Seasonality of the NAO

Diane H. Portis 1, 2, John E. Walsh 2, Mostafa El Hamly 1, 3, and Peter J. Lamb 1, 4

1 Cooperative Institute for Mesoscale Meteorological Studies, The University of Oklahoma, Norman, Oklahoma 73019
2 Department of Atmospheric Sciences, University of Illinois, Urbana, Illinois 61801
3 Moroccan Direction de la Météorologie Nationale -0.4
4 School of Meteorology, The University of Oklahoma, Norman, Oklahoma 73019

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Abstract

Monthly sea level pressure (SLP) data from the NCEP reanalysis for 1948-1999 were used to develop a seasonally and geographically varying “mobile” index of the North Atlantic Oscillation (NAOm). NAOm is defined as the difference between normalized SLP anomalies at the locations of maximum negative correlation between the subtropical and subpolar North Atlantic SLP. The subtropical nodal point migrates westward and slightly northward into the central North Atlantic from winter to summer. The NAOm index is robust across data sets, and correlates more highly than EOF coefficients with historical measures of westerly wind intensity across North Atlantic midlatitudes. As measured by this “mobile index”, the NAO’s nodes maintain their correlation from winter-to-summer to a greater degree than traditional NAO indices based on fixed stations in the eastern North Atlantic (Azores, Lisbon indices). When the NAOm index is extended back to 1873, its annual values during the late 1850s are strongly negatively correlated with official node indices. In contrast, after the mid-1950s, the values for different seasons sufficiently offset each other to make the annually-averaged excursions of NAOm smaller than those of winter-only indices. Global teleconnection fields show that the NAOm index is important for the winter NAO, particularly in the western North Atlantic, and adds to the utility of the NAO's nodes. The NAOm index shows some of the same spatial features as the NAO, but of smaller spatial scale than in late winter. The NAOm index is an important tool for understanding the seasonal and spatial changes in the NAO.

Seasonality of the NAO

The “mobile” subtropical high nodes are mainly clustered in the center of the Atlantic basin, with the exception of June and July (located over the Gulf Stream) and January (eastern Atlantic). There is a general southeast-to-northwest migration of the subtropical node from winter to summer, and a return from summer to winter, with the exception of southwestern excursions in February-March and especially November. The “mobile” subpolar and subtropical nodes undergo nearly “parallel” month-to-month displacements, so that their latitudinal separations remain generally constant. Sensitivity tests of the nodal locations were done by repeating the calculations for three other SLP data sets from 1958 onward and for two additional 40-year intervals: (1878-1917 and 1918-1957). The general conclusion of these sensitivity tests is that nodal NAOm locations are robust with respect to the SLP data source for a single period of 40-50 years, but that the location can change from one such period to another.

The monthly internode correlation plots indicate that the NAO signal weakness in February-March and especially November. The “mobile” NAO captures the winter NAO signal well, but only the NAOm captures the NAO signal for every calendar month.

Method

The framework we chose for a seasonally dependent NAO index was the identification of the NAO nodal locations that anchor coherent areas of maximum negative correlation of SLP in each calendar month. Two broad boxes encompassing potential nodal locations were selected. Both boxes spanned the same longitudinal range (70°W-0°), with the latitudinal range for the northern (southern) node being 55°N-80°N (20°N-45°N). For each calendar month, the SLP value at each grid point within the northern box was correlated with each grid point value in the southern box. The two most negatively correlated north-south points were selected as the NAO nodes for that calendar month. If more than one pair of nodes had similarly high negative correlations (i.e., the correlations differed by less than 0.05), the final selection criteria was proximity to the long-term monthly mean locations of the subpolar low and the subpolar high.

Validation of 2-Point NAO Index

While the internode correlation plot indicates that seasonal mobility is important in a two-point representation, this does not eliminate the possibility that a 2D pattern framework (e.g., EOF) may be required to capture the essence of NAO variations. We have tested the adequacy of our 2-point index (NAOm) by evaluating its ability to capture the North Atlantic surface westerly airflow. Specifically, we have computed the nodal NAOm, Rogers’ winter NAO index, and the EOF-based index maintained by NOAA's Climate Prediction Center with (i) Barry and Panoly's index of westwesterlies over the 35°N-55°N / 70°W-10°E region and (ii) a similarly westerly index used by H. Lamb. We conclude that at least for representations of the North Atlantic surface westerlies over the above domain, the EOF representation does not add to the utility of 2-point indices.

Temporal Variations

Applying the NAOm nodal locations developed from the NCEP reanalysis data set to the University of East Anglia (UEA) online data set, we constructed a low-frequency annual time series. The annual time series has a century-scale variation that began with a strong negative epoch in the 1870s-1880s, after which it was positive for an extended period (1900-1950s) before transitioning into a negative epoch in the 1960s. The latter was followed by an upward trend in the late 20th century. A variable feature of these low-frequency epochs is a coupling between the seasons that dominate the annual cycle (e.g. summer/autumn for the negative event of 1875-1885; winter/spring for the positive event of 1900-1914; autumn/winter for the negative event of the 1960s). A primary conclusion is that low-frequency variation of the NAOm has strong seasonal dependence. All seasons can significantly amplify or diminish the low-frequency annual values of NAOm.

Spatial Teleconnections of the NAO

Spatial correlations (1948-1997) of reanalysis SLP with the mobile NAO index and the winter based Hurrell (W4) index highlight the large-scale variability that each index represents. The comparisons are for March, May, July, and November since they particularly illustrate the seasonal differences in sign, strength, and associated teleconnections. The NAOm index, which has nodes mostly clustered in the central Atlantic basin, generally has correlation maxima in the center of the NAOm generally has correlation maxima along the eastern Atlantic rim. This is particularly evident in March. It is also noteworthy that the March subpolar NAOm node is the strongest and broadest of all calendar months and extends deep into the Arctic. In May, the NAOm exhibits a strong teleconnection to Mexico and the southwestern U.S., when a positive correlation feature is located over the area of the July-August “monsoon” of the U.S. Southwest, the interannual variability of this monsoon has been linked to the late spring circulation over Mexico and the southwestern U.S. In July, the NAOm has its significant nodal locations for the year, with a strong correlation dipole over the western Atlantic, but of smaller spatial scale than in late winter. The NAOm index has the same general character as in May, except that the November pattern does not include teleconnections with Mexico and the southwestern U.S.