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Natural Variability in Nested Climate Models: The North Atlantic Oscillation and its Implications on Central European Climate Patterns

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The ClimEx-project ("Climate change and hydrological extreme events"; www.climex-project.org) provides a single-model initial-condition ensemble that is unprecedented in terms of size, resolution and domain coverage: 50 members of the Canadian Earth System Model version 2 (CanESM2 Large Ensemble, 2.8° spatial resolution) are downscaled using the Canadian Regional Climate Model version 5 (CRCM5 Large Ensemble, 0.11° spatial and up to hourly temporal resolution) over two domains, Europe and northeastern North America. The high-resolution climate information serves as input for hydrological simulations to investigate the impact of natural variability and climate change on hydrometeorological extremes.

As the ClimEx-project focuses on two northern hemisphere domains, the North Atlantic Oscillation (NAO) is a relevant index for quantifying natural variability and its transfer from a driving global circulation model (GCM) into the driven regional climate model (RCM).

In this study, the NAO pressure dipole is quantified in the CanESM2-LE by an extended station-based index; the response of mean surface air temperature and total precipitation to changes in the index value is determined for a Central European domain in both the CanESM2-LE and the CRCM5-LE.

The analysis is conducted for each of the 50 ensemble members on the entire European domain and in sample regions following a N-S gradient to capture spatial variations. The NAO-response relationship is expressed via Pearson correlation coefficients (strength) and the slope of linear regression equations (change per unit index change) for historical (1981-2010) and future (2070-2099) winters.
Results show that a) statistically robust NAO patterns are found in the CanESM2-LE and b) impulses from the NAO in the GCM produce correct responses in the high-resolution CRCM5-LE. Mean temperature is positively correlated with the NAO, resulting in average changes of up to 2 K inside the study domain. Precipitation shows positive correlations north and negative correlations south of the Alps. Regions with low correlations are characterized by large member spreads, mostly due to non-uniform signs of changes. Regarding slope parameters, members disagree most in regions of high change where long-term average values also deviate strongly. In general, slopes and correlations are higher in the CRCM5-LE than in the CanESM2-LE. Correlations and slope parameters weaken in the future period compared to the historical one, but the spread shows no significant change.

The results strengthen the validity of the climate module for its use in the ClimEx model chain, as important large-scale teleconnections propagate properly to the fine scale dynamics in the RCM. They also stress the importance of single-model ensembles for evaluating natural variability and the relevance of natural variability for European weather and climate.