The scale dependence of uncertainty in the quantitative forecasting of heavy convective rainfalls

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Content

Experiments to assess the uncertainty in very short range QPF and to relate it to the forecast accuracy

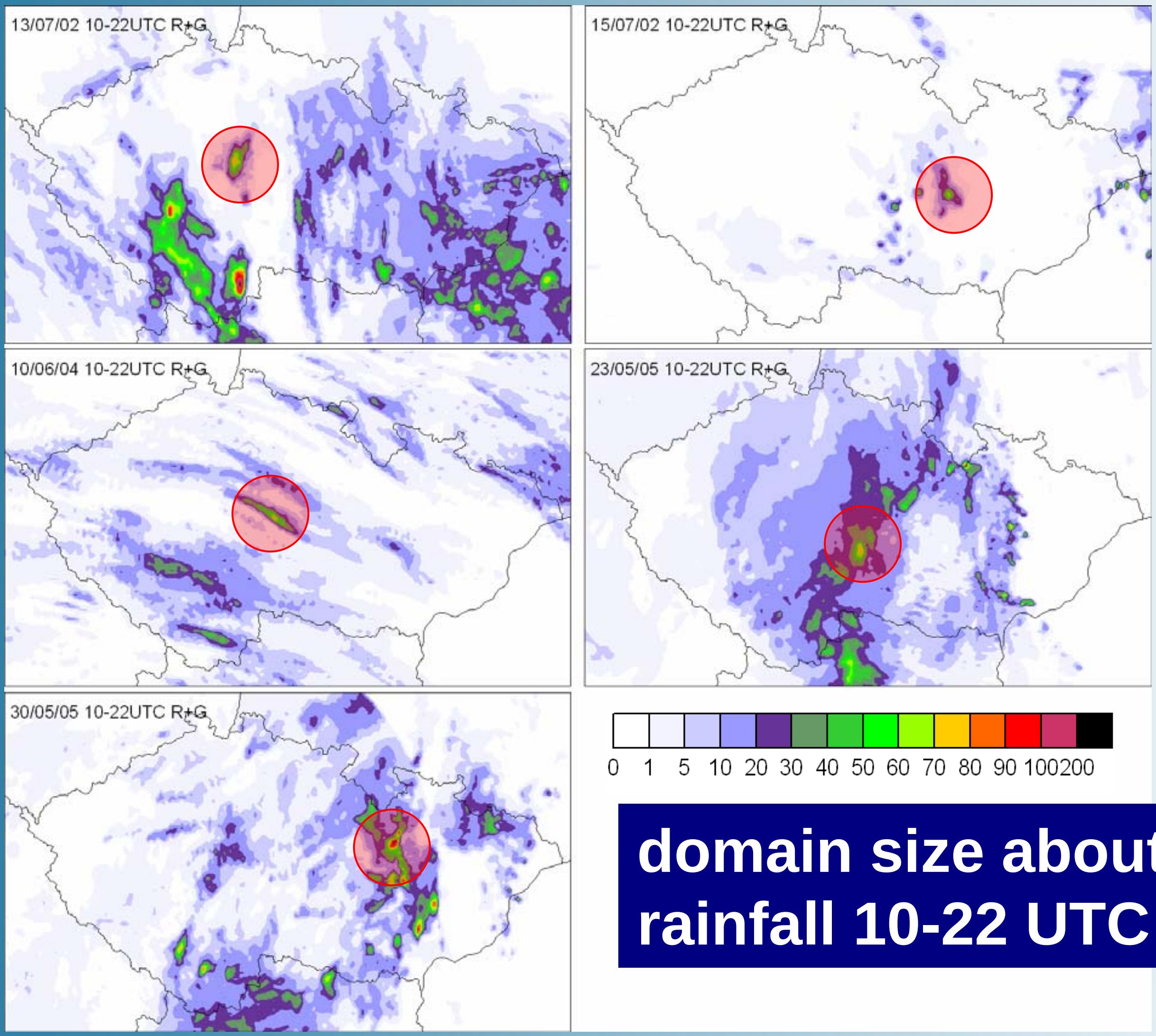
Local area precipitation at flash flood events

- Storm events – briefly
- NWP model – COSMO
- QPF accuracy - verification techniques
- QPF uncertainty - ensemble techniques
- Conclusions - outlook

Flash flooding in CR

- Multicellular storms – often nearly steady position
- Near cancellation of movement and propagation and/or train effect
- Repeated rainfall over given location
- 5 events were analysed

Events



13.7.2002

15.7.2002

10.6.2004

23.5.2005

30.5.2005

R+G

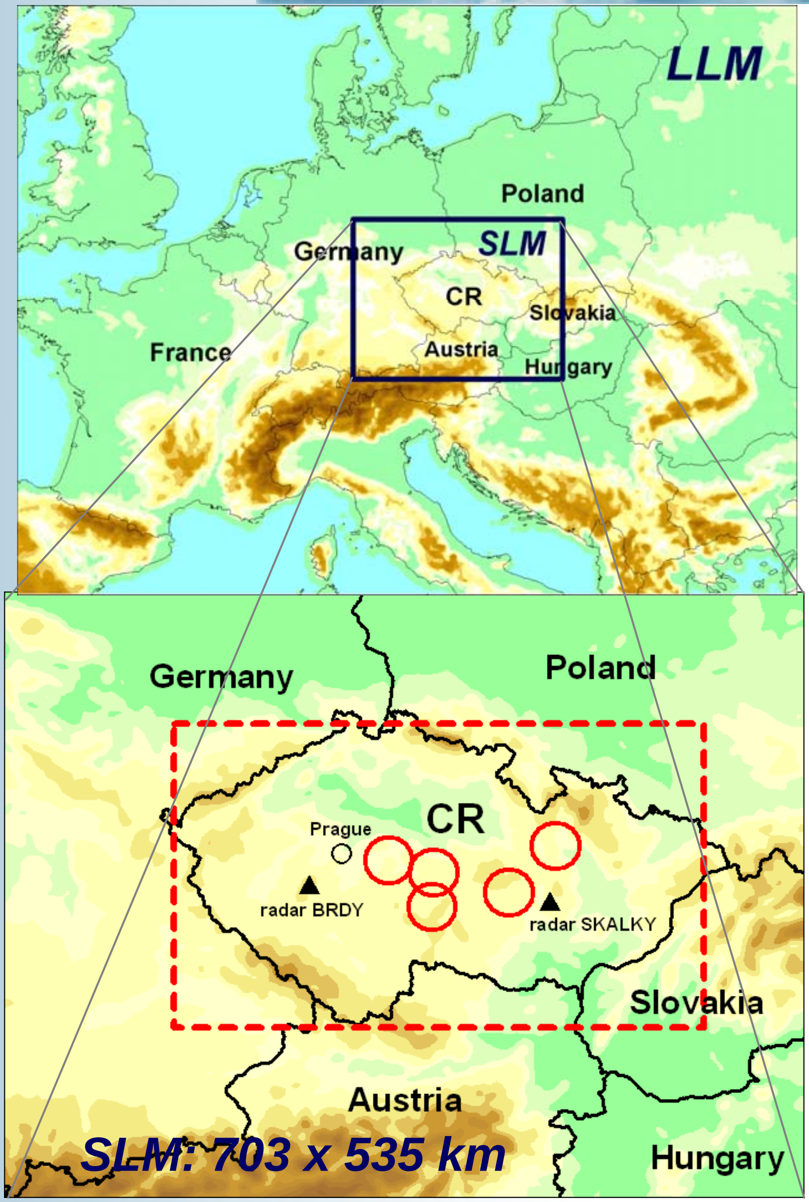
domain size about 500x300 km
rainfall 10-22 UTC

QPF – NWP COSMO

- **LLM :** 231x175 g.p., ~**<u>11 km</u>**,
- 00UTC+24h,
- init. cond. ECMWF
- **SLM** : 251x191 g.p., ~**<u>2.8 km</u>**,
- 06UTC+18h,
- init. cond. LLM

- CZRAD - 2 radars
- QPF verification : R+G
- 5 Local flash flood storms •

Verification domain
165x95 g.p. (**<u>462x266 km</u>**)



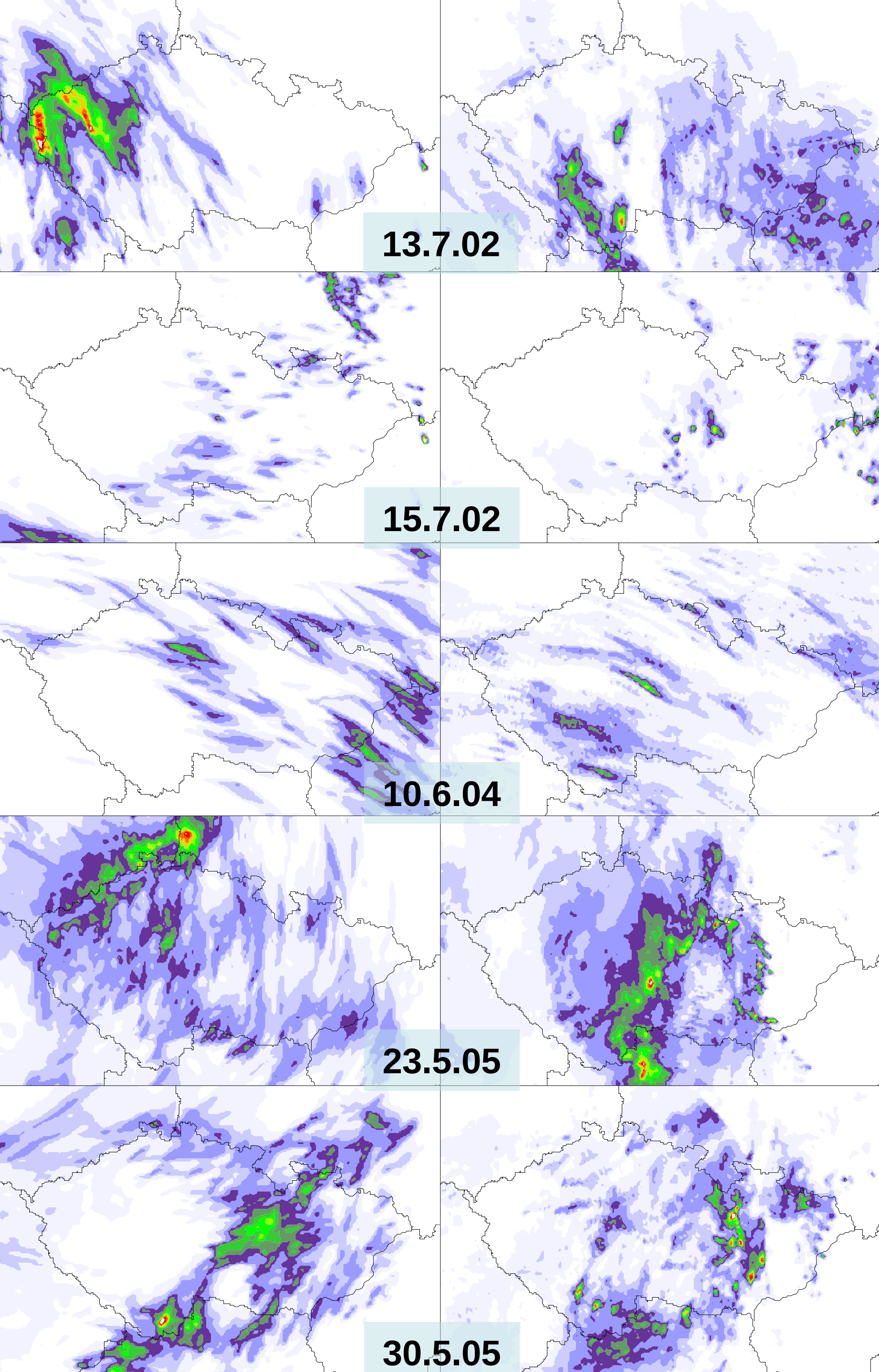
Trad. verification techniques

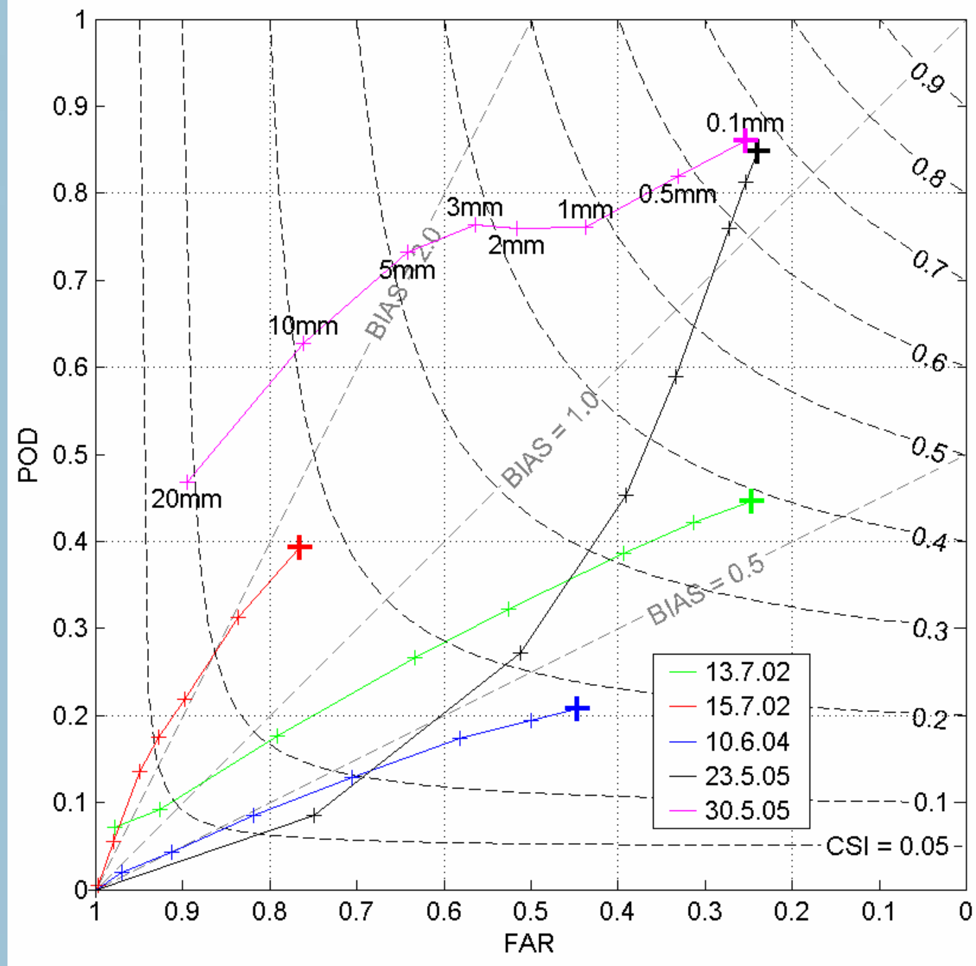
- Suitable predictand – area precipitation, accumulated rainfall …,
- Observation data – G, R, **R+G**

- Obs. data and forecast in identical grids
- Continuous prediction (MSE, RMSE,….)
- Binary prediction (Y/N) - Contingency table
- Categorical scores (POD, FAR, CSI, BIAS)

- <u>High resolution QPF - double penalty</u>

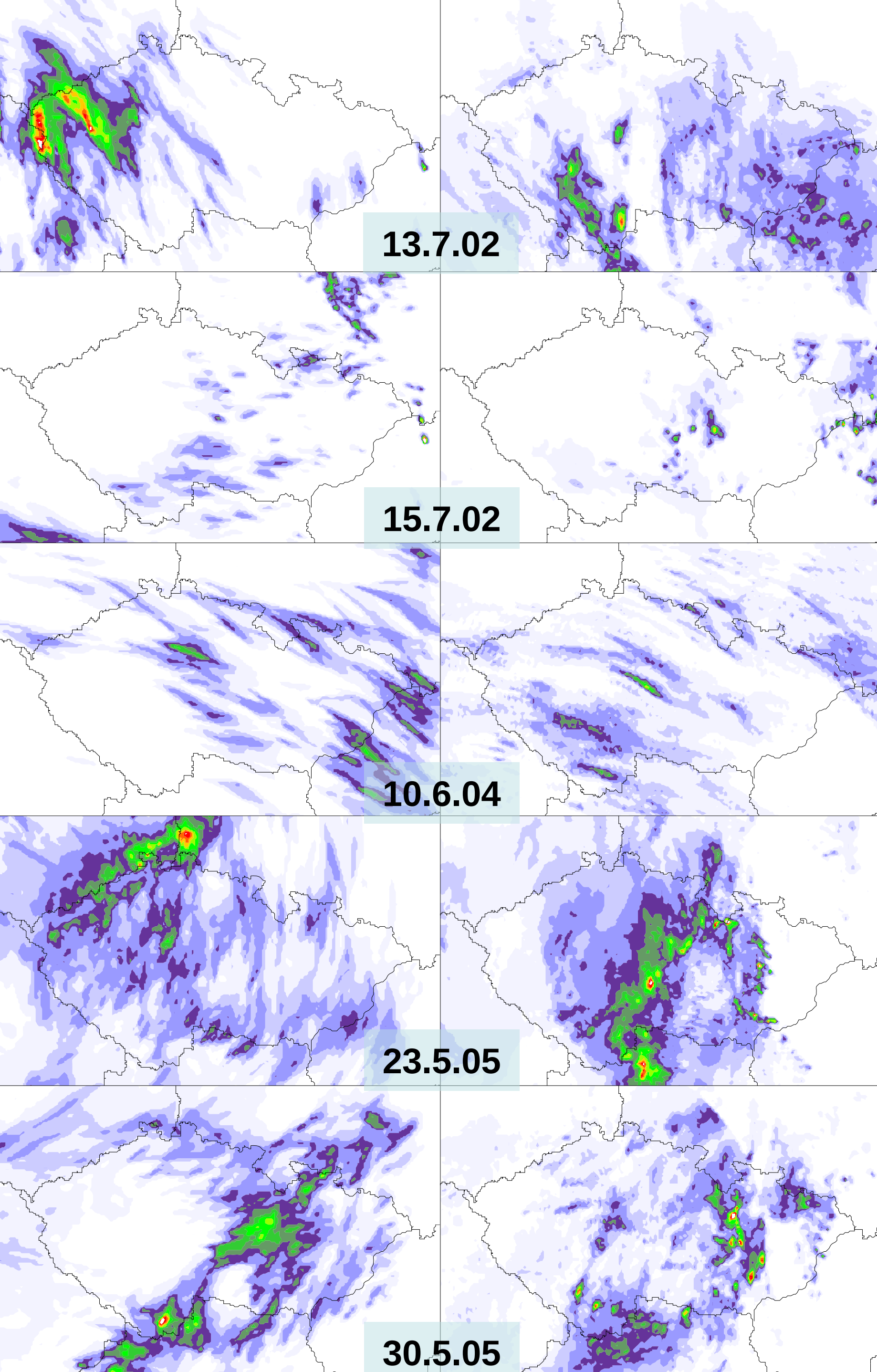
QPF(P_{th}, Area, duration)



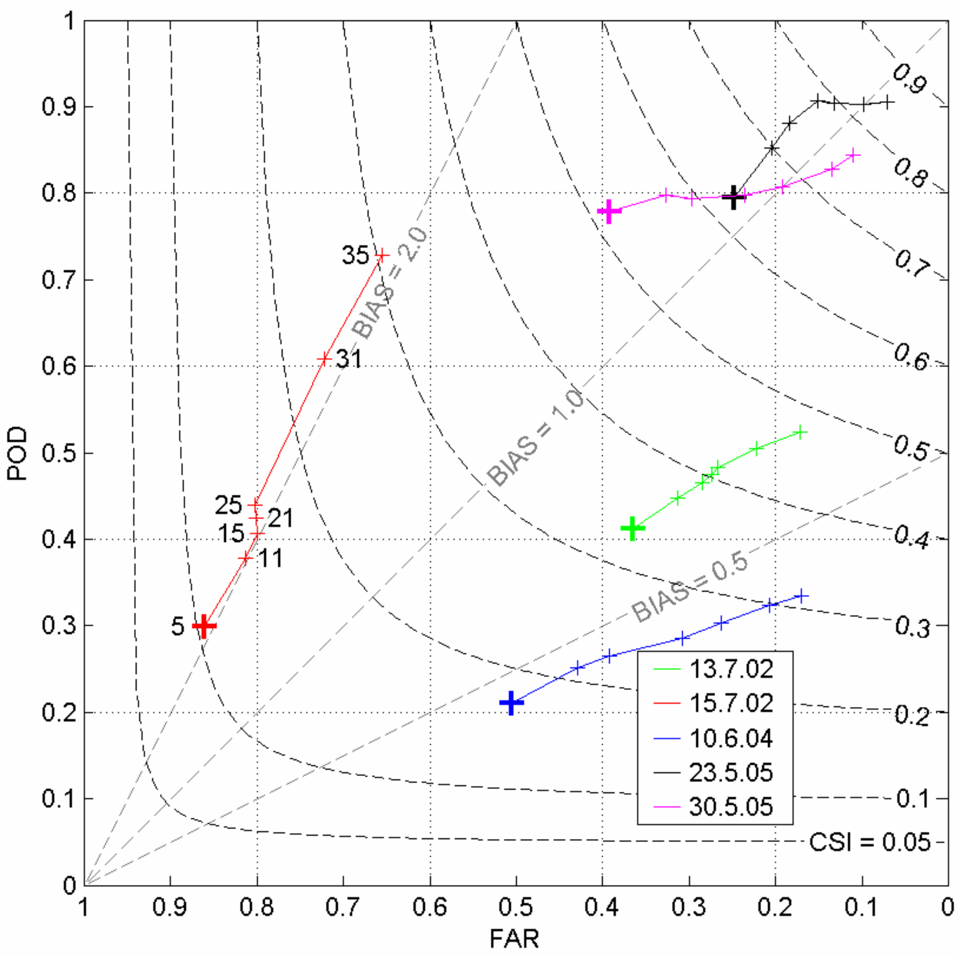


A ⇒ 1 g.p.; P_{th} : 0.1, 0.5, 1…20 mm

time: 6h ; 10-16 forecast (16-22 UTC)



QPF(P_{th}, **Area**, duration)

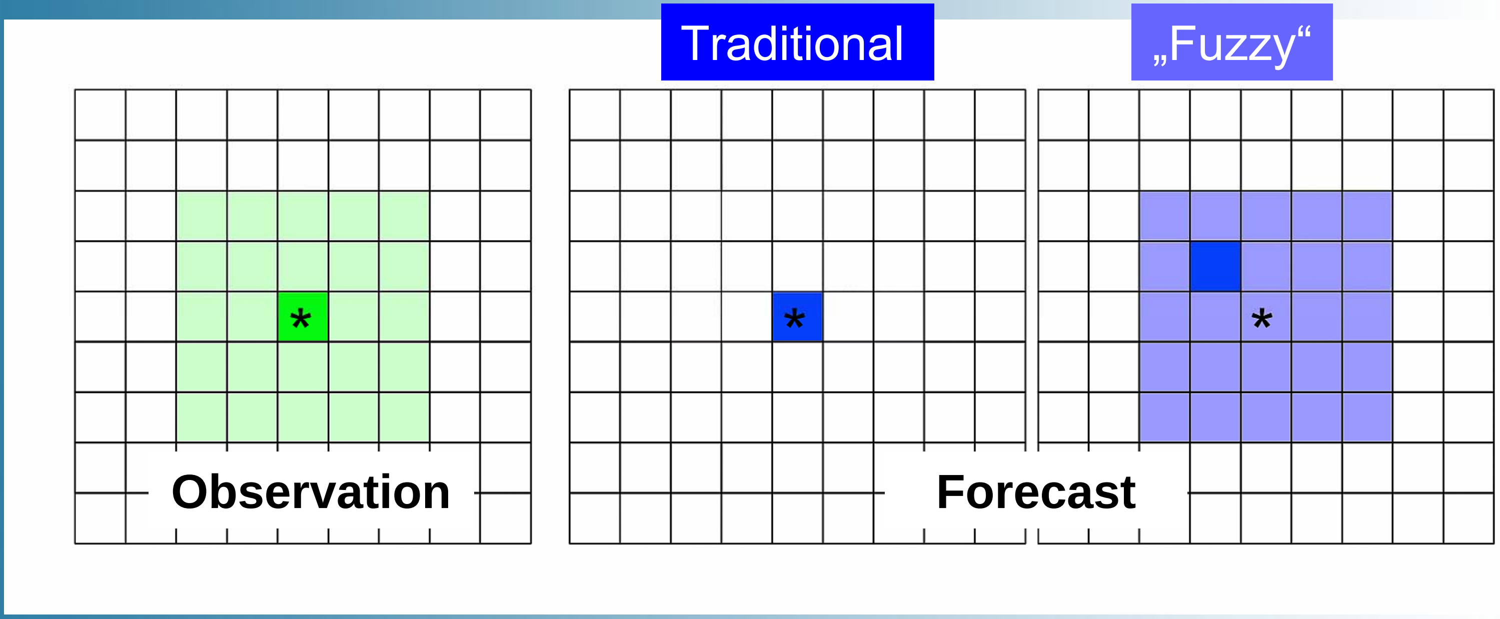


A ⇒ 5, 11, …35 g.p.; P_{th} : 1mm

time: 6h ; 10-16 forecast (16-22 UTC)

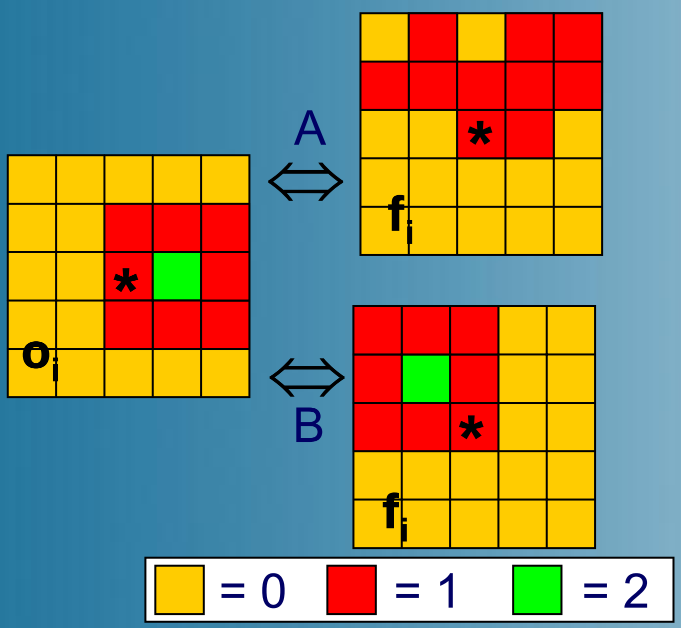
Traditional vs. „Fuzzy“ verification

Ebert (2007): **„Fuzzy“ verification** relaxes the exact match to the observation at high resolution



Area-Related RMSE

- AR_RMSE (Řezáčová, Sokol, Pešice, 2007)
- Precipitation over a square of **n×n** g.p. centered in each g.p.
- Comparison of precipitation distribution



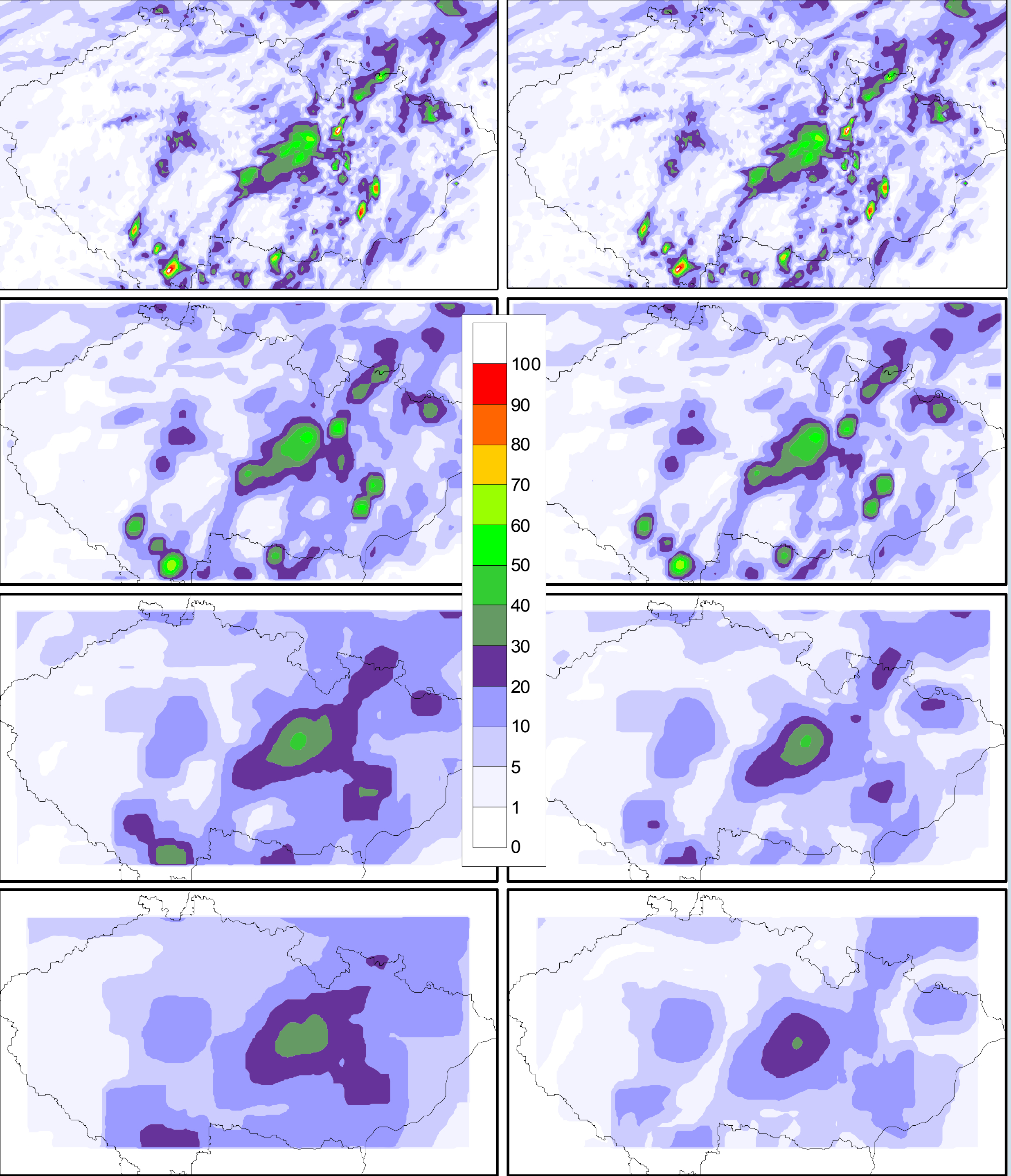
RMSE (F, O)

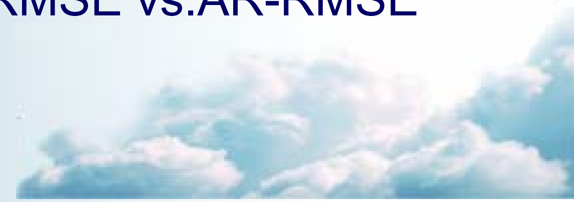
$$F \equiv \{f_i\},\ f_1 \le f_2 \le .. \le f_{n\,x\,n}$$

$$O \equiv \{o_i\},\ o_1 \le o_2 \le .. \le o_{n\,x\,n}$$

A =>	RMSE = 0.63	A-R_RMSE = 0.28
	MAE = 0.4	A-R_MAE = 0.08
	ME = 0	
B =>	RMSE = 0.89	A-R_RMSE = **0.0** !
	MAE = 0.64	A-R_MAE = 0.0
	ME = 0	

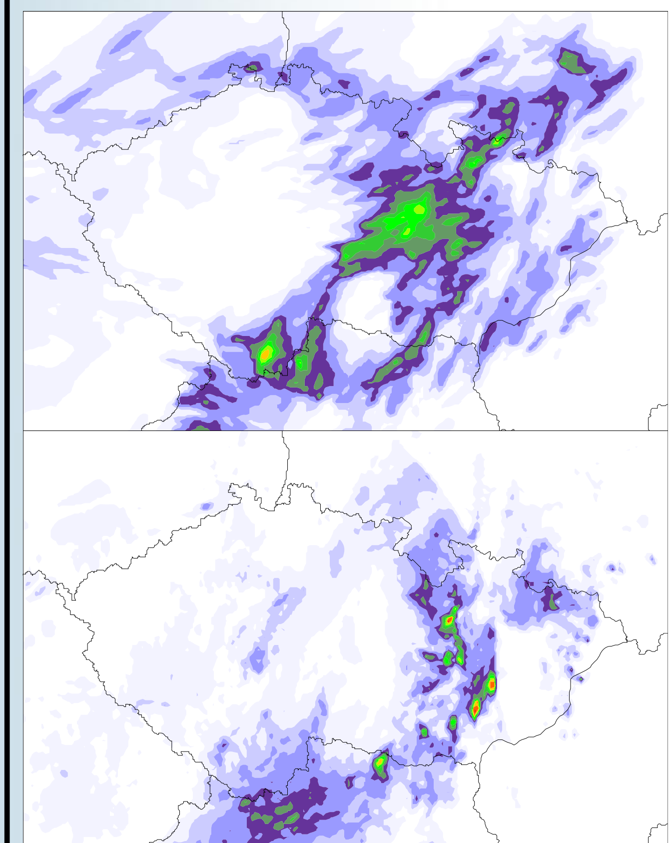
← RMSE vs.AR-RMSE





I) 1*1 g.p.
II) 5*5 g.p.
III) 13*13 g.p.
IV) 21*21 g.p.

forecast / radar



FSS (Fraction Skill Score)

- elementary area : $A_k \Rightarrow n_d \times n_d$ g.p.
- P_{th} threshold value
- p_k, o_k = $A_k(P > P_{th}) / A_k$;

$$FSS(A, P_{th}, D) = 1 - \frac{\frac{1}{n}\sum_{k=1}^{n}(p_k - o_k)^2}{\frac{1}{n}\left[\sum_{k=1}^{n} p_k^2 + \sum_{k=1}^{n} o_k^2\right]}$$

- FSS $\in$ <0,1> , FSS =1

FSS – 30.5.2005

precipitation threshold [mm] \ the size of elementary square [g.p.]	1	3	5	7	9	11	15	21	25	31	41	51	61	71
20.0	0.17	0.21	0.24	0.27	0.29	0.31	0.34	0.38	0.39	0.41	0.43	0.44	0.44	0.43
10.0	0.35	0.40	0.44	0.46	0.48	0.50	0.54	0.59	0.63	0.66	0.68	0.69	0.68	0.66
9.0	0.37	0.43	0.46	0.49	0.51	0.53	0.57	0.62	0.66	0.69	0.72	0.72	0.72	0.70
8.0	0.40	0.45	0.48	0.51	0.53	0.55	0.59	0.64	0.67	0.71	0.73	0.74	0.74	0.72
7.0	0.42	0.48	0.51	0.53	0.56	0.58	0.62	0.67	0.70	0.73	0.76	0.77	0.77	0.75
6.0	0.45	0.50	0.53	0.56	0.58	0.60	0.64	0.69	0.72	0.75	0.78	0.80	0.80	0.78
5.0	0.48	0.54	0.57	0.59	0.62	0.64	0.68	0.72	0.75	0.79	0.82	0.84	0.84	0.83
4.0	0.52	0.57	0.61	0.63	0.65	0.67	0.71	0.76	0.79	0.82	0.86	0.88	0.88	0.88
3.0	0.56	0.61	0.64	0.66	0.68	0.70	0.74	0.79	0.81	0.85	0.89	0.91	0.92	0.92
2.0	0.59	0.64	0.67	0.69	0.71	0.73	0.77	0.81	0.84	0.87	0.91	0.94	0.95	0.96
1.0	0.65	0.69	0.72	0.74	0.75	0.77	0.79	0.83	0.85	0.88	0.92	0.95	0.97	0.98
0.1	0.80	0.84	0.85	0.87	0.88	0.89	0.90	0.92	0.93	0.94	0.95	0.97	0.98	0.99

1 g.p.~2.8 km

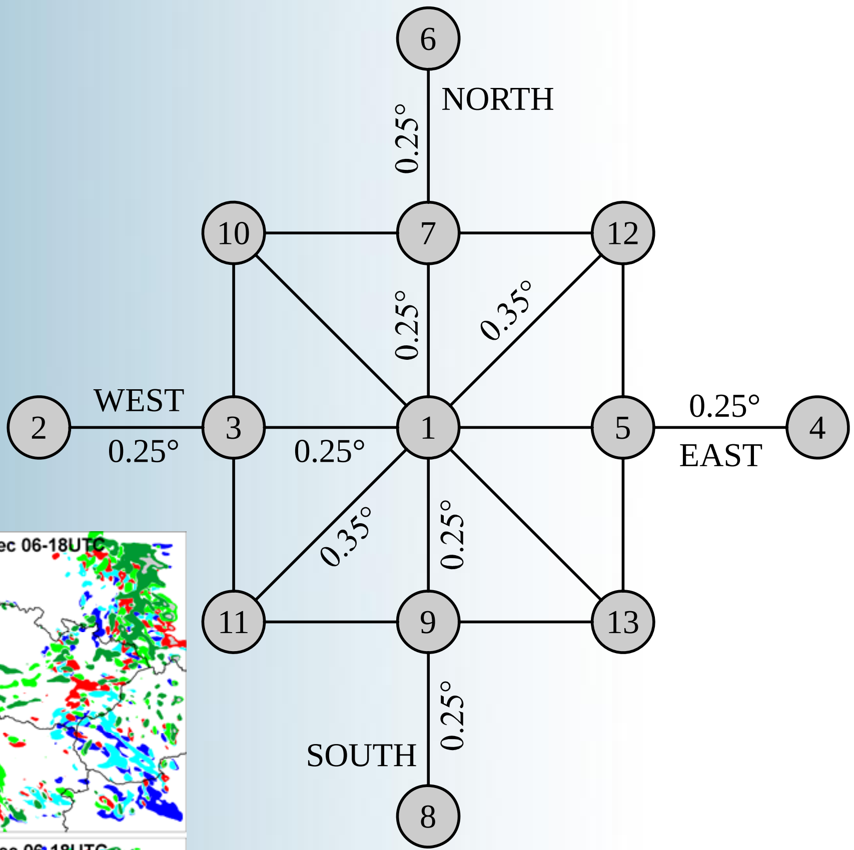
71 g.p.~200 km

QPF uncertainty, Ensemble prediction and evaluation

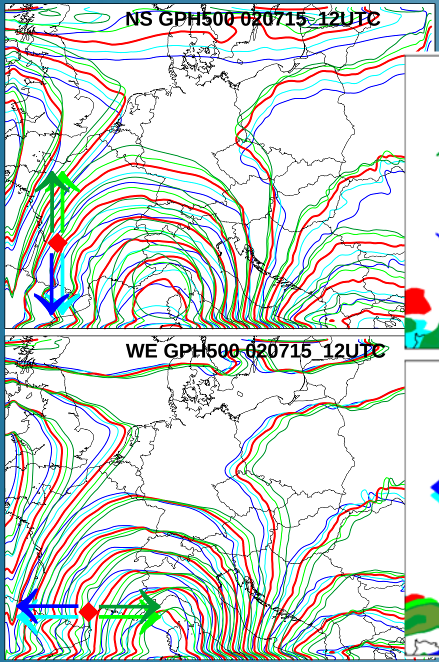
- ➲ Use fuzzy technique to describe ensemble Skill/Spread relationship
- ➲Grimit, Mass, 2007: Measuring the **ensemble spread - error relationship** with a probabilistic approach: Stochastic ensemble results.
- ➲ ensemble spread depends on EP
- ➲ ensemble error/skill depends on verification data
- ➲ ensemble spread ⇔ ensemble skill/error

Ensemble construction

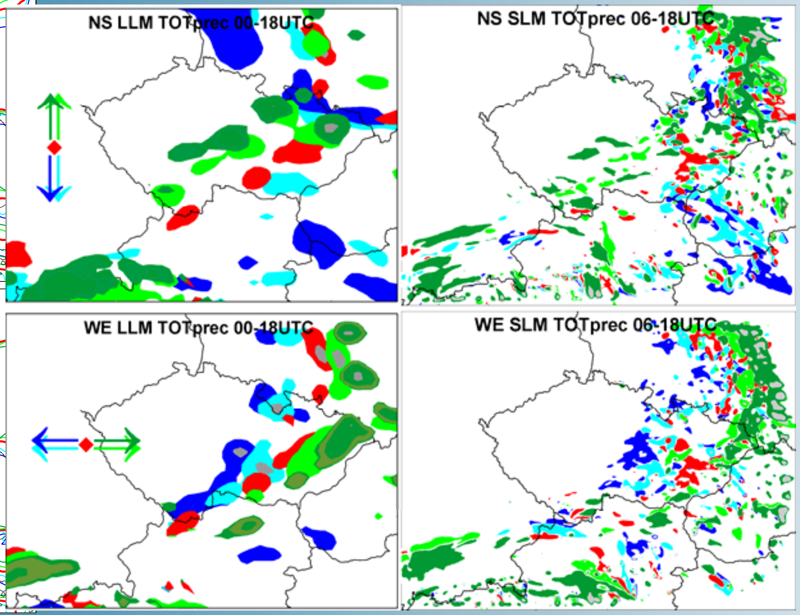
- Modification of LLM initial conditions - shifting,
- 13 initial fields
- Ensemble of 13 SLM forecasts



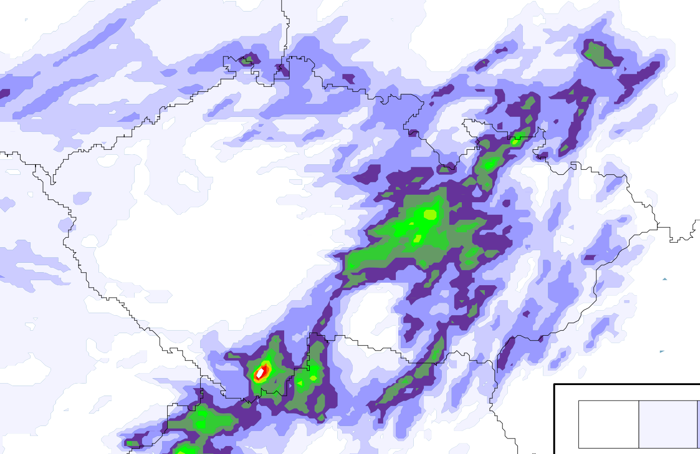
⇓ AT500

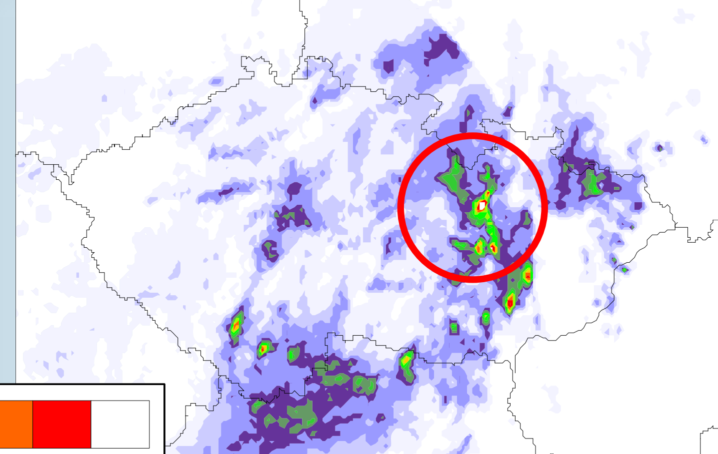


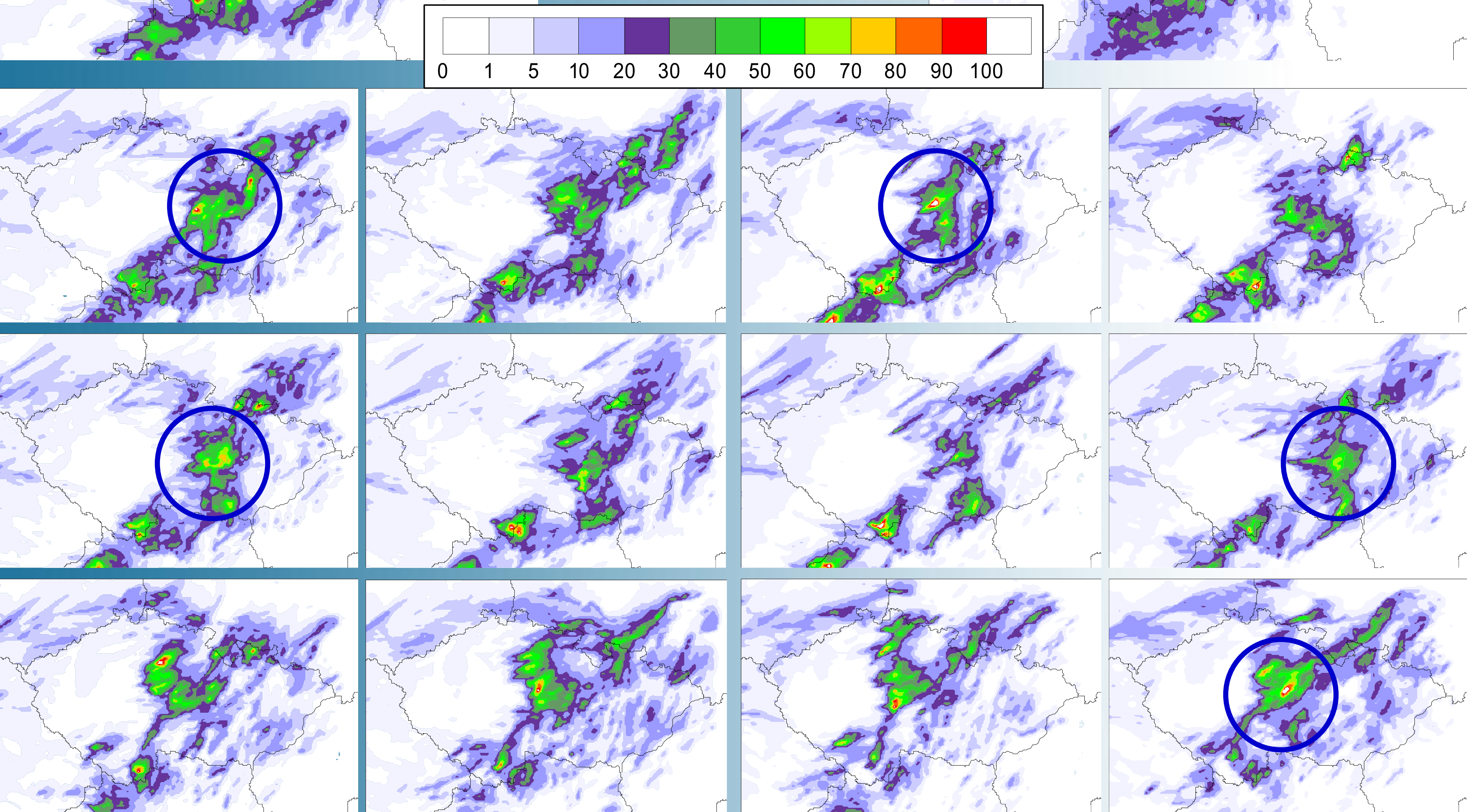
⇓ LLM + SLM QPF



30.5.2005
12h rainfall
12-24 UTC





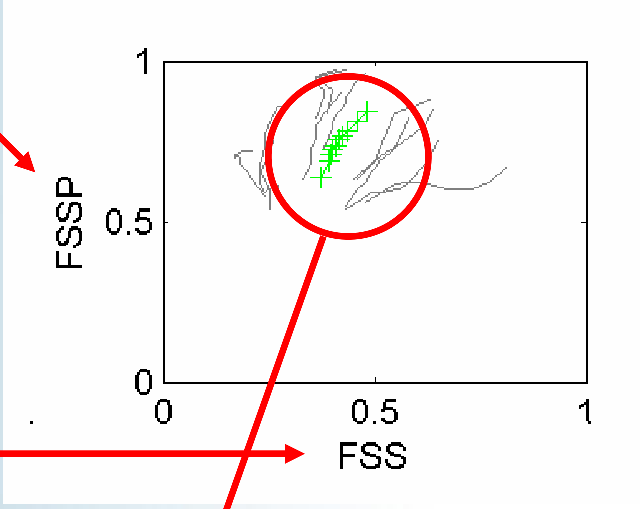


Skill (FSS), spread (FSSP)

- Ensemble spread :

predictions produced by ensemble members ⇔ reference forecast

$$FSSP(A, Th, t) = FSS(p_N, p_{ref})$$



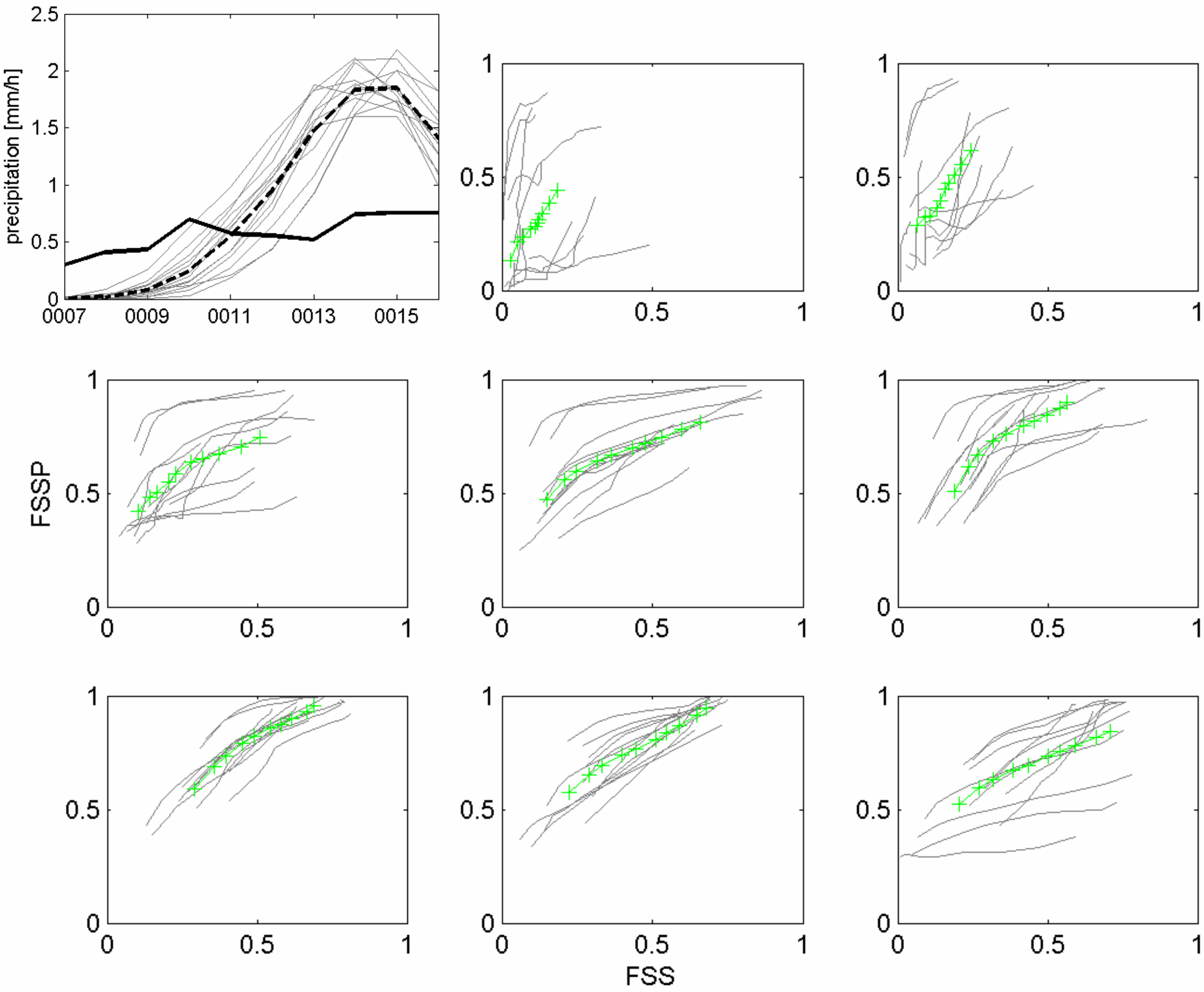
- Ensemble skill :

predictions produced by ensemble members ⇔ observation

$$FSS(A, Th, t) = FSS(p_N, o)$$

- FSSP/FSS relation dependence on A

Skill (FSS), spread (FSSP)



30.5.2005

D = 1h

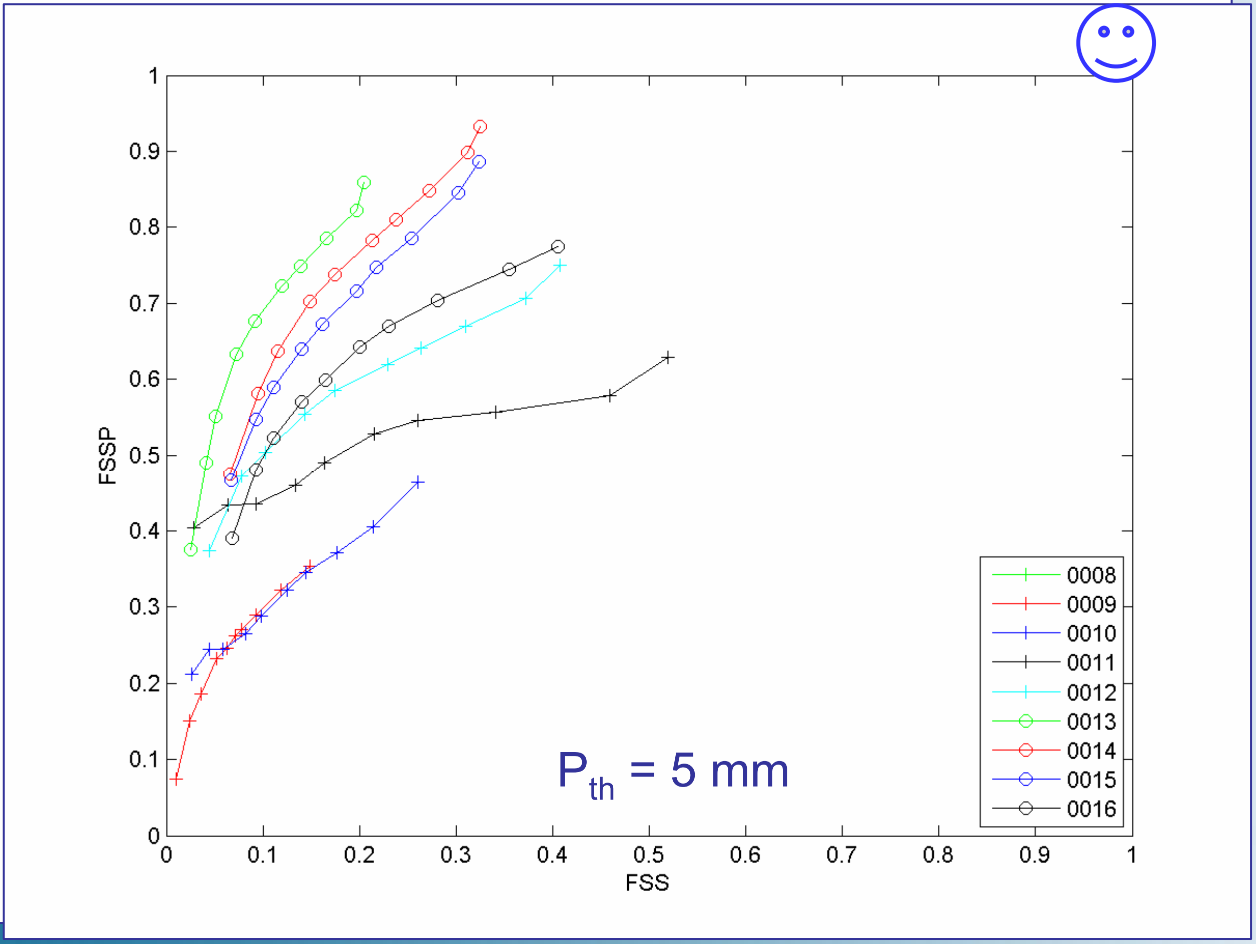
P_{th}= 2 mm

Integration time: 9 - 16 h

Time:
15 - 22 UTC

Mean FSS, mean FSSP

FSS(A, P_{th}, t = 3hod) vs. FSSP(A, P_{th}, t = 3hod)

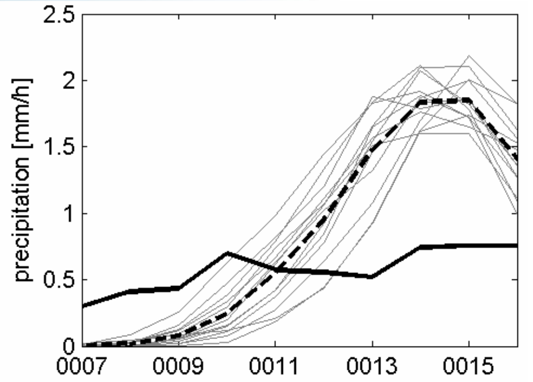


<u>30.5.2005</u>

D = 1h

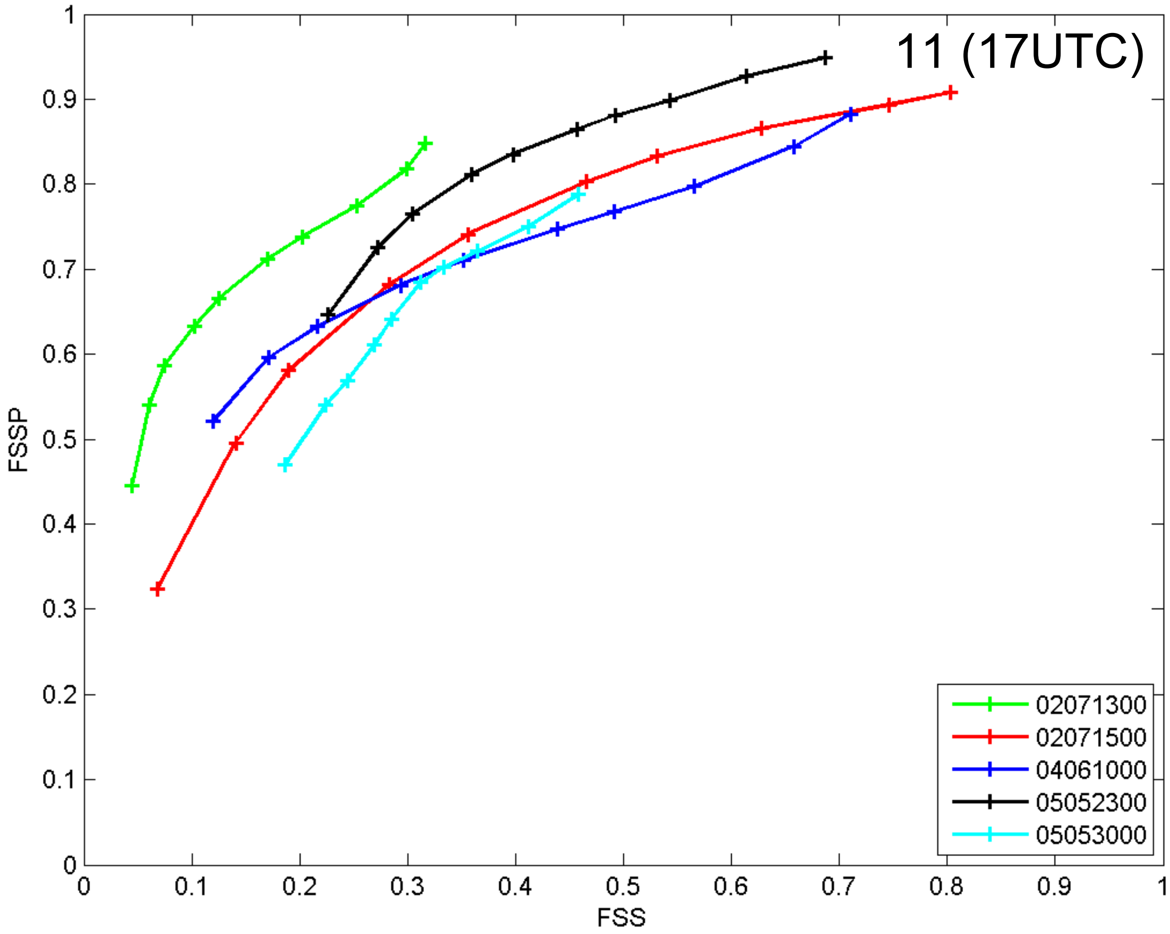
Integration time: 8 - 16 h

Time:
14 - 22 UTC



Mean FSS, mean FSSP

FSS(A, P_{th}, t = 1hod) vs. FSS(A, P_{th}, t = 1hod)



5 events

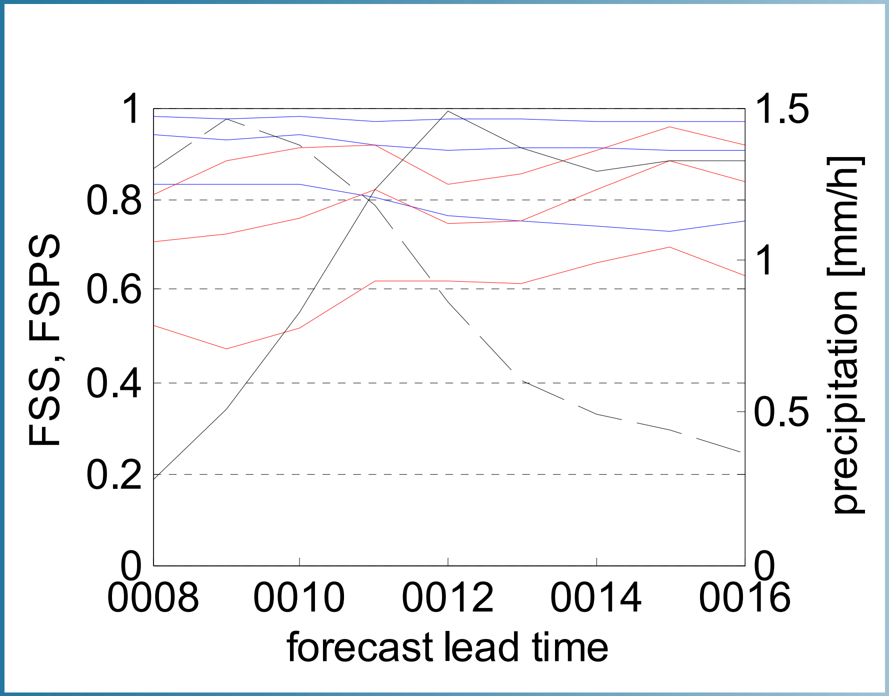
D = 1h

Last hour int. time: 11 h

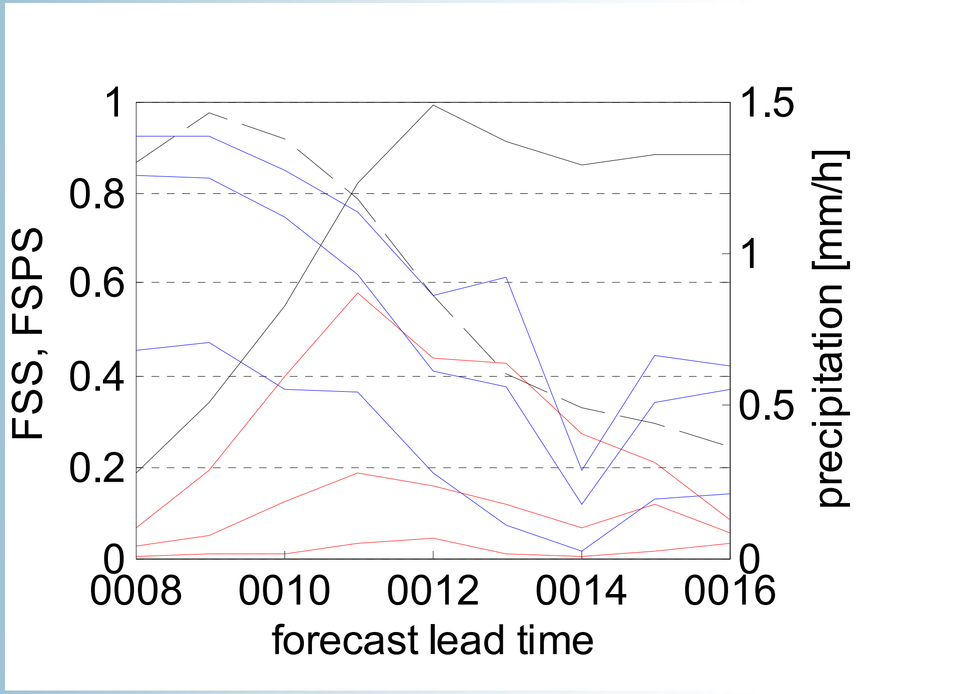
Time: 17 UTC

Mean FSS, mean FSSP

FSS(A = 5, 31, 61; P_{th} = 0.1mm, t) vs. FSPS(A = 5, 31, 61, P_{th} = 10mm, t)



radar
ensemble mean



FSS(A = 5, 31, 61, P_{th} = 10mm, t) vs. FSPS(A = 5, 31, 61, P_{th} = 10mm, t)

Conclusions and Outlook

- 1h, 3h and 6h rainfalls, 5 conv. events, FSS-FSSP, effect of A, Pth, integration time.
- The FSSP (spread) and FSS (skill) values are correlated. The correlation depends on area size, threshold value.
- Increasing area size causes an increase in FSS and FSSP – (positive effect). Increasing threshold value causes a decrease in FSS and FSSP – (negative effect). The both effects are case (event) dependent
- More convective events, more insight into S/S (timing, accumulation, the stratification of events according prec. cover and totals – model and or R+G)
- Modify the Ensemble Construction or test other variants of EC.

Thank you

Acknowledgement: DWD, CHMI, Cost 731

References

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