Verification against precipitation observations of a high density network – what did we learn?

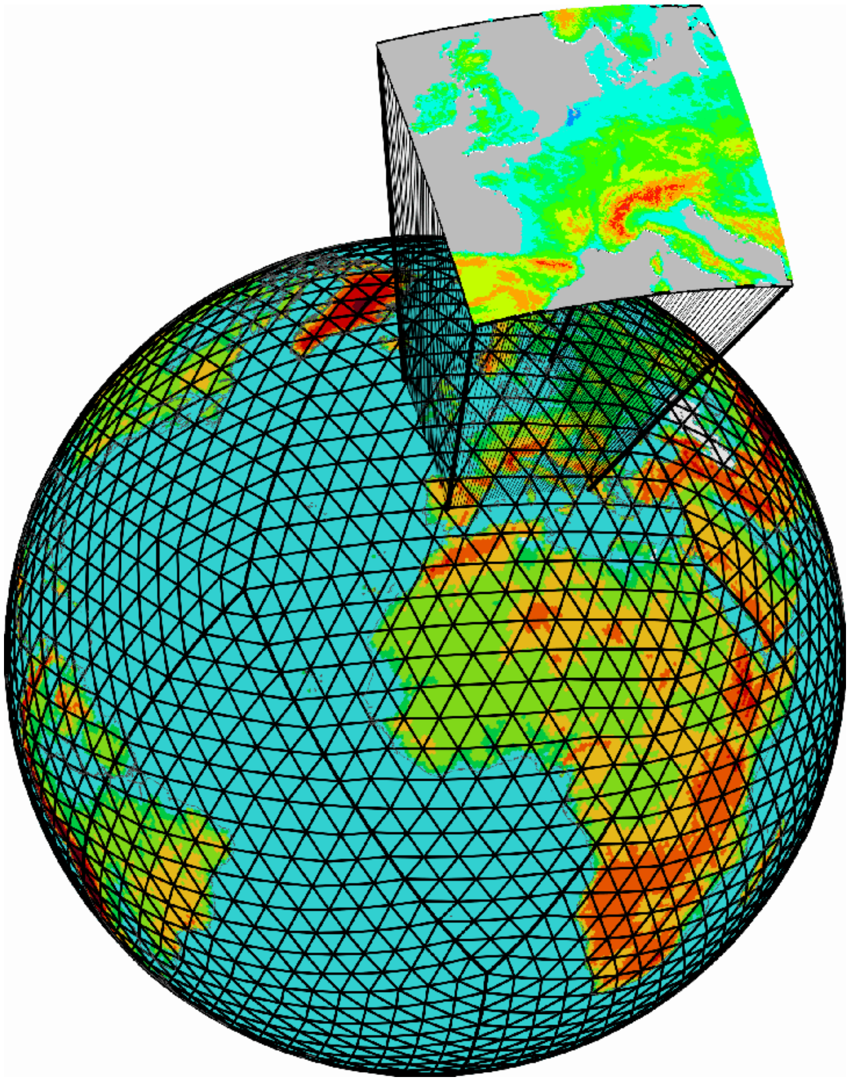
Ulrich Damrath

Deutscher Wetterdienst

Contents:

- Models under operational use at Deutscher Wetterdienst
- Typical precipitation structures over Germany
- Upscaling precipitation observations and forecasts
- Cross sections and pattern recognition
- Verification using elements of fuzzy logics

Operational models at Deutscher Wetterdienst (state: August 2004)



Globalmodell GME

mesh width: 60 km

layers: 31

forecast times:

174 h at 00 and 12 UTC

48 h at 18 UTC

Lokalmodell LM

mesh width: 7 km

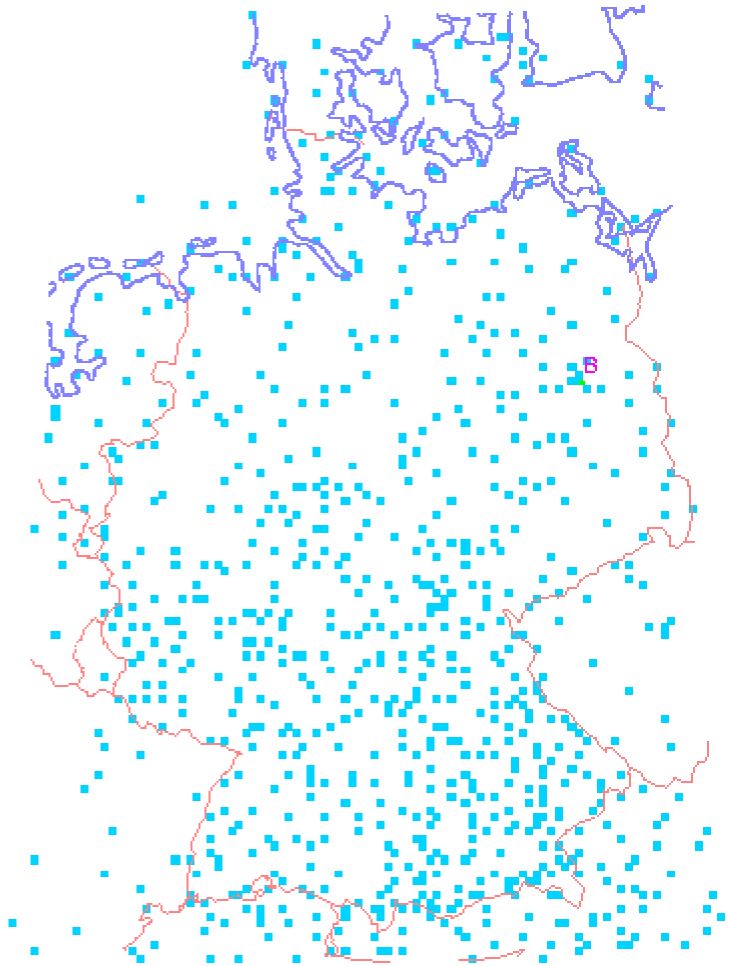
layers: 35

forecast times: 48 h

at 00, 12 und 18 UTC

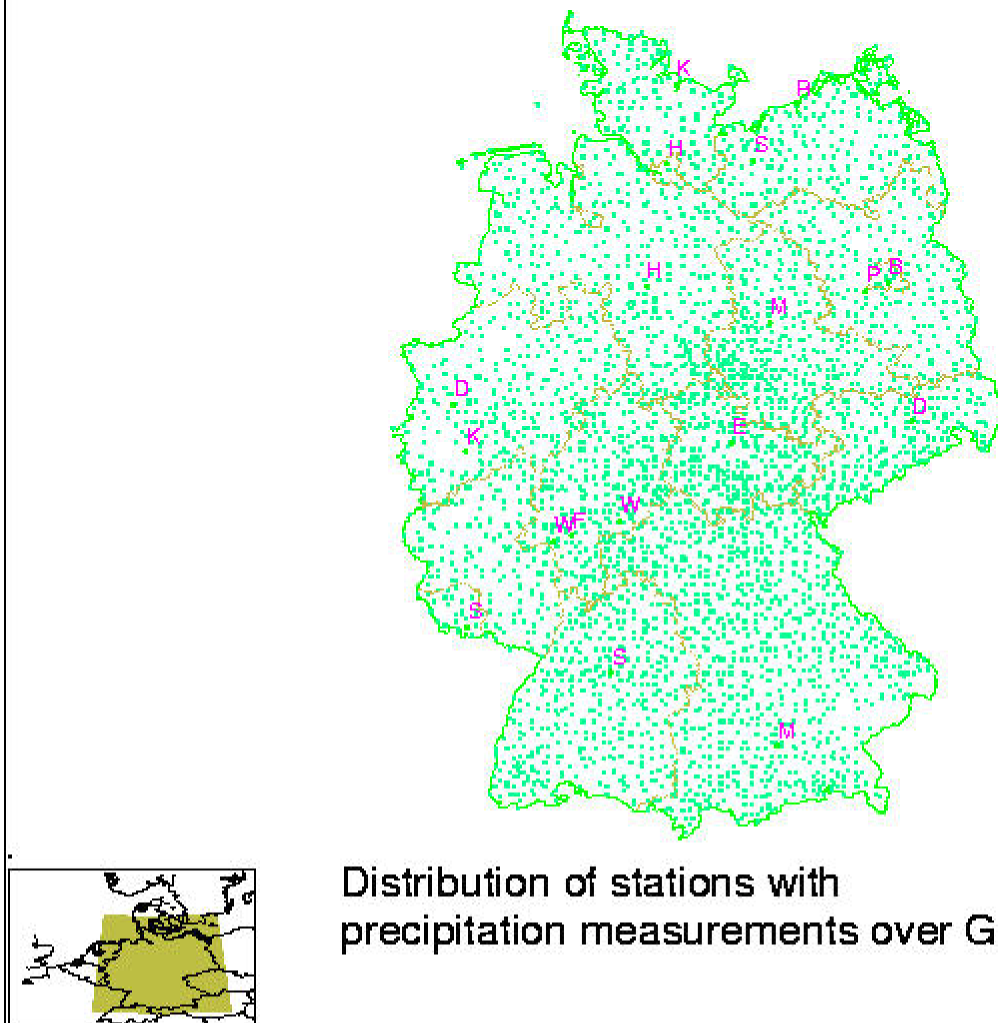
Distribution of stations in SYNOP-network for LM verification

OBS



resolution in time: 1-3h

Distribution of stations in the network with high resolution

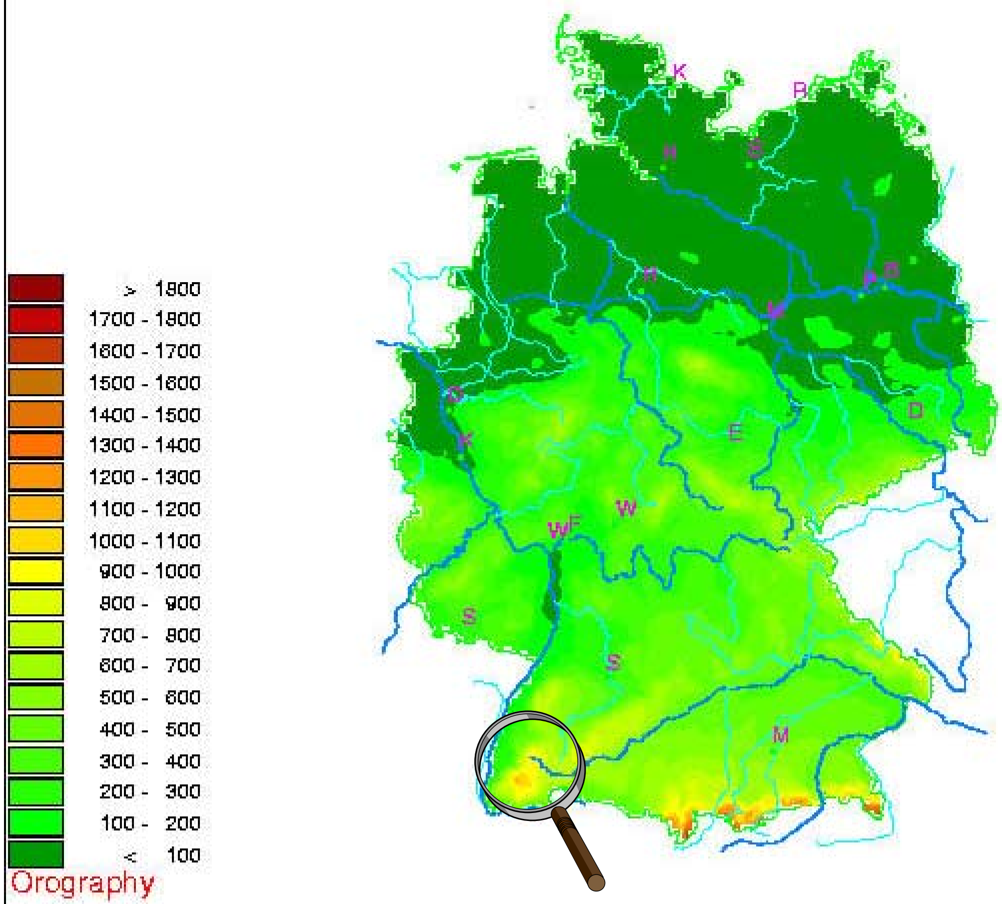


Distribution of stations with precipitation measurements over Germany

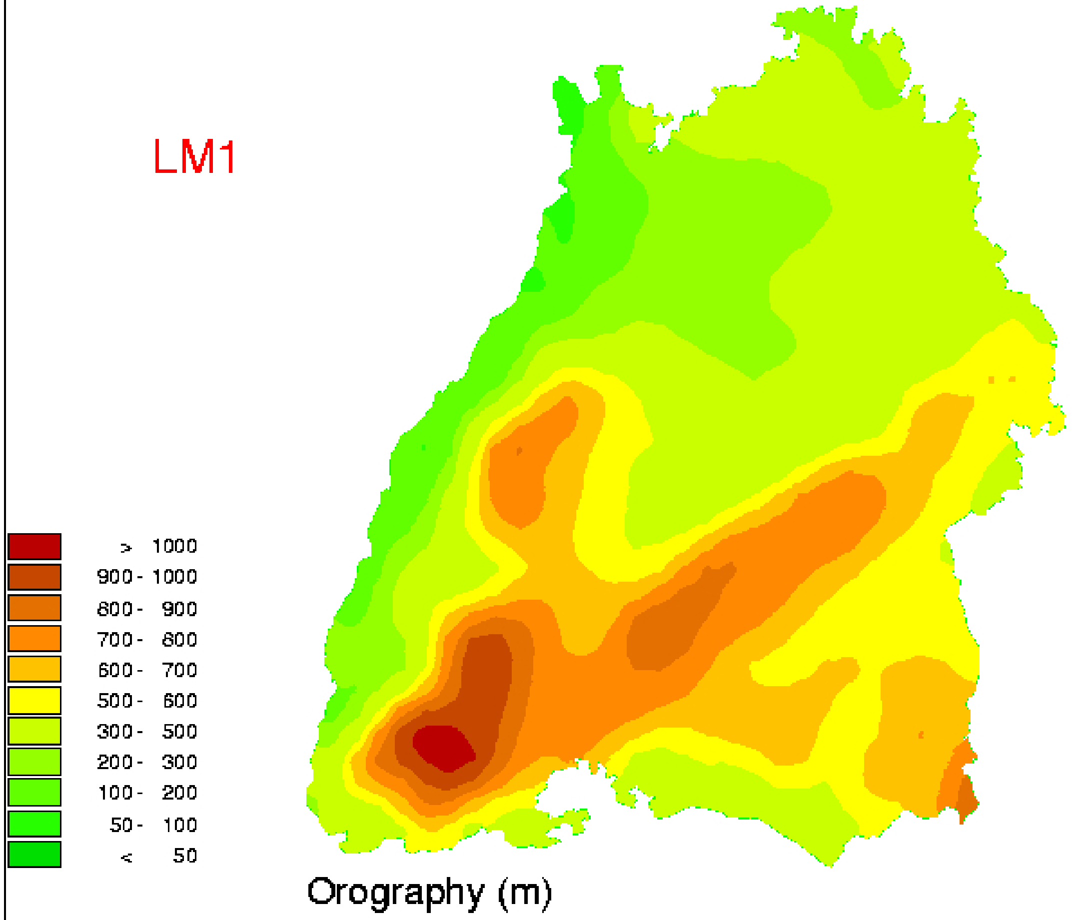
resolution in time: 24h

04.05.2001 11:58:04

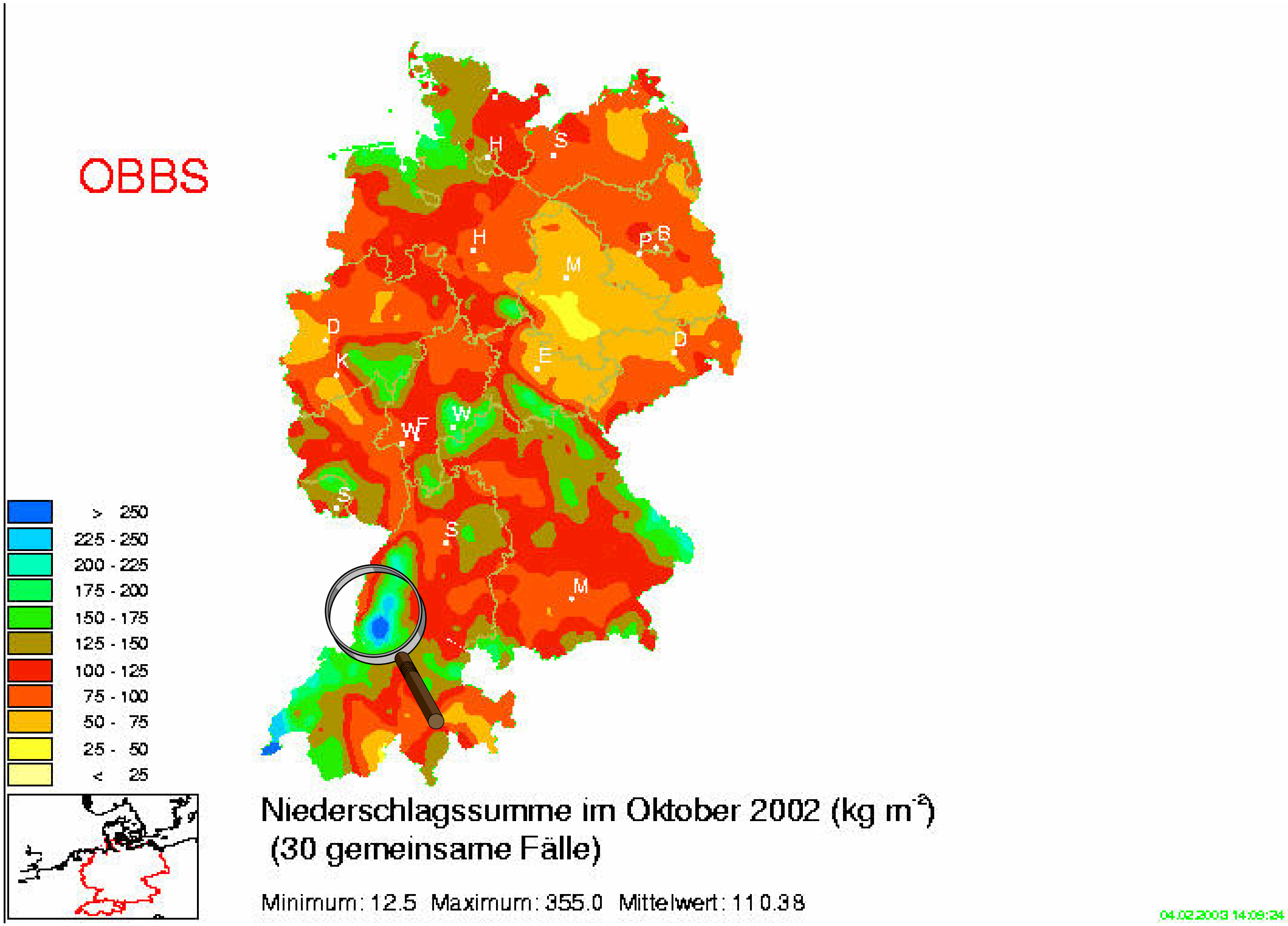
Orography over Germany



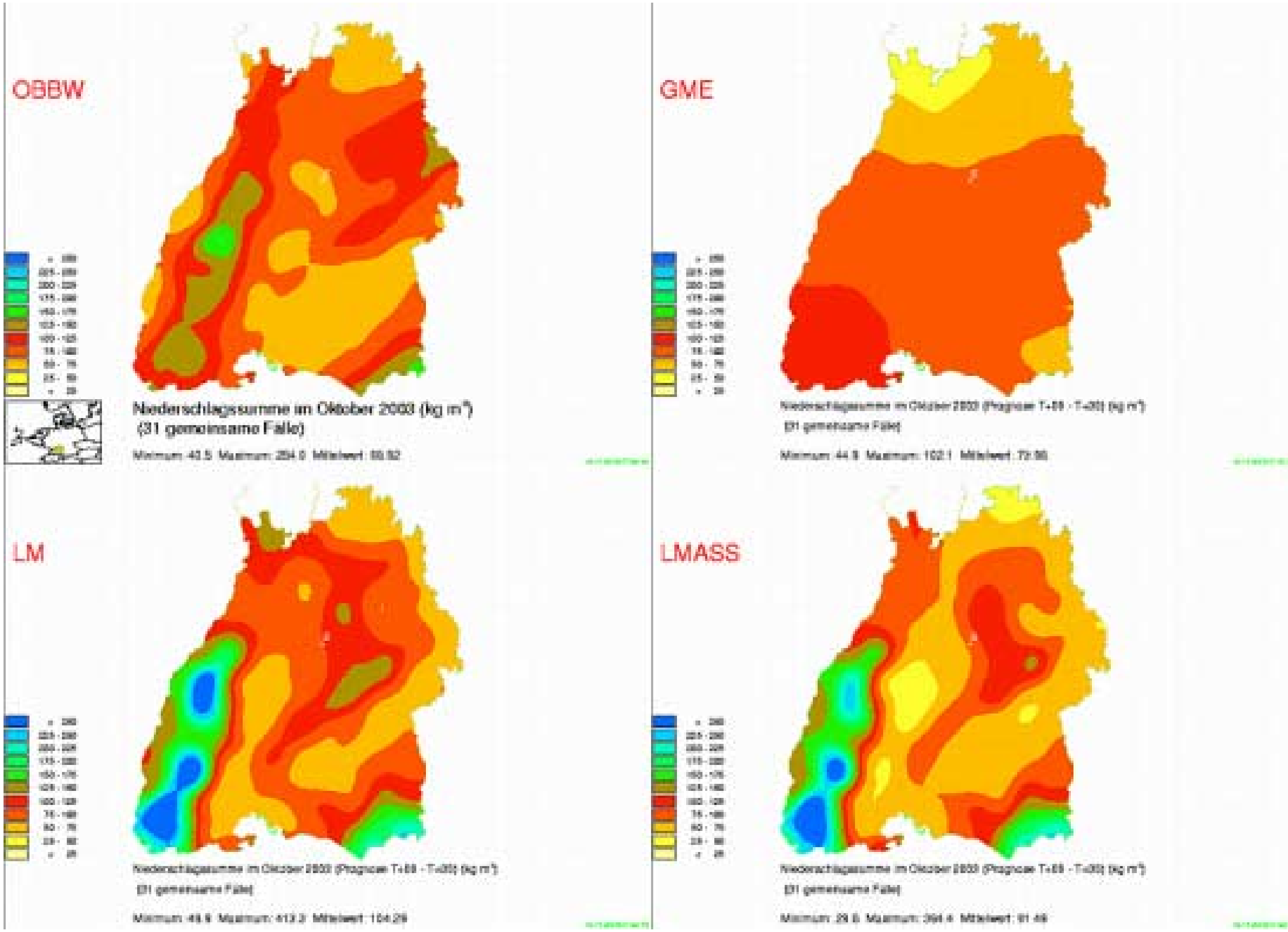
Orography over Southwest-Germany

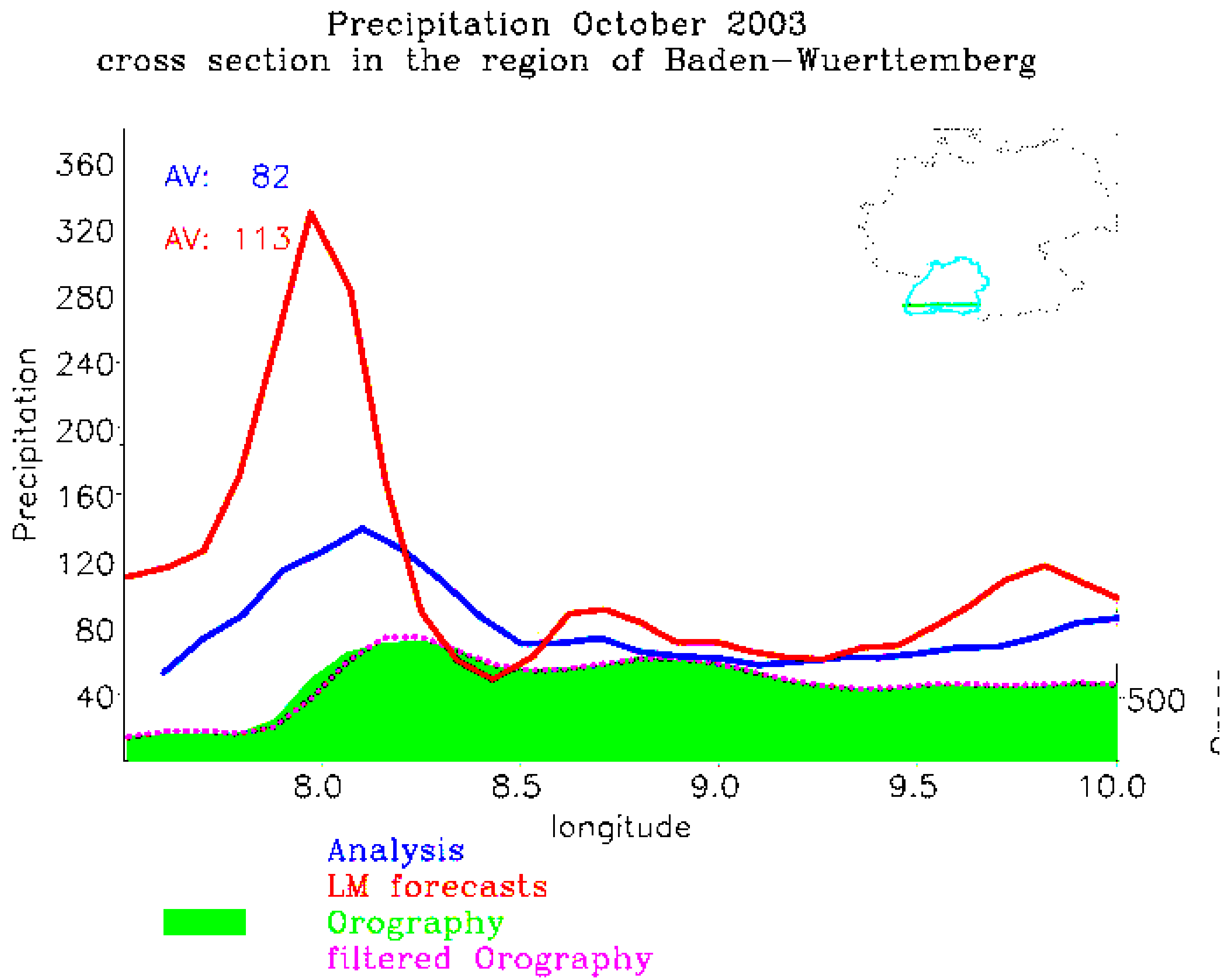


Typical precipitation structure over Germany



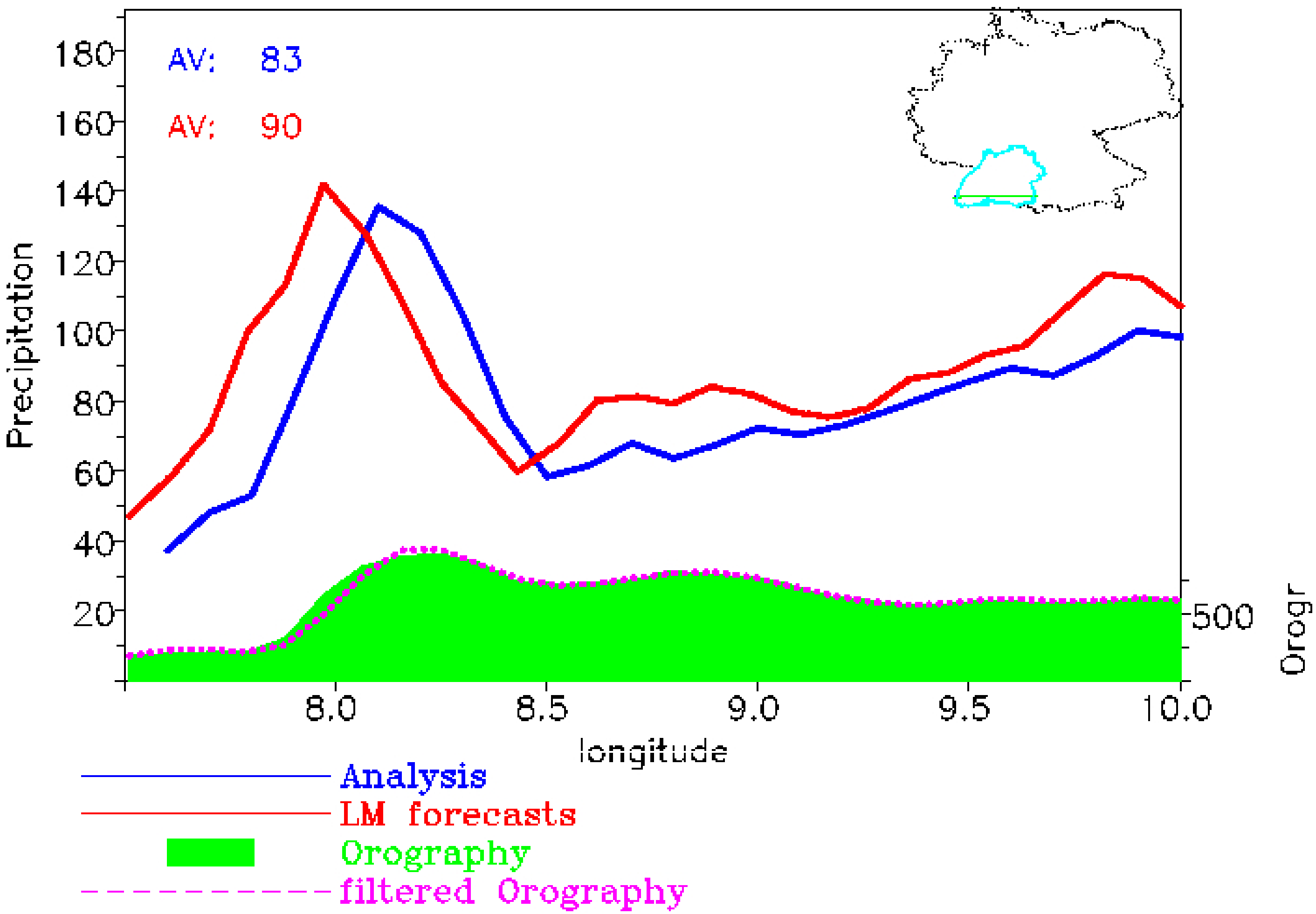
Typical precipitation structure over Southwest-Germany

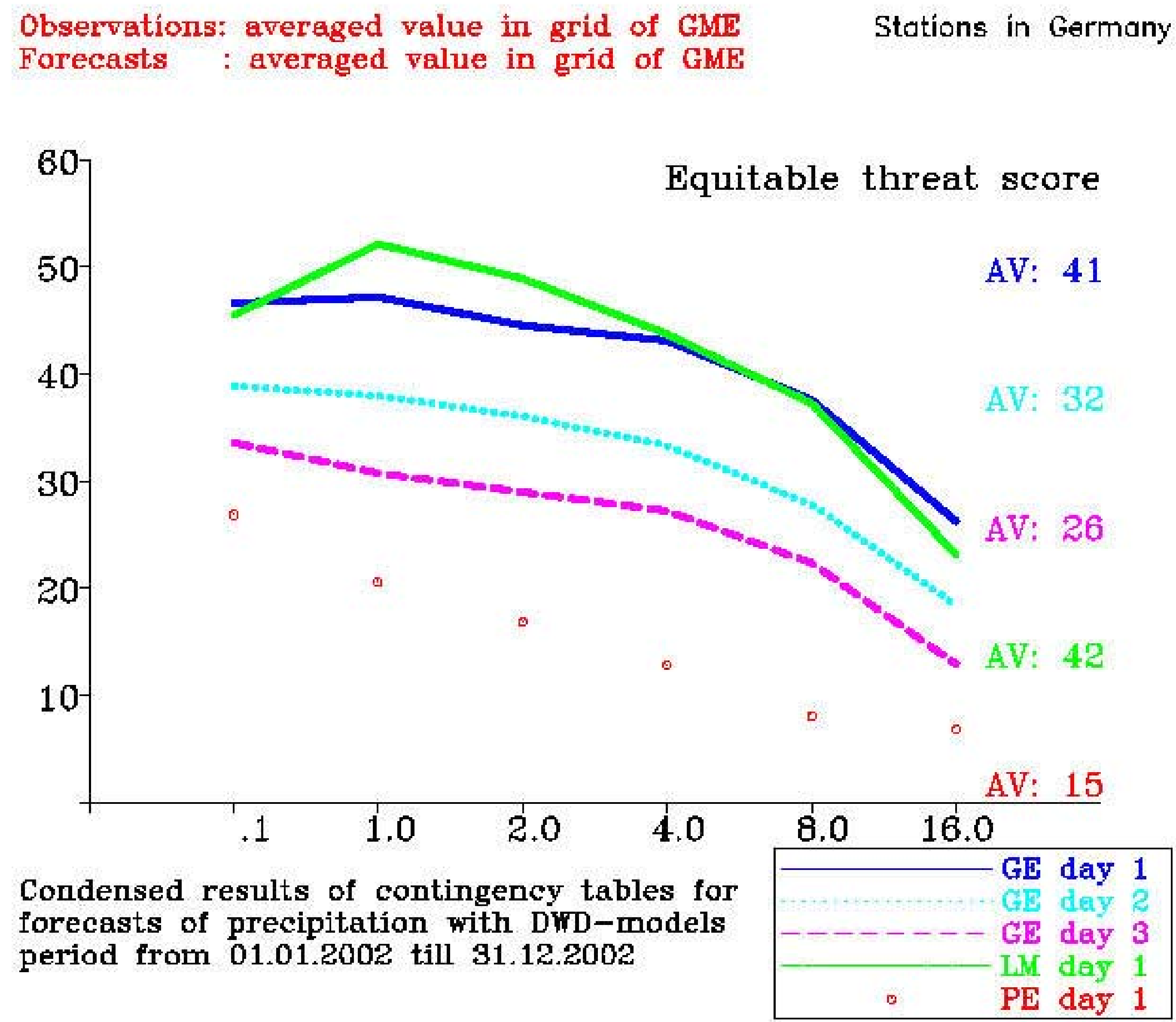




Precipitation October 2003
cross section in the region of Baden-Wuerttemberg
AV: 82
AV: 113
360
320
280
240
200
160
120
80
40
Precipitation
500
8.0
8.5
9.0
9.5
10.0
longitude
Analysis
LM forecasts
Orography
filtered Orography

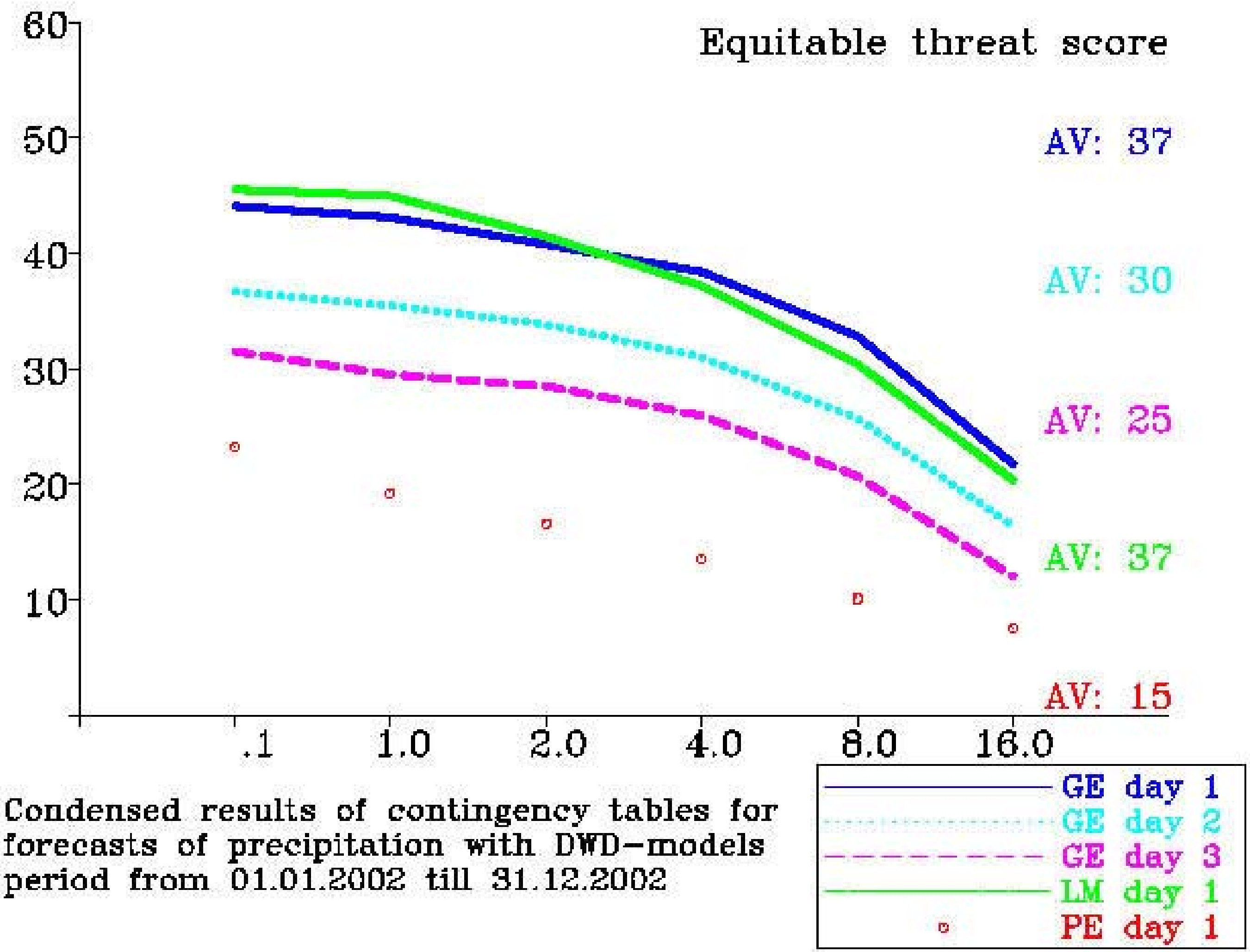
Precipitation May 2004
cross section in the region of Baden–Wuerttemberg



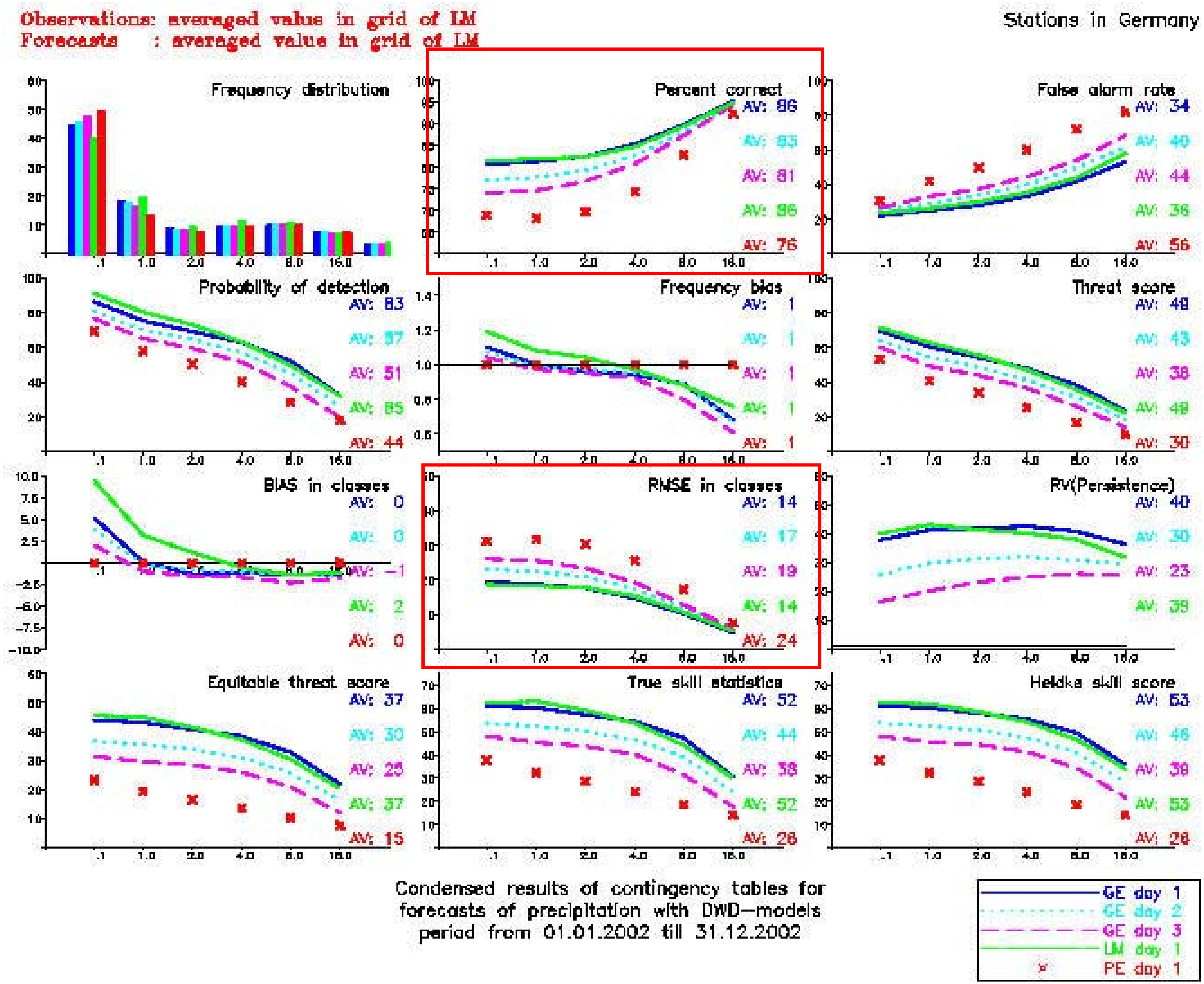

Observations: averaged value in grid of GME
Forecasts : averaged value in grid of GME
Stations in Germany
Equitable threat score
60
50
40
30
20
10
.1
1.0
2.0
4.0
8.0
16.0
AV: 41
AV: 32
AV: 26
AV: 42
AV: 15
Condensed results of contingency tables for forecasts of precipitation with DWD-models period from 01.01.2002 till 31.12.2002
GE day 1
GE day 2
GE day 3
LM day 1
PE day 1

Observations: averaged value in grid of LM
Forecasts : averaged value in grid of LM

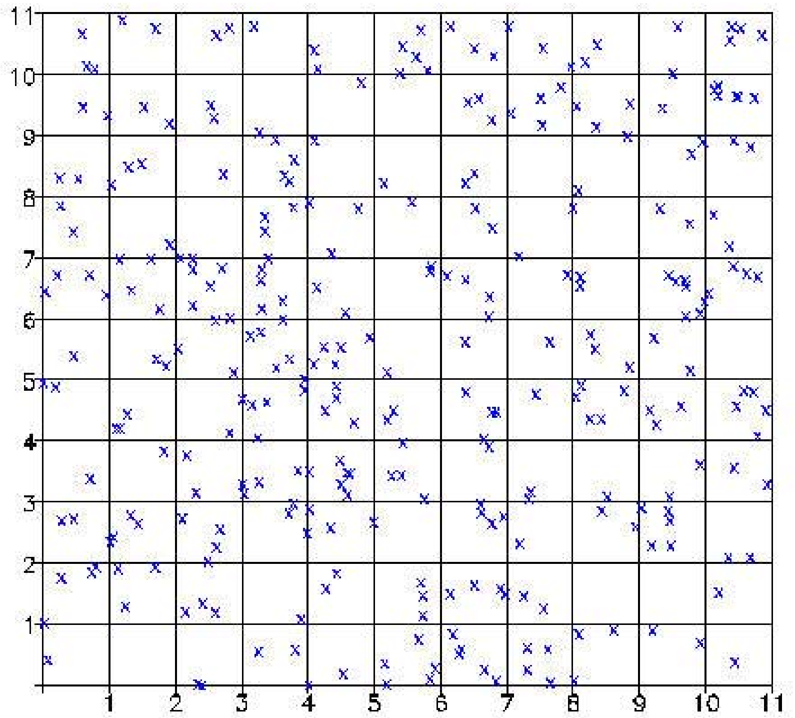
Stations in Germany



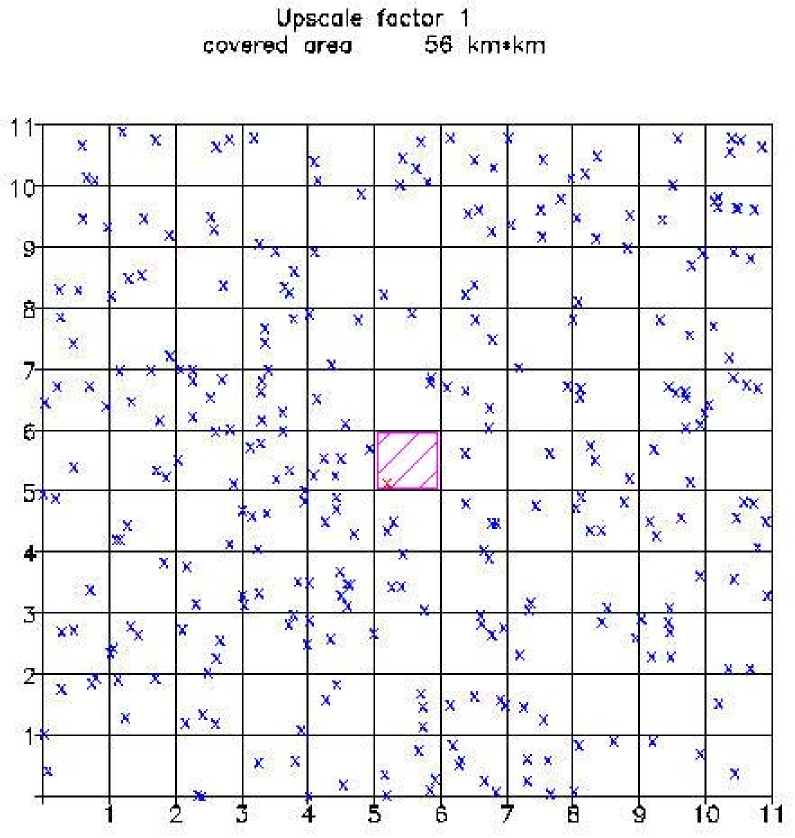
Condensed results of contingency tables for forecasts of precipitation with DWD-models period from 01.01.2002 till 31.12.2002


Observations: averaged value in grid of LM
Forecasts : averaged value in grid of LM
Stations in Germany
Frequency distribution
Percent correct
AV: 86
AV: 83
AV: 81
AV: 86
AV: 76
False alarm rate
AV: 34
AV: 40
AV: 44
AV: 36
AV: 56
Probability of detection
AV: 83
AV: 87
AV: 51
AV: 85
AV: 44
Frequency bias
AV: 1
AV: 1
AV: 1
AV: 1
AV: 1
Threat score
AV: 48
AV: 43
AV: 38
AV: 48
AV: 30
BIAS in classes
AV: 0
AV: 0
AV: -1
AV: 2
AV: 0
RMSE in classes
AV: 14
AV: 17
AV: 19
AV: 14
AV: 24
RV(Persistence)
AV: 40
AV: 30
AV: 23
AV: 39
Equitable threat score
AV: 37
AV: 30
AV: 25
AV: 37
AV: 15
True skill statistics
AV: 52
AV: 44
AV: 38
AV: 52
AV: 26
Heidke skill score
AV: 53
AV: 46
AV: 38
AV: 53
AV: 28
Condensed results of contingency tables for
forecasts of precipitation with DWD-models
period from 01.01.2002 till 31.12.2002
GE day 1
GE day 2
GE day 3
LM day 1
PE day 1

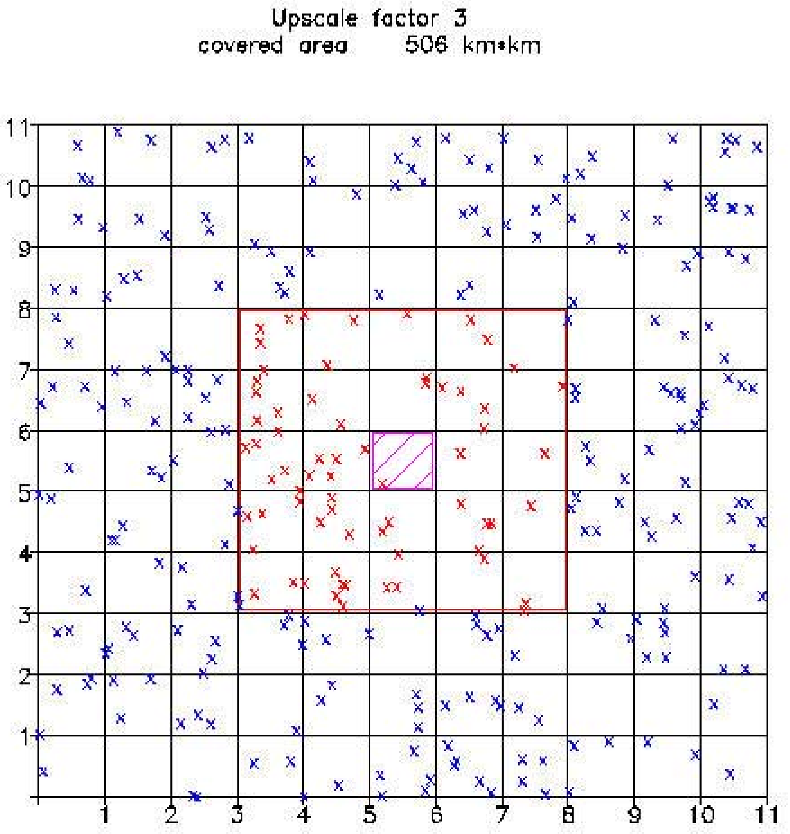
Upscaling observed and forecasted precipitation values



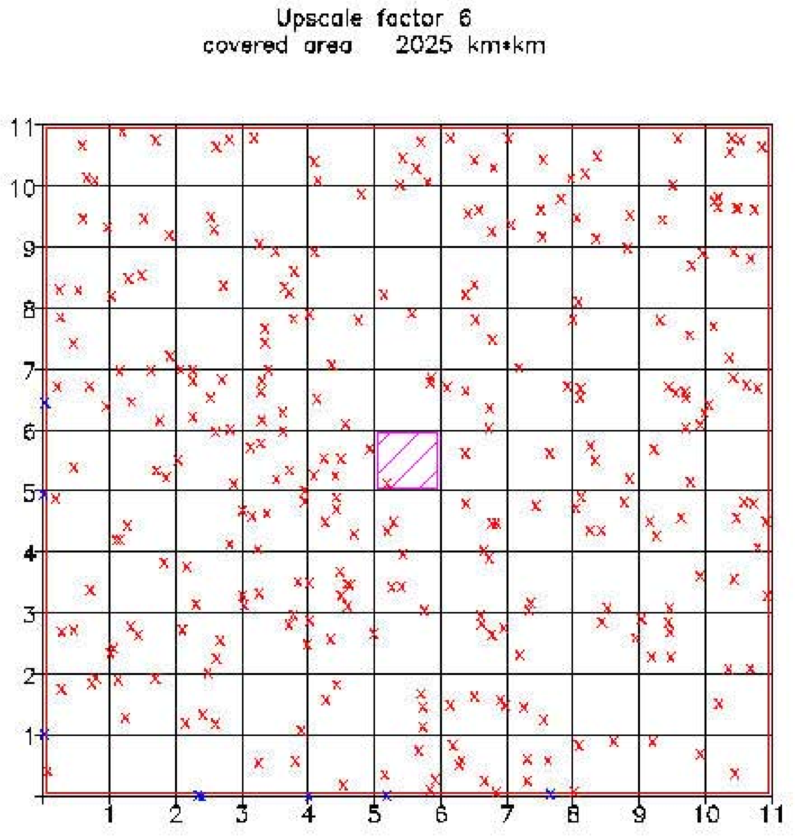
Upscaling observed and forecasted precipitation values (upscale factor 1)

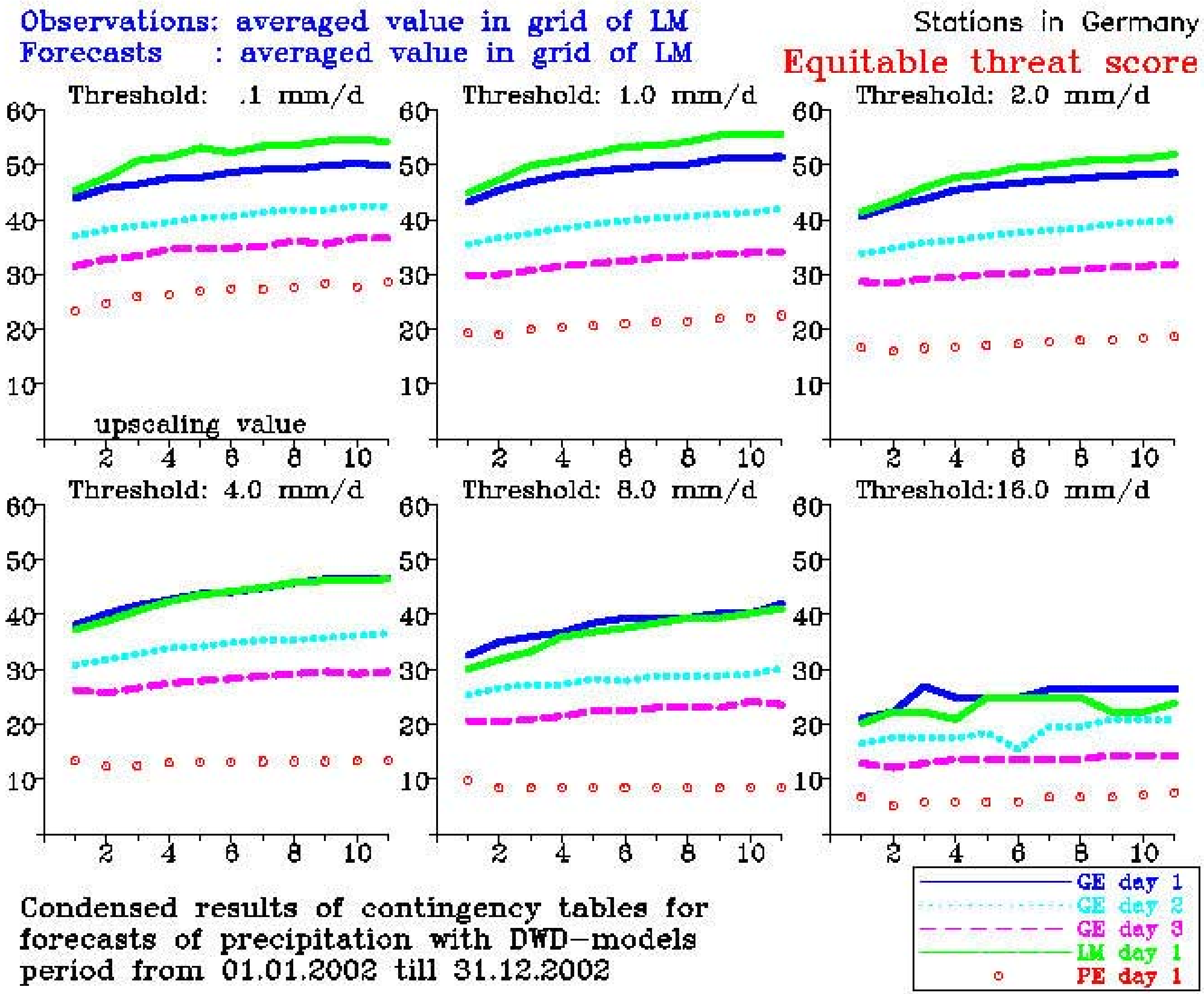


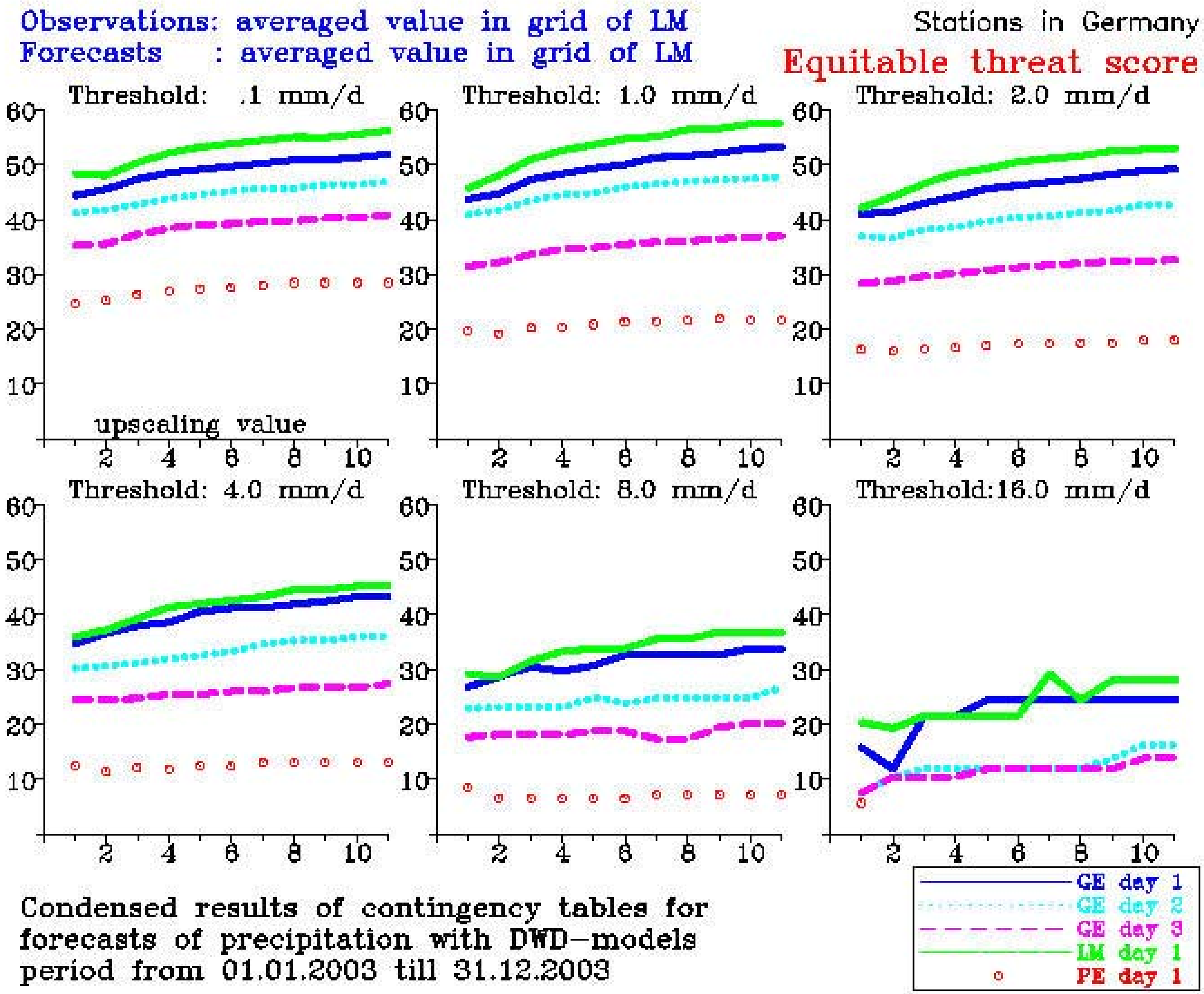
Upscaling observed and forecasted precipitation values (upscale factor 3)

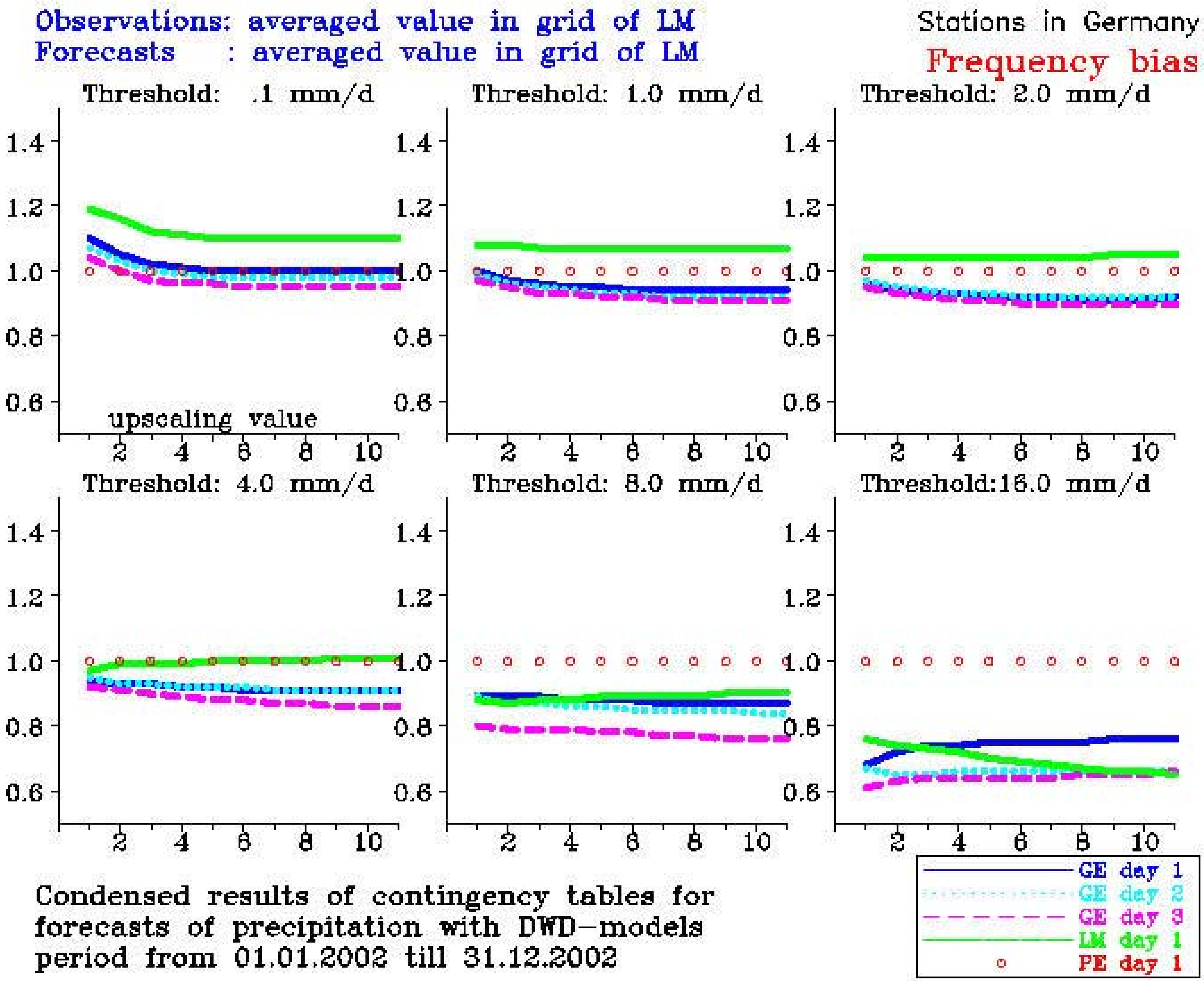


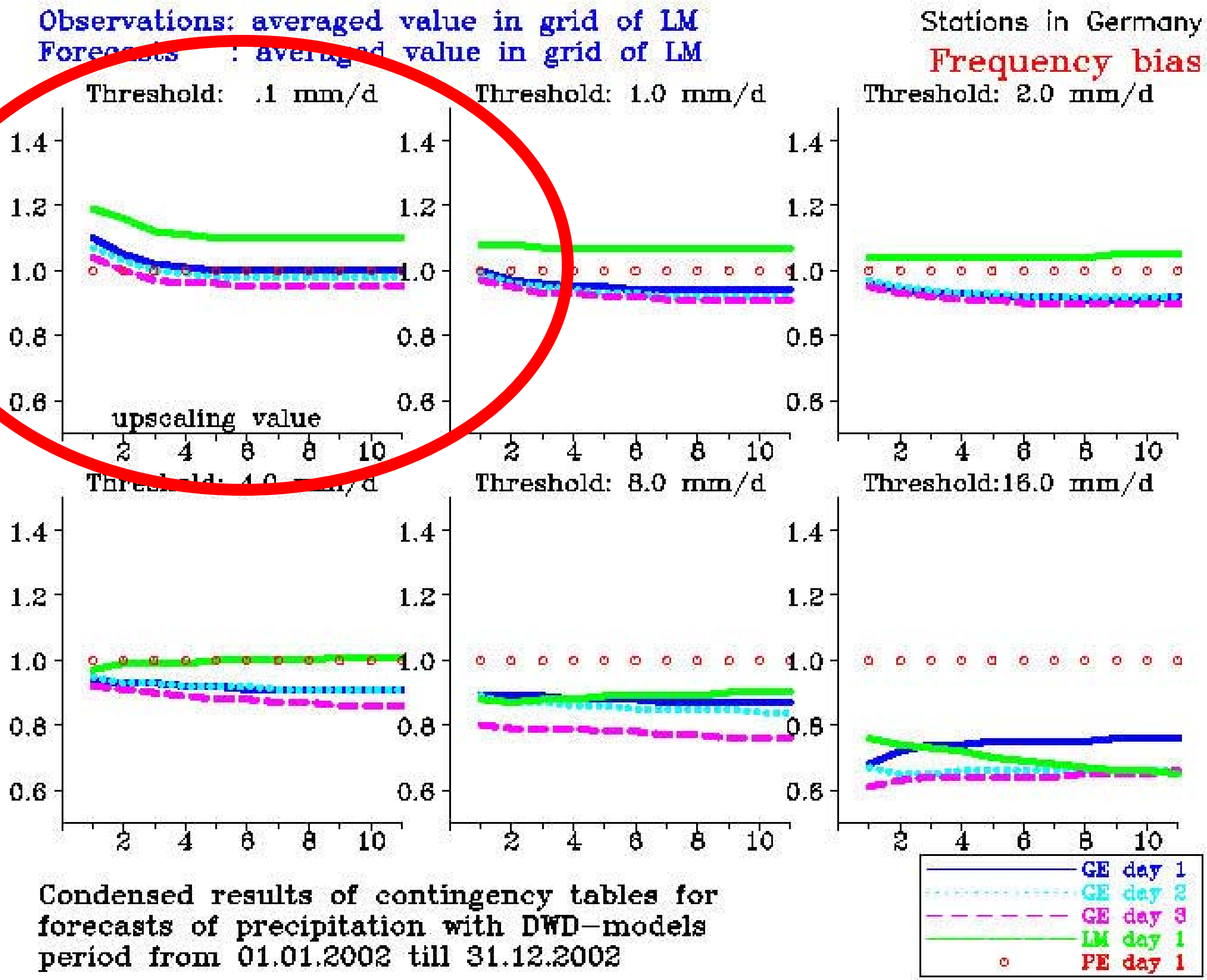
Upscaling observed and forecasted precipitation values (upscale factor 6)

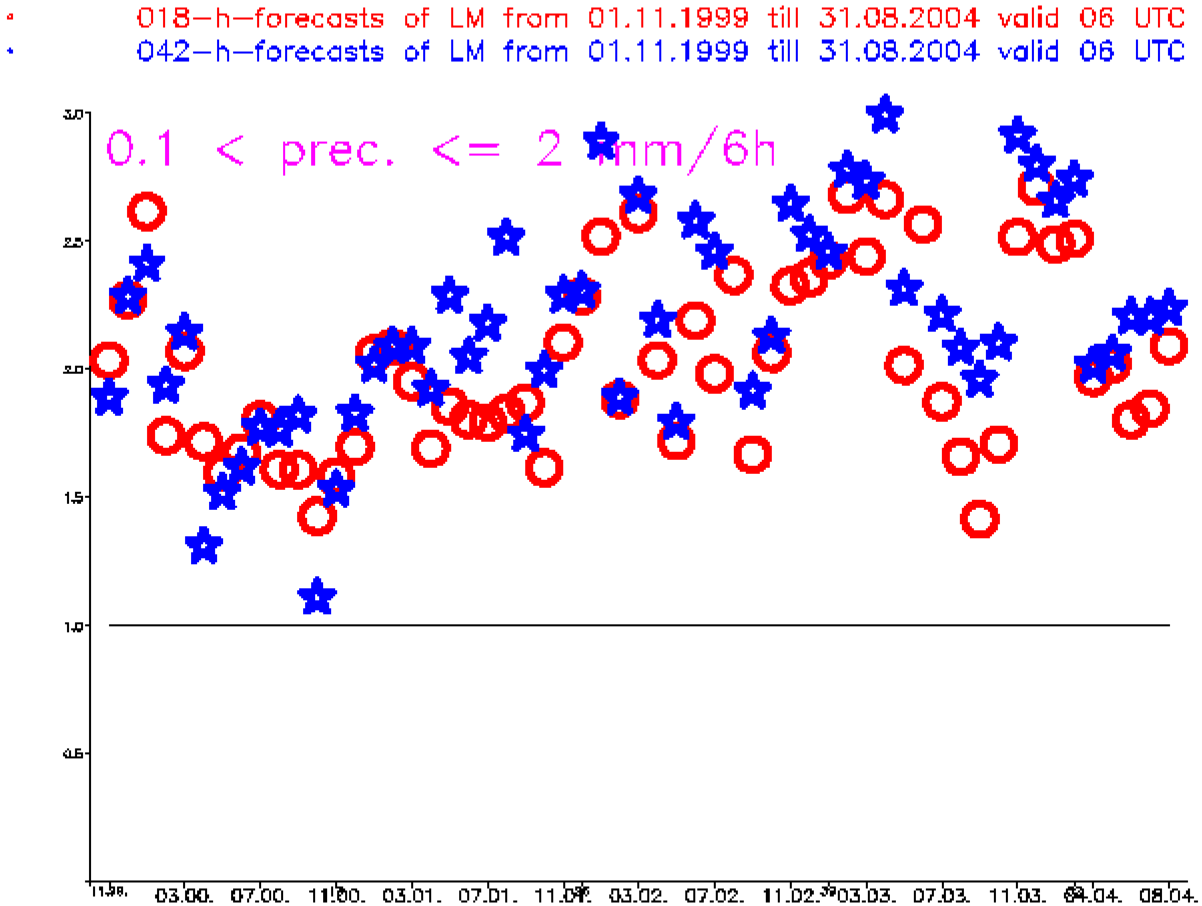



Observations: averaged value in grid of LM
Forecasts : averaged value in grid of LM
Stations in Germany
Equitable threat score
Threshold: .1 mm/d
upscaling value
Threshold: 1.0 mm/d
Threshold: 2.0 mm/d
Threshold: 4.0 mm/d
Threshold: 8.0 mm/d
Threshold:16.0 mm/d
Condensed results of contingency tables for
forecasts of precipitation with DWD-models
period from 01.01.2002 till 31.12.2002
GE day 1
GE day 2
GE day 3
LM day 1
PE day 1


Observations: averaged value in grid of LM
Forecasts : averaged value in grid of LM
Stations in Germany
Equitable threat score
Threshold: .1 mm/d
upscaling value
Threshold: 1.0 mm/d
Threshold: 2.0 mm/d
Threshold: 4.0 mm/d
Threshold: 8.0 mm/d
Threshold:16.0 mm/d
Condensed results of contingency tables for
forecasts of precipitation with DWD-models
period from 01.01.2003 till 31.12.2003
GE day 1
GE day 2
GE day 3
LM day 1
PE day 1


Observations: averaged value in grid of LM
Forecasts : averaged value in grid of LM
Stations in Germany
Frequency bias
Threshold: .1 mm/d
Threshold: 1.0 mm/d
Threshold: 2.0 mm/d
Threshold: 4.0 mm/d
Threshold: 8.0 mm/d
Threshold:16.0 mm/d
upscaling value
1.4
1.2
1.0
0.8
0.6
2
4
6
8
10
GE day 1
GE day 2
GE day 3
LM day 1
PE day 1
Condensed results of contingency tables for
forecasts of precipitation with DWD-models
period from 01.01.2002 till 31.12.2002


Observations: averaged value in grid of LM
Forecasts : averaged value in grid of LM
Stations in Germany
Frequency bias
Threshold: .1 mm/d
Threshold: 1.0 mm/d
Threshold: 2.0 mm/d
Threshold: 4.0 mm/d
Threshold: 8.0 mm/d
Threshold:16.0 mm/d
upscaling value
1.4
1.2
1.0
0.8
0.6
2 4 6 8 10
GE day 1
GE day 2
GE day 3
LM day 1
PE day 1
Condensed results of contingency tables for
forecasts of precipitation with DWD-models
period from 01.01.2002 till 31.12.2002



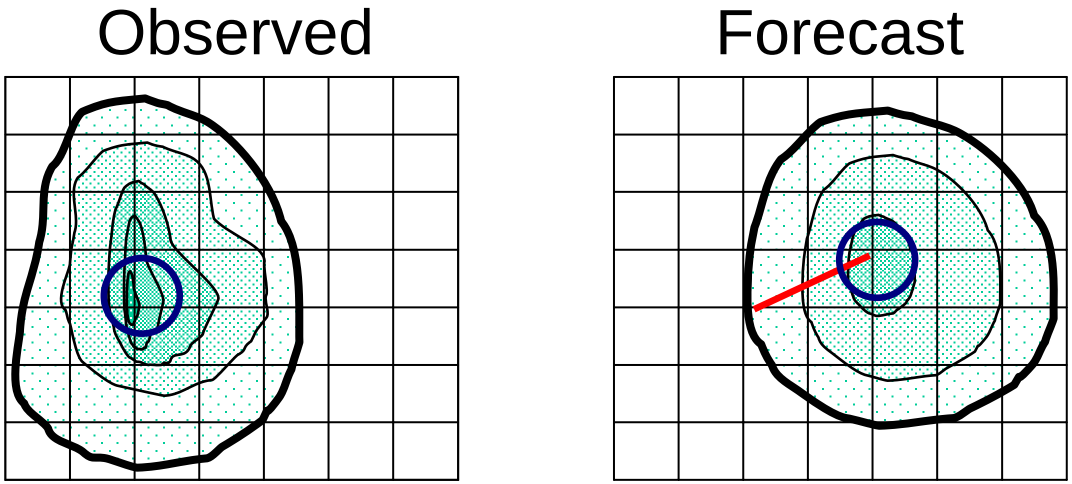
Time series of frequency bias: verification against SYNOP stations

Entity-based QPF verification (rain "blobs")

by E. Ebert (BOM Melbourne)

Verify the *properties* of the forecast rain system against the *properties* of the observed rain system:

- location
- rain area
- rain intensity (mean, maximum)

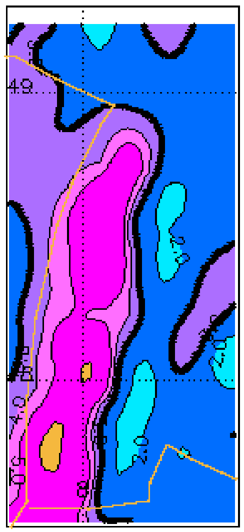


Total mean squared error (MSE):

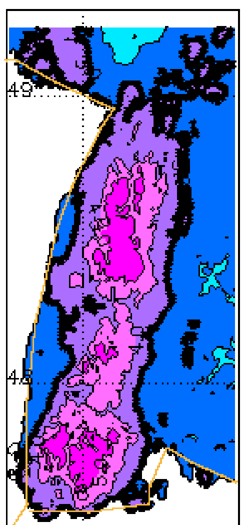
$$MSE_{total} = MSE_{displacement} + MSE_{volume} + MSE_{pattern}$$

Example of CRA-verification:
CRA-area: 3 mm/day for October 2003

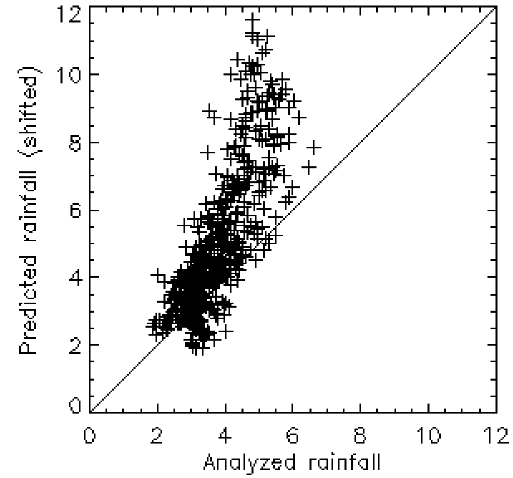
Im fcst 20031001–20031031



Analysis 20031001–20031031



CRA 20031001–20031031



Im 06–06 fcst 20031001–20031031 n=561
(47.55°,7.52°) to (49.25°,9.07°)
Verif. grid=0.034° CRA threshold=3.0 mm/d

	Analysed	Forecast
# gridpoints ≥3 mm/d	468	387
Average rainrate (mm/d)	3.79	5.07
Maximum rain (mm/d)	6.63	11.60
Rain volume (km³)	0.04	0.05

Displacement (E,N) = [–0.20°,–0.07°]

	Original	Shifted
RMS error (mm/d)	2.39	1.98
Correlation coefficient	0.349	0.789

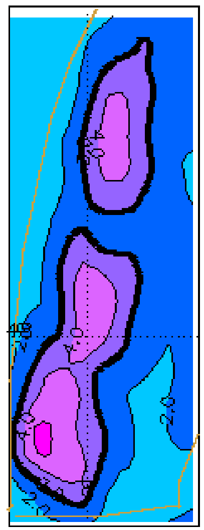
Displacement may be wrong – correlation not signif.

Error Decomposition:

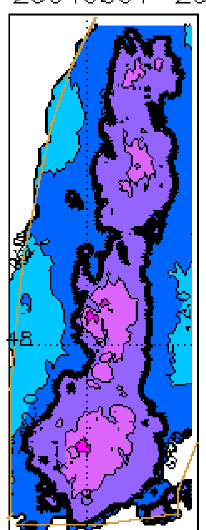
Displacement error	31.9%
Volume error	28.3%
Pattern error	39.8%

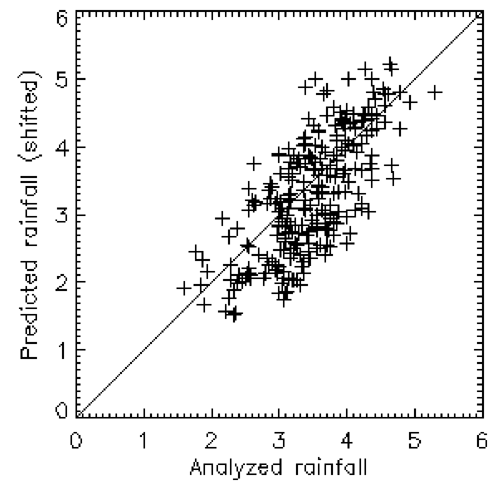
Example of CRA-verification:
CRA-area: 3 mm/day for May 2004

lm fcst 20040501–20040531



Analysis 20040501–20040531





lm 06–06 fcst 20040501–20040531 n=269
(47.58°,7.65°) to (48.77°,8.53°)
Verif. grid=0.034° CRA threshold=3.0 mm/d

	Analysed	Forecast
# gridpoints ≥3 mm/d	213	162
Average rainrate (mm/d)	3.45	3.29
Maximum rain (mm/d)	5.29	5.23
Rain volume (km³)	0.02	0.02

Displacement (E,N) = [–0.13°,0.00°]

	Original	Shifted
RMS error (mm/d)	1.03	0.64
Correlation coefficient	0.074	0.703

Displacement may be wrong – correlation not signif.

Error Decomposition:

Displacement error	61.7%
Volume error	2.5%
Pattern error	35.8%

What is a true forecast for a region of interest?

- What is the interest of the user?
- In which way the forecasts satisfy this interest?
- What is the decision process followed by the use of the forecast?
- How can we verify the forecasts depending on the decision process?

Possible decision models

- A forecast is useful if the event of interest is observed and forecasted at any point of the region of interest
- A forecast is useful if the event of interest is observed and forecasted at a minimum of the part of the region of interest (50%?)
- Forecasts and observations have a certain probability. How could this information used?

General idea concerning application of elements of fuzzy sets using a hypothetical precipitation distribution first part: basics

The contingency table contains in general four types of information, the unification of forecast yes/no and observation yes/no. In the traditional way theses unification sets are got by comparing point by point information. Due to the more or less statistical character of precipitation fields in a small scale verification can be done in a window of time and space, where the occurence of precipitation is verified as the part of the window, where precipitation was observed and forecasted. The sets of observation and forecast yes/no are **assumed to be not sharp**. That is: Observations yes means, observation yes to a certain degree i.e. the part of the window covered by observed and forecasted precipitation, respectively. Unification of different sets than can be calculated using the laws of fuzzy sets. (See: Bothe, H.H, Fuzzy Logic, Springer Verlag 1995, Zimmermann, H.-J., Fuzzy Set Theory and ist applications, Kluwer Dordrecht 1991

Contingency table for not sharp yes/no events according to fuzzy set theory

po - area or number of points with obervation yes
pf - area or number of points with forecasts yes

	OBS po	Obs (1-po)
FC pf	A=min(po,pf)	B=min((1-po),pf)
FC (1-pf)	C=min(po,(1-pf))	D=min((1-po),(1-pf))

Contingency table for yes/no events for a given limit of points/area

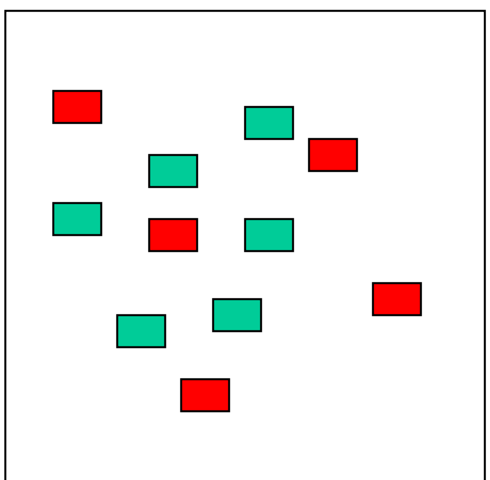
	OBS yes po > x%	Obs no po < x%
FC yes pf > x%	A	B
FC no pf < x%	C	D

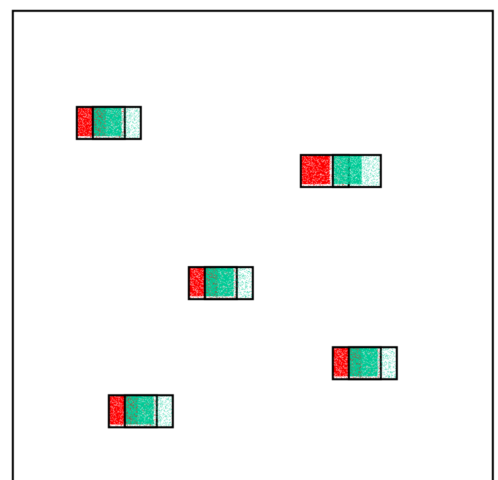
General idea concerning application of elements of fuzzy sets using a hypothetical precipitation distribution second part: traditional verification

„Forecast yes“ „Observation“ yes

Situation: all observations are at an other place than the forecasts
traditional verification: no coincidence of forecast and observation,
all scores lead to perfectly wrong results

Situation: all observations are at the same place as the forecasts
traditional verification: strong coincidence of forecast and observation,
all scores lead to perfectly good results



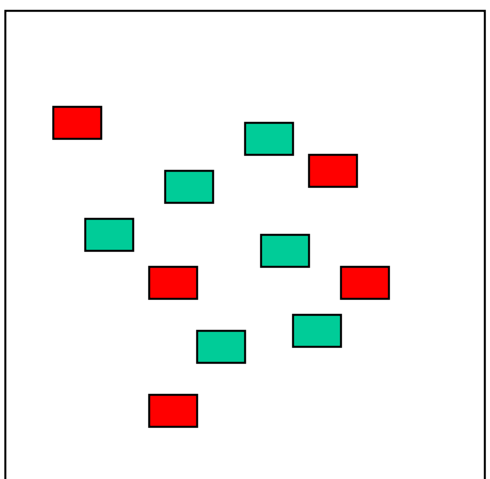


General idea concerning application of elements of fuzzy sets using a hypothetical precipitation distribution third part: application of fuzzy sets

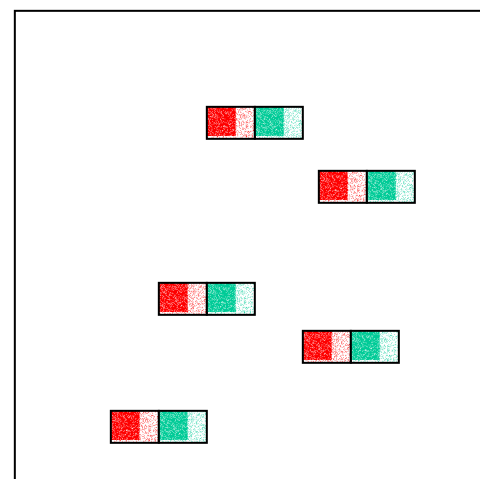
„Forecast yes“ „Observation“ yes

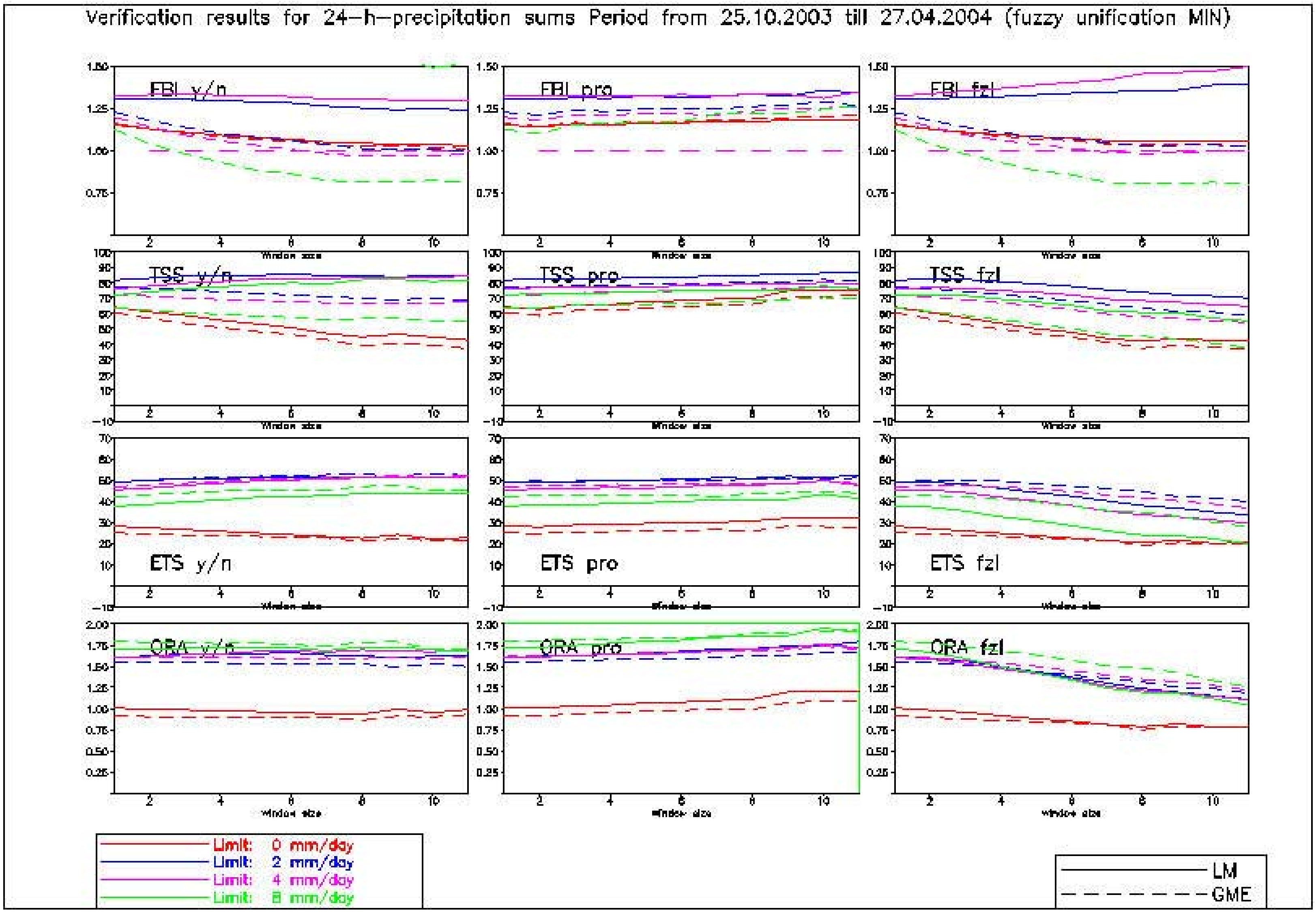
Situation: all observations are at an other place than the forecasts
verification using fuzzy sets: fuzzy coincidence of forecast and observation, all scores do not lead to perfectly wrong results

Situation: all observations are at the same place as the forecasts
verification using fuzzy sets: fuzzy coincidence of forecast and observation, all scores do not lead to perfectly good results



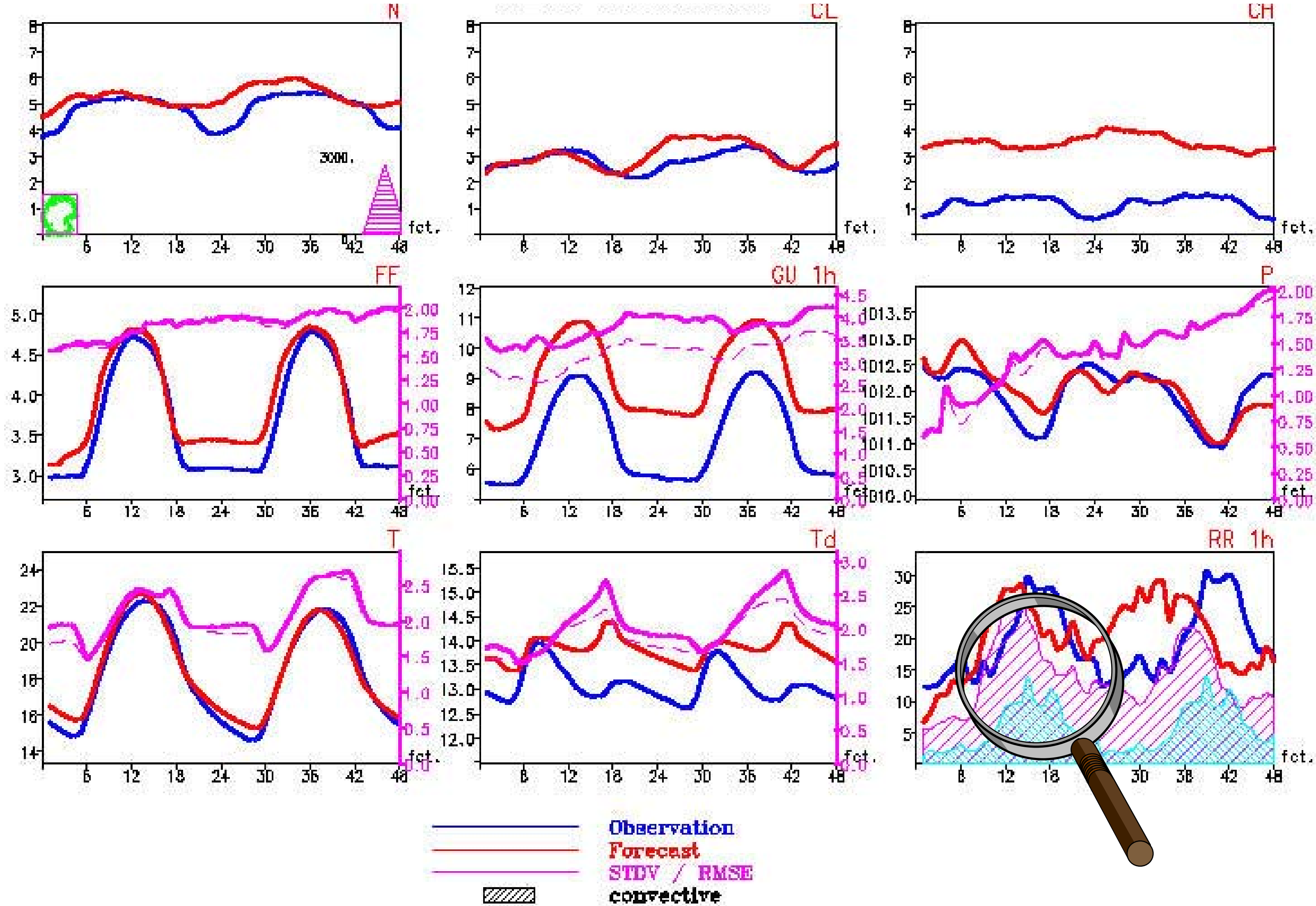
Both cases lead to the same verification results because the same part of the area is covered by forecasted and observed precipitation



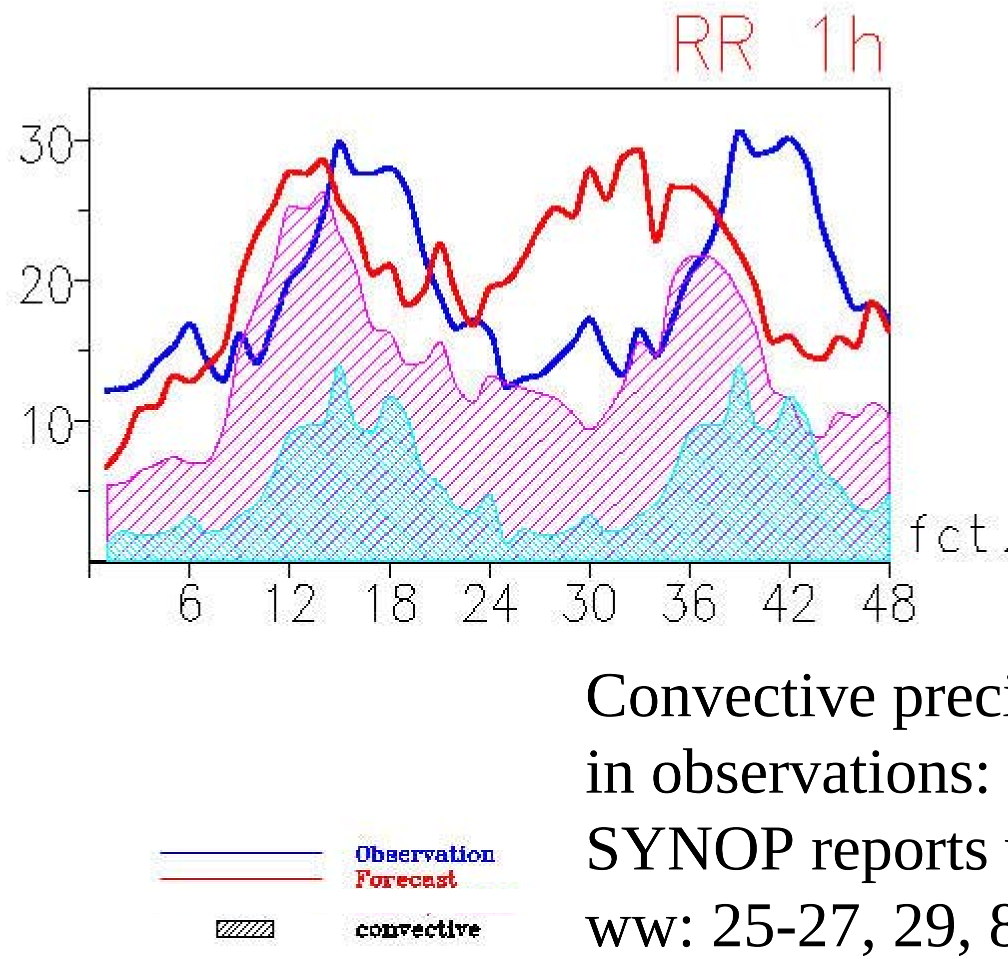


Verification results for 24-h-precipitation sums Period from 25.10.2003 till 27.04.2004 (fuzzy unification MIN)
FBI y/n
FBI pro
FBI fzl
TSS y/n
TSS pro
TSS fzl
ETS y/n
ETS pro
ETS fzl
ORA y/n
ORA pro
ORA fzl
Window size
Limit: 0 mm/day
Limit: 2 mm/day
Limit: 4 mm/day
Limit: 8 mm/day
LM
GME

Diurnal cycle of observed and forecasted weather elements, August 2004, start hour 00 UTC



Diurnal cycle of observed and forecasted precipitation, August 2004, start hour 00 UTC



Convective precipitation in observations: SYNOP reports with ww: 25-27, 29, 80-99

What did we learn?

- **Upscaling and cross sections:**
  forecaster: Do not look at a specific point, but around!
  modeller: Improve numerics, physics to reduce errors.
- **Pattern recognition:**
  forecaster: Be careful when interpreting orographically induced precipitation forecasts.
  modeller: Improve forecast mechanism of precipitation for mountainous regions by various methods!
- **SYNOP vs. high density network:**
  modeller: Do not overestimate high frequency biases for low precipitation values! Use SYNOP reports to study the diurnal cycles of surface weather elements.
- **Application of fuzzy logics:**
  potential user: Use such type of verification in a fuzzy logic forecast system.

That‘s all, thank you for your attention!