Convection-Resolving Model Simulations: Process-Based Comparison of LM Results with Observations

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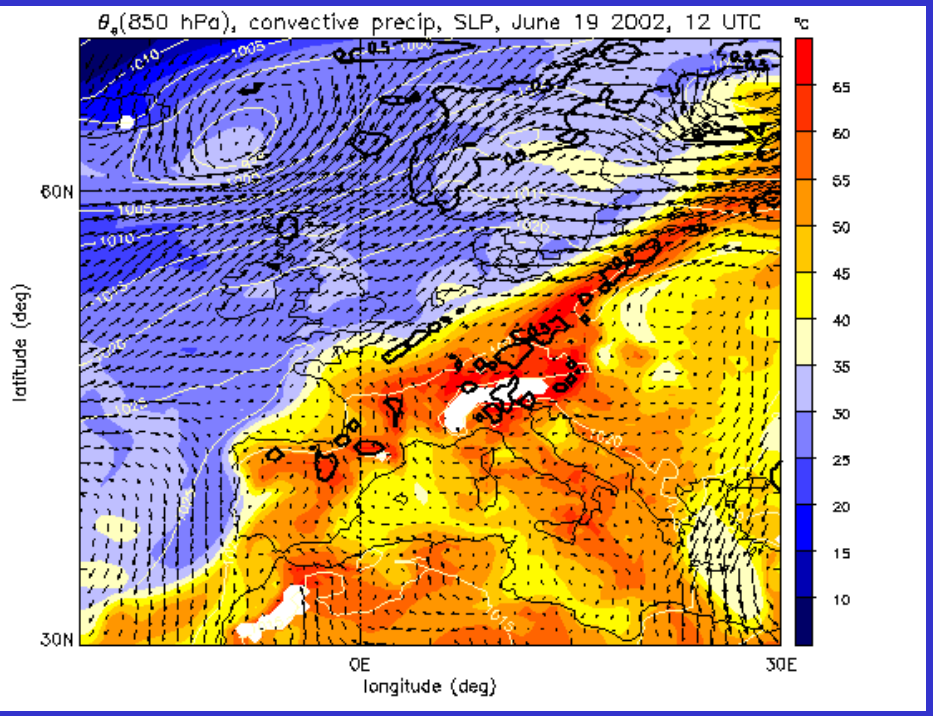
Goal

- **Improve our understanding of the processes leading to convective precipitation**
- **Investigate the inherent dynamical and microphysical processes in convective storms**

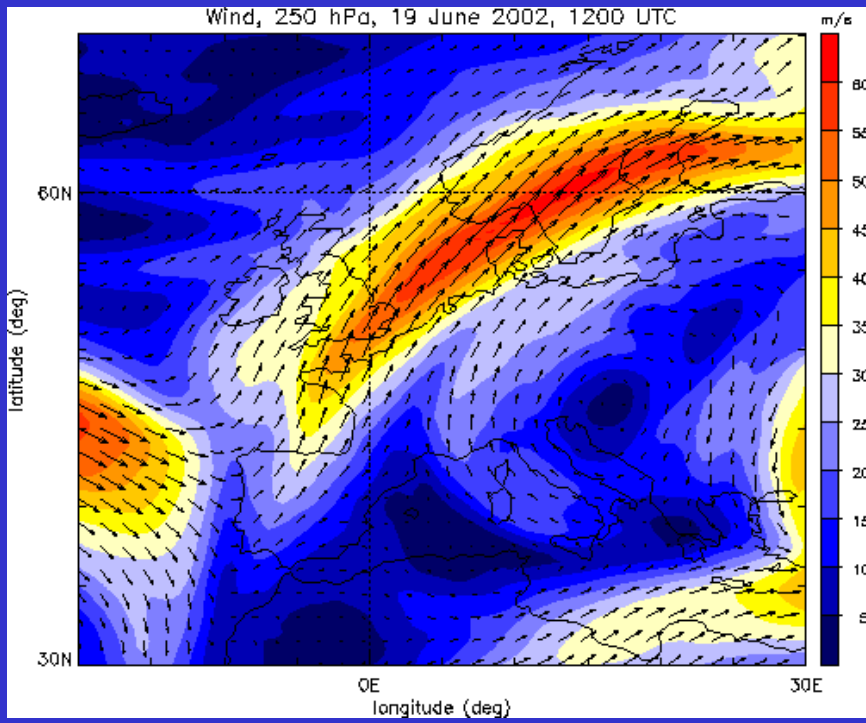
First case study: 19 June 2002

ECMWF Analysis, 19 June 2002, 1200 UTC

Equivalent potential temp., 850 hPa



Wind, 250 hPa

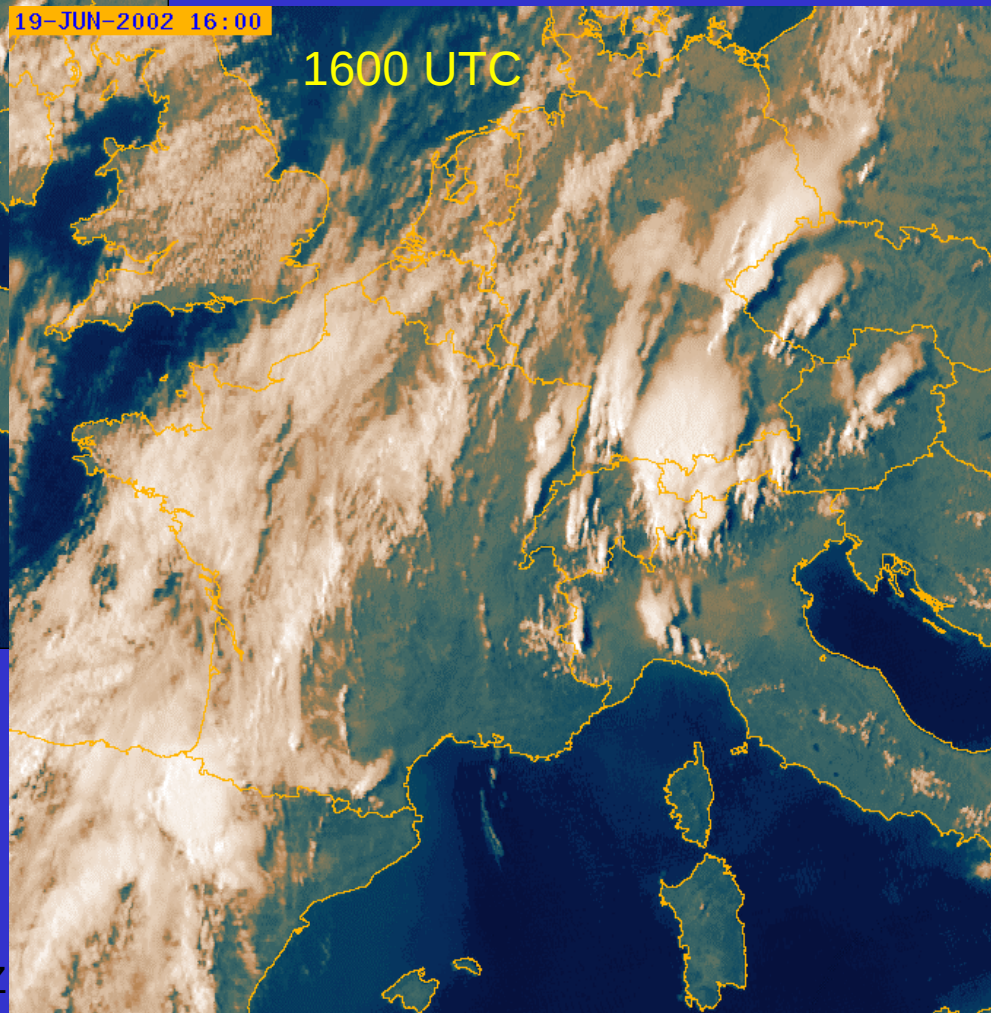


- Cold front across northern Germany, `Spanish plume' situation with high temperatures as far north as Finland
- Convective precipitation in the warm sector
- Strong upper level jet associated with the front; anti-cyclonic circulation south of the ridge associated with small positive PV anomaly

1430 UTC

METEOSAT, 19 June 2002

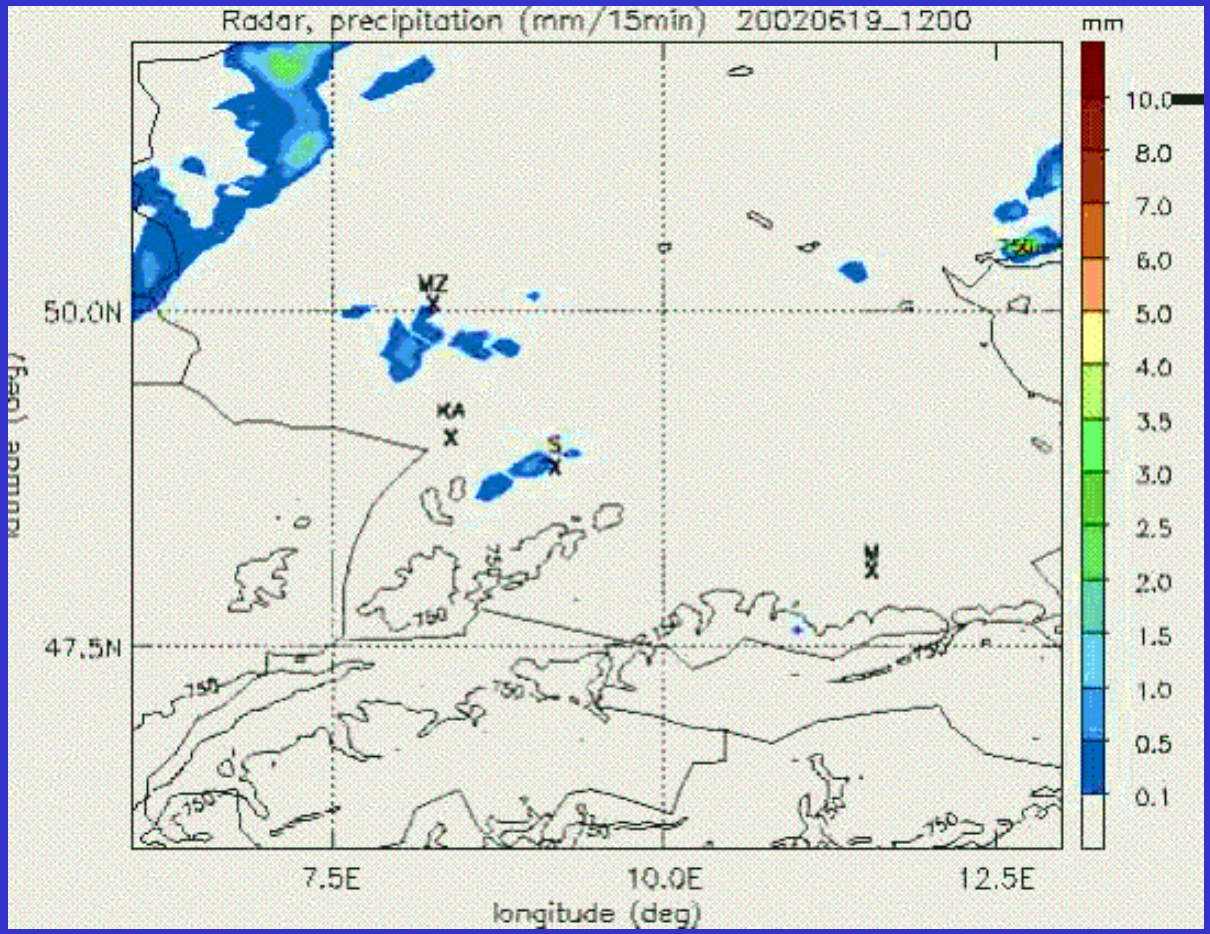
`coordinated`convection across Europ



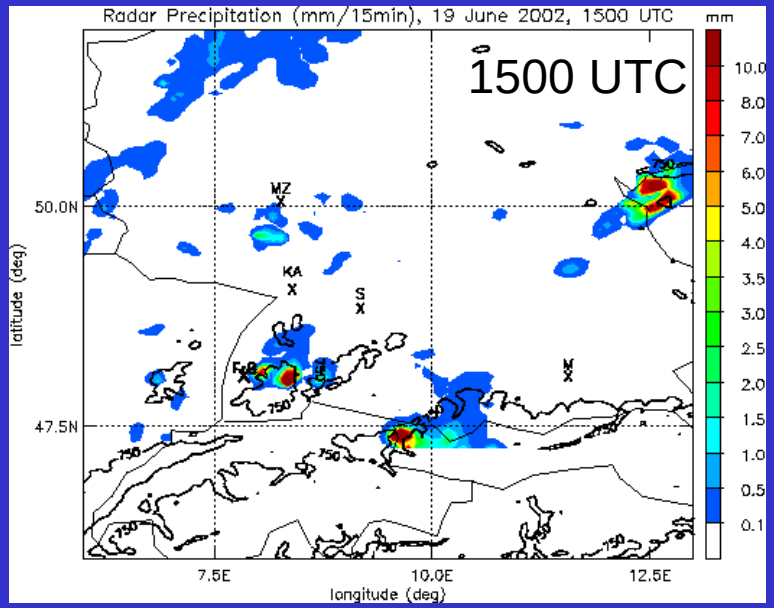
1600 UTC

Provided by Harald Sodemann, ETHZ

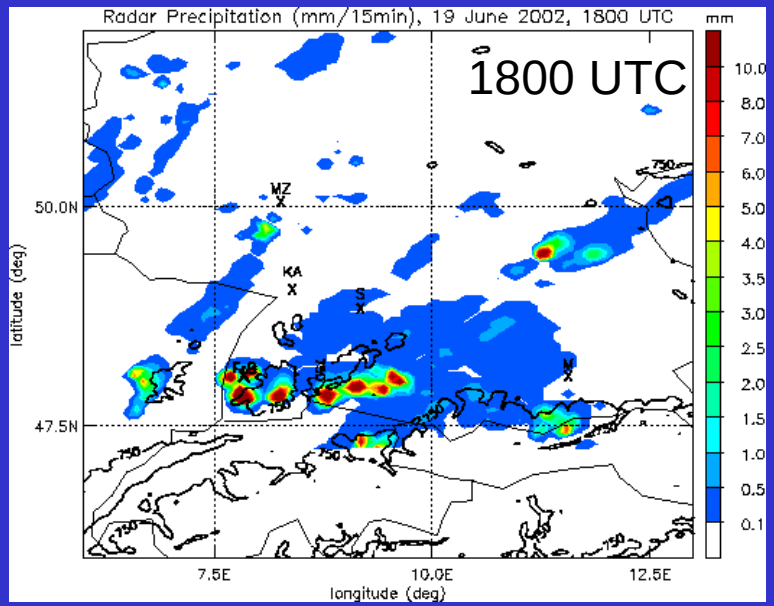
15 min radar-derived precipitation, 19 June 2002, 1200 -2400 UTC

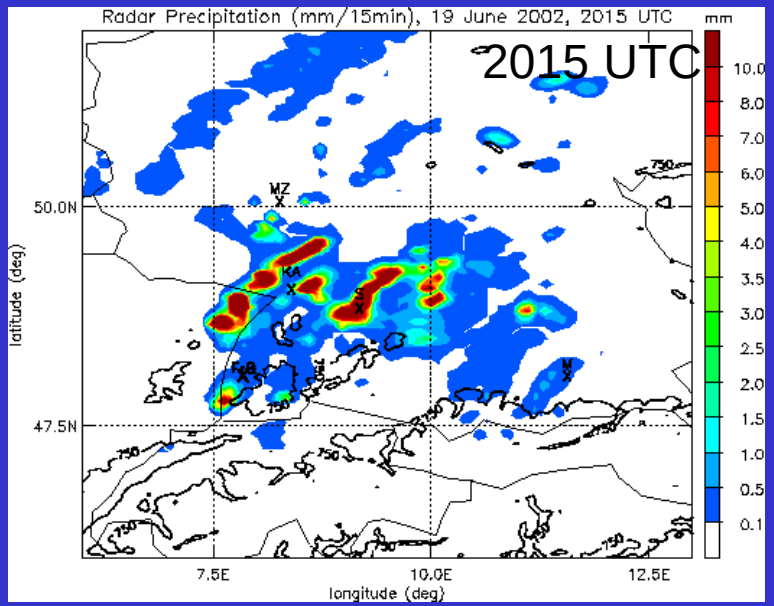


DWD PC product, processed by Martin Hagen, DLR



Local convection in the southern black forest region in the late afternoon (1500 UTC) and early evening (1800 UTC), more organized convection at late evening (2015 UTC) northern black forest.

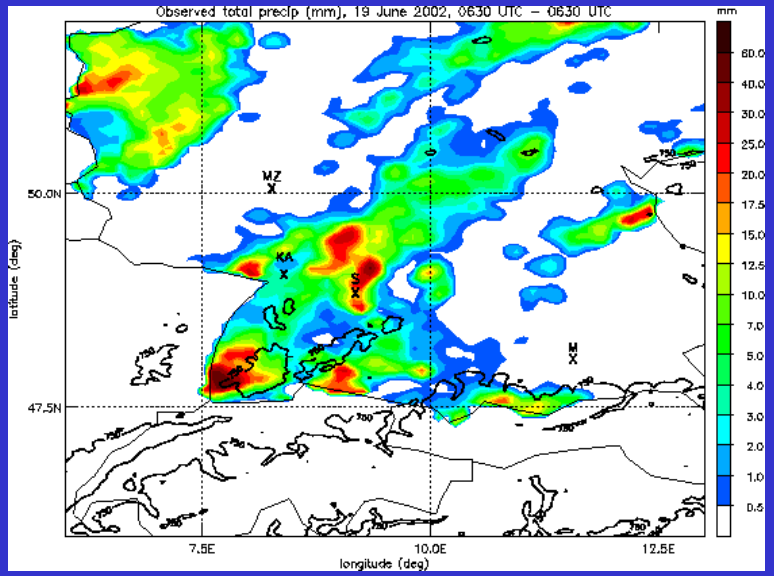




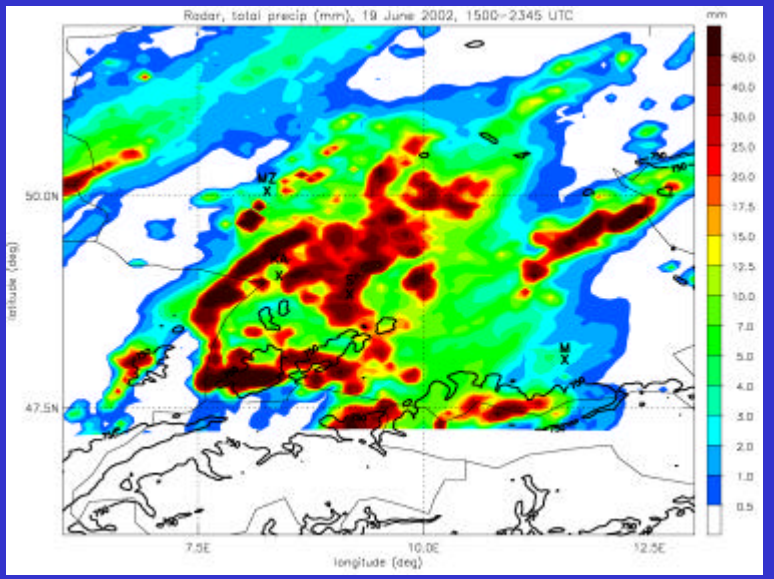
DWD PC Product processed by Martin Hagen, DLR

Total Precipitation, 19 June 2002

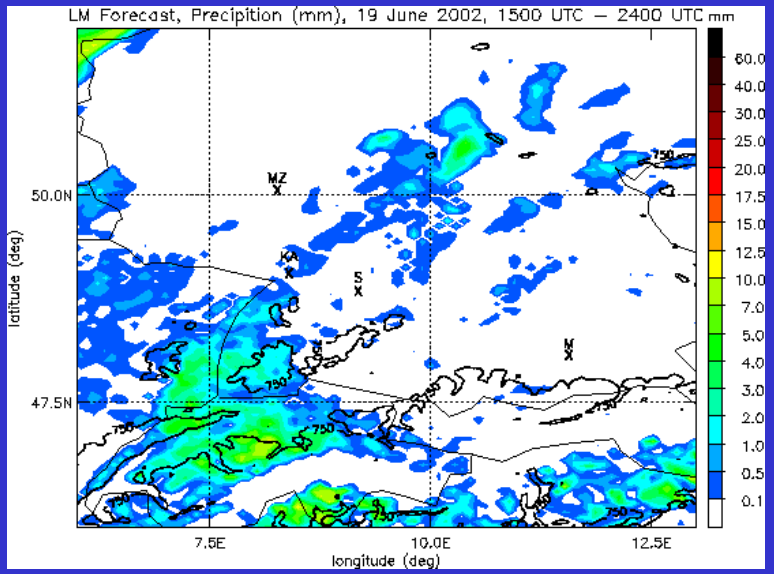
Surface observations, 24 h



Radar precipitation,15 - 24 UTC



Operational LM forecast,15 – 24 UTC



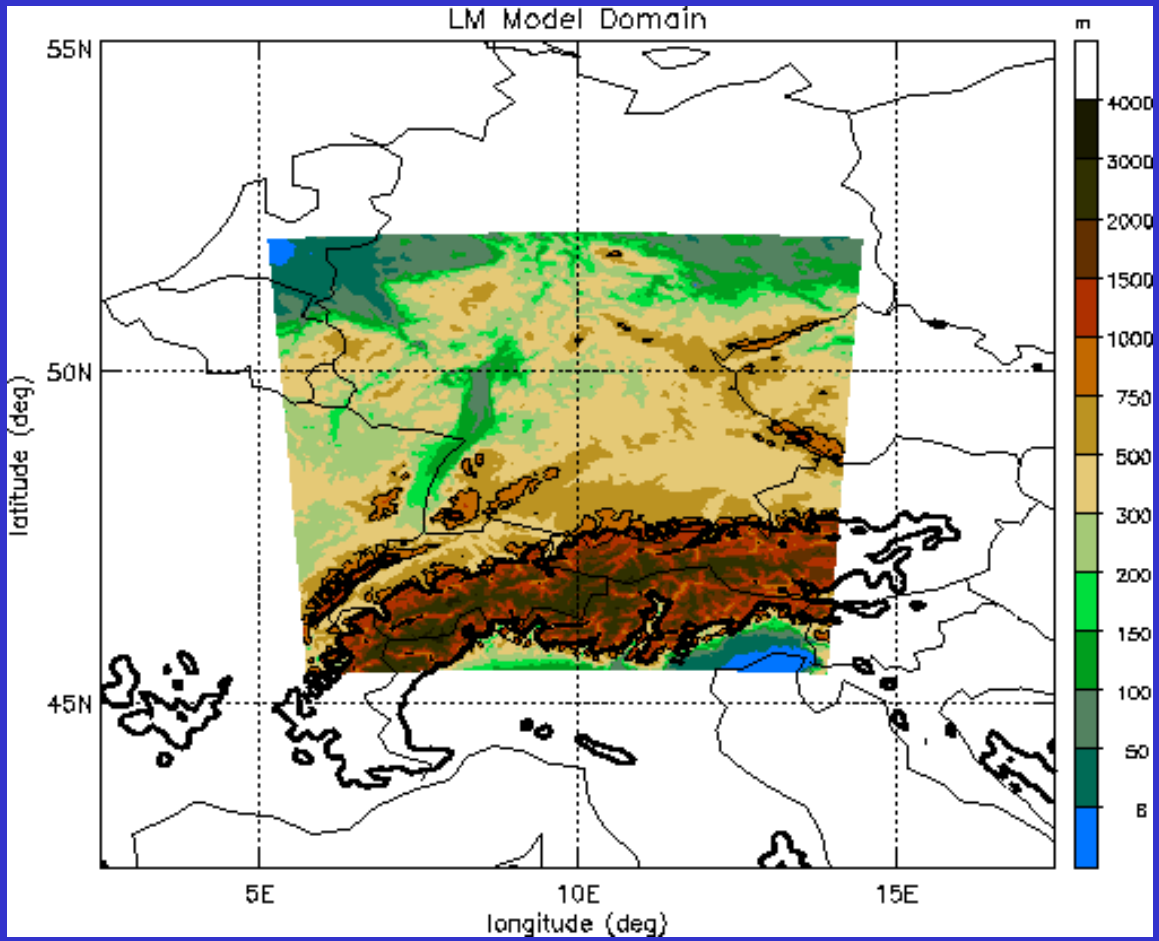
The LokalModell (LM)

- Installed at University Mainz on a Linux Cluster since September 2005, currently used in 2 projects.

- Special thanks for the support from DWD:
  Michael Baldauf, Jochen Förstner, Erdmann Heise, Christian Koziar, Thorsten Reinhard, Ulrich Schättler, Jan-Peter Schulz, Axel Seifert

- Here: 2.8 km resolution without parameterization of deep convection, initial and boundary conditions from hourly operational LM Analysis (7 km)

Model domain

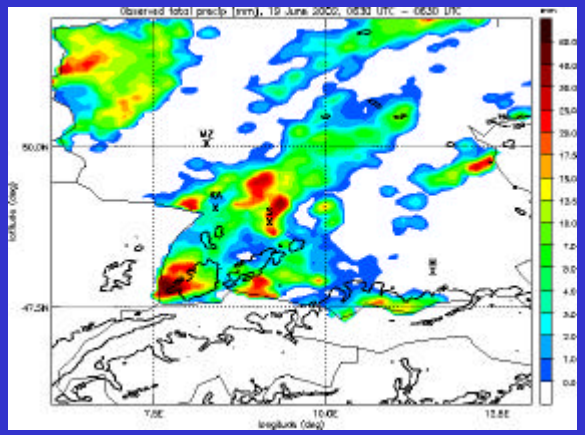


231 x 265 horizontal grid boxes, 50 vertical layers

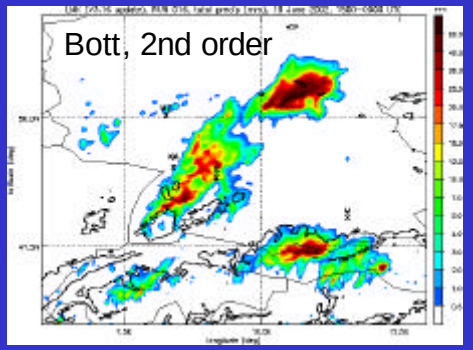
Several LM Simulations with varying parameter settings

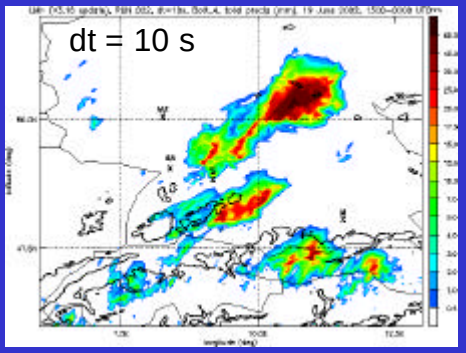
- all simulations with V3.16
- advection scheme: Bott, 2. order / Bott, 4. order
- Graupel / Ice microphysics scheme
- Timestep: 30 sec. / 10 sec.
- Implicit / Explicit vertical advection
- Start of model simulation at 06 / 07 / 08 am

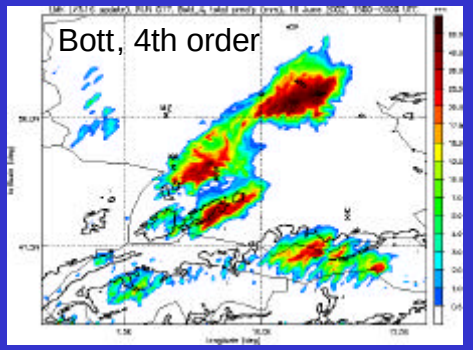
Observed and simulated precipitation between 1500 and 2400 UTC

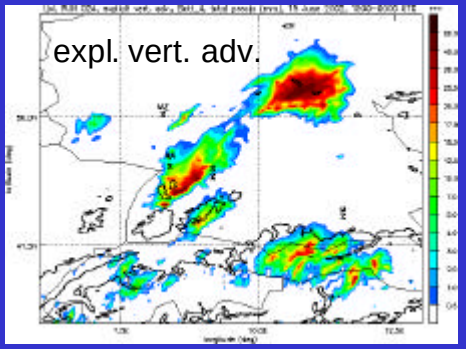


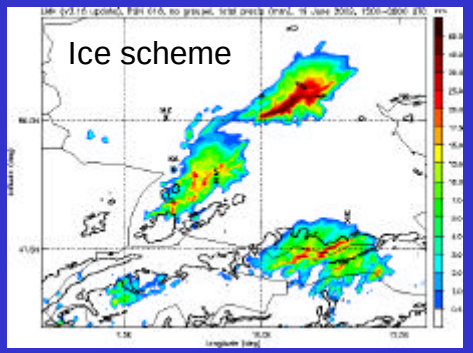
- significant spread across the model simulations
- no simulation predicts precipitation in the South-west
- Some simulations predict precipitation east of Swabian Alb

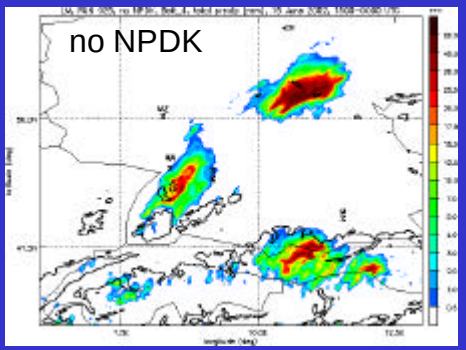






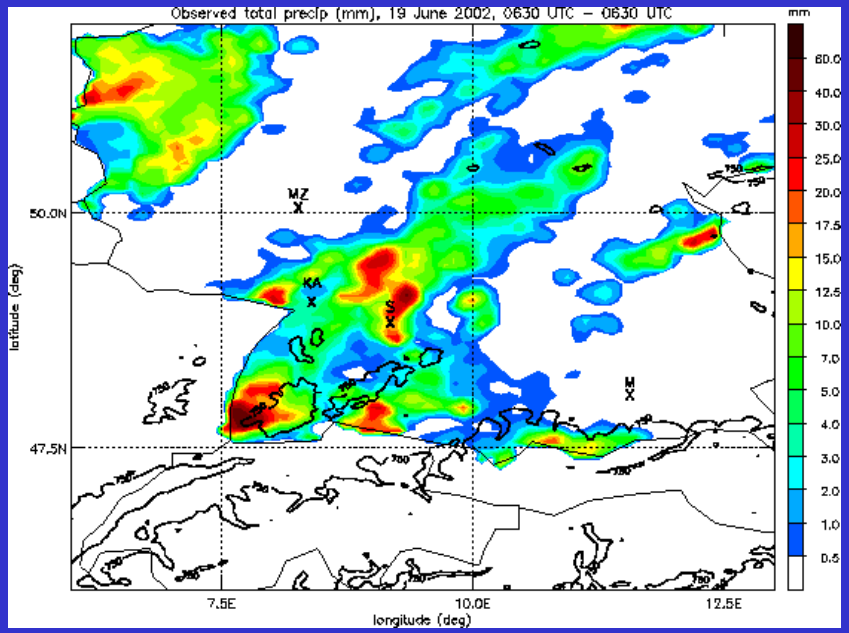




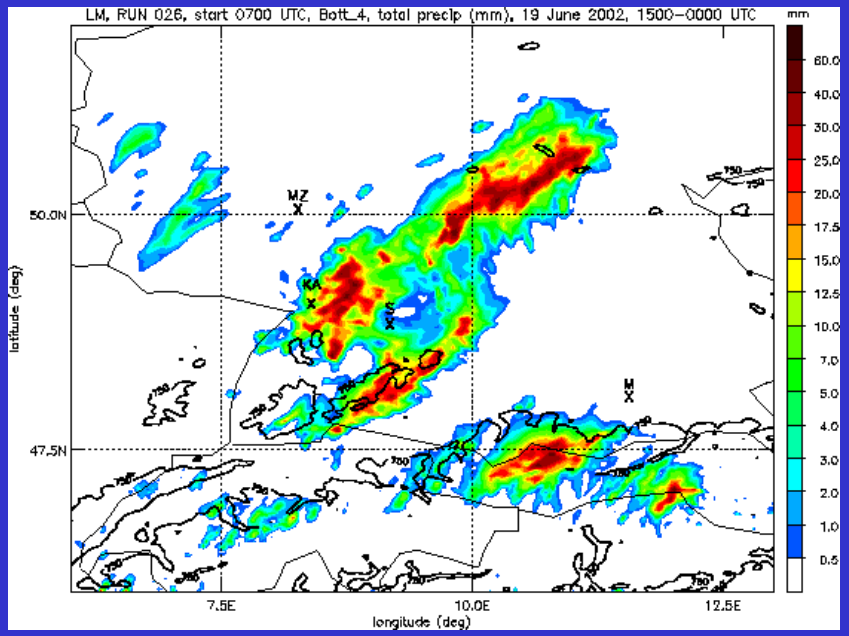


Simulated and observed precipitation

Surface observations

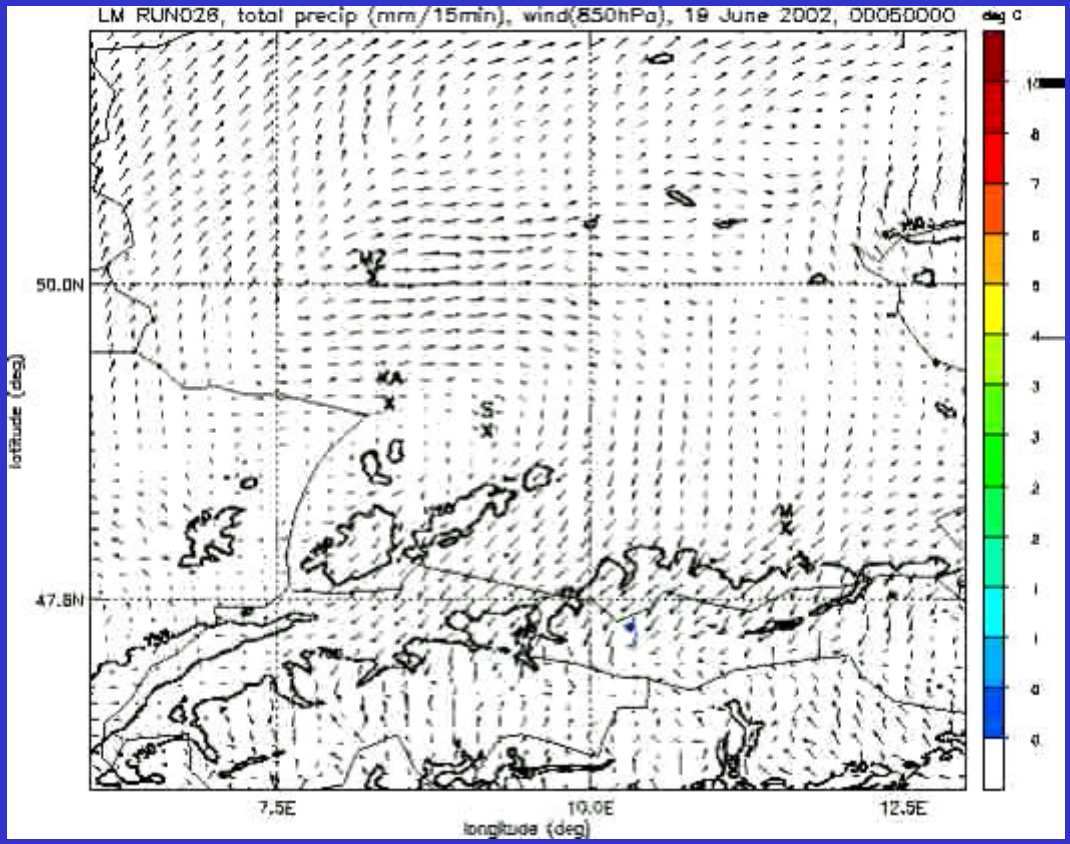


Most realistic LM simulation

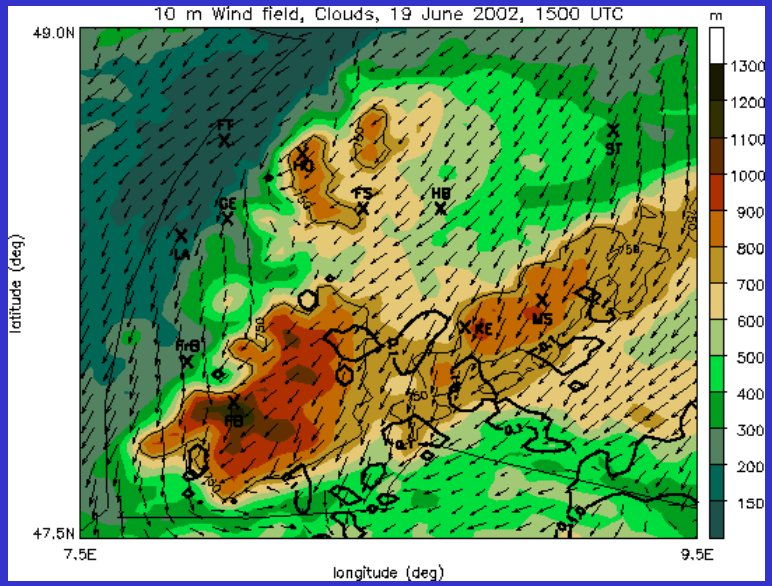


- 4th order Bott advection scheme
- start of the simulation at 07 UTC
- Timestep 30 sec
- Graupel scheme
- Implicit vertical advection

Simulated Precipitation 1200 – 2400 UTC

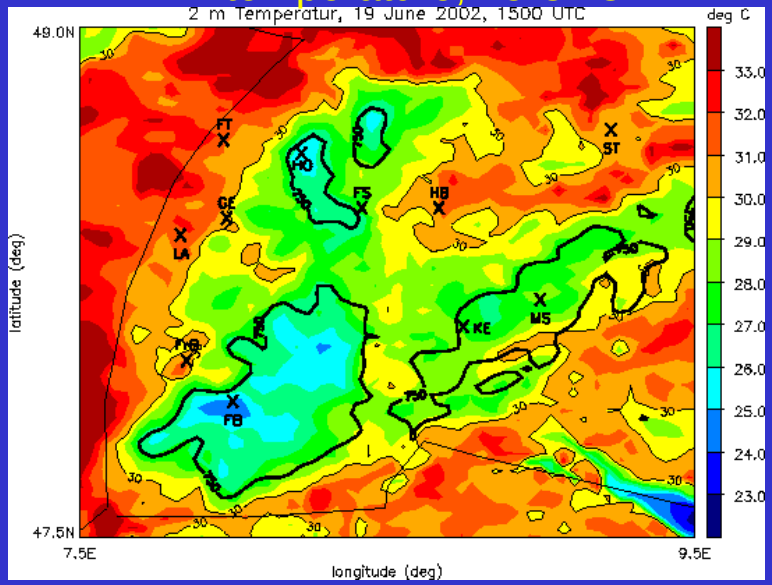


Topography, wind, cloud water, 15 UTC

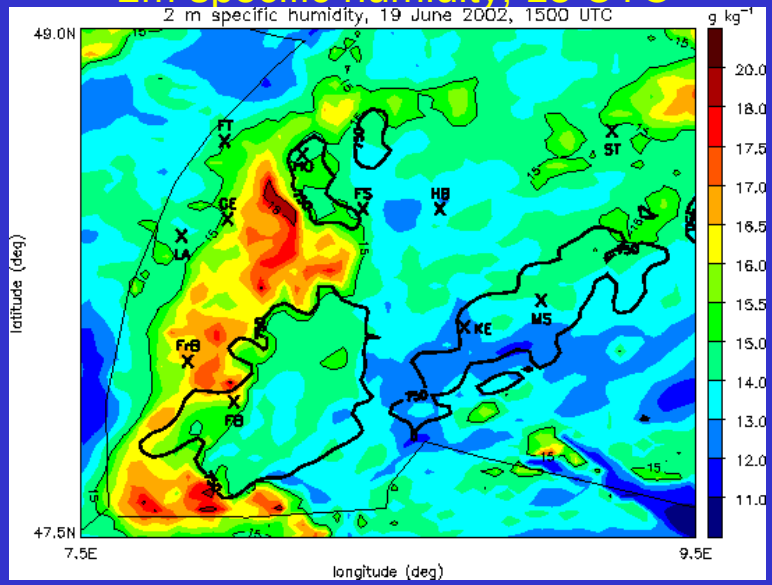


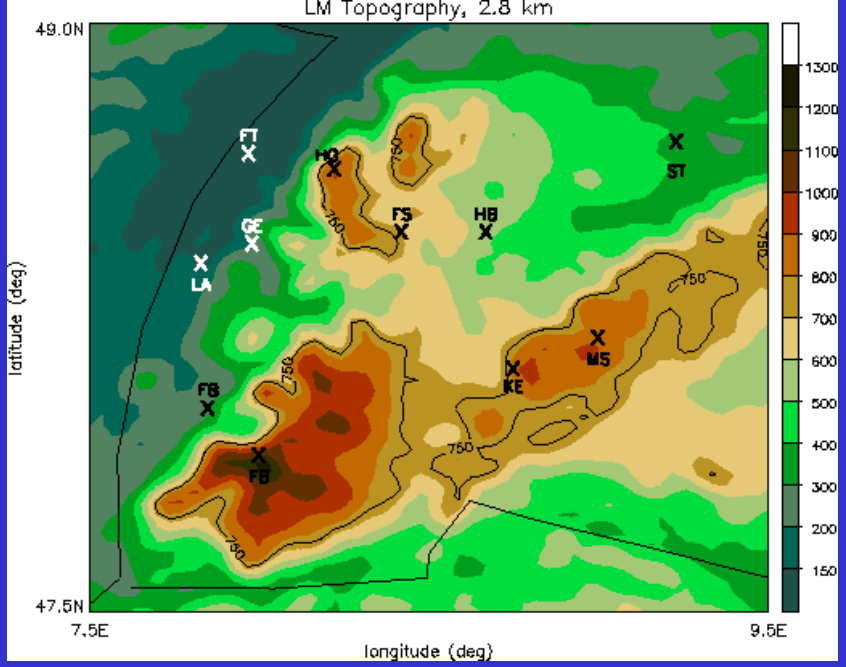
- North-easterly flow in the lower levels, surface winds modified by topography
- Maximum 2m-temperature and 2m-humidity in the Rhine valley, moisture is transported into the black forest
- Consistent with surface measurements

2m temperature, 15 UTC

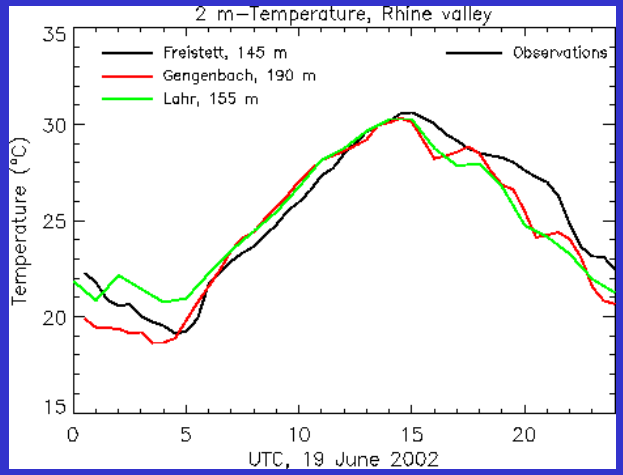


2m specific humidity, 15 UTC

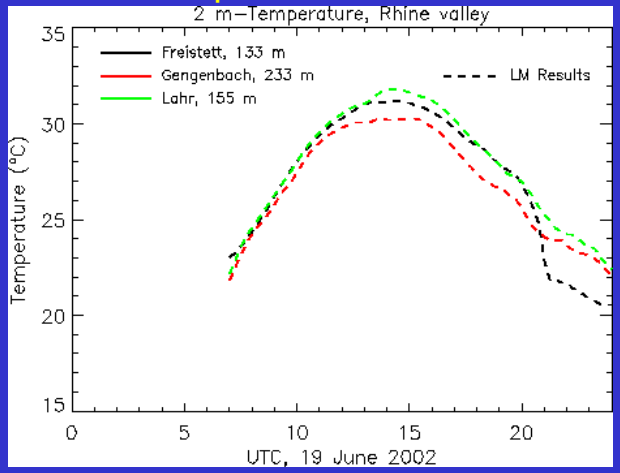


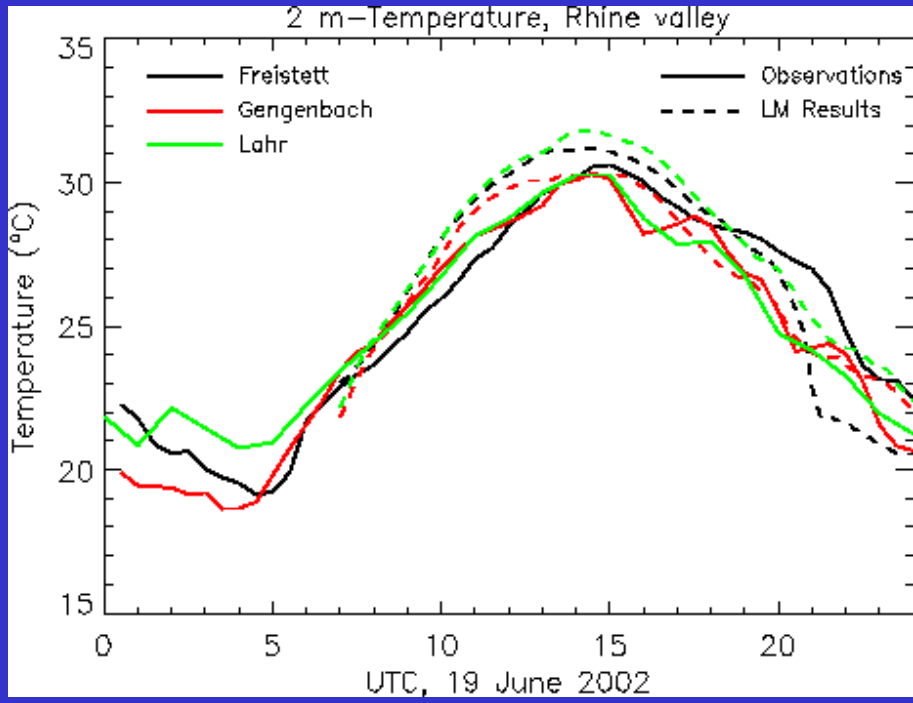


2m temperature, obs

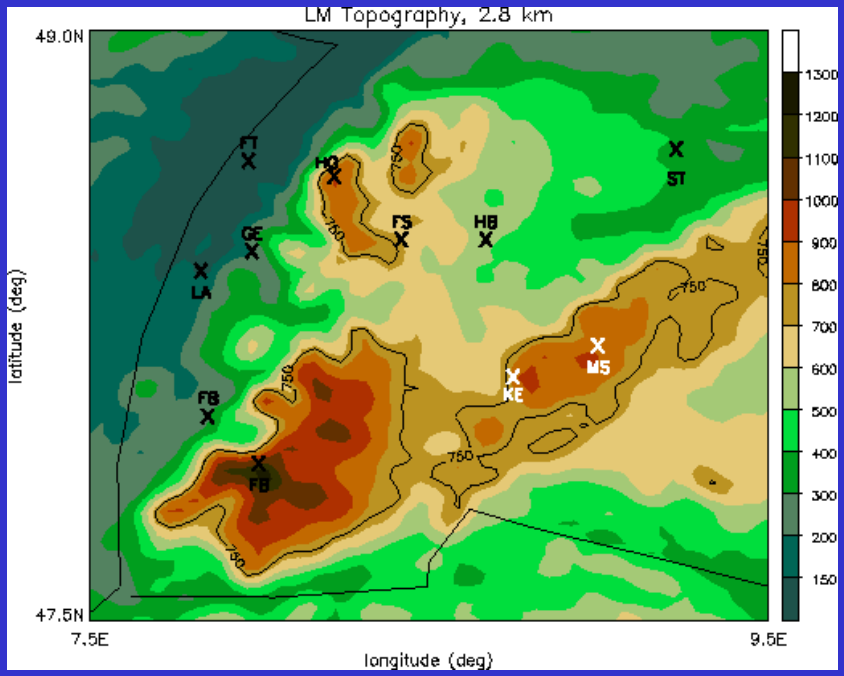


2m temperature, simulated

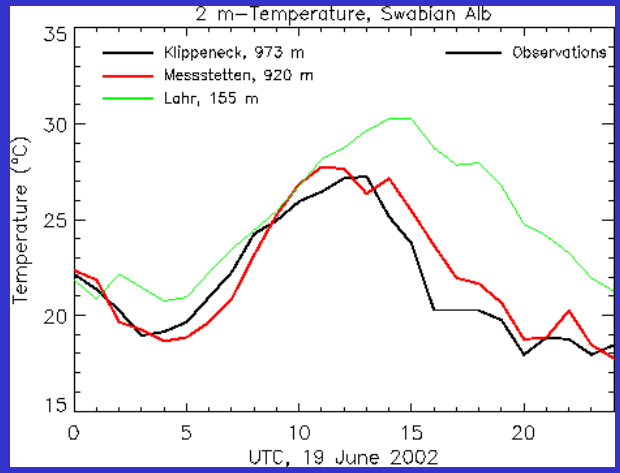




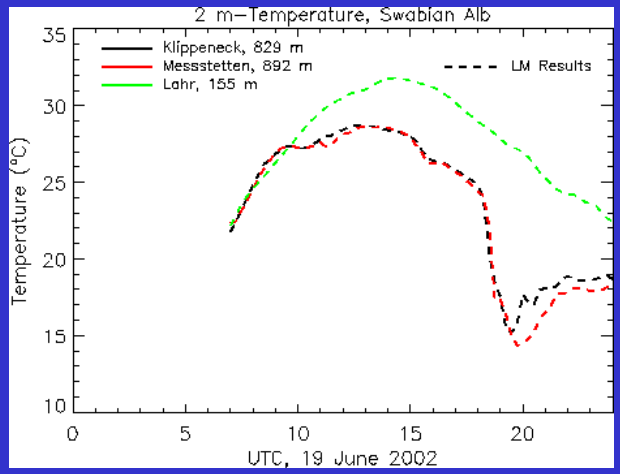
DWD Synop data provided by Barbara Früh

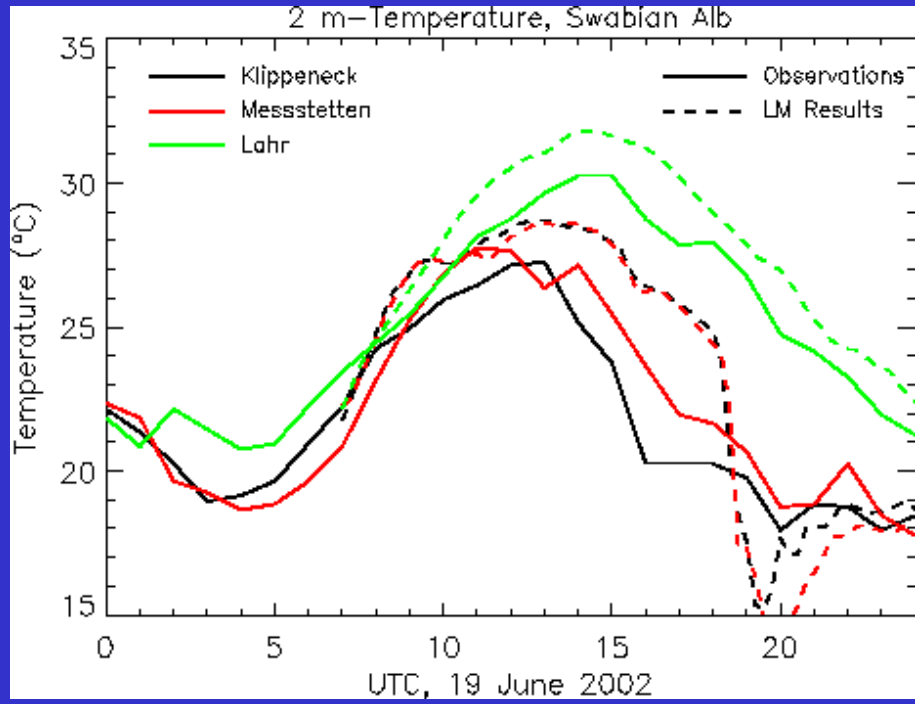


2m temperature, obs



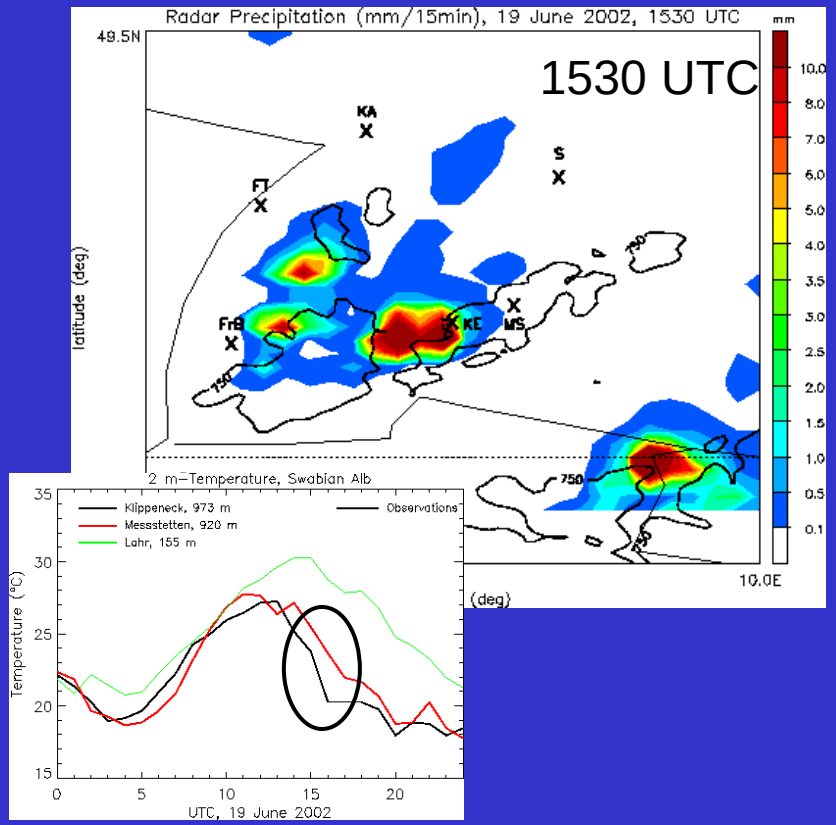
2m temperature, simulated



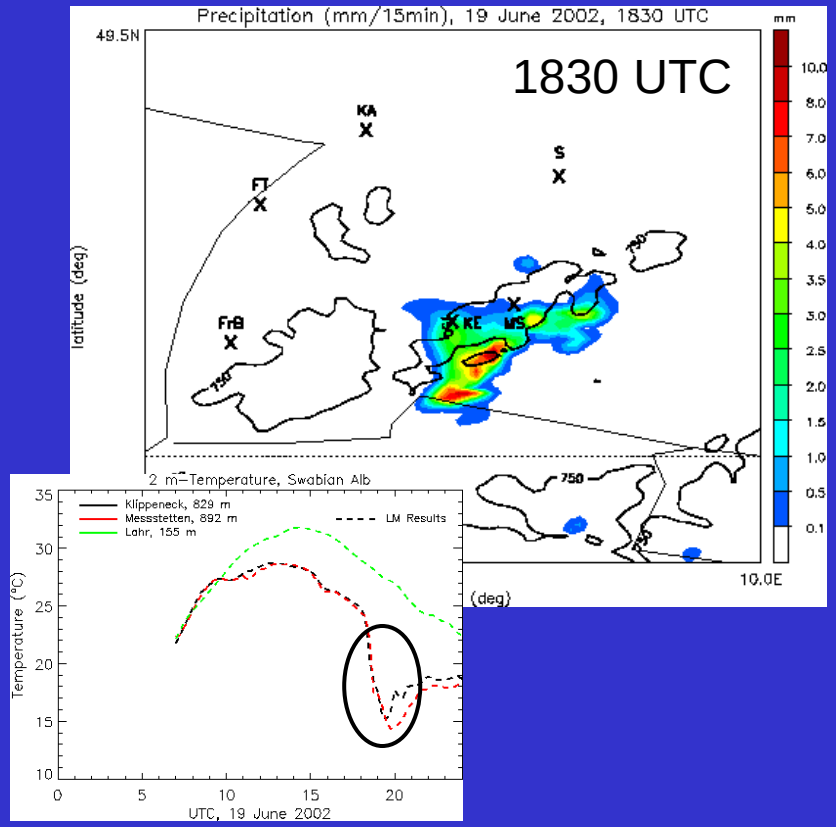


DWD Synop data provided by Barbara Früh

Observations

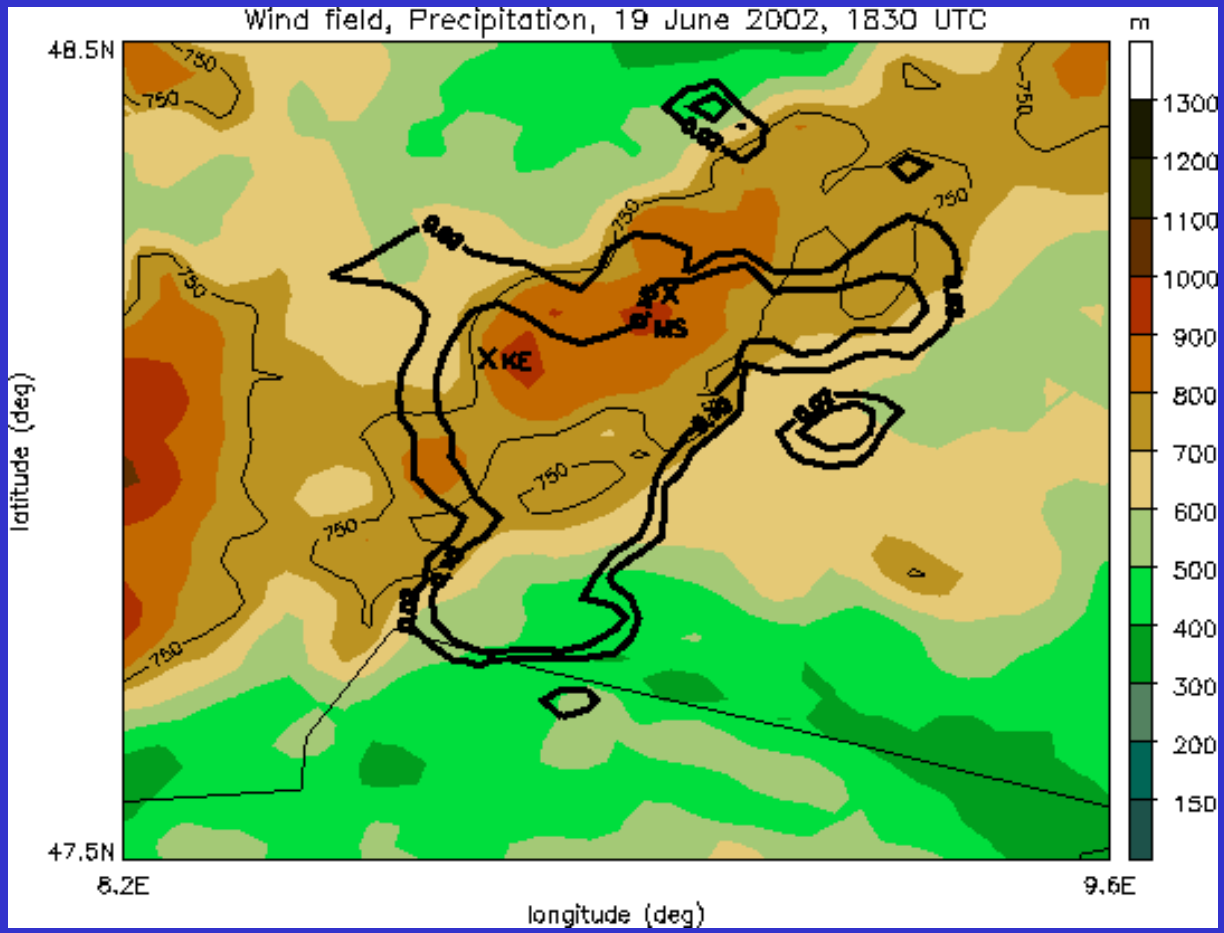


Model results

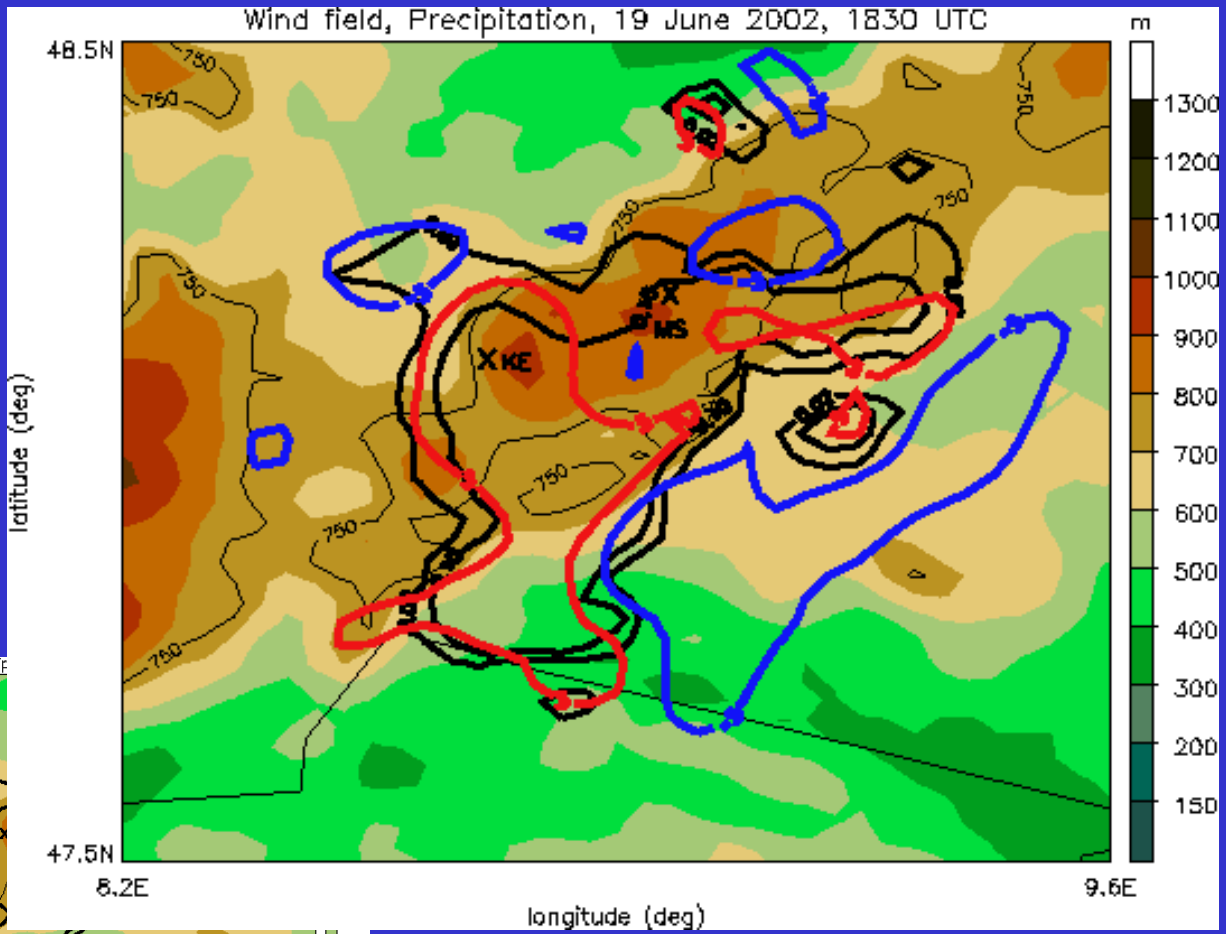


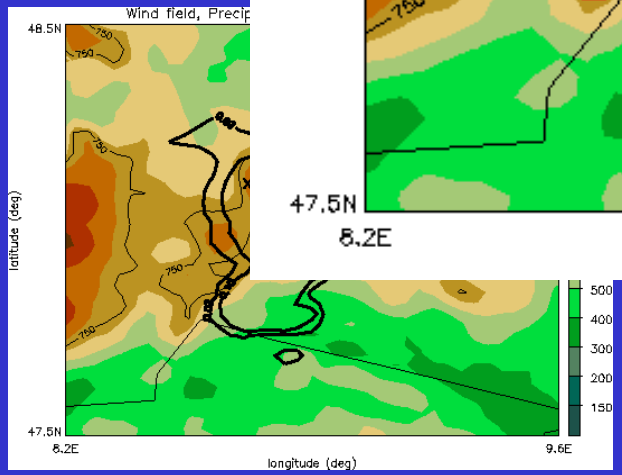
Temperature drop in the observations and the model simulations correlate with precipitation.

Simulated precipitation, 1830 UTC

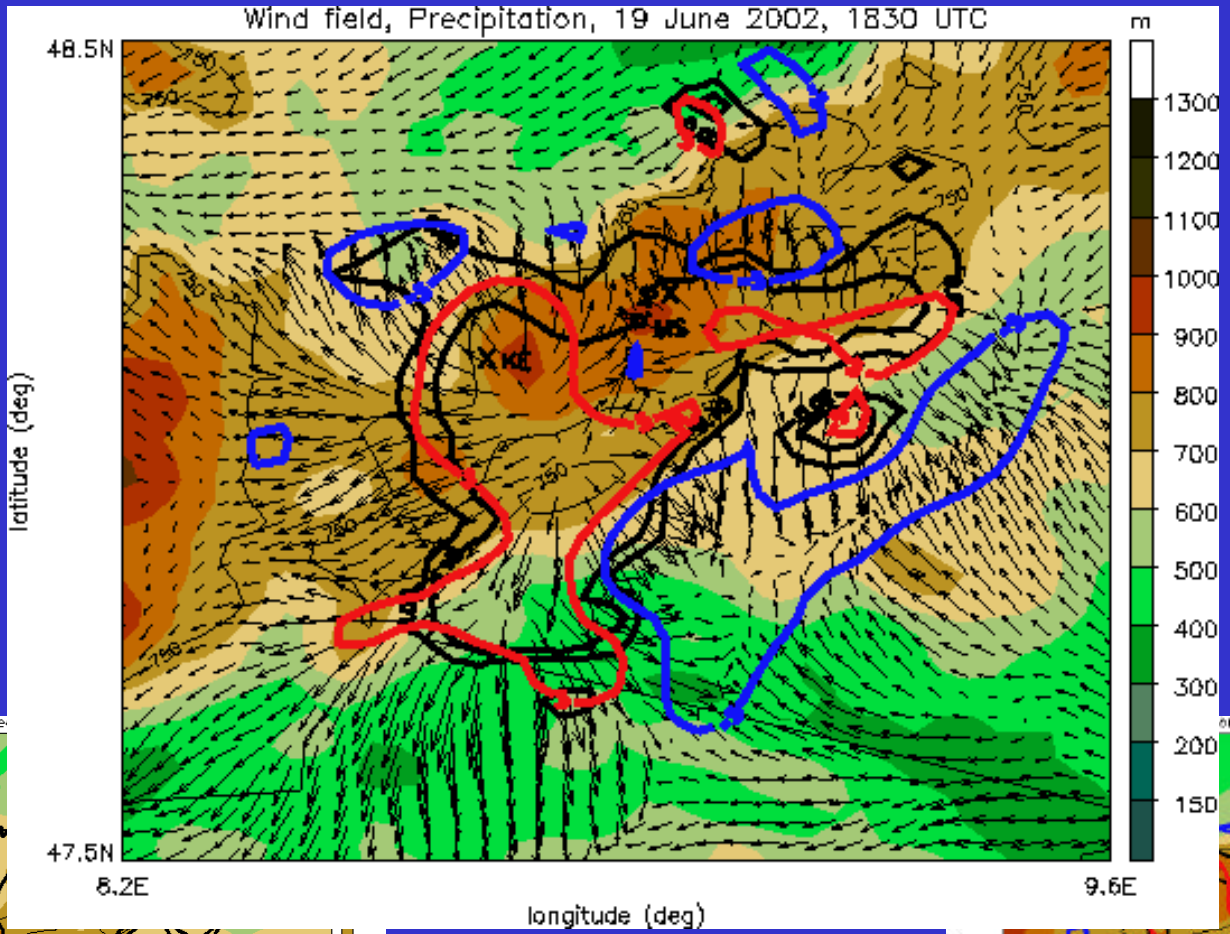


Simulated precipitation, up-/downdrafts

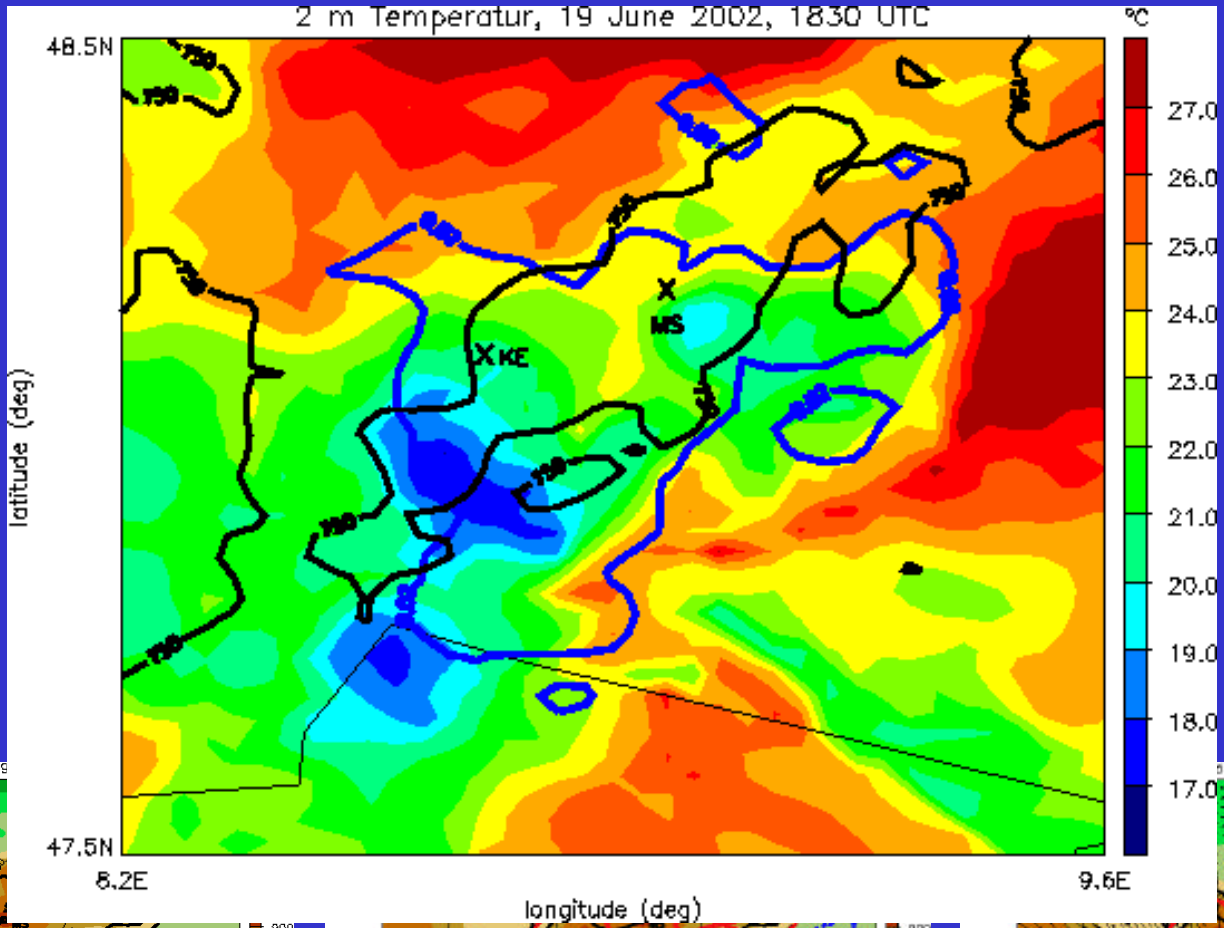


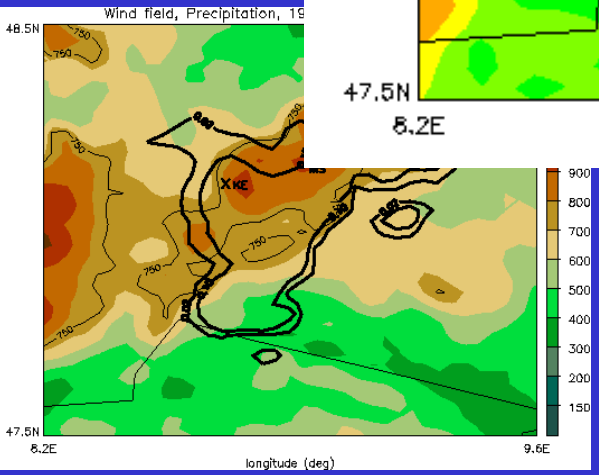


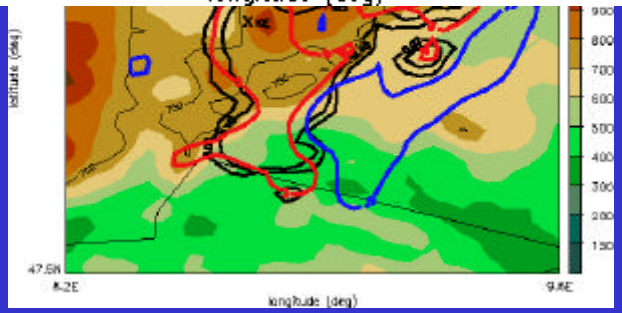
Simulated precipitation, wind field

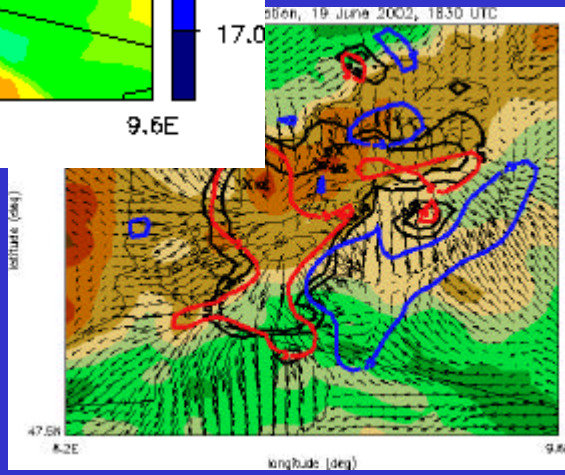


Simulated temperature, precipitation



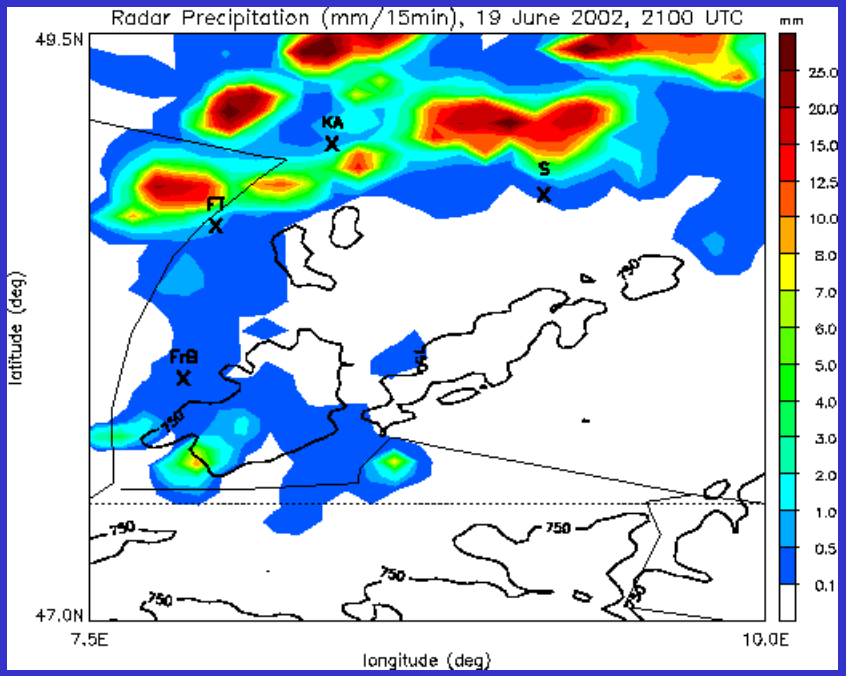




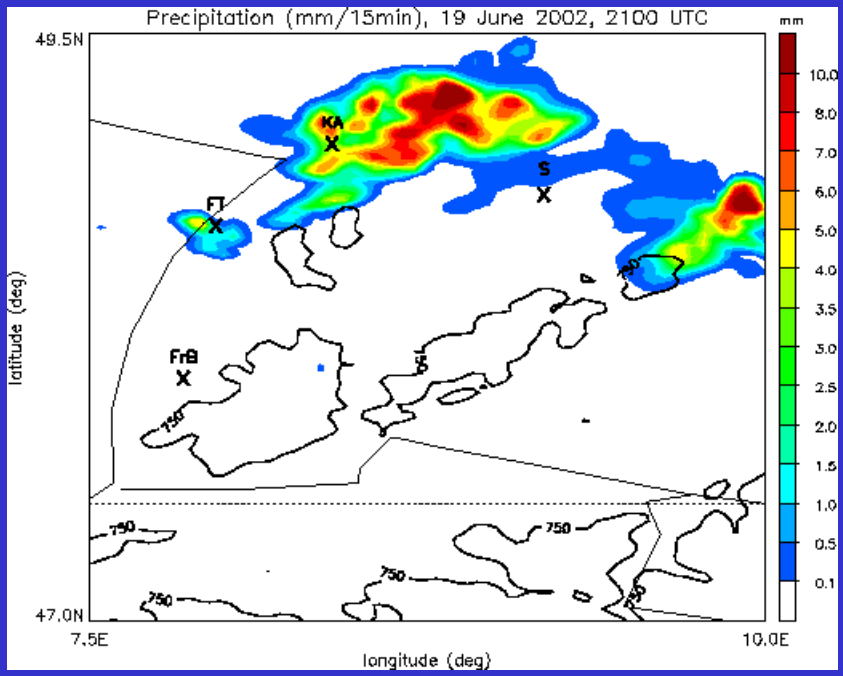


Evaluation of Cloud Structures

Radar precipitation, 21 UTC



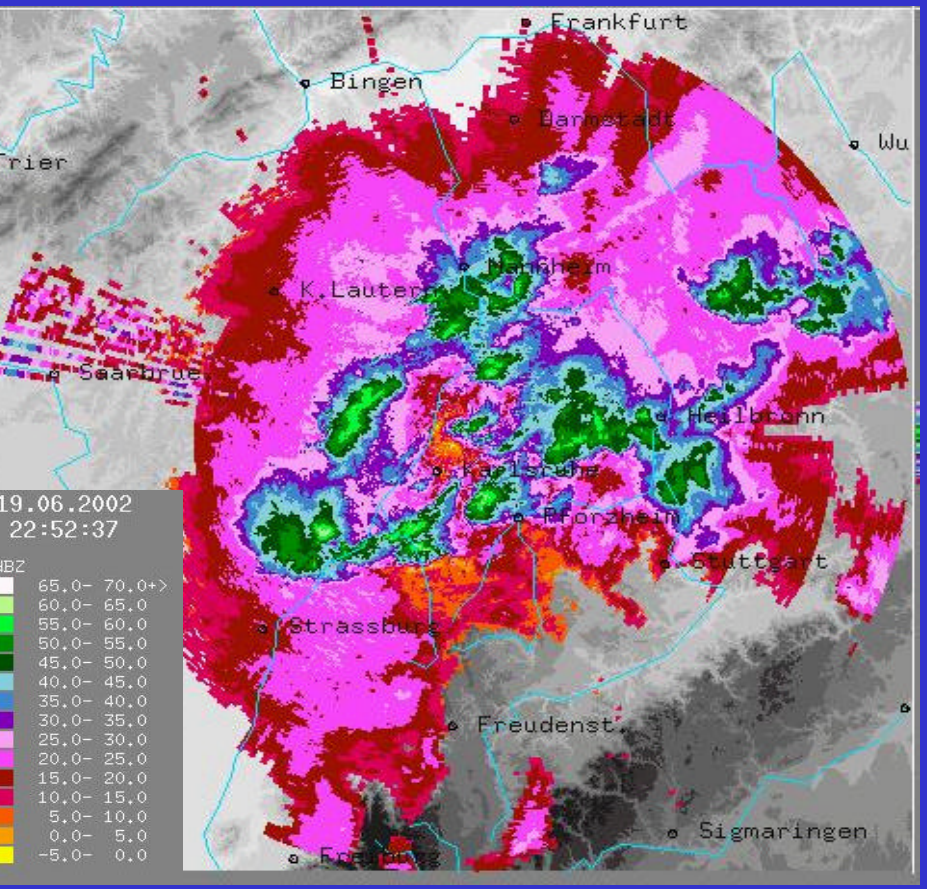
Simulated precipitation, 21 UTC



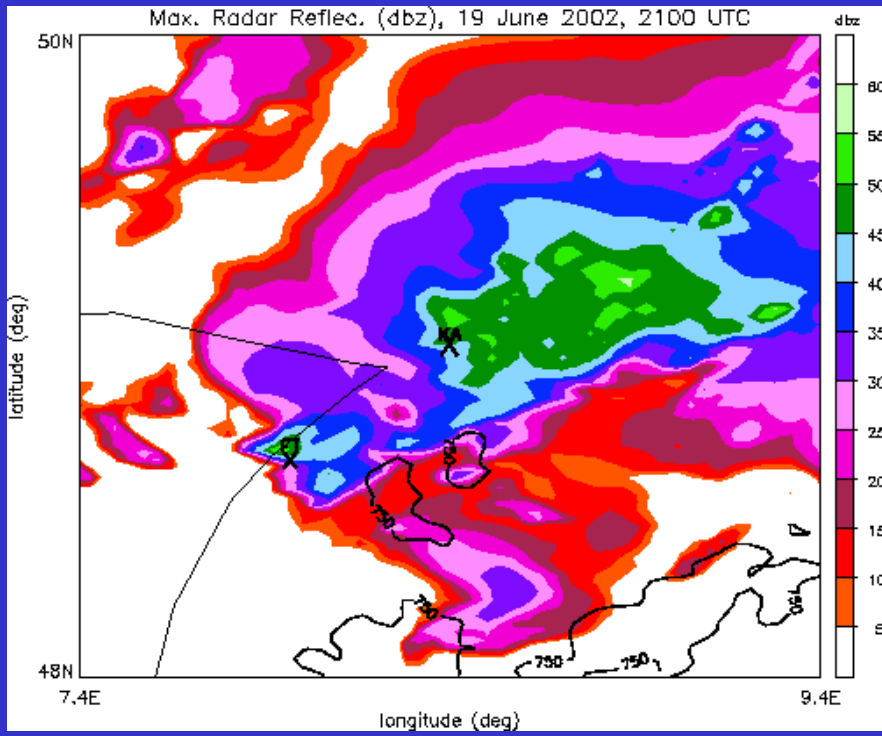
Note: different color scales!!

DWD PC Product processed by Martin Hagen, DLR

Karlsruhe Radar, IMK

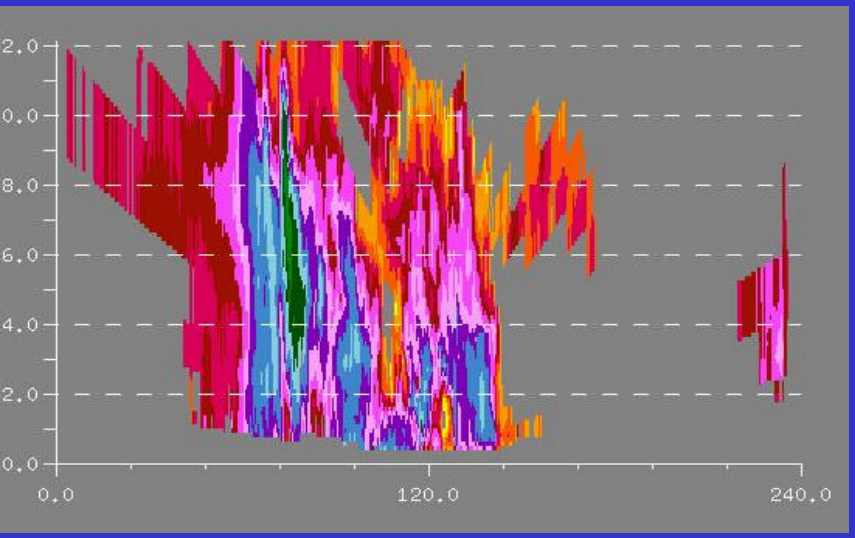


Radar reflectivity from LM

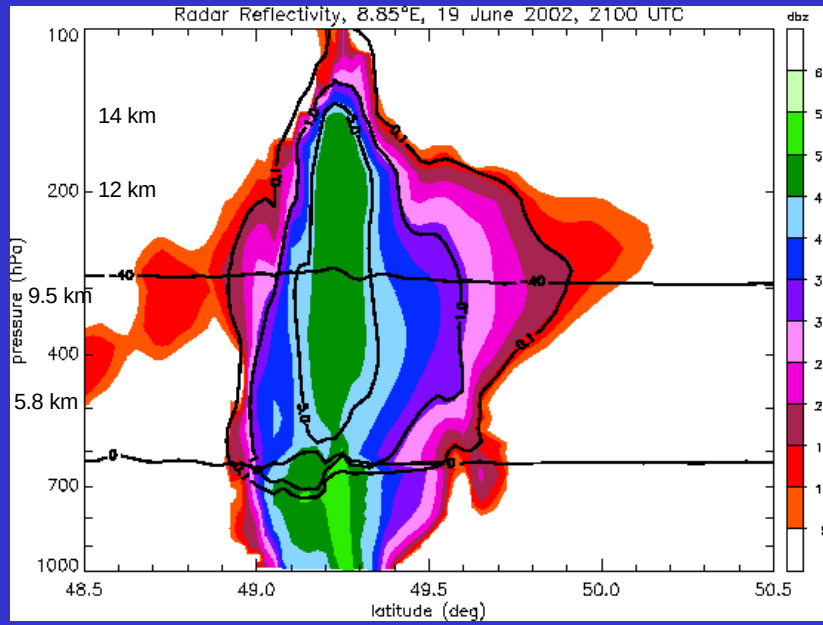


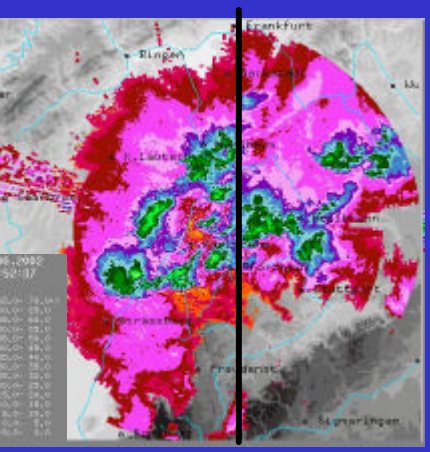
Individual small scale structure are not reproduced, but simulated DBZ values are in the right order of magnitude.

Karlsruhe Radar, IMK

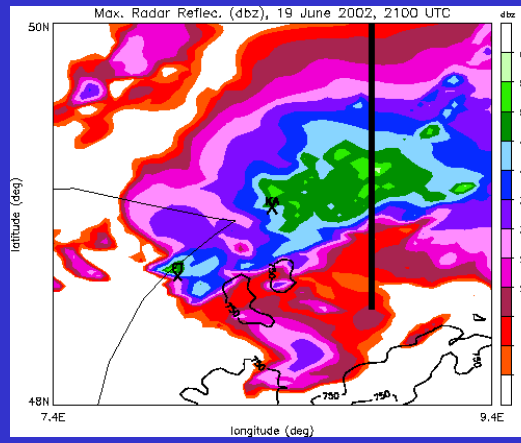


Radar reflectivity from LM





- Evaluation of the vertical structure of convection possible
- The intensity of the convections seems to be overestimated

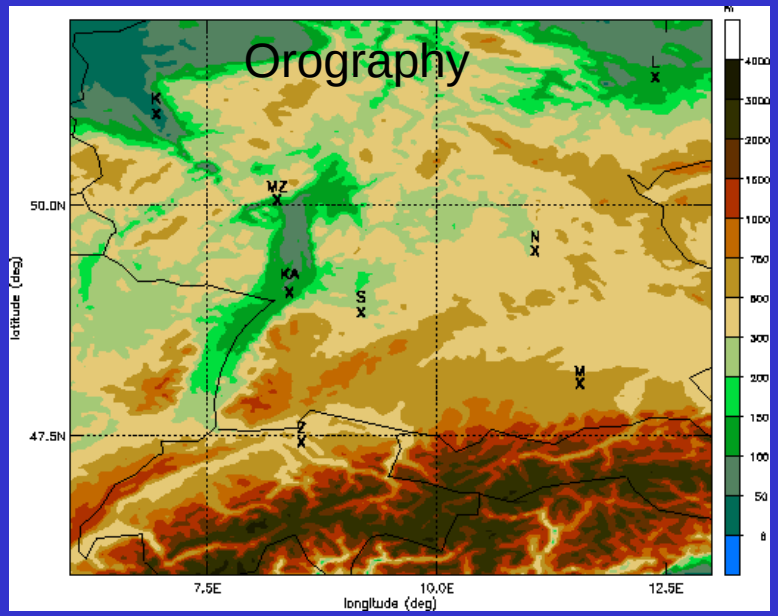


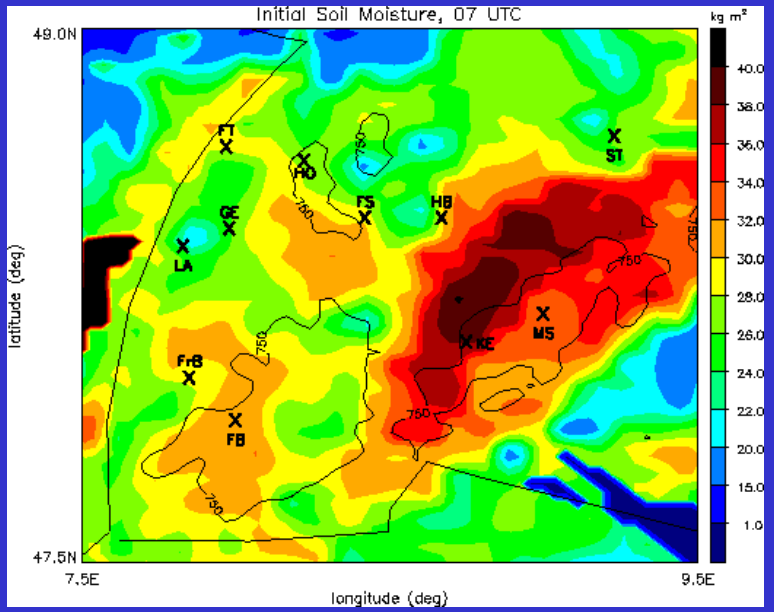
Conclusions:

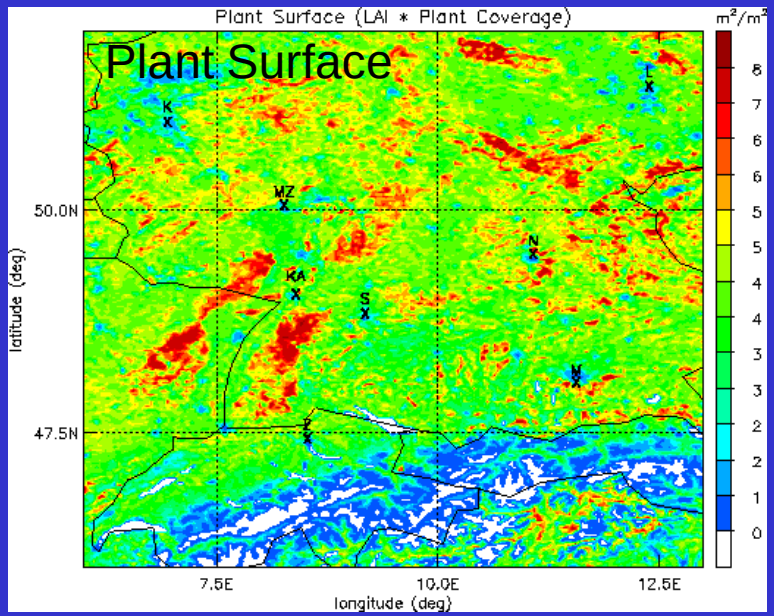
- LM is running at University Mainz
- 1. case study: 19.6.2002, convection in the black forest
- **Observations:** local convection in the afternoon and early evening, organized convection in the evening
- **Model:** Significant spread between different model setups
- no initiation of local convection, organized convection can be reproduced
- Processes related to convection, e.g., formation of a cold pool, are included
- LM provides realistic description of convective clouds

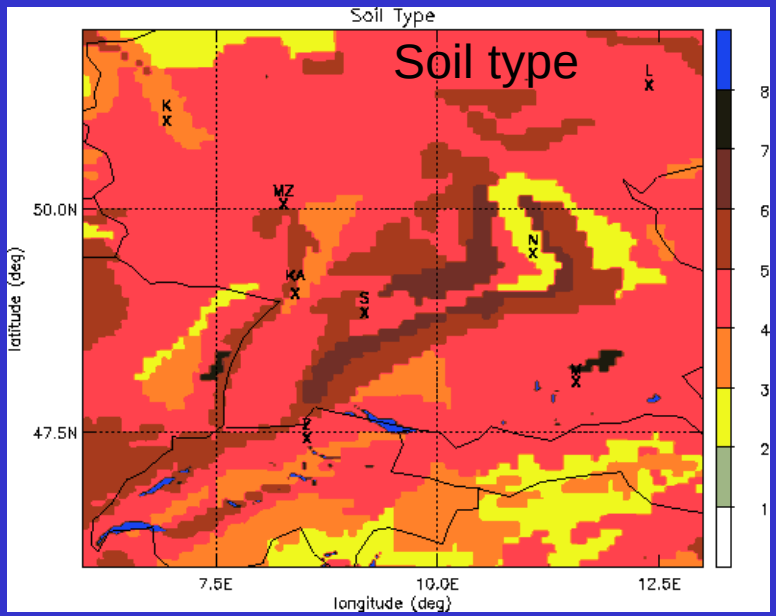
Outlook:

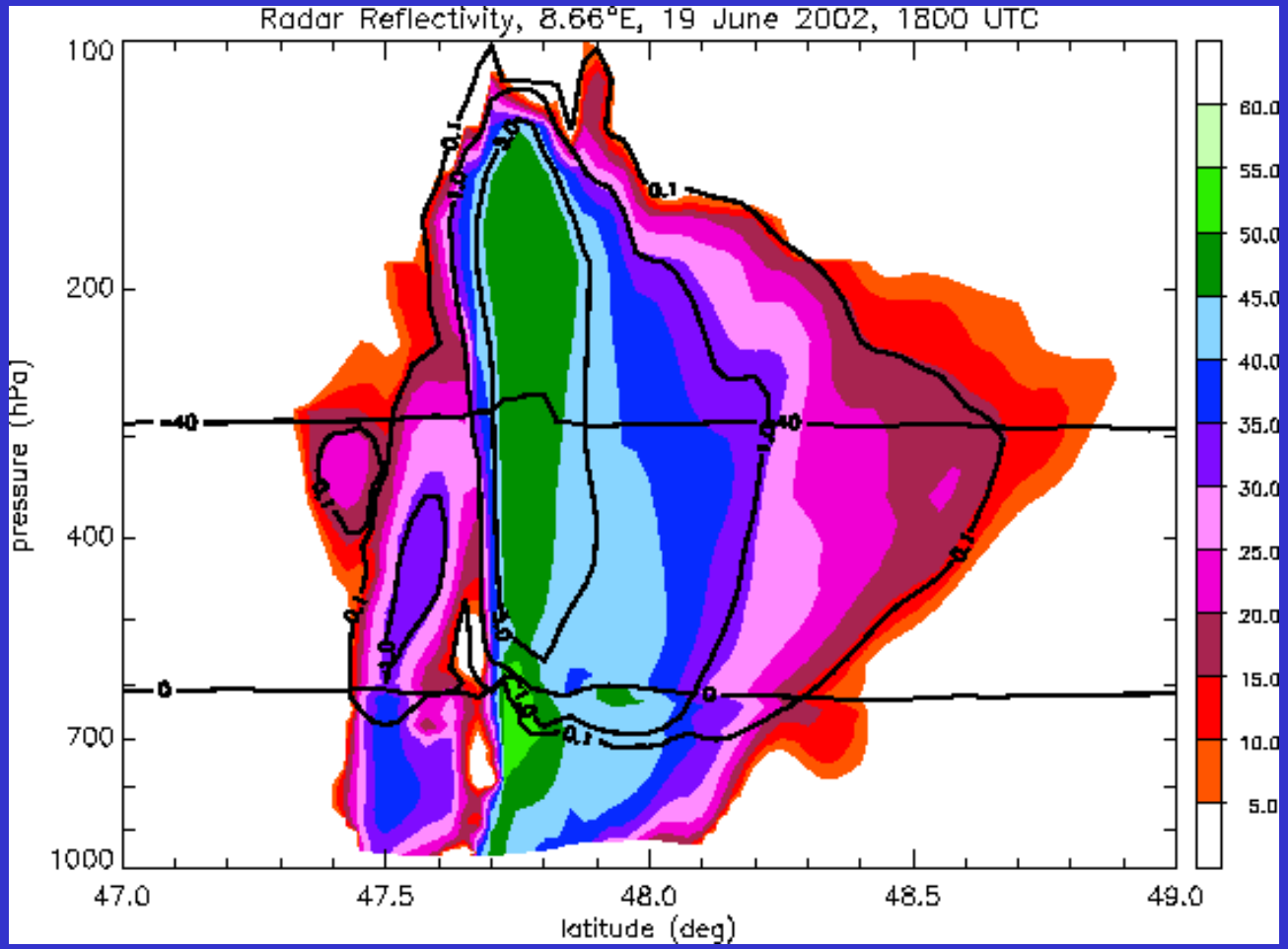
- Evaluate the model results with field observations (VERTIKATOR)
- Increase the model domain and the spatial resolution, use different initial and boundary conditions
- Conduct sensitivity studies: soil moisture, topography, etc.
- Use of more sophisticated physics packages (radiation, cloud microphysics)
- Evaluate other convective cases

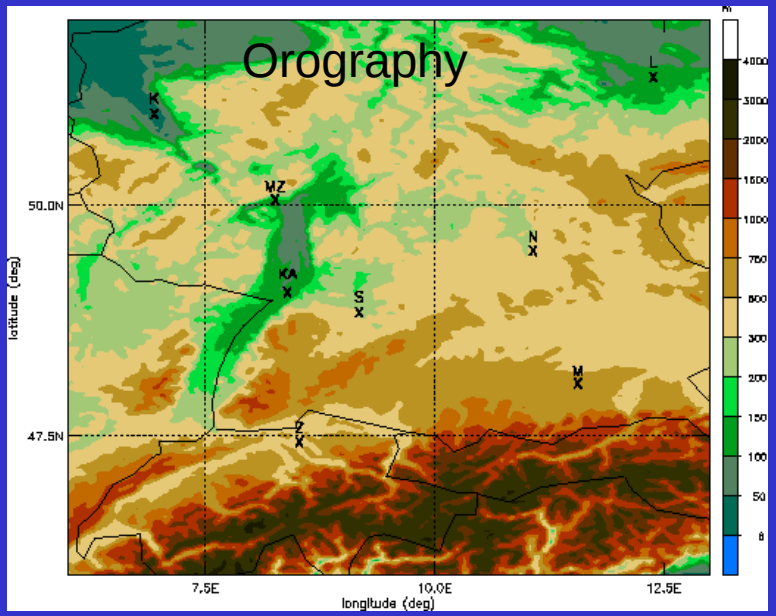

Orography
50.0N
47.5N
7.5E
10.0E
12.5E
latitude (deg)
longitude (deg)


Initial Soil Moisture, 07 UTC
kg m²
49.0N
47.5N
7.5E
9.5E
latitude (deg)
longitude (deg)

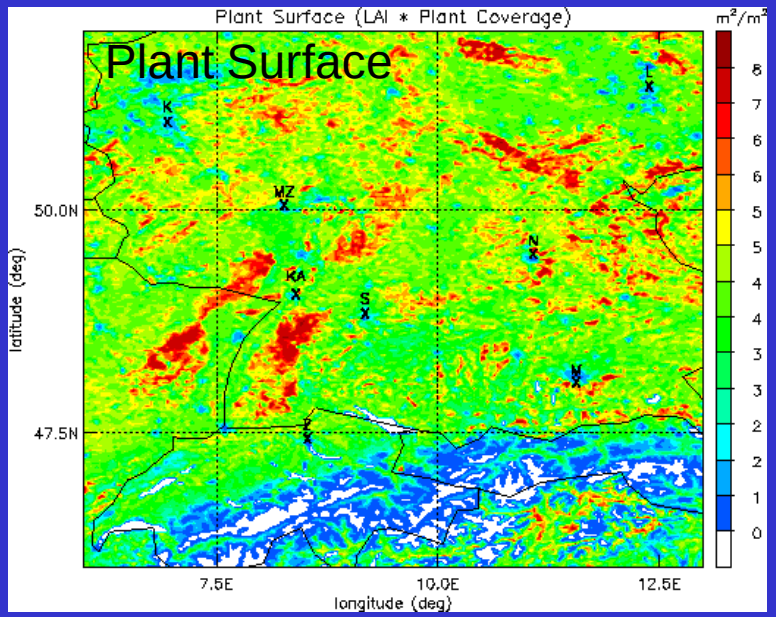

Plant Surface (LAI * Plant Coverage)
Plant Surface
m²/m²
50.0N
47.5N
7.5E
10.0E
12.5E
latitude (deg)
longitude (deg)

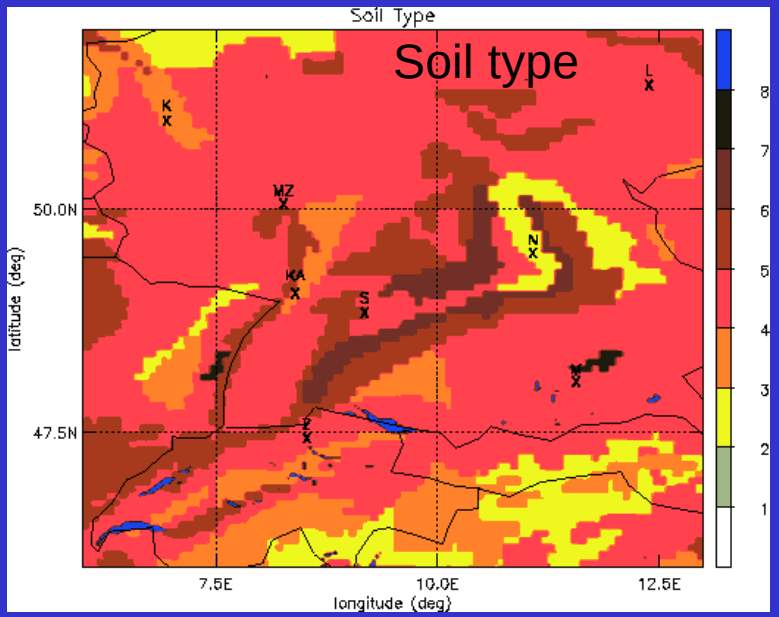

Soil Type
Soil type
50.0N
47.5N
7.5E
10.0E
12.5E
latitude (deg)
longitude (deg)

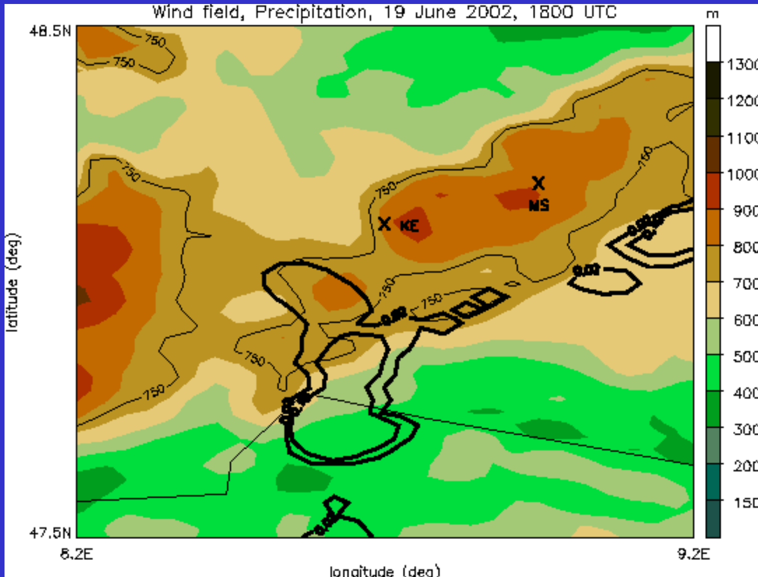

Radar Reflectivity, 8.66°E, 19 June 2002, 1800 UTC
pressure (hPa)
100
200
400
700
1000
47.0
47.5
48.0
48.5
49.0
latitude (deg)
60.0
55.0
50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
-40
0
0.1
1.0
5.0

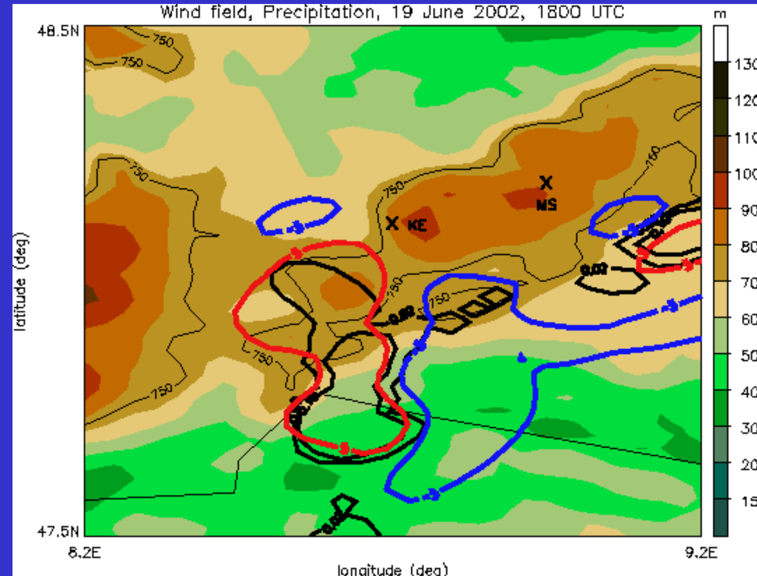


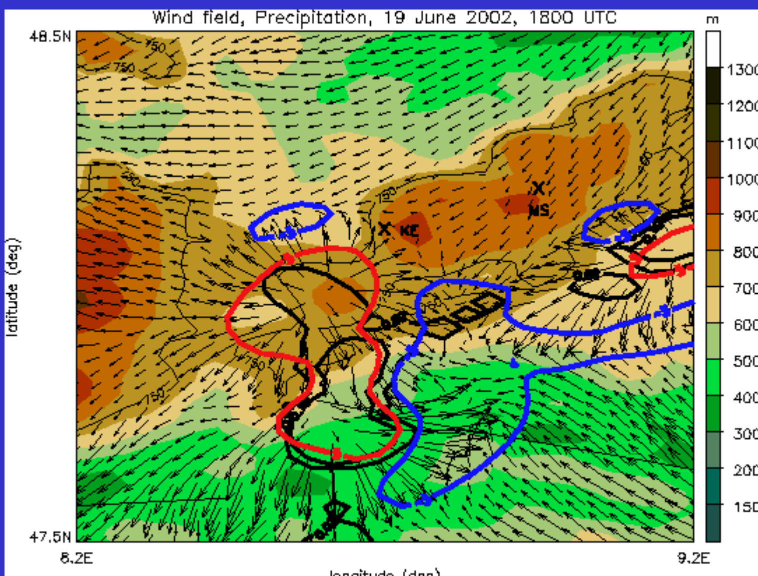
External parameters used in the LM at 2.8 km resolution. Some parameters (orography, plant surface) capture small sale structures, others (e.g., soil type) are rather coarse.

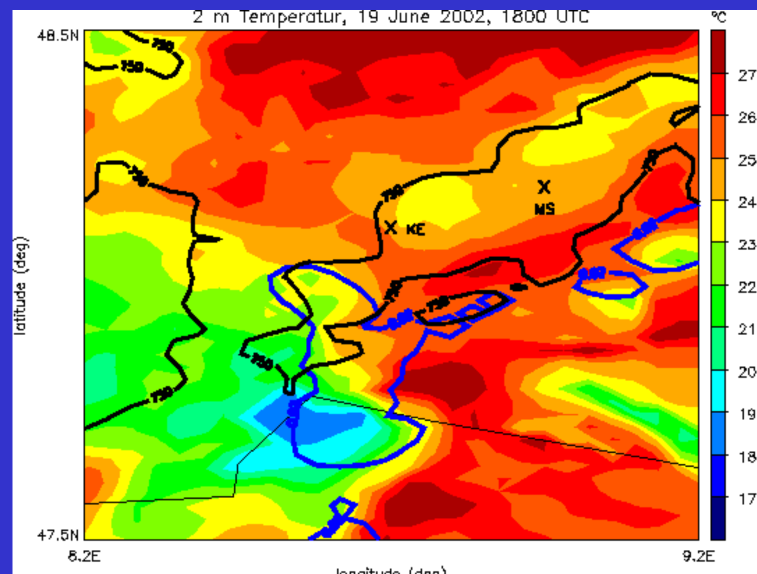


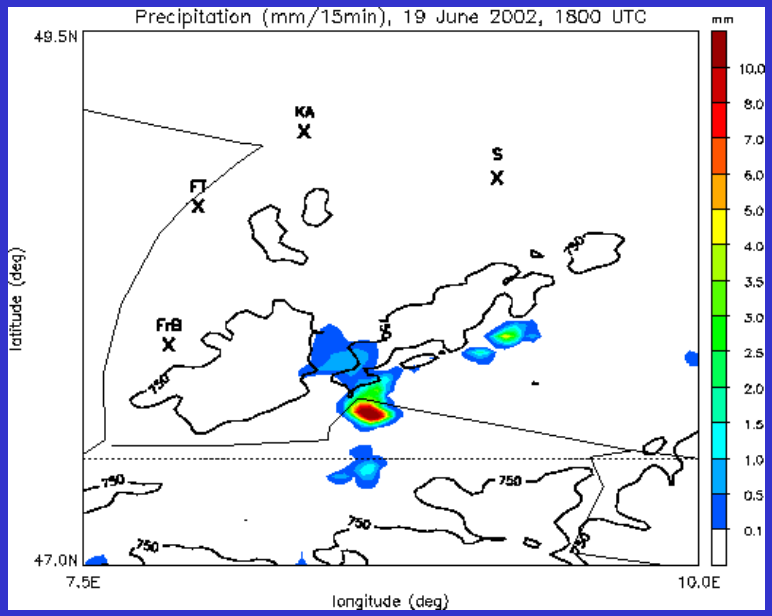


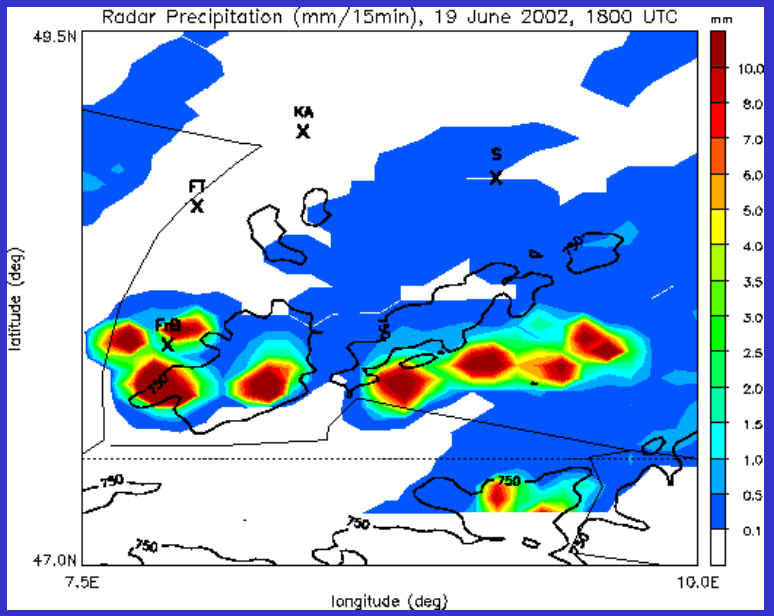

Wind field, Precipitation, 19 June 2002, 1800 UTC
m
1300
1200
1100
1000
900
800
700
600
500
400
300
200
150
48.5N
47.5N
8.2E
9.2E
latitude (deg)
longitude (deg)
KE
MS
750
0.02

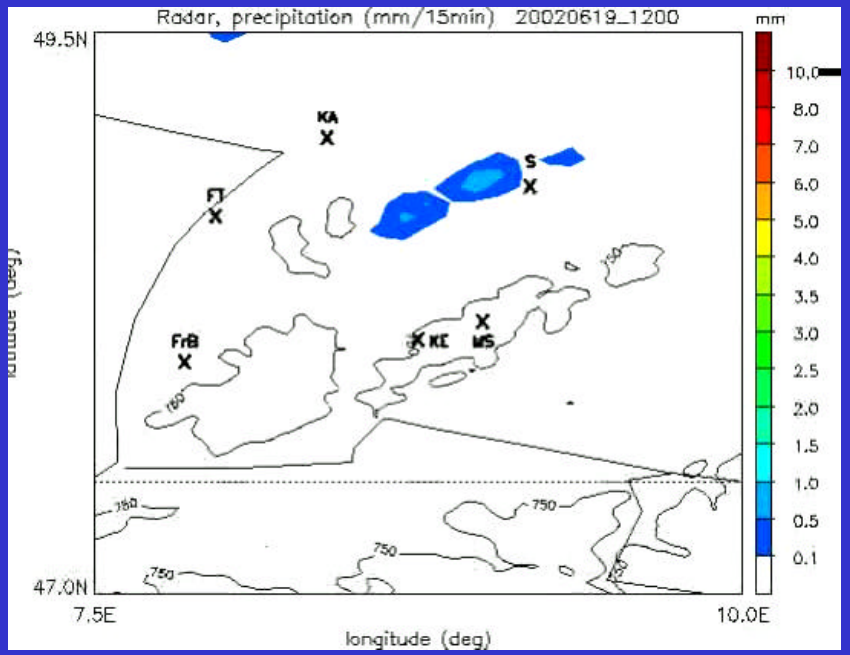

Wind field, Precipitation, 19 June 2002, 1800 UTC
m
1300
1200
1100
1000
900
800
700
600
500
400
300
200
150
48.5N
47.5N
8.2E
9.2E
latitude (deg)
longitude (deg)
KE
MS
750
0.02

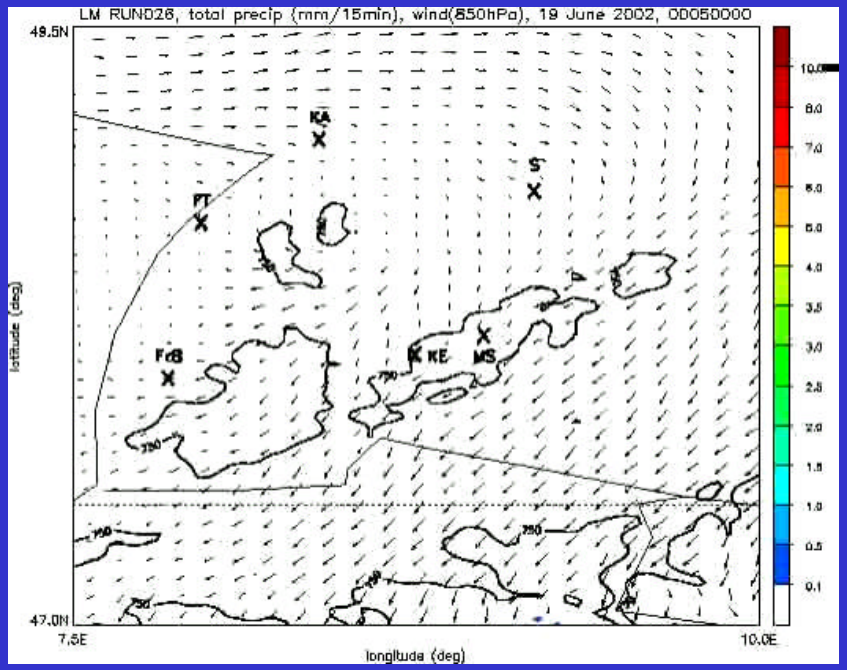

Wind field, Precipitation, 19 June 2002, 1800 UTC
m
1300
1200
1100
1000
900
800
700
600
500
400
300
200
150
48.5N
47.5N
8.2E
9.2E
latitude (deg)
longitude (deg)
KE
MS
750


2 m Temperatur, 19 June 2002, 1800 UTC
°C
27.0
26.0
25.0
24.0
23.0
22.0
21.0
20.0
19.0
18.0
17.0
48.5N
47.5N
8.2E
9.2E
latitude (deg)
longitude (deg)
KE
MS
750

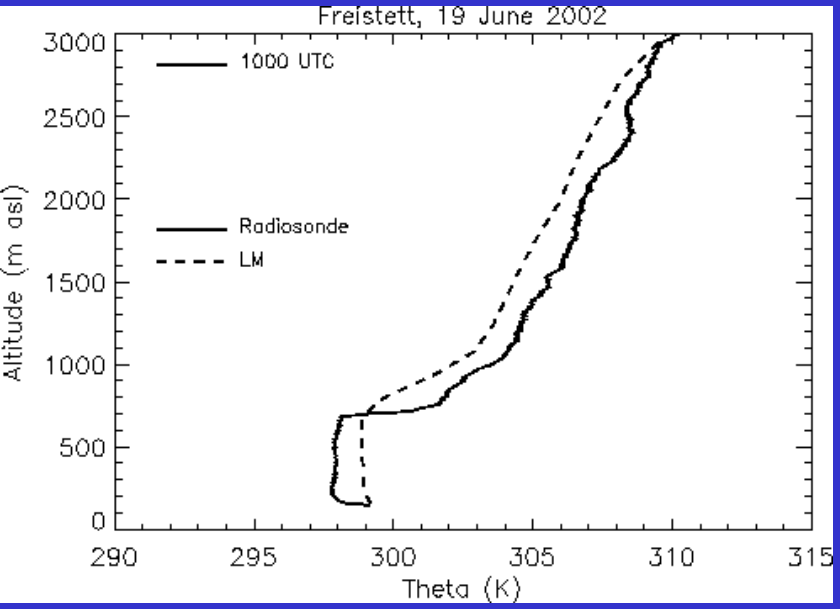

Precipitation (mm/15min), 19 June 2002, 1800 UTC
mm
10.0
8.0
7.0
6.0
5.0
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.1
49.5N
47.0N
7.5E
10.0E
latitude (deg)
longitude (deg)
KA
S
FT
FrB
750
755

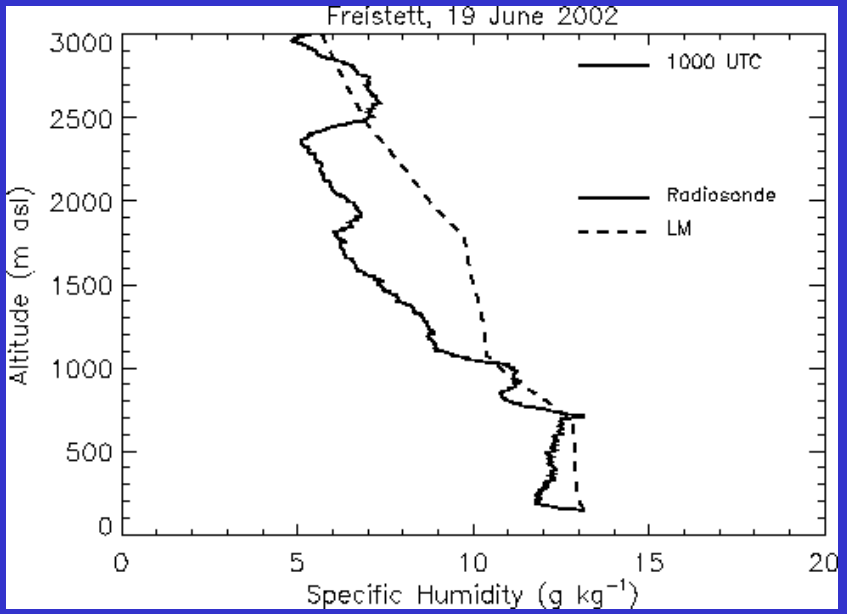

Radar Precipitation (mm/15min), 19 June 2002, 1800 UTC
mm
10.0
8.0
7.0
6.0
5.0
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.1
49.5N
47.0N
7.5E
10.0E
latitude (deg)
longitude (deg)
KA
S
FT
FrB
750
755

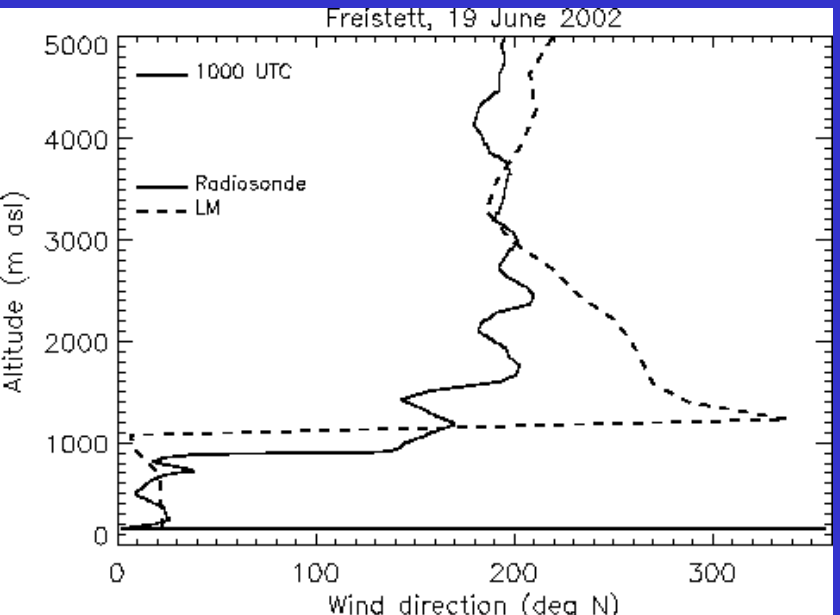

Radar, precipitation (mm/15min) 20020619_1200
mm
10.0
8.0
7.0
6.0
5.0
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.1
49.5N
47.0N
7.5E
10.0E
latitude (deg)
longitude (deg)
KA
S
FT
FrB
KE
MS
750


LM RUN026, total precip (mm/15min), wind(850hPa), 19 June 2002, 00050000
49.5N
47.0N
7.5E
10.0E
latitude (deg)
longitude (deg)
KA
S
FT
FrB
KE
MS
750

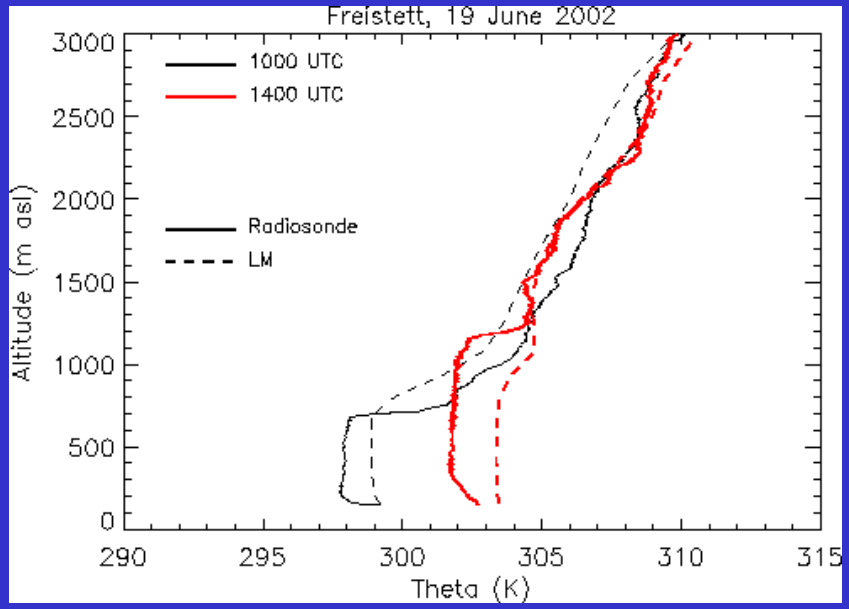
Evaluation of the vertical profiles

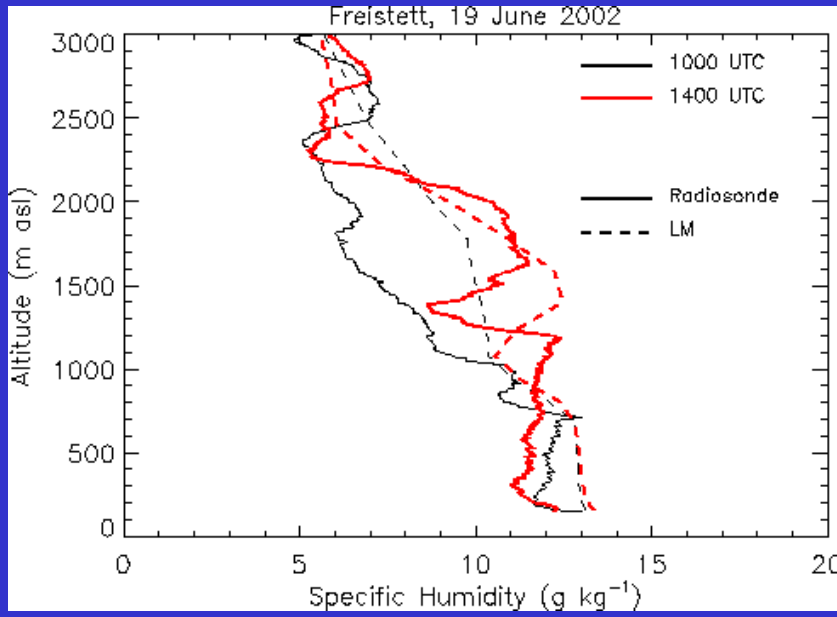


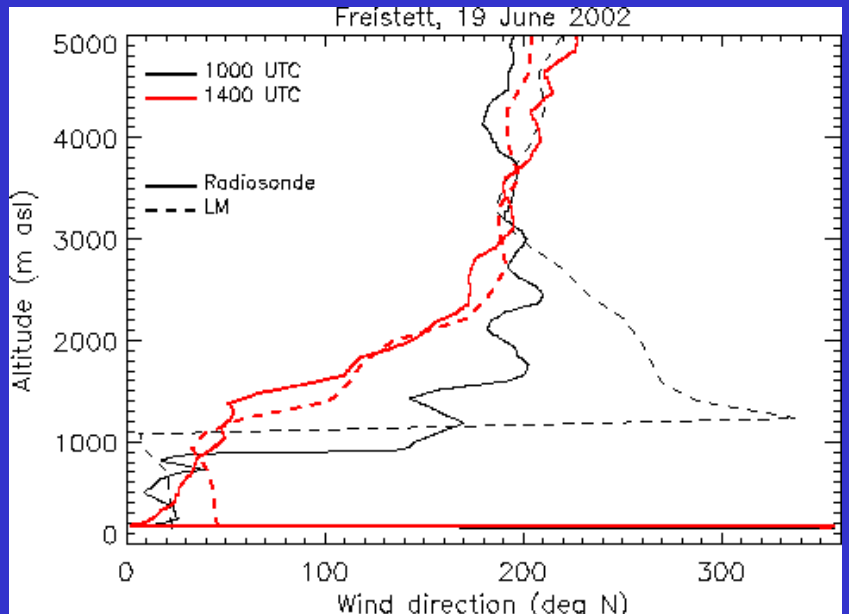




Evaluation of the vertical profiles

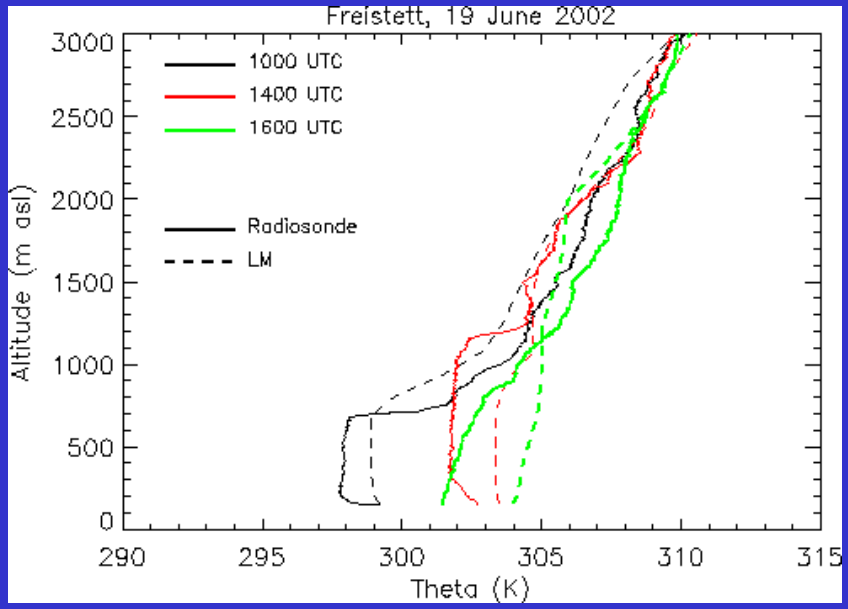


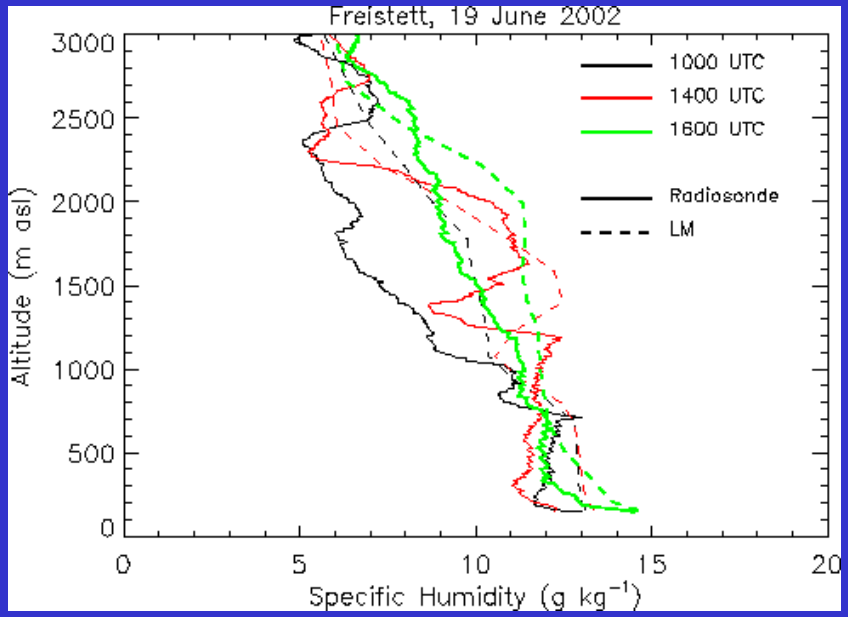


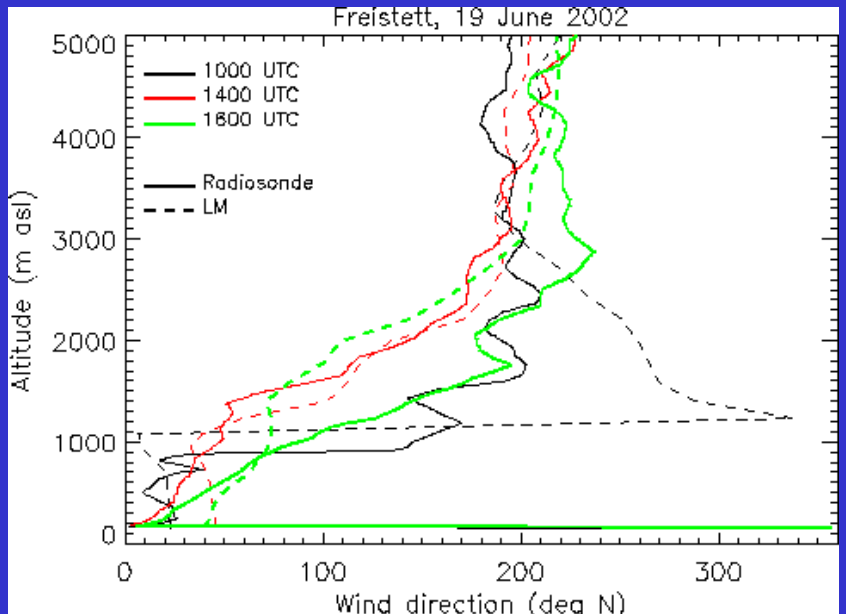


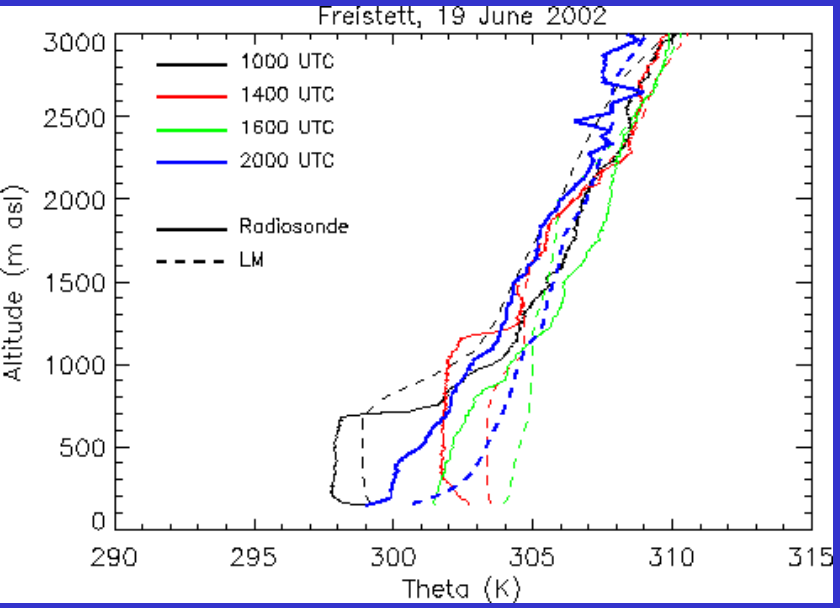
Transport of cold, moist air masses from the east (black forest) between 1.5 and 2 km.

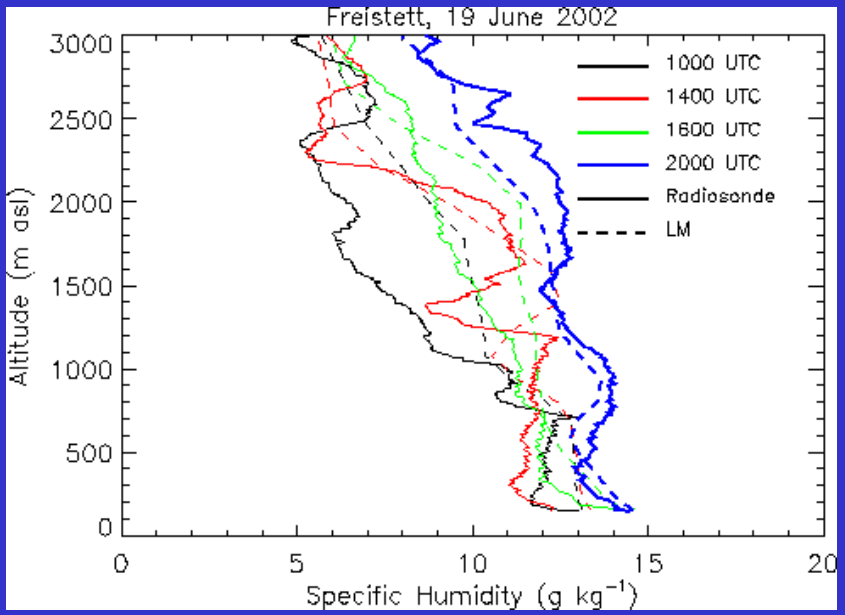
Evaluation of the vertical profiles

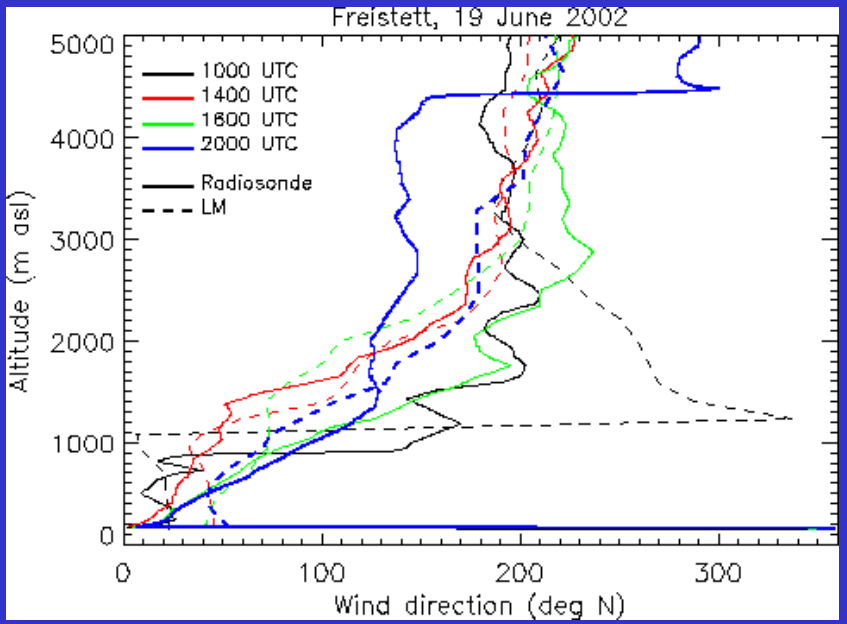






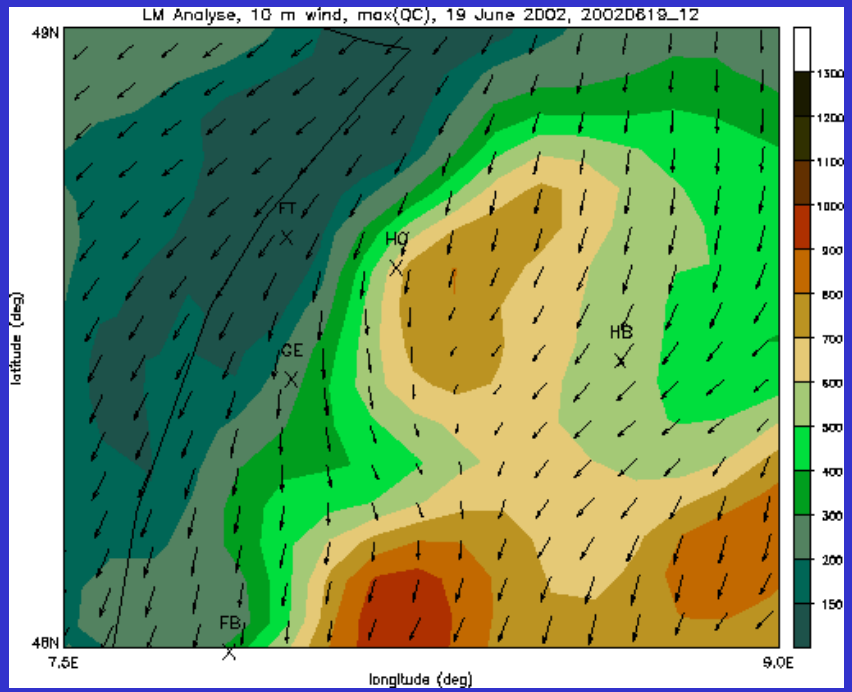

Freistett, 19 June 2002
1000 UTC
1400 UTC
1600 UTC
2000 UTC
Radiosonde
LM
Altitude (m asl)
Theta (K)
3000
2500
2000
1500
1000
500
0
290
295
300
305
310
315


Freistett, 19 June 2002
1000 UTC
1400 UTC
1600 UTC
2000 UTC
Radiosonde
LM
Altitude (m asl)
Specific Humidity (g kg^{-1})
3000
2500
2000
1500
1000
500
0
0
5
10
15
20

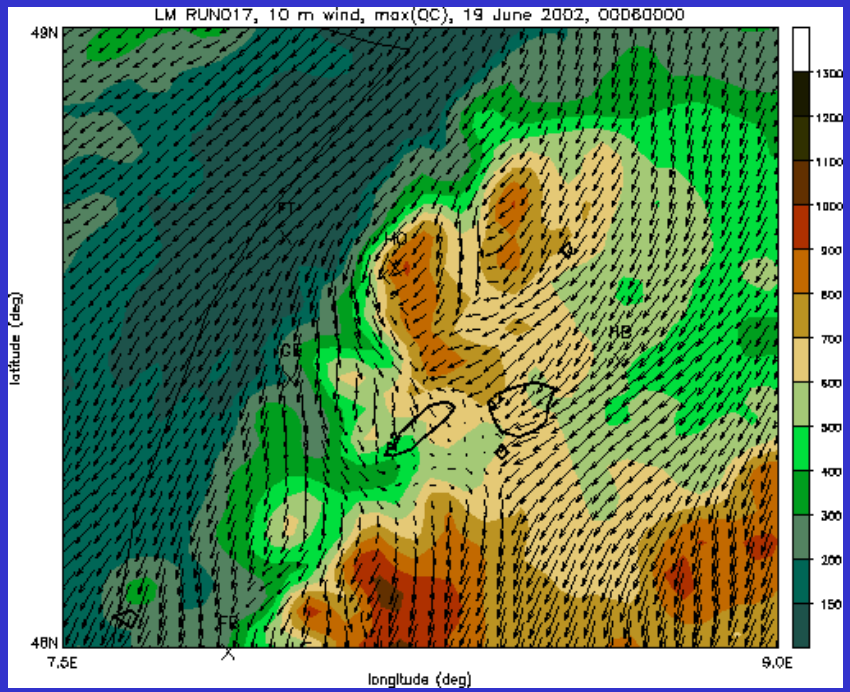

Freistett, 19 June 2002
1000 UTC
1400 UTC
1600 UTC
2000 UTC
Radiosonde
LM
Altitude (m asl)
Wind direction (deg N)
5000
4000
3000
2000
1000
0
0
100
200
300

Surface Wind in LM at 7 km and 2.8 km resolution

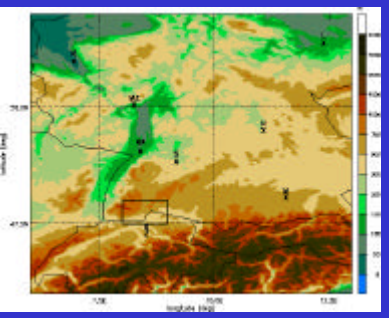
7 km



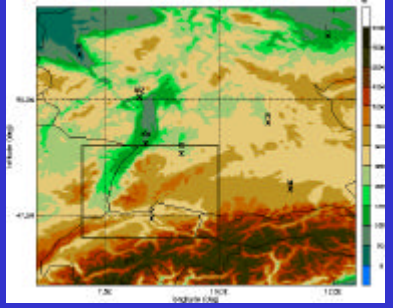
2.8 km



More realistic surface wind fields (especially in valleys) and formation of clouds. Realistic description of the processes that initiate convection !?

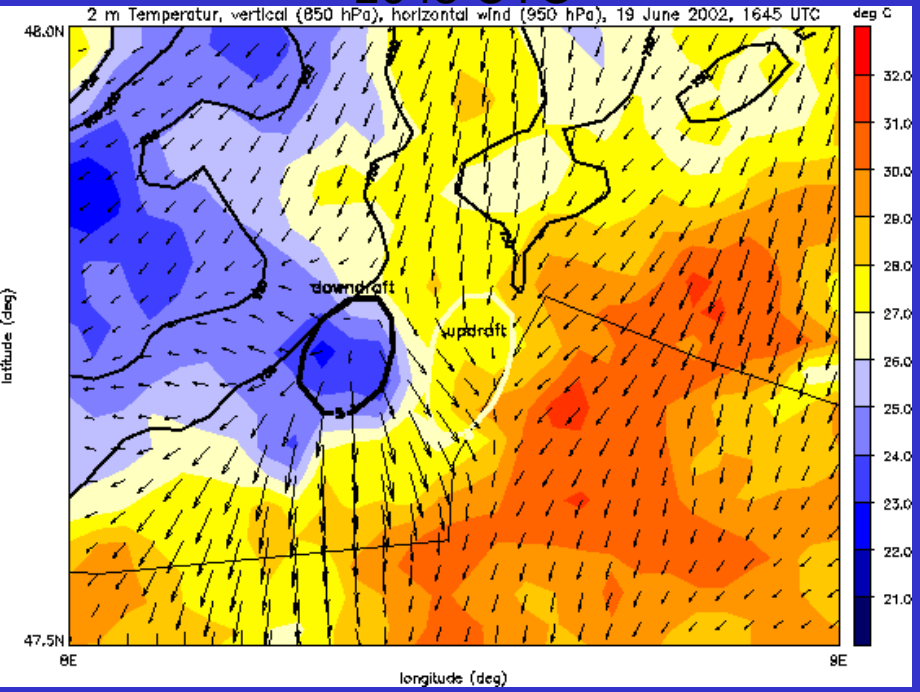


Surface Temperature and Wind Fields

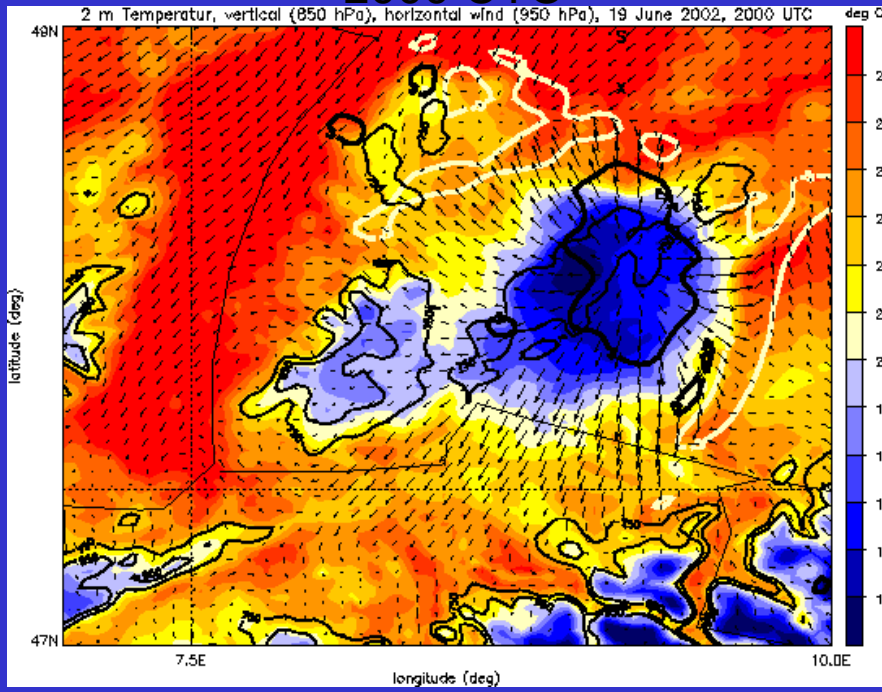


2 m temperature, horizontal wind at 950 hPa, vertical wind at 850 hPa

1645 UTC



2000 UTC



Wind convergence induces updrafts; cloud and precipitation formation induces downdrafts, creation of a surface cold pool:

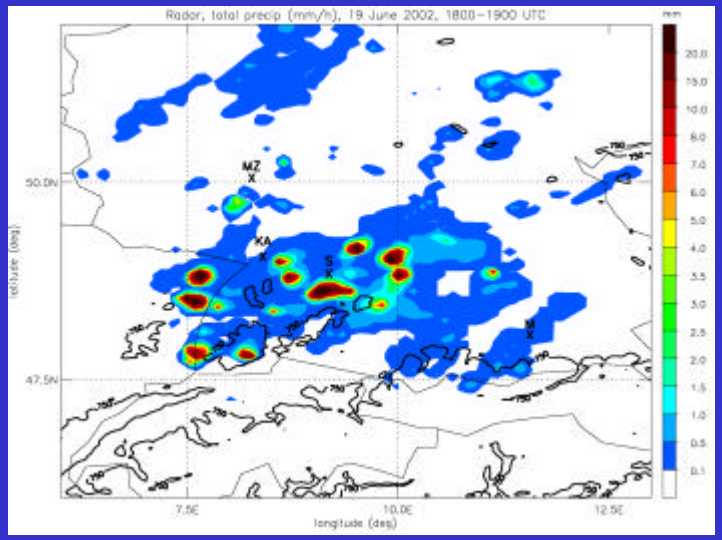
realistic description of convection dynamics

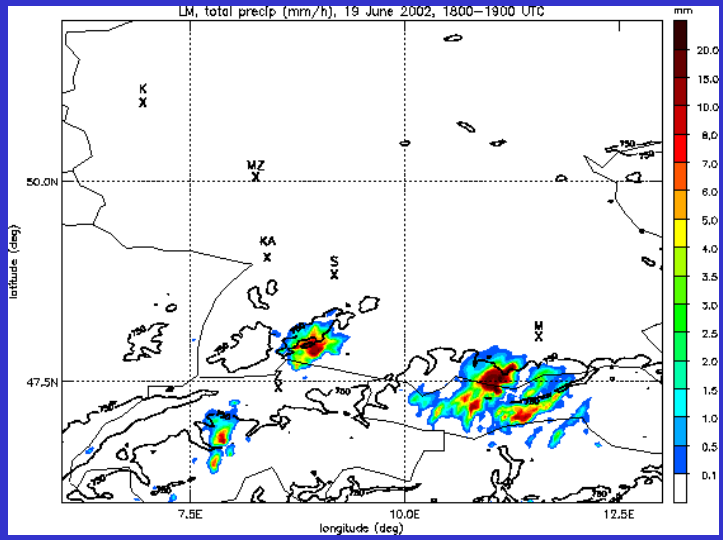
Hourly precipitation

Radar

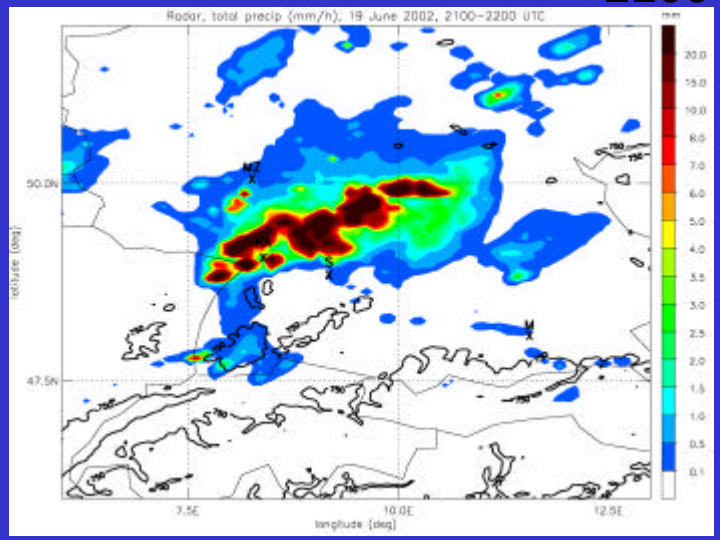
1800 – 1900 UTC

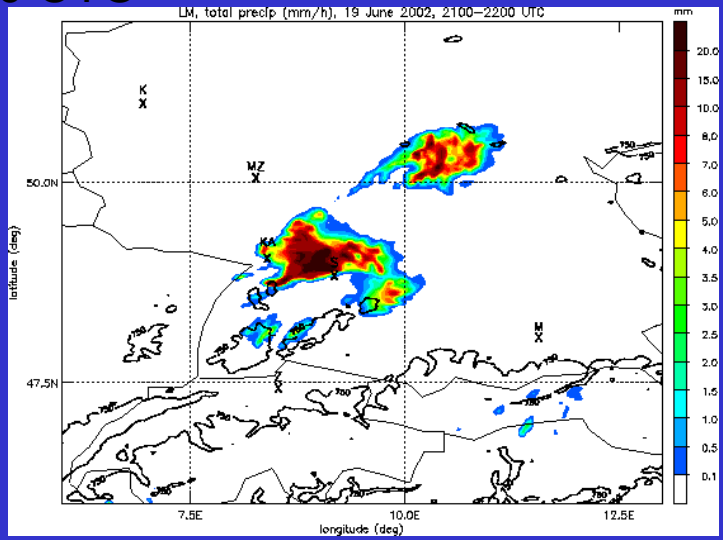
LM





2100 – 2200 UTC

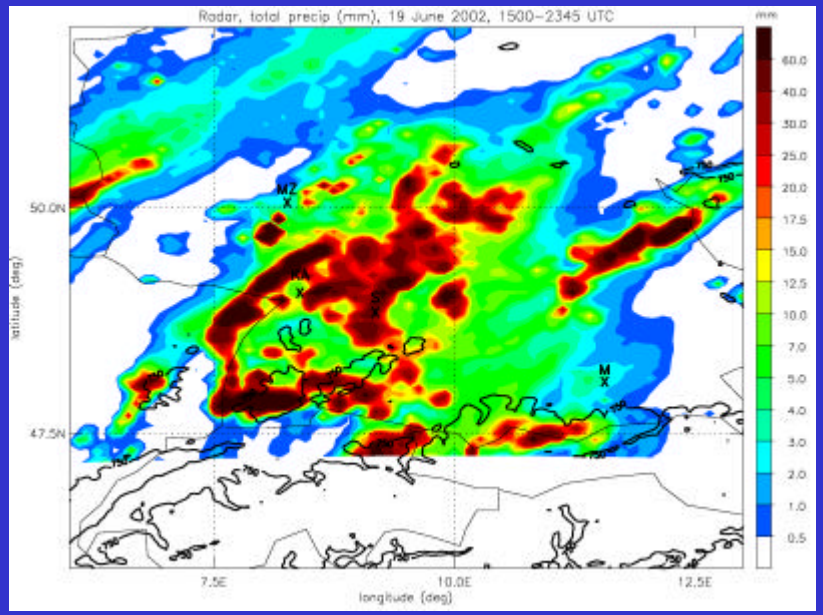




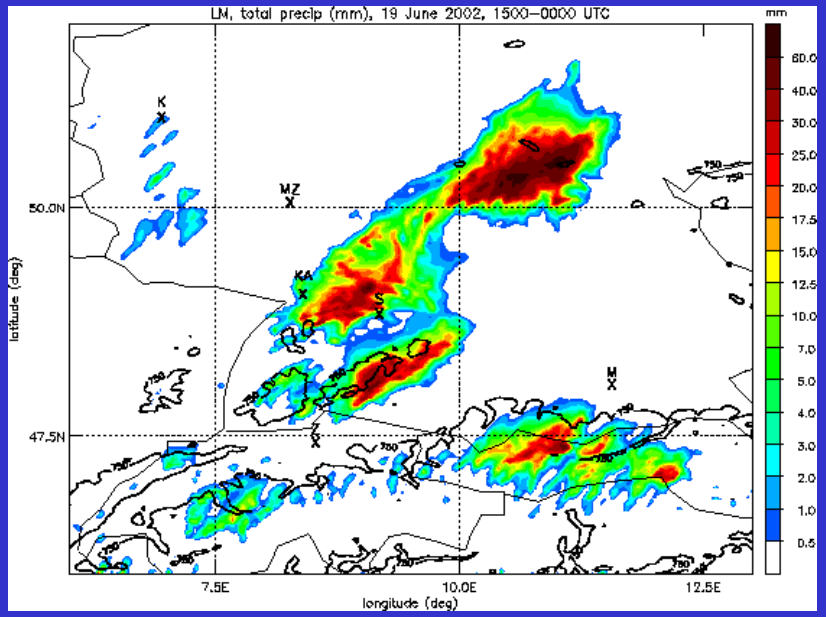
Total precipitation

1500 – 2400 UTC

Radar



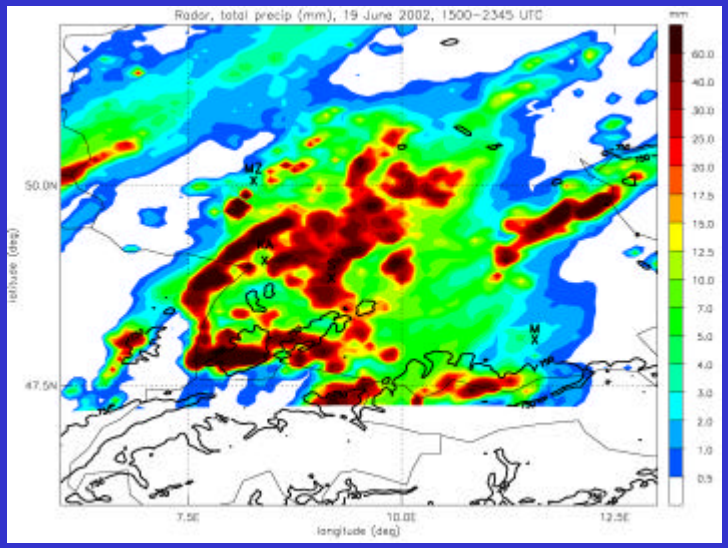
LM



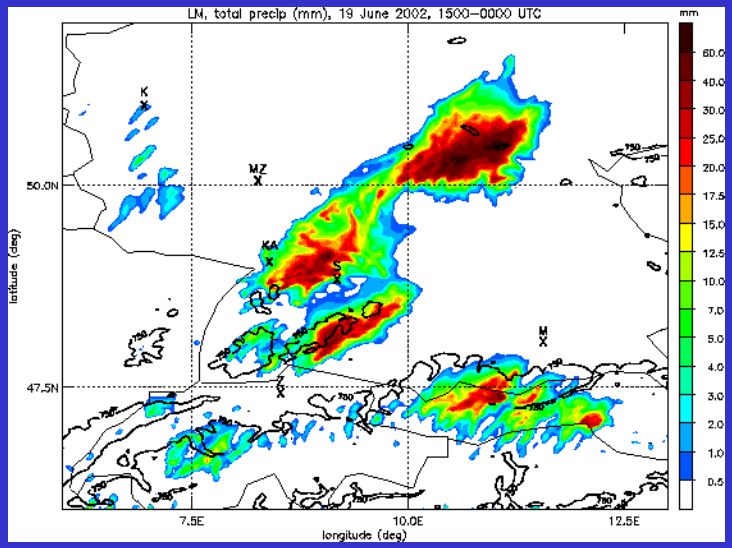
- Model underestimates the amount of precipitation
- misses the early part of the convection the SW-black forest area.

Total precipitation

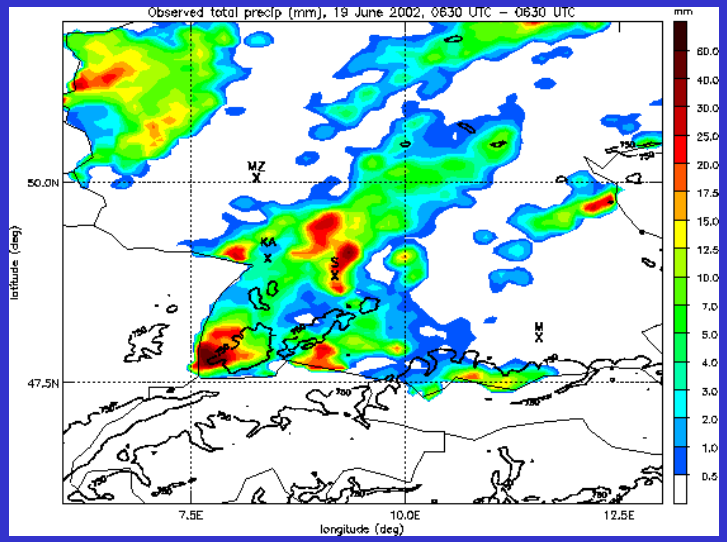
Radar



LM

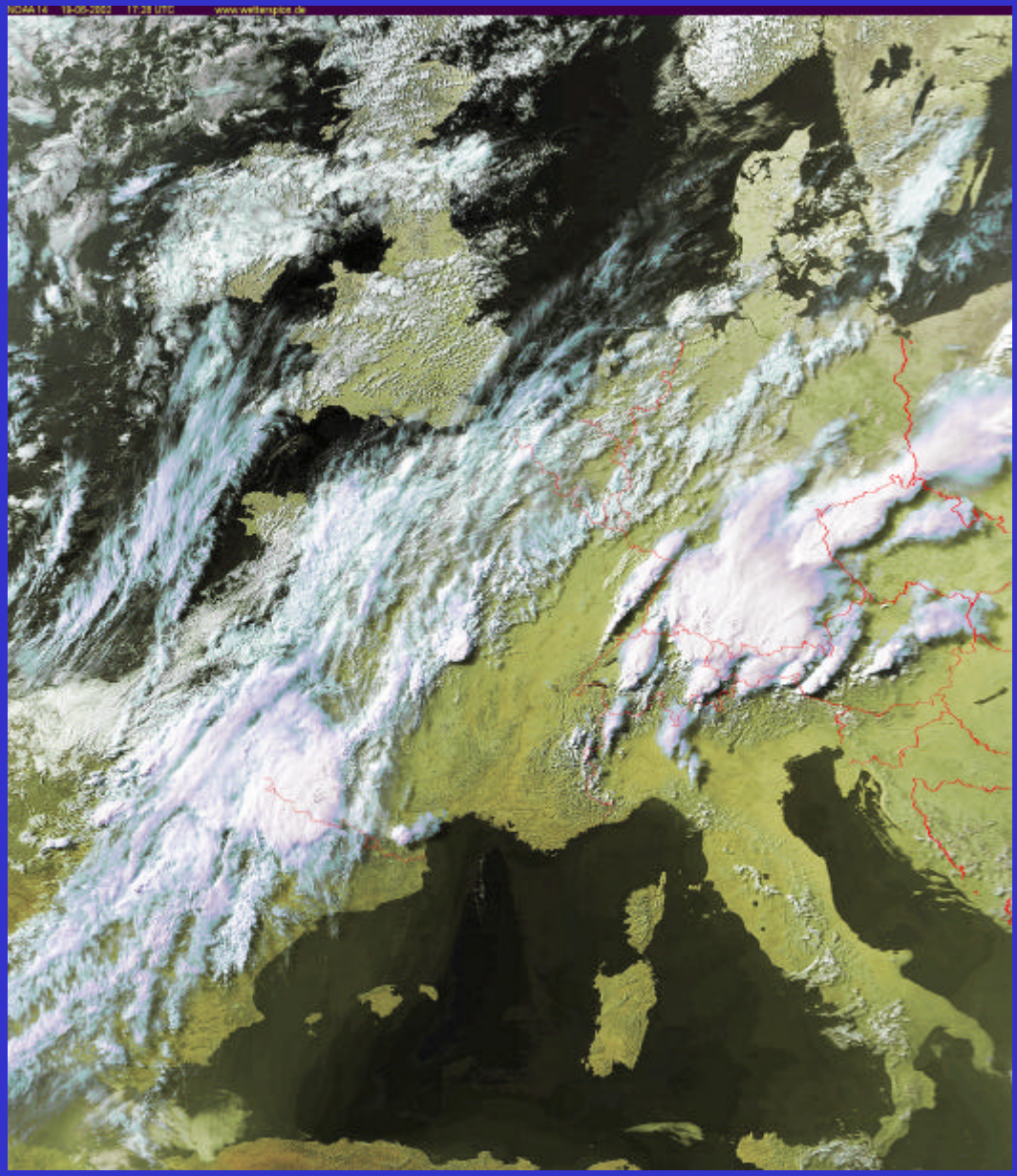


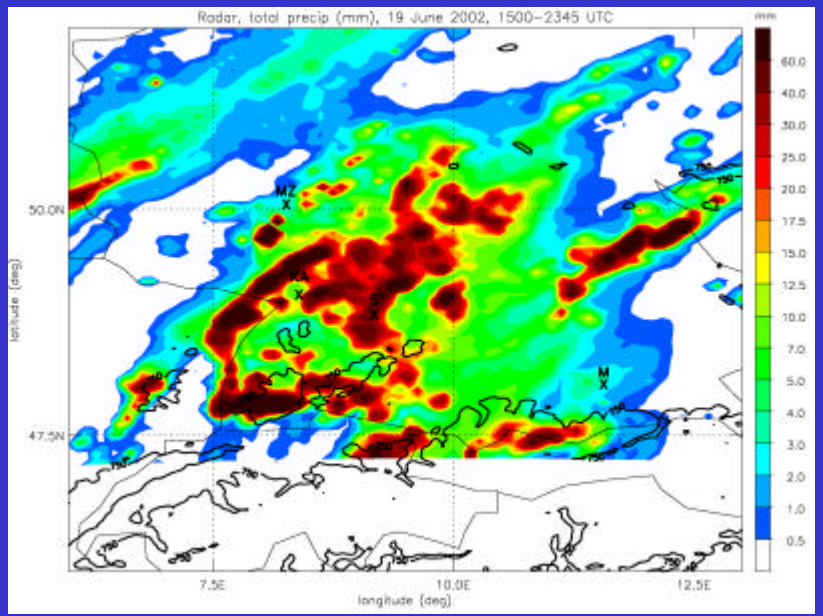
24 hour-precipitation from rain-gauges

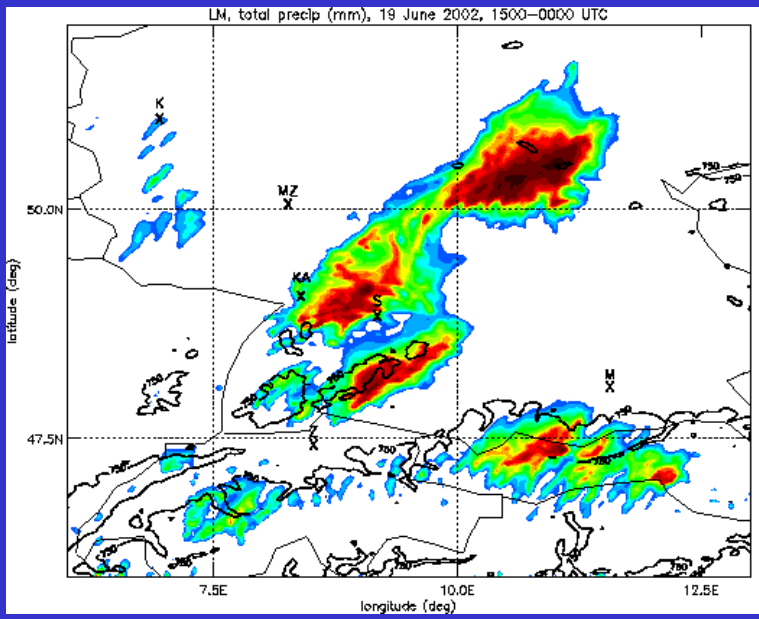


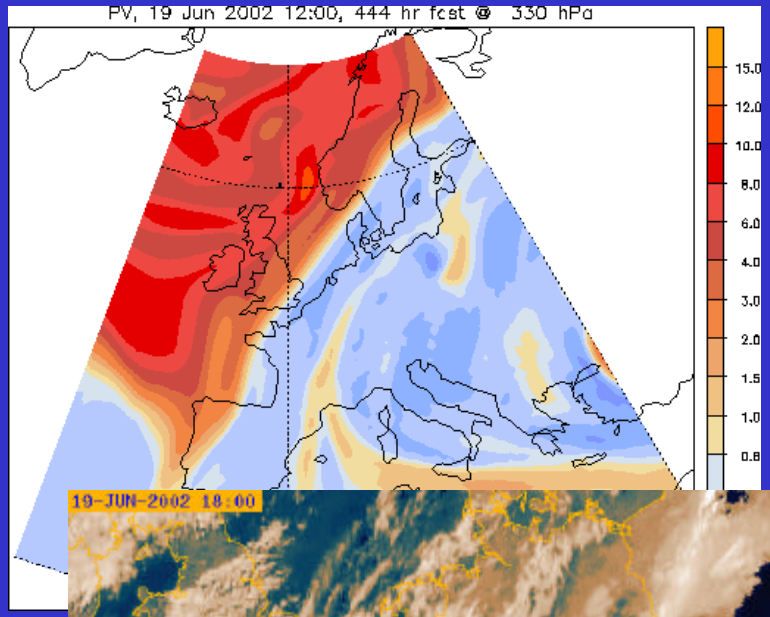
Provided by Christoph Frei

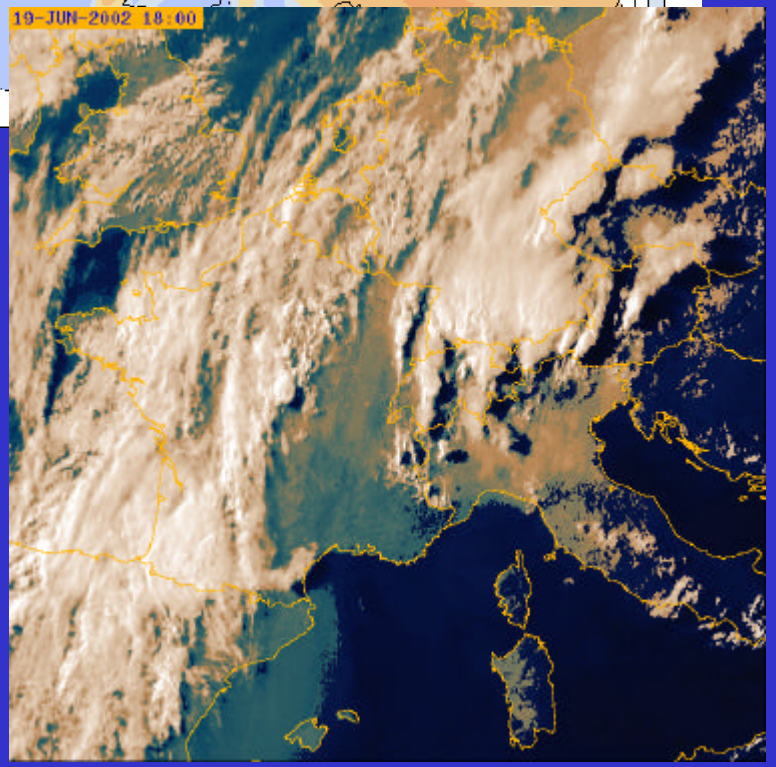
- Radar-derived precipitation significantly higher than measured by rain-gauges
- Heavy precipitation in the SW-black forest also present in rain-gauge data

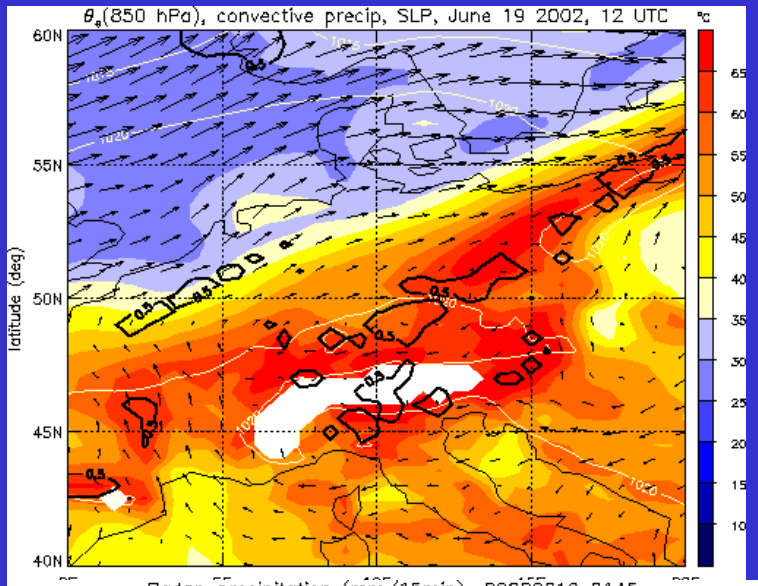

NOAA 14 19-05-2003 17:28 UTC www.wetterpool.de

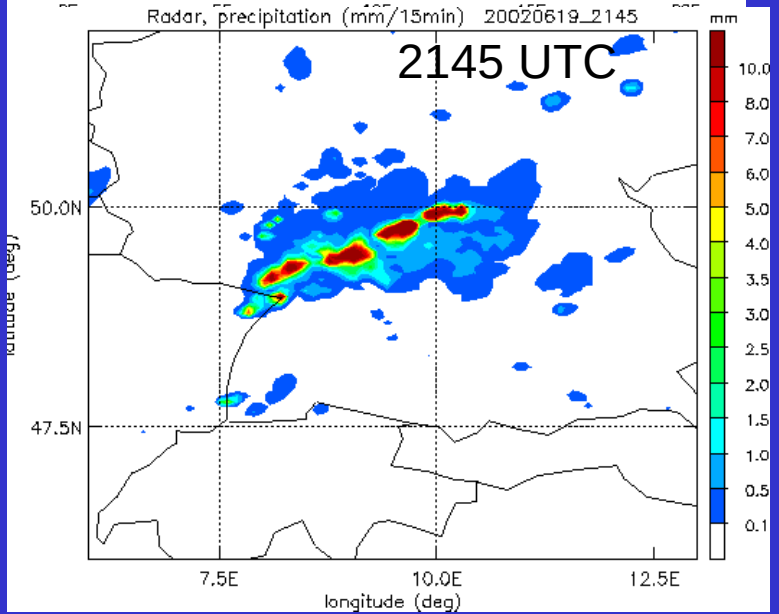

Radar, total precip (mm), 19 June 2002, 1500–2345 UTC
mm
60.0
40.0
30.0
25.0
20.0
17.5
15.0
12.5
10.0
7.0
5.0
4.0
3.0
2.0
1.0
0.5
MZ
KA
S
M
50.0N
47.5N
7.5E
10.0E
12.5E
latitude (deg)
longitude (deg)

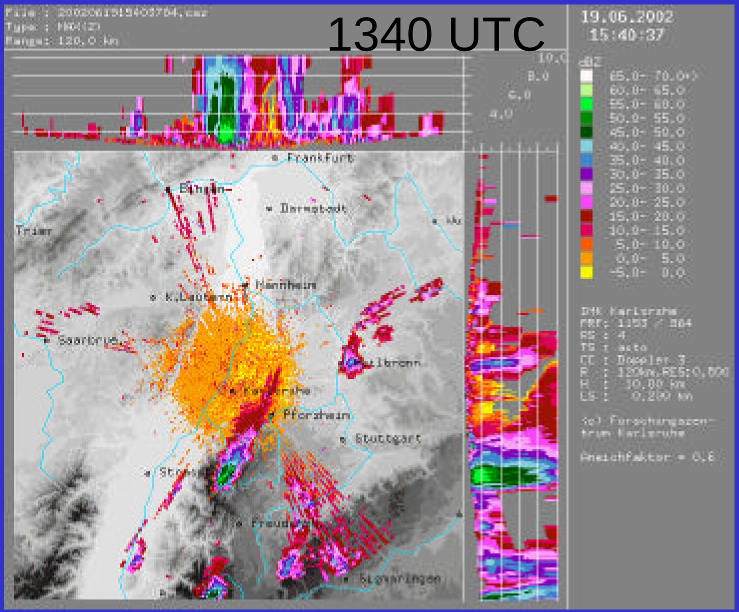

LM, total precip (mm), 19 June 2002, 1500–0000 UTC
K
MZ
KA
S
M
50.0N
47.5N
7.5E
10.0E
12.5E
latitude (deg)
longitude (deg)

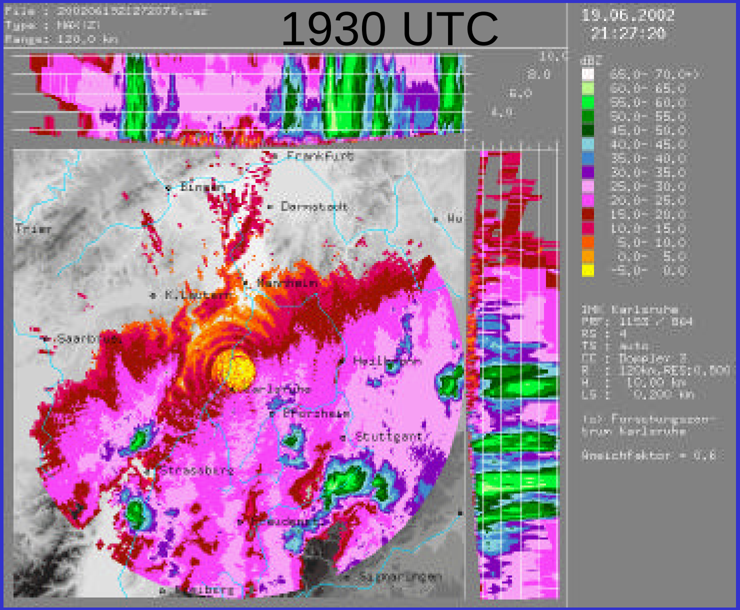

PV, 19 Jun 2002 12:00, 444 hr fcst @ 330 hPa
15.0
12.0
10.0
8.0
6.0
4.0
3.0
2.0
1.5
1.0
0.8

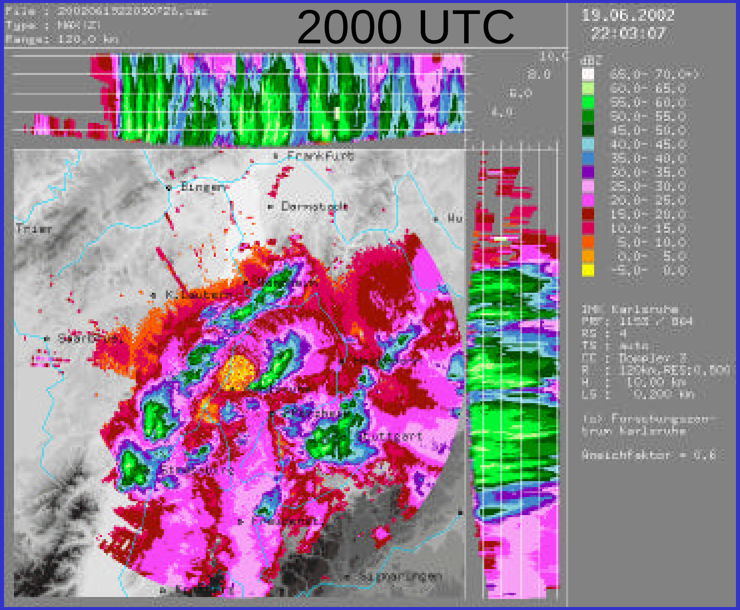

10-JUN-2002 18:00

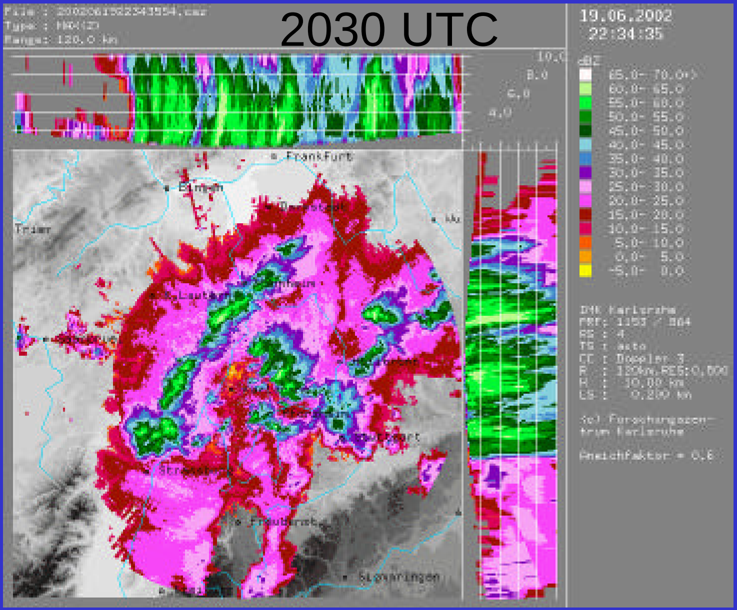

θe(850 hPa), convective precip, SLP, June 19 2002, 12 UTC
°C
60N
55N
50N
45N
40N
latitude (deg)
65
60
55
50
45
40
35
30
25
20
15
10

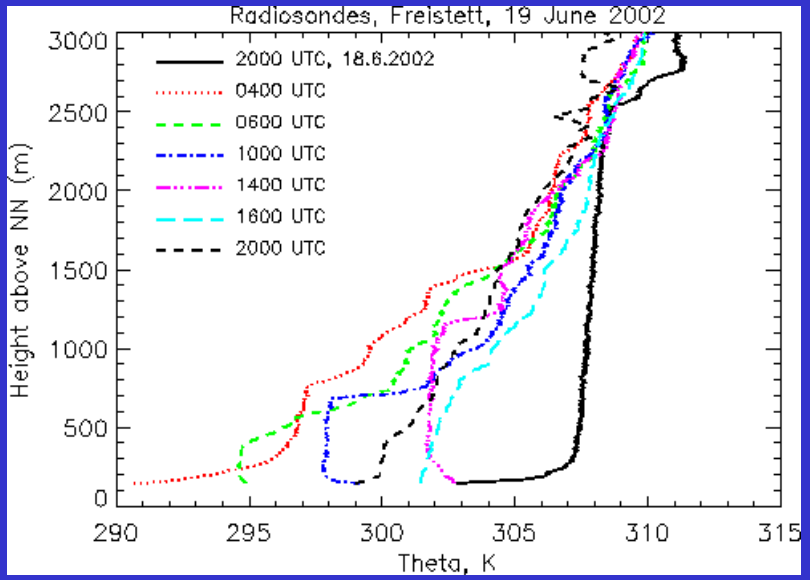

Radar, precipitation (mm/15min) 20020619_2145
2145 UTC
mm
10.0
8.0
7.0
6.0
5.0
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.1
50.0N
47.5N
7.5E
10.0E
12.5E
longitude (deg)

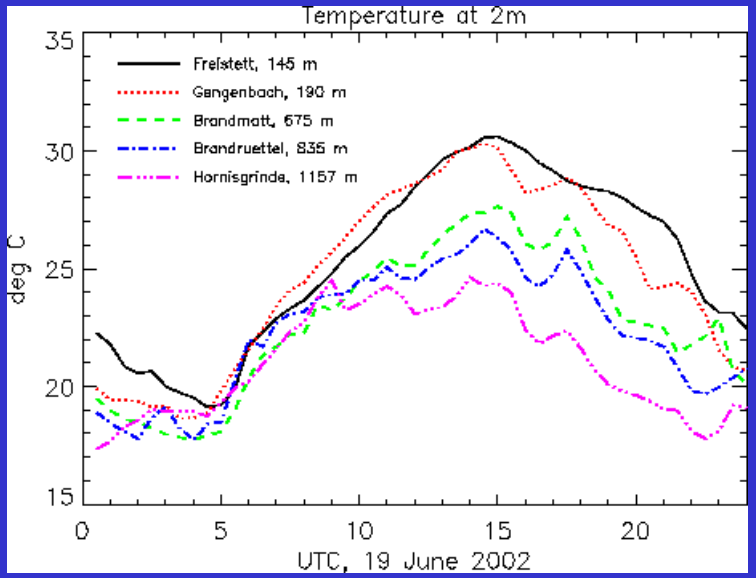

1340 UTC
19.06.2002
15:40:37

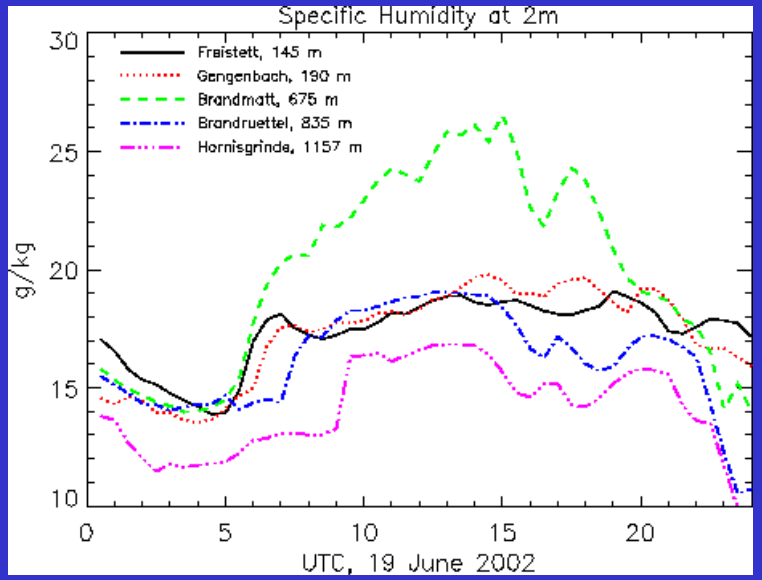

1930 UTC
19.06.2002
21:27:20

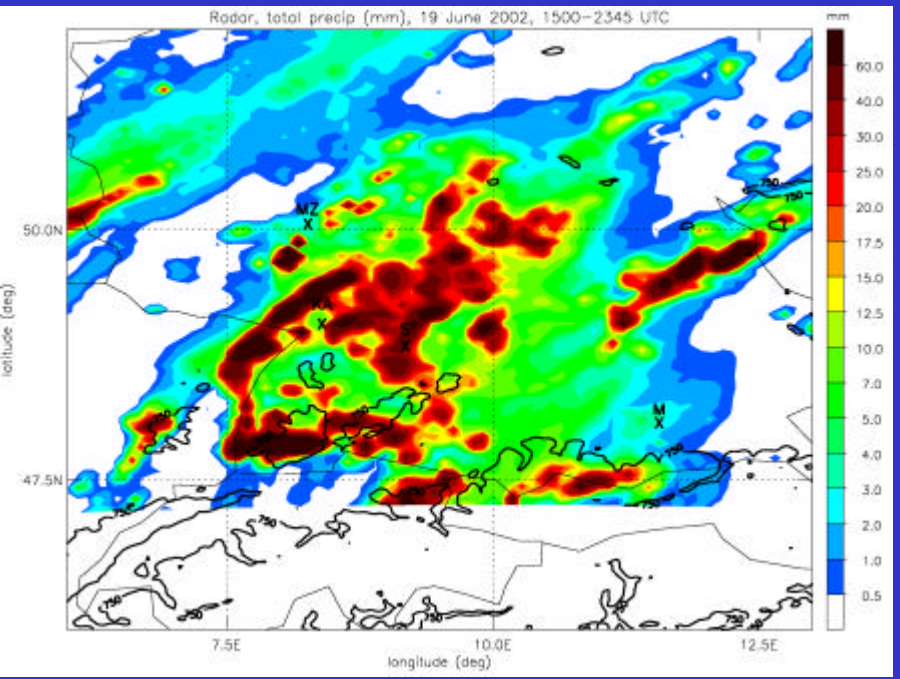

2000 UTC
19.06.2002
22:03:07

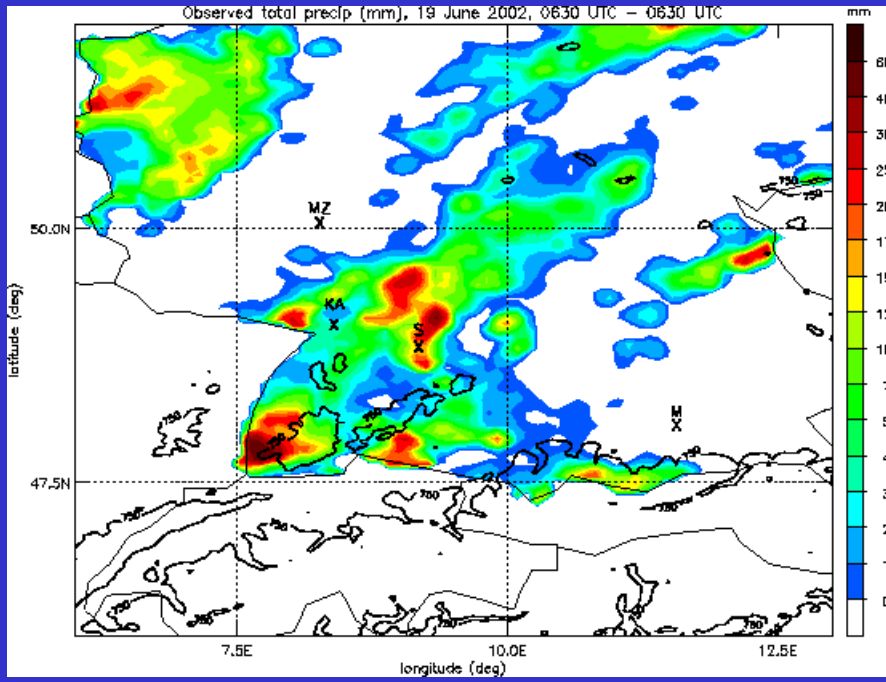

2030 UTC
19.06.2002
22:34:35


Radiosondes, Freistett, 19 June 2002
2000 UTC, 18.6.2002
0400 UTC
0600 UTC
1000 UTC
1400 UTC
1600 UTC
2000 UTC
Height above NN (m)
Theta, K


Temperature at 2m
Freistett, 145 m
Gengenbach, 190 m
Brandmatt, 675 m
Brandruettel, 835 m
Hornisgrinde, 1157 m
deg C
UTC, 19 June 2002


Specific Humidity at 2m
Freistett, 145 m
Gengenbach, 190 m
Brandmatt, 675 m
Brandruettel, 835 m
Hornisgrinde, 1157 m
g/kg
UTC, 19 June 2002

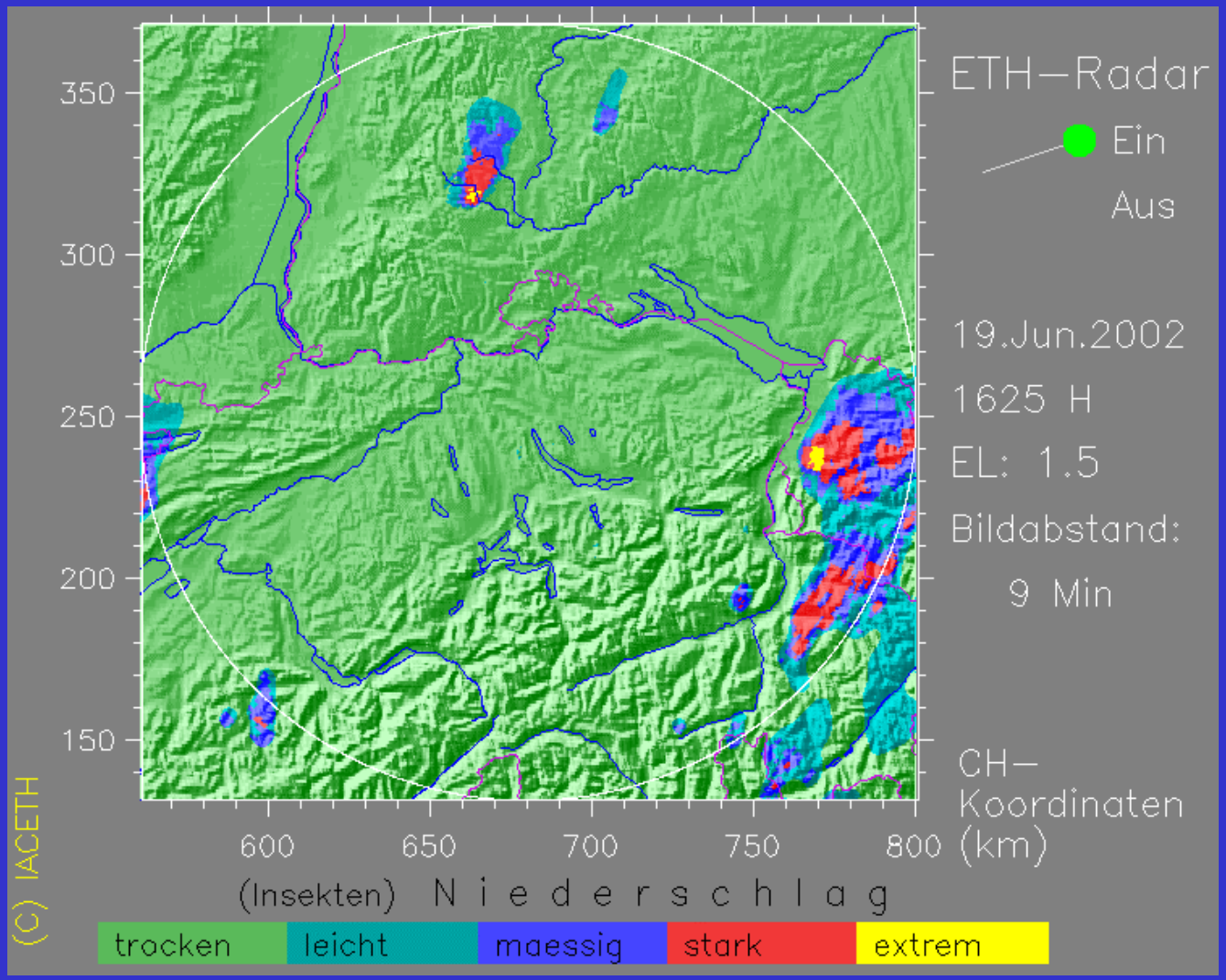

Radar, total precip (mm), 19 June 2002, 1500-2345 UTC
mm
60.0
40.0
30.0
25.0
20.0
17.5
15.0
12.5
10.0
7.0
5.0
4.0
3.0
2.0
1.0
0.5
MZ
KA
M
50.0N
47.5N
7.5E
10.0E
12.5E
longitude (deg)
latitude (deg)


Observed total precip (mm), 19 June 2002, 0630 UTC - 0630 UTC
mm
MZ
KA
M
50.0N
47.5N
7.5E
10.0E
12.5E
longitude (deg)
latitude (deg)

Tool kit:

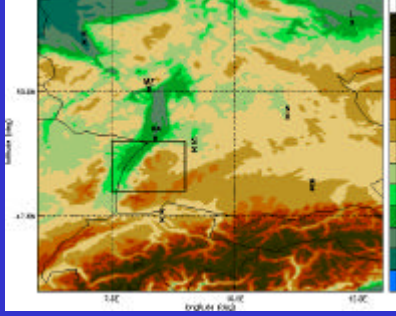
- **Lokal-Modell (LM) from DWD**
- **Observations**
  routine: Satellite, Radar
  field campaigns: ground-stations, additional radiosondes etc.

The `Monster from the Rhinevalley´, left-moving supercell up to 16 km

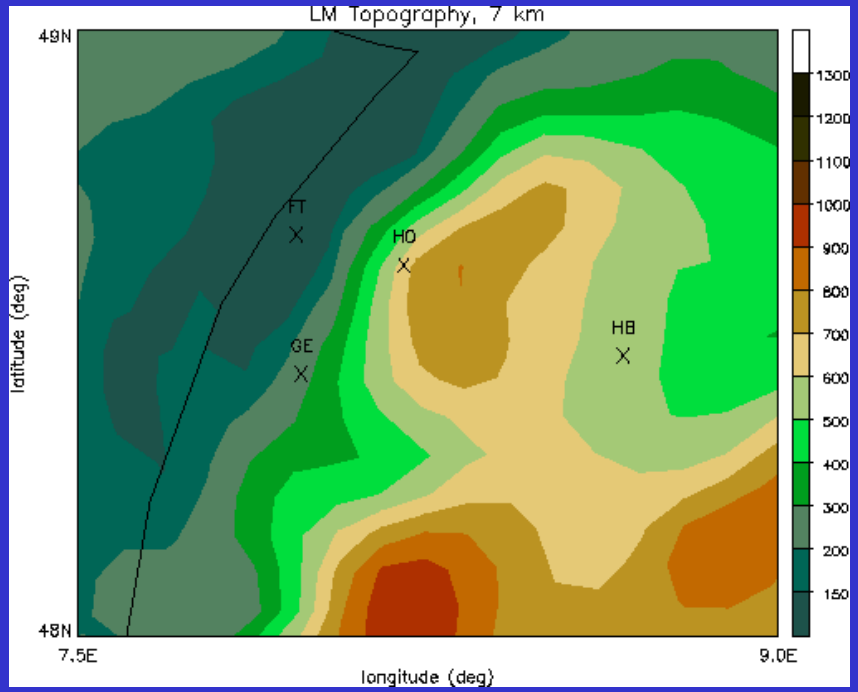


taken from http://www.radar.ethz.ch

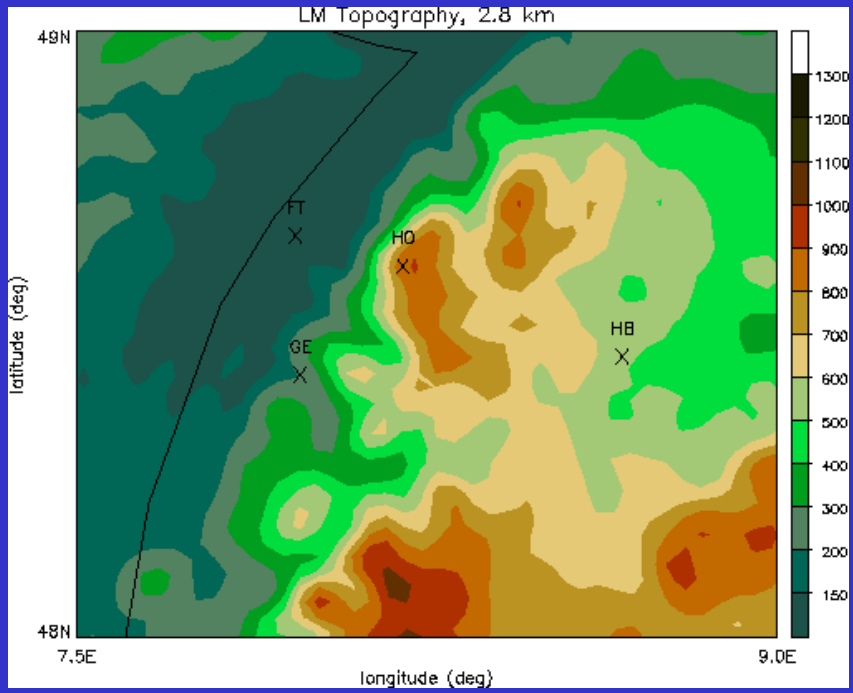
Orographie in LM at 7 km and 2.8 km resolution



7 km



2.8 km



Substantially more details of the orography at higher resolution.

Evaluation of the vertical profiles