Precipitation in complex orography simulated by the regional climate model RCA3

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1. Introduction

The aim of this study is to evaluate the improvement in simulated precipitation of the third version of the Rossby Centre Climate model (RCA3), when run at horizontal resolutions of 50, 25, 12 and 6 km.

The analysis is focused on the countries of Switzerland and Norway, where complex orography can play a dominant role in precipitation formation. Observation data sets used for model validation were for Switzerland, the RhiresD dataset, an approximately 2-km resolution product of the Swiss National Meteorological Service (MeteoSwiss), and over Norway, the KLIMAGRID dataset (Mohr, 2007), a 1-km resolution product of the Norwegian Meteorological Institute (METNO), is used. The range of horizontal resolutions in experiments facilitates a systematic analysis of the impact of increasing the horizontal resolution on precipitation, in two different climate regimes.

2. Methodology

We analyse the RCA3 (Jones et al. 2004, Samuelsson et al. 2011) simulations for the period 1987-2008 with horizontal grid resolutions of approximately 50 km, 25 km, 12 km and 6 km. In all simulations the model was forced by ERA-40 re-analysis (Uppala et al. 2005) from January 1987 to August 2002, followed by ECMWF operational analysis from September 2002 to December 2008 over the whole Europe. The geographical domain, the RCA3 model version and 24 vertical levels remain unchanged in all simulations. No double nesting procedure was applied in the dynamical downscaling for the highest RCA3 resolution(s) used here; for all four resolutions considered, a direct downscaling from ERA-40 and ECMWF operational analysis was carried out.

From the same set of experiments Walther et al. (2013) evaluated precipitation diurnal cycle over Sweden and Pryor et al. (2012) studied wind climate over the northern parts of Germany and Denmark. They showed that the increase in spatial resolution down to 6 km improved the simulation of the afternoon peak in the convective precipitation during summer (Walther et al., 2013) and increased wind variability at the synoptic time scales (Pryor et al. 2012).

3. Results and discussion

At all model resolutions, the simulated mean winter precipitation is generally higher in central Switzerland and lower compared to the observations, in both the southern and northern parts of the country (Fig. 1). The largest overestimation is seen in the eastern mountainous regions where small precipitation amounts of 1-3 mm day\(^{-1}\) are doubled; the largest underestimation is approximately -40%.

In the mountainous regions, part of the overestimation could be coming from the undercatch potentially present in RhiresD dataset which were not corrected as for the case of the KLIMAGRID dataset. The undercatch occurs for both solid and liquid precipitation during windy episodes because of the wind flow deformation near the observational field gauge (e.g. Neff 1977, Adam and Lettenmaier 2003). Frei and Schär (1998) found that the undercatch can reduce the total winter precipitation by up to 40%. Such an uncertainty in observations implies that some of the biases in modelled precipitation amount in the mountainous regions may not be as significant as they appear to be.

From Fig. 1 it could not be explicitly inferred that the increased horizontal resolution generally yields an improvement, i.e. a reduction of error, in the winter seasonal climatology.

The RCA3 precipitation over the southern Norway in winter (Fig. 2) is mostly underestimated in the coastal regions (typically about -50%) but also well into the land. On the other hand, it is overestimated over high orography and in the easternmost parts for high resolution runs (an overestimation of about 30%). The precipitation overestimation on the lee side of the Scandinavian mountains in RCA3 was also documented in Samuelsson et al. (2011). The underestimation on the windward side of the mountains was also detected in few very high-resolution simulations over Norway (Heikkilä et al. 2011) and Portugal (Soares et al. 2012) where the simulated precipitation by the WRF model was compared directly with the rain gauge station data.
Annual cycle analysis of the RhiresD area-mean shows that the total precipitation for Switzerland domain peaks at near 5 mm day$^{-1}$ in the summer (Fig. 3a). This recorded amount reflects the maximum in convection activity and its significance over the continental Europe. The minimum of around 3 mm day$^{-1}$ is reached in the month of January (Fig. 3a). The annual cycle is generally overestimated by the model with the largest errors emerging at the 50-km resolution, in the spring season. The 6-km simulation, however, does not always offer the best match with observations. From the month of June to August, the highest resolution model experiment consistently produces much too intense summer precipitation. The 6-km simulation is outperformed by both 12-km and 25-km simulations, whereas the 50-km simulation output is not far from these results either. Nevertheless, 6-km (and 12-km) RCA3 simulation over Switzerland seems to capture well month-to-month precipitation amount variability, compared to the observation.

Figure 3. Annual cycle of the total precipitation over a) Switzerland, b) southern Norway. Observations at 6 km in black and marked by circles. RCA3 simulations at 6 km and 12 km are in red and marked by squares and triangles, while RCA3 simulations at 25 km and 50 km are in blue and marked by squares and triangles.

The maximum values of the annual cycle of the precipitation in the southern Norway, region characterized by the dominant high mountains, peak in January, around 6 mm day$^{-1}$ (Fig. 3b). The peak extends throughout the cold season as well, degrading to its minimum in the month of April. (Fig. 3b). This is the time of the year when strong north Atlantic westerlies are blasting over the northern European shores. Decrease of precipitation intensity from the late spring into the summer is associated with the weaker westerlies. The shape of the annual cycle curve is simulated well by the model at all resolutions, however, the winter and autumn maxima are underestimated. This is in contrast with the results for the Switzerland area. The 6-km resolution model simulates the annual cycle with slight improvement, when compared to lower resolutions.

**References**


