Statistical Postprocessing of Weather Parameters for a High-Resolution Limited-Area Model

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Overview

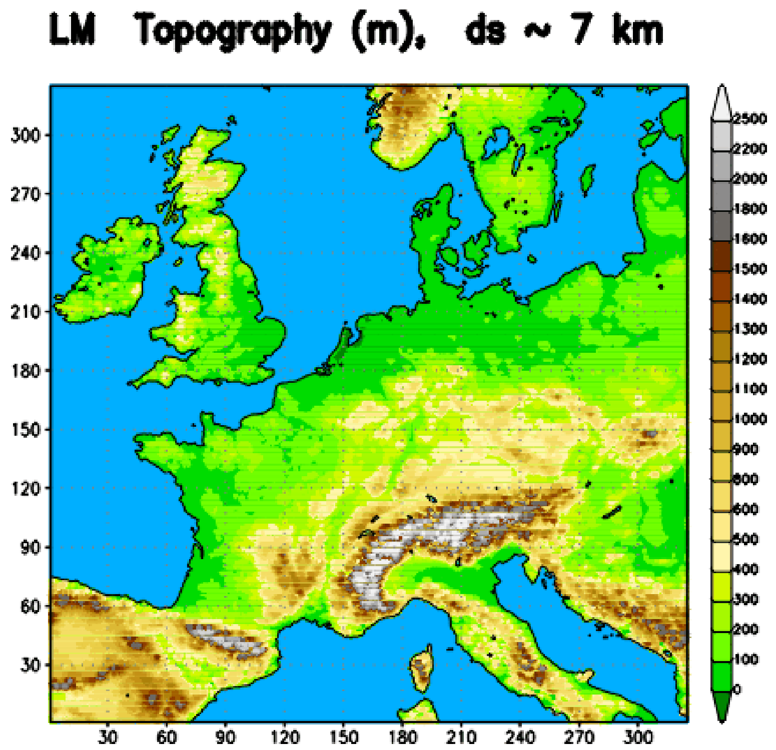
- Introduction
- Description of Method
- Examples
- Verification Results
- Calibration of Reliability Diagrams
- Concluding Remarks

Basic Set-up of the LM

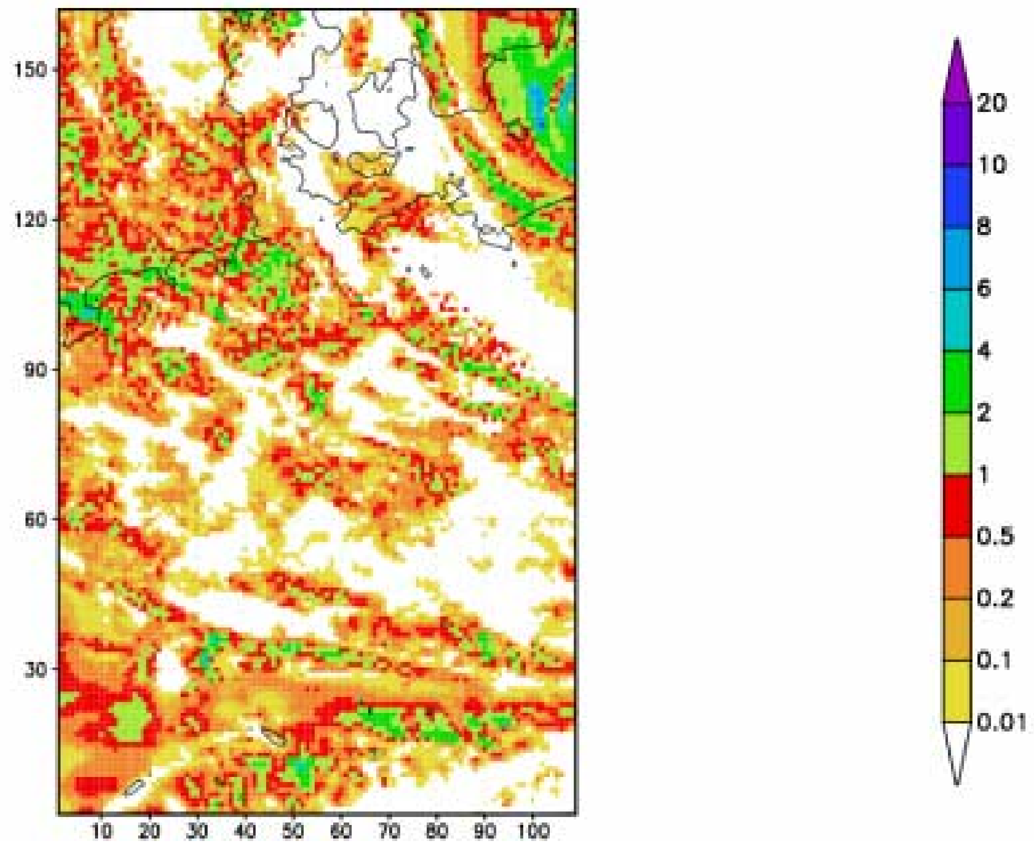
- **Model Configuration**
  Full DM model domain with a grid spacing of 0.0625° (~ 7 km)
  325 x 325 grid points per layer
  35 vertical layers
  timestep: 40 s
  three daily runs at 00, 12, 18 UTC

- **Boundary Conditions**
  Interpolated GME-forecasts with ds ~ 60 km and 31 layers (hourly)
  Hydrostatic pressure at lateral boundaries

- **Data Assimilation**
  Nudging analysis scheme
  Variational soil moisture analysis
  SST analysis 00 UTC
  Snow depth analysis every 6 h



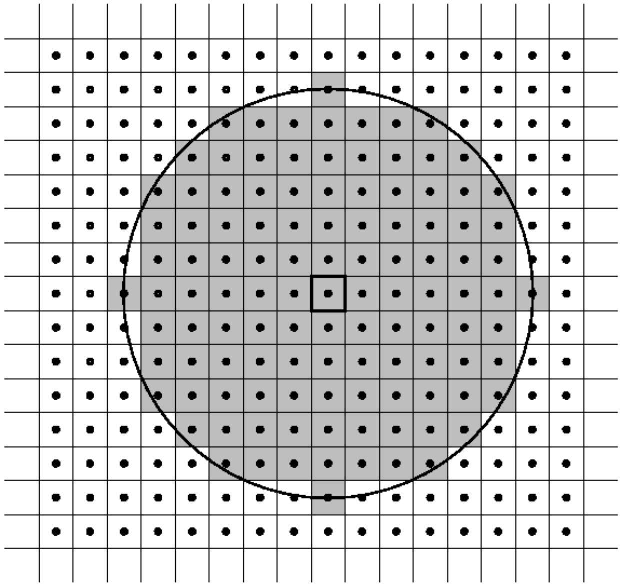
LM Total Precipitation [mm/h] 08.Sept.2001, 00 UTC, vv=14-15 h



Methods

- Neighbourhood Method (NM)
- Wavelet Method
- Experimental Ensemble Integrations

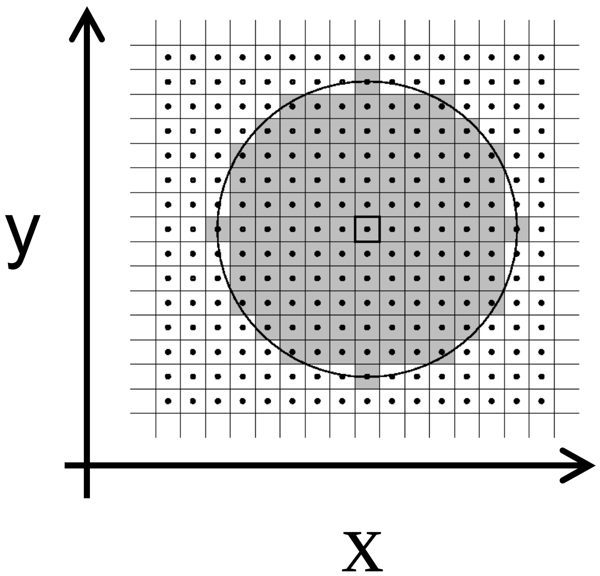
Neighbourhood Method

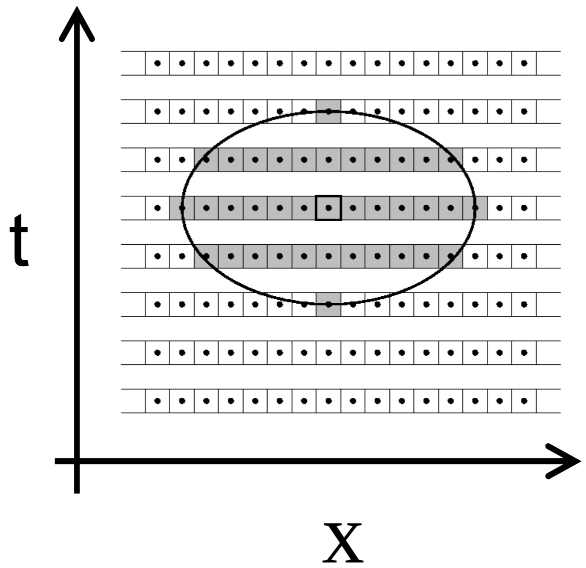


Assumption:

LM-forecasts within a spatio-temporal neighbourhood are assumed to constitute a sample of the forecast at the central grid point

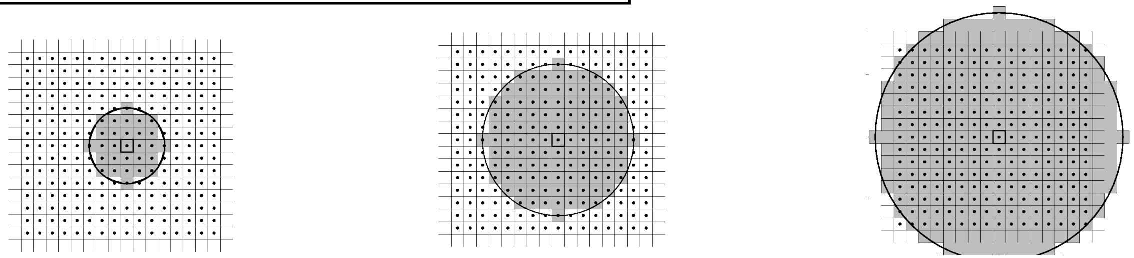
Definition of Neighbourhood I



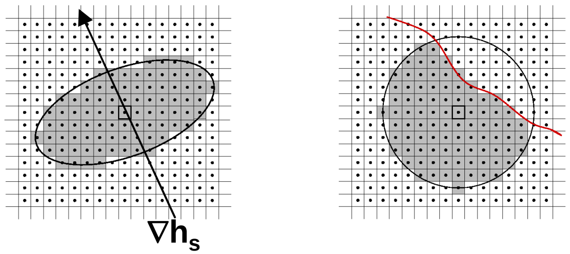


Definition of Neighbourhood II

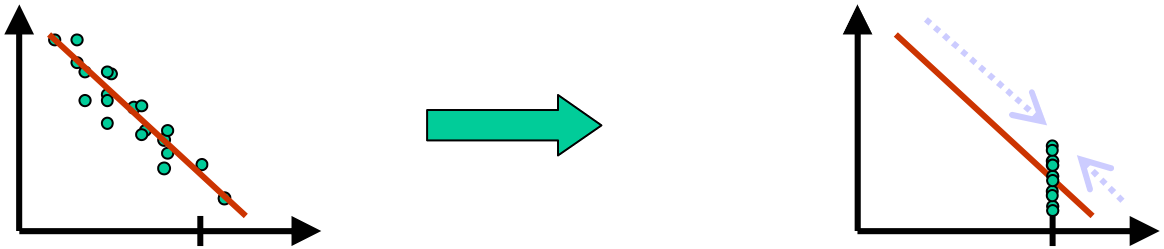
Size
of Area



Form
of Area



Linear
Regressions



Definition of the Quantile Function

The quantile function x is a function of probability p.

If the forecast is distributed according to the probability distribution function F, then

$$x(p) := F^{-1}(p) \text{ for all } p \in [0, 1].$$

There is a probability p that the quantile x(p) is greater than the correct forecast.

(Method according to Moon & Lall, 1994)

Products

„Statistically smoothed” fields

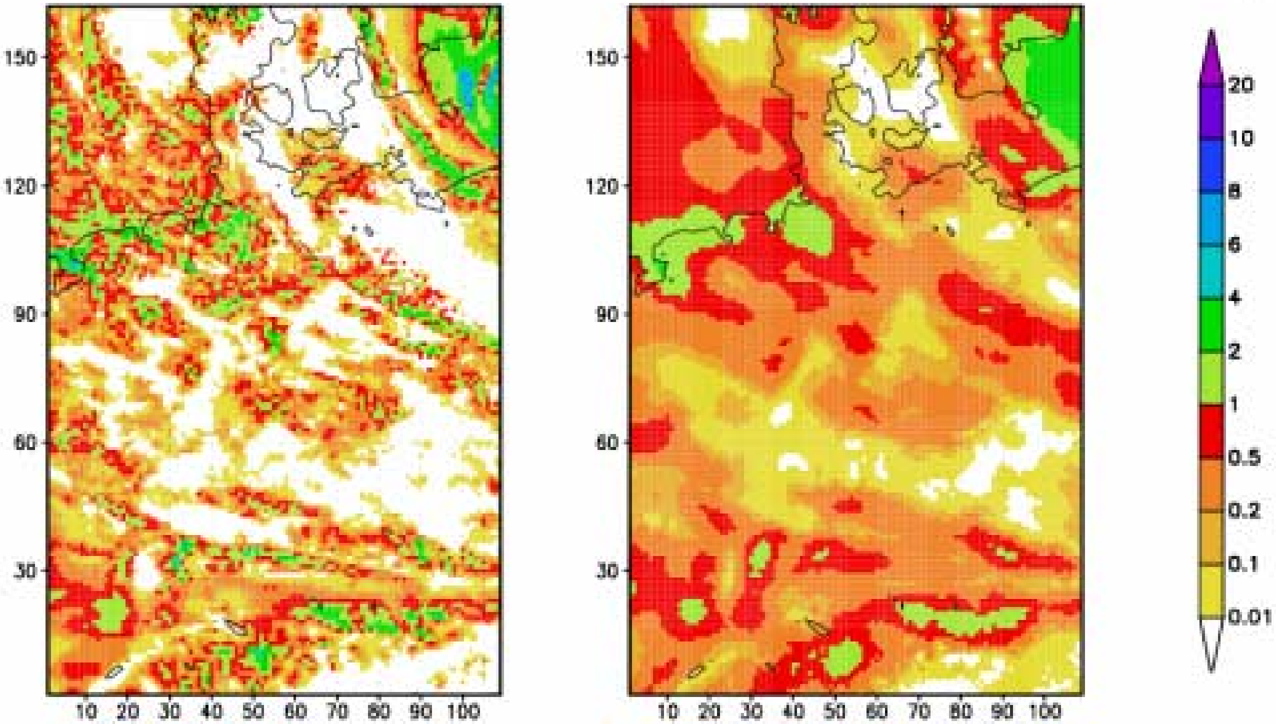
- Quantiles for p = 0.5
- Expectation Values

Probabilistic Information

- Quantiles
- (Probabilities for certain threshold values)

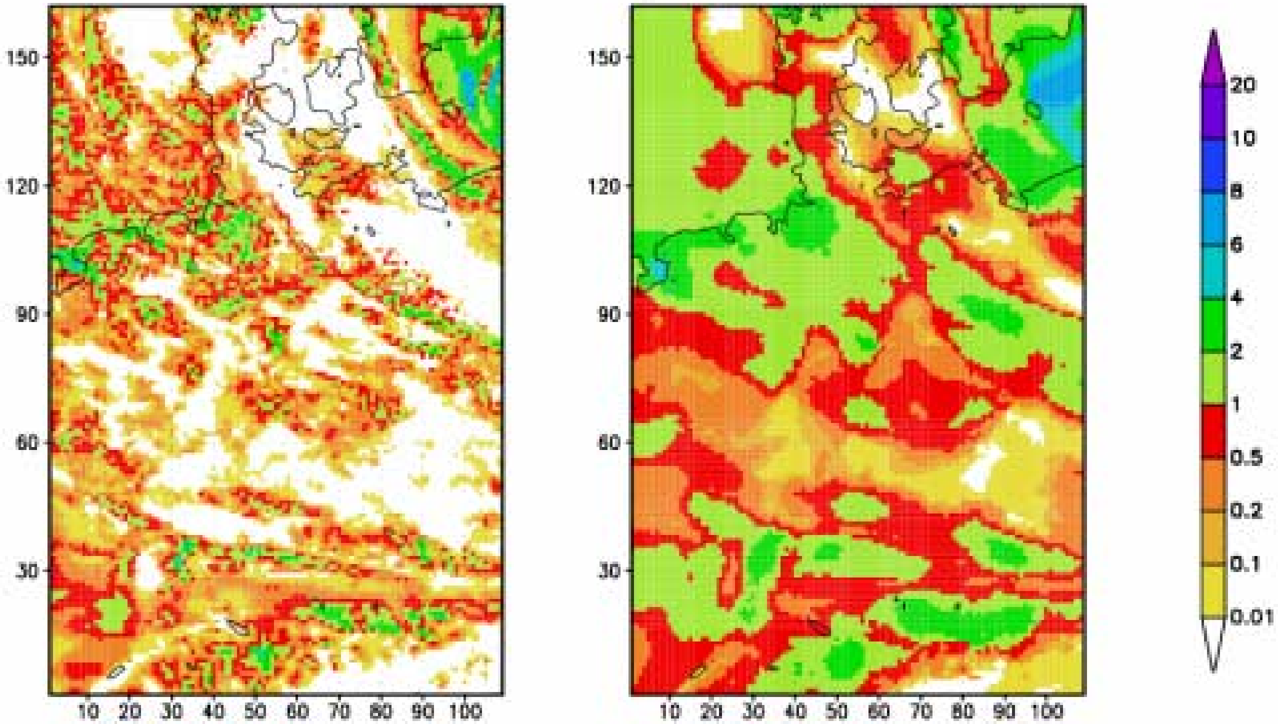
LM Total Precipitation [mm/h] 08.Sept.2001, 00 UTC, vv=14-15 h

Original Forecast Expectation Values



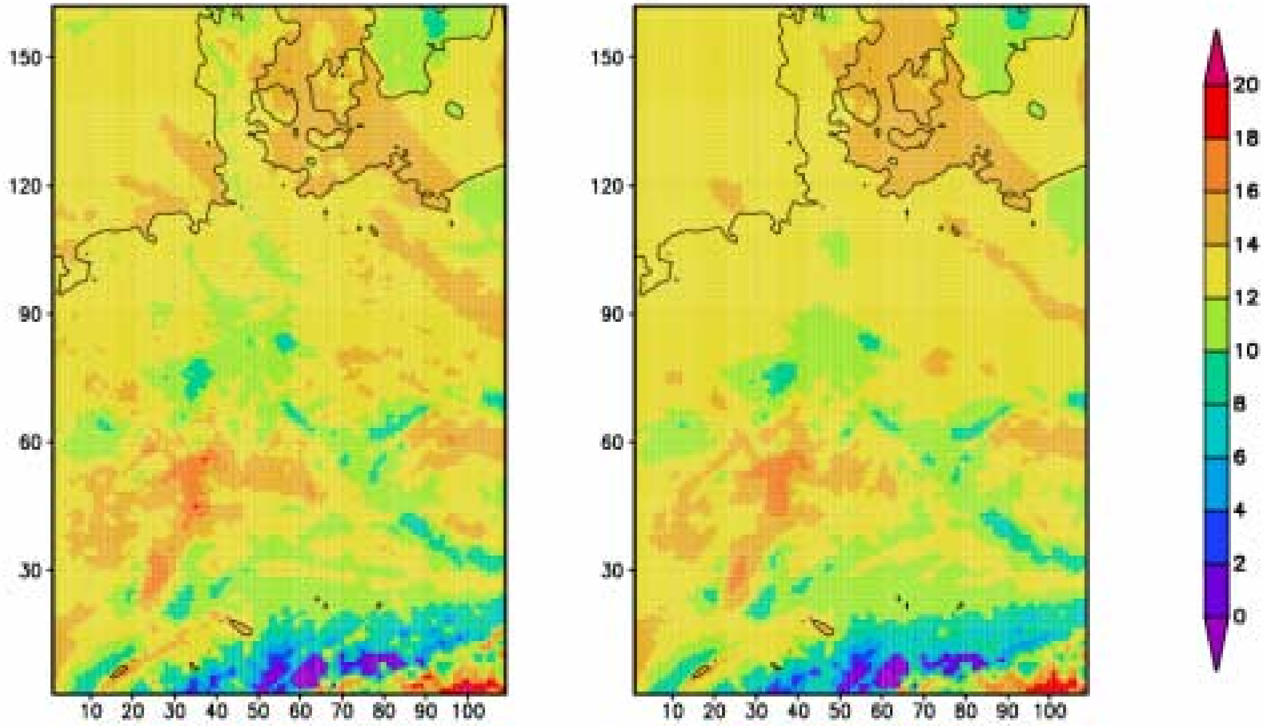
LM Total Precipitation [mm/h] 08.Sept.2001, 00 UTC, vv=14-15 h

Original Forecast **Quantiles for p=0.9**

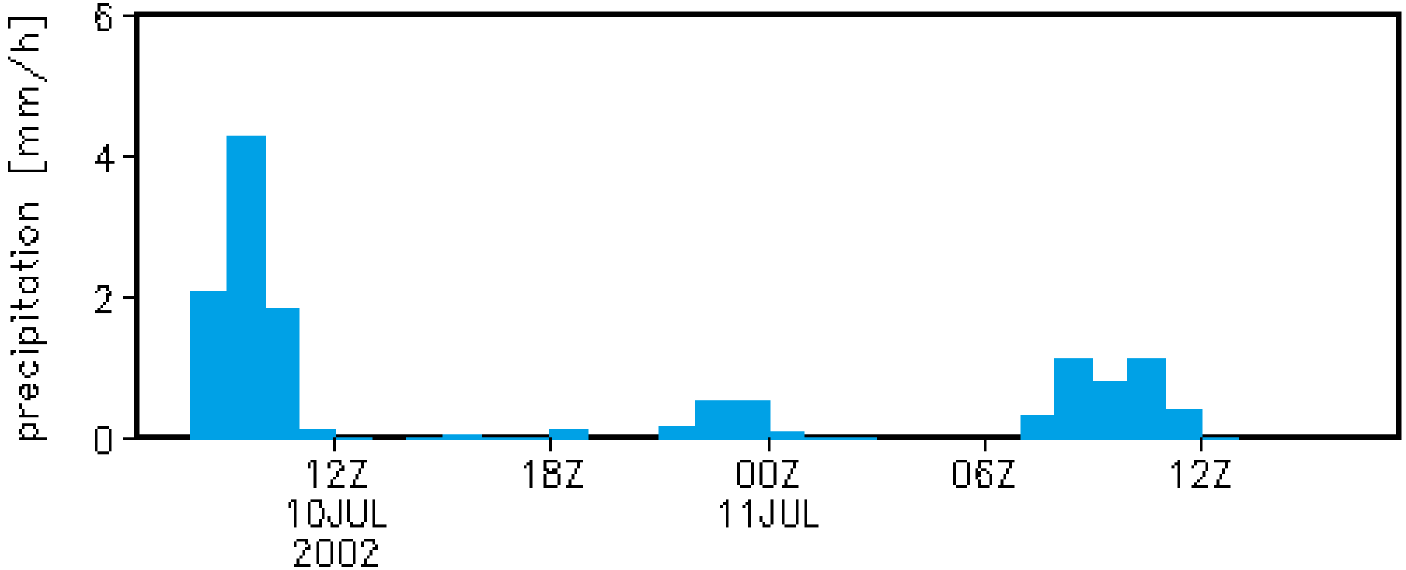


LM T2m [ºC] 08.Sept.2001, 00 UTC, vv=15 h

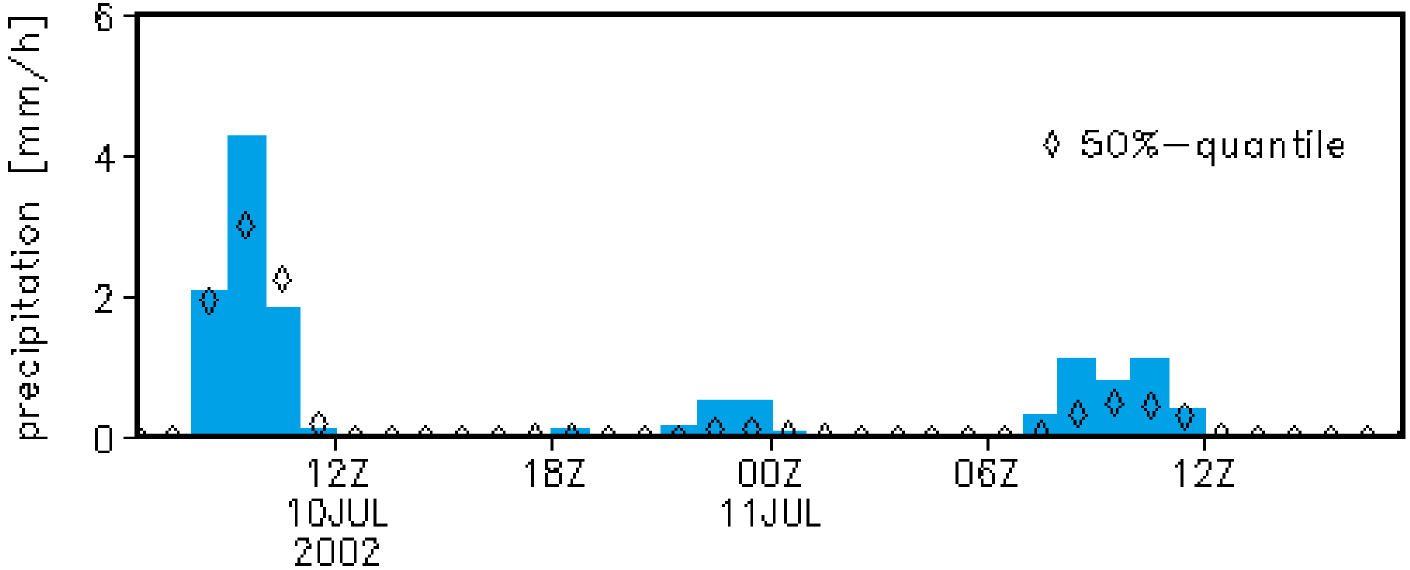
Original Forecast **Quantiles for p=0.5**



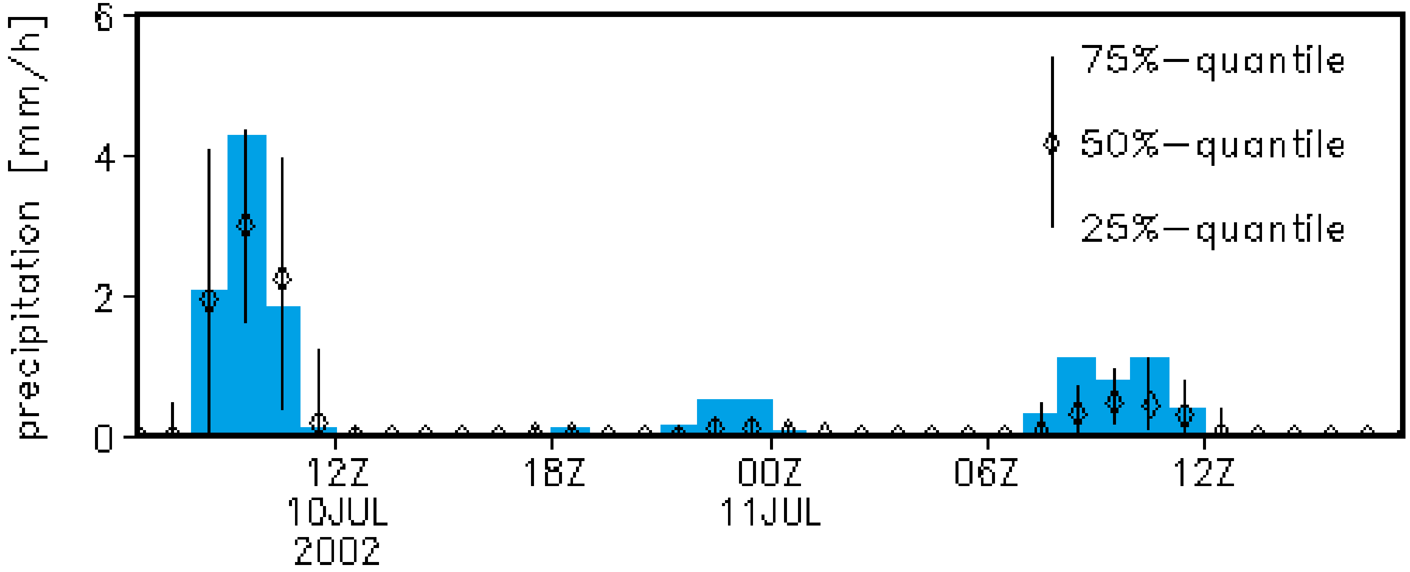
Direct model output of the LM for precipitation at a given grid point



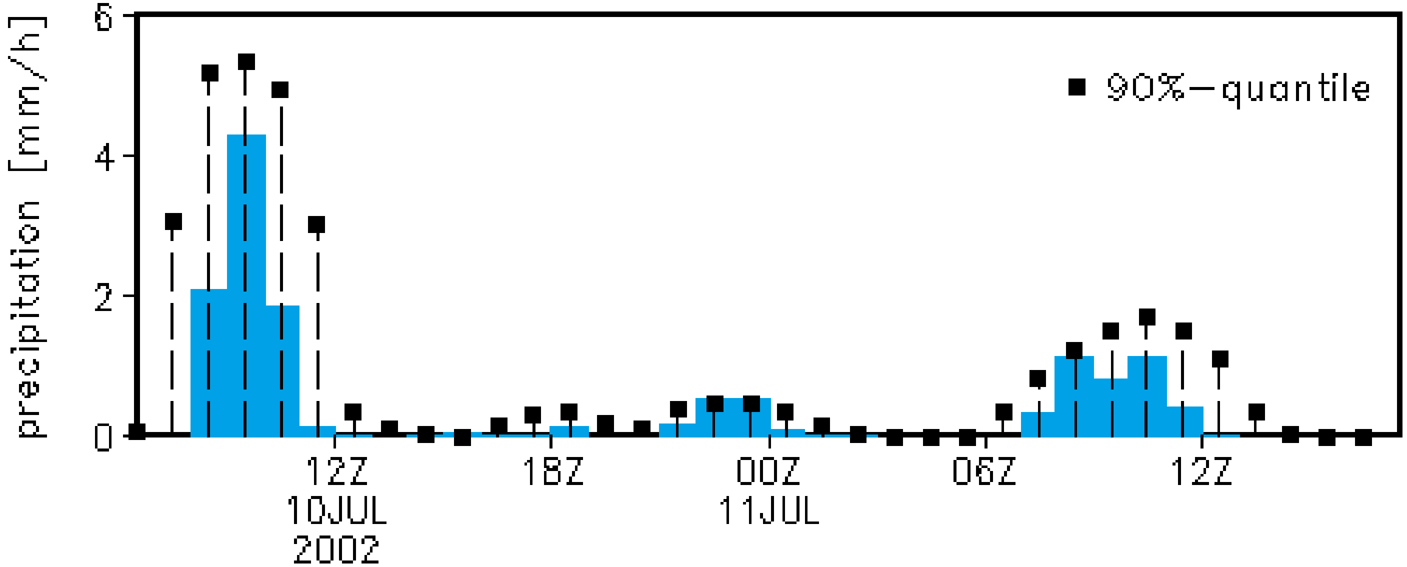
...supplemented by the 50 %-quantile



...supplemented by more quantiles (forecast of uncertainty)



...supplemented by the 90 %-quantile (forecast of risk)



Verification

Data

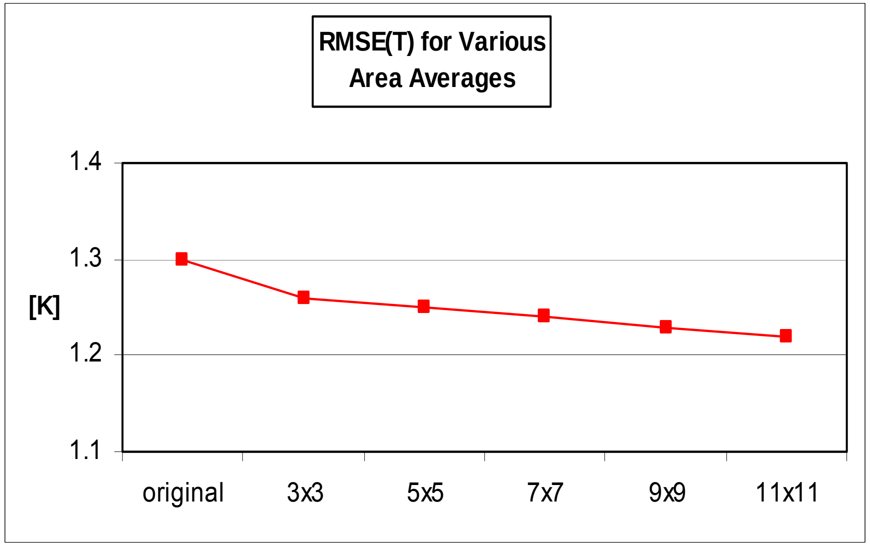
LM forecasts; 1.-15.09.2001; 00 UTC starting time
1 h values; 6-30 h forecast time
all SYNOPs available from German stations
comparison with nearest land grid point

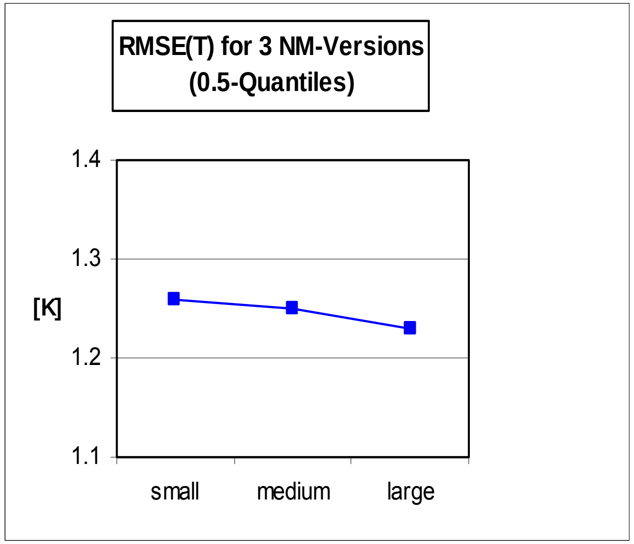
NM-Versions

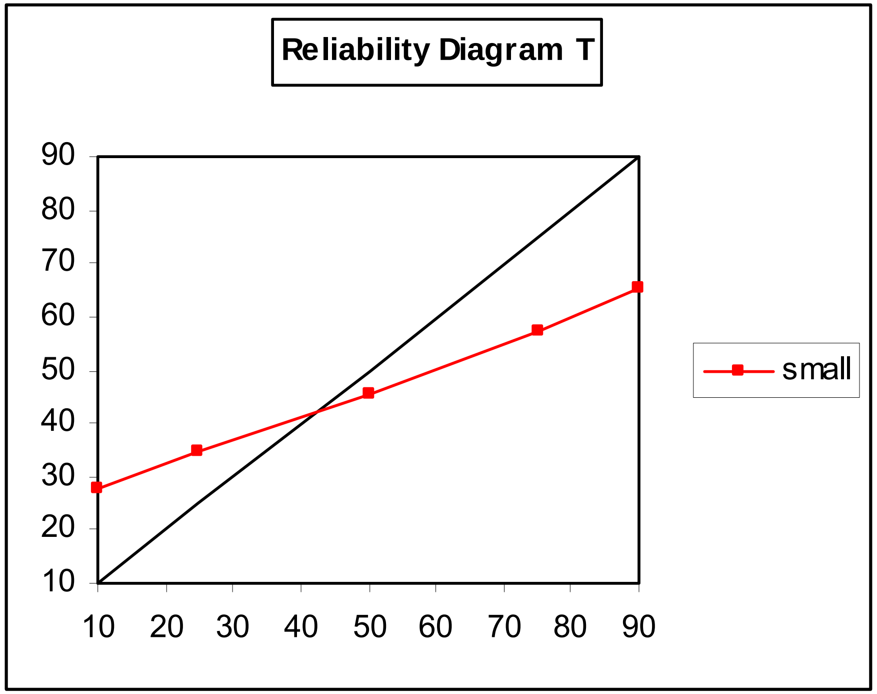
small:	3 time levels (3 h); radius: $3\Delta s$ ($\approx$ 20 km)
medium:	3 time levels (3 h); radius: $5\Delta s$ ($\approx$ 35 km)
large:	7 time levels (7 h); radius: $7\Delta s$ ($\approx$ 50 km)

Averaging

square areas of different sizes
temperatures adjusted with -0.65 K/(100 m)


RMSE(T) for Various
Area Averages
1.4
1.3
[K]
1.2
1.1
original
3x3
5x5
7x7
9x9
11x11


RMSE(T) for 3 NM-Versions
(0.5-Quantiles)
1.4
1.3
[K]
1.2
1.1
small
medium
large


Reliability Diagram T
90
80
70
60
50
40
30
20
10
10
20
30
40
50
60
70
80
90
small

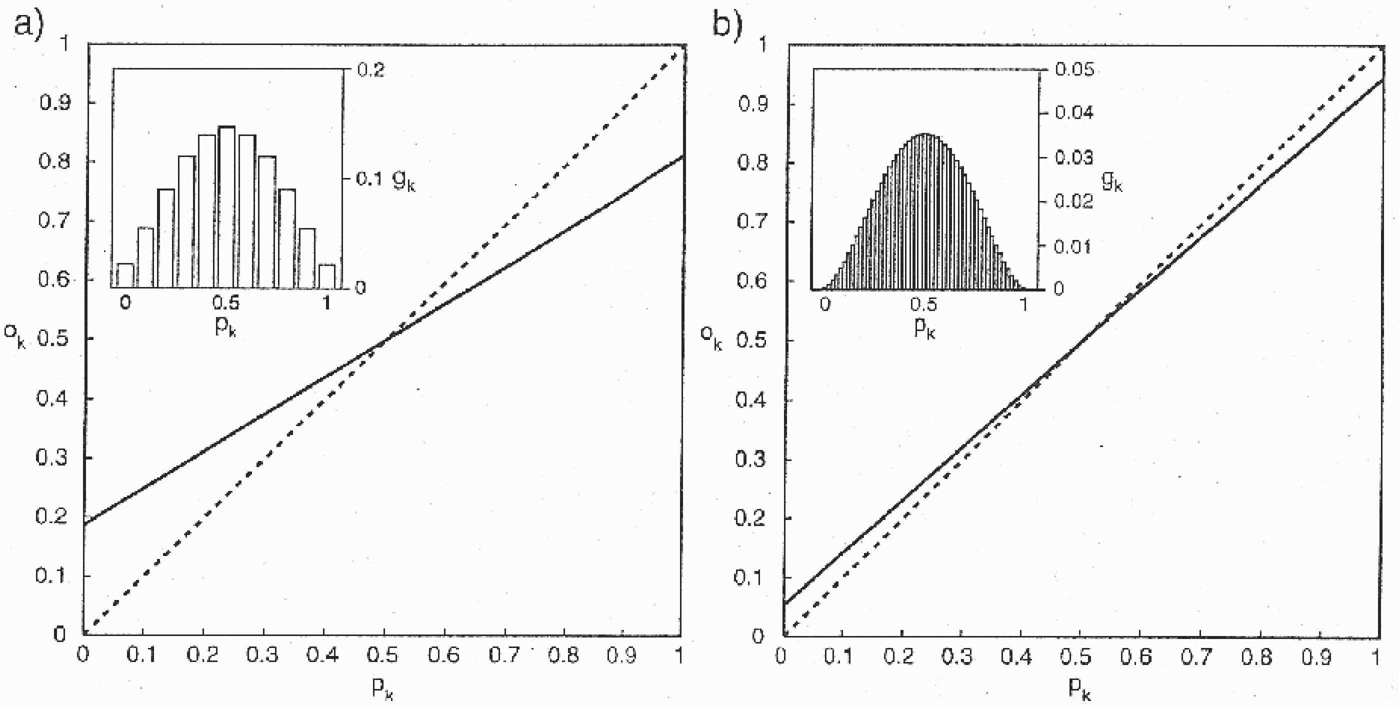
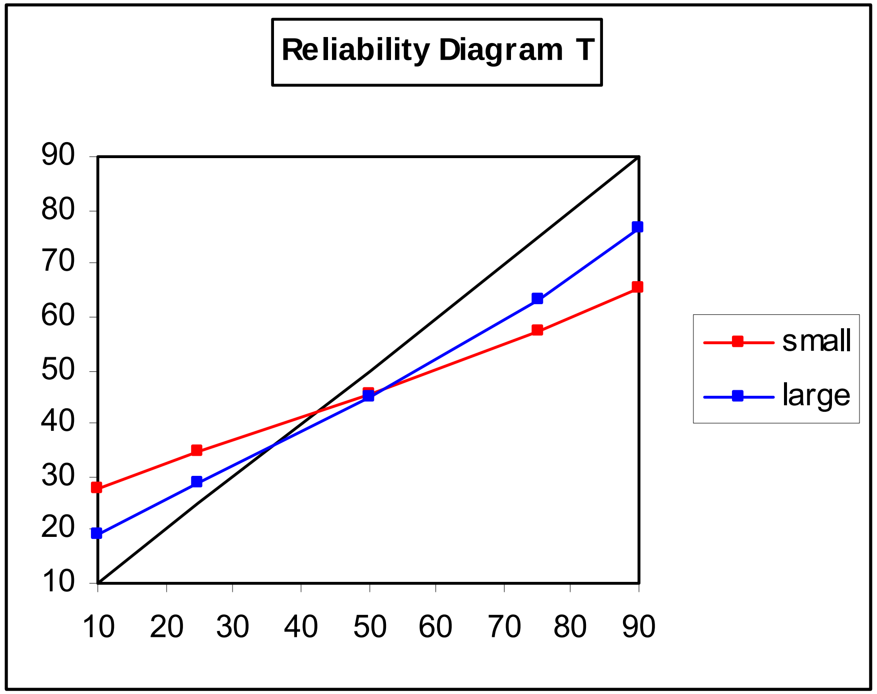
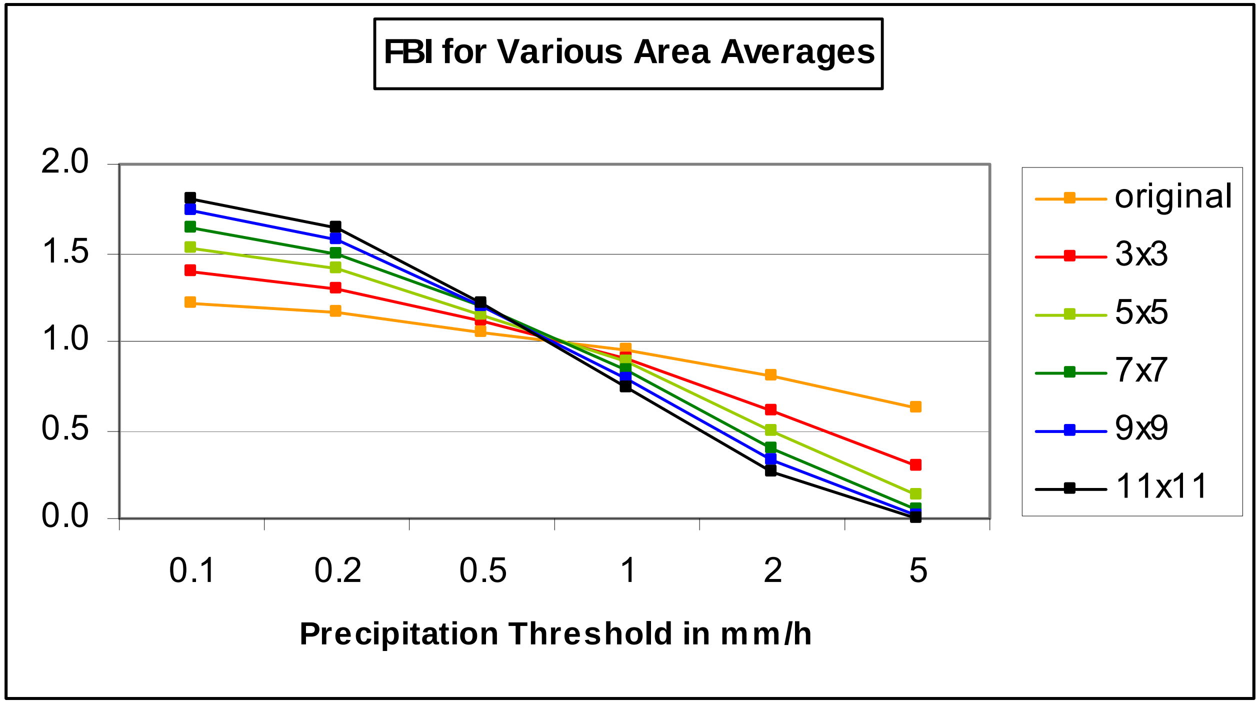
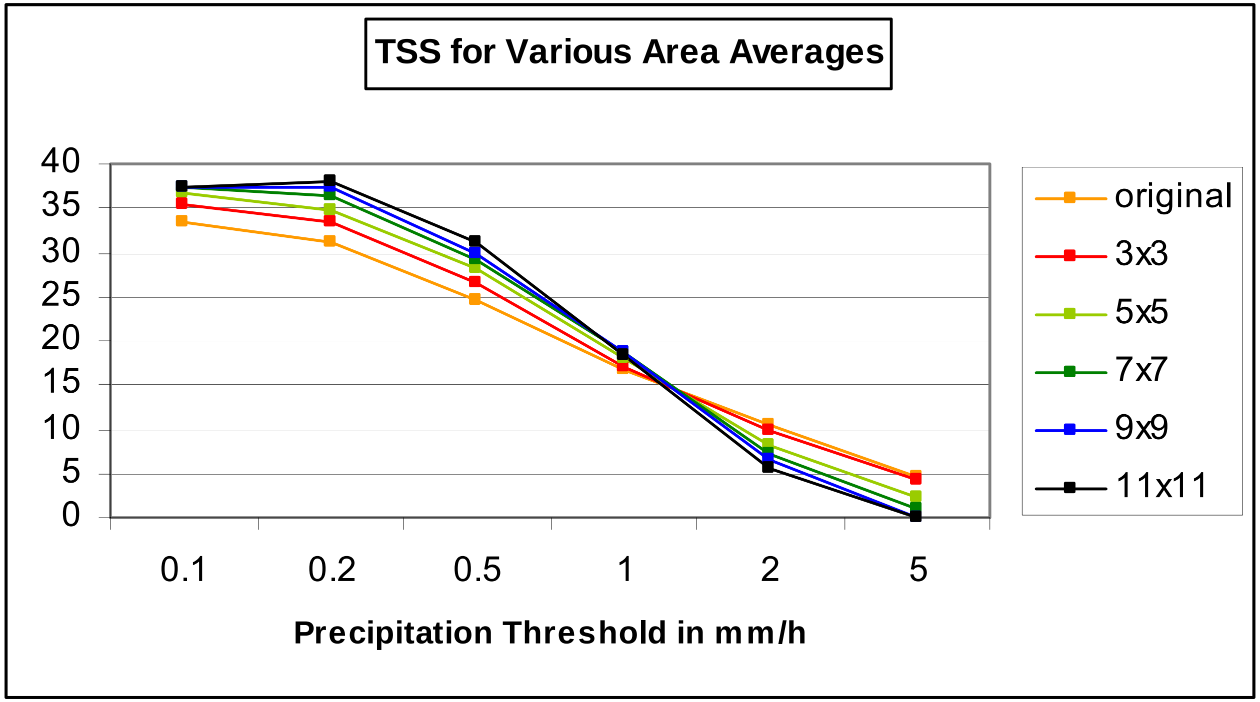


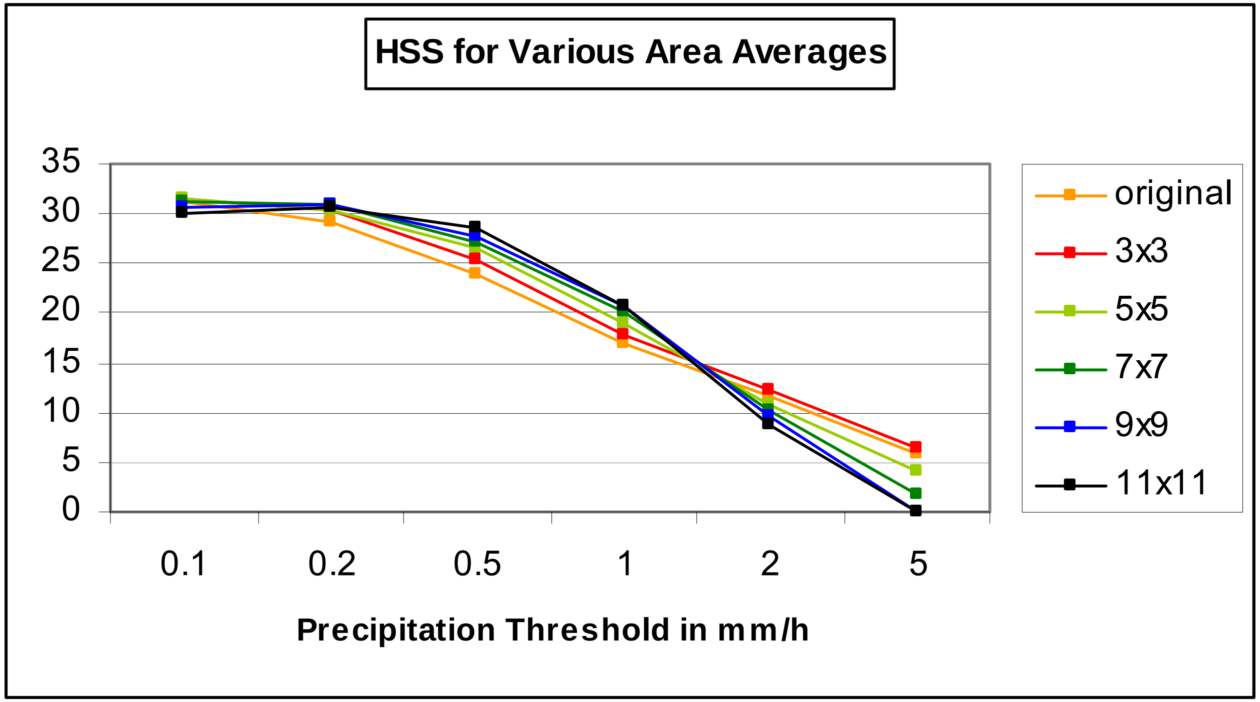
Figure 3. Reliability diagrams for theoretical ensemble forecasts for (a) a 10-member ensemble prediction system (EPS) and (b) a 50-member EPS. Distribution of underlying forecast probabilities is completely reliable and specified by a beta distribution with $r = s = 3$. See text for details and explanation of symbols.

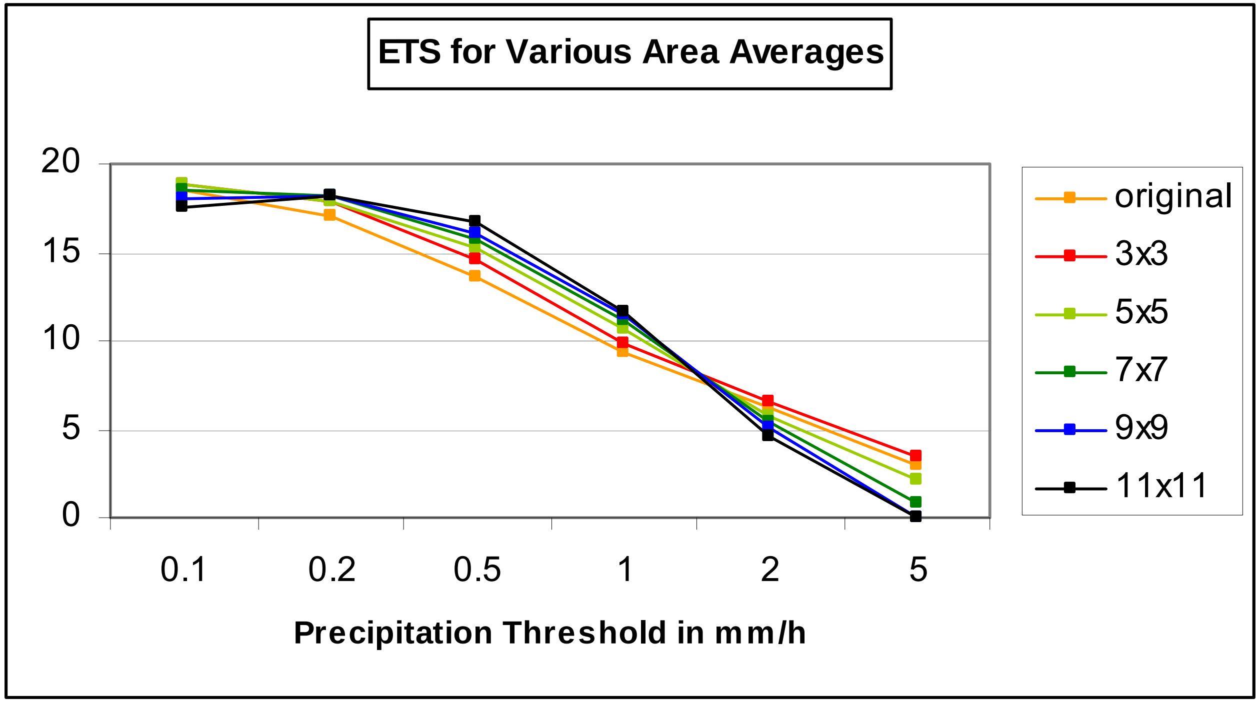
Richardson, D.S., 2001: Measures of skill and value of ensemble prediction systems, their interrelationship and the effect of ensemble size. Q.J.R.Meteorol.Soc., Vol.127, pp. 2473-2489)

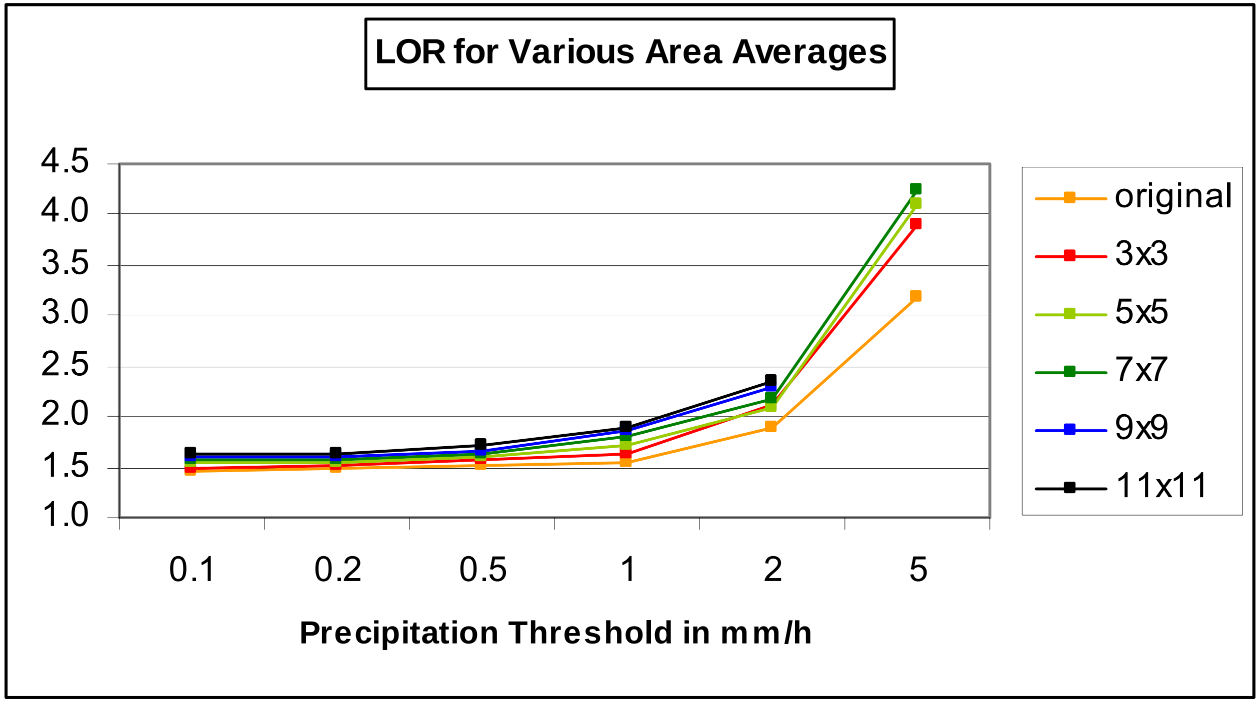

Reliability Diagram T
90
80
70
60
50
40
30
20
10
10
20
30
40
50
60
70
80
90
small
large


FBI for Various Area Averages
2.0
1.5
1.0
0.5
0.0
0.1
0.2
0.5
1
2
5
Precipitation Threshold in mm/h
original
3x3
5x5
7x7
9x9
11x11

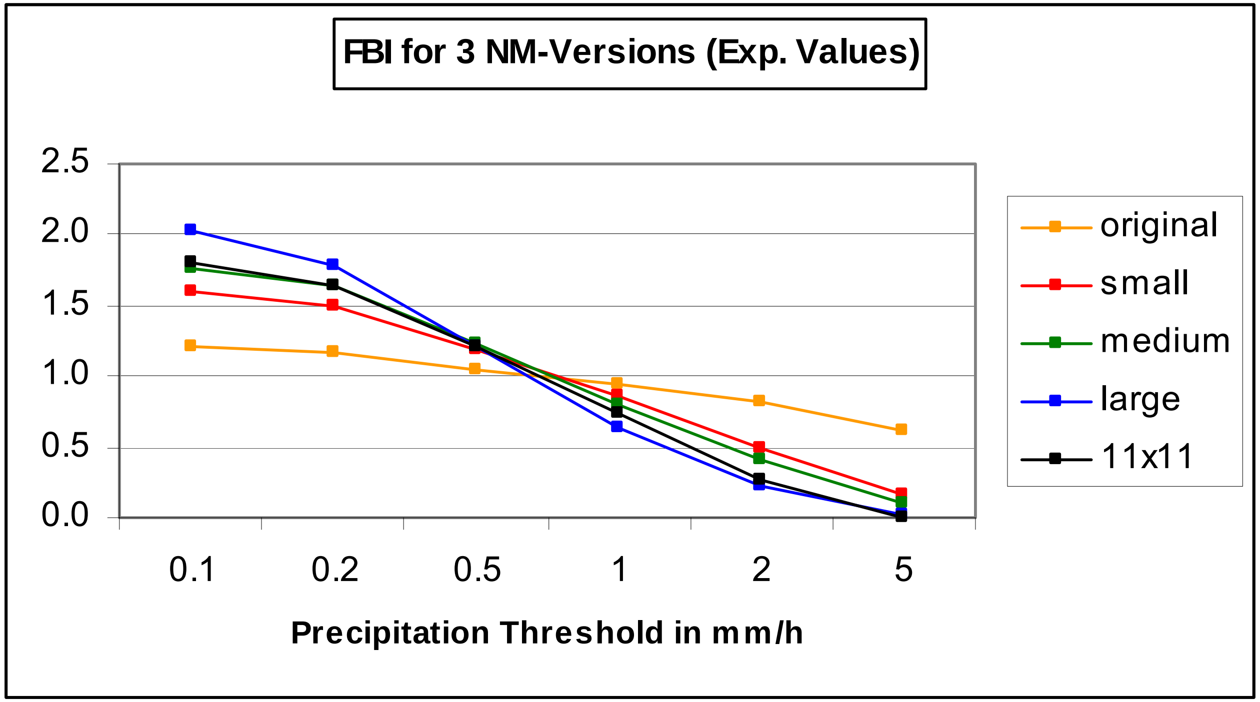

TSS for Various Area Averages
40
35
30
25
20
15
10
5
0
0.1
0.2
0.5
1
2
5
Precipitation Threshold in mm/h
original
3x3
5x5
7x7
9x9
11x11

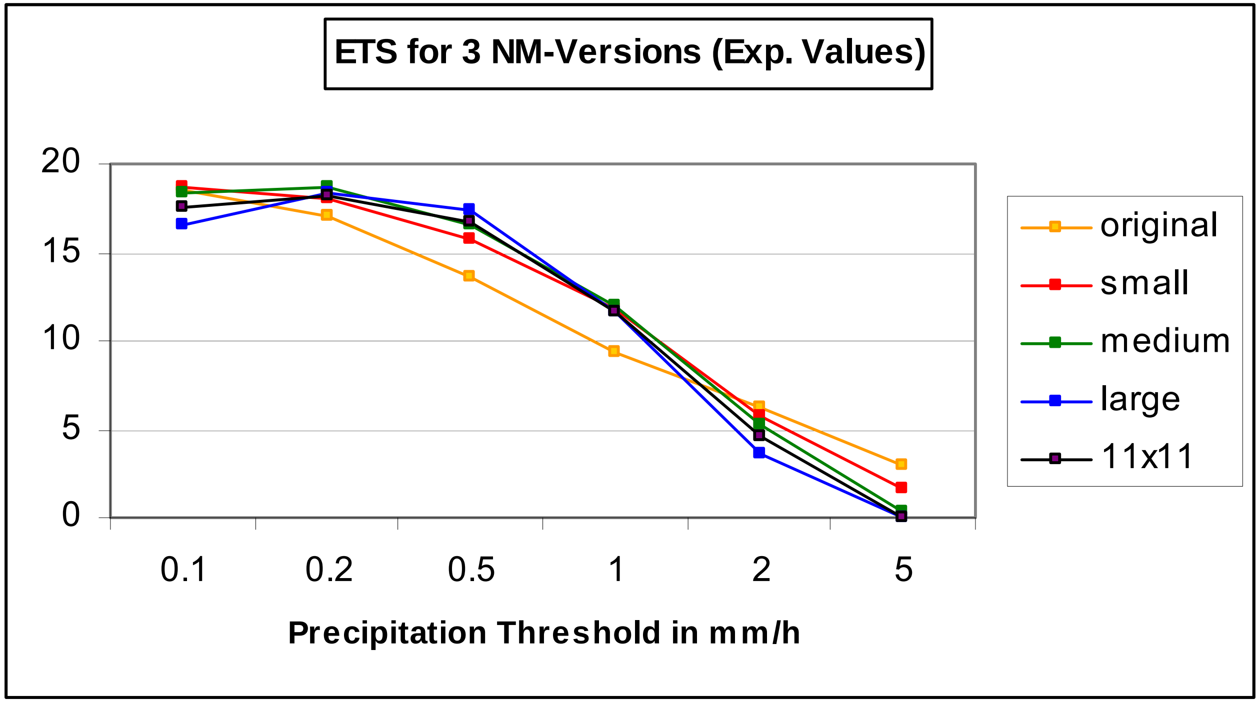

HSS for Various Area Averages
35
30
25
20
15
10
5
0
0.1
0.2
0.5
1
2
5
Precipitation Threshold in mm/h
original
3x3
5x5
7x7
9x9
11x11


ETS for Various Area Averages
20
15
10
5
0
0.1
0.2
0.5
1
2
5
Precipitation Threshold in mm/h
original
3x3
5x5
7x7
9x9
11x11

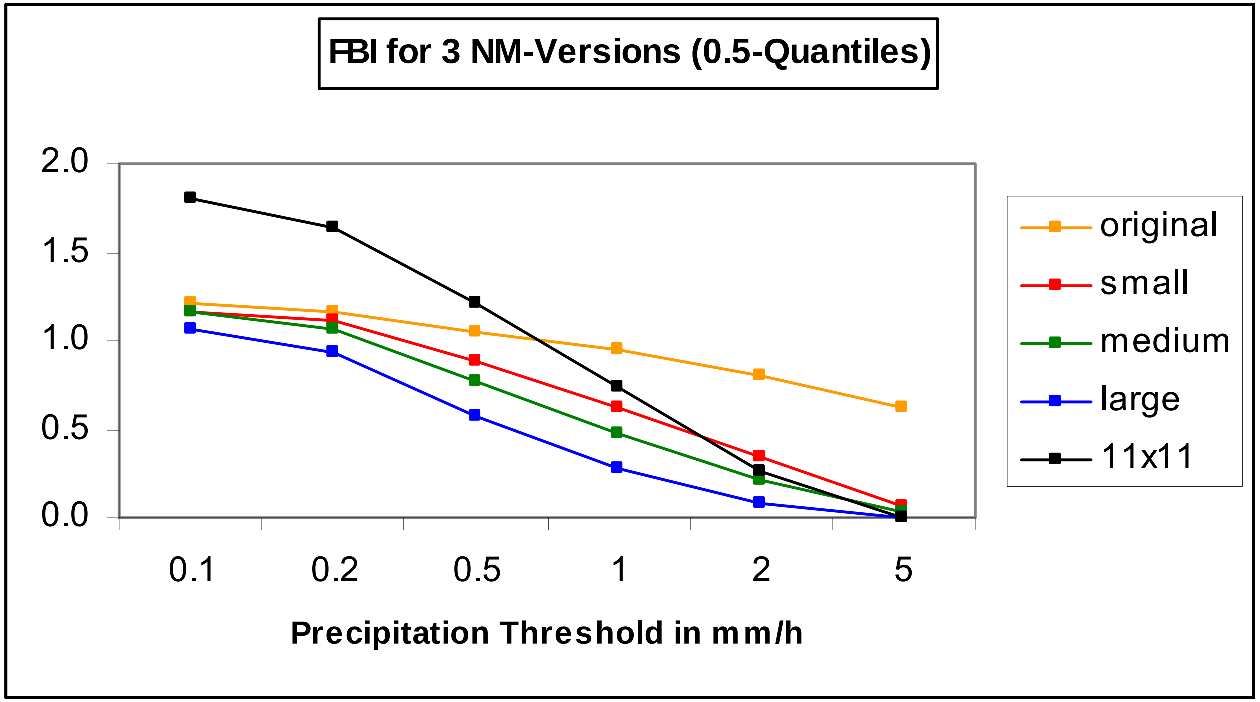


LOR for Various Area Averages
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.1
0.2
0.5
1
2
5
Precipitation Threshold in mm/h
original
3x3
5x5
7x7
9x9
11x11

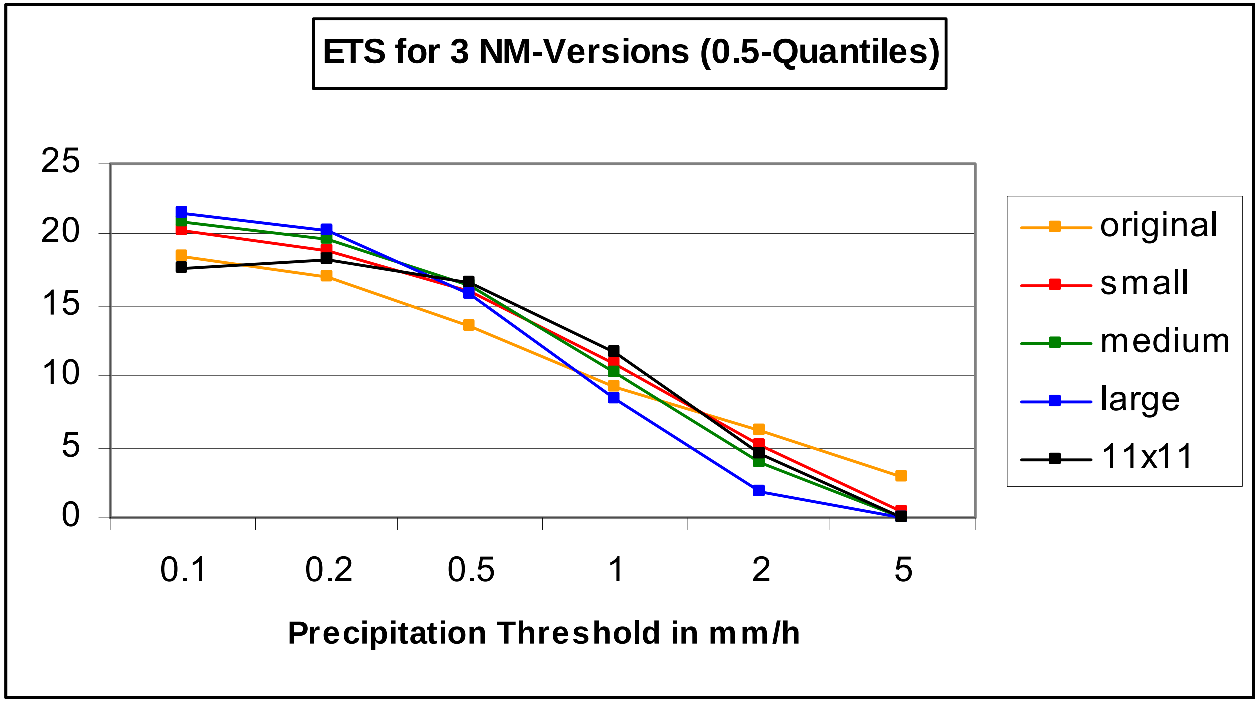

FBI for 3 NM-Versions (Exp. Values)
2.5
2.0
1.5
1.0
0.5
0.0
0.1
0.2
0.5
1
2
5
Precipitation Threshold in mm/h
original
small
medium
large
11x11

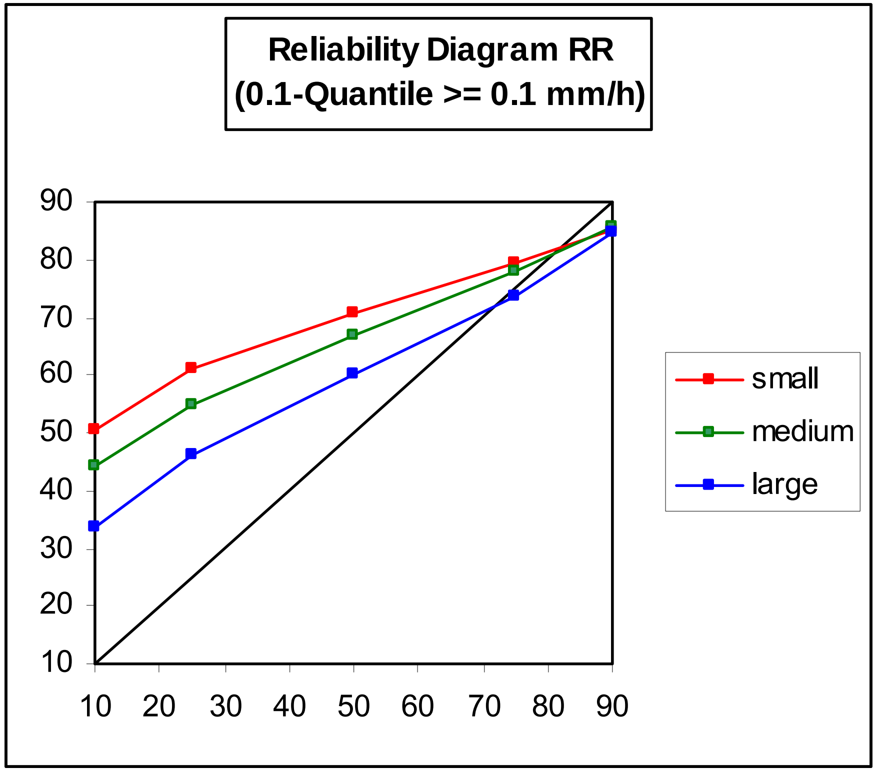


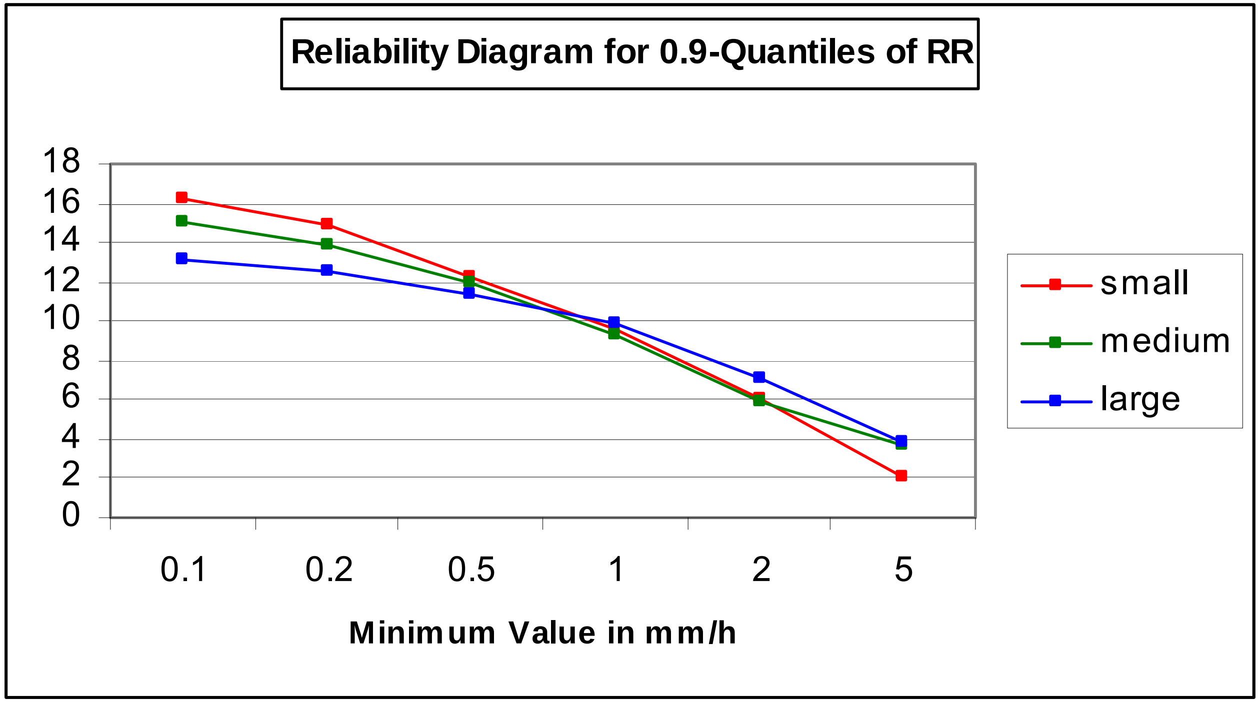
ETS for 3 NM-Versions (Exp. Values)
20
15
10
5
0
0.1
0.2
0.5
1
2
5
Precipitation Threshold in mm/h
original
small
medium
large
11x11

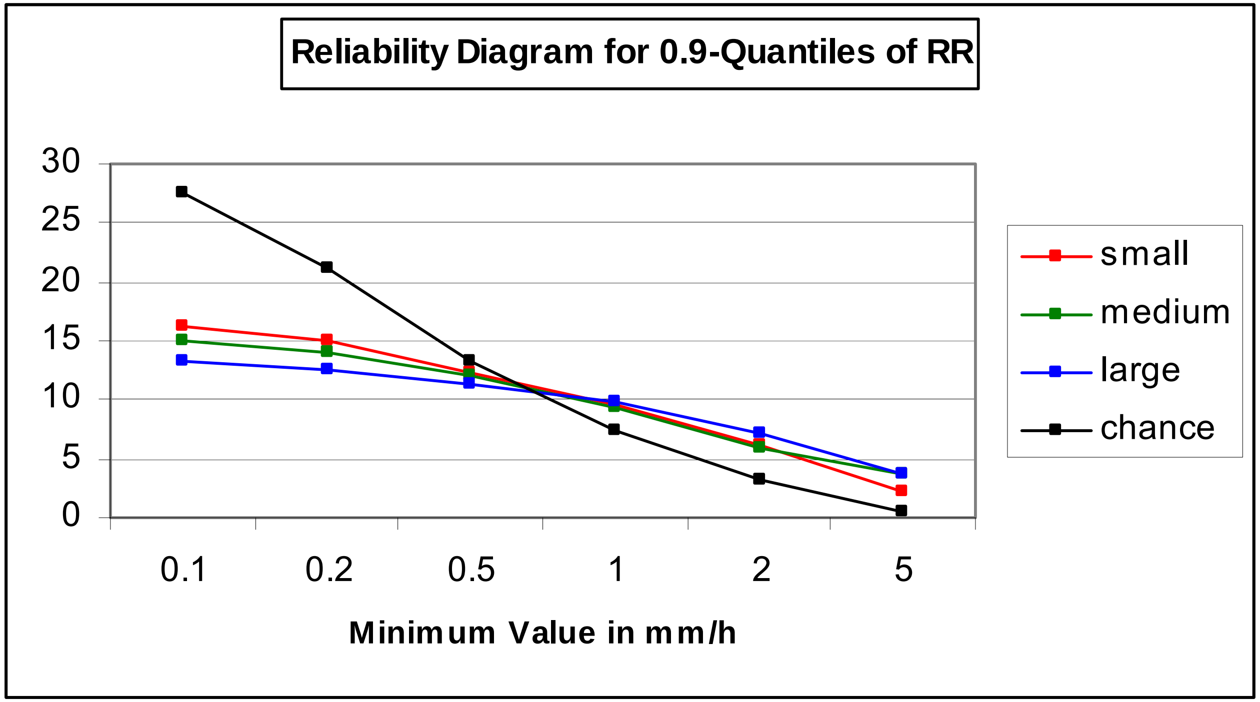


FBI for 3 NM-Versions (0.5-Quantiles)
2.0
1.5
1.0
0.5
0.0
0.1
0.2
0.5
1
2
5
Precipitation Threshold in mm/h
original
small
medium
large
11x11


ETS for 3 NM-Versions (0.5-Quantiles)
25
20
15
10
5
0
0.1
0.2
0.5
1
2
5
Precipitation Threshold in mm/h
original
small
medium
large
11x11


Reliability Diagram RR
(0.1-Quantile >= 0.1 mm/h)
90
80
70
60
50
40
30
20
10
10 20 30 40 50 60 70 80 90
small
medium
large


Reliability Diagram for 0.9-Quantiles of RR
18
16
14
12
10
8
6
4
2
0
0.1
0.2
0.5
1
2
5
Minimum Value in mm/h
small
medium
large


Reliability Diagram for 0.9-Quantiles of RR
30
25
20
15
10
5
0
0.1
0.2
0.5
1
2
5
Minimum Value in mm/h
small
medium
large
chance

Calibration

- Empirical Approach:
  use a large data sets of forecasts and observations

PRO: covers all relevant effects
CON: calibration is dependent on LM-version

- Theoretical Approach:
  focus on the effect of limited sample size only

PRO: effect can be quantified theoretically, without large data sets
calibration is independent of LM-version
CON: all other effects are neglected

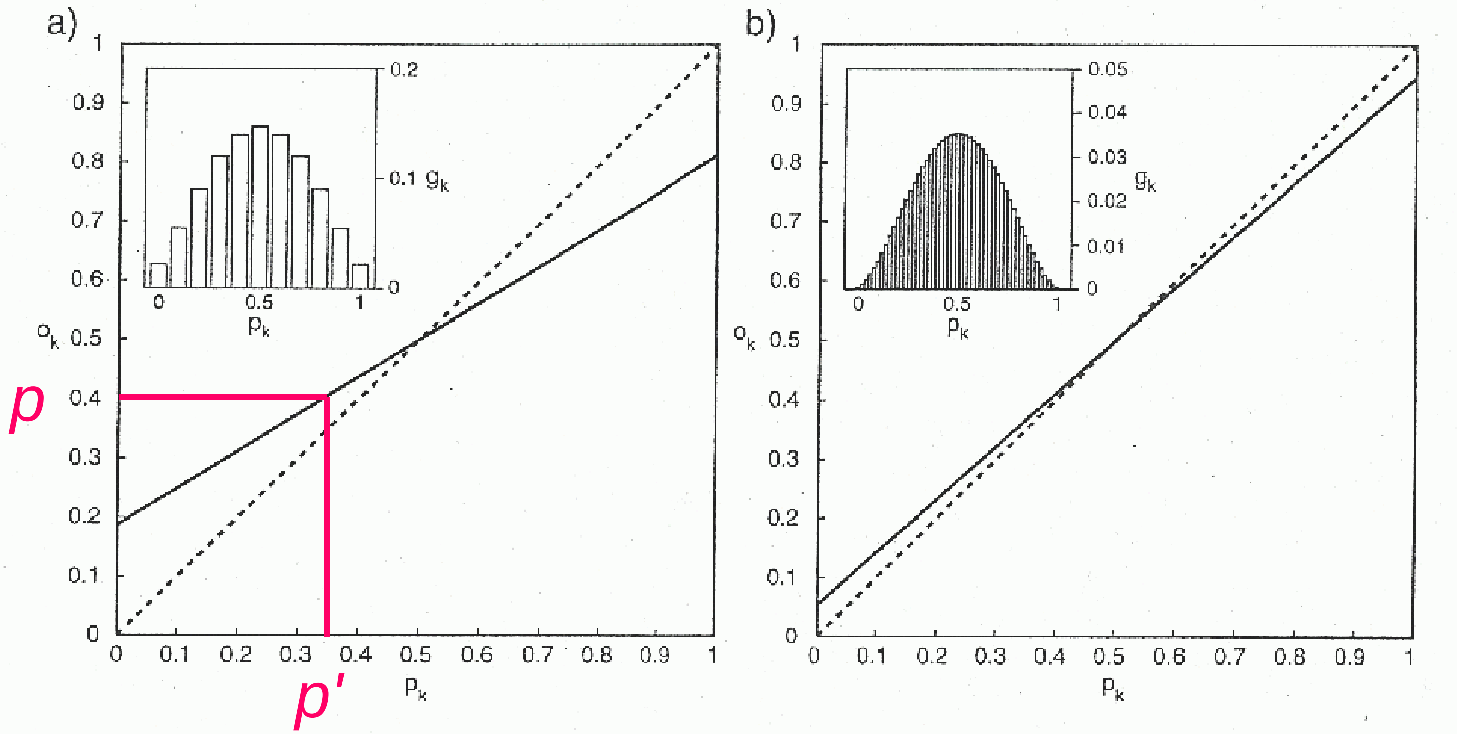
Calibration Procedure:

- choose probability *p* of the desired quantile (e.g. *p*=90%, if you would like to estimate the 90%-quantile)

- determine sample size *M*, frequency μ of the event and predictability σ of the event *(a priori)*

- calculate a probability $p' = p'(p, M, \mu, \sigma)$ from statistical theory (Richardson, 2001), let's say $p' = 95\%$

- estimate 95%-quantile and redefine it as a 90%-quantile



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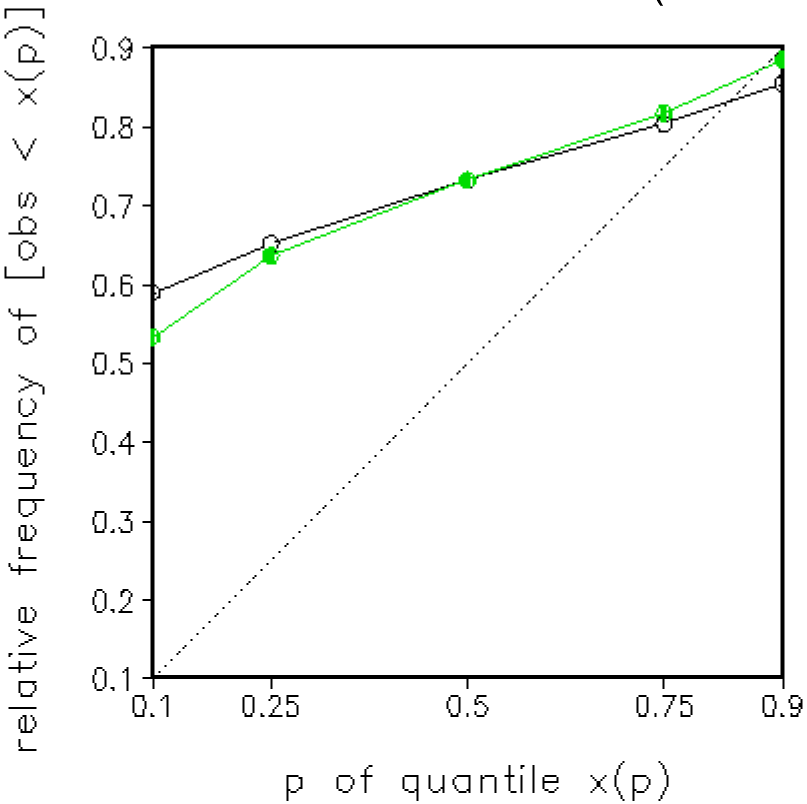
Preliminary Results of Calibration (small neighbourhood):

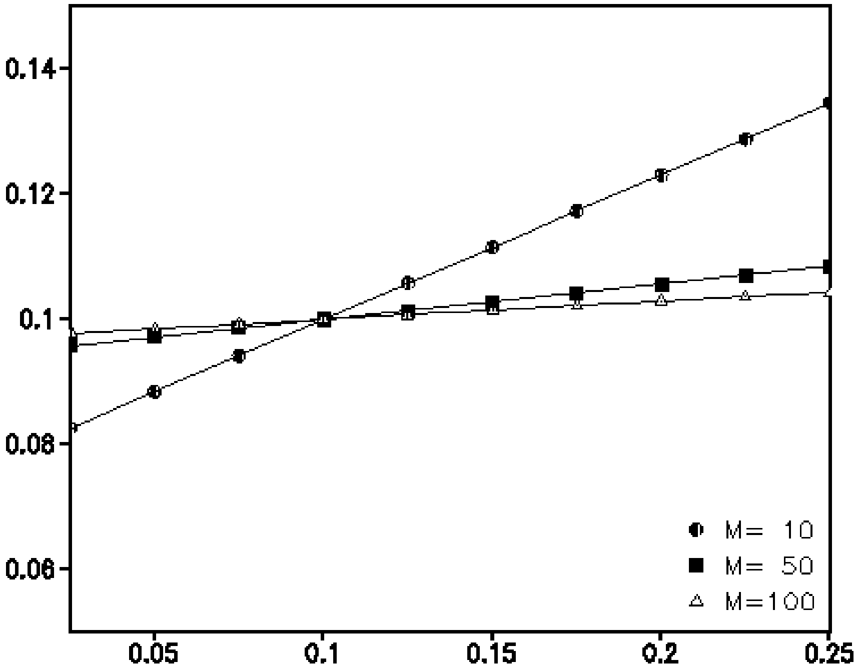
(LM forecasts; 10.-24.07.2002; 00 UTC starting time)



Determination of
$p' = p'(p, M, \mu, \sigma)$:

integrate $p' = p'(p, M, \mu, \sigma)$ over all possible values of μ and σ and over M=[1,80]

Effect of Limited Sample Size on Quantiles for p=0.9



Probability of exceedance of $\hat{x}(0.9)$ depending on the observed frequency μ for different values of effective sample size *M* and a prescribed value of $\sigma^2 = 0.25\,\mu\,(1-\mu)$

Concluding Remarks

“Statistically Smoothed” Fields

For temperature no mean advantage is to be seen in comparison with simple averaging

The results for precipitation are difficult to judge upon; proper choice amongst the various possibilities is still an open question

Reliability Diagrams

Possible improvement by calibration remains to be explored

The results for precipitation clearly demonstrate the need for improving the model (reduce the overforecasting of slight precipitation amounts)

Concluding Remarks (ctd.)

Application

The method might be useful not only for single forecasts but also in combination with small ensembles