dynamicAL ConstrAints on regional projections of future PrecipitatiON Extremes (AL CAPONE)
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Extreme precipitation events can lead to large financial and societal impacts by causing river flooding or landslides. It is thus particularly important to anticipate potential future changes in the occurrence and properties of these extreme events due to anthropogenic climate warming. During recent decades, an intensification of precipitation extremes has been observed when aggregating data over large regions, whereas on local scales such an intensification can still be masked by natural variability. A general increase of extreme precipitation intensities as a forced response to greenhouse gas emissions is consistent with theory and climate model simulations and is expected to continue into the future. The forced response will ultimately determine expected changes in return periods of precipitation extremes that are also used for planning purposes. In spite of this general agreement on an increasing trend in the intensity of extreme precipitation events on a global scale, large uncertainties remain with respect to changes in their spatial extent, persistence, seasonality, and, in particular, regional differences in their intensity changes. This project will focus on the last aspect and propose a methodology to reduce uncertainties in future changes in extreme precipitation intensities on regional scales based on global climate model simulations. The focus will be on large-scale precipitation events (in contrast to local convective extremes), which may lead to flooding in large river basins, and for which global model results are reliable.

To first of order, the increase of extreme precipitation intensity in a warming climate is due to the thermodynamic principle that a warmer atmosphere, according to the Clausius-Clapeyron equation, is able to carry more water vapor. Nevertheless, the fact that the spatial variability of projected future changes in extreme precipitation intensity is much larger than the variability of water vapor changes points to the importance of other factors on regional scales. As it turns out, changes in dynamical processes shape regional patterns of extreme precipitation intensities and are mainly responsible for the large uncertainties in regional projections across climate models. To reduce these uncertainties, we will thus focus on quantifying, understanding and constraining this dynamical component. This requires global climate model simulations, since large-scale processes (such as Rossby waves, teleconnections between tropics and extratropics, and scale-interactions between the regional to hemispheric scales) can be relevant for extreme precipitation dynamics.

Physical storylines or narratives have become a widely used approach to characterize uncertain future changes in climate in order to inform risk assessment. Storylines have been loosely defined as self-consistent and plausible unfoldings of a physical trajectory of the climate system. They provide an attractive framework to quantify plausible changes, e.g., in the hydrological cycle conditional on uncertain changes in atmospheric circulation. The storyline approach will further be used to quantify changes in intensity and frequency of extreme precipitation conditioned on changes in dynamical features such as fronts. Such an approach using physical understanding may inform risk assessments on plausible future trajectories of regional changes in extreme precipitation in the presence of large model uncertainties.

A potential means to reduce uncertainties in future climate projections is to apply observational ("emergent") constraints. To this end, a multi-model ensemble of climate simulations is explored for correlations, across individual models, between projected future changes of one or more climate variables and the model representation of other, observable quantities in present-day or past climate. For an emergent constraint to be robust there must be a plausible sequence of physical mechanisms explaining the correlation. Based on this emergent relationship observations are then used to constrain uncertainties in the projected quantities taking into account observational uncertainties and internal variability. This approach is useful if the uncertainty of the estimated ("constrained") future change is smaller than the spread of the raw model ensemble. In this project, we aim to develop observational constraints for changes in patterns and large-scale regional averages of extreme precipitation, focusing on dynamical processes that are largely responsible for current uncertainties.