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Large Scale Secondary Circulations in Regional Climate Models

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Simulations with Regional Climate Models (RCMs) without spectral nudging often show large scale deviations from the driving data in the middle and upper troposphere. However, little research has been conducted on the sources of these large scale differences. In this study we show, that these differences are the footprints of a secondary circulation that develops within RCM domains.
A 40-year RCM simulation with COSMO-CLM (CCLM) run at a resolution of 0.165° on a domain covering Europe and parts of the North Atlantic is analysed. A simulation with the Global Climate Model (GCM) ECHAM5 at T63 was used as lateral boundary forcing.
The RCM wind fields are interpreted as the sum of a Primary Circulation (PC) and a Secondary Circulation (SC). The PC is equal to the driving GCM wind field, while the SC equates to the wind vector difference between RCM and GCM. Thus, the SC represents the modification of the PC by the RCM. A clustering approach based on k-means is used to classify the ECHAM5 500 hPa geopotential height fields, in order to analyse impact of the circulation type on the characteristics of the SC.
It is shown that large scale vortices with scales larger than 1000 km are found in the SC climatology. The location, intensity and shape of the SC vortices is changing with the circulation type. Due to the different resolution of RCM and GCM, the air currents in the vicinity of mountains play a major role in driving the SC by adding (removing) momentum relative to the PC through funnelling (shading) effects. Because these changes in momentum cannot exit the model domain due to the prescribed boundary conditions, the SC acts as a balancing flow, which is confined by the RCM domain. The resulting SC vortices spread vertically through the whole troposphere and are directly linked to anomalous balancing motions along the lateral boundaries.