Modeling orographic precipitation at small scales: The importance of the autoconversion scheme

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Motivation

- For flow over narrow mountains, the advective time scale is comparable to or smaller than the microphysical time scale of precipitation initiation (via autoconversion)
- Thus, pure orographic clouds do not generate significant precipitation
- Nevertheless, the seeder-feeder mechanism may greatly intensify preexisting precipitation

➔ Do high-resolution models reproduce this basic feature?

➔ How sensitively do the results depend on the autoconver-sion scheme?

Setup of simulations

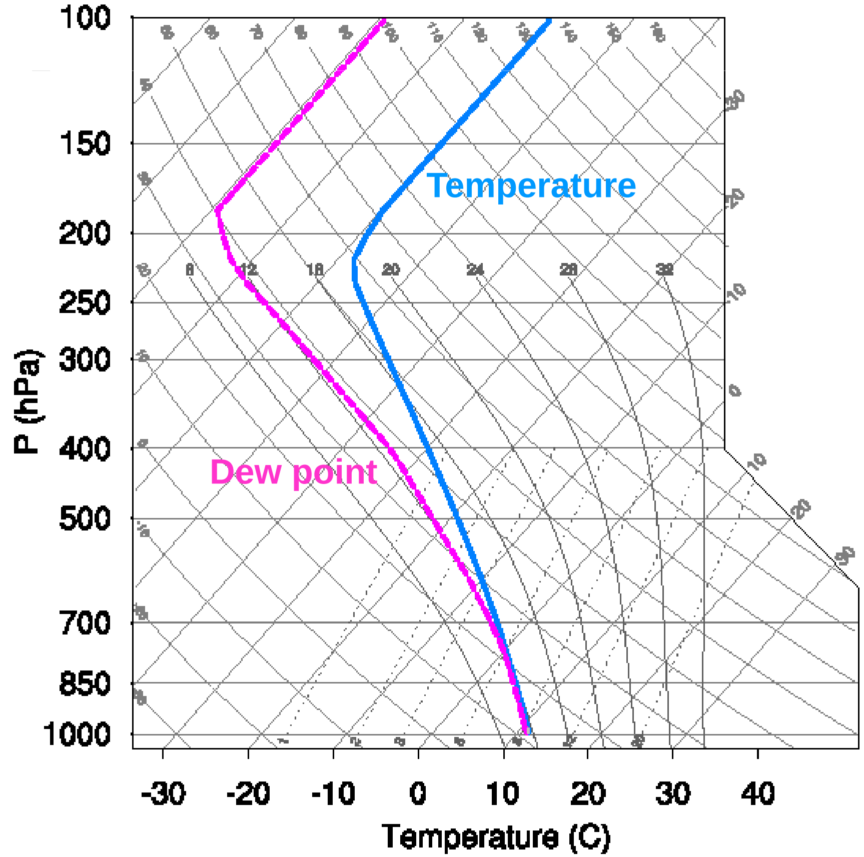
- **Idealized simulations using COSMO model, horizontal resolution 750 m, 250x101 grid points, 50 levels**

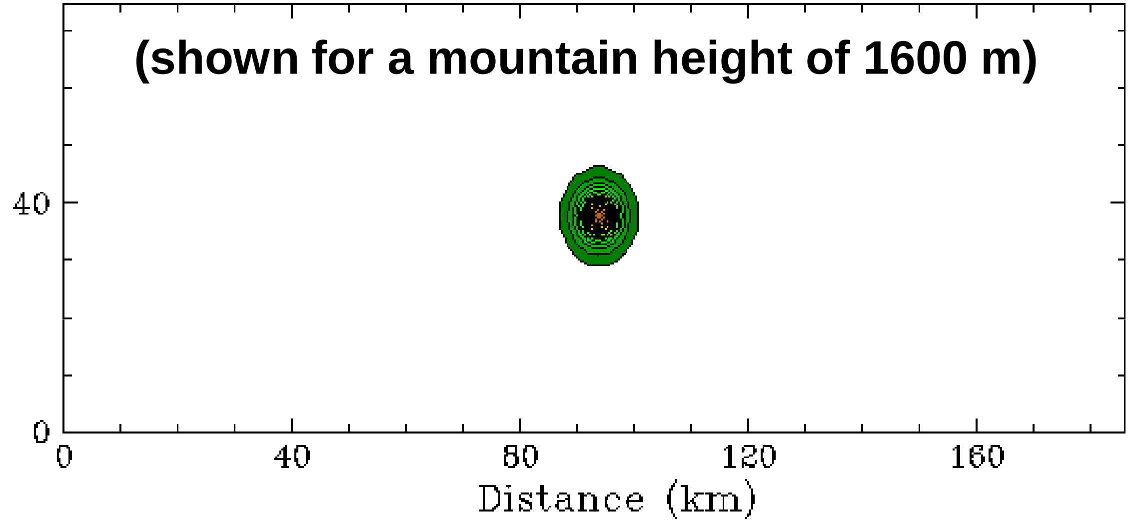
- **Topography: isolated mountain in domain center, half-width about 2.5 km, height 400 m, 800 m, 1200 m or 1600 m; superimposed large-scale slope for experiments with seeder cloud**

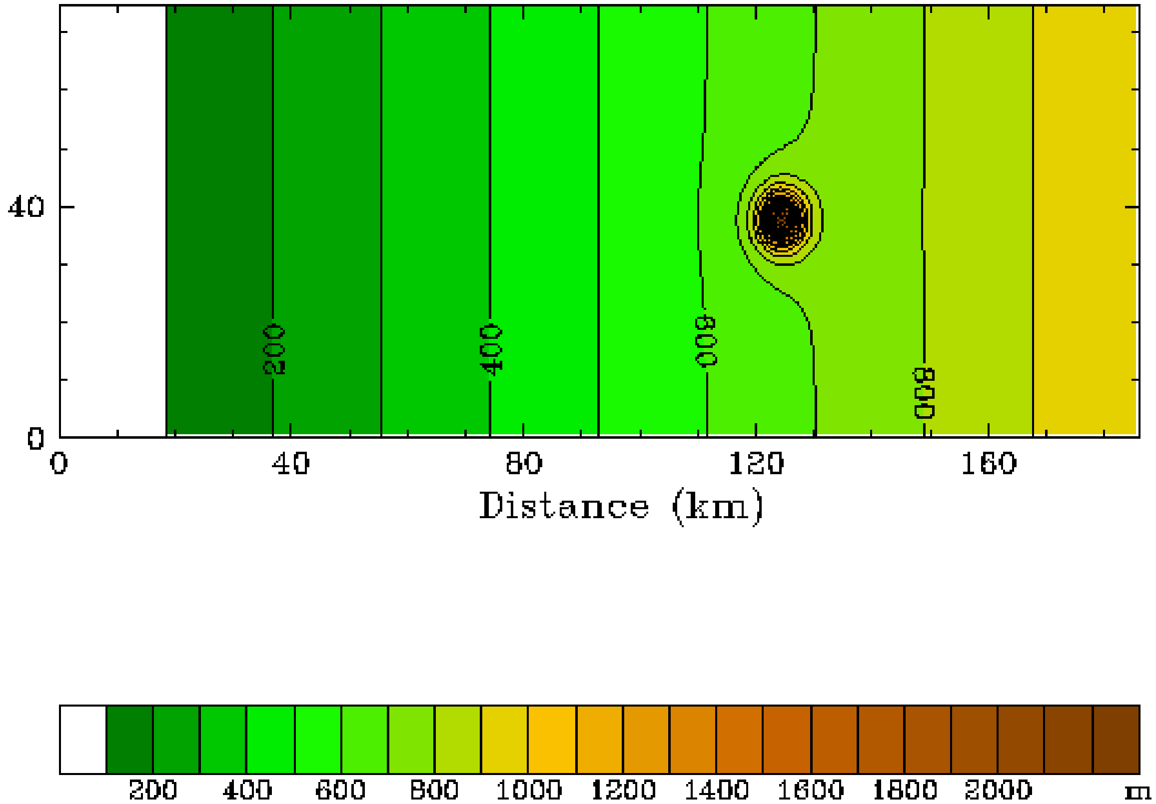
- **Basic flow: positive shear from 10 m/s at sea level to 30 m/s at tropopause level, close to ice saturation up to 400 hPa**

Topography for tests with pure orographic lifting and seeder-feeder effect

Thermodynamic diagram of basic flow







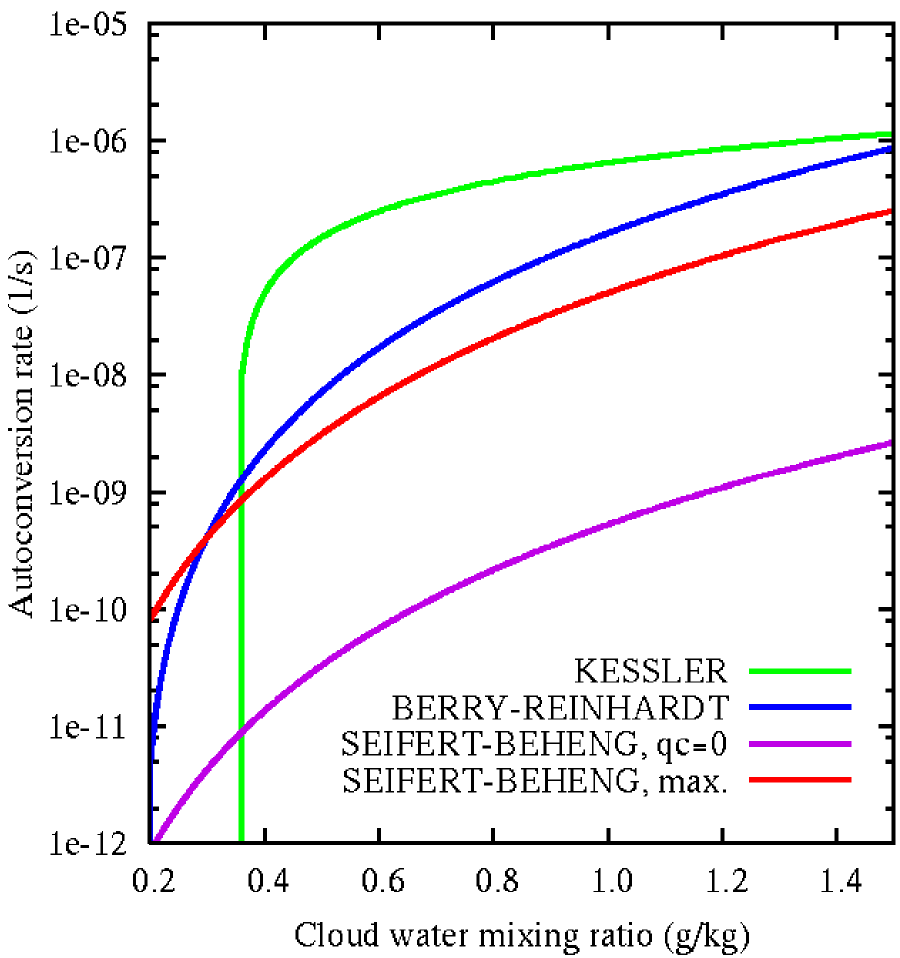
Setup of simulations

- **Parameterization for cloud microphysics including cloud ice, snow and graupel**

Three different autoconversion schemes:

- **Kessler (1969): empirical approach; linear in q_c when exceeding a certain threshold**
- **Berry and Reinhardt (1974): derived from stochastic collection equation; conversion rate depends on q_c and N_c**
- **Seifert and Beheng (2001): also derived from stochastic collection equation, conversion rate depends on q_c, N_c and q_r**

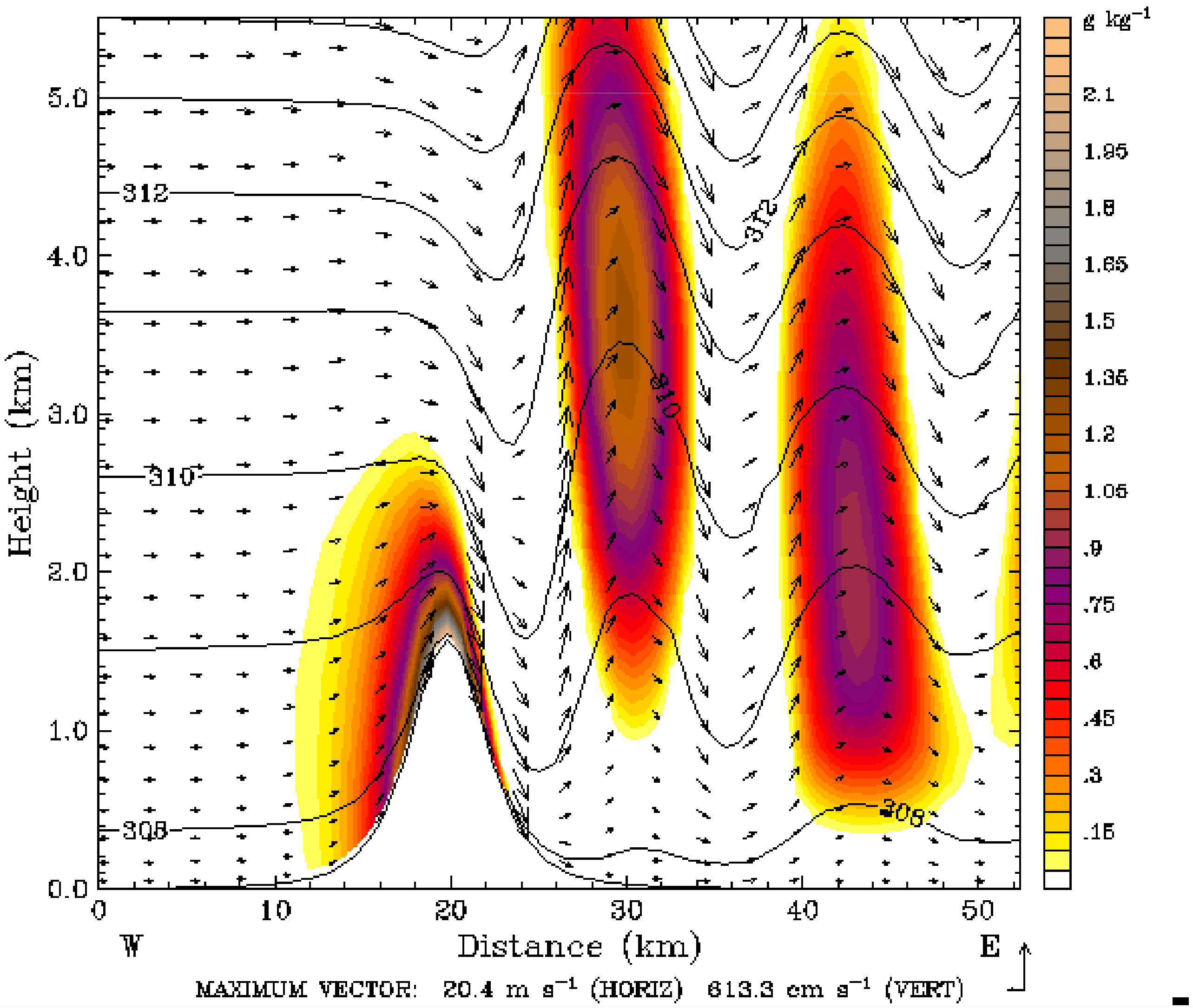
(plot assumes N_c = 100 cm^{-3})



Flow pattern and cloud field

Vertical cross-section across mountain peak: θ_e (contour interval 1 K), q_c (colors)

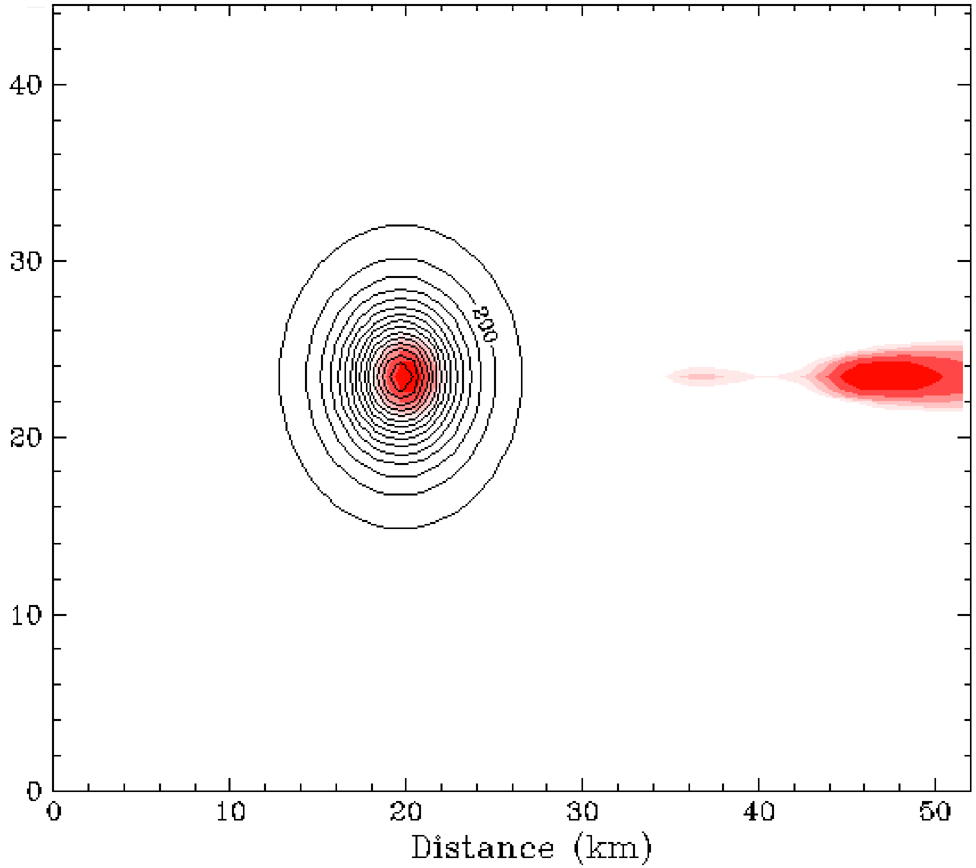
SB autoconversion



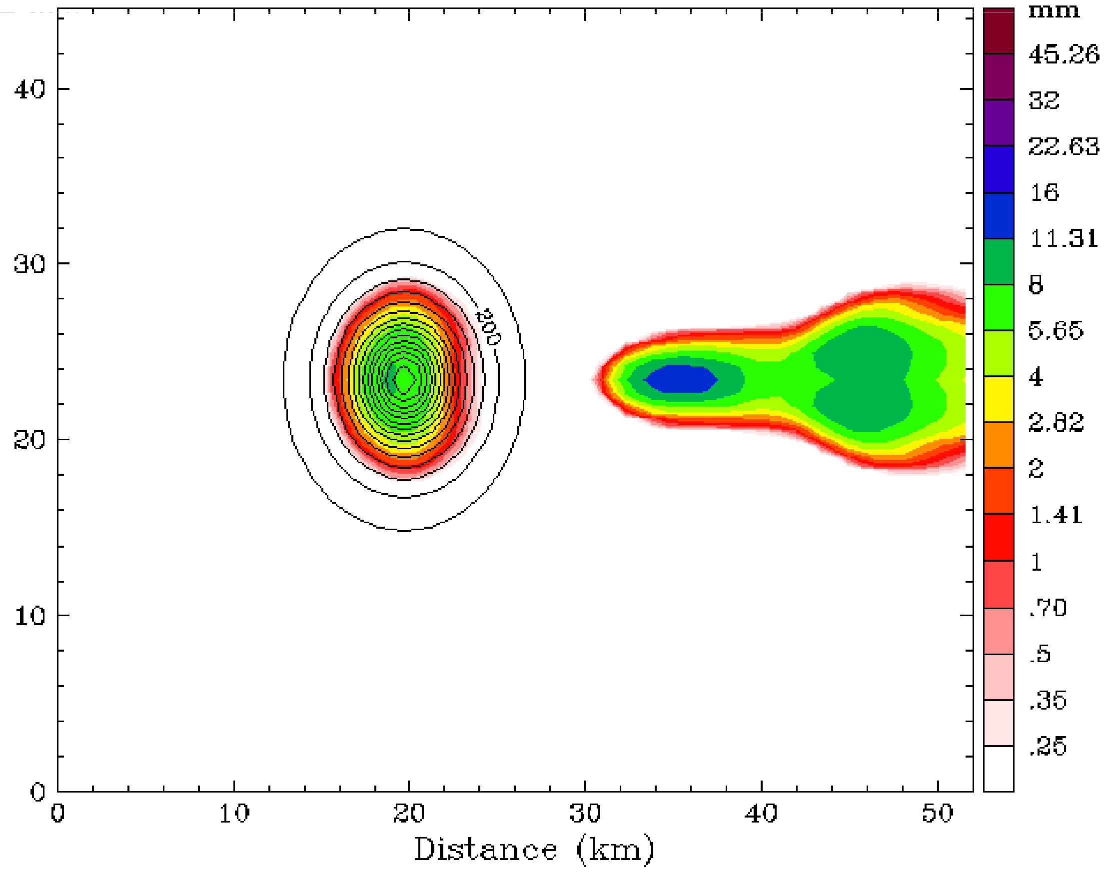
Precipitation field

3-hour accumulated precipitation (mm)

SB autoconversion

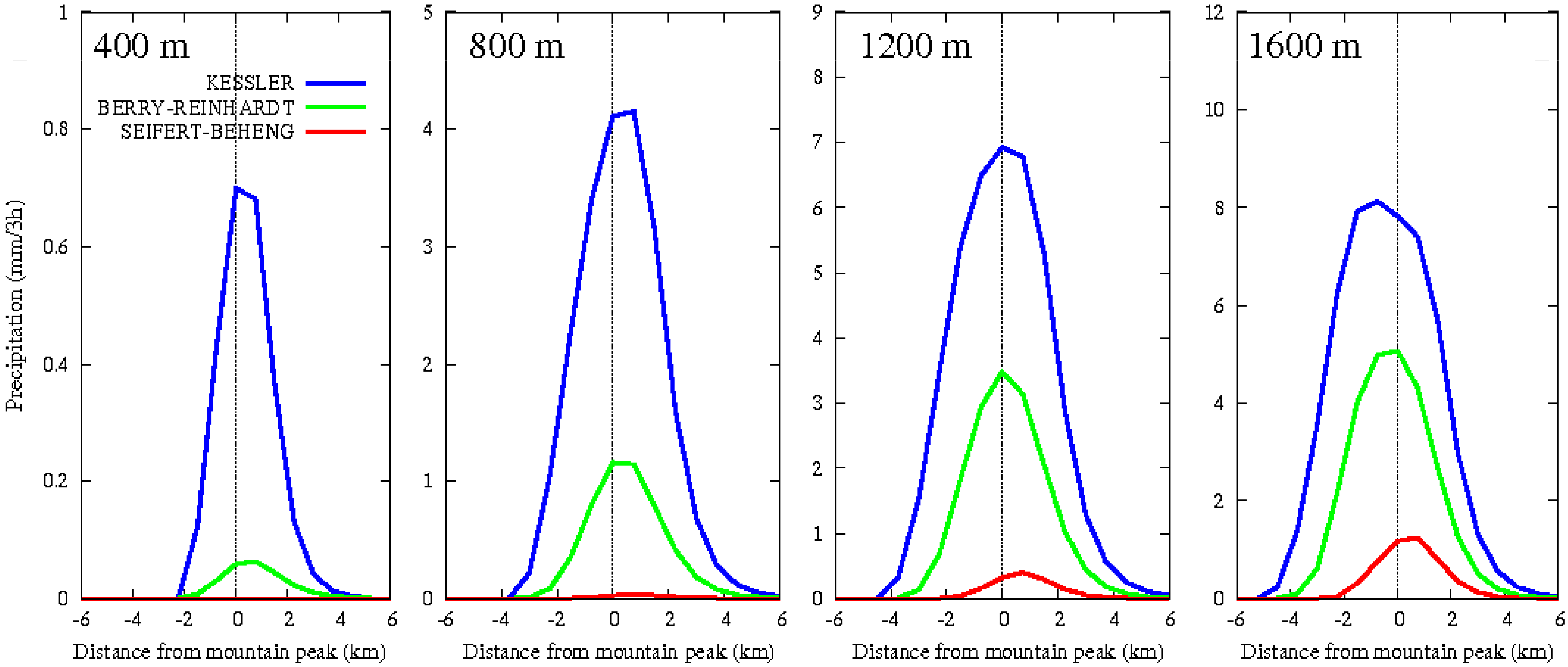


KESSLER autoconversion



Precipitation structure

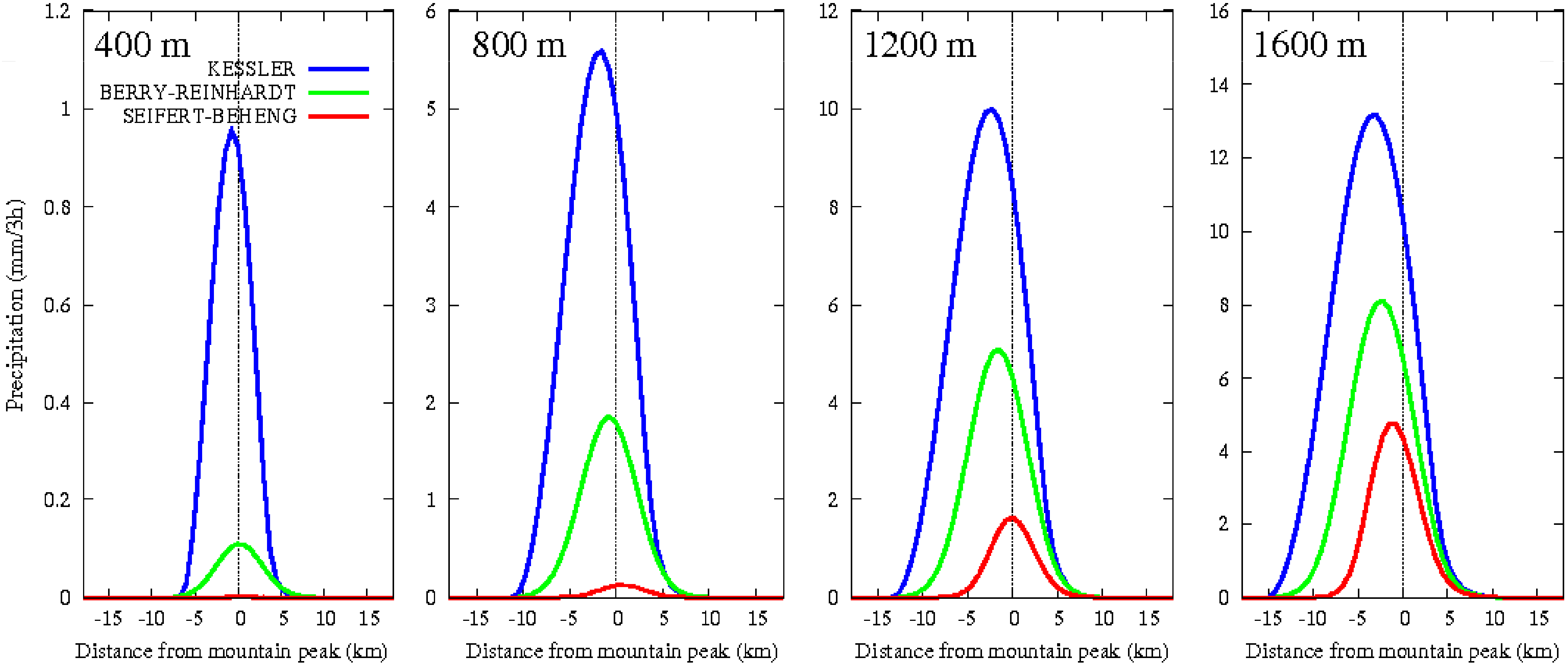
3-hour accumulated precipitation (mm) along a section crossing the mountain peak



Precipitation structure

3-hour accumulated precipitation (mm) along a section crossing the mountain peak

Mountain width increased by a factor of 3

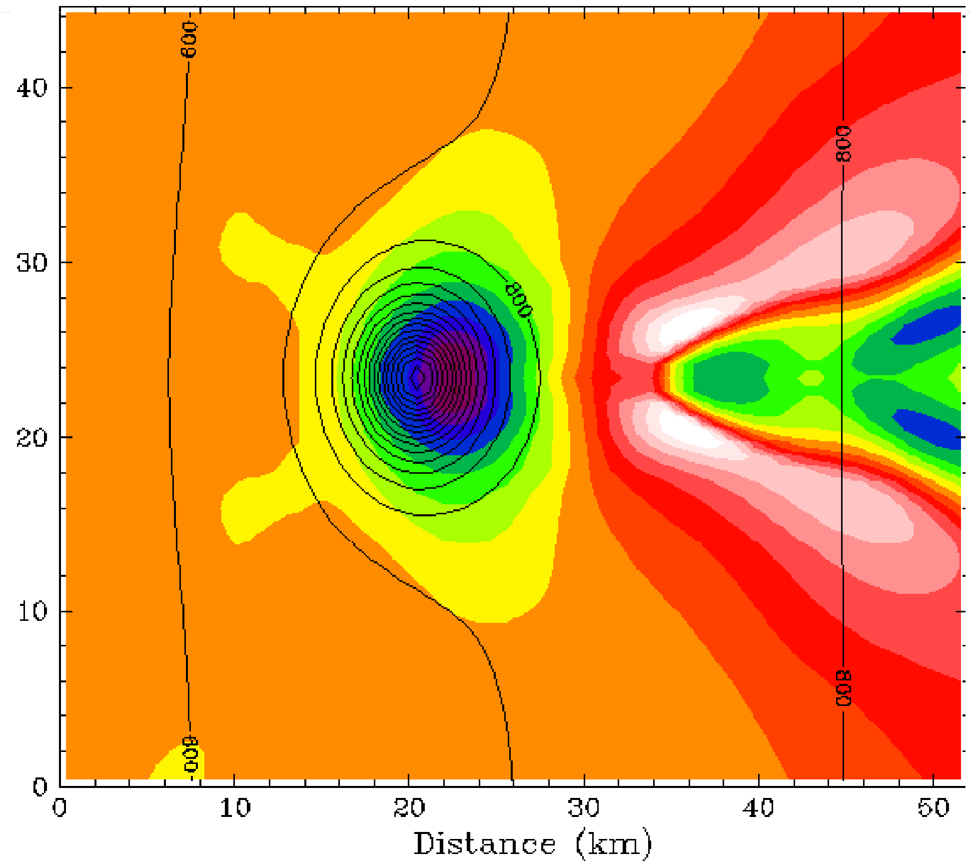


Precipitation field

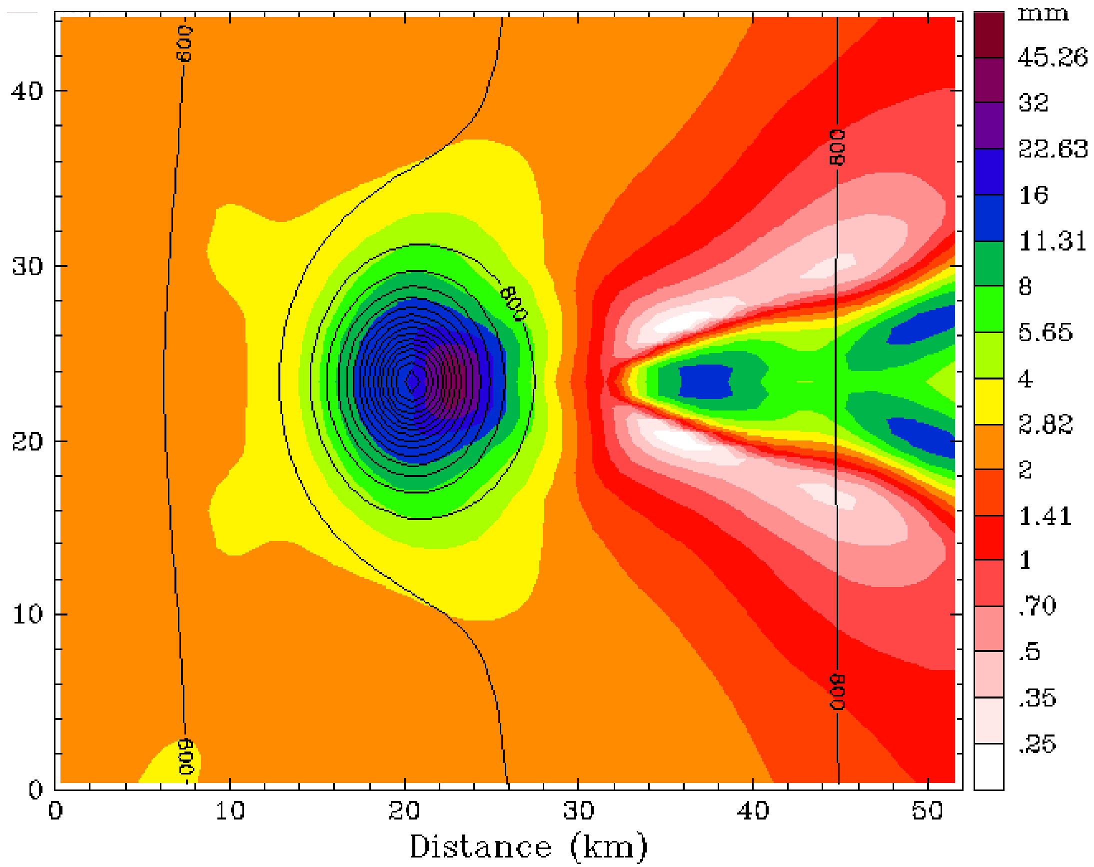
3-hour accumulated precipitation

Experiments with large-scale slope

SB autoconversion



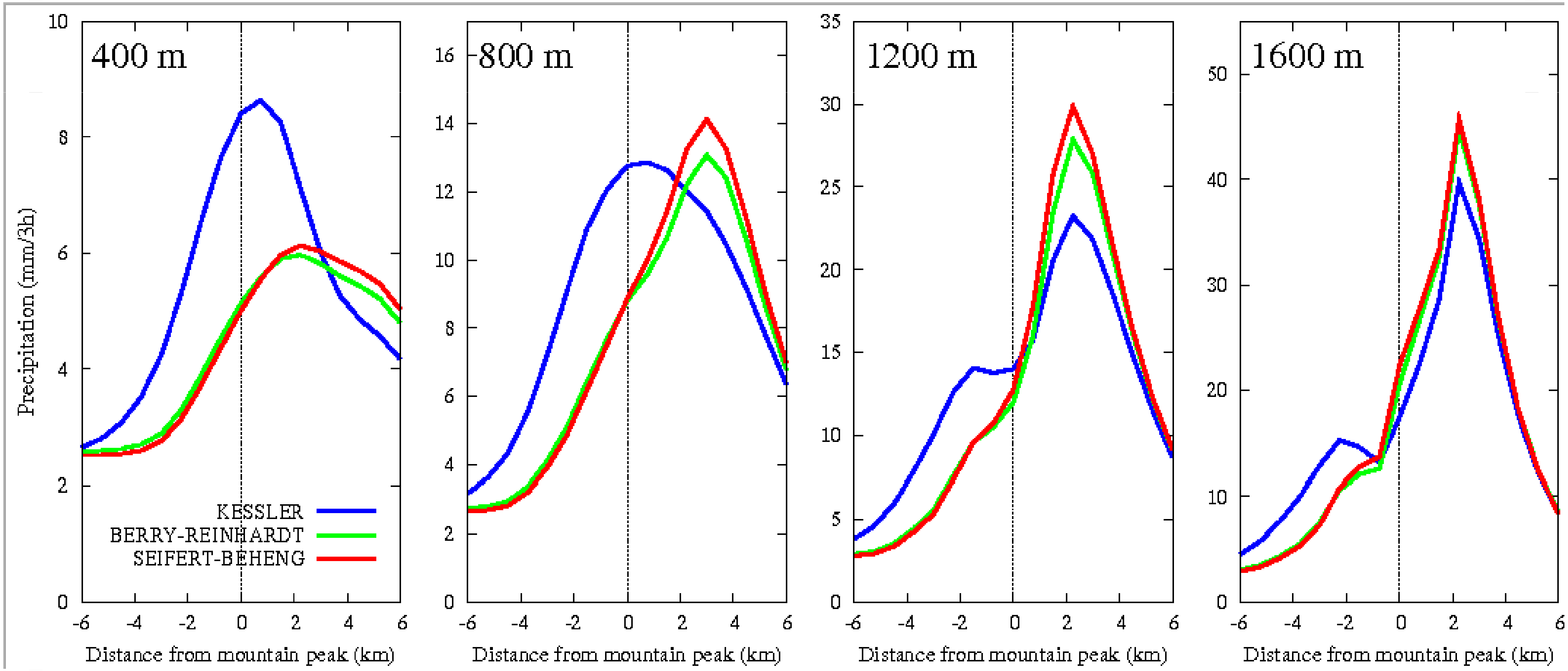
KESSLER autoconversion



Precipitation field

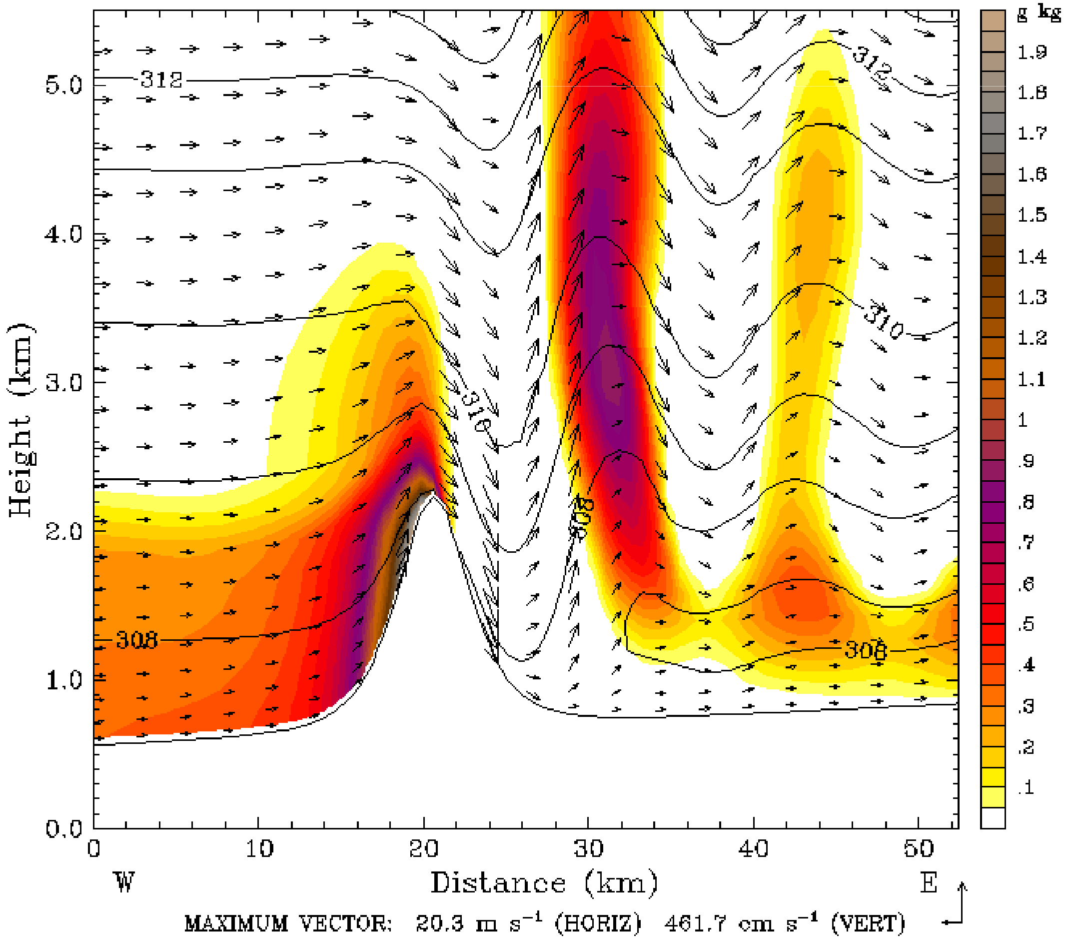
3-hour accumulated precipitation along a section crossing the mountain peak

Experiments with large-scale slope

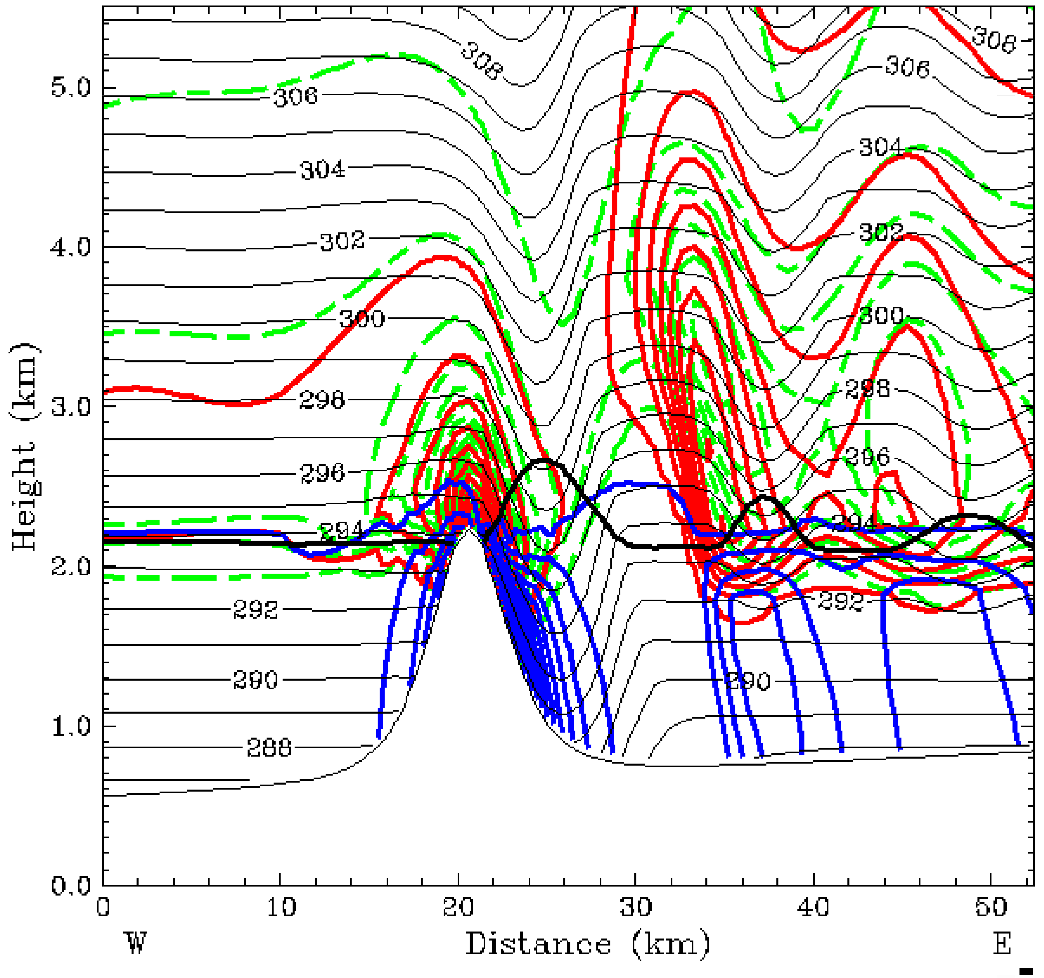


Flow pattern, clouds and precipitation

θ_e (contour interval 1 K), q_c (colors)



θ (contour interval 1 K), rain/snow/graupel (contour interval 0.1g/kg)



Conclusions and outlook

- Results for pure orographic rainfall vary by more than an order of magnitude depending on autoconversion scheme
- For the seeder-feeder configuration, the sensitivity to autoconversion is comparatively small
- Enhancement in the seeder-feeder case is much stronger than pure orographic rainfall for all autoconversion schemes
- However, the autoconversion scheme is important for a quantitative distinction between seeding and non-seeding situations
- Comparison with spectral microphysics model (ongoing collaboration) indicates that SB is the most realistic scheme