Deutscher Wetterdienst

On the Luv-Lee Problem in the Simulation of Orographic Precipitation

G. Doms, J.-P. Schulz[a], D. Majewski[a], J. Förstner[a], V. Galabov[b]

1. Spatial Distribution of Precipitation in Southwest Germany

2. Formation of Stratiform Precipitation and Parameterization

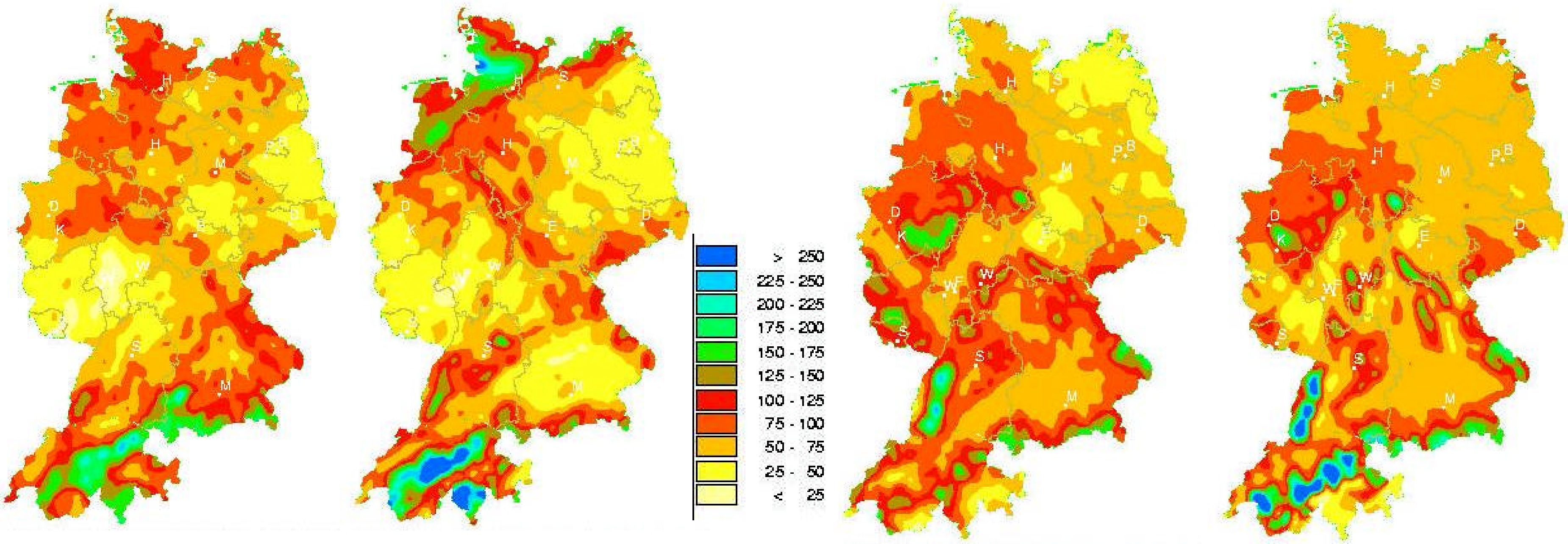
3. Sensitivity to Seeder-Feeder and Prognostic Precipitation

4. Conclusions

a) (DWD) b) National Institute of Meteorology and Hydrology, Bulgaria

Monthly mean precipitation amount for Germany/Switzerland

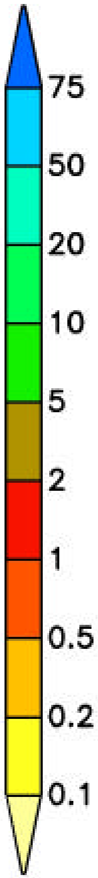
June 2002 January 2003

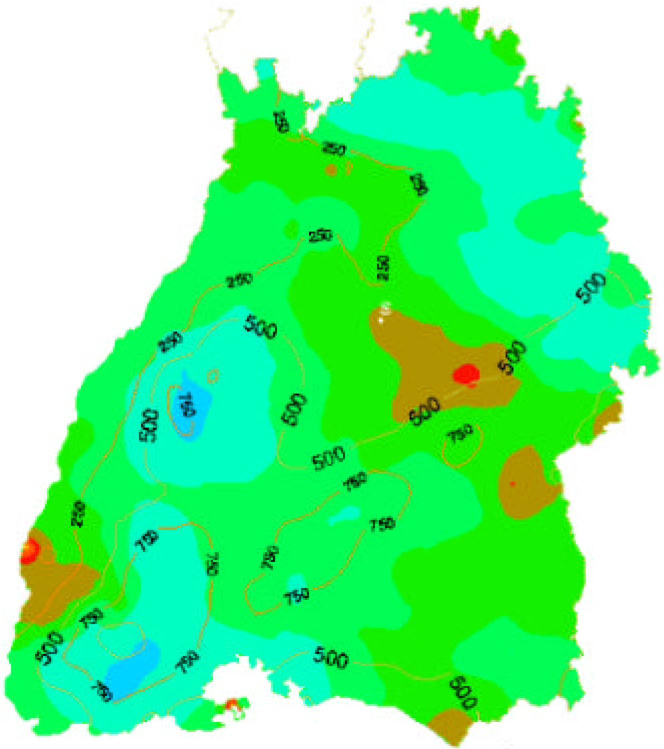


OBS (74mm) LM (69mm) OBS (84mm) LM (80mm)

Precipitation 20/02-21/02/2002

Observation

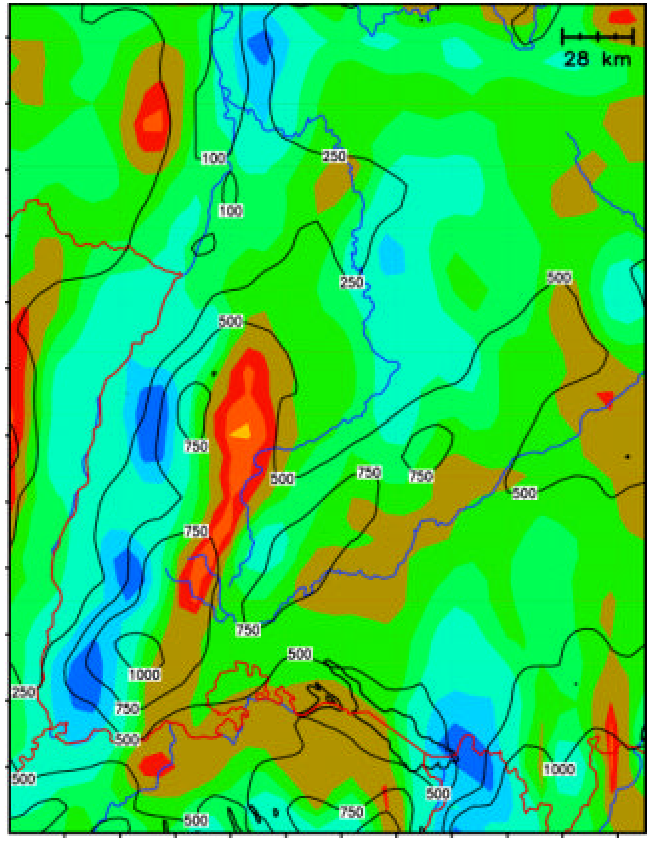




Beobachteter Niederschlag (kg m^{-2})
20.02.2002 06 UTC bis 21.02.2002 06 UTC

Minimum: .50 Maximum: 60.00 Mittelwert: 16.148

LM 00 UTC + 06h-30h



Operational LM

Working Hypothesis

The erroneous spatial distribution of precipitation over mountainous terrain (mainly during wintertime) might be due to

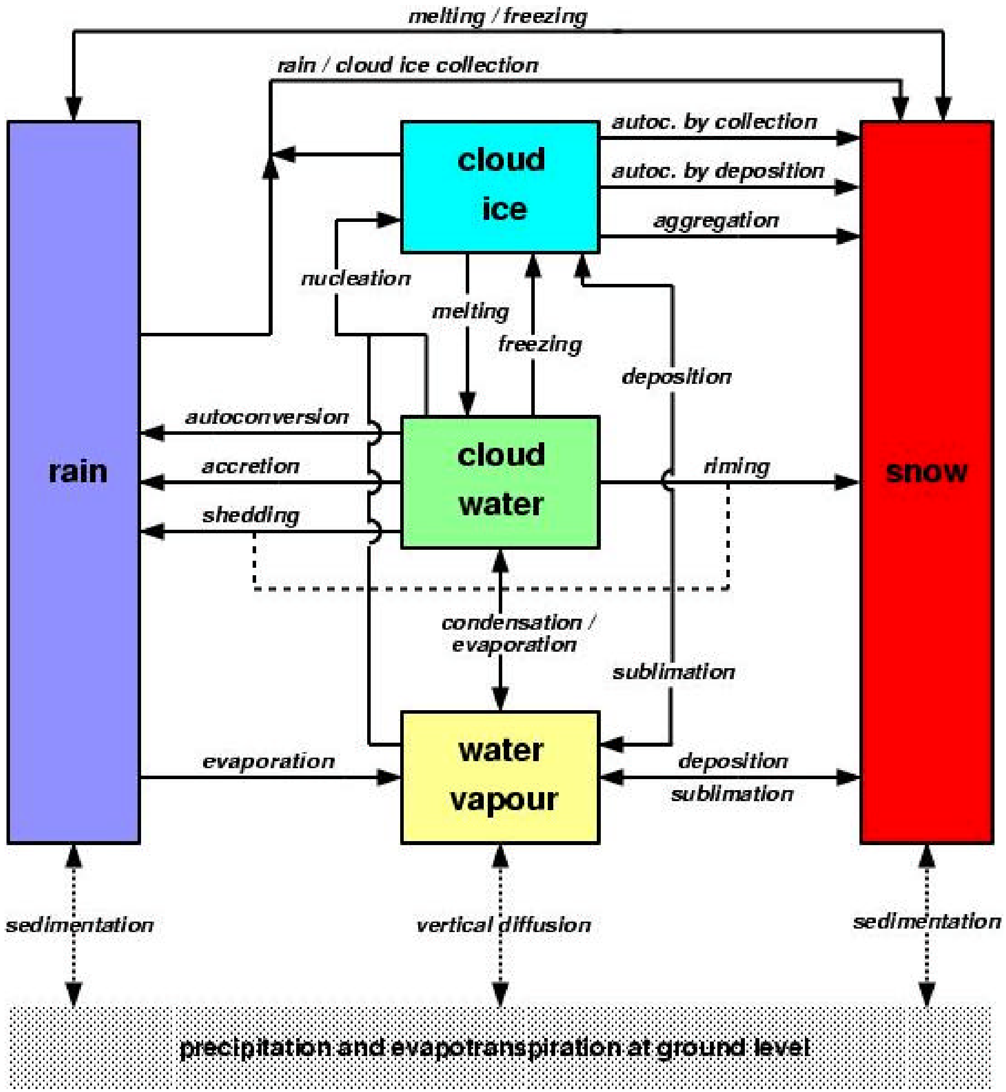
dynamical-numerical mechanisms

over-estimation of the mountain wave amplitude in case of stable stratification and high wind speeds

dynamical-microphysical mechanism

over-estimation of precipitation enhancement by the seeder-feeder effect due to neglecting the horizontal and vertical advective transport of snow (and rain) in the present parameterization scheme

Parameterization of cloud microphysical processes

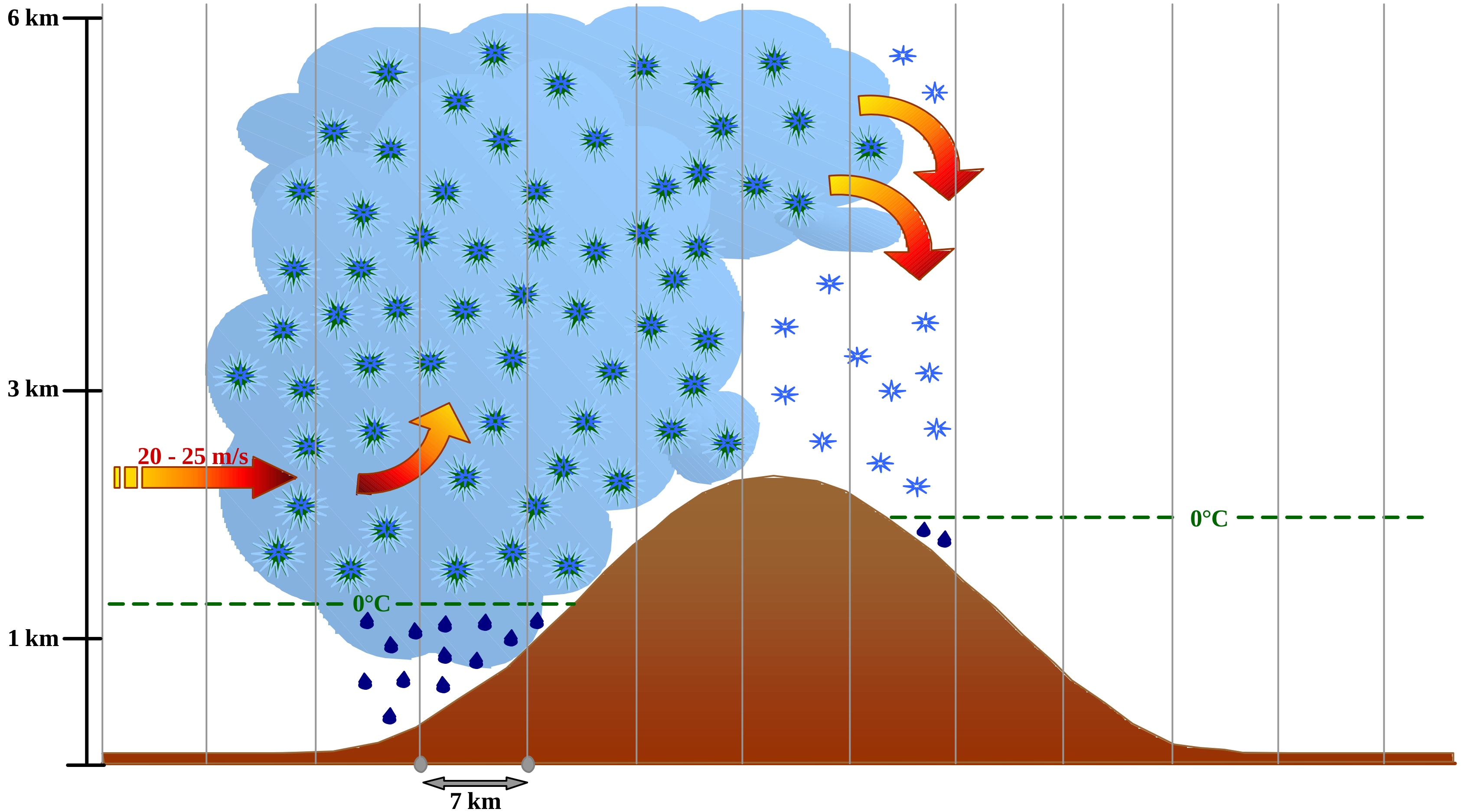


Precipitation enhancement in mixed pase clouds:

Bergeron-Findeisen process

Seeder Feeder mechanism

Formation of precipitation over a mountain



Treatment of Precipitation in NWP Models

Diagnostic Scheme

- Simplified budget equations for rain and snow precipitation fluxes

$$-\frac{1}{\rho}\frac{\partial P_x}{\partial z} = S_x$$

- Column equilibrium saves CPU time and core memory
- High accuracy at larger scales
- Standard in NWP models

Prognostic Scheme

- Full 3D budget equations for rain and snow mixing ratios

$$\frac{\partial q_x}{\partial t} + \mathbf{v}_h \cdot \nabla q_x + w\frac{\partial q_x}{\partial z} - \frac{1}{\rho}\frac{\partial P_x}{\partial z} = S_x$$

- Computational expensive
- Requires a special numerical treatment of the sedimentation term due to CFL for fallout
- Necessary to account for horizontal and vertical transport in small-scale modelling (lee-side precipitation, life-cycle in convective clouds)
- Standard in CRMs

Calculation of trajectories for LM to estimate the drifting of snow

Start level [hPa]	Distance [km]	Duration of drift [min]
500	71.4	40
550	59.5	35
600	47.6	29
650	40.5	25
700	32.1	21
750	13.1	9

Fall speed: 2 m/s

Fall down to the melting zone » 850 hPa

Experiments

- Re-run of PYREX-IOPs
- LM case studies with 28, 14 and 7 km grid-spacing
- Switch-off riming and accretional growth (sensitivity to seeder-feeder mechanism)
- LM case studies using the 2-time-level scheme with diagnostic and prognostic treatment of rain and snow (seeder-feeder cut-off)

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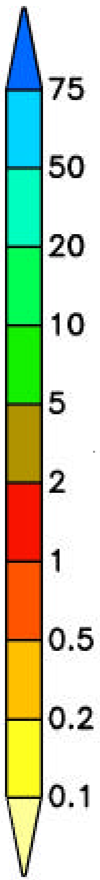
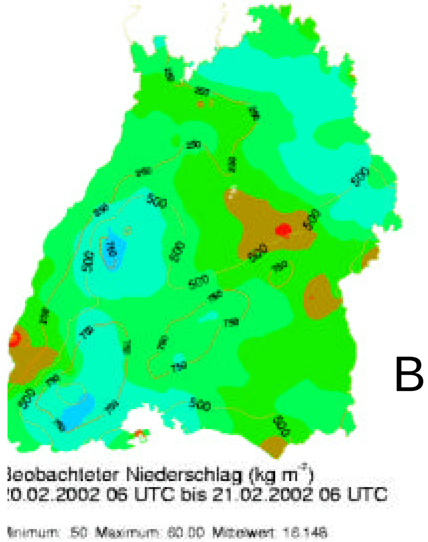
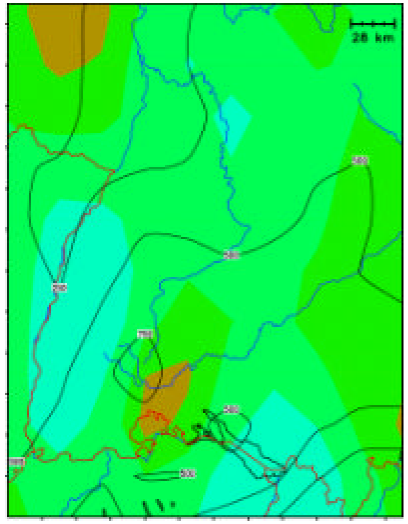
24-h precipitation amount 20.2.-21.2.2002

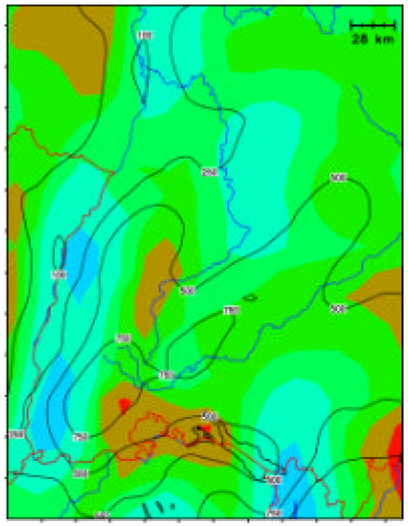




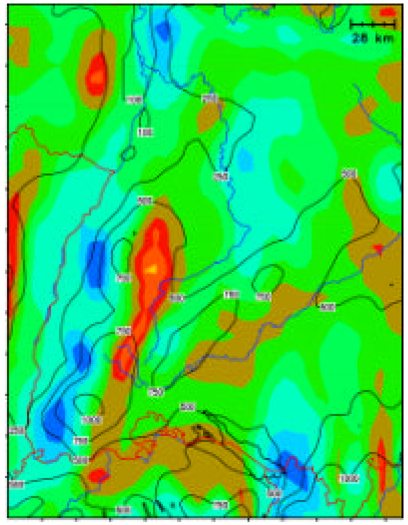
Beobachtung



LM 28 km



LM 14 km



LM 7 km

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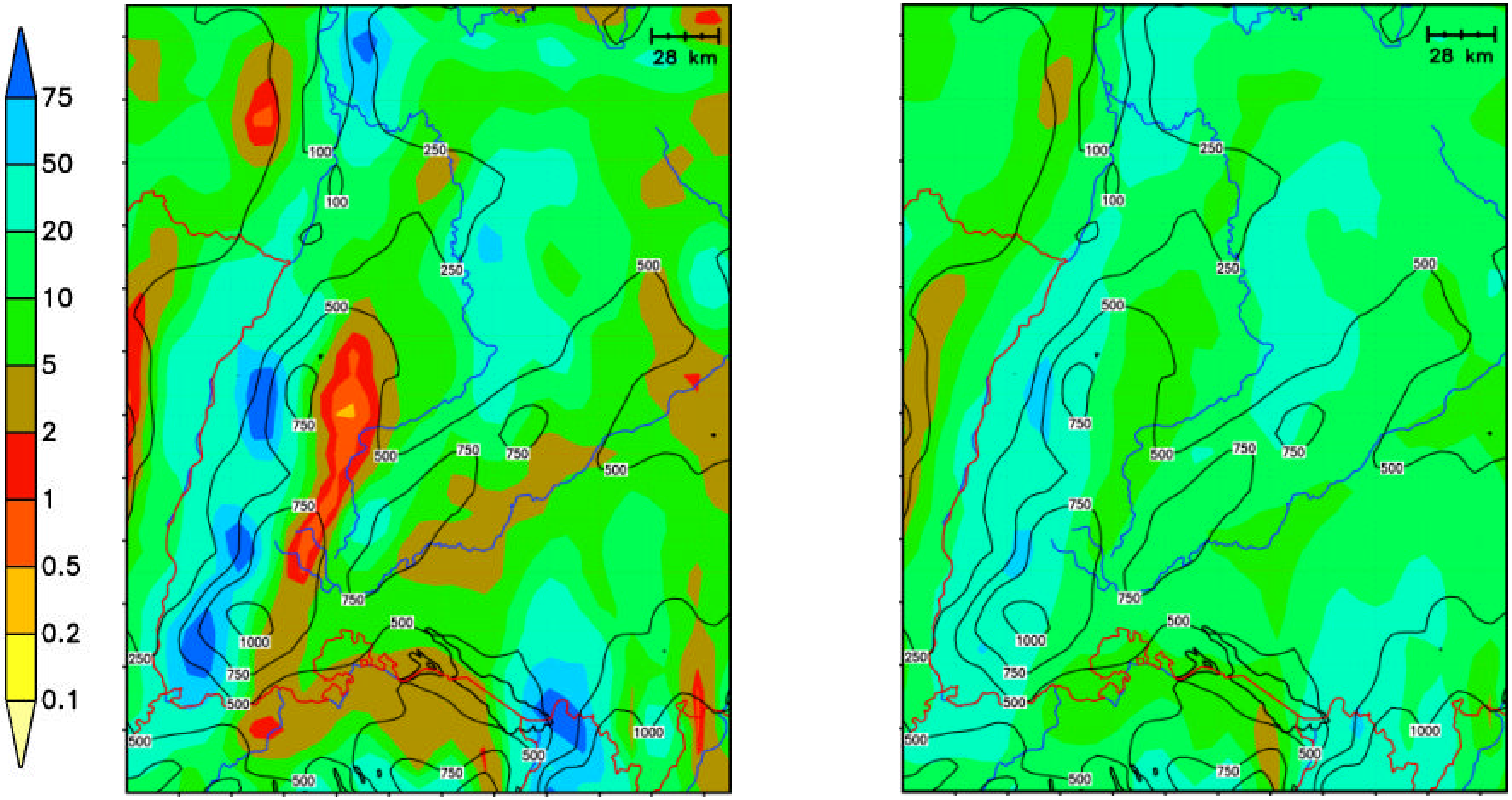
24-h precipitation amount 20.2.-21.2.2002

00 UTC + 06h-30h

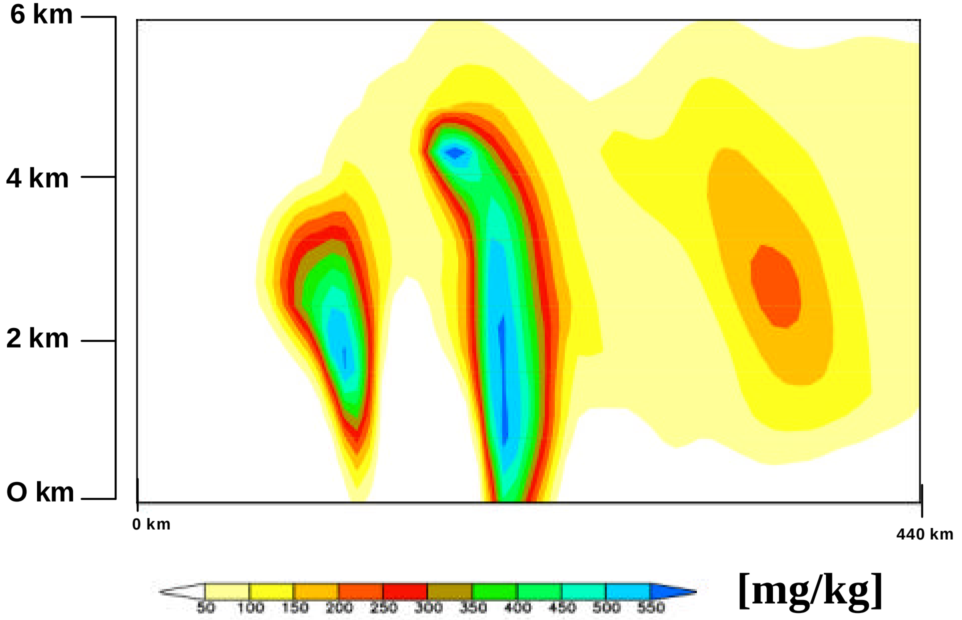


Operational LM | **LM without accrection and riming**

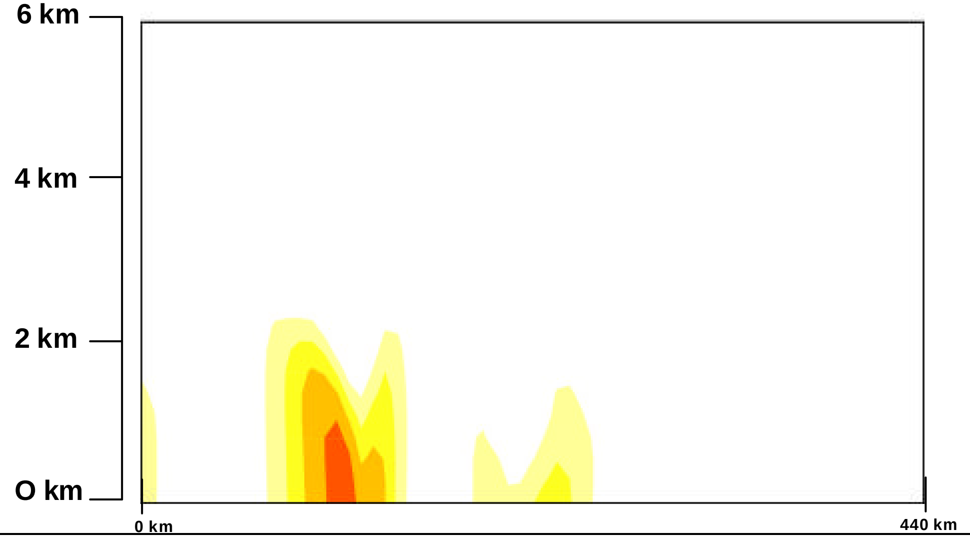
Vertical cross sections at 48.4°N

LM with drifting of precipitation

00 UTC + 15h



Specific water content of snow



Specific water content of rain

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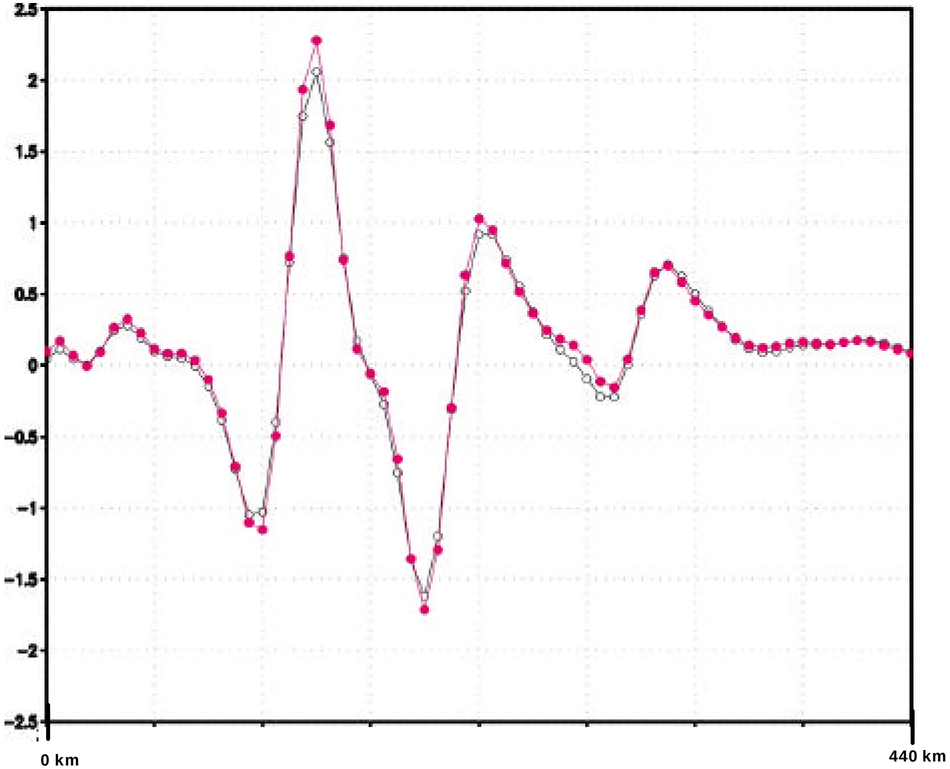
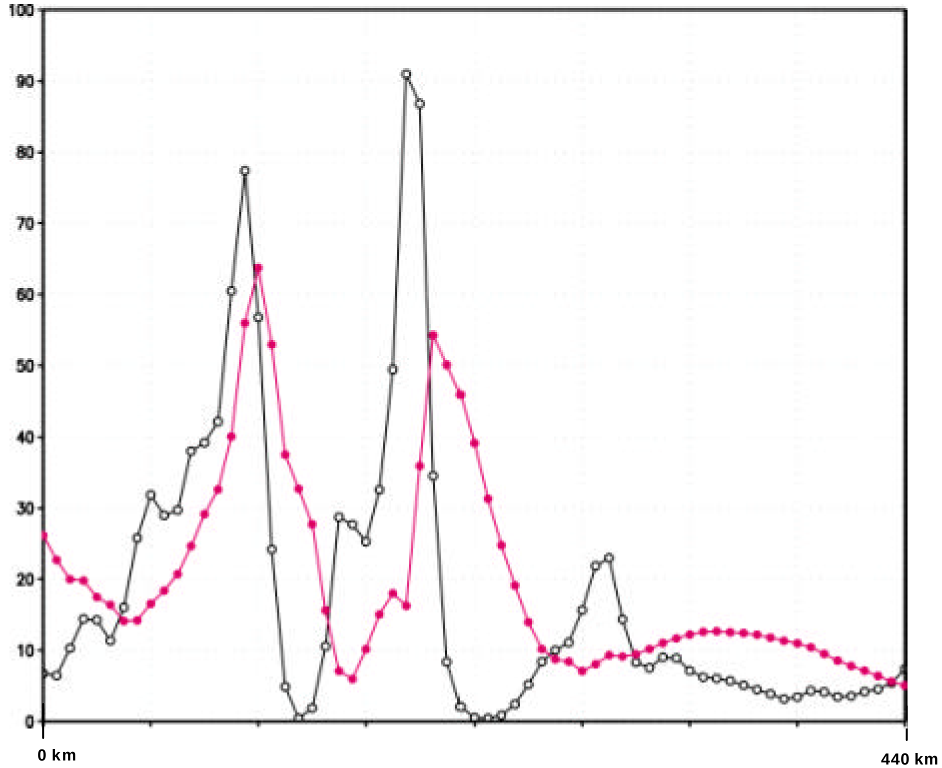
Cross sections at 48.4°N

Mean vertical motion [Pa/s] at 600 hPa



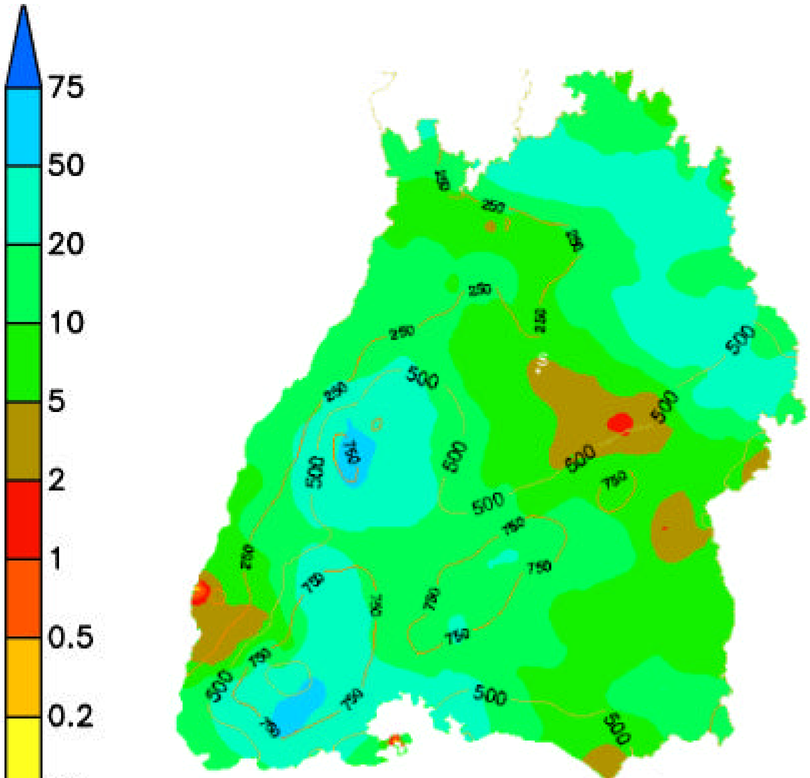
Precipitation [mm] 00 UTC + 06h-30h



Black: Operational LM
Red : LM with drifting of precipitation

Precipitation 20/02-21/02/2002

Observation



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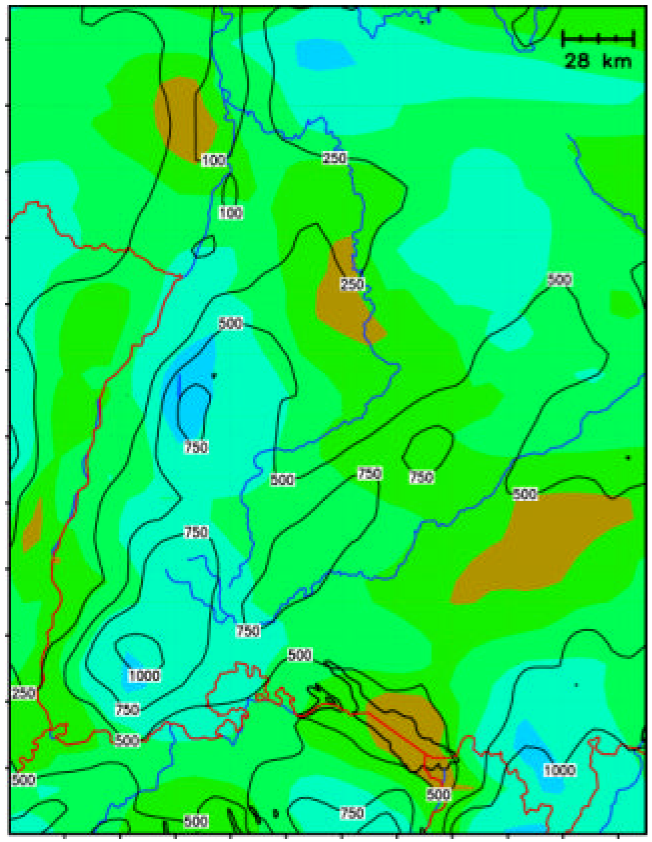

LM with drifting of precipitation

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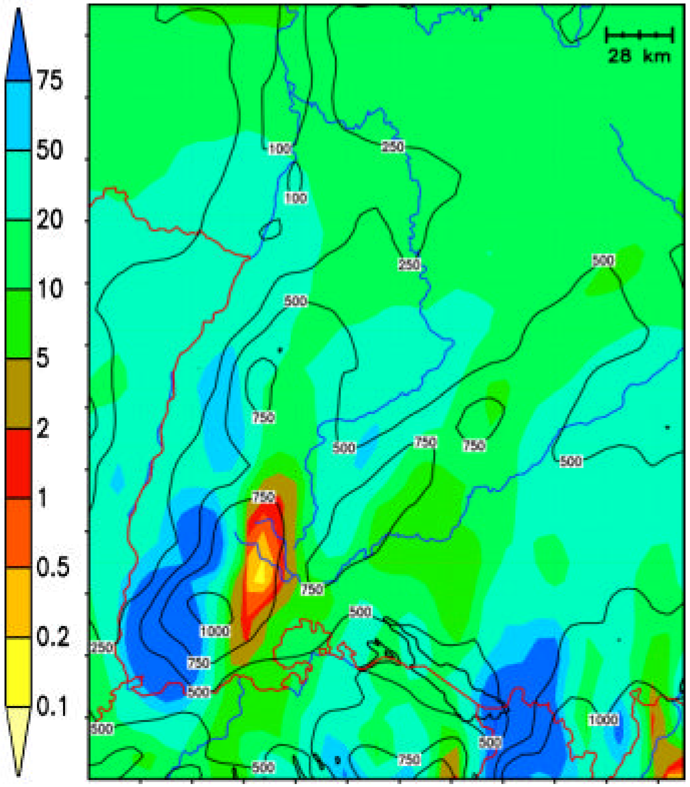
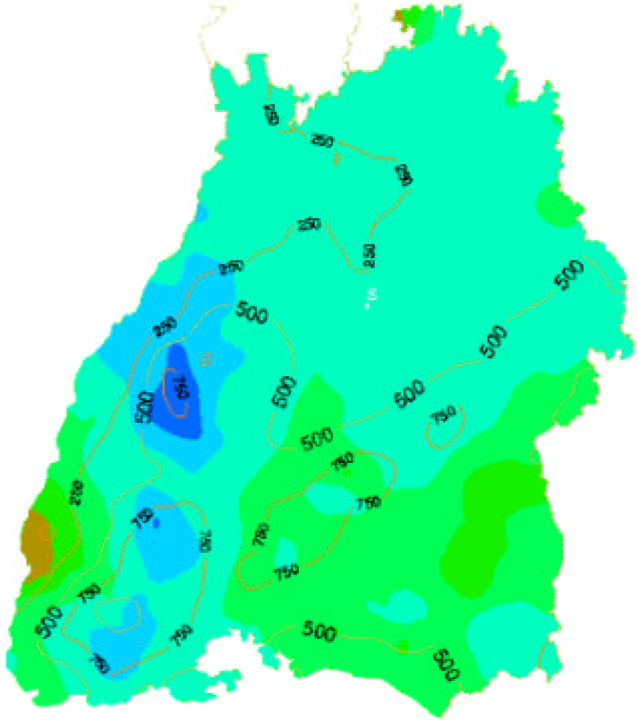
24-h precipitation amount 29.12.-30.12.2001

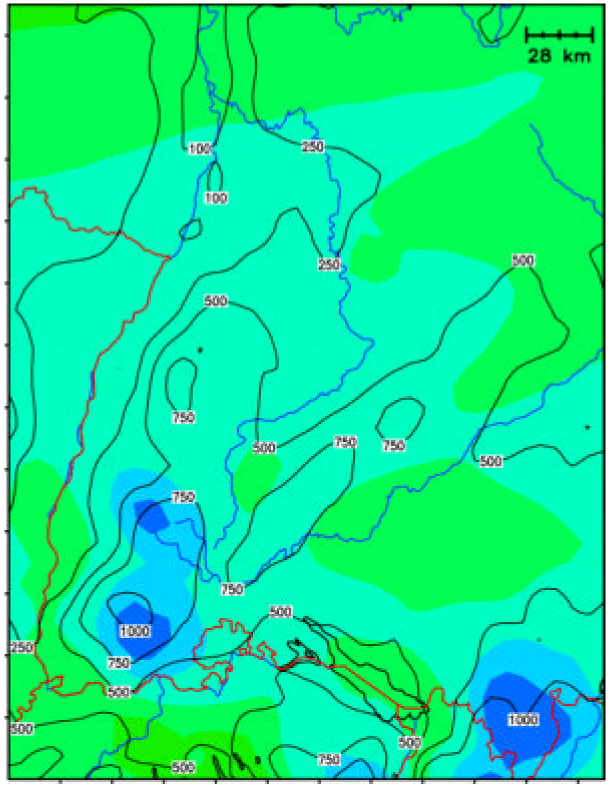


Operational LM (LM-7km)



Beobachteter Niederschlag (kg m^{-2})
29.12.2001 06 UTC bis 30.12.2001 06 UTC

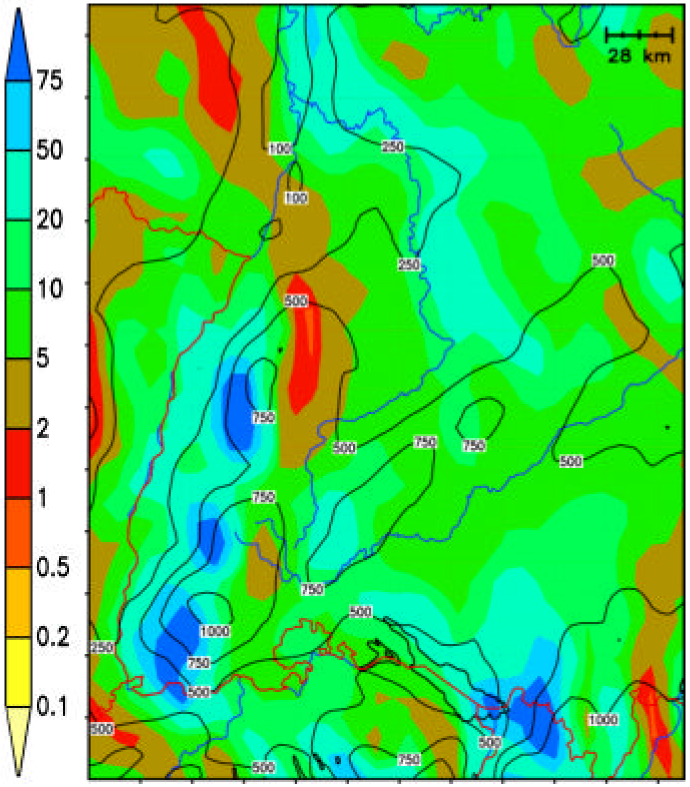
Minimum: 1.10 Maximum: 97.40 Mittelwert: 28.269



LM-7km with 3-d transport of precipitation

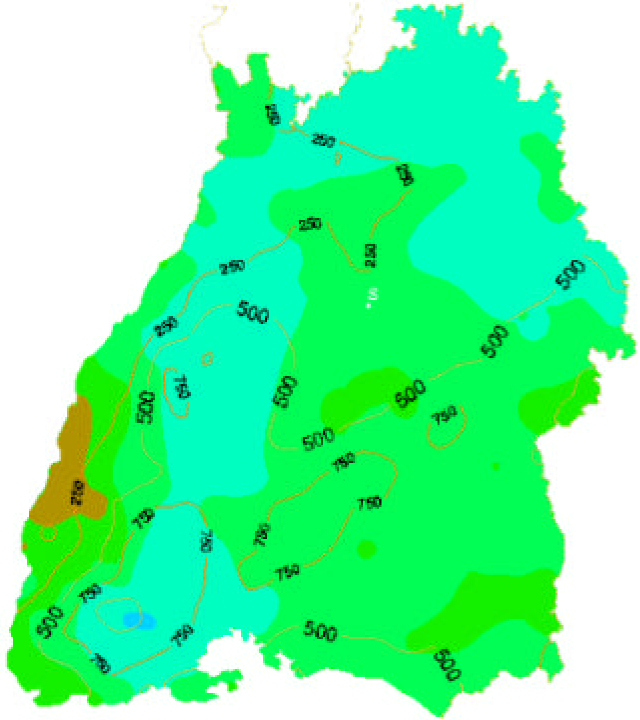
24-h precipitation amount 2.1.-3.1.2003

LM 00 UTC + 06h-30h



Operational LM (LM-7km)

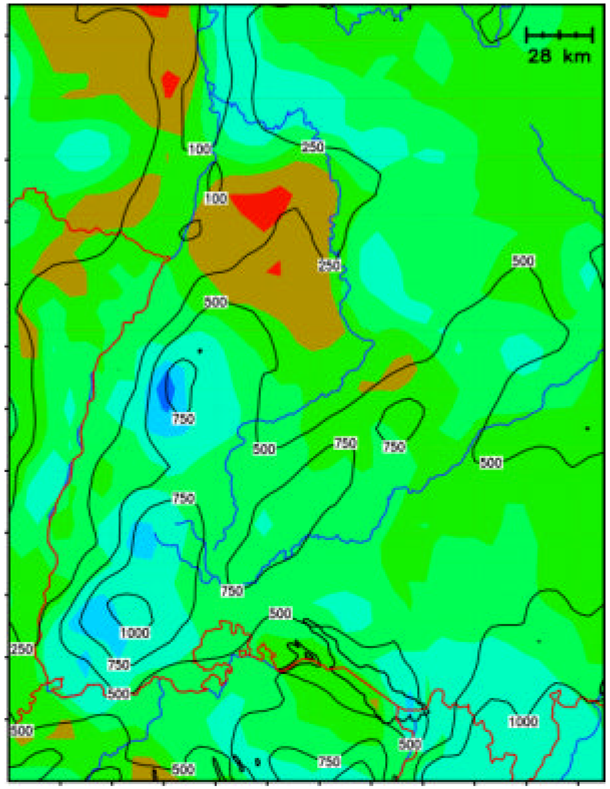
Beobachtung



Beobachteter Niederschlag (kg m^{-2})
02.01.2003 06 UTC bis 03.01.2003 06 UTC

linimum: .90 Maximum: 54.60 Mittelwert: 19.708

LM 00 UTC + 06h-30h



LM-7km with 3-d transport of precipitation

Conclusions

- **Gravity and mountain wave dynamics is well represented by the LM (PYREX)**
- **Lee-side distribution of precipitation is very sensitive to the seeder-feeder mechanism**
- **Including the 3-D transport of precipitation (in particular of snow) appears to significantly improve the distribution of precipitation on the upwind side and in the lee of mountains**
- **more case studies are necessary**

- prognostic treatment of rain and snow needs about 50% more computing time for the total LM,
- new numerics (2-time-level scheme) have to be optimized and tested thoroughly,
- as an intermediate step, the prognostic precipitation scheme will be implemented within the operational 3-TL integration scheme using a semi-Lagrangian transport scheme (2Q 2004)