2B.4 ATMOSPHERIC BLOCKINGS – THEIR INFLUENCE ON THE NAO AND PNA

Croci-Maspoli, M., Schwierz, C., and Davies, H.C.
Institute for Atmospheric and Climate Science, ETH Zürich, Switzerland

1. INTRODUCTION

The identification of individual blocking events in climatological data sets using various objective blocking index definitions (e.g. Dole and Gordon, 1983, Tibaldi and Molteni, 1990) shows a general consistency in the spatial blocking distribution and the temporal scale of episodes. Namely, the overall geographical distribution shows a bimodal frequency structure, indicating maximum blocking frequency along the storm track regions in both, the North Atlantic and Pacific basin. The temporal scale of individual blocking events is not always explicitly defined in the literature, but minimum life-times have been proposed in the range from 3 to 10 days. However, entire blocking life cycles can be of the order of several days up to weeks.

The predilection for blocking occurrence in the two ocean basins and the relatively long blocking life-times prompt consideration of a link between atmospheric blocking and the dominant large-scale patterns of inter-annual/seasonal climate variability in the Northern Hemisphere. The patterns considered in this study are the North Atlantic Oscillation (NAO) and the Pacific North American (PNA) pattern.

The recent number of studies based upon the relation between atmospheric blocking and the dominant modes of climate variability demonstrates the ongoing attempt for a better understanding of their interrelation. However, previous findings focus primarily on purely statistical correlations, whereas hardly any emphasize is put on the dynamical linkage between blocks and the variability patterns. From a dynamical standpoint, several questions arise which are not intrinsically clear from previous findings. Some of them include the question on how and to what extent do blocks influence the variability patterns or vice versa? One reason for this consideration is based upon the studies on the dynamics of the establishment of the NAO (Benedict et al., 2004, Feldstein, 2003) and PNA (Feldstein, 2002), respectively. They accentuate the importance of nonlinear processes for NAO life cycles and primarily linear processes for the PNA evolution. In addition they point to the importance of synoptic-scale waves in the establishment of opposed NAO phases that either break cyclonically (negative NAO) or anti-cyclonically (positive NAO). Since wave breaking can also have an influence on blocking formation, a connection to atmospheric blocking appears reasonable and it can be speculated that the block's life cycle can play an integral part in the major processes of the NAO/PNA establishment.

The study is based upon the Northern Hemispheric blocking climatology (Croci-Maspoli et al., 2007) derived from the ERA-40 re-analysis (Uppala et al., 2005) data from the European Centre for Medium Weather Forecast (ECMWF) and the blocking index by Schwierz et al. (2004). The time frame covers the boreal winter between Dec 1957 to Feb 2002 (DJF).

2. TEMPO- SPATIAL CORRELATION

A clear temporal co-variability has been found between the NAO (PNA) index values and blocking frequency and duration in the Atlantic (Pacific) basins (Fig. 1, only NAO- shown), which are the climatological centers of blocking activity in the Northern Hemisphere.

The above findings are based upon a simplification of the actual resolution of the underlying data set. Hence, using a two-dimensional blocking indicator would allow temporal and spatial correlations. The newly established two-dimensional blocking climatology also forms the data base for composite maps of blocking for opposed PNA/NAO phases (Fig. 2, only NAO). These provide a detailed spatial description of the co-variability. It is shown that the northwest Atlantic exhibits significantly higher blocking frequencies during the negative NAO phase. The corresponding positive index phase is characterised by the near absence of blocking in these regions. Hence the two-dimensional representation of blocking composites provides detailed information on the exact blocking location and frequencies and considerably extends prior studies focusing basically on the longitudinal blocking distribution (e.g. Pavan et al., 2000, Shabbar et al., 2001).

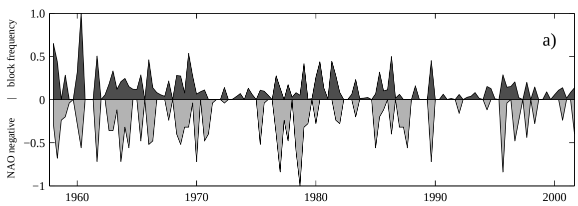

Figure 1: Comparison between the regional monthly mean APV* blocking frequency (dark shading) in the West Atlantic (55°-65°N, 70°-50°W) and the corresponding monthly negative NAO index (light shading).

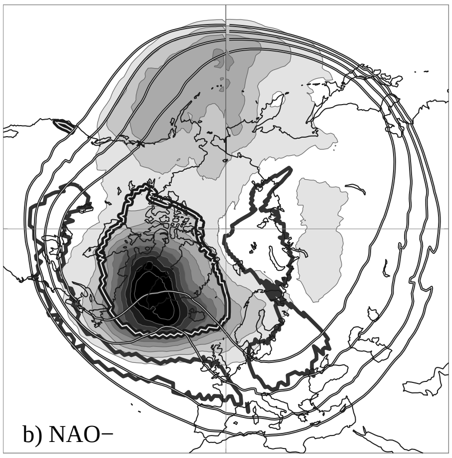

Figure 2: Blocking frequency (DJF) composite maps for NAO-. Contours indicate % of blocking during the pattern phase. Significance at 98% is shown in bold black (negative) and bold block-white (positive) contours. Circumpolar black-white contours indicate the 2pvu isolines at 310K to 325K with 5K steps.

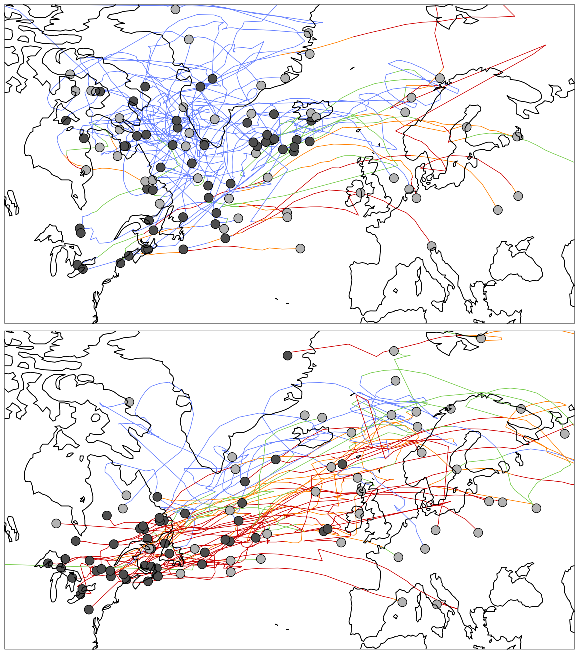

Figure 3: Distribution of winter blocking genesis (dark dots) and lysis (light dots) with the corresponding track lines during NAO- (top) and NAO+ (bottom) in the Atlantic region. Only tracks are displayed with genesis in the corresponding index phase. The color scaling indicates four partitions of the index values;
NAO < -0.34, PNA < -0.39; green: NAO < 0, PNA < 0; orange: NAO > 0, PNA > 0; red: NAO > 0.52, PNA > 0.52.

Recent other two-dimensional blocking representations of NAO-only composites (Barriopedro et al., 2006, Scherrer et al., 2006) agree with our findings of significantly higher blocking frequencies over the western/central North Atlantic during the negative NAO phase and over Northern Europe during the positive phase.

3. BLOCKING INFLUENCE ON THE NAO AND PNA

Following the benefit of the underlying dynamical blocking climatology is exploited by examining the individual blocking tracks during the different NAO/PNA phases. The purpose of this analysis is first to provide novel insight on characteristic blocking tracks and their corresponding genesis and lysis region during different NAO and PNA phases, and second to analyse the typical NAO/PNA index evolution during the blocking life-cycle.

It is found that the typical genesis and lysis regions during opposed pattern phases exhibit dramatic changes (Fig. 3). Whilst blocks starting in the positive NAO phase show a relatively confined area of genesis around Nova Scotia and clearly separated lysis over Northern Europe, their negative counterpart shows an undefined blocking genesis region encompassing a comparatively large area over the Bering Strait with lysis in the same region. In the North Pacific the number of blocking events starting in the positive and negative PNA phase is considerably different (not shown). Pacific blocking formation is highly favoured during the negative PNA phase (87 events) compared to the positive PNA phase (33 events). Associated with these variations in genesis and lysis locations is a marked variation in blocking track direction, speed and length.

In addition all individual blocking tracks have been combined with the corresponding phase of the NAO and PNA respectively (Fig. 4). The major finding from the blocking life-cycle analysis is that, independent of the geographical location, blocks are linked to significantly modified NAO and PNA (not shown) variability. Specifically, (i) when the large-scale flow is in a negative NAO phase, the existence of blocks is associated with an increased life-time of the negative phase of the patterns. This suggests that blocks sustain the negative NAO phase from genesis to lysis and extend the decay time scale of the variability patterns; (ii) in a NAO neutral environment, blocking occurs together with an index development into the negative phase; (iii) this phase shift is particularly prominent for the NAO in combination with long-lived blocks in the Atlantic. An equivalent, albeit non-significant, interrelation is found for long-lived Pacific blocks and PNA positive-to-negative phase shifts (not shown).

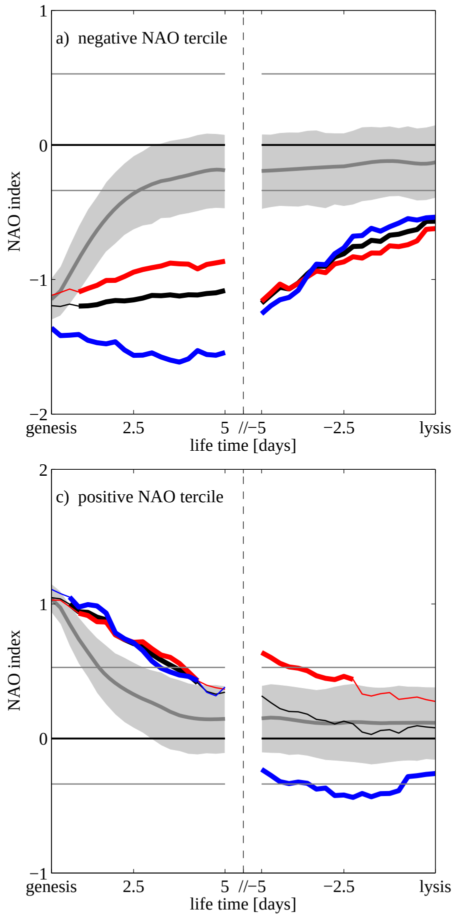

Figure 4: Evolution of the NAO index values for blocking events with onset in different pattern phases (index tercile boundaries indicated by the horizontal thin lines). In red only short (<10 days), in blue only long (≥10 days) and in black the total number of blocking events is considered. The mean randomized index evolution (1000 re-samplings) is indicated in bold grey and the grey shading indicates the corresponding 95% confidence interval. Significant different index evolutions from the randomized sample are indicated in bold. Note that the abscissa is split in a genesis (left) and lysis (right) phase.

The findings of this study emphasize the strong relation between atmospheric blocking and the dominant climate modes in both the Atlantic and Pacific basin and indicate a causal relationship in the North Atlantic. The potential of atmospheric blocking to establish in particular negative index phases can have considerable implications in relation to seasonal and climate model predictions. Misrepresentation of the blocking dynamics will have a considerable impact on the position, shape and life-times of the model variability patterns.

4. REFERENCES

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