A multivariate analysis of the NAO influence on Europe: climate impacts and associated physical mechanisms

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1. INTRODUCTION

A multivariate analysis of the influence of the North Atlantic Oscillation (NAO) on the climate of the North Atlantic and European sectors is presented using the 40 year (1958−97) consistent data set from NCEP. Anomaly fields of climate variables are then interpreted based on physical mechanisms associated with the anomalous mean flow (characterised by the surface wind field) and the anomalous eddy activity, characterised by the surface vorticity and the 500 hPa storm track fields (**Figure 1**). It is shown that NAO−related temperature patterns are mainly controlled by the advection of heat by the anomalous mean flow. However, large asymmetries between minimum and maximum temperatures, and more significantly, between positive and negative phases of NAO imply the importance of a different mechanism, namely the modulation of short wave and long wave radiation by cloud cover variations associated with the NAO (**Figures 2 and 3**). Furthermore, NAO influence over two different precipitation−related variables, namely, precipitation rate and precipitable water display different patterns. Precipitable water is shown to be strongly related to the corresponding anomaly fields of temperature while (**Figure 5**). precipitation rate appears to be controlled by the surface vorticity field and associated strength of the tropospheric synoptic activity (**Figure 4**) .

2. DATA & METHOD

All data used in this study are large−scale gridded data retrieved from the NCEP Reanalysis data sets for the period 1958-1997. The Reanalysis were derived through a consistent assimilation and forecast model procedure that incorporated all available weather and satellite information (Kalnay *et al*., 1996). Six−hourly values of SLP, 500 hPa geopotential height, precipitable water, precipitation rate, 2m height maximum and minimum temperatures and 10m u and v wind components were extracted for the NCEP 2.5° latitude by 2.5° longitude grid, for the area 80°N − 30°N; 60°W − 70°E. Daily values were computed by averaging those six−hourly values, with the exception of Tmax and Tmin, for which one daily value was used.

Composites of all analysed fields between December and March from 1958 to 1997 were derived following the procedure developed by Hurrell (1995). However, unlike Hurrell, composites of high (low) NAO index were produced using a monthly (not seasonal) criteria, *i.e.* we have grouped all individual months with an NAO index > 1.0 (NAO index < −1.0). The number of months with high NAO index is slightly higher (64) than those characterized by a low NAO index (43). The remaining months (53) are characterized by "near normal" values of the NAO index. The spatial signature of the NAO is represented by the difference in SLP between composites of winter months (DJFM) with an NAO index > 1.0 and with an NAO index < −1.0 from 1958 to 1997 (Fig. 1).

SYNOPTIC ACTIVITY

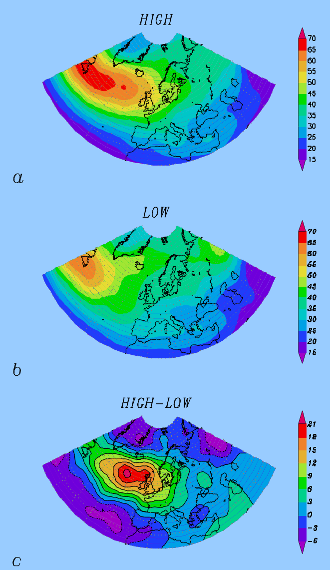


Figure 1 Composites of synoptic activity (gpm) for the winter months (DJFM) of the 1958−1997 period: (a) NAO index > 1.0, (b) NAO index < −1.0 and, (c) their difference.

TMAX

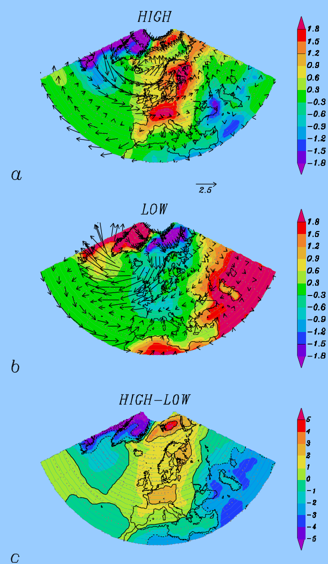


Figure 2 Tmax anomaly fields (°C) for winter months with (a) high NAO index > 1.0, (b) low NAO index < −1.0 and, (c) their difference. Vectors of the anomaly 10m wind field (ms^{-1})for months with (a) high, and (b) low NAO index are also represented.

TMIN

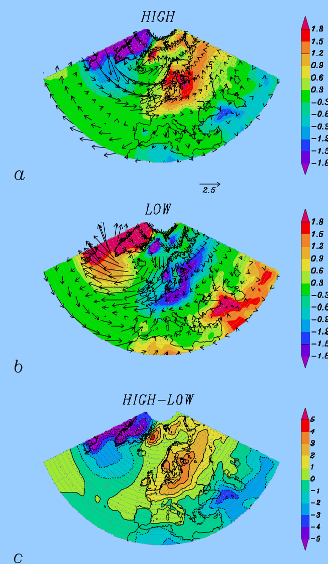


Figure 3 Tmin anomaly fields (°C) for winter months with (a) high NAO index > 1.0, (b) low NAO index < −1.0 and, (c) their difference. Vectors of the anomaly 10m wind field (ms^{-1})for months with (a) high, and (b) low NAO index are also represented.

PRECIPITATION RATE

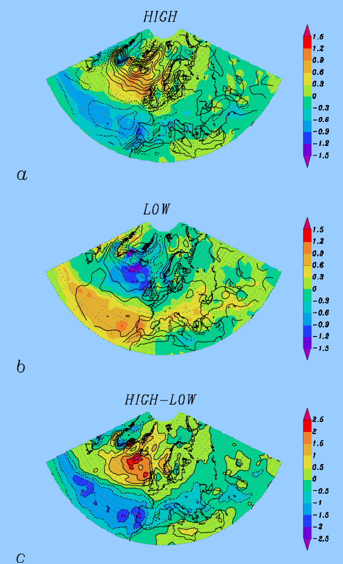
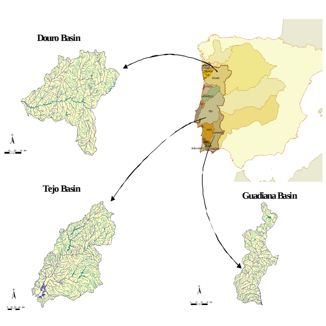


Figure 4 Precipitation rate anomaly fields (mm/day) for winter months with (a) high NAO index > 1.0, (b) low NAO index < −1.0 and, (c) their difference. Positive (solid) and negative (dashed) isolines of the 10m anomaly vorticity field, for months with (a) high and (b) low NAO index are also represented.

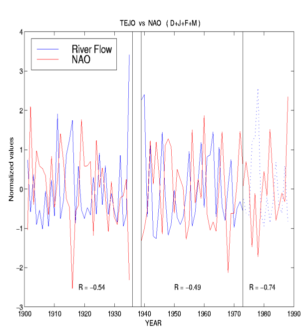
NAO CONTROL OF IBERIAN RIVER FLOW

We have assessed the impact of the NAO in winter river flow regimes for the three main international Iberian rivers, namely the Douro (north), the Tejo (centre) and the Guadiana (south). Results show that the large inter−annual variability of flow of these three rivers is largely modulated by the NAO. Such modulation, associated with the recent positive trend of the NAO index, might implicate a significant decrease of the available flow. This reduction can represent an important hazard for the Portuguese economy due to its negative impact in agricultural yield and hydroelectric power production.

A



B



C

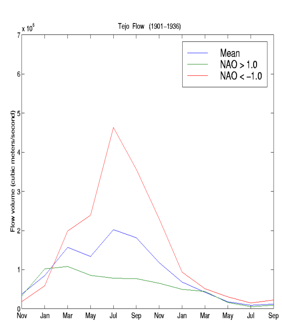


Figure 6 (a) The three main Iberian river sy
1989 period, and (c) seasonal cycle of composi
value (blue) of the 1901−1936 period.

PRECIPITABLE WATER

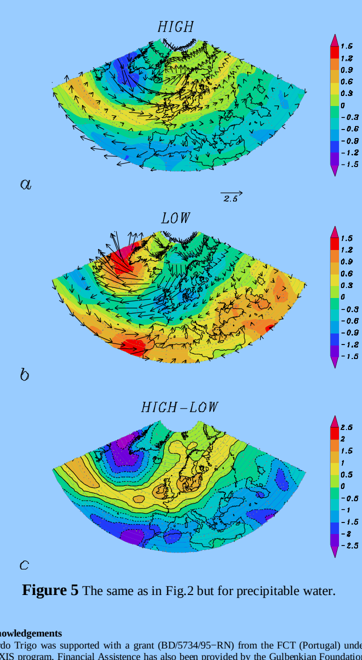


Figure 5 The same as in Fig.2 but for precipitable water.

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