

# **NAO and Tree Rings - A dendroclimatological network analyses of Central European chronologies**

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## **Introduction**

Tree ring width chronologies are appropriate and often used proxies for reconstructing past climate conditions, especially in areas with extreme climate. In general such areas have only one dominant climatic forcing factor influencing tree ring growth (FRITTS 1976). In boreal (BRIFFA et al. 1998) or high mountain areas (ESPER 2000, BRÄUNING 1999) temperature is the limiting factor, in arid to semiarid regions (TREYDTE 2003) precipitation is decisive.

Recently, the North Atlantic Oscillation (NAO) has been reconstructed with (COOK et al. 1998, GLUECK & STOCKTON 2001, COOK et al. 2002) with some of the predictors being tree ring chronologies from West and Central Europe. Recognizing that tree ring growth in Central Europe is forced by changing influences of climatic factors, namely temperature and precipitation (SCHMIDT 2003), a greater knowledge of the NAO as forcing factor for tree-ring growth is necessary.

This study analyzes the NAO fingerprints in tree-ring width chronologies in the Central European region by investigating following questions:

- Is there a significant correlation between NAO and tree rings in Central Europe?
- Are there species specific differences in these correlations?
- Where are highest correlations located?
- Are there spatial pattern in the distribution of site related correlations?

The NAO can be regarded as a dominant pattern of atmospheric circulation variability and refers to a meridional oscillation in atmospheric mass with centers of action near Iceland and over the subtropical Atlantic. It is considered to be the dominant mode of atmospheric variability in the Northern Hemisphere, especially in the North Atlantic region. The NAO affects the spatial pattern of air pressure areas and is responsible for the variability of precipitation and temperature over Europe.

An index can be constructed that representing the phases of the NAO. The corresponding index (the NAOI) is commonly based on the normalized surface pressure (SLP) difference between meteorological stations representing the Azores high and the Iceland low. HURRELL et al. (1995) calculated a NAOI from the stations Ponta Delgada (Azores) and Reykjavik (Iceland) from AD1865 to 1995. The Climate Research Unit (CRU) used the data from Gibraltar (Spain) and Reykjavik (Iceland) for calculating an index over the longer time window from AD1825 to 2000. We abbreviate these two indices as PON and GIB, respectively. Based on these data many NAO reconstructions have been calculated. In detail

they show different results depending on the chosen index and especially the chosen tree-ring data.

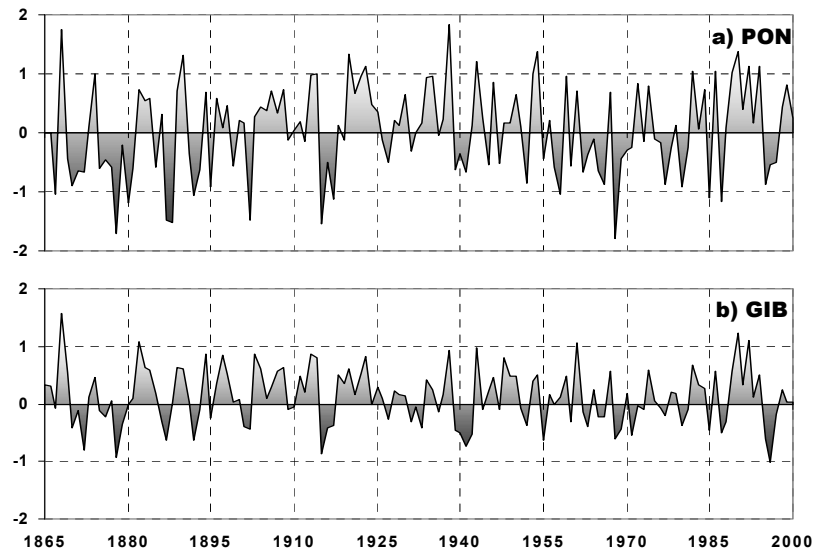


Figure 1: In this study used NAO indices as normalized sea pressure differences between a) Ponta Delgada and Reykjavik and b) Gibraltar and Reykjavik for the common time window AD1865 to 2000.

A positive NAO phase in the winter months results from a relatively high subtropical pressure centre and a deep Icelandic low, and yields warm and wet winters in Northern Europe and dry winters in Southern Europe. A negative winter NAOI results from weak a subtropical high and a weak Icelandic low. This causes fewer and weaker winter storms on a west-easterly track and brings moist air into the Mediterranean. For Northern Europe the consequences are cold and dry winter conditions.

### Database and methods

In addition to the NAO data the network analyses is based on a dendrochronological database containing more than 300 tree ring width chronologies that all span the AD1875 to 1974 time window. This dataset includes the major forest tree species in Central Europe (*Abies alba*, *Fagus sylvatica*, *Larix decidua*, *Pinus cembra*, *Pinus uncinata*, *Picea abies*, *Quercus petraea*, *Quercus robur*) with a heterogeneous distribution. More than 38% of all chronologies are spruce, while all deciduous chronologies together amount to only 24%. The spatial distribution of the sites is shown in Figure 2. The dendroclimatological network is connected with a Geographical Information System (GIS) that includes all site related metadata such as altitude, elevation, exposition, inclination, soil conditions.

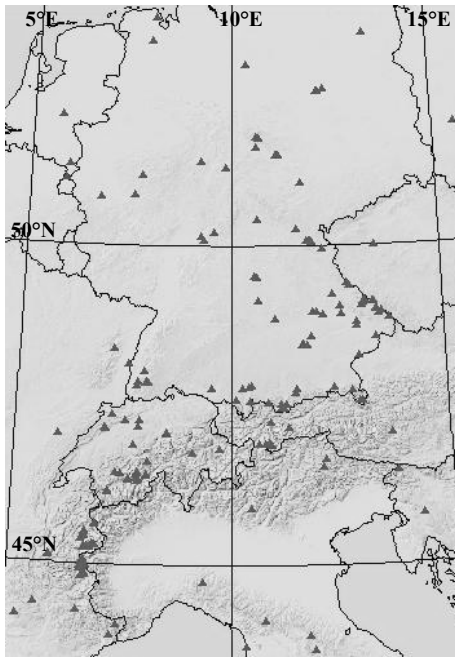


Figure 2: Sites of the tree-ring width chronologies spanning ad1875 to 1974 in Central Europe.

All tree ring width (TRW) series were detrended using a) residuals from a 5-year moving average (here abbreviated as 5gs) and b) residuals from a 25-year moving (25gs). Using simple correlation analysis, the index TRW series were compared to i) monthly NAOI data for PON and GIB using a 19-month period from April of the previous year to October of the growth year and ii) the winter (DJFM), the summer (AMJJ), and the annual (J to D) NAO. These NAOI windows allow the assessment of the influence of previous and present year's climate on the current year's growth. According to this the dendroclimatological network for the study consists of three tree ring datasets (TRW-raw, TRW-5gs, TRW-25gs) for 300 sites and 22 NAOI windows for each GIB and PON. The whole dataset is composed of 944 time series all spanning the AD1875 to 1974 common period.

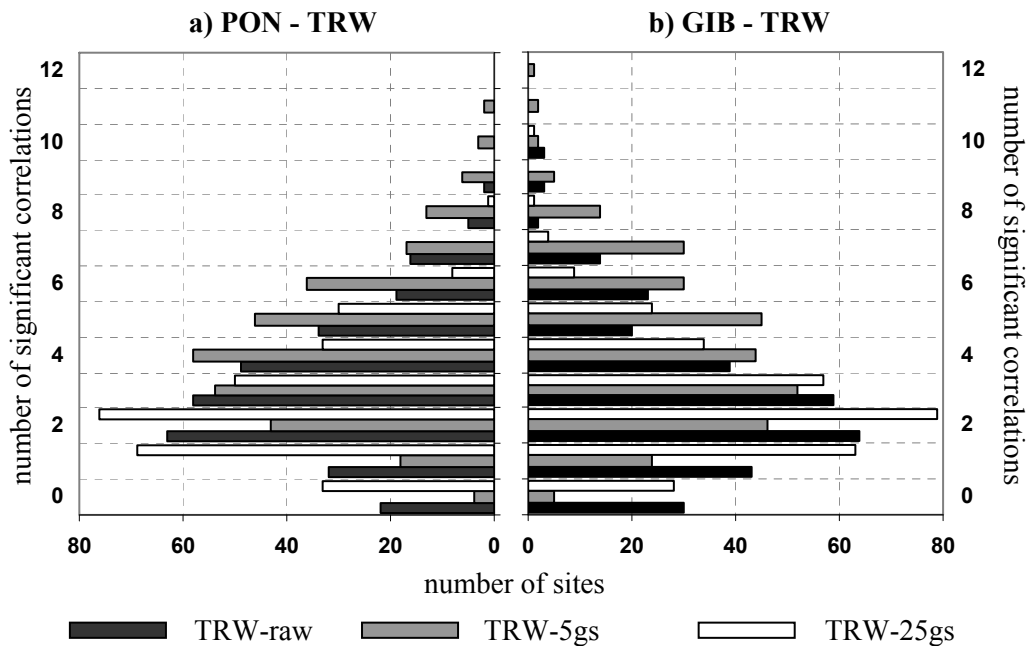


Figure 3: Significant correlations between NAOI based on the data from a) Ponta Delgada (PON) and b) Gibraltar (GIB) and TRW chronologies; black - raw tree-ring width data, grey - index data after 5gs detrending, white - index data after 25gs detrending.

## Results and discussions

A total of 39,600 correlation pairs between the NAO and TRW data were computed. Figure 3 shows the number (from a maximum of 22) of correlations significant at the  $p < 0.05$  level for each tree-ring site with the PON-data (Fig. 3a) and the GIB-data (Fig. 3b).

The 5gs filter yields the strongest link between NAO and the chronologies, evidenced by the 5gs filter having many more chronologies that have around 5 or more significant correlations in comparison to the raw or 25gs filtered chronologies. Surprisingly, the 25gs indexation results in a low number of significant correlations (white beams). Approximately 10% of all 25gs indexed sites (33 for PON and 28 sites for GIB) have no significant correlation, and only 39 sites have 5 or more significant correlations with the 22 NAO windows. In contrast, the 5gs indexation has 123 and 129 sites that correlate significantly with the PON and GIB data, respectively. We interpret this fact to suggest that there are differences in the longer term NAOI and TRW data. Therefore the following discussion focuses on the 5gs filtered TRW data.

In comparing results from PON with GIB in figure 3, only negligible differences are found. The greatest differences are found in the group with 7 significant correlations, where 30 and 17 sites fall into this group for the GIB and PON indexes, respectively. Regarding the lowest row of figure 3 (number of significant correlations is equal to zero) for the TRW-5gs-data there are only 4 and 5 sites with no significant correlations to the PON and GIB NAOI, respectively. Consequently, at least 295 from a total of 300 sites, representing over 98% of the chronologies, have at least one or more significant correlations with monthly and seasonal NAOI.

Figure 4 shows these correlations at monthly resolution. The grey bars in the background illustrate the range of the correlation coefficients. For every NAOI-window there are sites with positive and negative correlations. The mean of all sites for each NAO-window generally results in values that fluctuate around zero. Therefore the correlations must be investigated in a more detailed manner.

The smaller bars show the number of sites with significant correlations to the various NAOI windows differentiated into three levels of significance. For the PON-data the greatest peak is found in summer. Nearly 100 sites react significantly to the summer NAOI with maximum correlation of 0.4457 for a high-elevation, northerly exposed spruce site in the Tarantaise valley (French Alps). For the winter NAOI there are only a few sites with significant correlations, 25 with positive and 20 sites with negative correlations. The GIB-data have nearly the same pattern: 30 sites with positive and 34 sites with negative correlations to the winter NAOI, and 119 sites with positive correlations and only 5 sites with negative correlations to the summer NAOI.

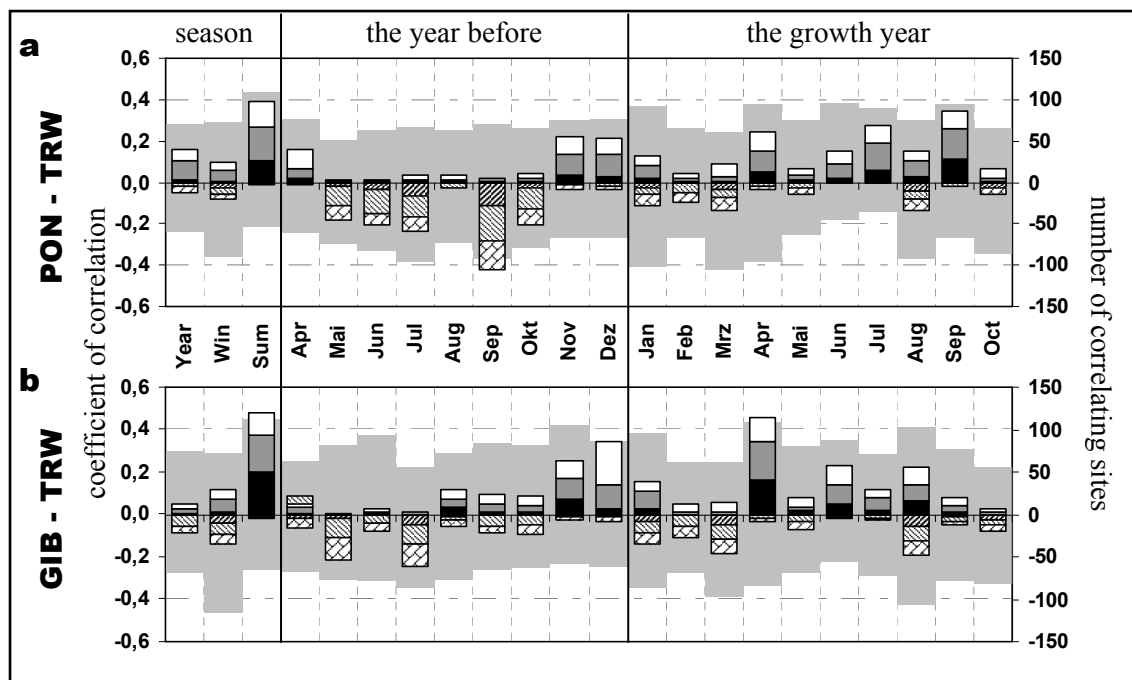


Figure 4: Correlations between a) PON – NAOI and b) GIB – NAOI and tree ring width chronologies detrended by residuals from a 5 year moving average. The grey background areas show the range of correlation coefficients, the bars show the number of sites with significant correlations, differentiated in following levels:

positive correlations:	■ 99 %	■ 95 %	□ 90 %
negative correlations:	▨ 99 %	▨ 95 %	▨ 90 %
levels of significance:	0.2593	0.1998	0.1673

For these calculations at monthly resolution, the greatest number of sites correlate significantly with the September PON. 86 sites have positive correlations to the September NAO of the growth year and 104 sites show negative correlations to the September of the prior year. For the GIB data, April of the growth year is the dominant month with 115 sites having significant positive correlations. In sharp contrast to the PON index, the September GIB index has nearly no correlations with radial growth. However, in August 94 sites with significant correlations are found, divided into 56 positive and 48 negative reactions. This split reaction appears contradictory initially.

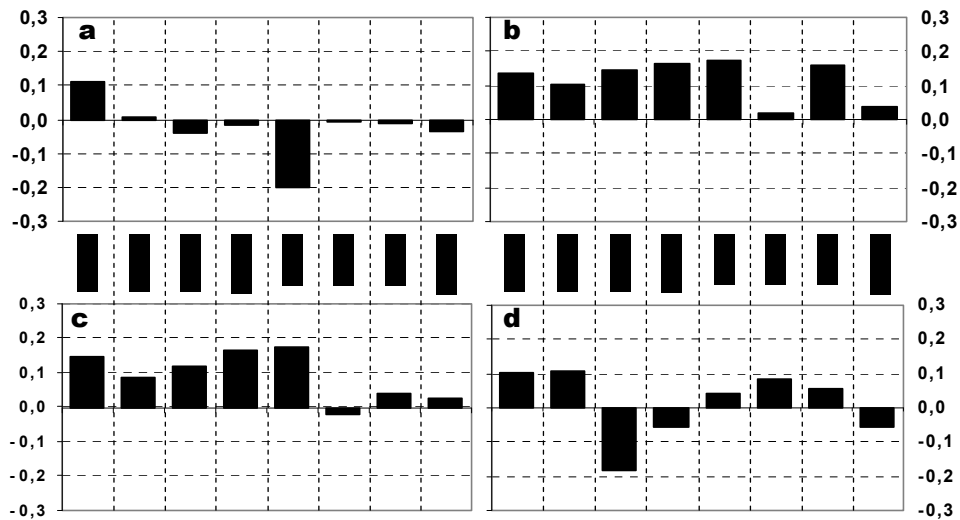


Figure 5: Species specific average correlations between the NAOI derived from Gibraltar and Reykjavik and the TRW chronologies detrended by residuals from 5 year moving average for specifically chosen NAOI windows: a) winter (December to March), b) summer (April to July), c) April, and d) August.

To help address this apparent contradiction species specific correlations are shown in Figure 5. Particularly in August (Fig. 5d), the various species show unequal correlations to the GIB NAOI. While fir, beech, and pine are positively correlated with the NAOI, spruce, oak, and especially larch show negative correlations to the August NAOI. April (Fig. 5c) and the summer NAOI (Fig 5b) show more homogeneous distributions, with nearly all species having positive correlations to these NAO data. For the winter NAOI (Fig. 5a), only positive correlations are found with the fir and negative correlations with the stone pine.

To explain the negative correlations of stone pine the spatial distribution of this species must be taken into account. The present network only includes stone pine sites from near the upper tree line, constrained to a small area in the Western Austrian and the Northeastern Italian Alps. In figure 6d, which shows the spatial distribution of correlations between winter NAOI and TRW, only negative correlations to the NAOI are displayed in this area. Therefore the species specific information of stone pine (see Fig. 5a) can only be explained by the specific site ecological conditions. Furthermore all sites with negative correlations (see small bars in Fig 4) are stone pine sites. This leads to the conclusion that the wintertime negative correlations in Central Europe are mainly a reflection of the special ecological behavior of stone pine.

Regarding the spatial distributions of the correlations for summer, April, and August (Fig. 6a-c) different reasons are expected, and so far, a universally valid explanation for the various spatial patterns cannot be given.

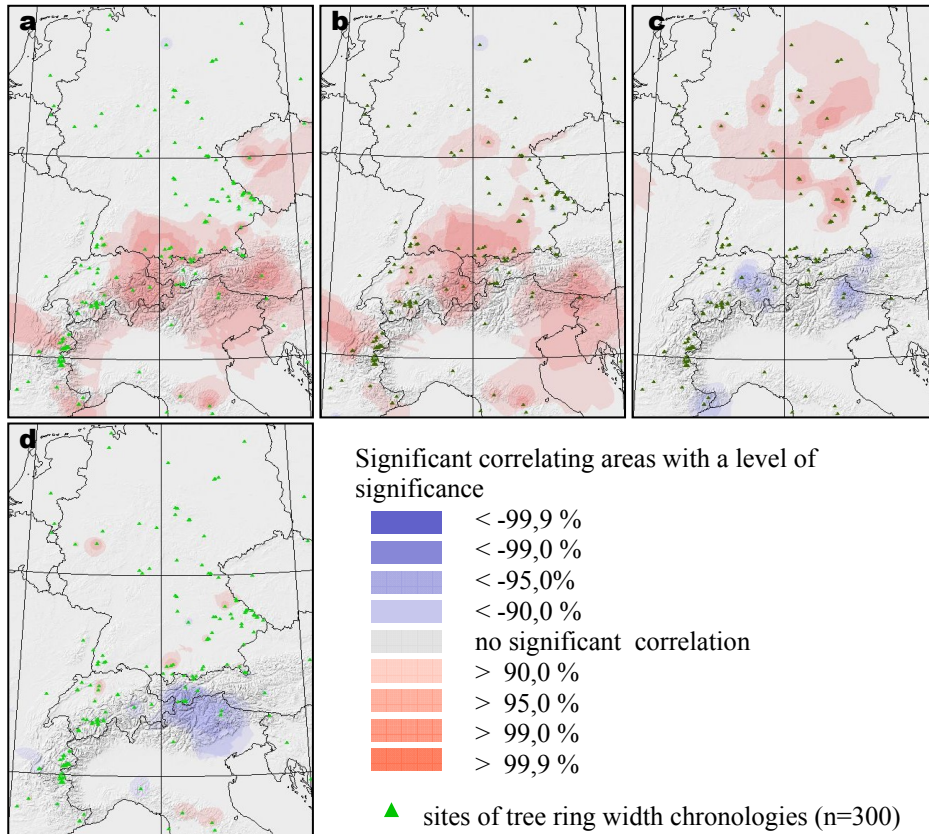


Figure 6: Spatial correlation pattern between GIB-NAOI and TRW-index-data for a) summer (April to July), b) April, c) August, and d) winter- (December to March) NAOI. Red colours represent positive and blue negative significant correlations.

## Conclusion and outlook

The entire connection between NAO and TRW is not yet predictable as a general rule, due to the complexity of this system and network. But the first results of this study permit us to give some general remarks.

Most of the tree ring width chronologies include a significant NAO-signal. But this signal may differ depending on the specific NAO index. More sites show significant correlations to the NAOI derived from the meteorological station of Gibraltar in comparison to that of Ponta Delgada.

The correlations to the summer NAOI are substantially higher than those of the winter NAOI. Additionally they are more uniform, with mostly significant positive correlations to the summer NAOI. For the months April to July all species show positive correlations to the NAO, for the months of the late growing season and the winter period differing correlations are found.

The spatial correlation patterns show no clear relationship between NAO and TRW. So far we have only been able to explain some spatial patterns.

Further investigations are necessary, with the following steps deemed useful:

- to increase the number of sites in sparsely covered regions of the dendrochronological network (western and northern Germany, south eastern Alps),
- to use a NAO index that considers the spatial dynamics of the air pressure fields over the North Atlantic (PAETH 2000),
- to compare the NAO fingerprints with tree ring pointer years (NEUWIRTH & WINIGER 2003, NEUWIRTH et al. 2003)

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