A WAVELET APPROACH TO THE COMBINED EFFECTS OF THE NORTH ATLANTIC OSCILLATION AND ARCTIC OSCILLATION ON ARCTIC SEA ICE EXTENT

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Abstract

The goal of this study is to determine the effects of the North Atlantic Oscillation (NAO) and Arctic Oscillation (AO) on Arctic sea ice extent. Sea ice extent oscillates annually. Wavelet analysis was used to determine the frequencies that the NAO and the AO oscillate at. Results show that the AO will lead changes in the NAO and the AO has a stronger effect on sea ice extent than the NAO because of this relationship. The AO and NAO were very strongly correlated for a period of about 20 years where they shared a 3 year oscillation period. They became decoupled in 2005 and the 2007 sea ice minimum may have resulted from the decoupling. A local sea ice minimum occurred every 5 years, which wavelet analysis did not indicate. This period suggests a relationship to El Niño-Southern Oscillation . It is very likely that ENSO affects sea ice extent, but sea ice extent should follow the AO and NAO more closely than ENSO.

Background and Methods

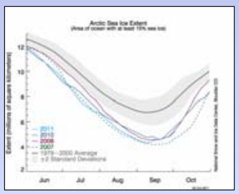

Figure 1. Late Summer Arctic sea ice extent from 2007 to October 2011 (NSIDC, 2011).

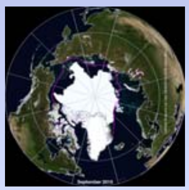

Figure 2. Arctic sea ice extent, September, 2010 compared to long-term mean (NSIDC/NASA Earth Observatory, 2012).

Arctic Sea Ice extent oscillates seasonally between a winter maximum and a late summer minimum. Since 1979 late summer sea ice extent by over 40% with record lows in 2007, 2008, 2010, and 2011 (**Fig. 1 & 2**). Previous studies have shown both NAO and AO (**Fig. 3 & 4**) can influence Arctic sea ice extent (Ambaum et al., 2001)

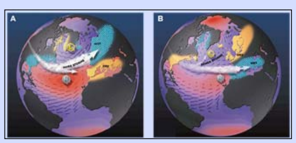

Figure 3. Position of air masses, circulation, and regional weather associated with: (**A**) Positive NAO phase and (**B**) Negative NAO phase (Modified from Bell and Visbeck, 2010).

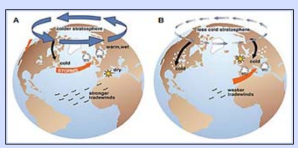

Figure 4. Position of air masses, circulation, and regional weather associated with: (**A**) Positive AO phase and (**B**) Negative AO phase (NSIDC, from J. Wallace, Univ. of Wash., 2010).

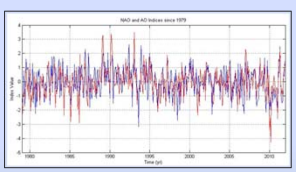

Figure 5. Time series of AO and NAO indices. The red curve is AO index and the blue curve is NAO index (generated from NWSCPC ,2011 monthly NAO/AO index data)

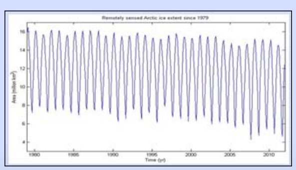

Figure 6. Time series of remotely sensed Arctic sea ice extent (generated from the Arctic sea ice data downloaded from the University of Washing Polar Science Center, 2011).

In order to determine the frequency and potential climate effects of the NAO and AO on Arctic sea ice extent, a mathematical method was used. The NAO Index and the AO Index (**Fig. 5**) were compared to monthly Arctic sea ice extent (**Fig. 6**) using wavelet analysis in an attempt to reveal trends, and draw a connection to Arctic climate, potentially to predict future changes in Arctic sea ice extent.

Results and Discussion

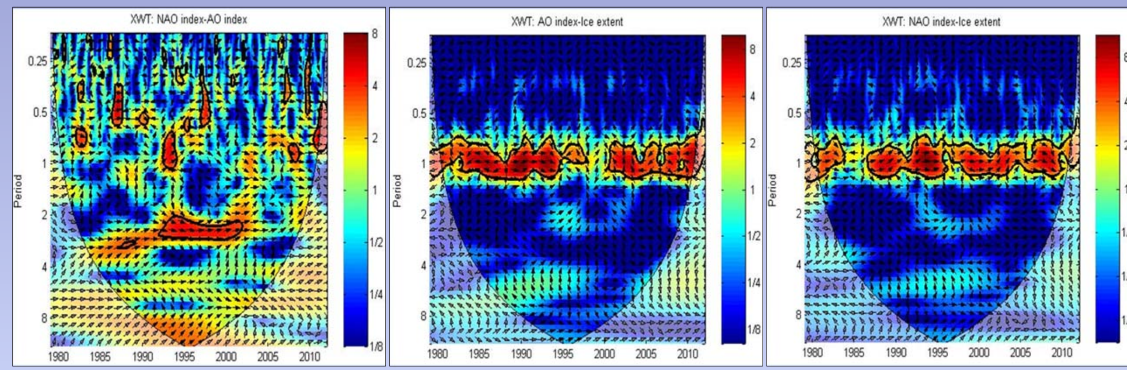

Figure 7. Cross wavelet transform (XWT) of NAO and AO indices, AO and Ice Extent, and NAO and ice extent.

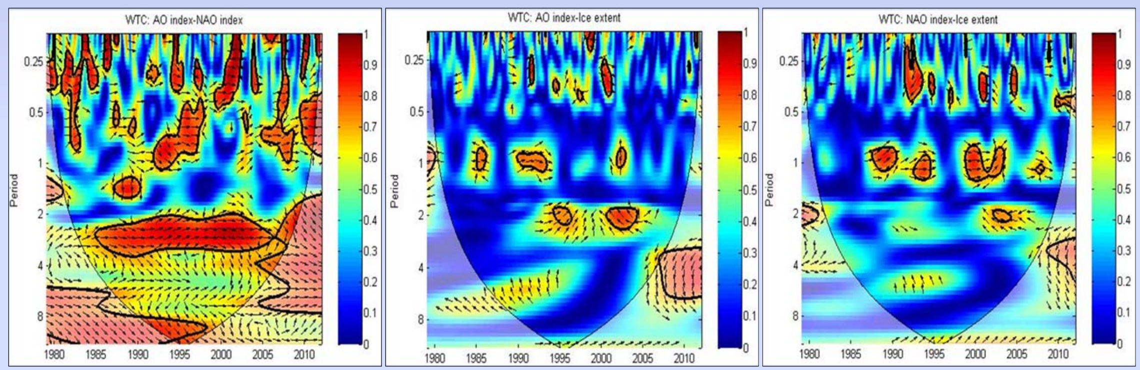

Figure 8. Cross Wavelet Transform Coherence Test (WTC) of NAO and AO indices, AO and Ice Extent, and NAO and ice extent.

The NAO and AO index cross wavelet transform (**Fig. 7; left**) is confirmed the AO and NAO index wavelet coherence test (**Fig. 8, left**). As well, the NAO and Sea ice extent cross wavelet (**Fig. 7; right**) and AO and Sea ice cross wavelets (**Fig. 7; right**) are confirmed by their associated coherence tests (**Fig. 8 right and middle, respectively**). Theses wavelet transforms show that the AO and NAO shared a common oscillation of a 3 year period until about 2001. The arrow direction on the NAO and AO cross wavelet transform (**Fig. 7, left**) suggests that the AO dominates the relationship between the two oscillations. This assertion makes sense because the AO would affect the Polar Front Jet (PFJ) before it reaches the North Atlantic. As a result the PFJ may become either more meridional or more zonal depending on the strength and phase of the AO (**Fig. 4**). Arctic sea ice extent appears to reach a local minimum approximately every 5 years (**Fig. 6**). During these years, the three cross wavelet transforms show deviations (**Fig. 7**). This 5 year local extreme sea ice minimum period suggests a relationship to El-Niño Southern Oscillation (ENSO) and in fact these minimums correspond to El-Niño years. Wavelet analysis in this study did not indicate this relationship explicitly. Further study should be conducted to determine ENSO relationship to the AO, NAO, and Arctic sea ice extent.

Conclusions

The cross wavelet transforms show that the NAO and AO were strongly coupled for a period of ~20 years. During this time the phase of the AO leads the phase of the NAO. Beginning in 2001 the AO and NAO begin to decouple; rapid decoupling occurred in 2005. The record sea ice minimum in 2007 may have resulted from the decoupling of the NAO and AO. Results also show that ENSO may influence Arctic sea ice extent and NAO and AO do not affect sea ice the same during an El Niño event. It is not apparent from the results that ENSO has a direct effect on the NAO or AO. This implies that, compared to ENSO, the NAO and the AO dominate the effects on sea ice extent. This study serves as a jumping off point for further analysis using wavelets analysis to research Arctic climate scenarios.