Convection-Resolving Climate Change Simulations: Short-Term Precipitation Extremes in a Changing Climate

Nikolina Ban[1], David Leutwyler[1], Daniel Lüthi[1], and Christoph Schär[1]

[1]Institute for Atmospheric and Climate Science, ETH Zürich

Climate change projections of precipitation are of great interest due to potentially important hydrological impacts such as droughts, floods, erosion, landslides and debris flows. For the southern part of the European continent, climate models consistently project substantial decreases in mean summer precipitation in response to greenhouse gas forcing. Despite this trend towards dryer conditions, many models also project increases of heavy precipitation events, and some theoretical studies have raised the possibility of dramatic increases in hourly events (by up to 14% per degree warming). However, conventional climate models are not suited to assess short-term heavy events due to the limited spatial resolution and the associated need to parameterize convective precipitation (i.e. thunderstorms and rain showers).

Here we employ a regional climate model at a horizontal resolution of 2.2 km across an extended region covering the European Alps and its larger-scale surrounding from Northern Italy to Northern Germany. Validation using ERA-Interim driven simulations with rain-gauge observations reveals significant improvements with the 2.2 km resolution, in particular regarding the diurnal cycle of mean and extreme precipitation, the representation of hourly extremes, and replication of observed super-adiabatic and adiabatic scaling at precipitation stations. Analysis of climate change simulations, which use an RCP8.5 greenhouse gas scenario, reveals a significant decrease of mean summer precipitation, but increase in the intensity of extreme events consistent with Clausius-Clapeyron scaling, i.e. 6-7% per degree warming, for both daily and hourly events. While the super-adiabatic scaling is simulated within the control period, we demonstrate that it cannot be extrapolated into the future.

In a second set of simulations, we have extended our analysis to decade-long convection-resolving climate simulations at horizontal resolution of 2.2 km over Europe using the COSMO model on a computational domain with 1536x1536x60 grid points. Such simulations have become feasible with a COSMO model version that runs entirely on Graphics Processing Units. We will demonstrate the applicability of this approach to continental-scale climate simulations.