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Observing and Modeling Precipitation in the Tibetan Plateau region

From large-scale processes to convective systems

Julia Kukulies
Institutionen för geovetenskaper
Naturvetenskapliga fakulteten

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Abstract

Climate change in mountain regions has far-reaching societal impacts such as increased risks for natural hazards and water scarcity that may affect billions of people in the downstream regions. Precipitation changes play a critical role in these impacts due to their effects on river runoff and flooding. However, these changes remain hard to predict due to uncertainties in climate models and a lack of reliable observations.

This dissertation aims to enhance the understanding of precipitation and its underlying large-scale and mesoscale processes in the Tibetan Plateau (TP) region, one of the most extensive and vulnerable mountain regions in the world. More specifically, the dissertation combines gauge measurements, satellite observations, reanalysis data, and high-resolution model simulations to investigate present-climate characteristics of clouds and precipitation over TP and its downstream regions.

A key outcome is a data set of large storms, so-called mesoscale convective systems (MCSs), based on two decades of high-resolution satellite observations of clouds and precipitation. This data set is used to study MCS characteristics and their relation to large-scale atmospheric circulation systems and water vapor transport. Satellite observations reveal that MCSs are important precipitation producers in the river basins surrounding the TP, while convection over the TP occurs in a more scattered manner with significantly less precipitation. In addition, satellite observations are used to evaluate kilometer-scale simulations of MCSs. The model simulations capture the general spatial pattern and magnitude of MCS-associated precipitation but show also systematic biases in MCS frequencies in some regions south and east of the TP.

It was found that interactions between large- and mesoscale processes affect the formation and evolution of MCSs over the TP and its downstream regions. The results identify several processes, e.g. interactions between the TP and the mid-latitude westerly circulation, that may drive future precipitation changes and need to be realistically represented in future climate model projections. As such, this dissertation constitutes a step towards reliable projections of climate change in the TP region.

Keywords: Tibetan Plateau, Water cycle, Precipitation, Large-scale circulation, Mesoscale convective systems, Kilometer-scale climate models, Satellite observations