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Aerosol-cloud interactions and orographic precipitation

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Introduction and Motivation

- Anthropogenic and natural aerosols serve as a source of cloud condensation nuclei (CCN) and influence the microphysical properties of clouds
- An increase of the aerosol load leads to an increase of the cloud droplet number concentration and, for a fixed liquid water content, to a decrease of the average cloud droplet size (e.g. Peng et al., 2002).
- Since the collision efficiency is small for small droplets (Pruppacher and Klett, 1997), an increased aerosol load induces a deceleration of the cloud drop coalescense process in warm phase clouds and leads to an extension of the cloud life time (Albrecht, 1989)
- In the case of low-level orographic clouds the aerosol-cloud interactions are suspected to reduce the amount of precipitation on the upslope side of the mountain and to enhance the precipitation on the downslope side of the mountain (Borys et al., 2003; Givati and Rosenfeld, 2004, 2005; Jirak and Cotton, 2006).
- The shift of the precipitation distribution towards the leeward side of mountain ranges would affect the hydrological cycle on the local scale

Main goals

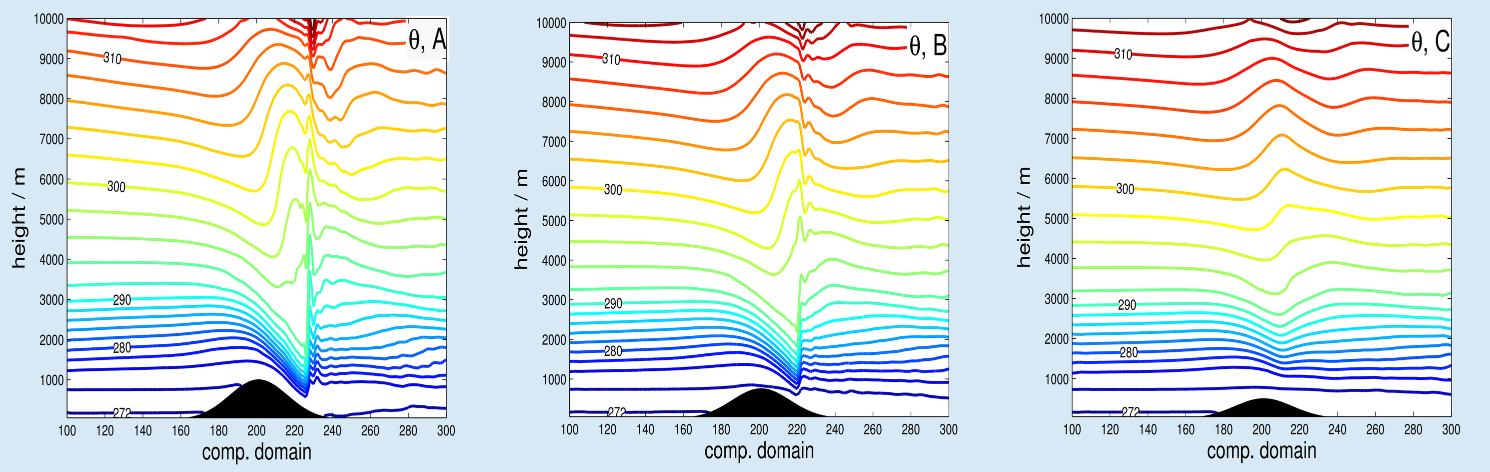
- Investigation of aerosol-cloud interactions in case of low-level (warm phase) orographic clouds
- **Which moist orographic flows are most sensitive to aerosol modification?**
- **How does the aerosol load affect the orographic precipitation pattern?**

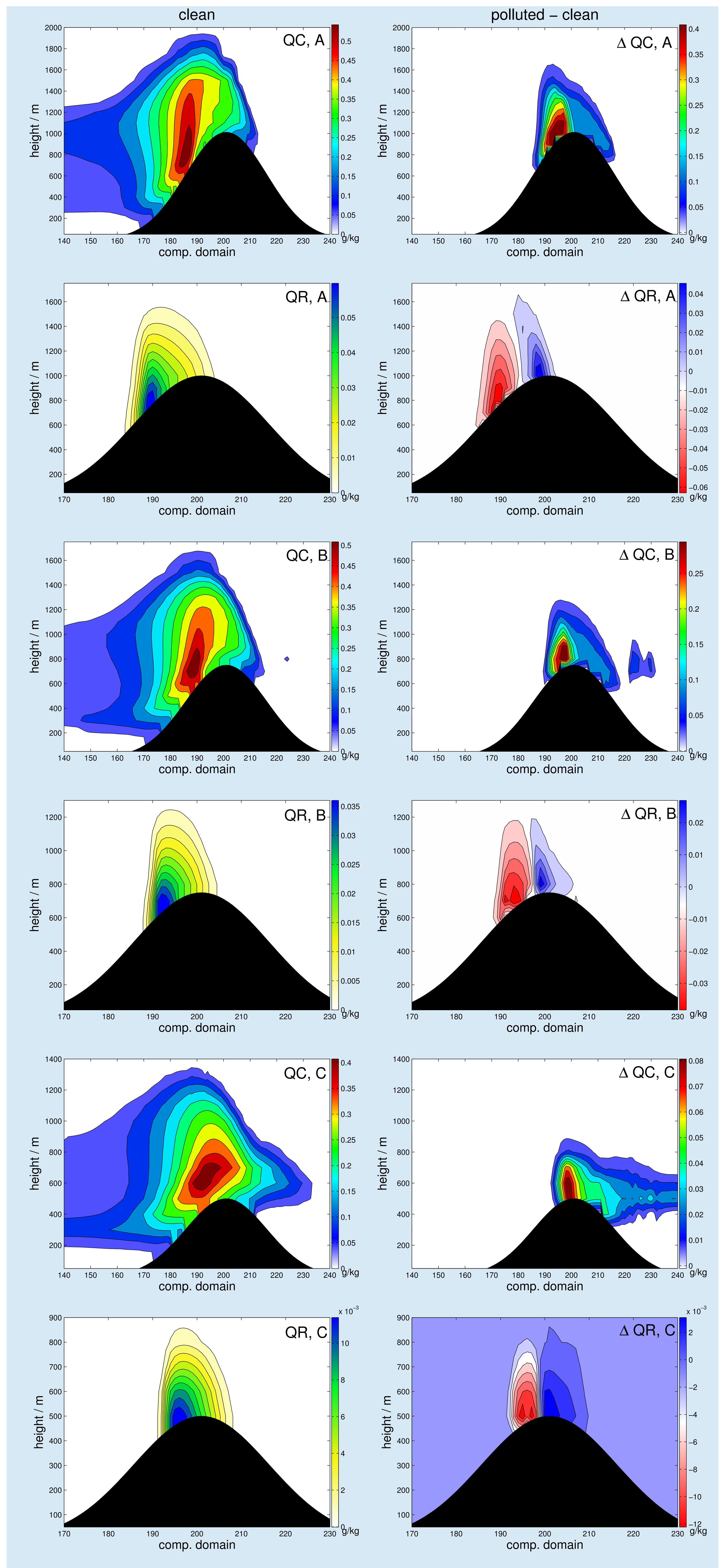
Model

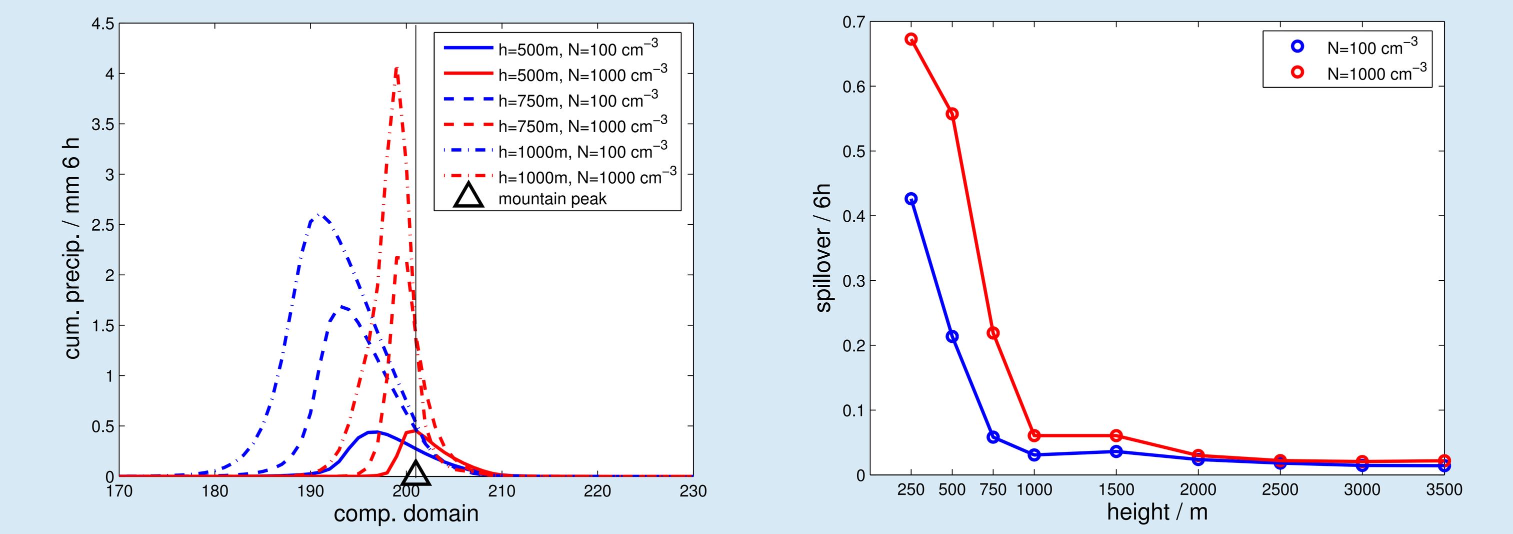
- Nonhydrostatic limited area shortrange weather prediction model (Local Model, LMK 3.16) from the German weather service (DWD)
- 2.8 km horizontal resolution and timestep of 10 s
- 2D computational domain with 400 gridpoints in the horizontal and 38 vertical levels
- Davies-type open lateral boundary conditions
- Cloud-microphysical processes treated within the two-moment scheme of Seifert and Beheng (2006)
- Here only warm phase processes considered

Simulations

- Idealized 2D simulations of moist orographic flows over topography
- Idealized topography (Gaussian mountain) with a half-width of $a = 50$ km and varying mountain height
- Idealized initial condition (p, T, q_v) with a moist boundary layer and a dry inversion above similar to Thompson et al. (2004).
  The horizontal windspeed u is prescribed with 15 m s^{-1} constant with height
- Initial number concentration of CCN spezified with 100 cm^{-3} (clean case) and 1000 cm^{-3} (polluted case)
- Simulation time is 6 h
- The following figures show the fields of potential temperature for 3 different simulations after 6 h. For these simulations the mountain height varies from 1000 m (A), 750 m (B) to 500 m (C) and the flow regimes change from a hydraulic jump (A,B) to a smooth mountain wave (C)







Results

The figures in the second column show the cloud water content (QC), the rain water content (QR) and the difference fields (polluted-clean) ΔQC and ΔQR for the simulations A-C after 6 h.
The figures in the third column show the spatial precipitation distribution and the spillover factor. The spillover factor is defined as the fraction of leeward precipitation to the total precipitaion (Jiang, 2003).

- The cloud water content is higher in the polluted case than in the clean case
- The rain water content shows a decrease of the upslope precipitation and an increase of the precipitation close to the mountain top
- Total precipitation increases (with mountain height) in clean and in polluted case with more total precipitation in clean case
- Maximum precipitation is larger in the polluted than in the clean case
  –> Change in spatial precipitation distribution
- In the polluted case the spatial precipitation distribution narrows and the maximum precipitation shifts towards the mountain peak –> increasing spillover factor (SP)
- Difference in SP (polluted minus clean) is largest for mountain heights of 500 m

h_m	SP (clean)	SP (poll.)	Δ SP
250	0.43	0.67	0.25
500	0.21	0.56	0.34
750	0.06	0.22	0.16
1000	0.03	0.06	0.03
1500	0.04	0.06	0.02
2000	0.02	0.03	0.01
2500	0.02	0.02	0

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