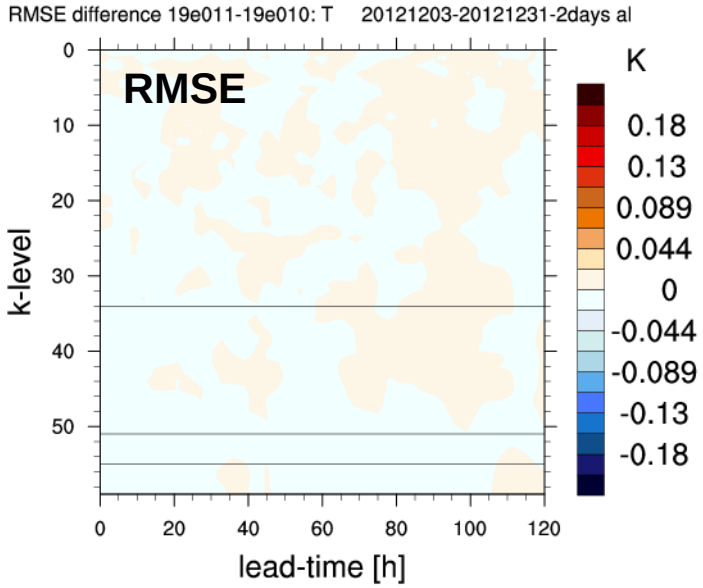
- **generally (very) small differences between different tested SPPT parameter settings**
- larger differences found for summer
- no differences seen for humidity; no drying observed!
- no significant quality degradation observed with SPPT, even for very strong stochastic perturbations of physical tendencies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

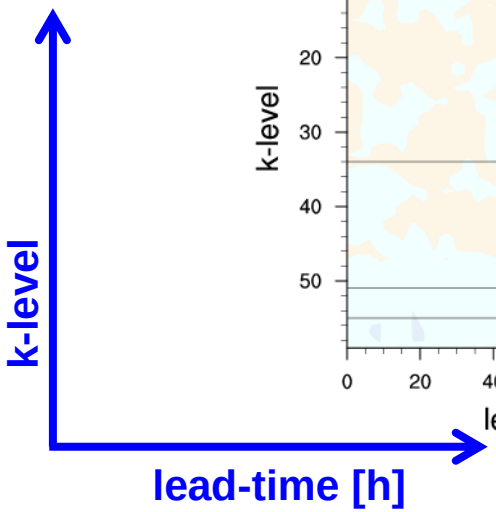
spread / error: T, 19e011-19e010



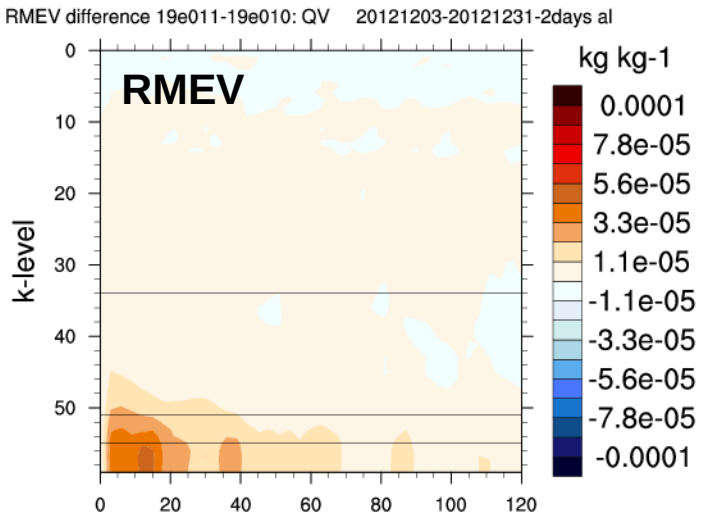


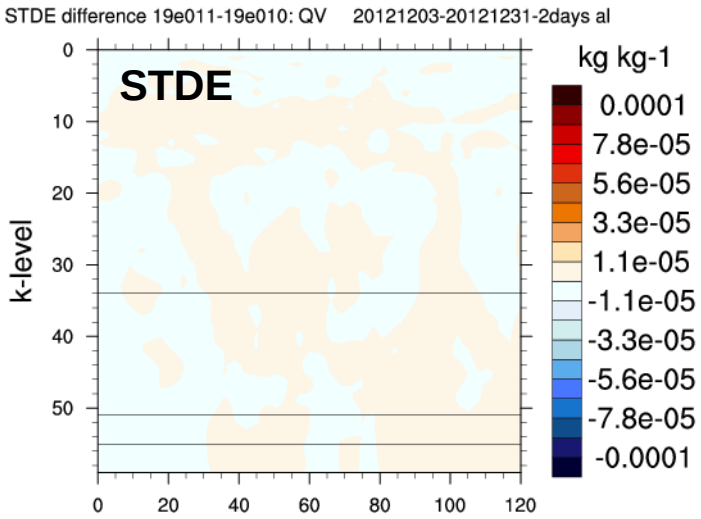


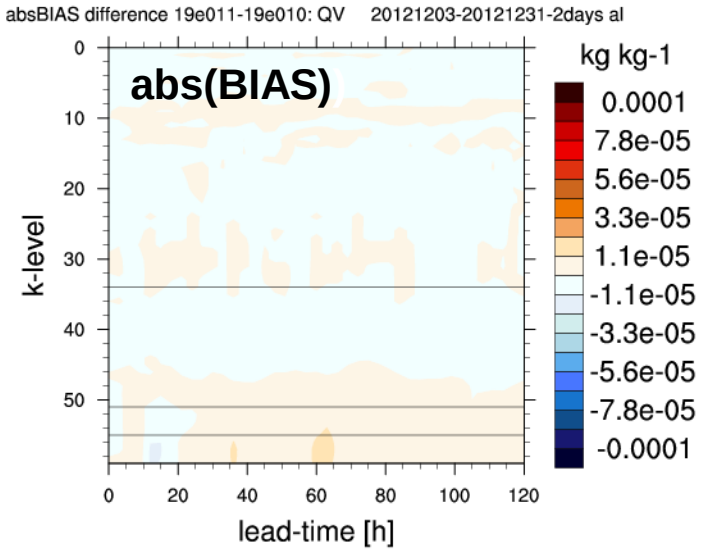


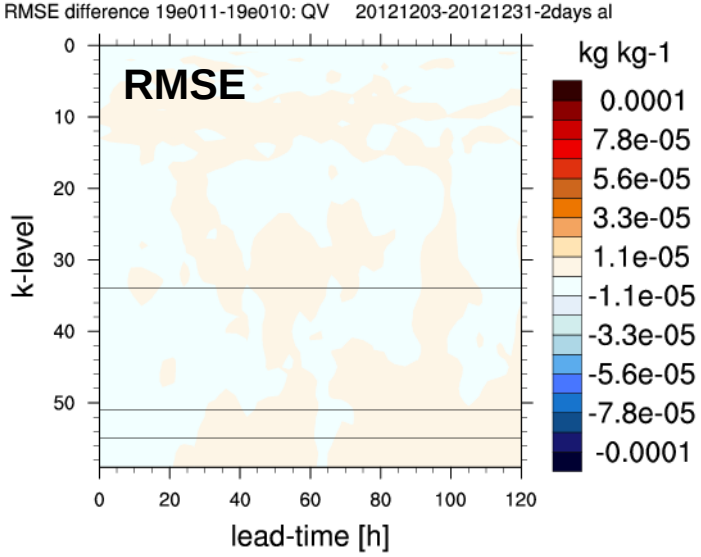


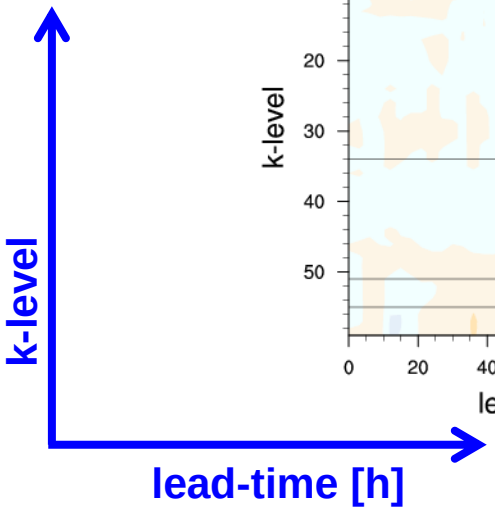
spread / error: QV, 19e011-19e010



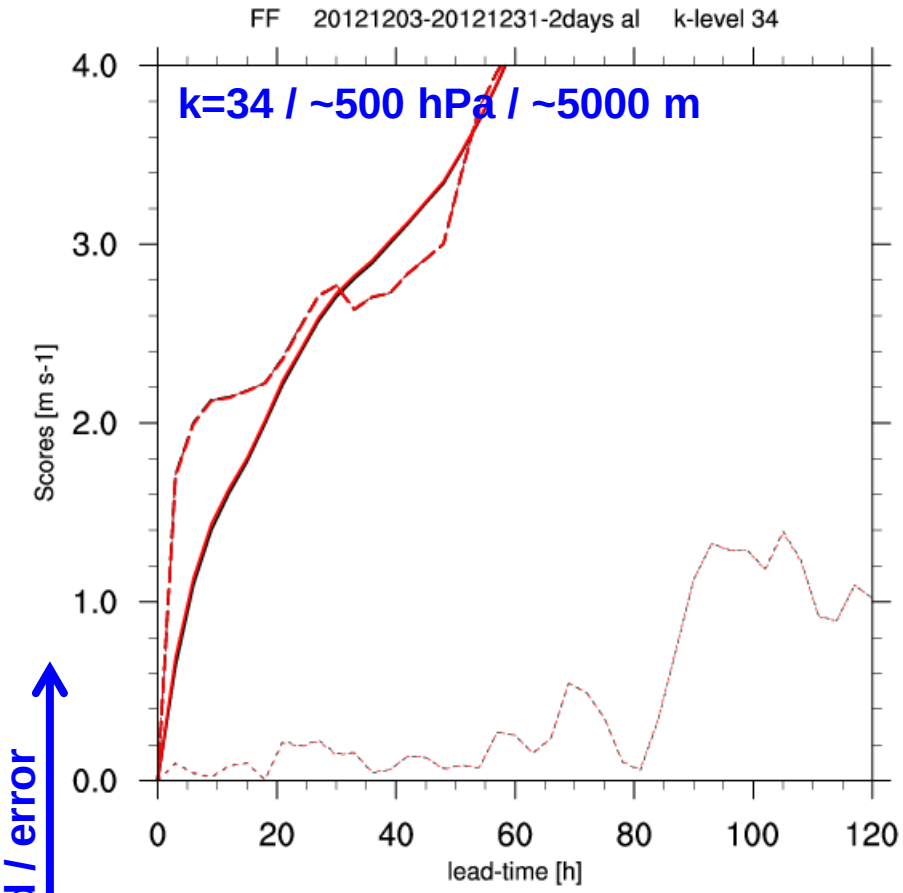


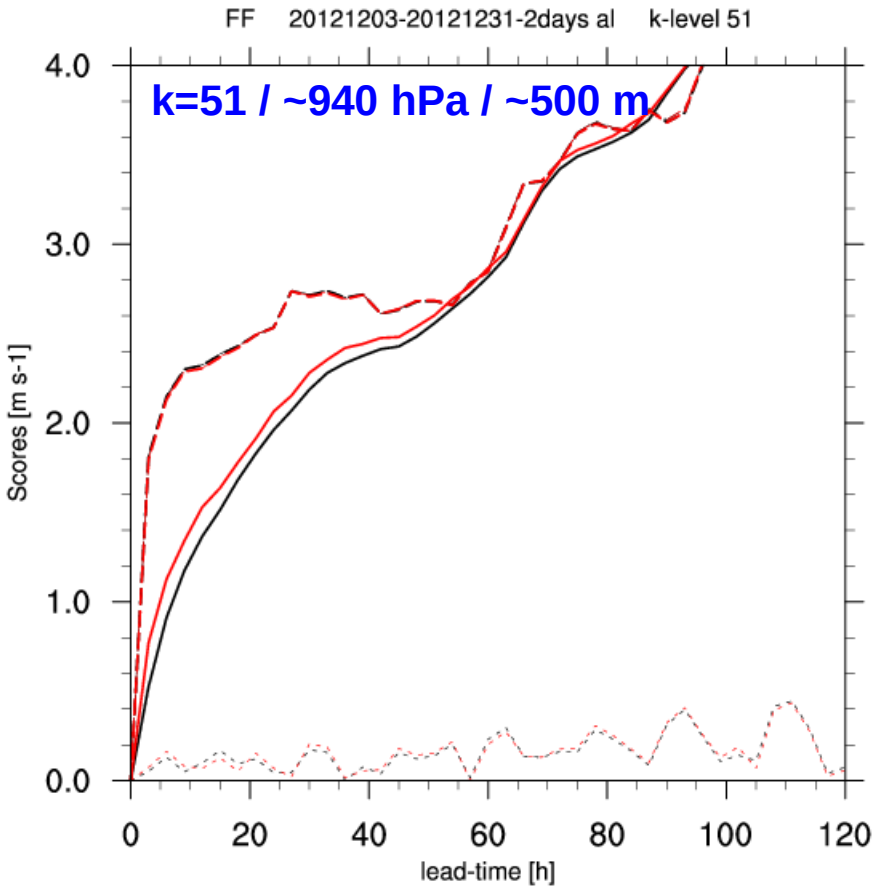






spread / error: wind speed





spread / error

lead-time [h]

LBCs plus SPPT

LBCs

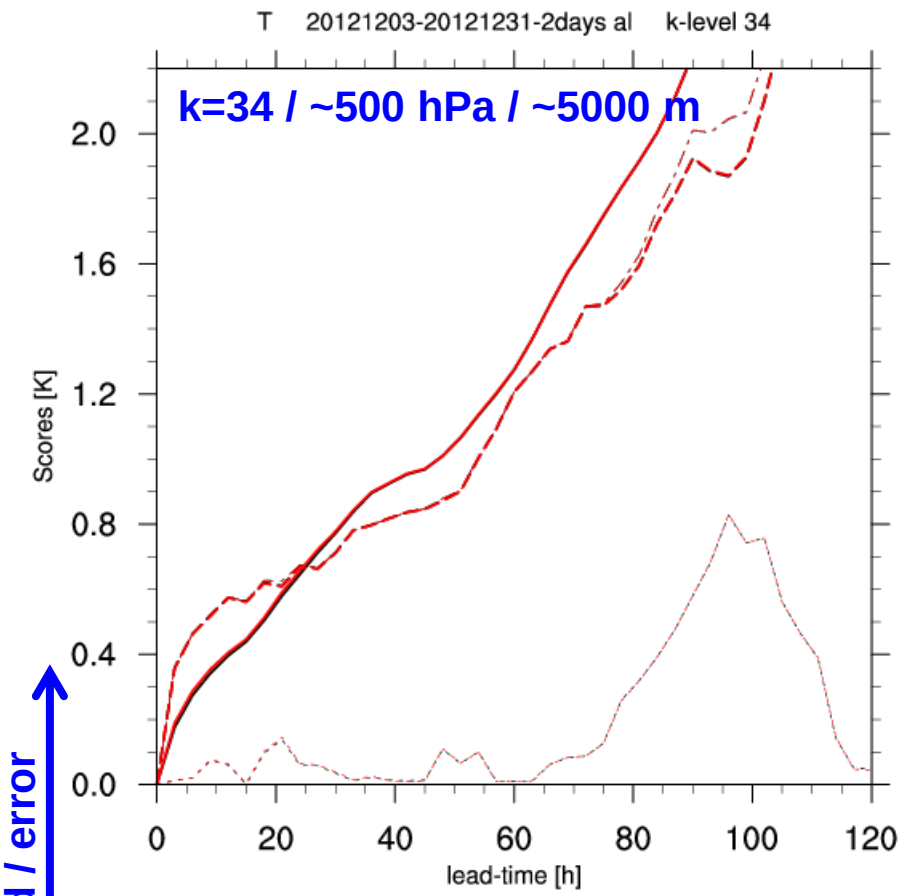
RMEV

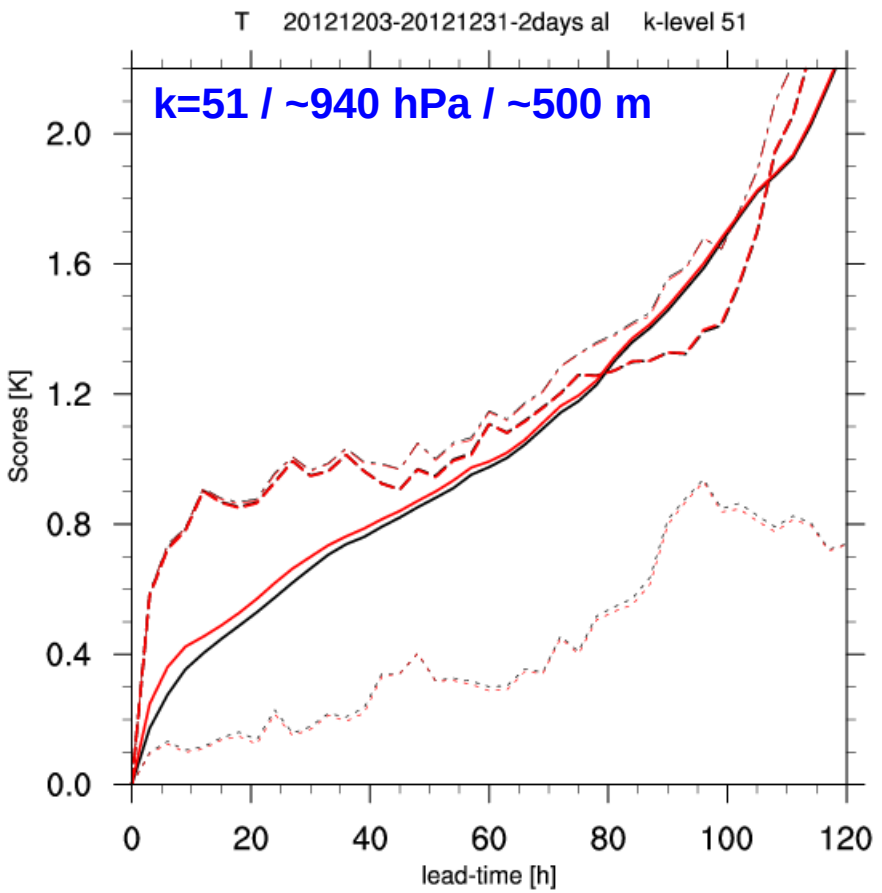
STDE

RMSE

abs(BIAS)

spread / error: temperature





spread / error

lead-time [h]

LBCs plus SPPT

LBCs

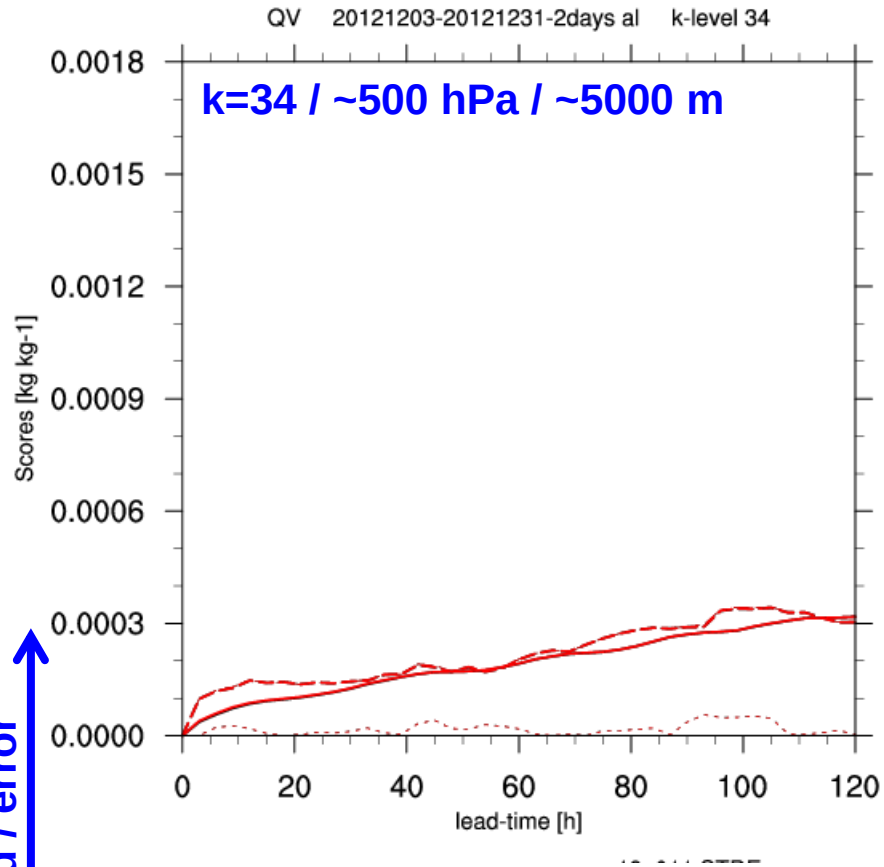
RMEV

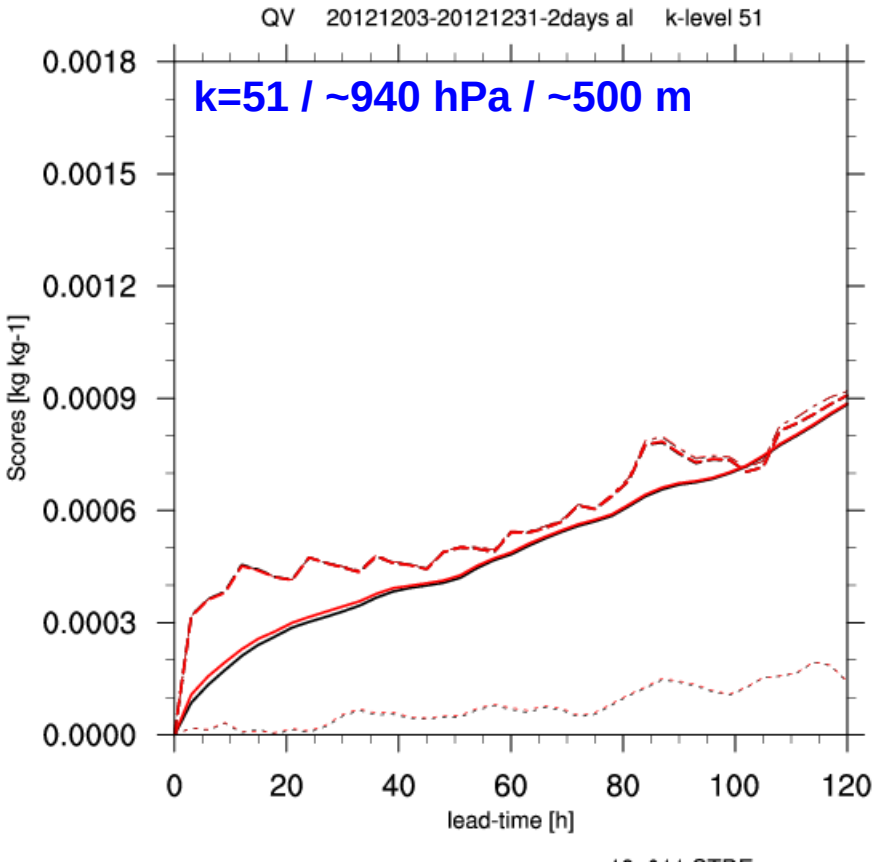
STDE

RMSE

abs(BIAS)

spread / error: humidity





spread / error

lead-time [h]

LBCs plus SPPT

LBCs

RMEV

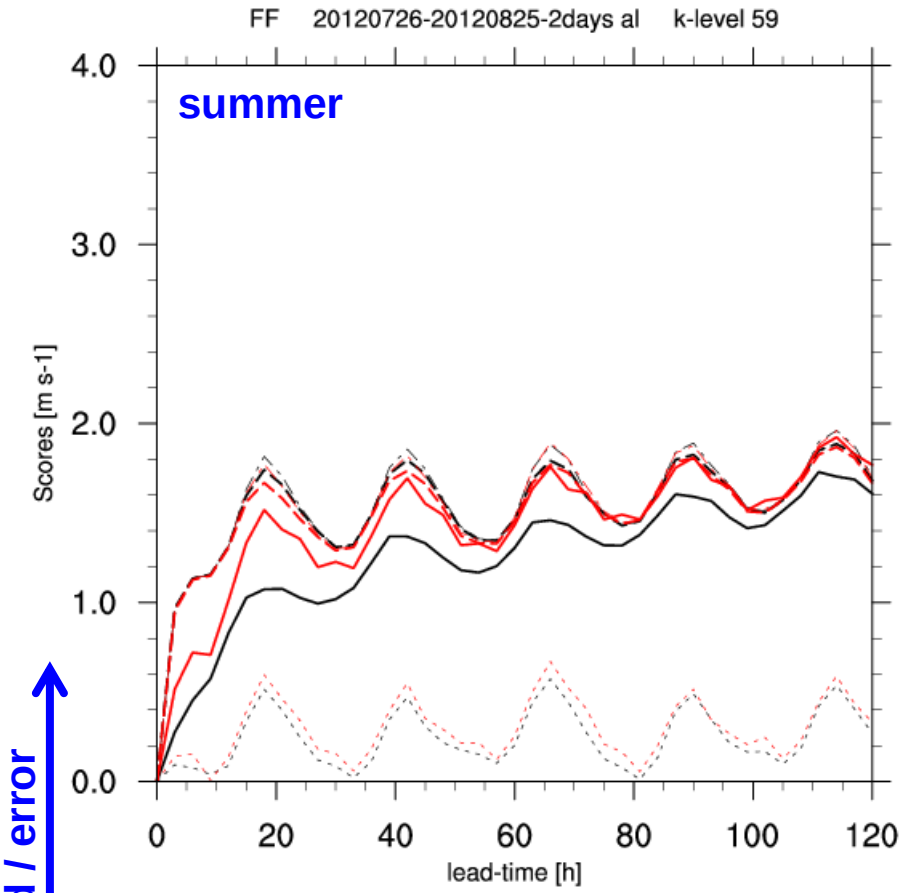
STDE

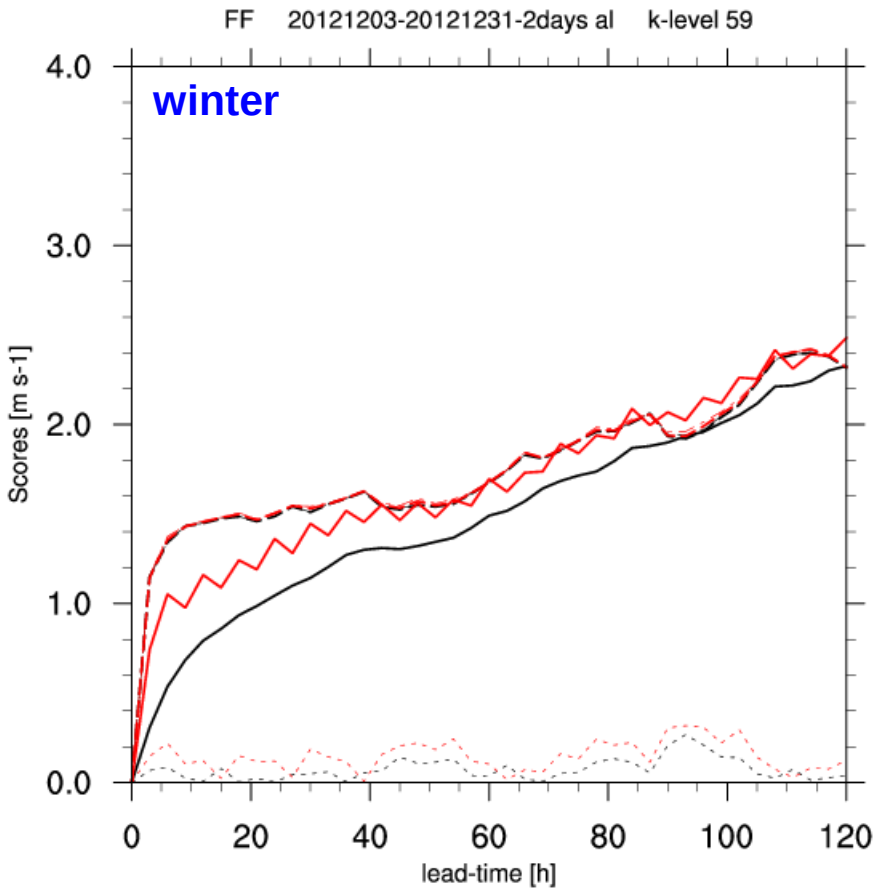
RMSE

abs(BIAS)

spread / error: wind speed

k=59 / ~10 m





LBCs plus SPPT

LBCs

RMEV

STDE

RMSE

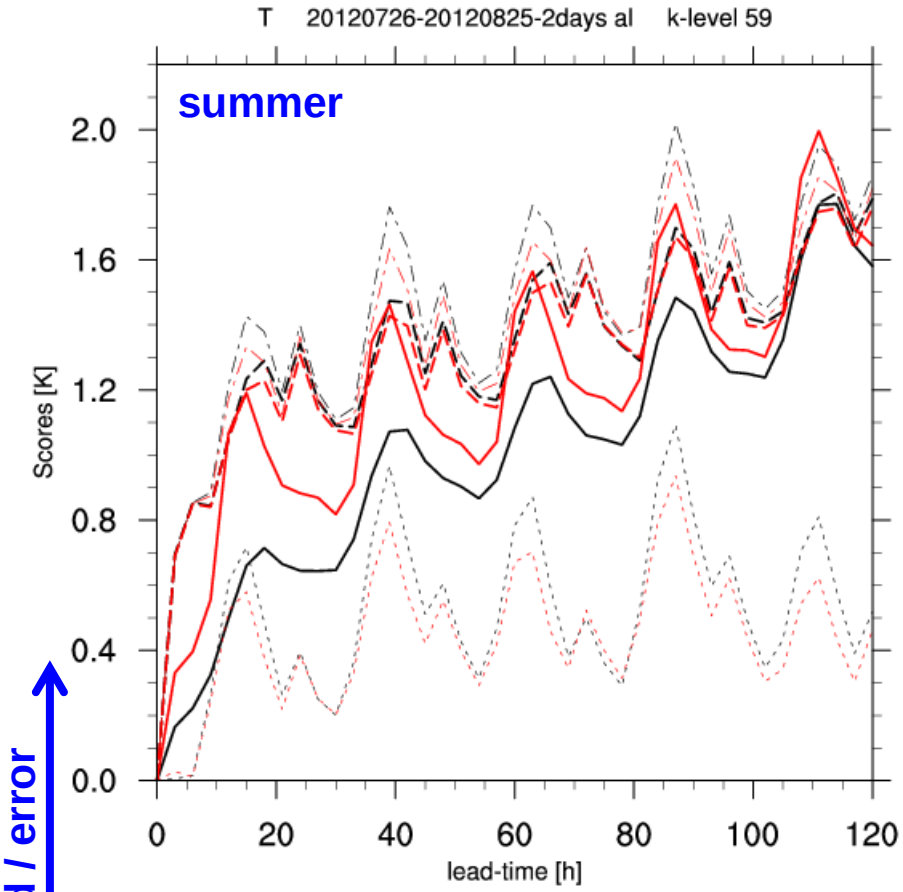
abs(BIAS)

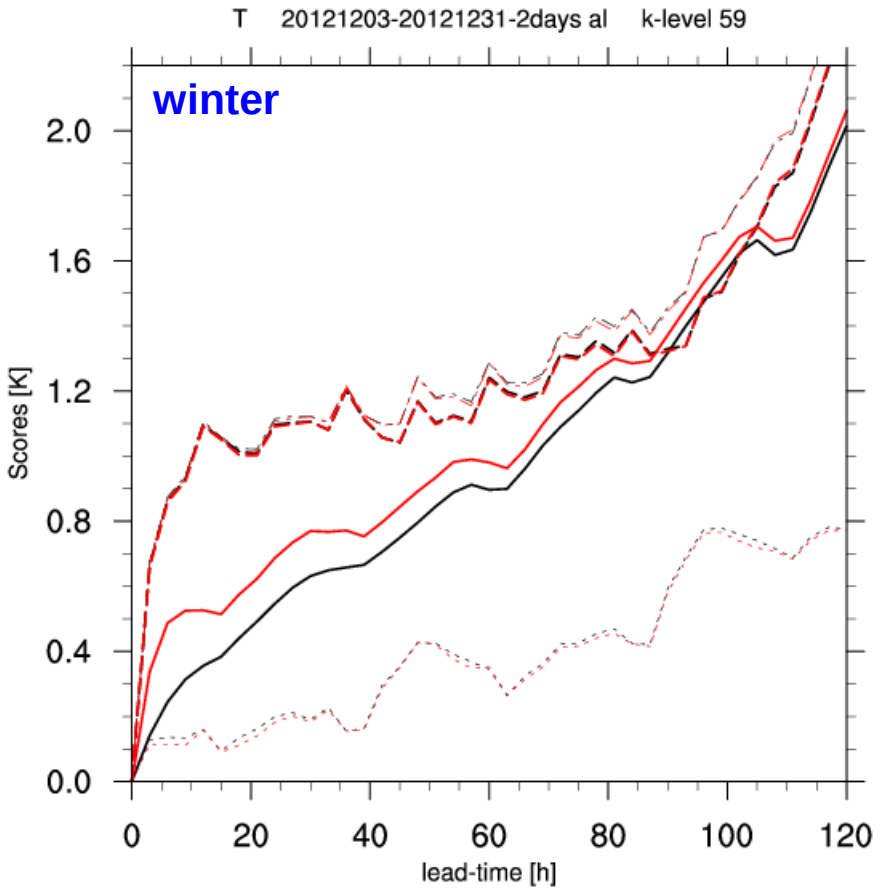
spread / error

lead-time [h]

spread / error: temperature

k=59 / ~10 m





spread / error

lead-time [h]

LBCs plus SPPT

LBCs

RMEV

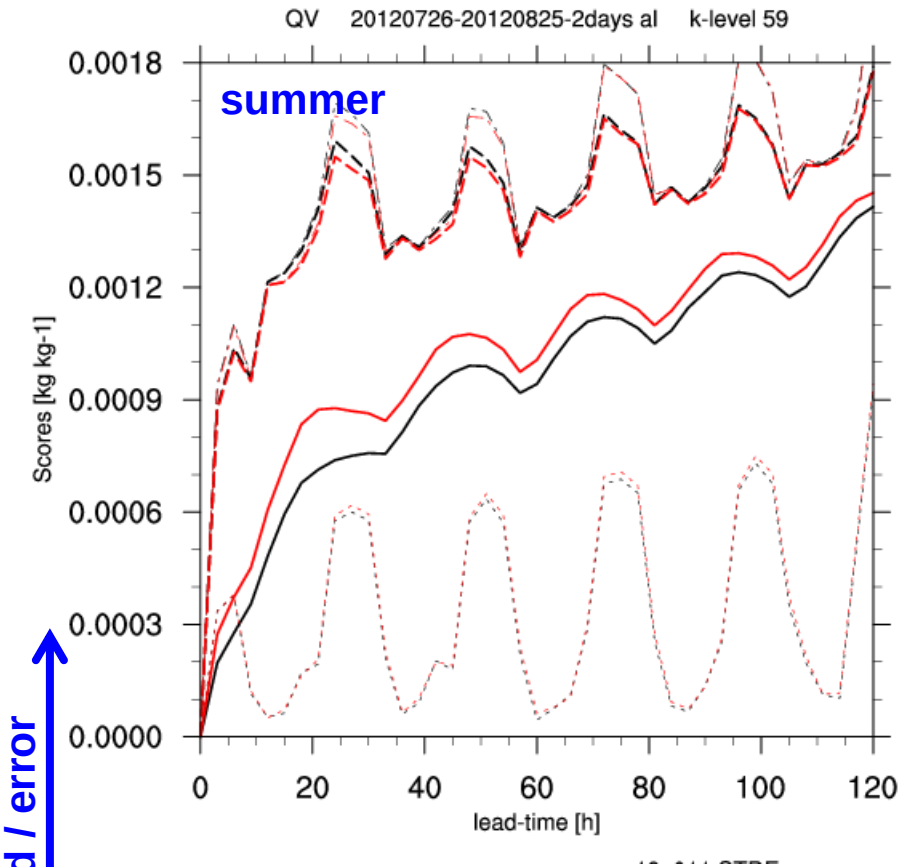
STDE

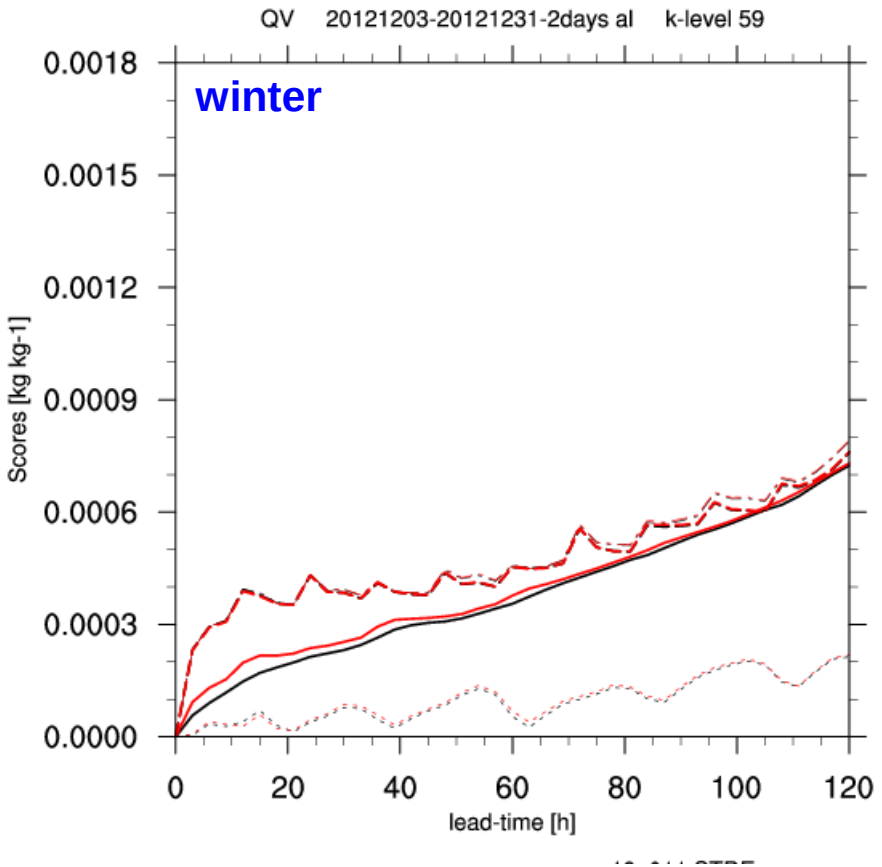
RMSE

abs(BIAS)

spread / error: humidity

k=59 / ~10 m





spread / error

lead-time [h]

LBCs plus SPPT

LBCs

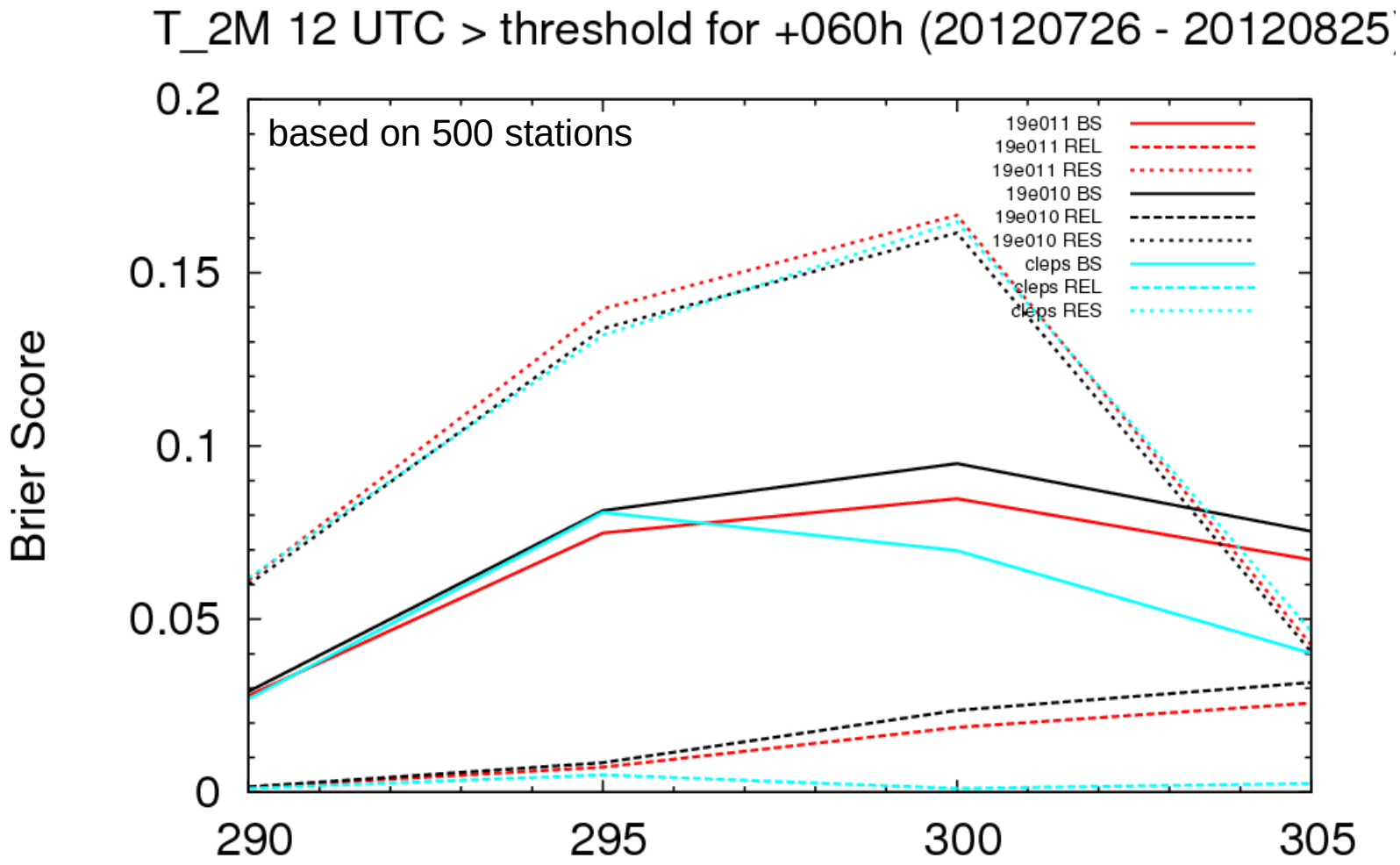
RMEV

STDE

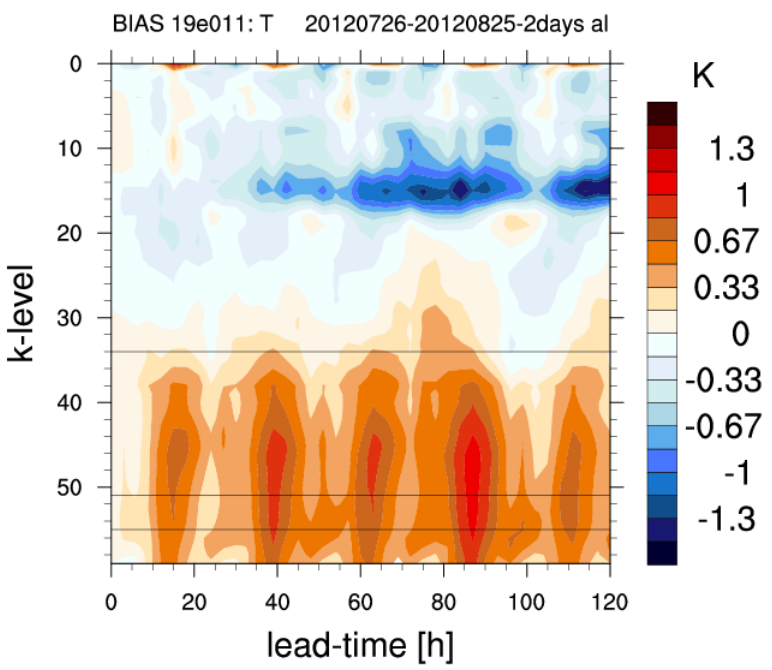
RMSE

abs(BIAS)

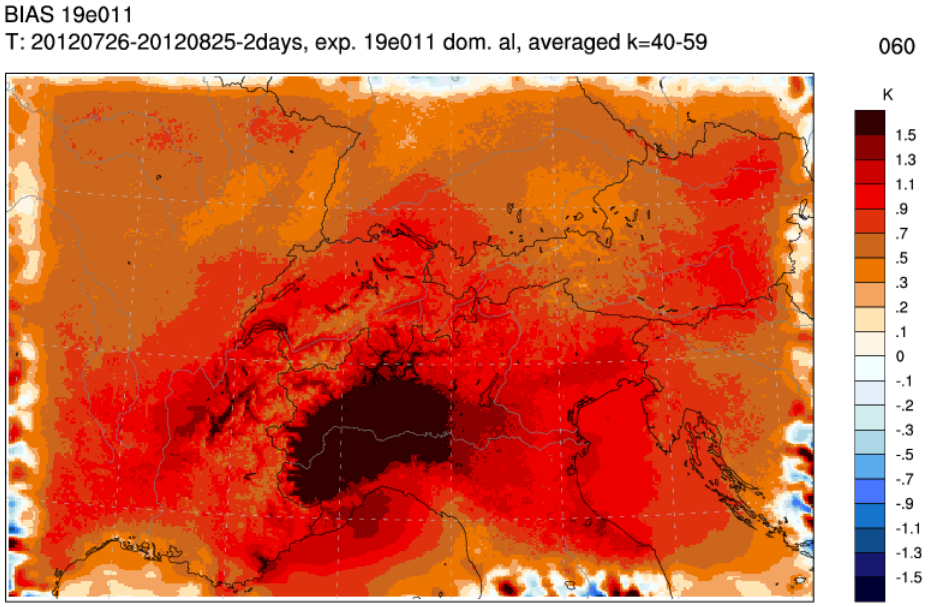
Brier Score: T2m, 12 UTC, +60h, Aug



warm BIAS in summer …



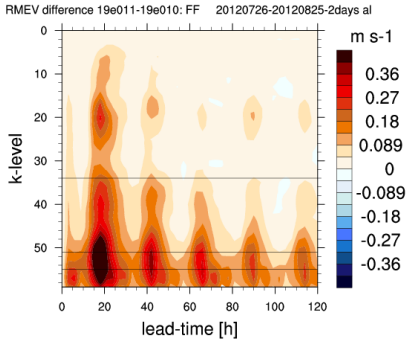
domain average as a function of height and lead-time



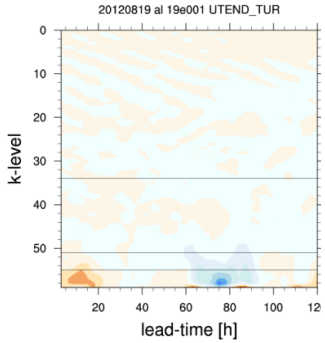
average of k-levels 40-59 for lead-time +60h as a function of lat/lon

Tendencies: vertical, wind speed

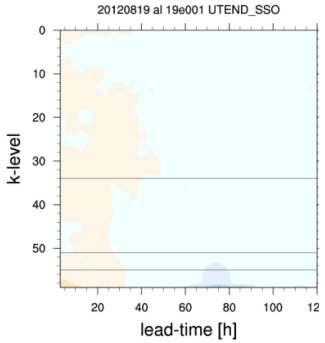
RMEV Diff, Aug 2012



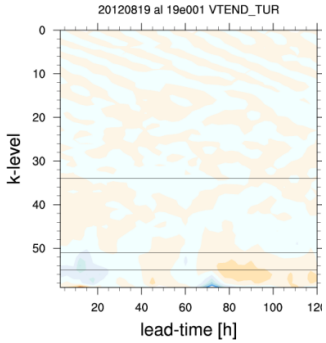
tendencies for 19.08.2012



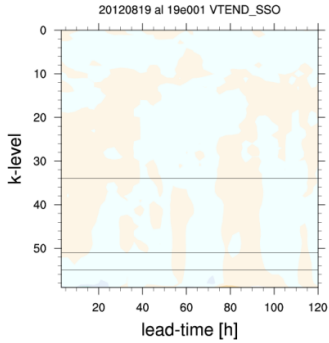
turbulence



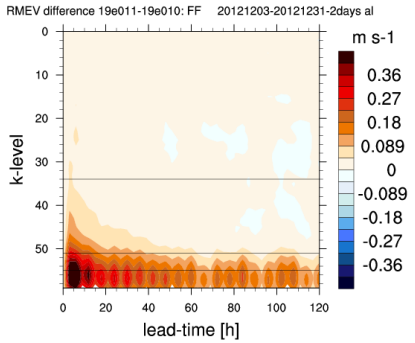
SSO



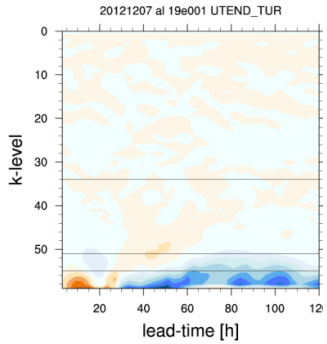
turbulence



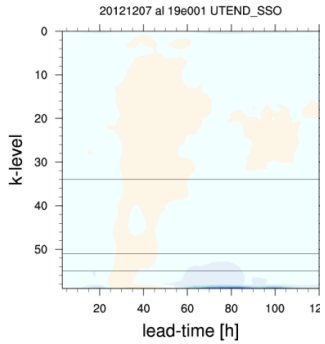
SSO

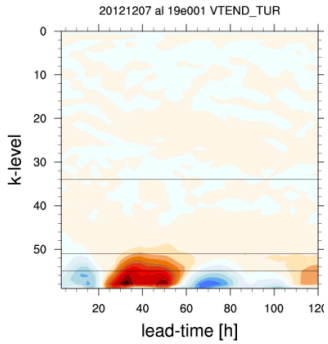


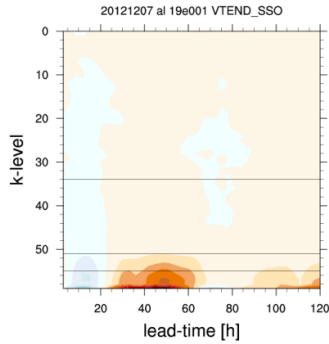
RMEV Diff, Dec 2012



tendencies for 07.12.2012

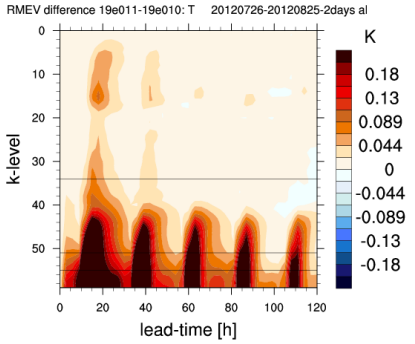




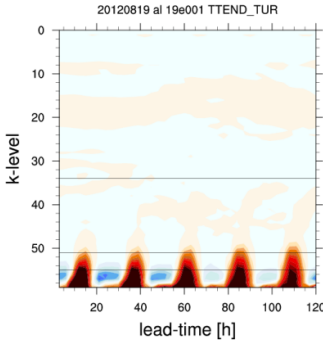


Tendencies: vertical, temperature

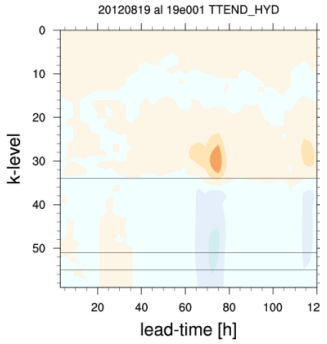
RMEV Diff, Aug 2012



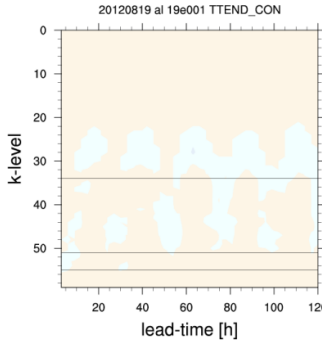
tendencies for 19.08.2012



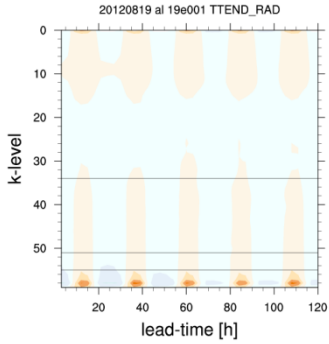
turbulence



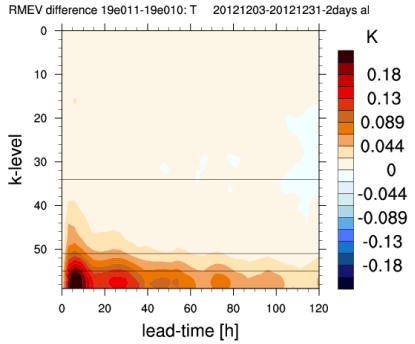
micro-physics

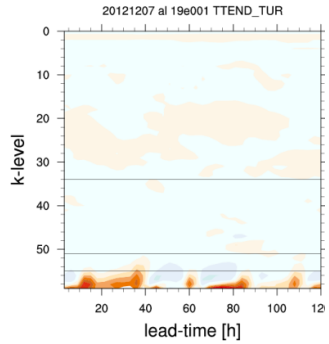


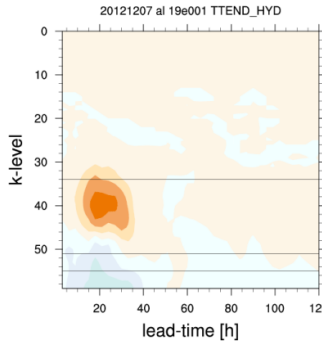
shallow convection

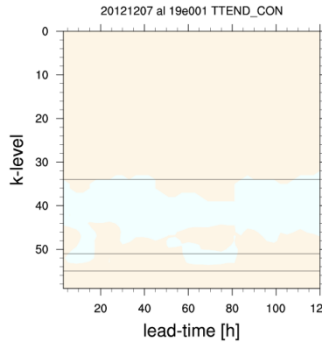


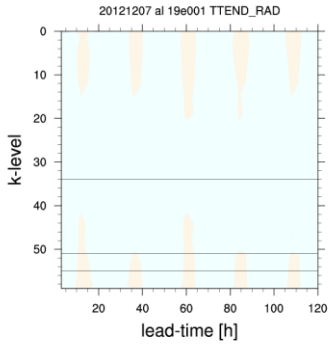
radiation









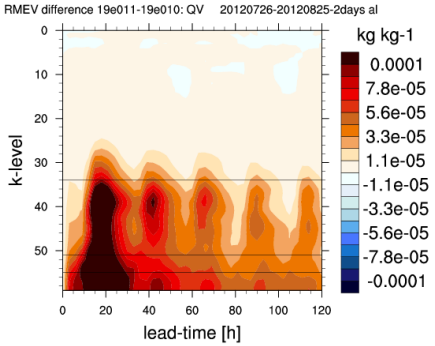


RMEV Diff, Dec 2012

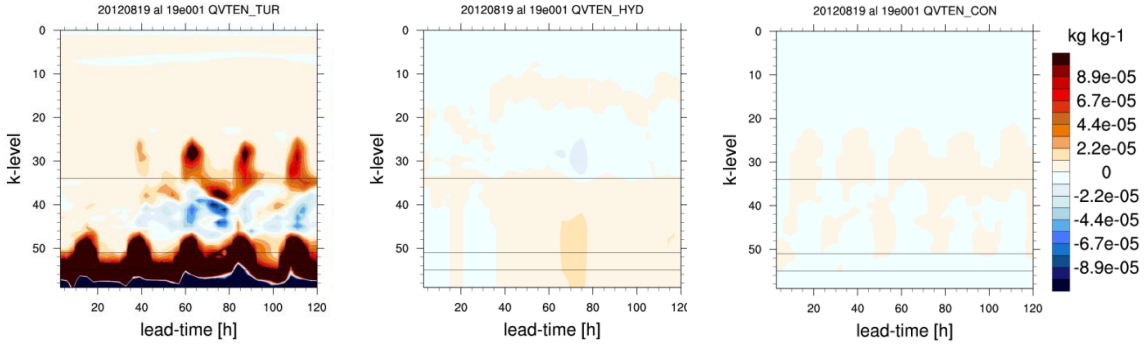
tendencies for 07.12.2012

Tendencies: vertical, humidity

RMEV Diff, Aug 2012



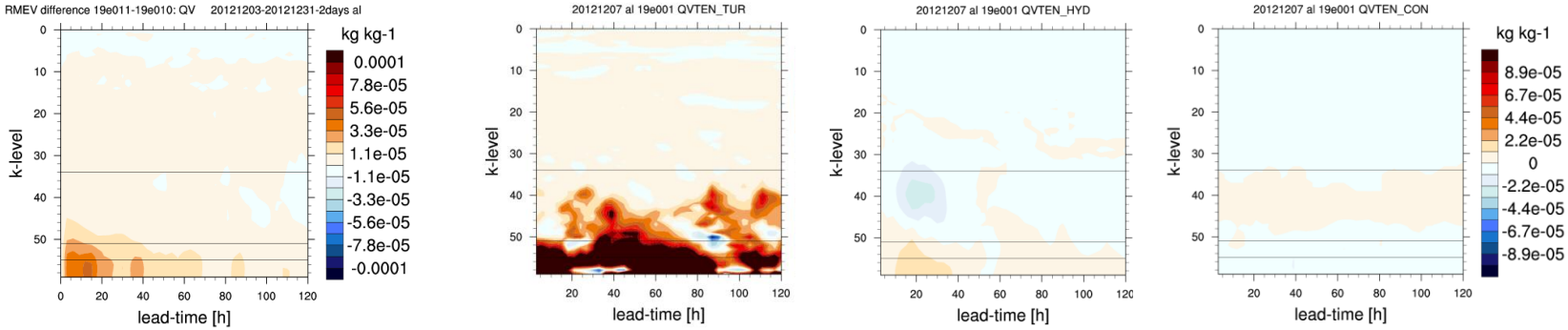
tendencies for 19.08.2012



turbulence

micro-physics

shallow convection



RMEV Diff, Dec 2012

tendencies for 07.12.2012