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Non-stationarity in the NAO-temperature relation over the Baltic Sea catchment

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Much attention is spent today to the reconstruction of past climates, increasing the amount and quality of (multi-)proxy-reconstructions from different regions. However, these reconstructions by means of statistical models usually assume a constant spatiotemporal relationship between the predictor variables and the predictands. Due to the complex nature of externally and internally forced climate variability on different time scales, reasoning arises to question and probably quantify the assumption about stationarity particularly for longer time scales. An advantage of the Baltic region is the high amount of quality-checked and long historical measurements (e.g. SLP, station temperature, gauge and sea-ice data) which make it possible to study the relationship between the large-scale forcing by the North Atlantic Oscillation (NAO) and the near-surface climate of the Baltic Sea catchment area in more detail.

In a first step of our approach we relate the NAO to the near-surface climate of the Baltic region on monthly and seasonal basis using running correlation analysis on decadal time scales. Results indicate that the circulation-climate-relationship shows large amounts of non-stationarities. For example, the running correlations between the NAO and station temperatures over the Baltic Sea catchment area in winter (DJF) vary in a range between $0.45<r<0.8$ for 1824-2004, indicating the linear model explains between 20% and 64% on decadal time scales. The spatial comparison of running correlations of different stations especially previous to 1900 indicates decreasing trends in the influence of the NAO for far stations in the north and east, whereas more western stations remain on higher values. One possible explanation for non-stationarities in the NAO-temperature relationship is therefore the recurrent regime shift from more continental [low correlations] to maritime [high correlations] conditions. Moreover, this raises the question about the trustworthiness of NAO reconstructions from proxies far from the vicinity of the centres of the NAO over the Northeast Atlantic Ocean during periods with low correlations, such as the more continental climate during the period of the Little Ice Age (LIA). Other explanations, also affecting stations closer to the centres of action of the NAO, are not investigated here.

Based on these findings, climate reconstructions using constant relationships in the circulation-climate relationship can therefore not be used for studies about non-stationarities for the last millennium. To overcome this problem we use in a second step climate simulations carried out with the comprehensive coupled atmosphere-ocean model ECHO-G. For the analysis of running correlations between large-scale atmospheric circulation (NAO) and its impact on the near-surface temperature of the Baltic Sea catchment area, we use simulations with solar, volcanic and greenhouse gas forcing as well as a control-simulation with constant conditions like in 1990. Similar to the findings in the first step, all modelling results with and without external forcing are showing large non-stationarities with decadal running correlations between $0<r<0.8$ for winter (DJF). Future model studies have to be carried out to clarify possible mechanistic explanations concerning non-stationarities in the relationship between the NAO and the regional climate.