An estimation of QPF uncertainty by forecasting the radar-based ensemble skill

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1 Summary

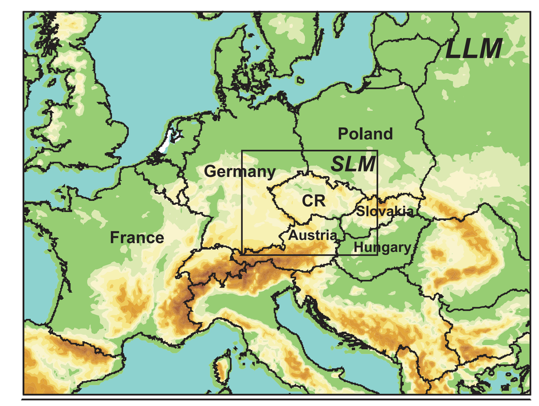
We summarize the results dealing with estimating QPF uncertainty by using the relationship between ensemble skill and ensemble spread. The results refer to five convective storms, which occurred over the Czech territory and caused local flash flooding. The regional ensembles were formed by using COSMO model in an experimental mode. A driving COSMO (LLM) was run with the horizontal resolution of 11 km and with initial and boundary conditions derived from ECMWF analyses. The driven COSMO (SLM) used the horizontal resolution of 2.8 km and the initial and lateral data from LLM. The SLM integration started at 06 UTC and finished at 24 UTC of the same day. The ensemble of 13 SLM members resulted from a simple modification of LLM initial conditions. **Poster block 2.**

We focused on the assessment of the relationship between ensemble spread and ensemble skill. The spread and skill values were calculated by using Fractions Skill Score which depends on elementary area size (scale) and rainfall threshold. The ensemble member skill was evaluated by comparing the forecast with radar-based rainfalls and the ensemble member spread was estimated comparing the ensemble member forecast with the undisturbed control forecast. The ensemble FSS_skill and FSS_spread was determined by averaging the member skill and spread values. The spread and skill values were calculated for (a) various scales, (b) thresholds, (c) rainfall accumulations, and (d) integration times. We considered square elementary areas centered in grid points of the verification domain. **Poster block 3.**

A: We tested the prediction of FSS_skill on the basis of FSS_spread. The regression between ensemble FSS_spread and FSS_skill was constructed for data from 4 events. The predicted skill values FSS_skill_fit were evaluated for the fifth event. **Poster block 4.**

B: We tested the effect of (a) elementary area definition, and (b) ensemble skill and spread determination by averaging the ensemble member FSS_skill and FSS_spread. **Poster block 5 and 6.**

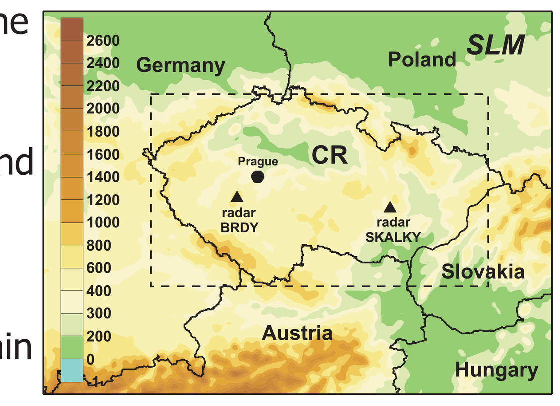
2 The use of COSMO model

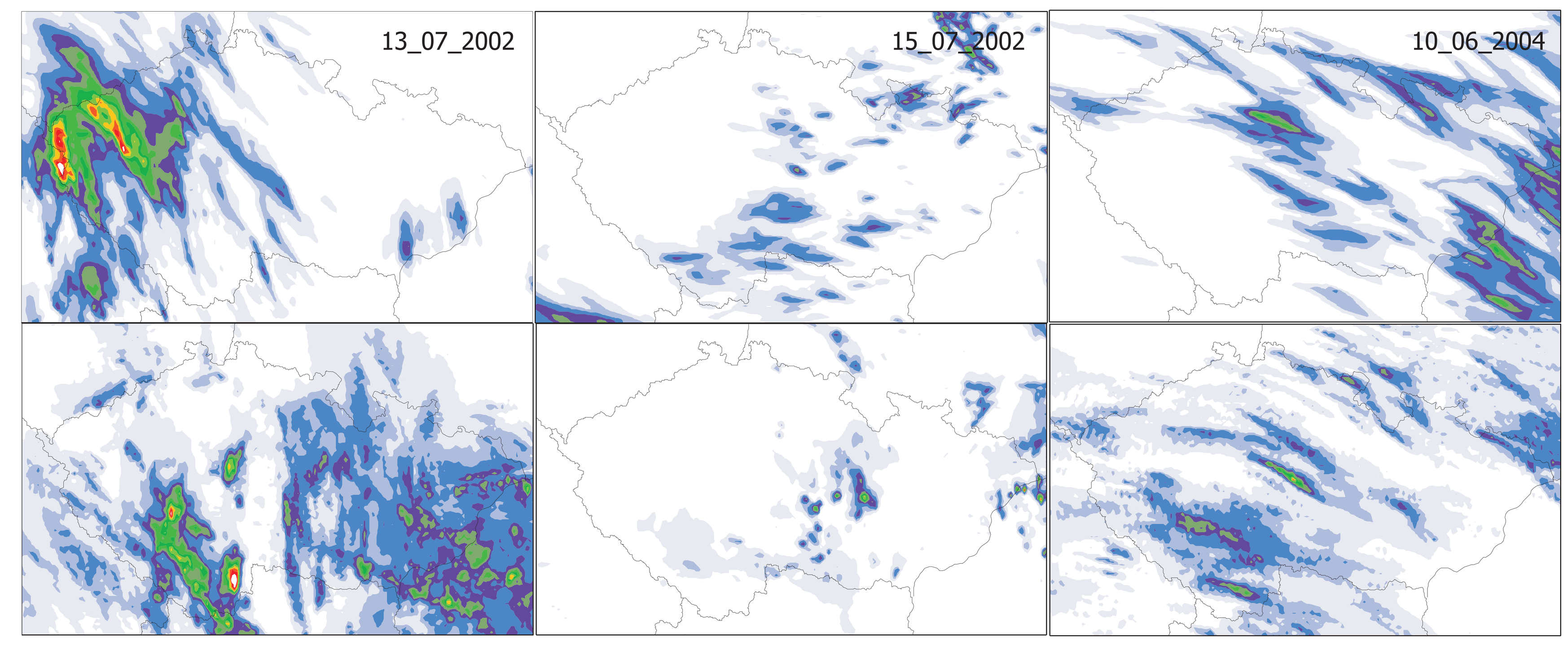


NWP model domains and orography. The altitude is indicated in the legend.

Fig.1a - left: The LLM domain. The inner rectangle indicates the position and size of the SLM domain

Fig.1b - right: The SLM domain. Triangles mark the positions of two Czech radars. The verification subdomain is indicated by dashed rectangle.





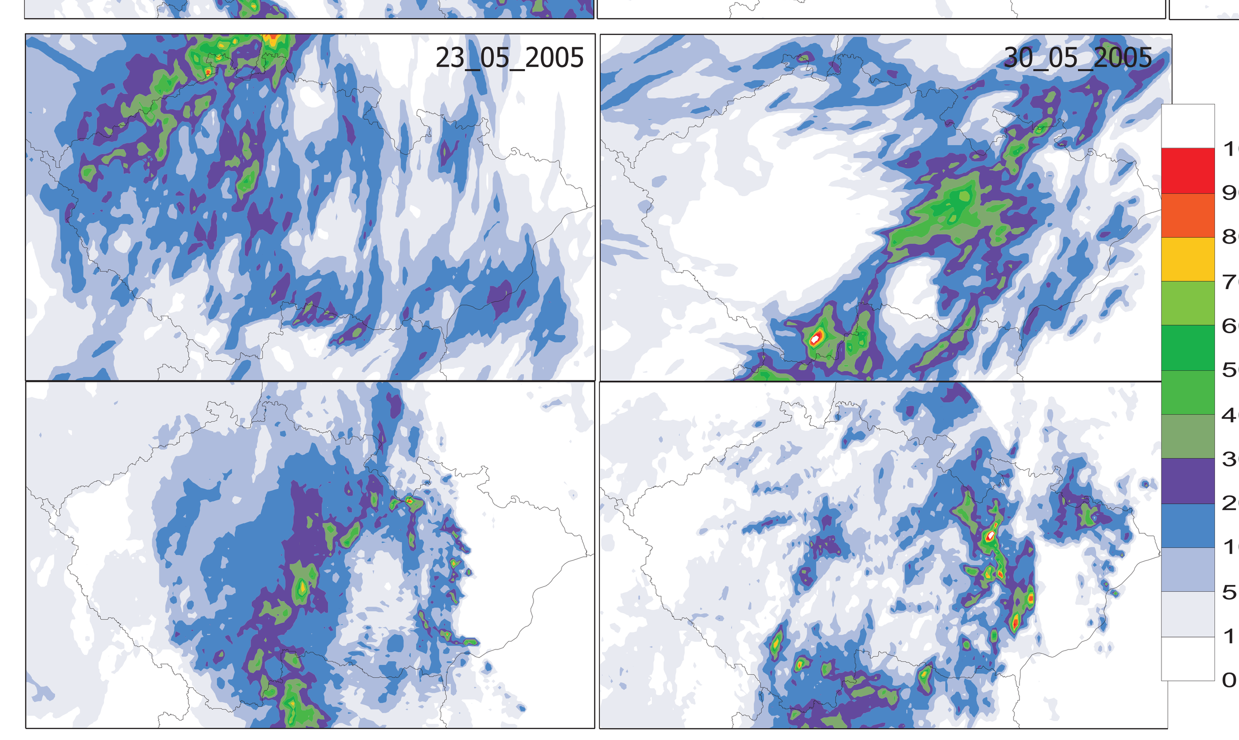


Fig. 2 Events with heavy convective precipitation; the comparison between (upper row) predicted and (lower row) gauge adjusted radar-based 12h rainfall (10.00UTC – 22.00UTC). The horizontal resolution of both forecasted and observed precipitation fields is 2.8 km. The date is marked in each panel. The scale indicates the rainfall values in mm.

3 The definition of the FSS-based SKILL and SPREAD

The Fraction skill score (FSS) represents a version of Fractions Brier Score normalized by maximum error (e.g. Ebert, 2008), which can be interpreted as the RMSE of the fractional coverage of gridpoint surroundings by precipitation over some specific threshold (Roberts and Lean, 2008).

Notation

i = 1, 2, ...Ne, where **Ne** is the number of ensemble members;
j = 1, 2, ... Na, where **Na** is the number of elementary areas (EA);
k = 1, 2, ... Ng, where **Ng** is the number of gridpoints in elementary area (EA);
Rth - threshold rainfall;
$I_{ref}(j,k)$ = 0/1 - indicates if the rainfall Rref(j,k) exceeds Rth (YES - 0, NO - 1) in the k-th g.p. of the j-th EA in the reference field;
$I_{for}(i,j,k)$ = 0/1 - indicates if the rainfall Rfor(i,j,k) exceeds Rth (YES - 0, NO - 1) in the k-th g.p. of the j-th EA in the i-th ensemble member forecast;
$P_{ref}(j)$ - fractional cover by the rainfall > Rth of the j-th EA in the field of reference;
$P_{for}(i,j)$ - fractional cover by the rainfall > Rth of the j-th EA in the i-th ensemble member forecast

$$P_{ref}(j) = N_g^{-1} \sum_{k=1}^{Ng} I_{ref}(j,k)$$

$$P_{for}(i,j) = N_g^{-1} \sum_{k=1}^{Ng} I_{for}(i,j,k)$$

$$FSS(P_{for}(i), P_{ref}) = 1 - \frac{\sum_{j=1}^{Na} \left(P_{ref}(j) - P_{for}(i,j)\right)^2}{\sum_{j=1}^{Na} P_{ref}^2(j) + \sum_{j=1}^{Na} P_{for}^2(i,j)}$$

In the first studies (Rezacova et al. 2009, Zacharov and Rezacova 2009) the **ensemble FSS_skill** and **ensemble FSS_spread** were defined as the mean FSS values over the ensemble members. The reference data were the observed radar-based values at FSS_skill determination (ref = obs) and the results of control forecast at FSS_spread calculation (ref = contr).

$$FSS\_skill = \underset{i=1,\dots Ne}{mean}\ FSS\left(P_{for}(i), P_{obs}\right) \qquad FSS\_spread = \underset{i=1,\dots Ne}{mean}\ FSS\left(P_{for}(i), P_{contr}\right)$$

4 Forecasting the FSS-skill

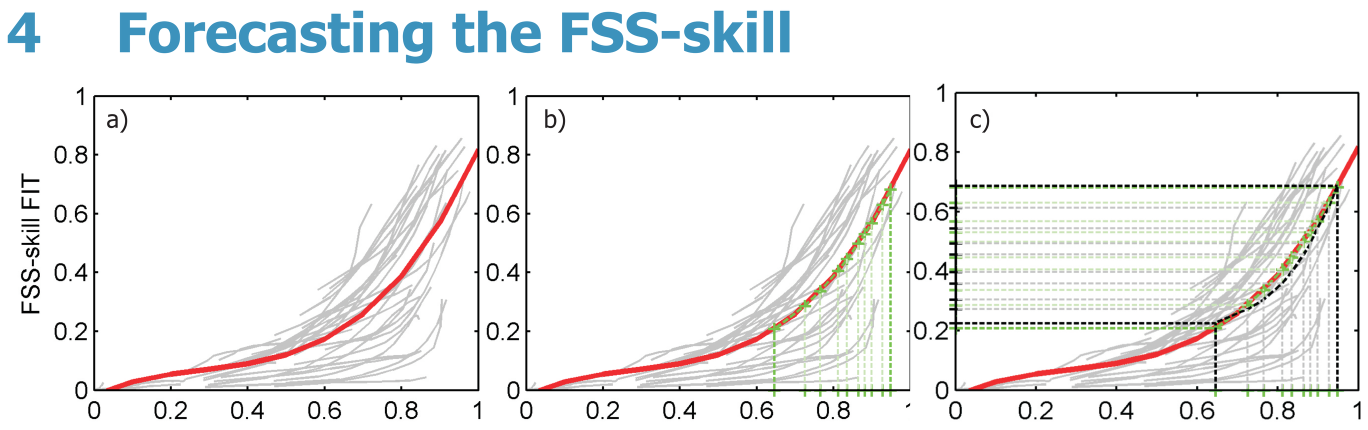


Fig. 3. A scheme showing how the FSS-skill estimate (FSS-skill FIT – vertical axis) is constructed on the basis of FSS-spread (horizontal axis). 10 scales were considered altogether. a): Mean ensemble member curves (gray) for 4 events and the polynomial regression (red line). b) FSS-spread values for the 5th event (23 May 2005, 10-11 h of integration time, precipitation threshold of 1 mm) and corresponding FSS-skill projection (green). c) measurement-based FSS-skill for the 5th event (black).

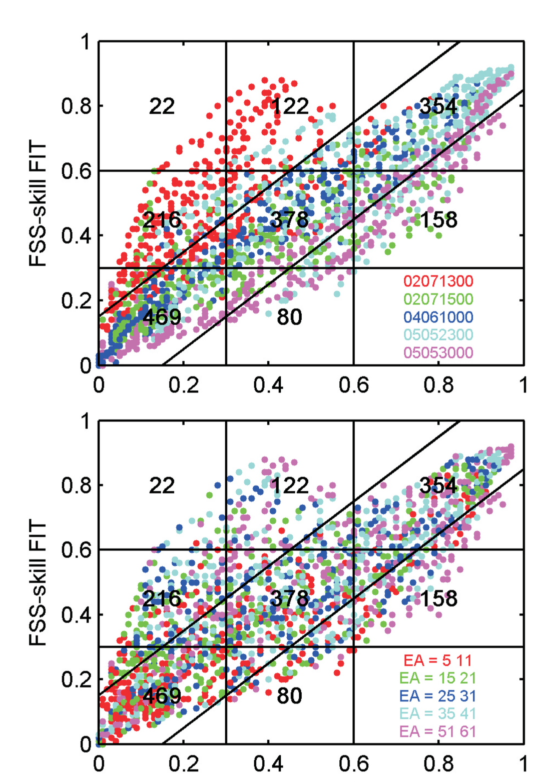


Fig. 4. Forecast skill (FSS-skill FIT, vertical axis) and measurement-based skill (FSS-skill, horizontal axis) for 3 h rainfall and all the scales, thresholds, and intgration times together. The numbers inside the blocks give absolute frequency values in the FSS intervals: FSS < 0.3, 0.3 <= FSS < 0.6, and 0.6 <= FSS. The values referring to various days are distinguished by colors in the upper panel. The values referring to scale are distinguished by colors in the lower panel.

5 Determination of ensemble FSS-skill and FSS-spread (testing various techniques)

2 ways how to define square elementary areas (EA) inside the verification domain;
2 ways how to determine ensemble FSS_spread / ensemble FSS_skill

1. Ensemble member FSS(P_{for}, P_{ref}) – Elementary Areas	
notation	definition
FSS1	The FSS calculation according to (Rezacova et al., 2009, Zacharov and Rezacova, 2009). The square EA's centered on the grids of the verification domain under the condition that all of the EA was inside the domain.
FSS2	The square EA's centered on all grids inside the verification domain (Roberts and Lean, 2008). Zero rainfall covers the EA part outside the verification domain.

2. Ensemble FSS_spread / FSS_skill	
M(FSS*)	mean FSS(P_{for},P_{ref}) over the ensemble members. ensemble FSS = mean [ensemble member FSS(P_{for},P_{ref})]
FSS*_M	The ensemble FSS value included the ensemble mean P_{for}(i), i=1,2...Ne. ensemble FSS = FSS(mean P_{for}, P_{ref})

The figures 5 - 10 in the Part 6 are structured as follows

FSS1_M vs. FSS2_M	**M(FSS1) vs. M(FSS2)**
FSS1_M vs. M(FSS1)	**FSS2_M vs. M(FSS2)**

6 The results of testing various techniques to evaluate the relationship between ensemble FSS-skill and FSS-spread

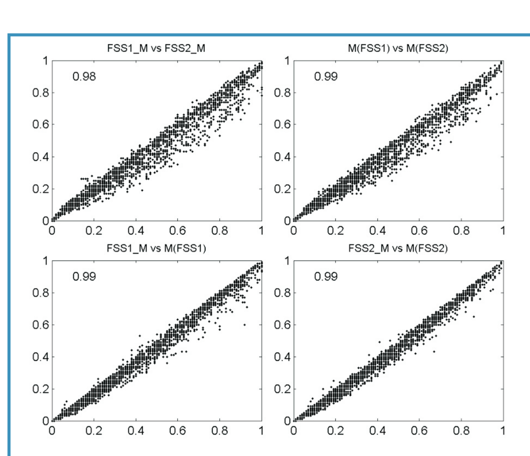
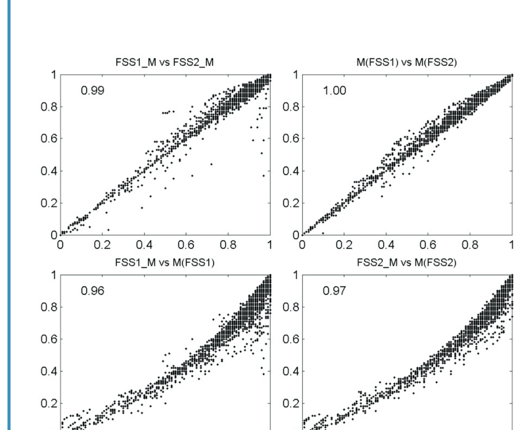


Fig.5 FSS_**skill**: 3h rainfall, all events and data

Fig.6 FSS_**spread**: 3h rainfall, all events and data



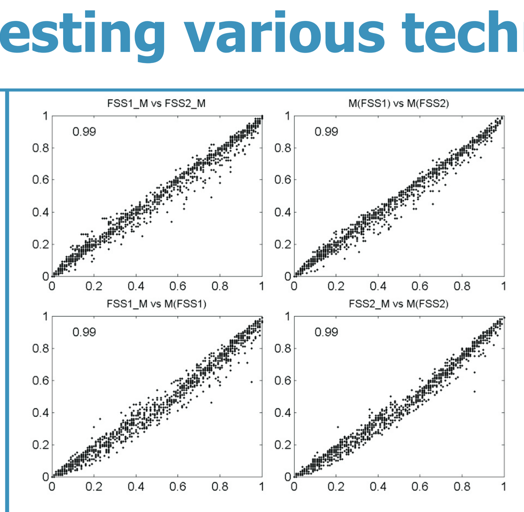
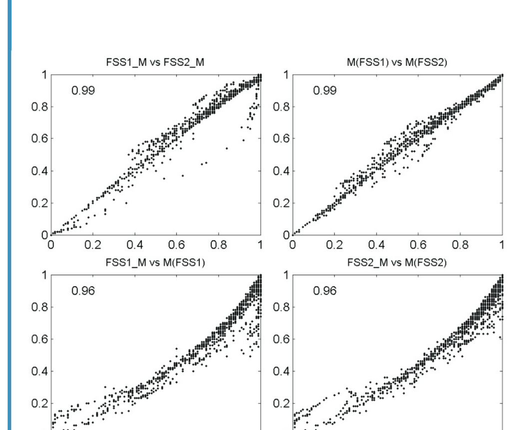


Fig.7 FSS_**skill**: 30 May 2005, all data

Fig.8 FSS_**spread**: 30 May 2005, all data



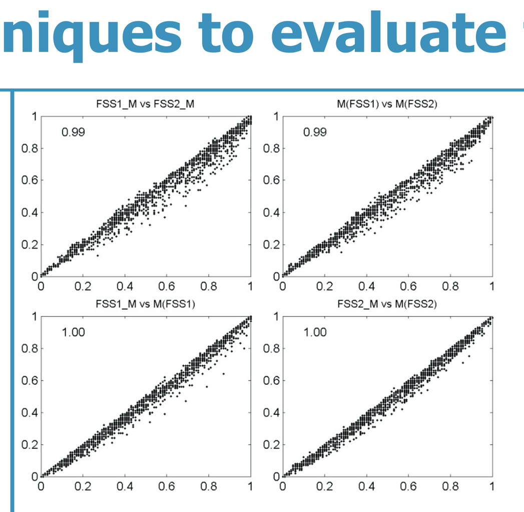
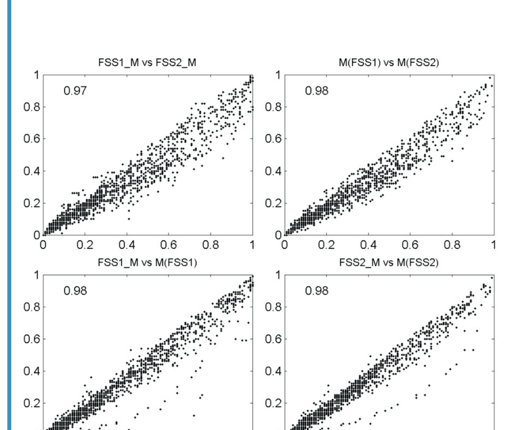


Fig.9 FSS_skill: threshold **1mm**, all events and data

Fig.10 FSS_skill: threshold **10 mm**, all events and data



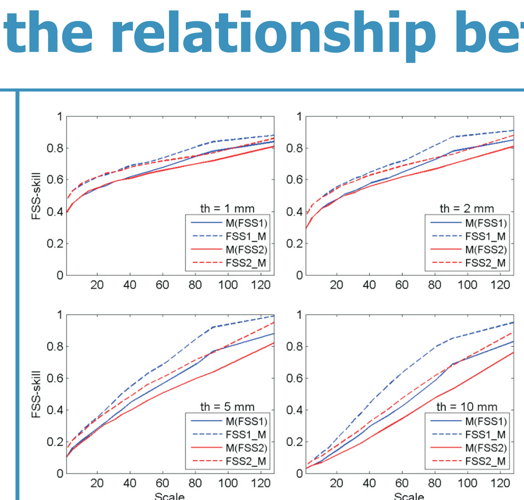
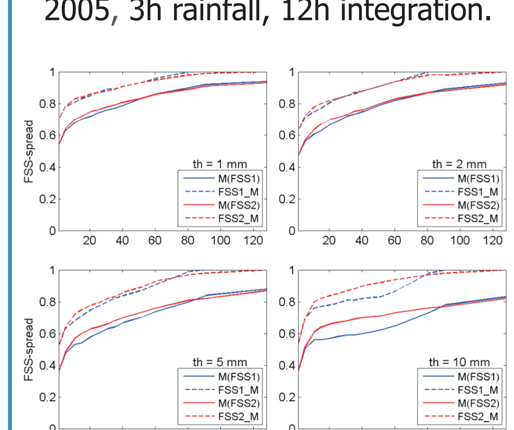


Fig.11 Mean relationship FSS_**skill** vs. scale: 30 May 2005, 3h rainfall, 12h integration

Fig.12 Mean relationship FSS_**spread** vs. scale: 30 May 2005, 3h rainfall, 12h integration.



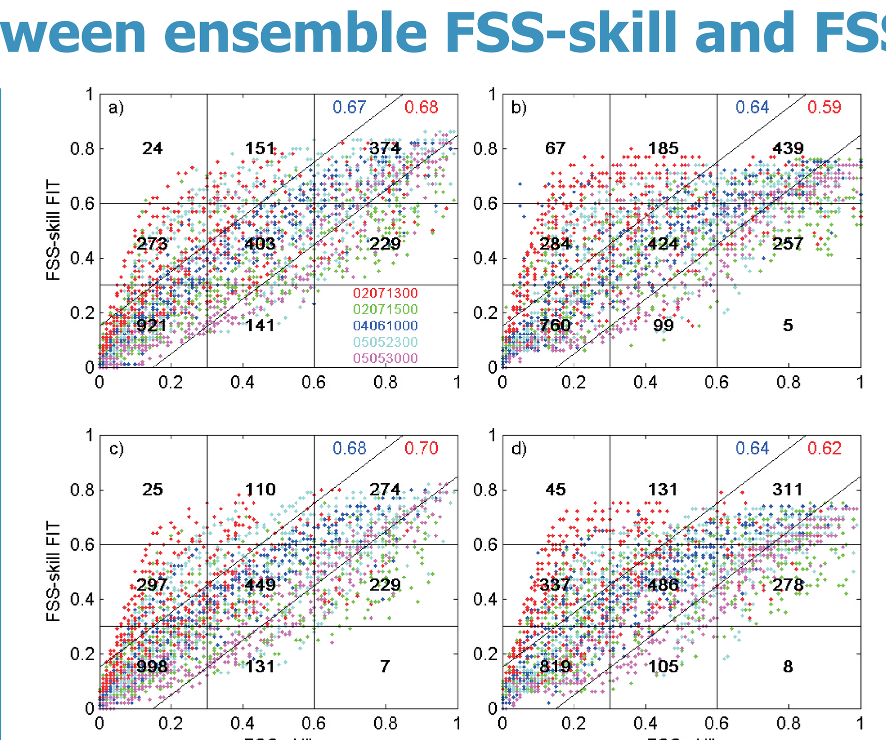


Fig.13 Like Fig.3 - the relationship between prognostic and diagnostic FSS_skill for 3h accumulation. a) M(FSS1), b) FSS1_M, c) M(FSS1), d) FSS2_M. Note, that there is a difference between a) and Fig.3 as a wider spectrum of elementary areas was used in a)- d).

7 Conclusions

1. The results show that the prediction of the ensemble FSS_skill based on a simple statistical evaluation of the spread-skill relationship appears to be a useful technique with an operational potential.

2. The tests of EA definition and averaging showed, that (a) the way of covering the verification domain by EAs does not play a significant role in spread_skill_prognostic skill relationships. (b) the average of the ensemble member FSS, using M(FSS*), shows better skill quality than the use of mean relative cover.

3. The main shortcoming of the study consists in a limited number of convective events. More data are needed to prove the results.

References

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