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The AO-Index, what can it tell us?

by

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Abstract

A climate index, the Arctic Oscillation (AO_i) Index, was presented to NAFO STACFEN. The AO is a natural pattern of climate variability. It consists of opposing patterns of atmospheric pressure between the polar regions and middle latitudes. The **positive** phase of the AO exists when pressures are lower than normal over the Arctic, and higher than normal in middle latitude. In the **negative** phase, the opposite is true; pressures are higher than normal over the Arctic and lower than normal in middle latitudes. The long-term mean of AO_i indicates a significant positive trend ($r^2=0.34$, $p < 0.001$). The negative and positive phases of the AO set up opposing temperature patterns. A record negative AO_i during winter 2009/2010 led to warmer than usual air temperatures over the Arctic Ocean and cooler than normal temperatures over central Eurasia, the United States and southwestern Canada.

Introduction

Back in 1996, the NAFO Standing Committee on Fisheries Environment (STACFEN) during its June meeting started the discussion of potential impacts of climate on the distribution of water masses and fish in the Northwest Atlantic Region. Being quite recent findings in those times, Newell (1996) identified a link between sea-ice clearing dates off the coast of Labrador and the Southern Oscillation. He found that in recent decades (1951-1984) low values of the Southern Oscillation Index (SOI) during the September to May period are associated with earlier than normal sea-ice clearing dates in the western Labrador Sea. Conversely, high values of the SOI during the same period lead to later clearing dates. Newell (1996) proposed that this relationship is a result of the SOI influencing sea-level pressure patterns over the north-west Atlantic which subsequently influence sea-ice clearing dates off Labrador.

Further evidence was given in those times by Wohlleben and Weaver (1995) on the statistical relationships between various components of the subpolar North Atlantic air-sea-ice climate system. They examined data in order to investigate potential processes involved in interdecadal climate variability. They found that sea surface temperature anomalies concentrated in the Labrador Sea region, have a strong impact upon atmospheric sea level pressure anomalies over Greenland, which in turn influence the transport of freshwater and ice anomalies out of the Arctic Ocean, via Fram Strait. These freshwater and ice anomalies are advected around the Subpolar Gyre into the Labrador Sea affecting convection and the formation of Labrador Sea Water. This has an impact upon the transport of North Atlantic Current water into the subpolar gyre and thus, also upon sea surface temperatures in the region.
Wohlleben and Weaver (1995) proposed an interdecadal negative feedback loop as an internal source of climate variability within the subpolar North Atlantic. They found time scales for one cycle of this feedback loop to have a period of about 21 years.

Finally, STACFEN recognized during its June 1996 meeting that the North Atlantic Oscillation (NAO_i) index which represents the sea level pressure difference between Iceland and the Azores explains largely the hemispheric conditions in the North Atlantic Ocean (Stein, 1996).

During the 2010 STACFEN meeting, the Arctic Oscillation (AO_i) index was presented to the Committee as a potential further indicator of climate variability. The AO is a natural pattern of climate variability. It consists of opposing patterns of atmospheric pressure between the polar regions and middle latitudes. The **positive** phase of the AO exists when pressures are lower than normal over the Arctic, and higher than normal in middle latitude. In the **negative** phase, the opposite is true; pressures are higher than normal over the Arctic and lower than normal in middle latitudes.

The negative and positive phases of the AO set up opposing temperature patterns (NOAA, 2010). With the AO in its negative phase this season (winter 2009/2010), the Arctic is warmer than average, while parts of the middle latitudes are colder than normal. The phase of the AO also affects patterns of precipitation, especially over Europe.
The phase of the AO is described in terms of an index value. In December 2009, the AO_i was **-3.41**, one of the most negative values since at least 1950, according to data from the NOAA Climate Prediction Center. While a negative AO leads to warmer temperatures over the Arctic, it also tends to reduce the flow of sea ice out of the Arctic by affecting the winds that can export the ice to warmer waters, where it melts. In this way, a negative AO could help retain some the second- and third-year ice through the winter, and potentially rebuild some of the older, multiyear ice that has been lost over the past few years.

Data and Methods

According to NOAA (2010), the daily AO index is constructed by projecting the daily (00Z) 1000mb height anomalies poleward of 20°N onto the loading pattern of the AO**.** The loading pattern of the AO is defined as the leading mode of Empirical Orthogonal Function (EOF) analysis of monthly mean 1000mb height during 1979-2000 period. Year-round monthly mean anomaly data have been used to obtain the loading pattern of the AO. To identify the leading teleconnection patterns in the atmospheric circulation, Emperical Orthogonal Function (EOF) was applied to the monthly mean 1000-hPa (700-hPa) height anomalies poleward of 20° latitude for the Northern (Southern) Hemisphere. The leading EOF modes capture the maximum amount of explained variance. The NCEP/NCAR reanalysis dataset was employed at a horizontal resolution of (lat,lon)=(2.5°X2.5°) for the period 1979 to 2000. The seasonal cycle has been removed from the monthly mean height field. The covariance matrix is used for the EOF analysis. To ensure equal area weighting for the covariance matrix, the gridded data is weighted by the square root of the cosine of latitude. Since the AO has the largest variability during the cold season, the loading patterns primarily capture characteristics of the cold season patterns.

Results and Discussion

Fig. 1a,b reveals that monthly values of AOi mostly vary between +2 and -2. The long-term mean indicates a significant positive trend ($r^2=0.34$, $p < 0.001$), and the 1950s to mid-1970s were characterized by negative AOi . Most of the 1980s again had negative AOi , while at the end of this decade, positive values were seen which pertained until the mid-1990s. Since then, the AOi is about normal. Negative extremes were encountered during JAN 1963, JAN 1966, FEB 1969, JAN 1977, FEB 1978 and DEC 2009.

The sea level pressure (mb) anomalies as given in Figs. 2 to 6, indicate the **negative** phase of the Arctic Oscillation for the negative extremes given in Fig. 1: Pressures are higher than normal over the Arctic and lower than normal in middle latitudes. As can be seen from the December 2009 situation, this leads to the anomalous air temperature conditions given in Fig. 7.

Fig. 7 shows air temperature anomalies for December 2009, at the 925 millibar level (roughly 1,000 meters [3,000 feet] above the surface) for the region north of 30°N. Warmer than usual temperatures prevail over the Arctic Ocean and cooler than normal temperatures over central Eurasia, the United States and southwestern Canada. Areas in orange and red correspond to strong positive (warm) anomalies. Areas in blue and purple correspond to negative (cool) anomalies.

References

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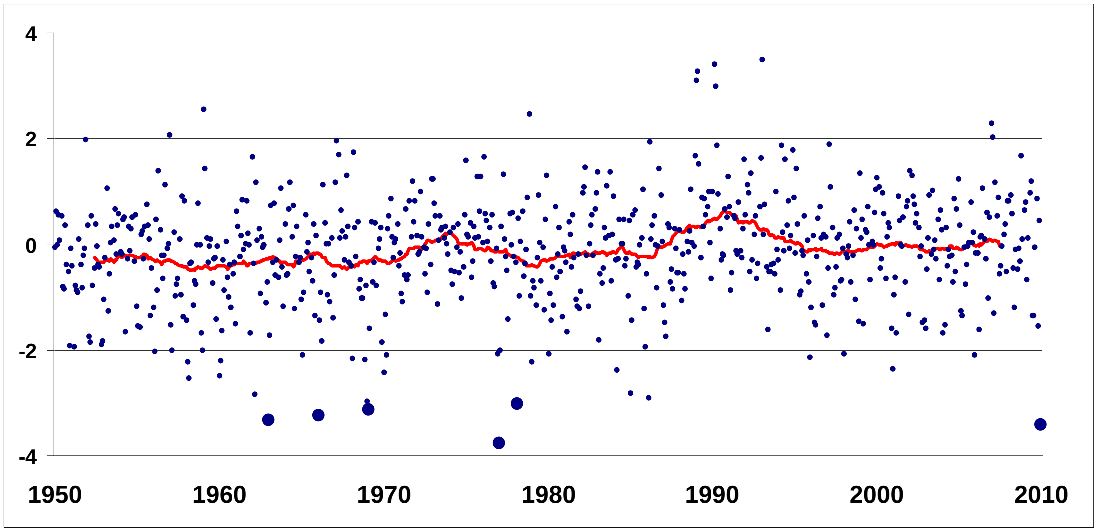

Fig. 1(a) Monthly values of AOi (data: 1950-2009) dots and 5 yr running mean (red line); bold dots indicate negative extremes during JAN 1963, JAN 1966, FEB 1969, JAN 1977, FEB 1978 and DEC 2009

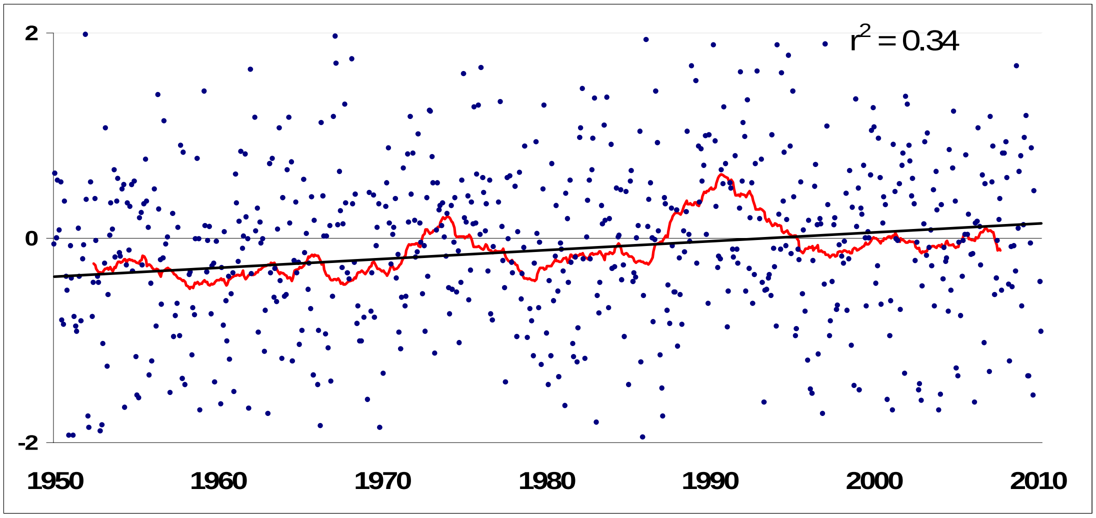

Fig. 1(b) Zoom of Fig. 1(a): Monthly values of AOi (data: 1950-2009) dots and 5 yr running mean (red line); linear trend of mean added

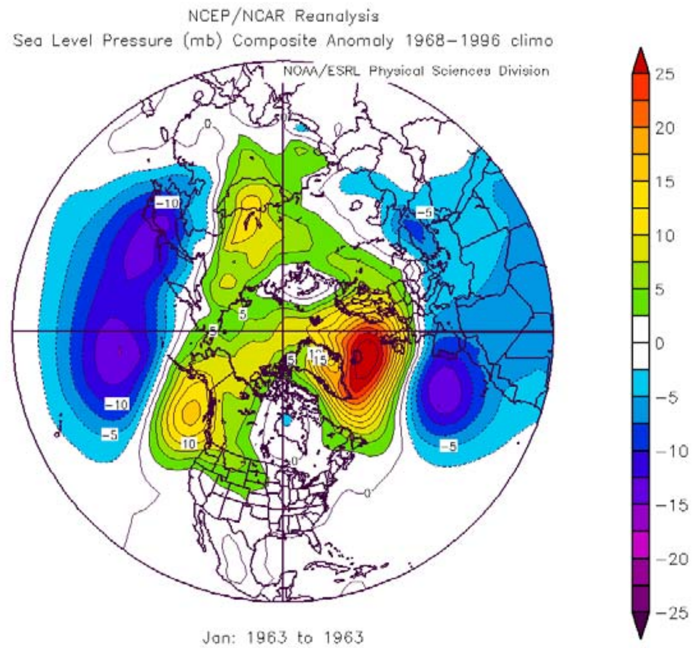

Fig. 2 Sea Level Pressure (mb) Composite Anomaly (rel. 1968-1996) JAN 1963.

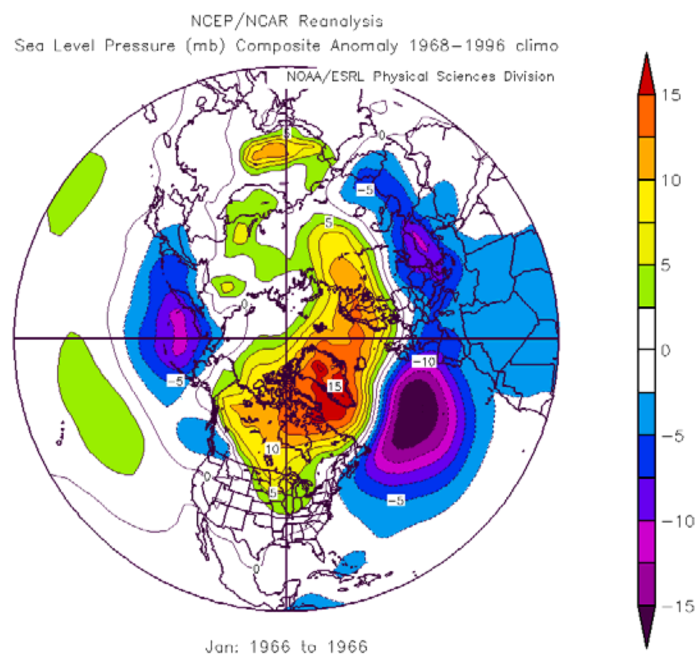

Fig. 3 Sea Level Pressure (mb) Composite Anomaly (rel. 1968-1996) JAN 1966.

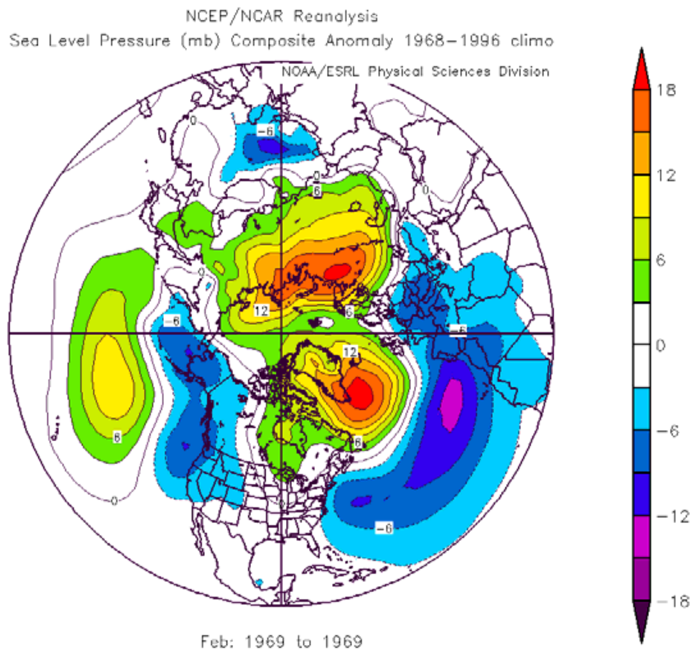

Fig. 4 Sea Level Pressure (mb) Composite Anomaly (rel. 1968-1996) FEB 1969.

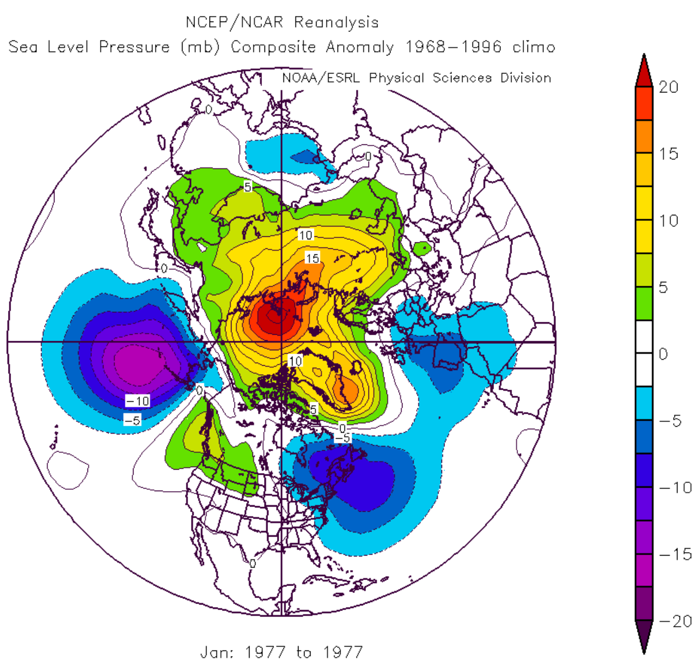

Fig. 5 Sea Level Pressure (mb) Composite Anomaly (rel. 1968-1996) JAN 1977.

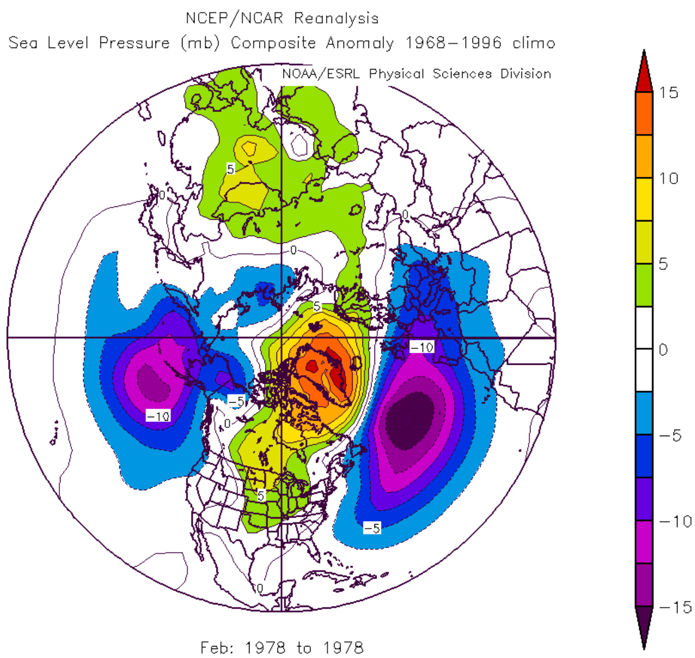

Fig. 5 Sea Level Pressure (mb) Composite Anomaly (rel. 1968-1996) FEB 1978.

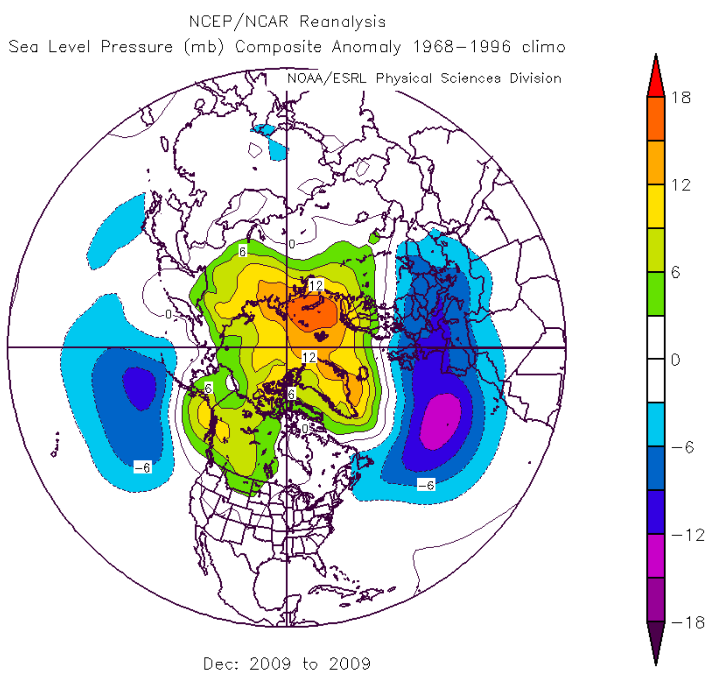

Fig. 6 Sea Level Pressure (mb) Composite Anomaly (rel. 1968-1996) DEC 2009.

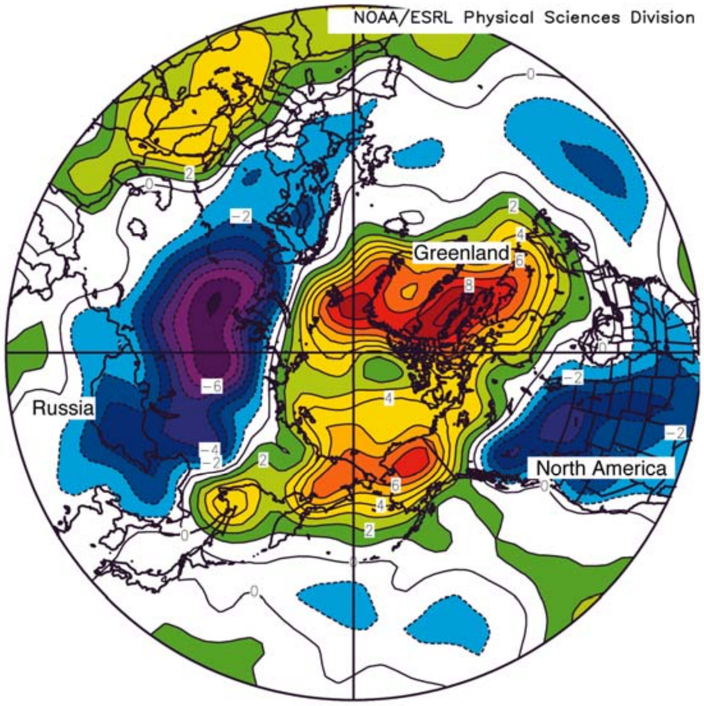

Fig. 7 Average Air Temperature Anomaly DEC 2009 (courtesy NOAA/ESRL Physical Sciences Division)