Simulating orographic precipitation: Sensitivity to physics parameterizations and model numerics

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Overview

- A highly idealized test of numerical model errors over steep topography
- Model sensitivities for a real case of orographic precipitation (MAP-IOP 10)

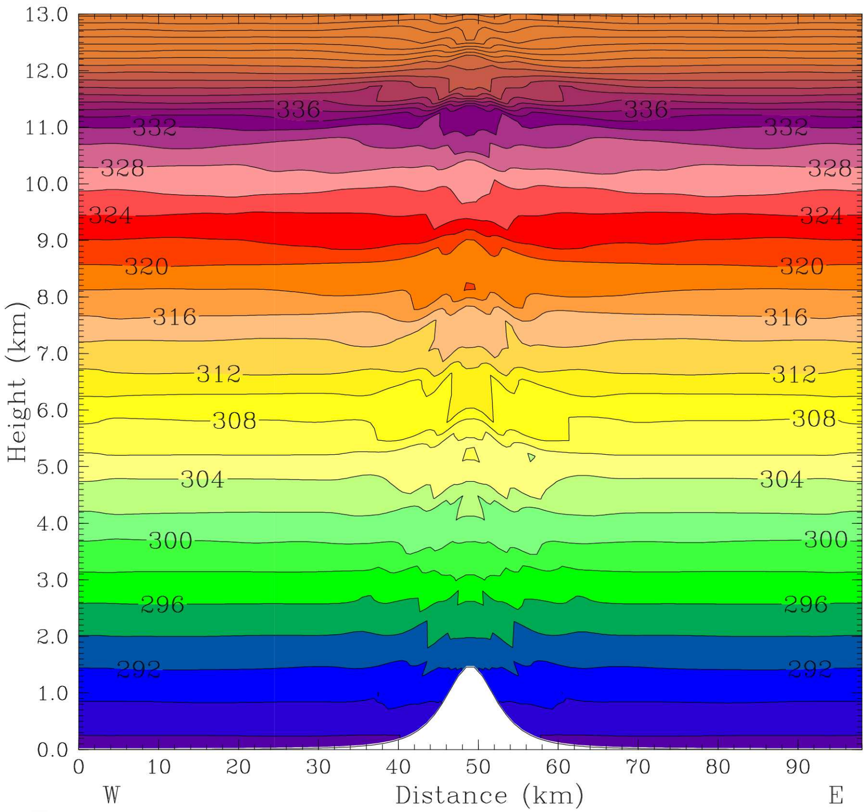
Part I: A highly idealized test of numerical model errors over steep topography

(Zängl et al. 2004, Met. Z. 13, 69-76)

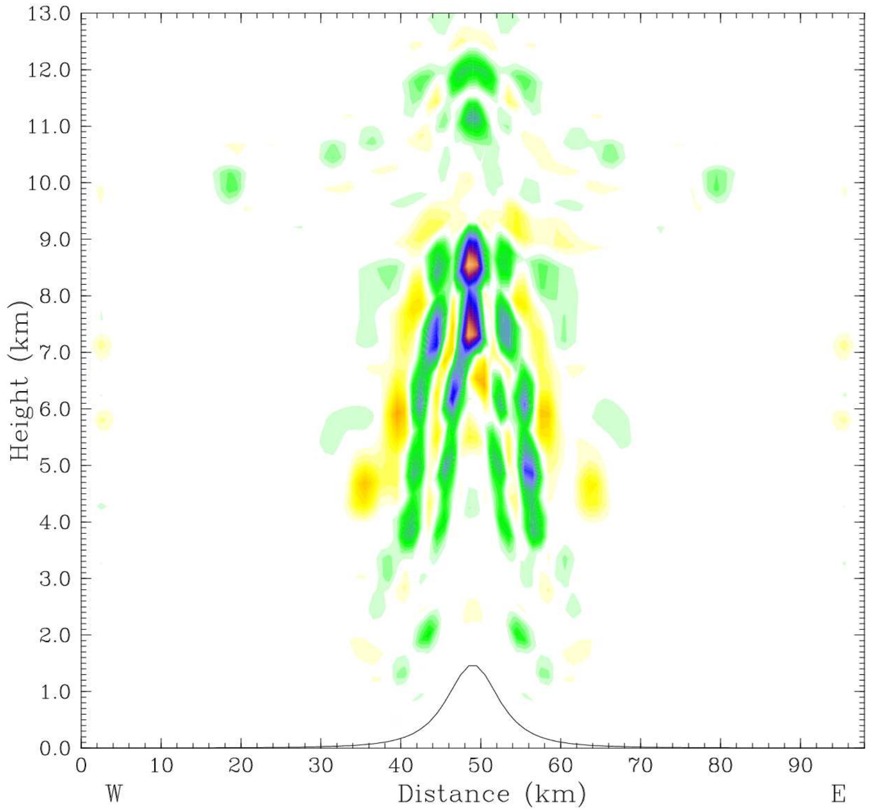
Setup:

- 1 domain with 1 km mesh size and 101 x 101 grid points; 50 vertical levels up to 100 hPa
- 1500-m-high Witch-of-Agnesi mountain in center
- standard atmosphere temperature profile
- no large-scale winds, no radiation, no moisture
- integration time 24 hours
- sensitivity experiment with moisture and a convectively unstable temperature/moisture profile (Weisman and Klemp 1982)

Potential temperature and vertical wind speed after 24 hours, Standard-MM5 (version 3.6 or earlier)



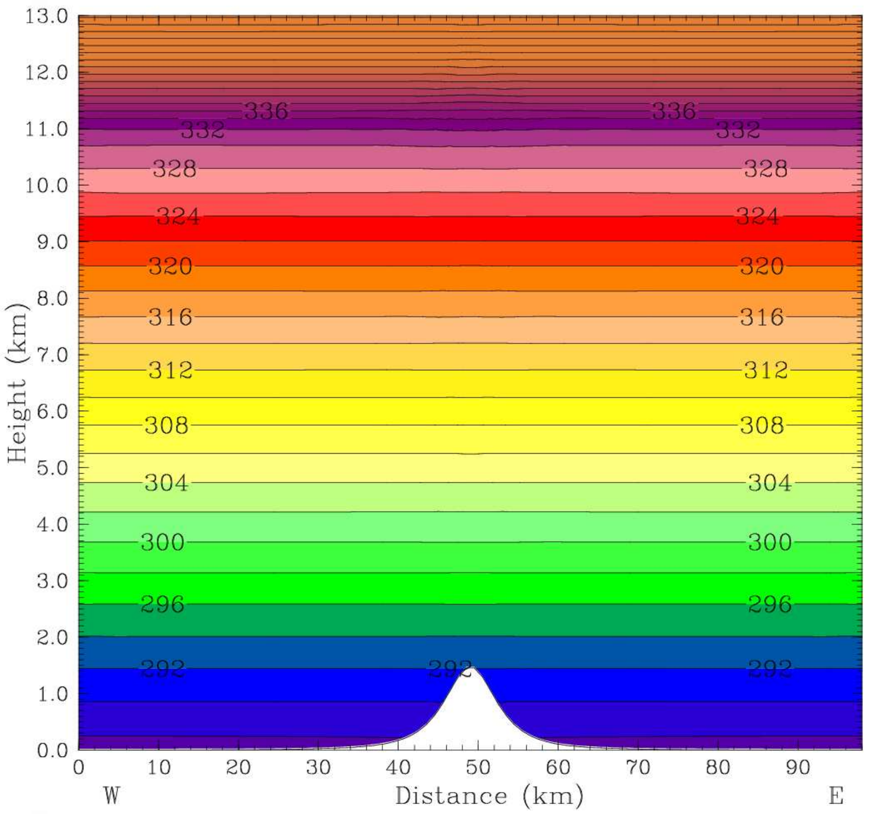
contour interval 2 K



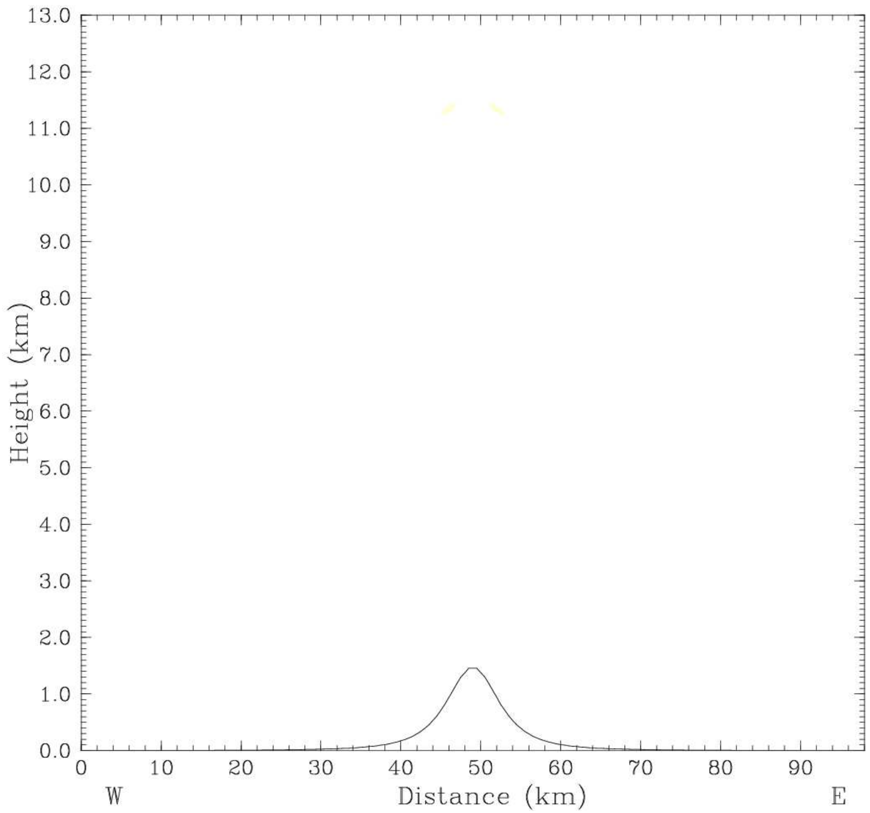
contour interval 5 cm/s

Potential temperature and vertical wind speed after 24 hours, MM5 with truly horizontal numerical diffusion of temperature (available since MM5 v. 3.7)

(Zängl 2002, Mon. Wea. Rev. 130, 1423-1432)



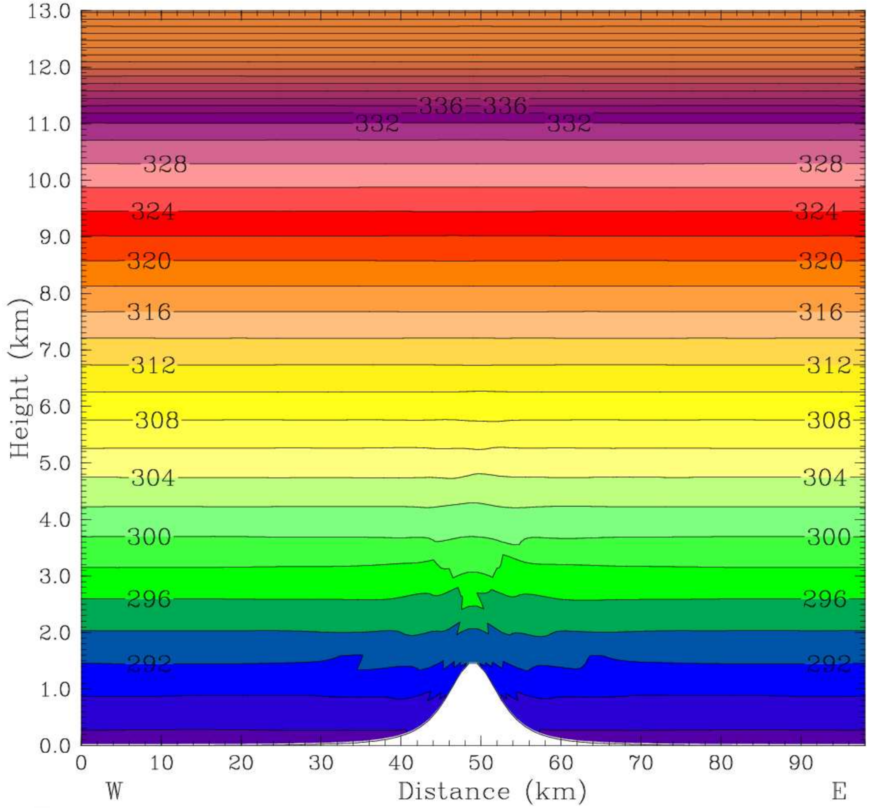
contour interval 2 K



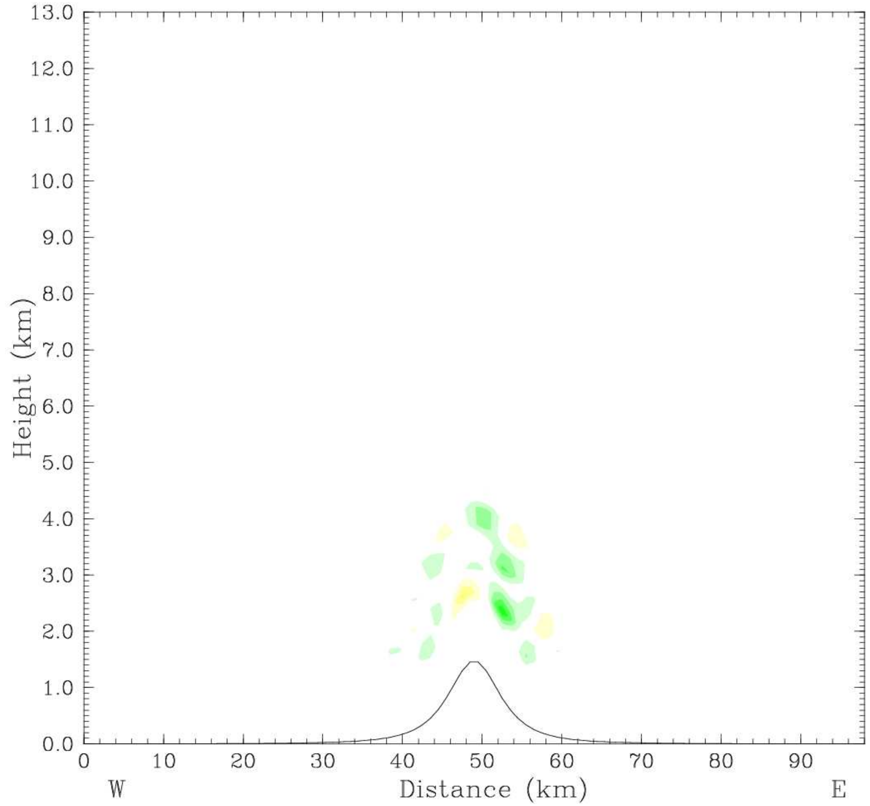
contour interval 5 cm/s

Potential temperature and vertical wind speed after 24 hours, MM5 with „SLEVE“ coordinate but diffusion along model surfaces

(Schär et al. 2002, Mon. Wea. Rev. 130, 2459-2480; Zängl 2003, Mon. Wea. Rev. 131, 2875-2884)

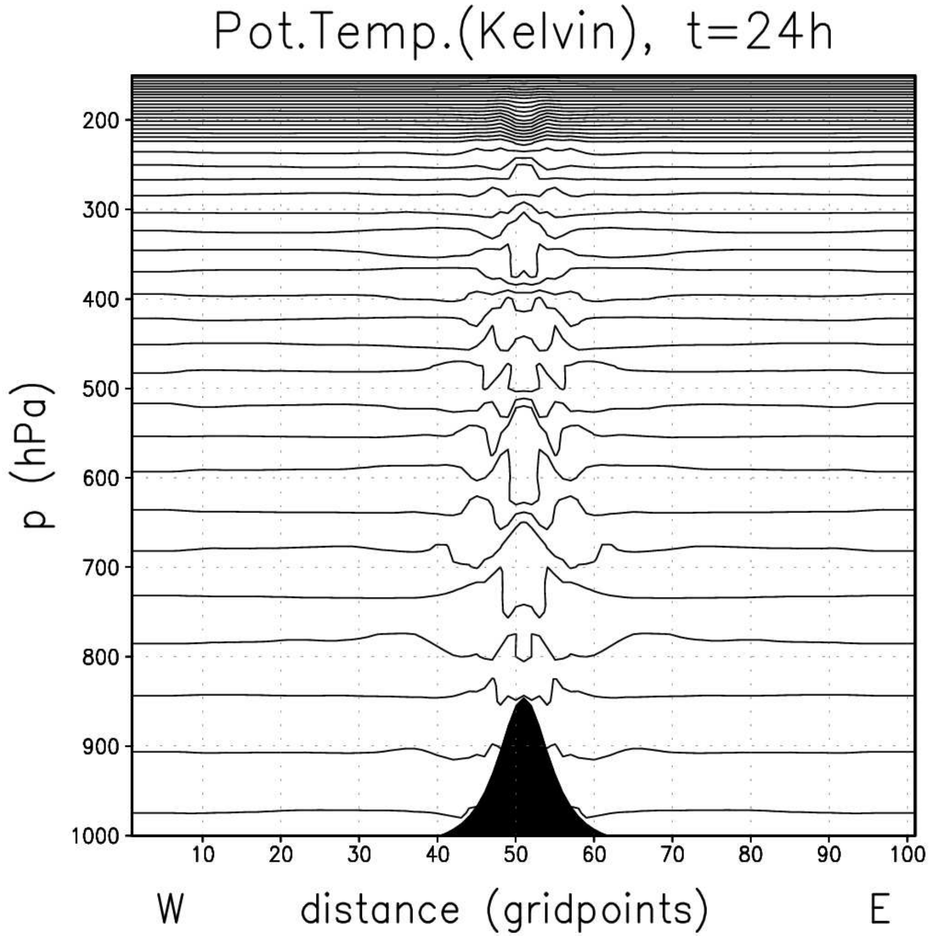


contour interval 2 K

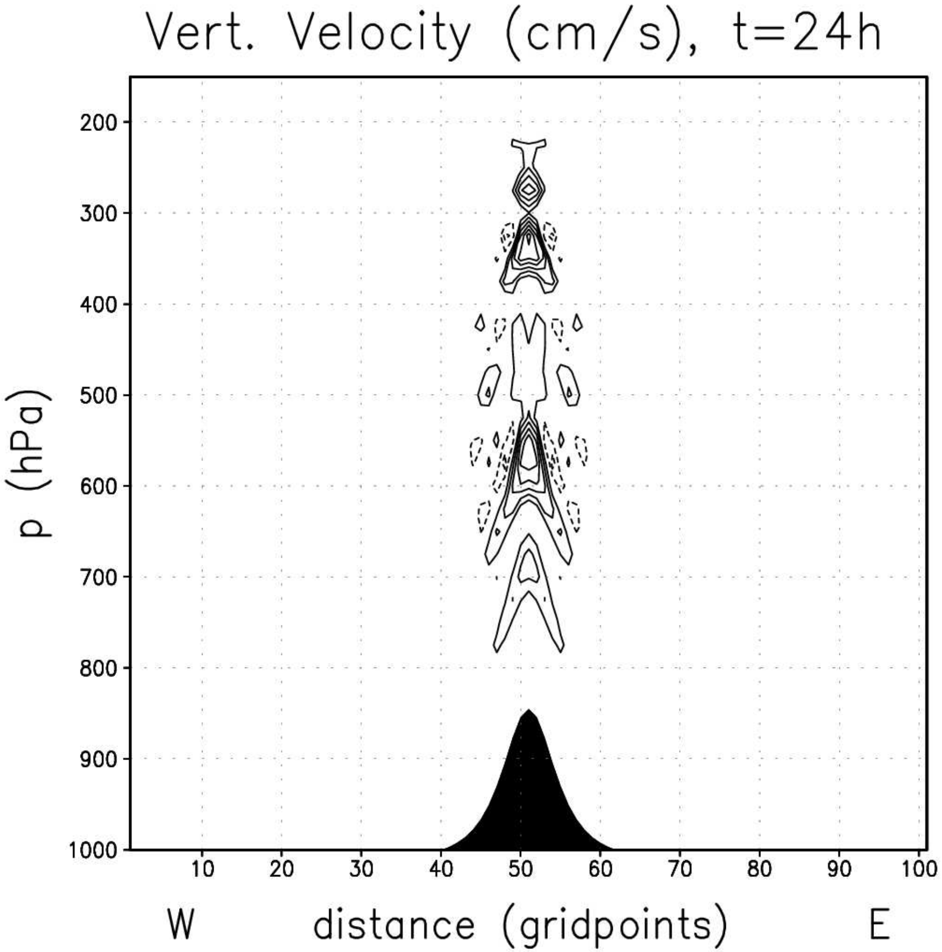


contour interval 5 cm/s

Potential temperature and vertical wind speed after 24 hours, LM

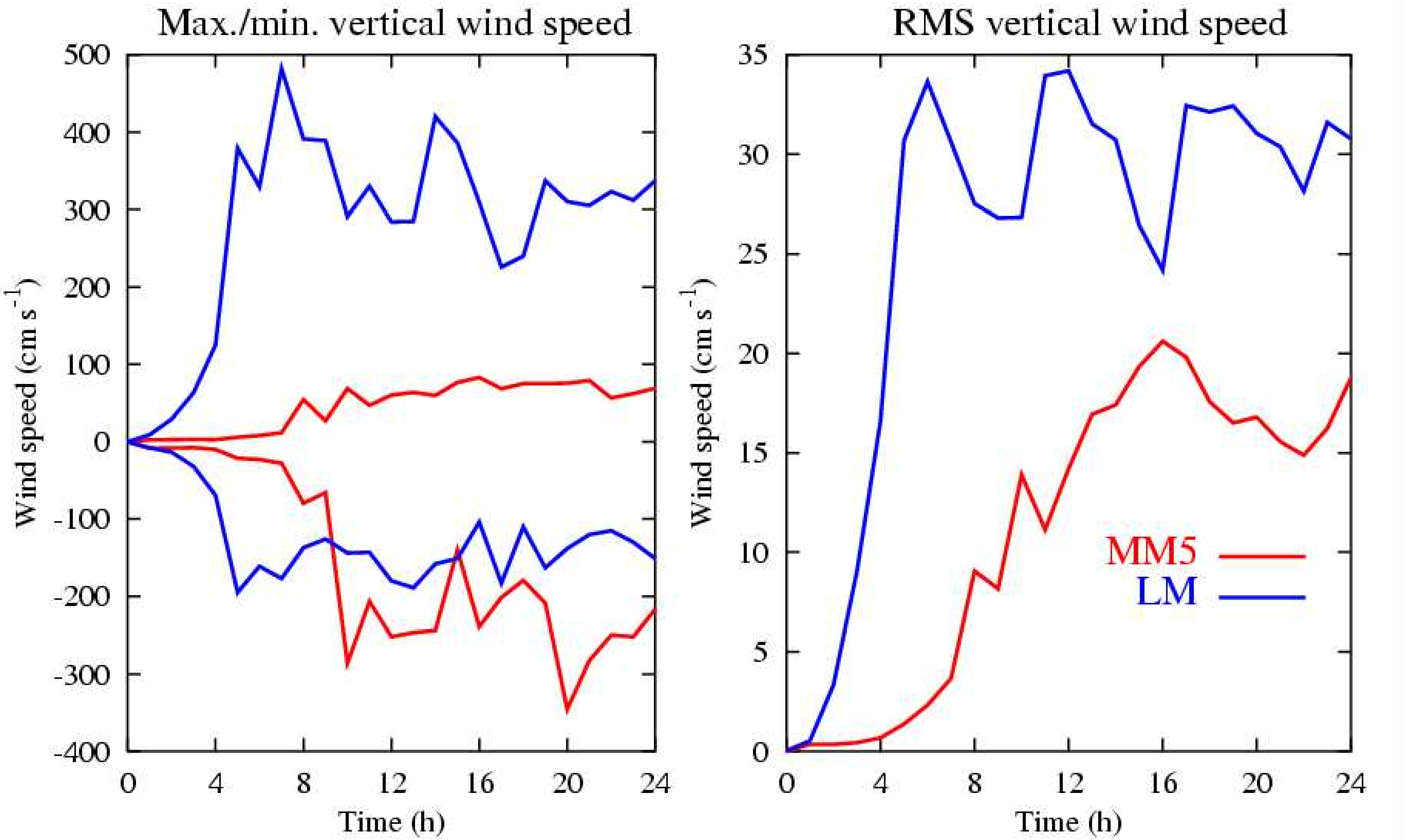


contour interval 2 K



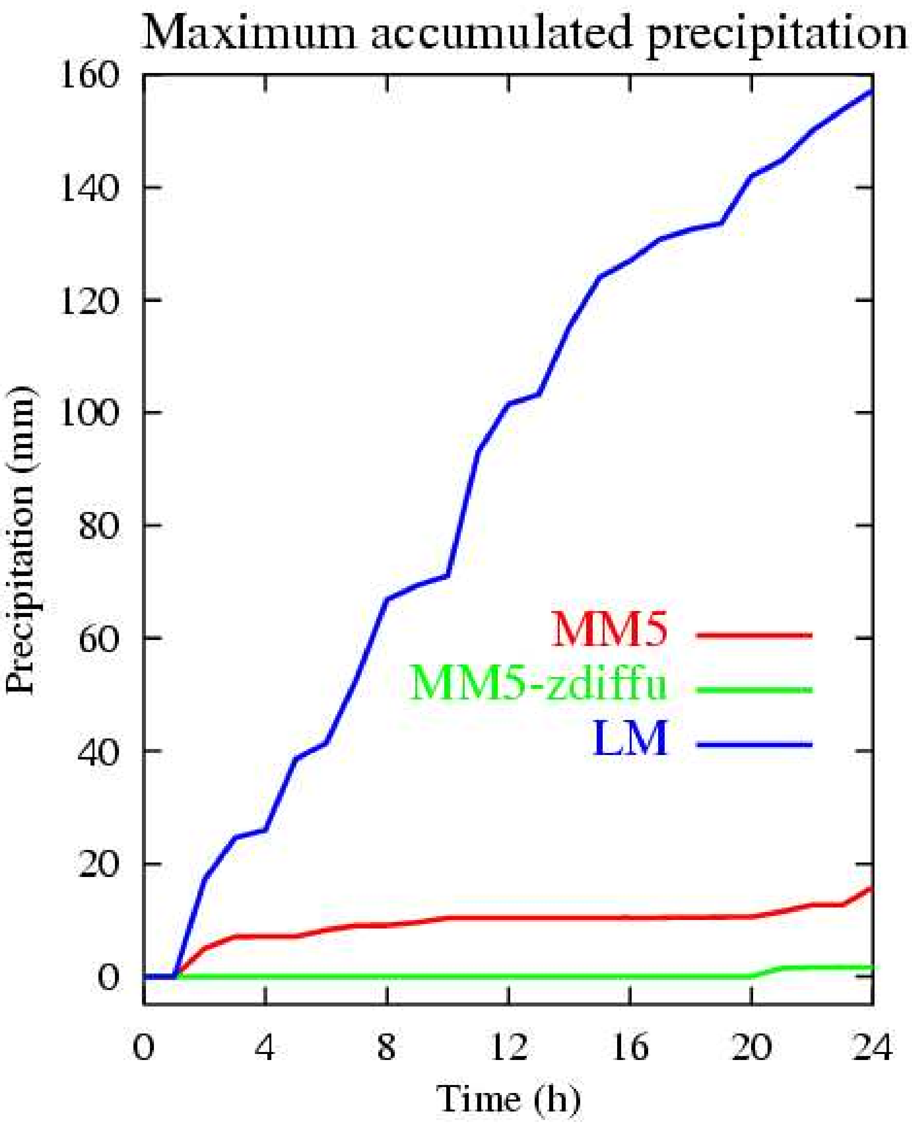
contour interval 50 cm/s

Time series



Max./min. vertical wind speed
RMS vertical wind speed
Wind speed (cm s-1)
Time (h)
MM5
LM

Maximum accumulated precipitation for sensitivity tests with moisture and convectively unstable atmosphere



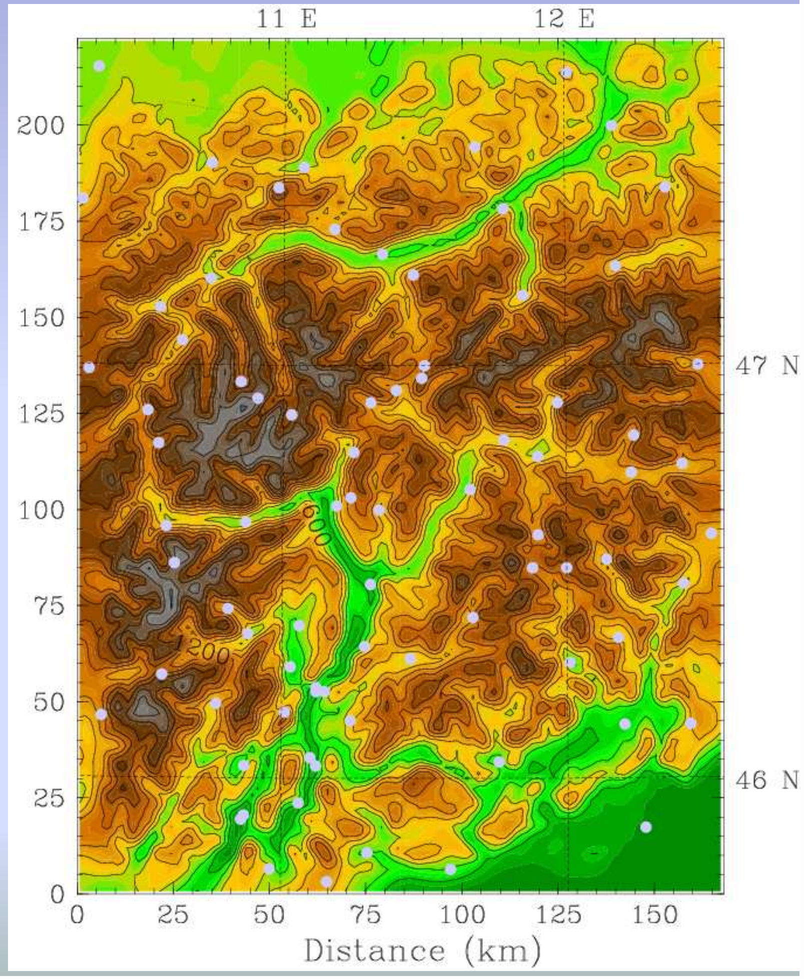
Practical relevance:

Numerical errors can shift the initiation of orographic convection to earlier times

Part II: Model sensitivities for a real case of orographic precipitation (MAP-IOP 10)

(Zängl 2004, QJRMS 130, 1857-1875)

- **Model: MM5**
- **4 nested domains, finest horizontal resolution 1.4 km (see figure)**
- **38 model levels in the vertical**
- **Initial / boundary data: Operational ECMWF analyses**
- **Period of simulation: Oct. 24, 00 UTC - Oct. 25, 18 UTC**
- **Validation against 81 surface stations for Oct. 24, 06 UTC - Oct. 25, 18 UTC (see figure for location)**

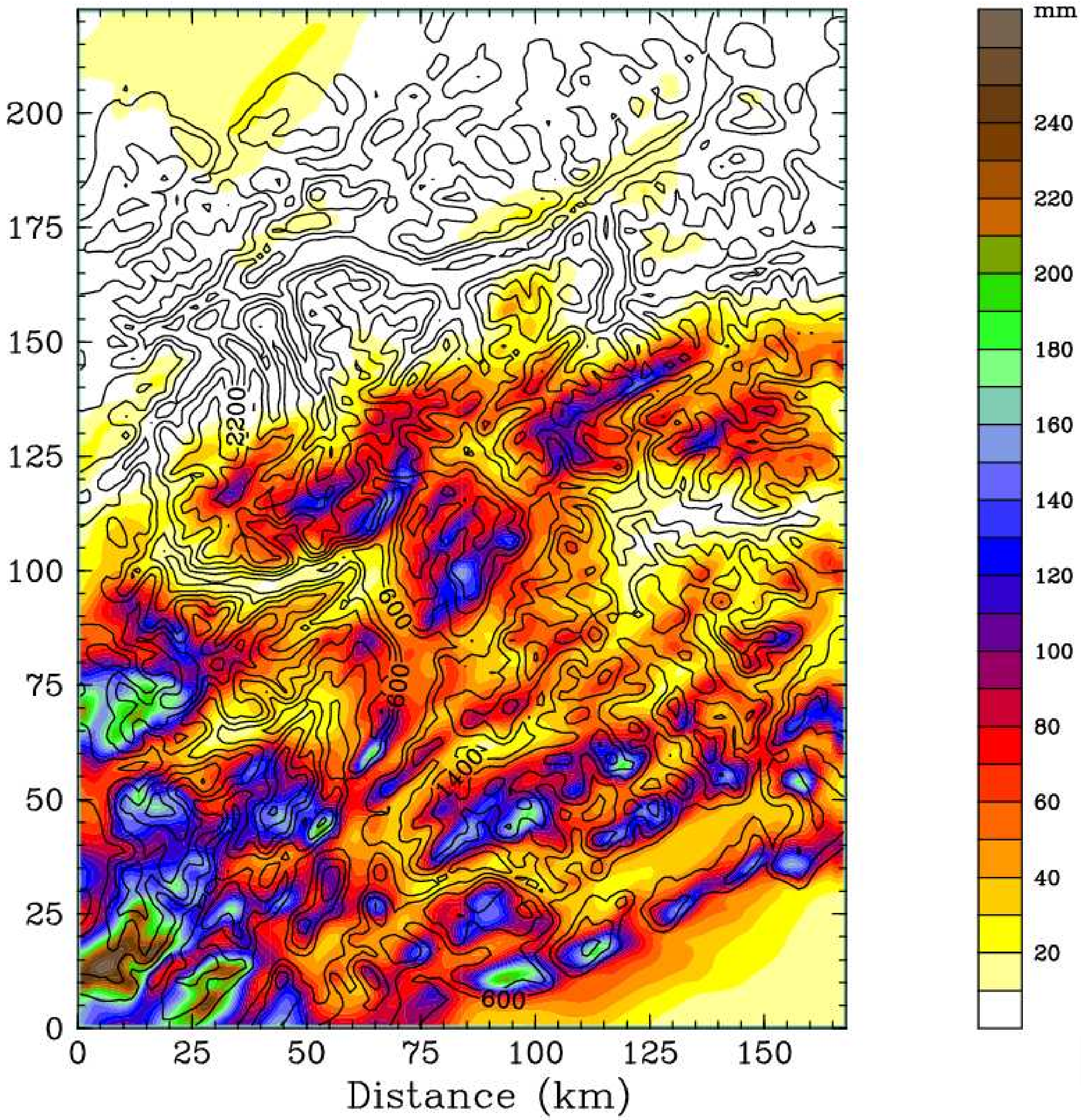


Test strategy:

Compare the spread among five different microphysical parameterizations against the effect of changing

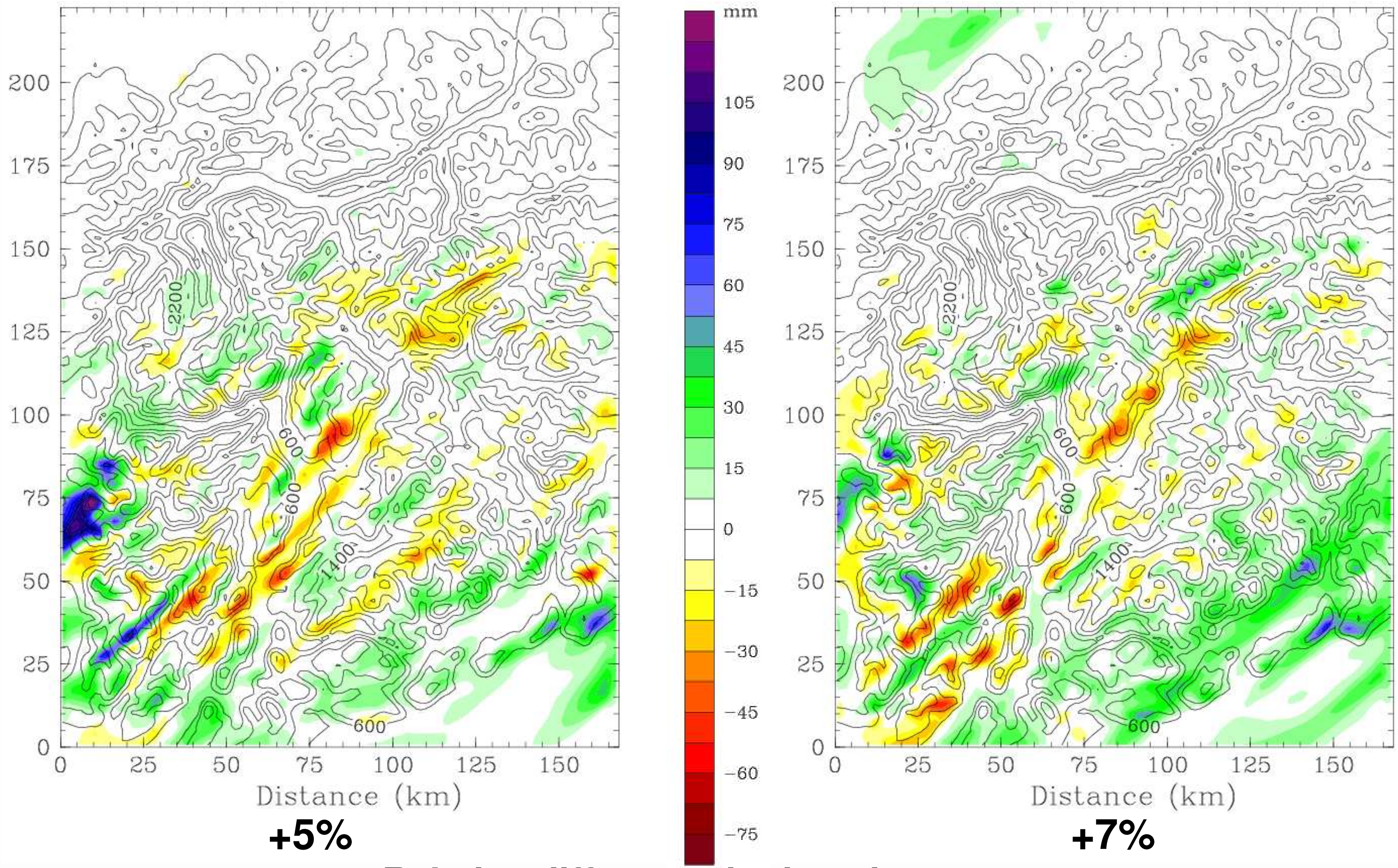
- **the convection parameterization in the coarse domains**
- **the soil moisture specification**
- **the PBL parameterization**
- **the vertical coordinate formulation**
- **the implementation of horizontal diffusion**

36h-accumulated precipitation in the reference run



Difference fields (sensitivity experiment - REF run)

Reisner1 microphysics (REF Reisner 2) **Goddard micph.**



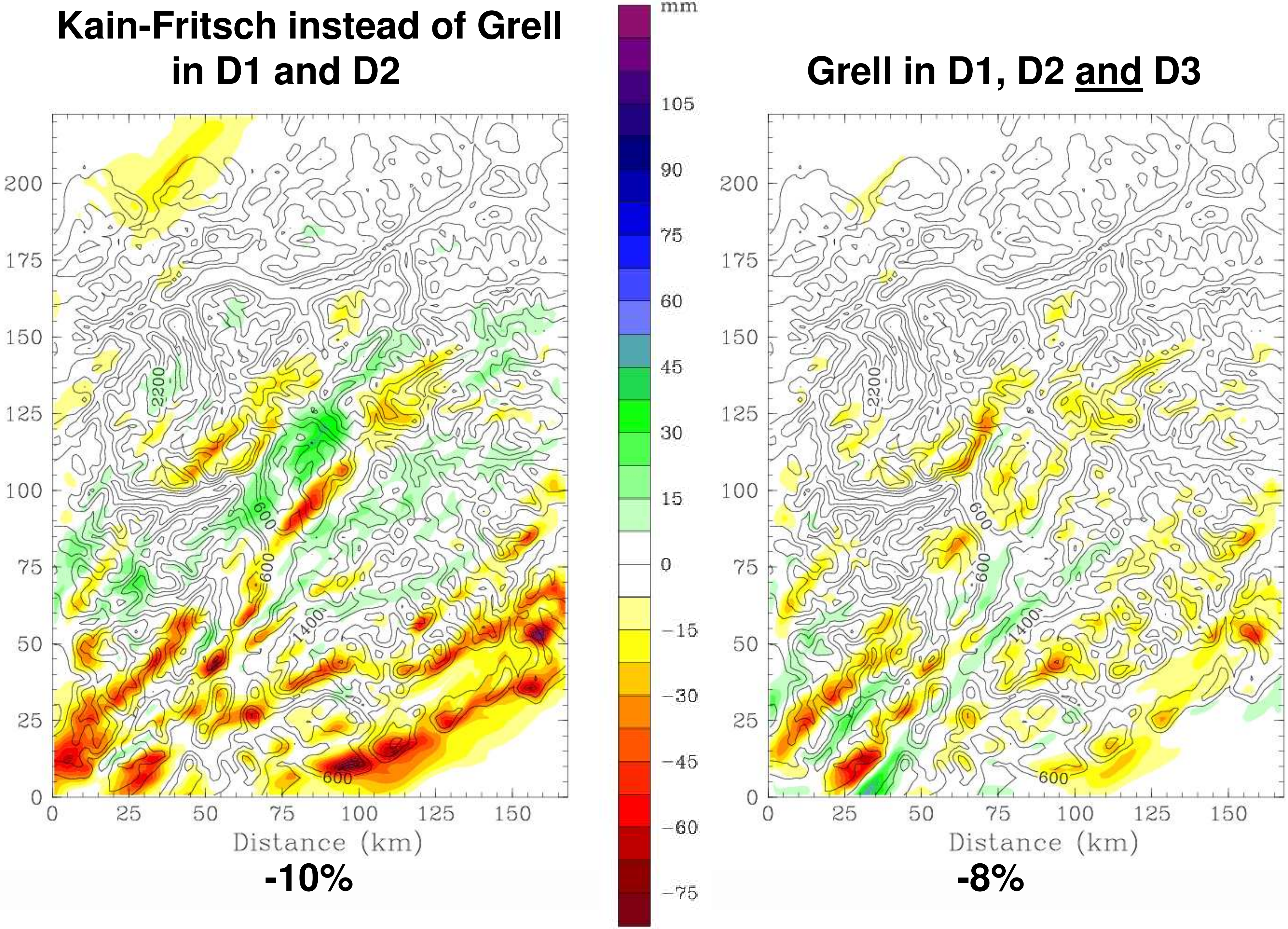
+5% **+7%**

Relative difference in domain-average

Cumulus parameterizations

Kain-Fritsch instead of Grell in D1 and D2

Grell in D1, D2 <u>and</u> D3

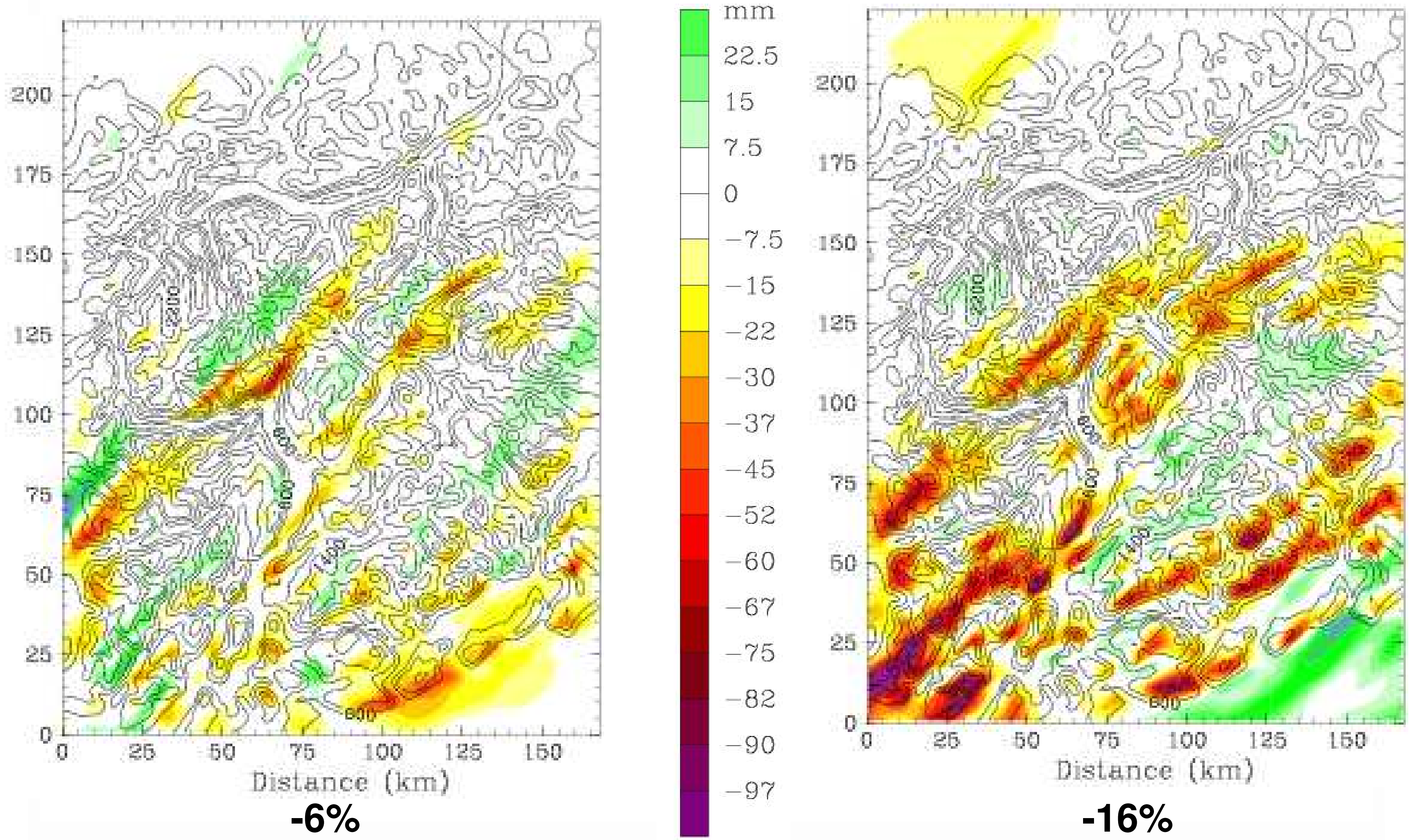


-10%

-8%

Boundary-layer parameterization (reference: Gayno-Seaman PBL)

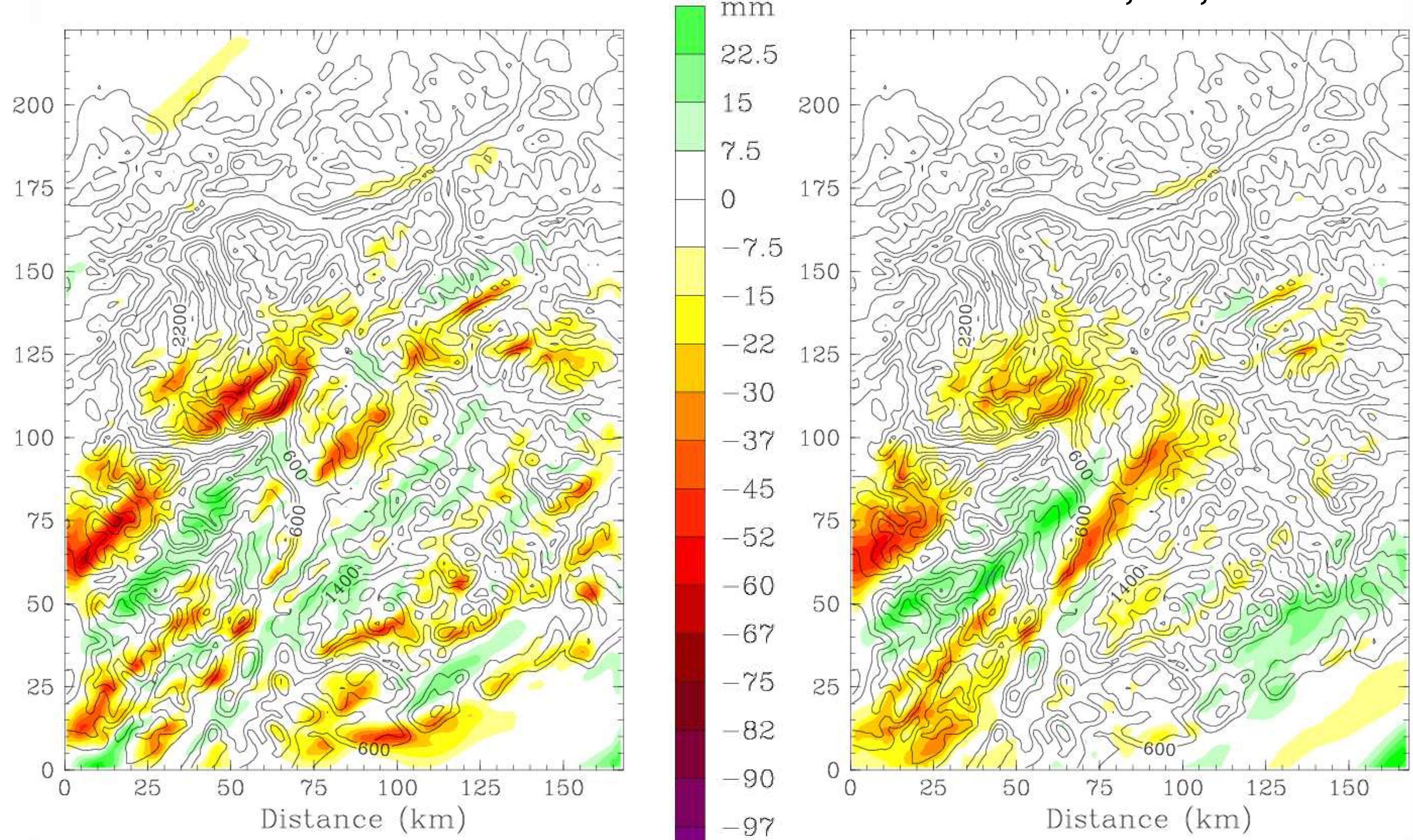
Blackadar PBL | **MRF PBL**



-6% | **-16%**

Smooth-level vertical coordinate system

Parameterizations as in REF run | **Kain-Fritsch in D1, D2; Grell in D3**

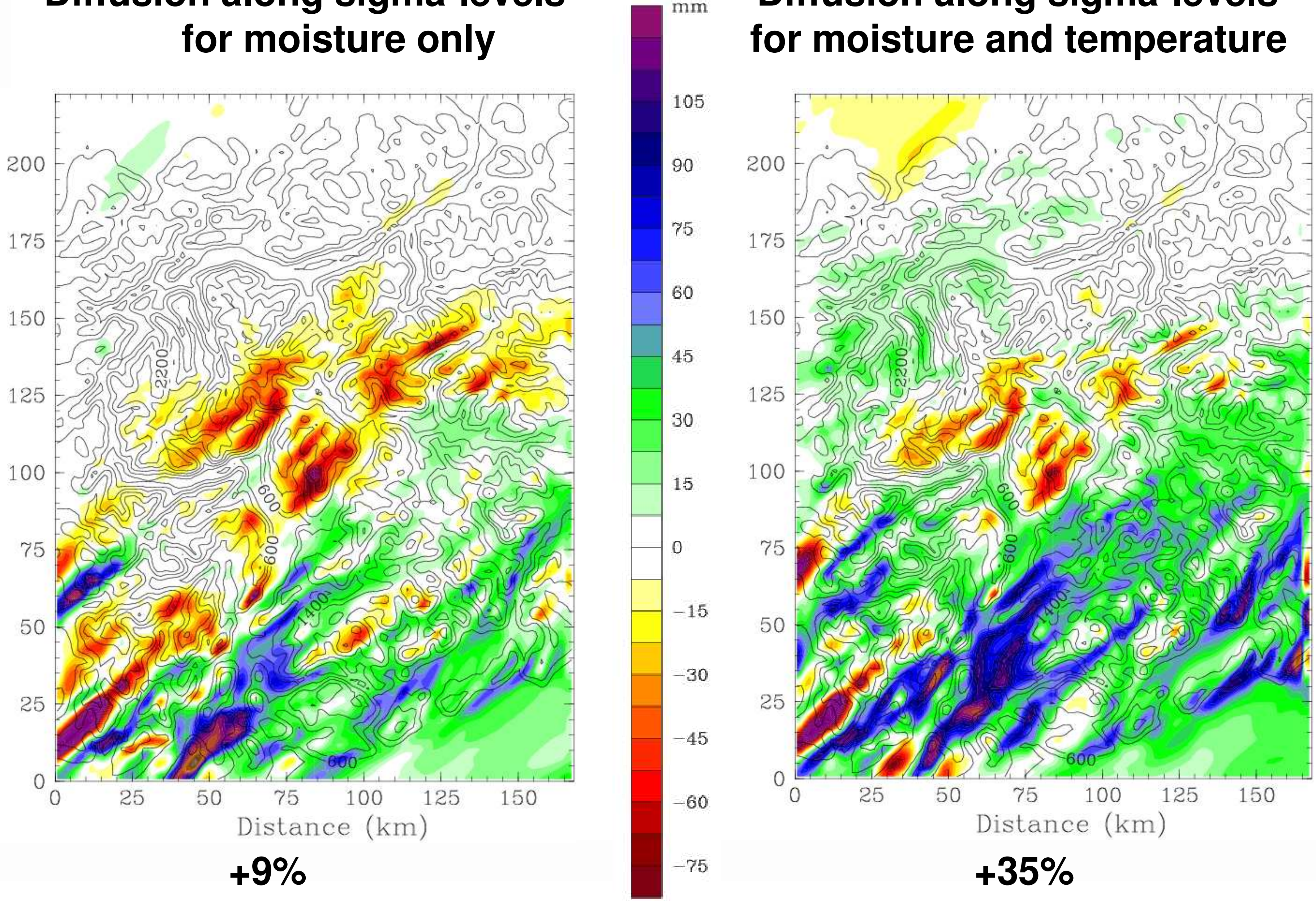


-7% | **-9%**

Implementation of horizontal diffusion

Diffusion along sigma-levels for moisture only

Diffusion along sigma-levels for moisture and temperature



+9%

+35%

Conclusions

- The side effects of model numerics and PBL/convection parameterizations on simulated precipitation can be of the same order as (or even larger than) the spread among different microphysical parameterizations
- To improve forecasts of orographic precipitation, it is necessary

  1. to ensure the absence of systematic numerical errors
  2. to consider the whole physics package of a model rather than focusing on a single parameterization