Does increased model resolution improve simulated precipitation fields?

A case study of two north-Alpine heavy precipitation events

7th SRNWP workshop, Bad Orb

6 November 2007

Günther Zängl

Reference:

Zängl, 2007, Met. Z., 16, 571-580

Meteorologisches Institut der Universität München

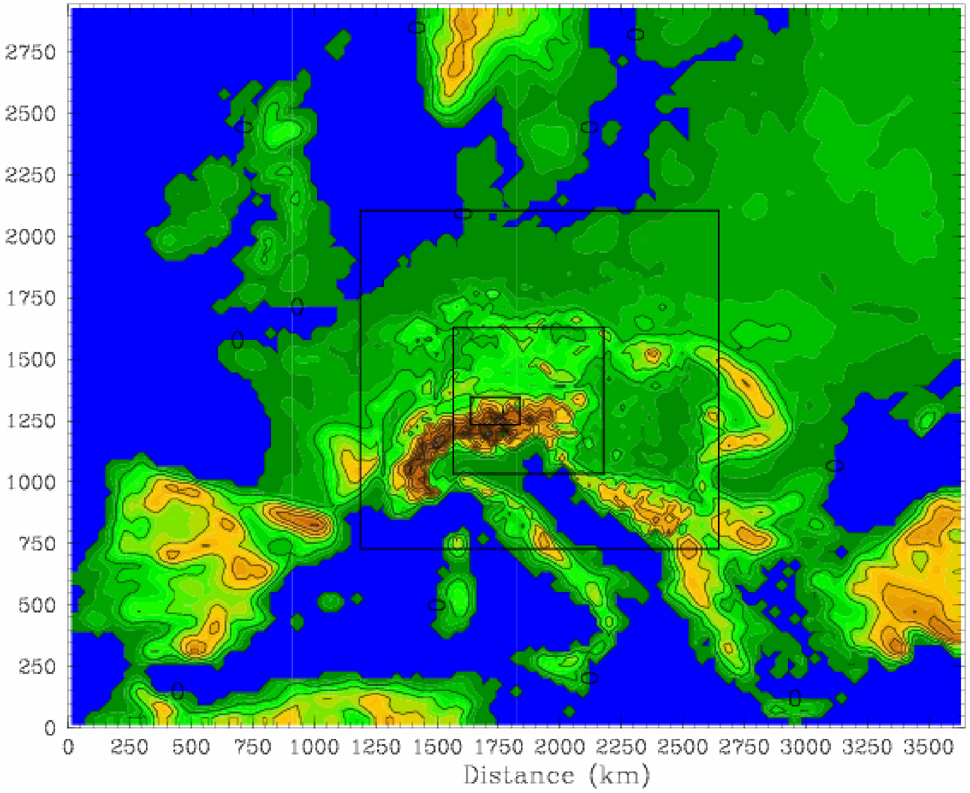
Outline

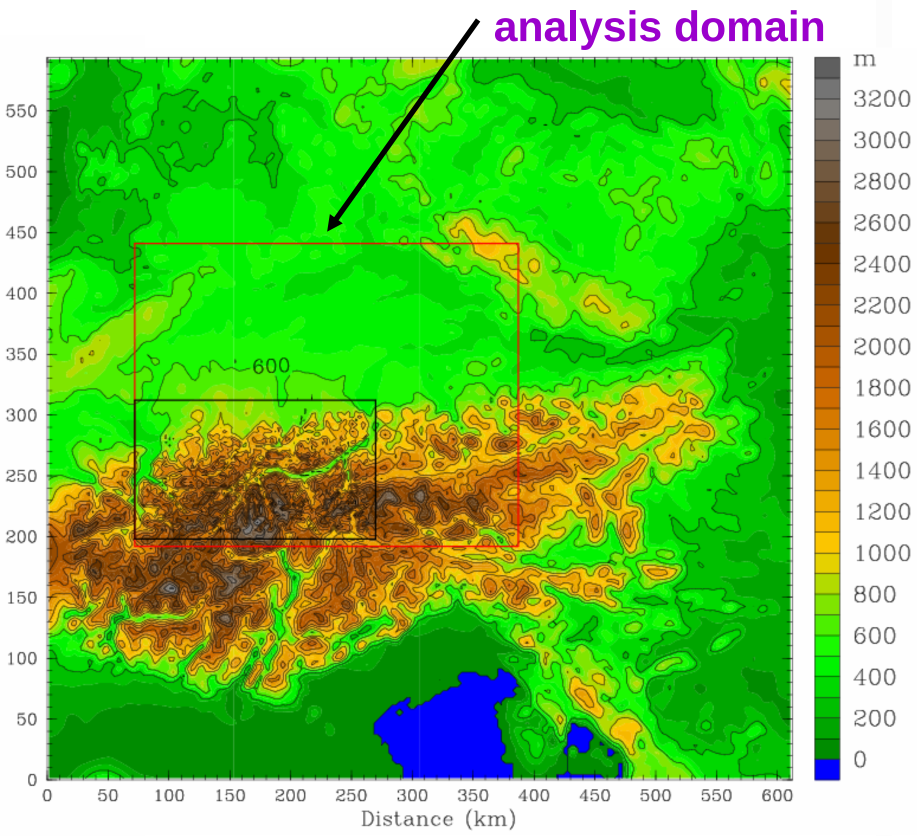
- Setup of the simulations
- Synoptic situation and simulated rainfall fields
- Validation of model results against observations
- Conclusions

Setup of simulations

- Model: MM5
- 4 interactively nested domains, horizontal resolution 27/9/3/1 km
- 38 σ-levels, lowest one ~ 15 m AGL; vertical layer spacing ~ 40 m near the ground, increasing to ~ 750 m near the top (100 hPa)
- Initial and boundary conditions: ECMWF-analyses
- Cases investigated: 20-22 May 1999, 22-23 August 2005
- Integration time 54 h for case 1 and 42 h for case 2, analysis of model results starts after 6-hour spinup period
- Parameterizations for PBL, radiation, cloud microphysics and cumulus convection
- Sensitivity tests with 2 microphysics schemes (Reisner-Thompson and Goddard), various combinations of Kain-Fritsch and Grell cumulus schemes; coarser-resolved simulations with 3 / 2 domains and corresponding finest mesh sizes of 3 km and 9 km

Model topography, domains 1 and 3

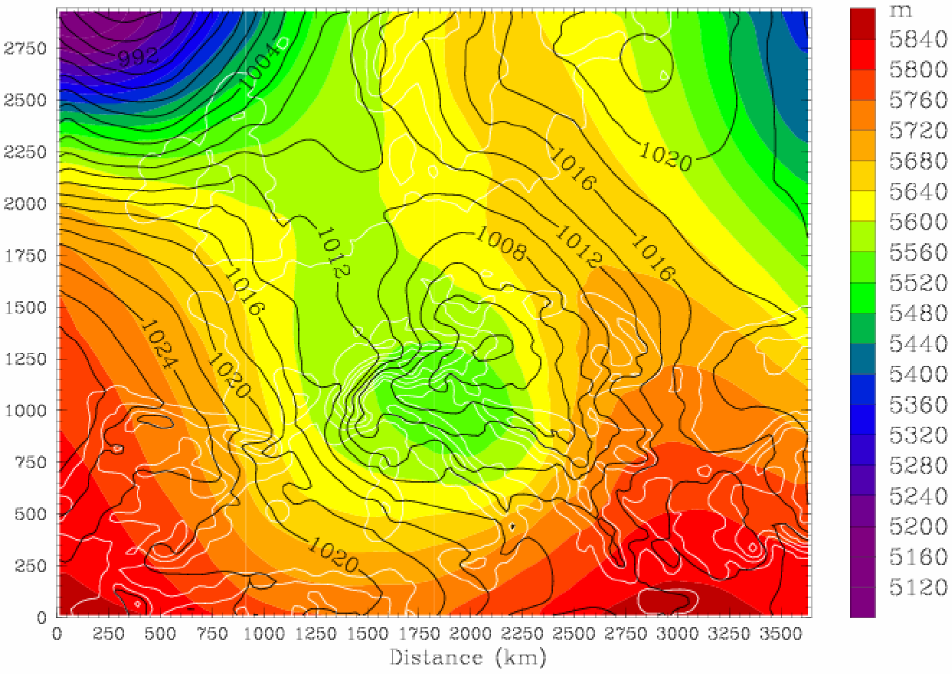




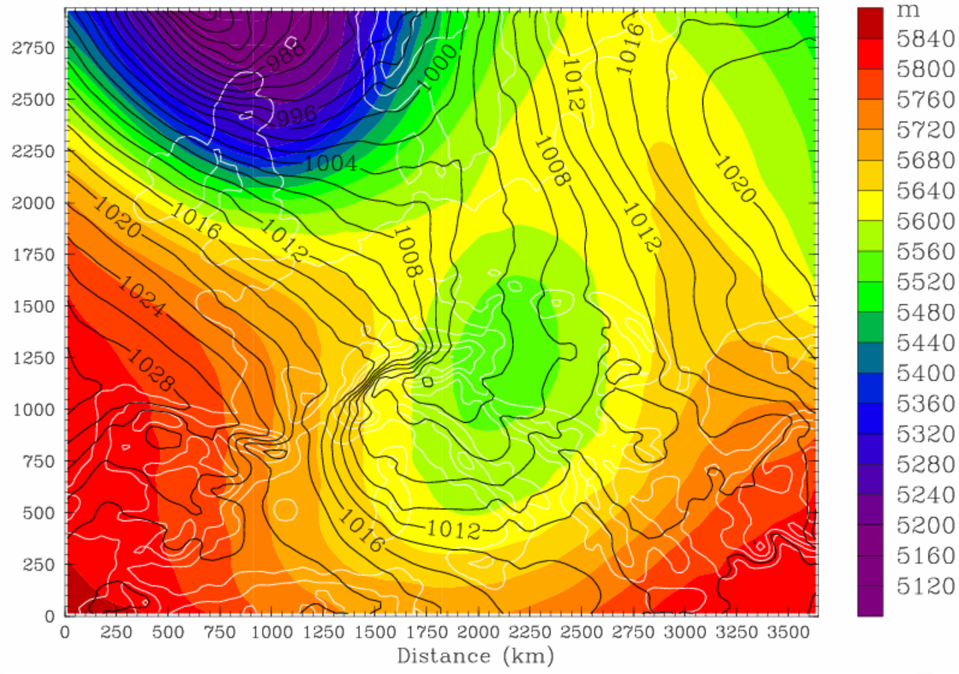
Synoptic environment

Sea-level pressure (contour interval 2 hPa) and 500-hPa geopotential (colours)

Case 1: **21 May 1999, 00 UTC**



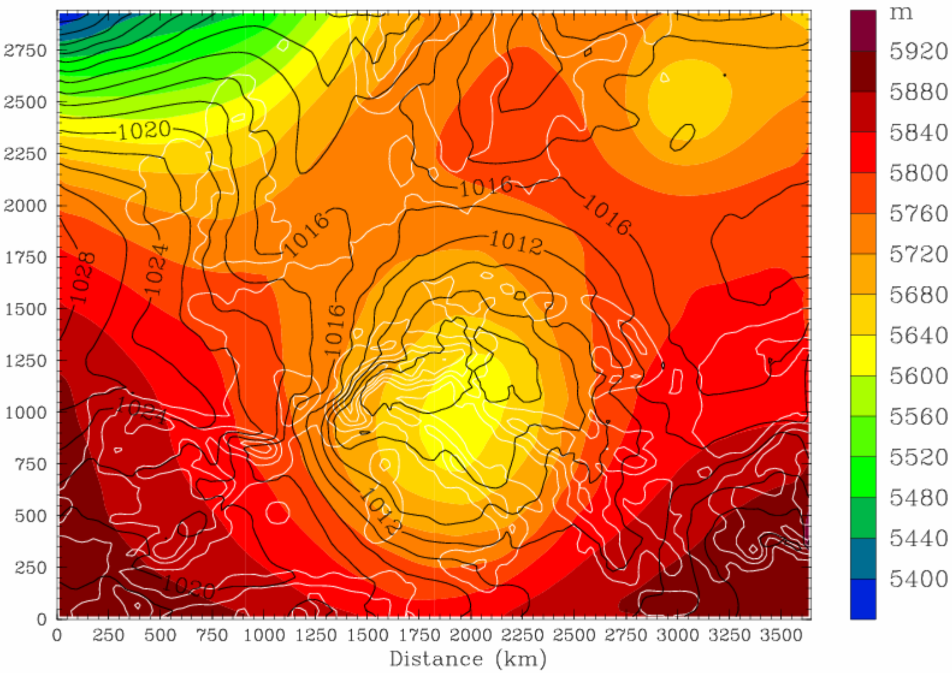
22 May 1999, 00 UTC



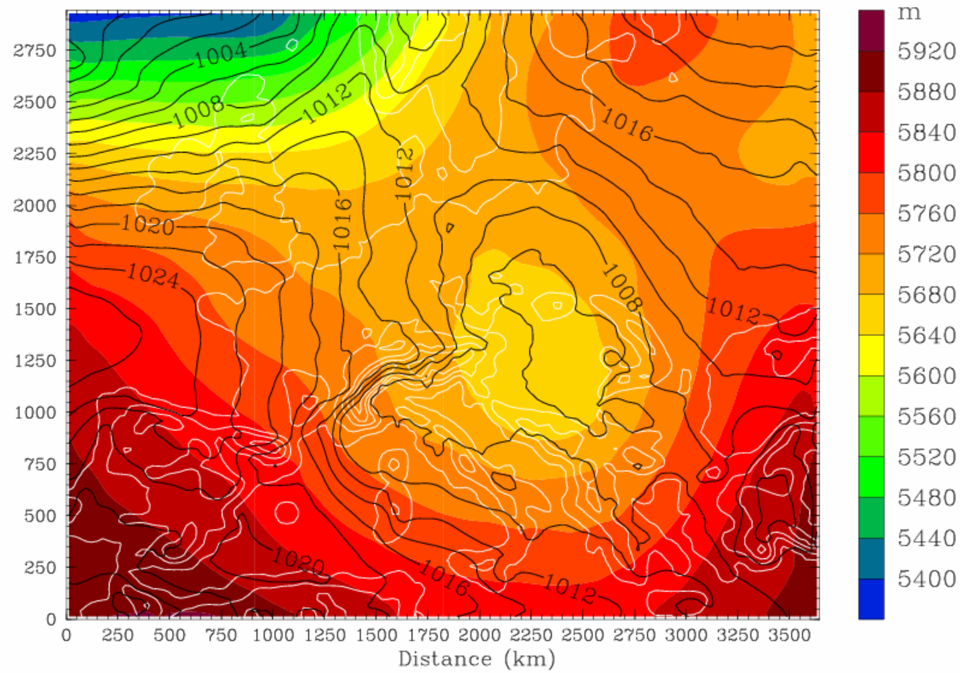
Synoptic environment

Sea-level pressure (contour interval 2 hPa) and 500-hPa geopotential (colours)

Case 2: **22 August 2005, 12 UTC**

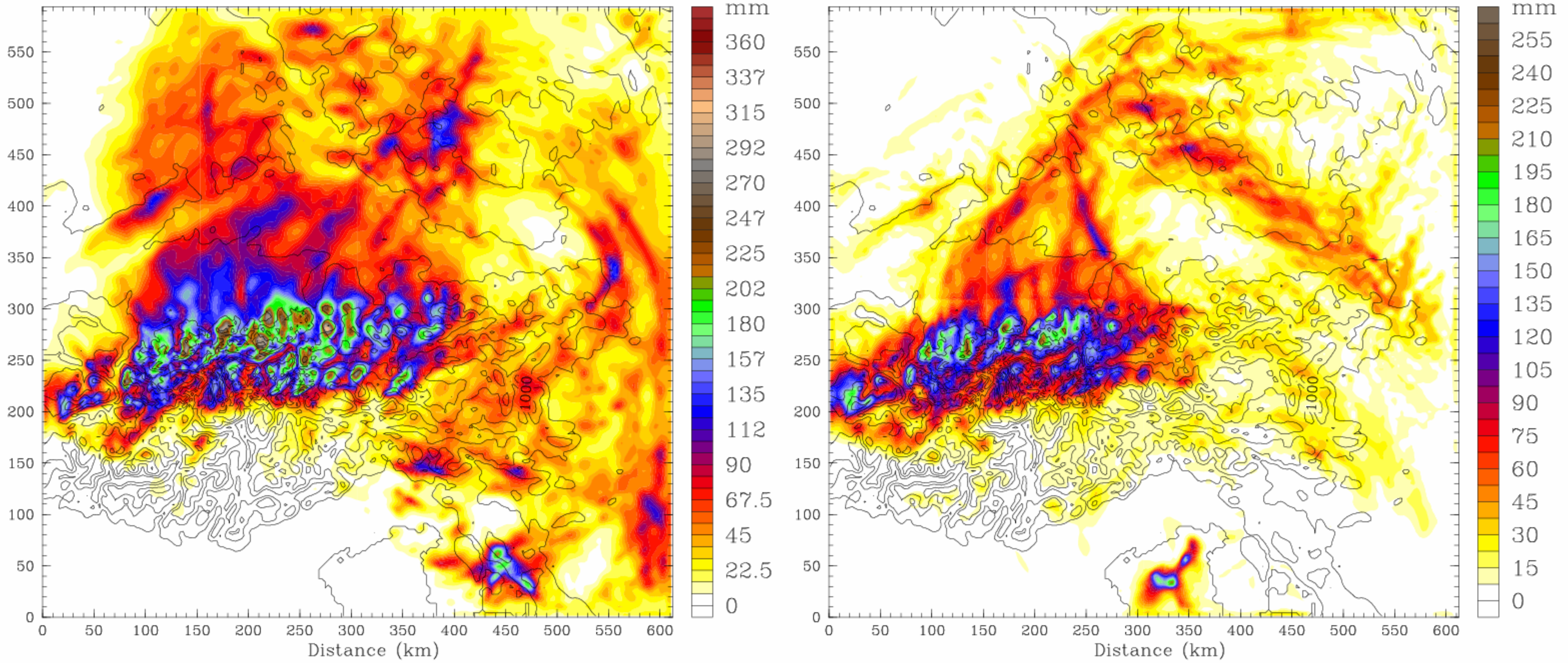


23 August 2005, 12 UTC



Simulated precipitation fields

Left: case 1, accumulation period 20 May 18 UTC – 22 May 18 UTC
Right: case 2, accumulation period 22 Aug 06 UTC – 23 Aug 18 UTC

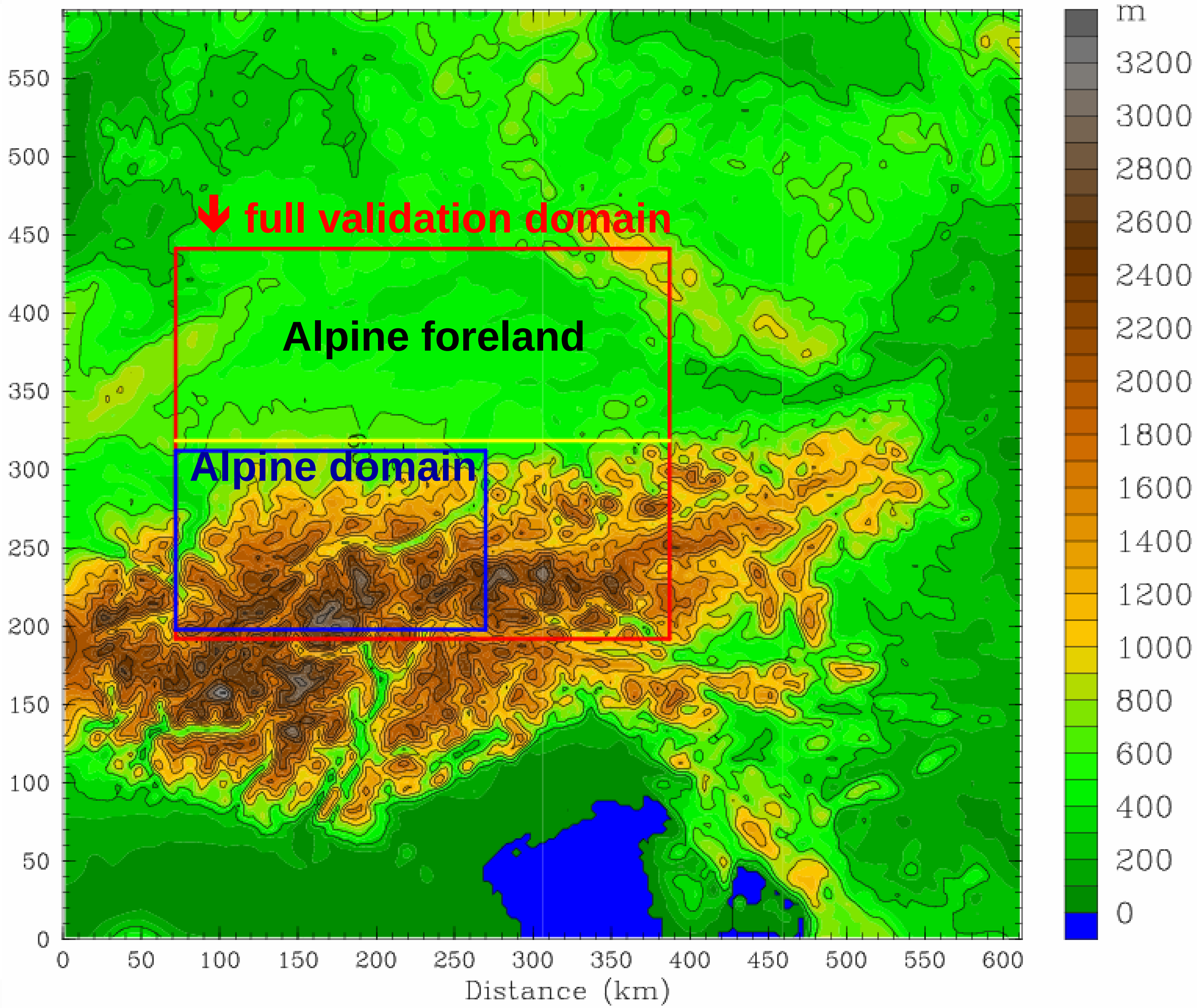


Validation measures

- Data base: SYNOP, climate and precipitation stations from Bavaria and Austria; linear interpolation of model precipitation to station locations
- Consideration of station-averaged amounts, canonical correlation coefficient, RMS error and normalized absolute error:

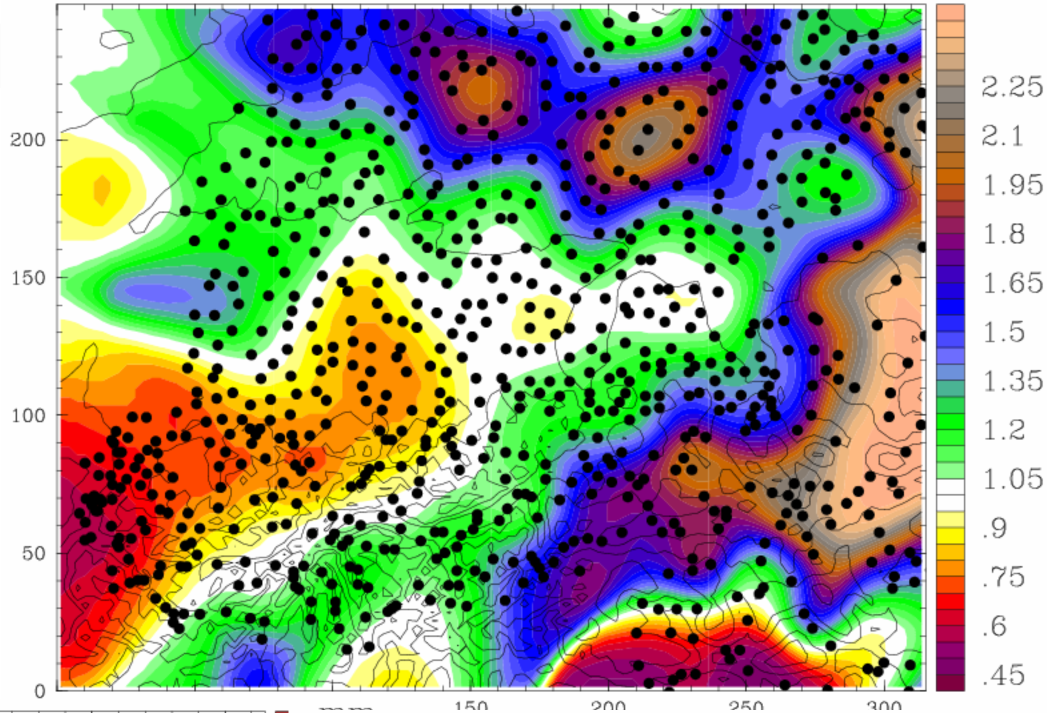
$$NAE = \frac{1}{N}\sum_{i=1}^{N}\frac{(o_i - s_i)^2}{0.5(o_i + s_i)}$$

- Equitable threat score for threshold intervals of 10 mm
- Relative bias as a function of observed accumulated precipitation
- For displaying: scaling of simulated precipitation with ratio between simulated and observed precipitation; ratio between original and scaled model output shows spatial distribution of relative bias



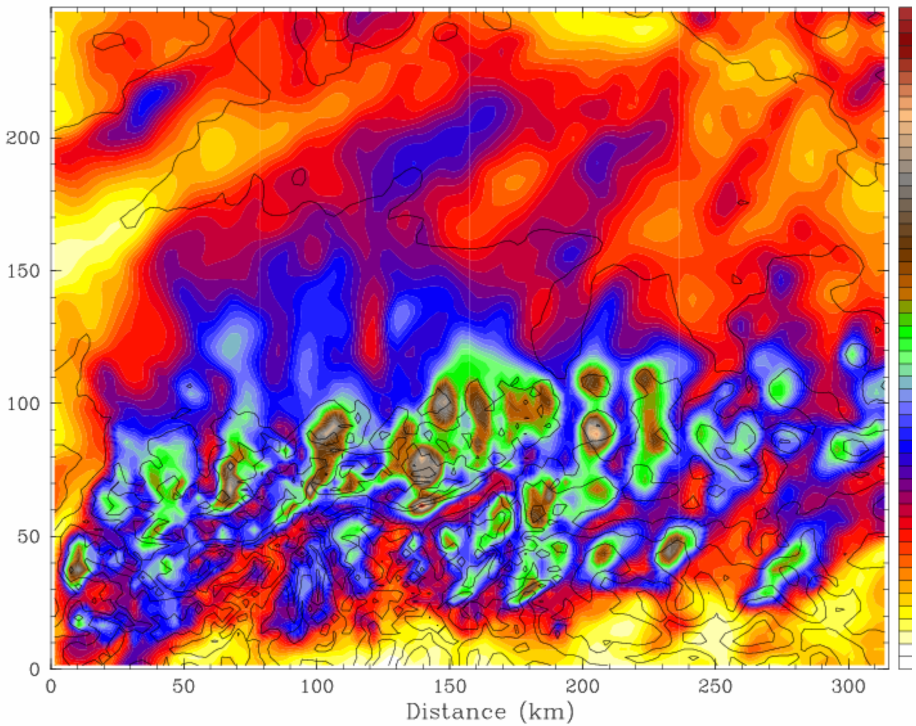
full validation domain
Alpine foreland
Alpine domain
Distance (km)
m

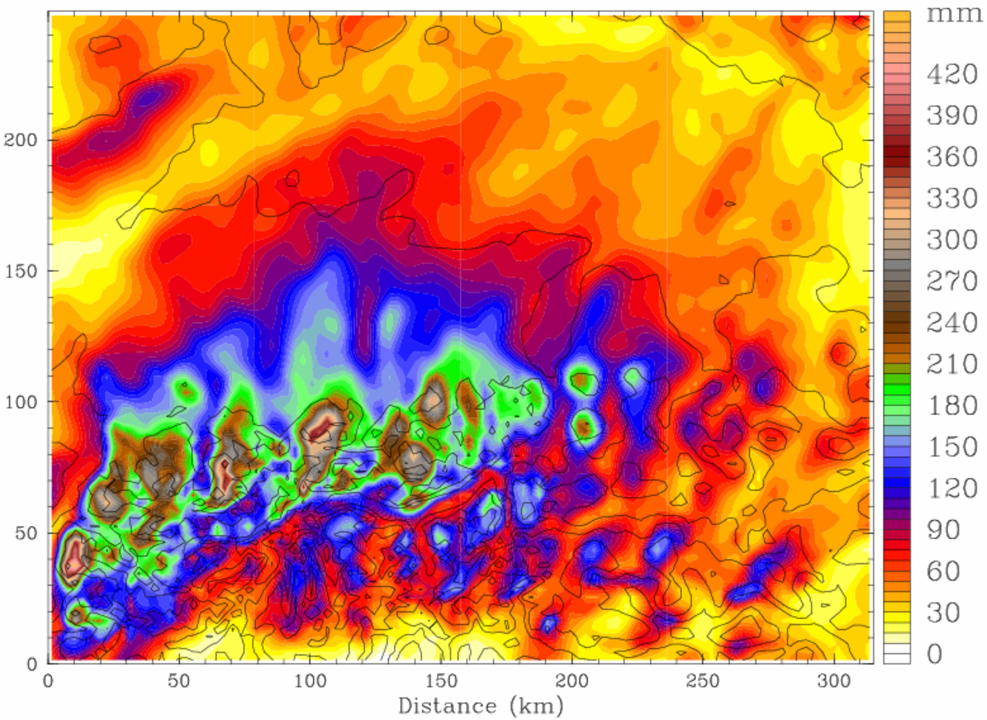
Distribution of relative bias ➔



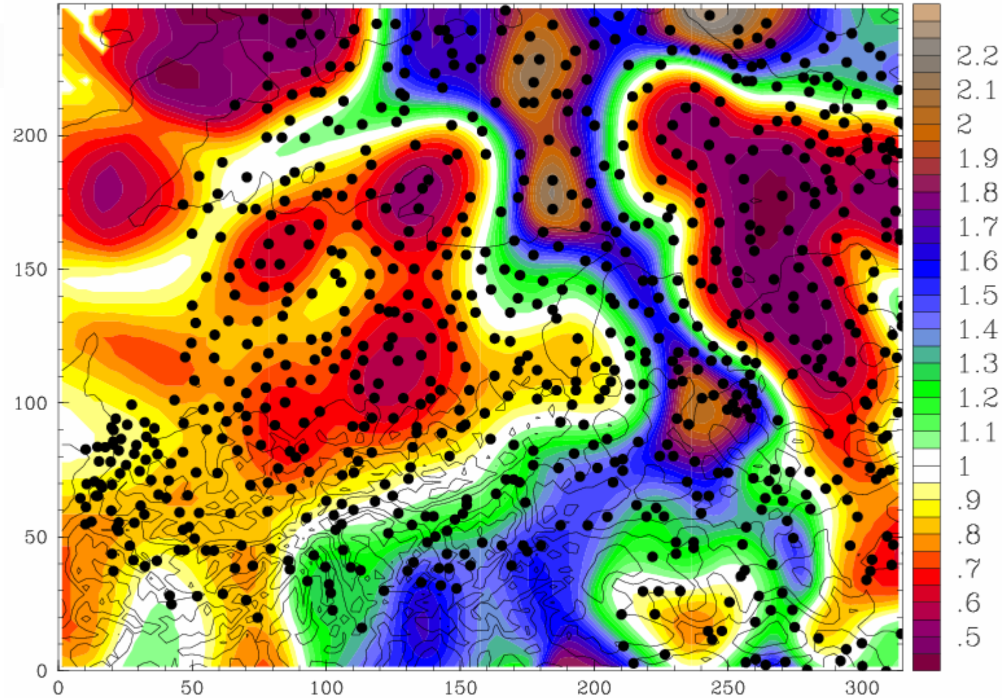
Case 1

Original and scaled simulation 🡇



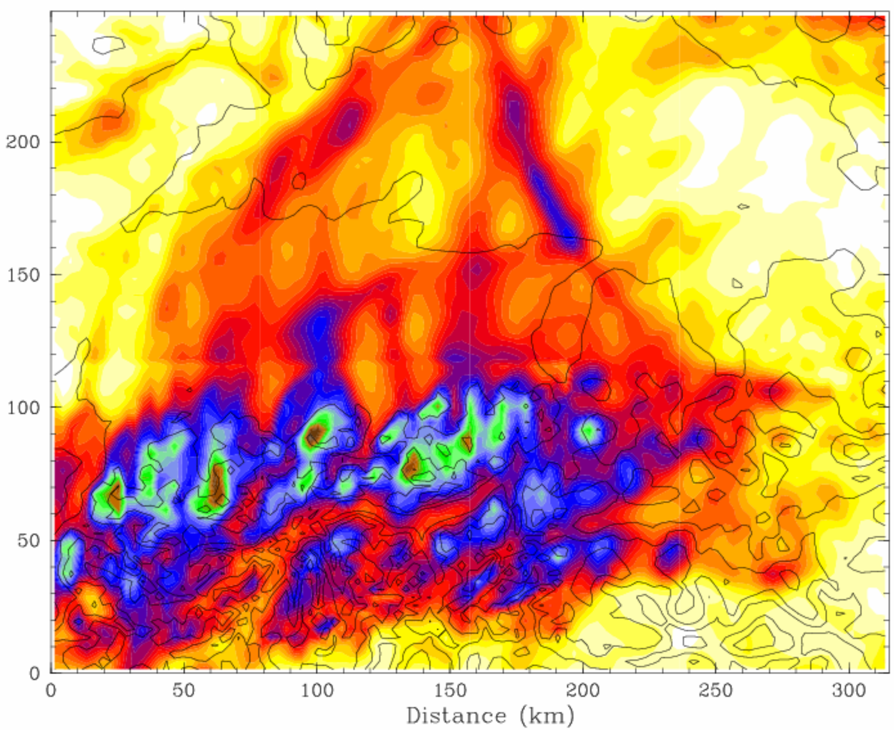


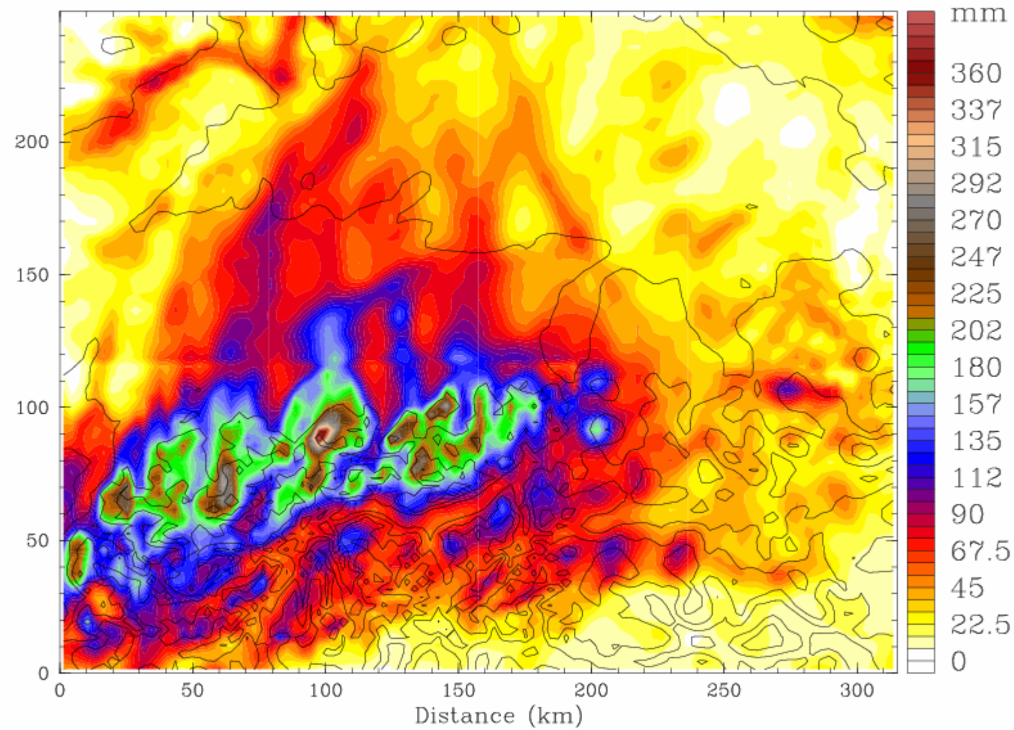
Distribution of relative bias ➔



Case 2

Original and scaled simulation 🡻



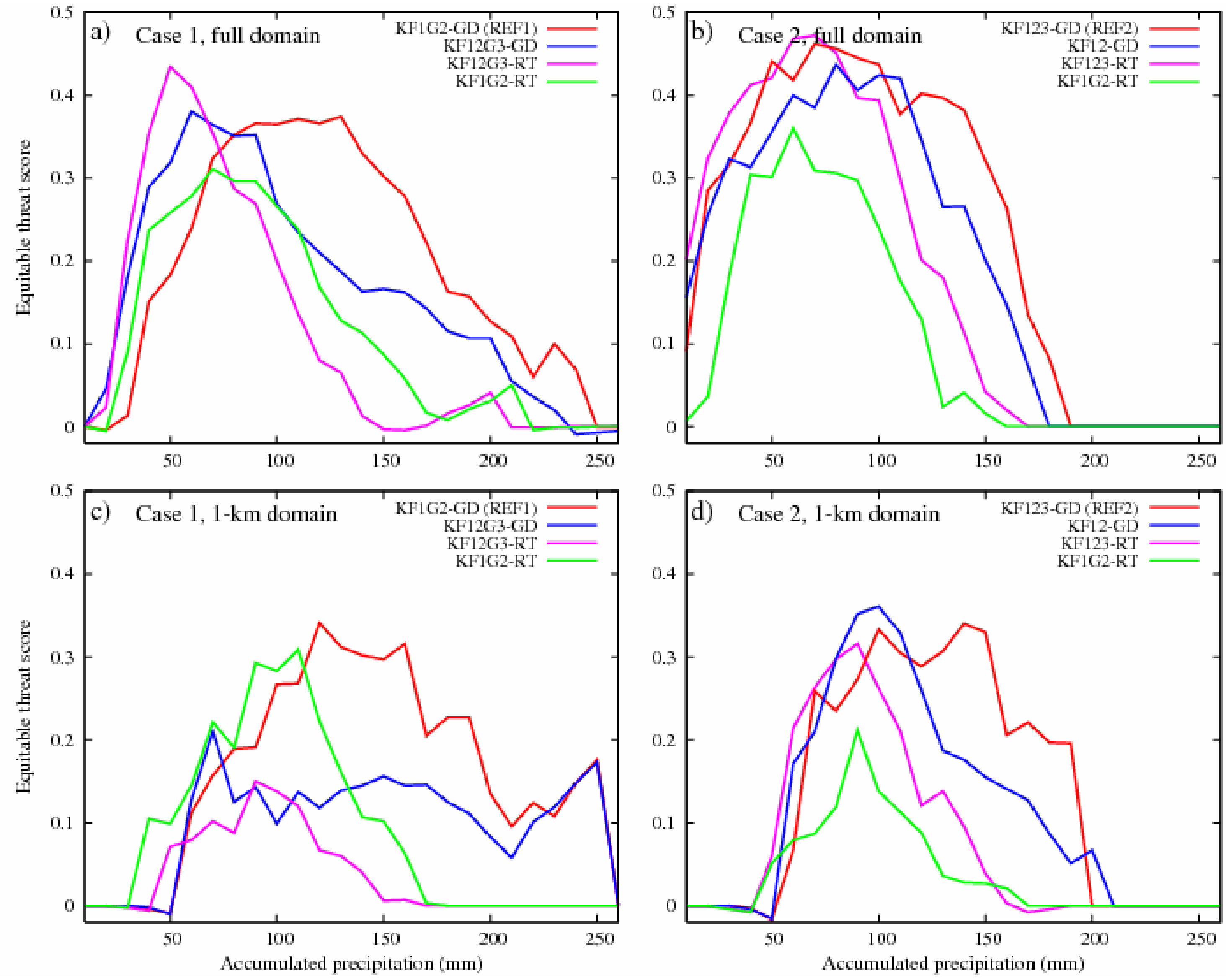


Basic validation measures (full validation domain)

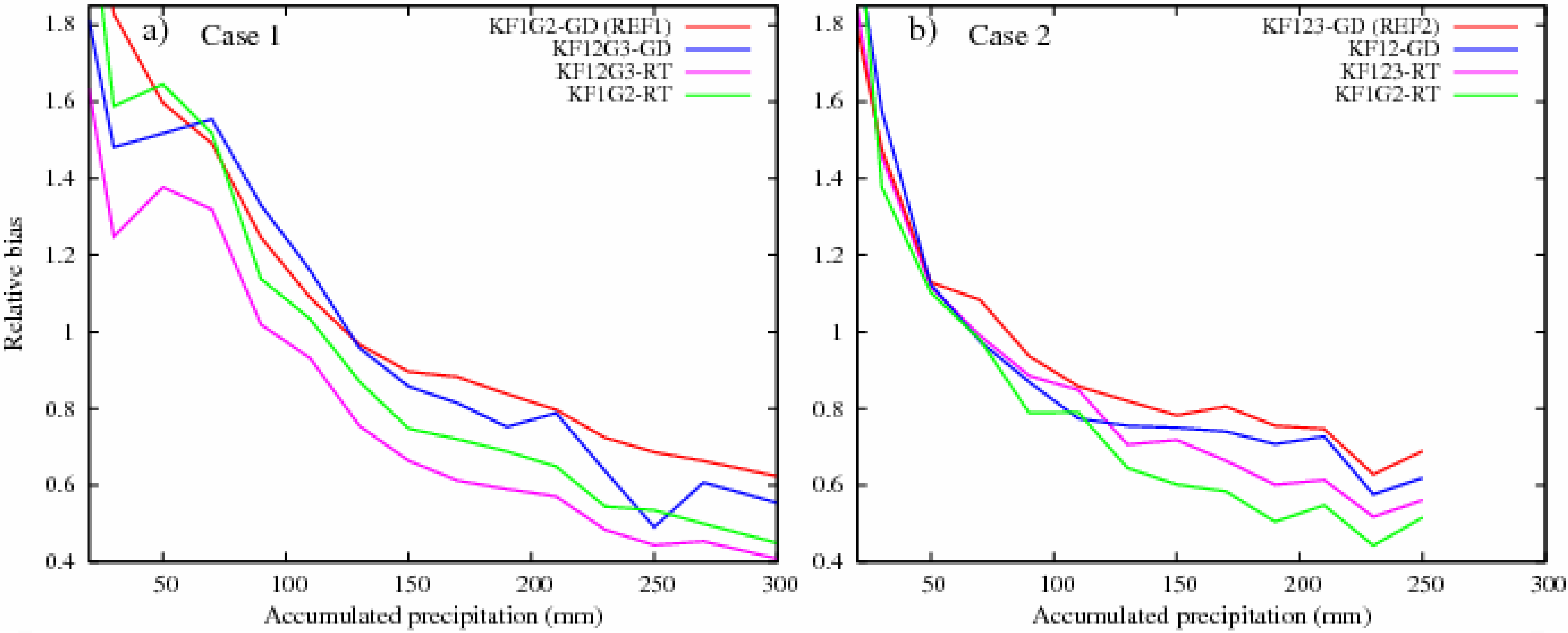
Experiment	average	correlation	RMSE	NAE
Case 1 obs.	91.0	---	---	---
KF1G2-GD	103.8	0.71	42.0	17.2
KF12G3-GD	101.2	0.58	51.0	21.5
KF1G2-RT	94.8	0.56	47.3	20.6
KF12G3-RT	81.9	0.54	48.8	21.1
Case 2 obs.	63.7	---	---	---
KF123-GD	64.6	0.81	29.5	13.6
KF12-GD	62.6	0.79	31.2	14.7
KF123-RT	60.7	0.80	31.6	13.1
KF1G2-RT	58.3	0.65	38.9	21.3

KF=Kain-Fritsch cumulus scheme, G=Grell cumulus scheme, GD=Goddard microphysics, RT=Reisner-Thompson microphysics; numbers are model domains

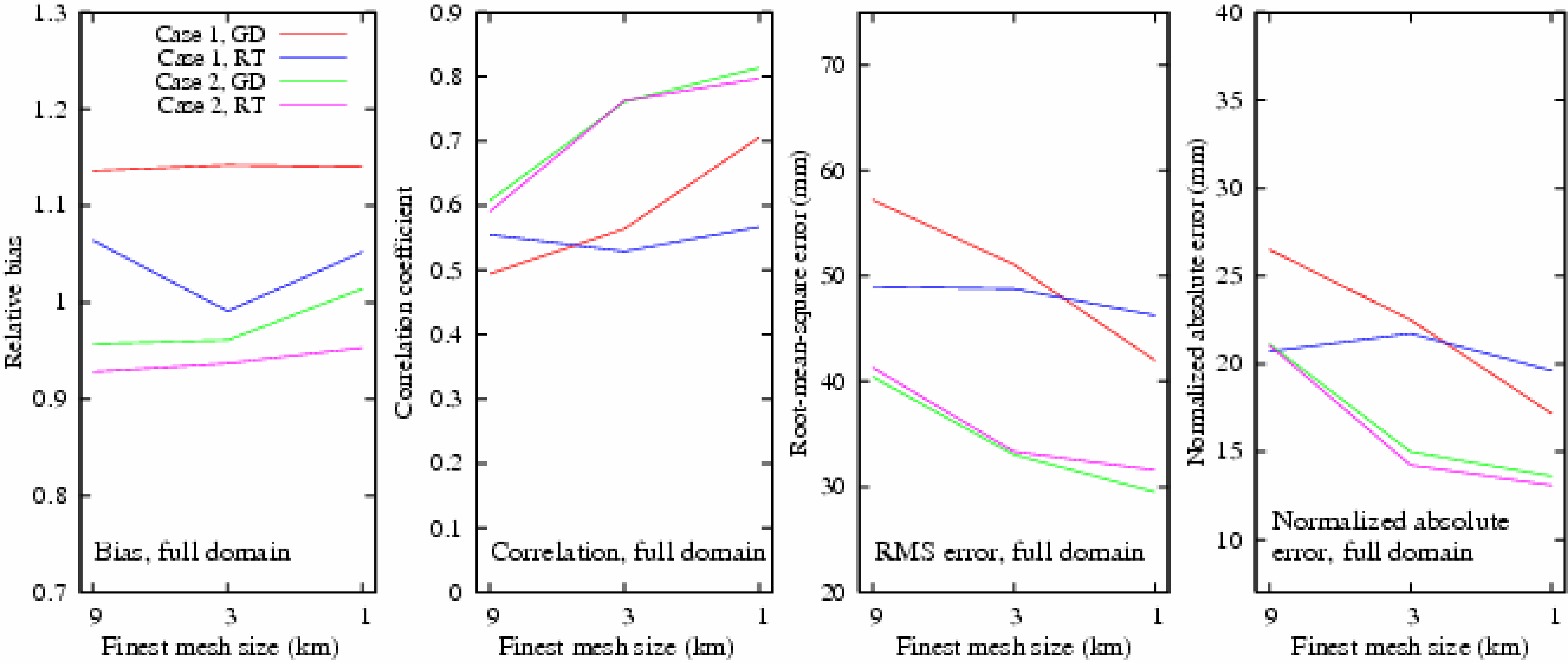
Equitable threat scores (full domain and Alpine (1-km) domain)



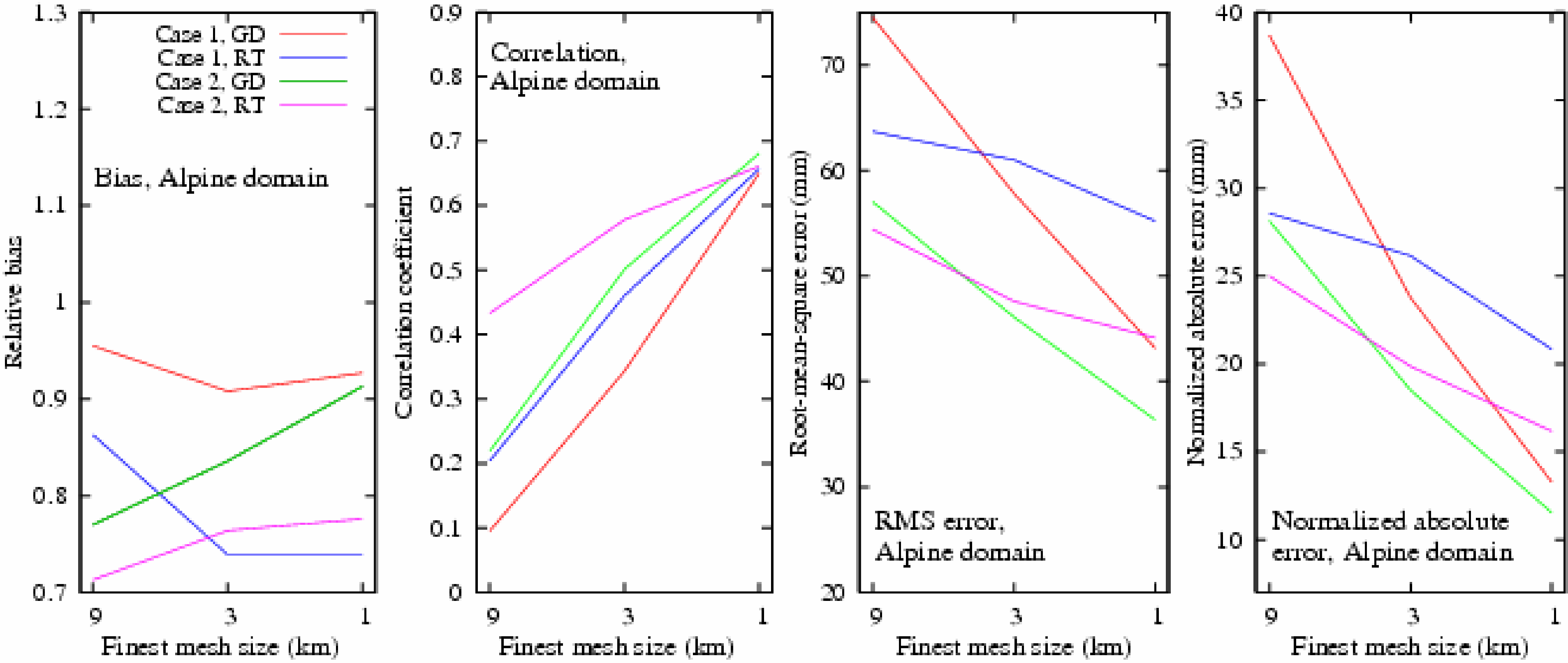
Relative bias as a function of observed accumulated precipitation (full domain)



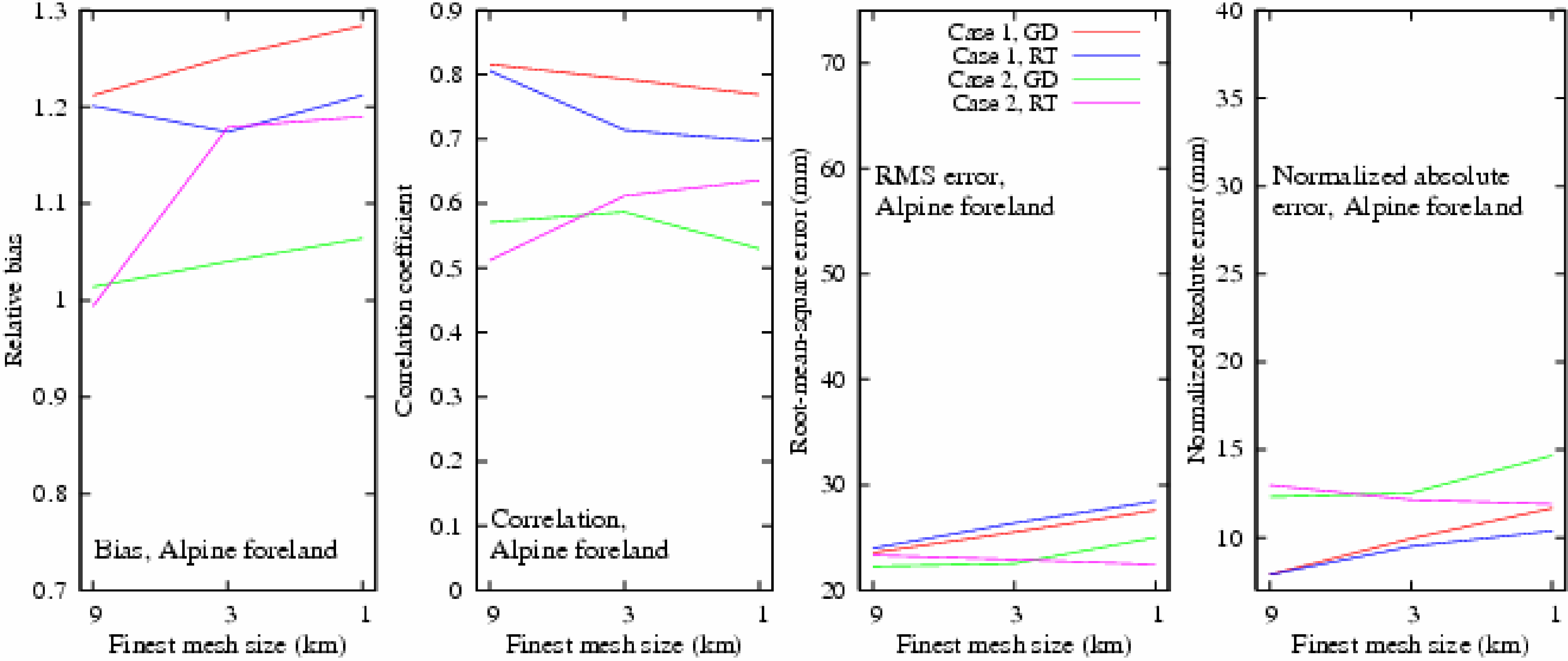
Dependence of skill measures on finest model resolution, full analysis domain



Dependence of skill measures on finest model resolution, Alpine domain



Dependence of skill measures on finest model resolution, Alpine foreland



Summary

- The movement of the frontal zone (and thus the location of the precipitation field) is better captured for case 2 than for case 1; the more sophisticated analysis data available for 2005 might play a role
- The MM5 tends to overestimate low precipitation amounts (partly due to location errors) and to underestimate high amounts
- The underestimation of high precipitation amounts related to orographic rainfall enhancement is more pronounced for the Reisner-Thompson scheme than for the Goddard scheme
- Refining the model resolution from 9 km to 1 km yields a huge improvement in Alpine terrain but none in the Alpine foreland; the resolution-dependence of model skill is more pronounced with Goddard microphysics than with Reisner-Thompson microphysics