ANALYSIS OF THE (N)AO INFLUENCE ON ALPINE TEMPERATURES USING A DENSE STATION DATASET AND A HIGH-RESOLUTION SIMULATION

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Abstract: Both the North Atlantic Oscillation (NAO) and the Arctic Oscillation (AO) have a strong influence on European climate due to the associated change in the intensity and location of the westerlies, especially in winter (DJF). The influence of the (N)AO on the climate of the European Alps has been analysed in earlier studies either based on a few single stations or on gridded data not higher resolved than 1 deg. To analyse finer structures in the temperature response to the (N)AO caused by the complex topography, a very dense homogenised station dataset (extended version of HISTALP) has been used in this study for the winters 1958/59 to 1998/99 in the Greater Alpine Region. Additionally, the temperature response has been analysed using a high-resolution (1/6 deg.) model simulation performed with the regional climate model REMO to receive more information about the temperature response pattern and to validate the model.

Keywords: *REMO, NAO, AO, Alpine winter temperature, ALP-IMP*

1. INTRODUCTION

The North Atlantic Oscillation (NAO) describes a change in the intensity of the Icelandic Low and the Azores High (Walker and Bliss, 1932) leading to a stronger or weaker than normal pressure difference between the two systems. This changes the intensity and location of the westerly winds across the North Atlantic. The Arctic Oscillation is defined as the leading EOF of the wintertime monthly mean sea level pressure (SLP) anomaly field on the Northern Hemisphere poleward of 20°N (Thompson and Wallace, 1998) and is characterised by SLP anomalies of one sign in the Arctic and anomalies of opposite sign over middle latitudes. Over the North Atlantic this pattern resembles the NAO pattern, but the AO pattern covers also the North Pacific.

The NAO and AO pressure patterns have a well known impact on the large-scale structure of temperature over Europe. The stronger (weaker) westerly flow across the North Atlantic in the positive (negative) phase brings in winter relatively warm and moist (cold and dry) air to middle and northern Europe, whereas in southern Europe the winter is drier (wetter) than normal due to the more northerly (southerly) track of the westerly winds.

In this study the structure of these two oscillation patterns over Europe and their different impact on temperature in a particular region, the Alps, is analysed in detail based on station data. The temperature response is also analysed using high-resolution model data to receive information about the response in areas where no station data are available. Additionally, the investigation based on model data is used for validation of the model which is relevant for climate change analyses looking at temperature change due to circulation change in future.

2. STATION AND MODEL DATA

The NAO index (NAOI) is defined as the normalised pressure difference between a station on the Azores or Gibraltar and one on Iceland. The NAOI used in this study is calculated by the climatic research unit from Gibraltar and South-West Iceland (Jones et al., 1997). The AO index (AOI) is the leading principal component of the SLP anomalies based on the NCEP/NCAR Reanalysis (Thompson and Wallace, 2000).

For the analysis of the temperature we used a densely distributed station temperature dataset and a high-resolution model simulation. The station dataset is an extended version of the HITSTALP monthly mean temperature dataset (Auer et al., 2007) consisting of the 131 HISTALP stations and 36 additional Swiss and Austrian stations covering the Greater Alpine Region (GAR). The high-resolution simulation for the GAR has been performed with the regional climate model REMO (REgional MOdel, Jacob and Podzun, 1997), which has a resolution of 1/6 deg and was forced by the ERA40 reanalysis on the lateral boundaries und through spectral nudging of the large-scale horizontal wind field.

For all data the winter (DJF) means were calculated from 1958/59 to 1998/99. Based on these means regressions between both observed and simulated temperature and both NAOI and AOI were calculated.

3. RESULTS

3.1 (N)AO patterns

The NAO and the AO pattern over Europe displayed as the regression coefficients between the circulation index and the ERA40 mean sea level pressure (Fig. 1) show slightly different locations and dimensions of the centres of action. For the NAO this leads to a stronger pressure gradient over the Alps than for the AO causing stronger advection. For the AO with the weaker gradient and the larger dimension the higher pressure causes subsidence over the Alps in the positive phase.

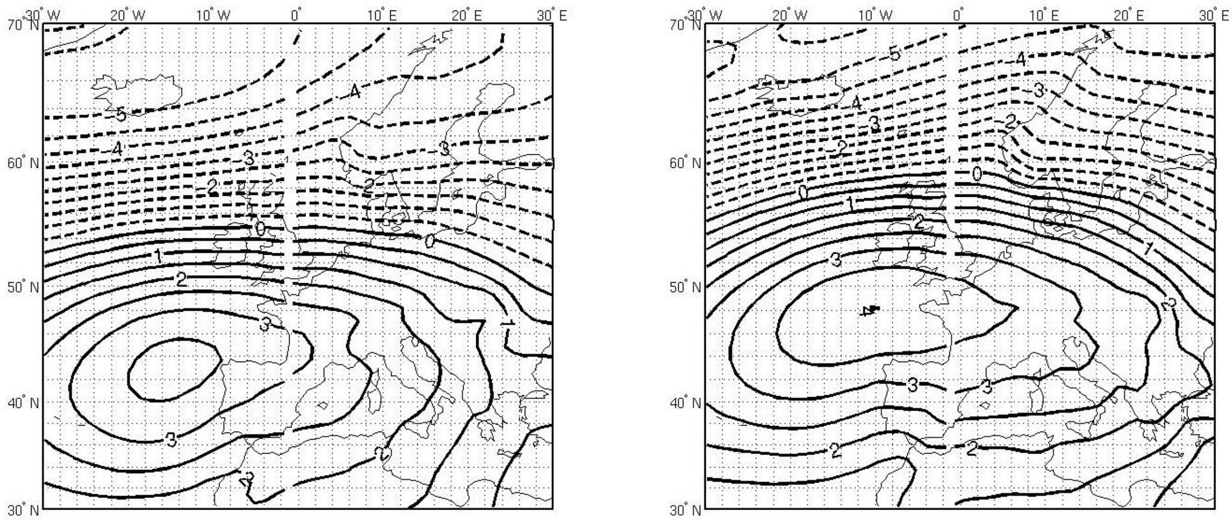

Figure 1: Regression coefficients between both NAOI (left panel) and AOI (right panel) and winter mean sea level pressure from the ERA40 Reanalysis. Units in hPa per unit deviation of the circulation index.

3.2 Station based temperature response

In agreement with the well known European-wide temperature response to the NAO (Hurrell and van Loon, 1997) we find that the change in observed winter temperature corresponding to a positive change of one standard deviation of the NAOI (Fig. 2, left) shows a strong north to south gradient with largest values of 1.3°C in the northeast and smallest values around 0.2°C around the Adriatic coast. An altitudinal dependency of the temperature response has been described by earlier studies (Beniston and Rebetz, 1996; Giorgi et al., 1997) using several Swiss station data and has been explained by the connection of the high elevation stations to the free atmosphere and therefore to the large-scale circulation influenced by the NAO. This altitudinal dependency is absent in our analysis. Potential reasons for this discrepancy are that we analysed winter mean temperature in contrast to minimum temperature used by Beniston and Rebetz (1996) and linear regression in contrast to an analysis based on composites used by Giorgi et al. (1997).

The temperature response to the AO in the GAR (Fig. 2, right) fits to the results of Thompson and Wallace (1998). It has a north to south gradient and largest values are found for the high-elevation stations above 1500m above mean sea level.

By comparing the temperature response to the NAO with that to the AO, larger values and a stronger north to south gradient are found for the former. Another difference is the altitudinal dependency which is found for the AO and which is absent for the NAO. The difference between the temperature response to the NAO and to the AO is probably caused by the slightly different circulation patterns describing the NAO and the AO, described above.

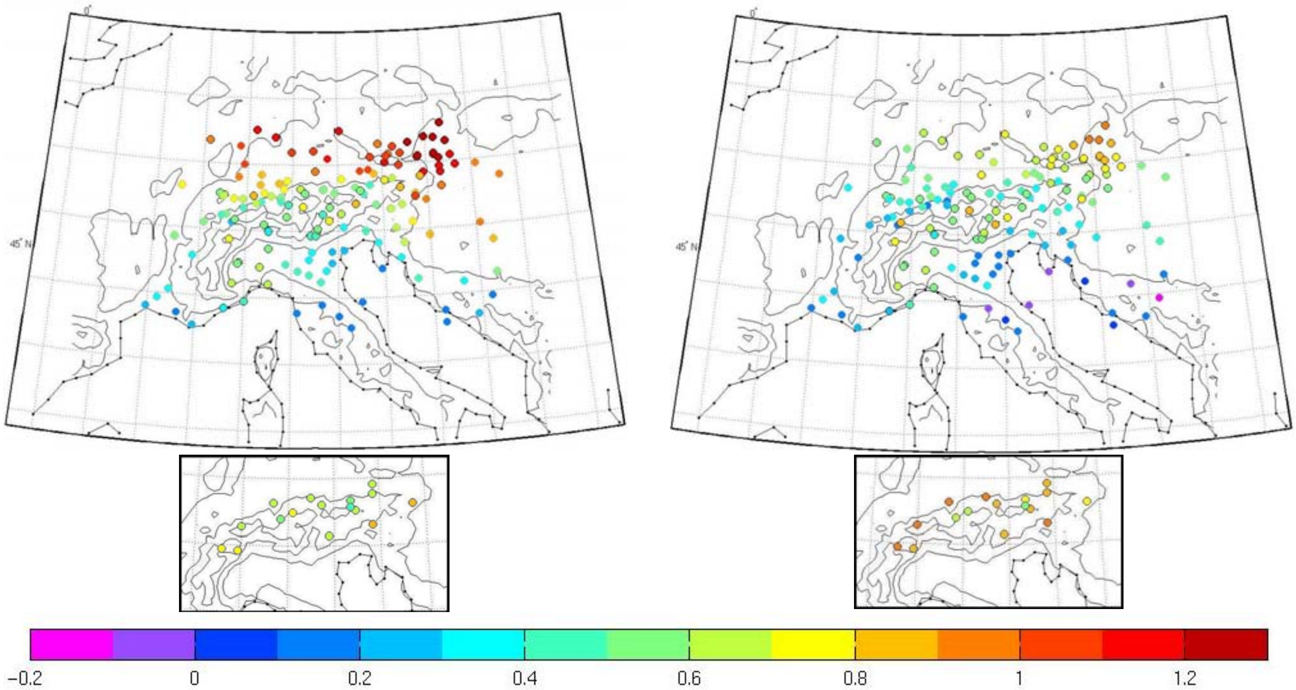

Figure 2: Regression coefficients between both NAOI (left panels) and AOI (right panels) and winter temperature from low elevation (upper panels) and high elevation (lower panels, >1500m a.s.l.) stations. Significant values have a black circle. Units in °C per unit deviation of the circulation index.

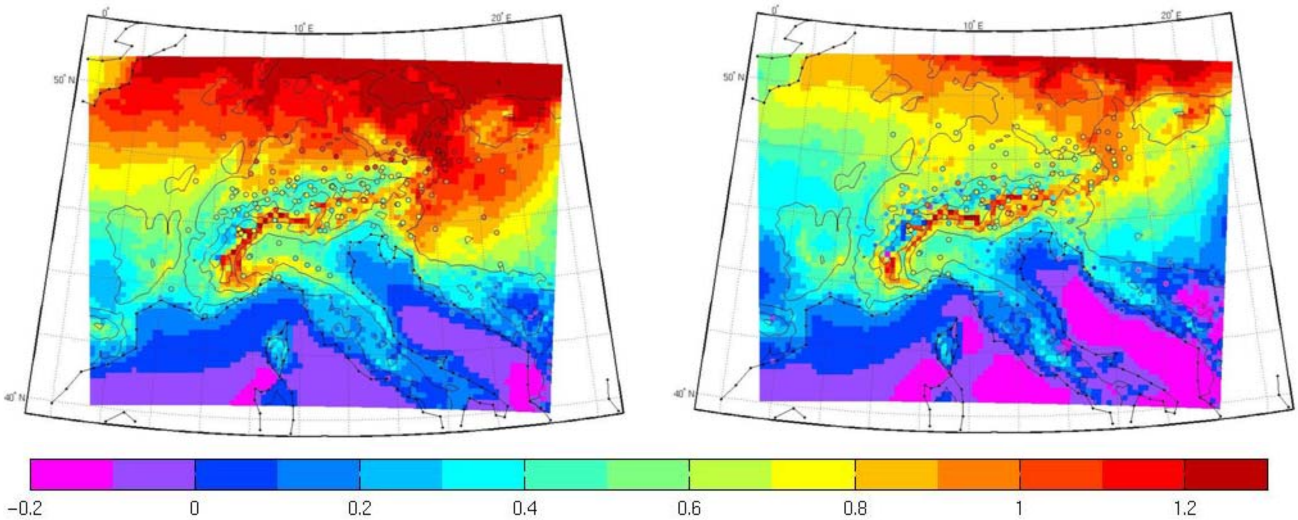

Figure 3: Regression coefficients between both NAOI (left panel) and AOI (right panel) and winter temperature from REMO on the grid in the background and winter temperature from stations on the dots in the foreground. Units in °C per unit deviation of the circulation index.

3.2 Model based temperature response

The temperature response to the NAO simulated by REMO (Fig. 3, left) shows a generally very similar pattern to the observed temperature response. However, south of the main Alpine ridge REMO simulates a very strong positive response which is absent in the station data. This absence might be due to different locations represented by the stations and the grid boxes. The differences between REMO and station regression values are generally small, but they indicate that REMO does not fully capture the strength of the north to south gradient of the regression.

For the AO the simulated temperature response (Fig. 3, right) also agrees well with the observed response, but REMO has more often higher regression coefficients than the stations. However, for the high elevation stations REMO has lower coefficients. Again south of the main Alpine ridge the simulated and the observed temperature response disagree.

The differences between the response to the NAO and to the AO found for the stations, namely the different values and different strength of the north to south gradient, are also found for the simulated temperature response.

4. CONCLUSIONS

To get detailed information in the Greater Alpine Region about the influence of the (N)AO on winter temperature, a dense homogenised station dataset was used. The pattern based on these stations is in agreement with the well known European-wide pattern for both the NAO and the AO; however, the altitudinal dependency in our station data is only present for the AO. This discrepancy is currently under investigation.

In addition to the station data we used a high-resolution simulation to receive information about the temperature response in an area without any gaps and to validate the model for possible climate change simulations. The simulated temperature response is in agreement with the observed response and shows a strong influence of the (N)AO in an area along the southern side of the main ridge, which needs more investigation.

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