On the Relationship Between ENSO, the NAO, the PNA and Anomalous Spring Ice Cover in Hudson Bay

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SUMMARY

Motivated by the need for more detailed and accurate seasonal forecasts of spring break-up in Hudson Bay, low frequency modes of winter atmospheric variability are linked to anomalous spring ice conditions. Over the period 1972-2002, the three simultaneous El Nino and positive NAO events of 72/73, 82/83, 91/92 preceded high ice years, as documented by Mysak et al. (1996). The strongest El Nino episode of 97/98 preceded the lowest ice year on record; and the weakest PNA event of 71/72 preceded the highest ice year on record. Composites of winter (NDJFM) averaged northern hemisphere 500mb height anomalies illustrate the features of these winter modes over the Hudson Bay region. Inferred near-surface winds and the position of the polar front suggests a link between dominant modes of large-scale winter atmospheric variability and spring ice severity in Hudson Bay that can be exploited to improve seasonal forecasts.

Spring Ice Severity in Hudson Bay 1972-2002

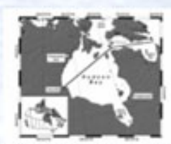
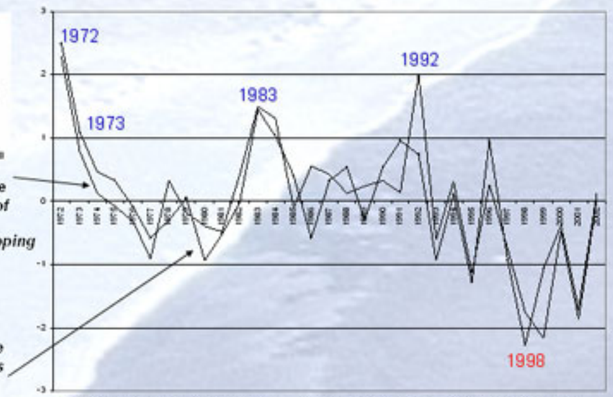


Figure 2. Open Water Route to Churchill (solid line: Hudson Strait)



The OWRC is defined as the date when a stable region of open water 20 miles wide develops in across the shipping region (Figure 2)

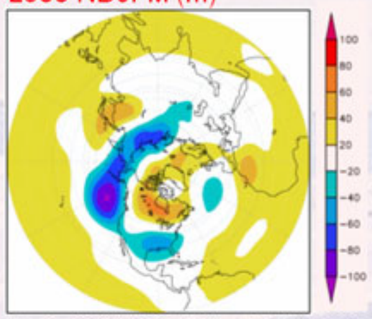
Spring TAC (the sum of the weekly ice coverage values over the 12 week season

Figure 1. Standardized time-series of the spring TAC (light black line) and the Open Water Route to Churchill (dark black line)

The severity of the ice season in Hudson Bay during spring break-up (June 25 – September 10) is represented by standardized values of: **(a) the 'total accumulated ice coverage' (TAC),** a robust seasonal sea ice parameter (Crocker, 2000), and **(b) the Open Water Route to Churchill (OWRC),** the date that marks the beginning of the shipping season and is the parameter currently forecasted by the Canadian Ice Service (FIGURES 1 and 2)

El Nino Event: '98

z500 NDJFM (m)

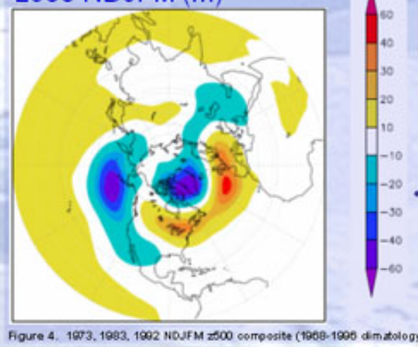


- pattern strongly resembles El Nino composite (Figure 10)
- anomalous high heights over Hudson Bay weakens westerlies and reflects a more northerly position of the polar front

Figure 3. 1998 NDJFM 500mb height anomaly field (1968-1996 climatology)

El Nino/NAO Events: '73, '83, '92

z500 NDJFM (m)

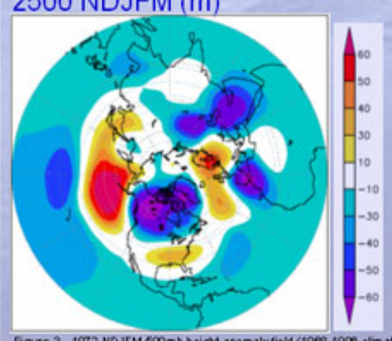


- NAO pattern over the North Atlantic; anomalous region of high heights over central Canada associated with El Nino is shifted south
- anomalous north-westerlies over the Hudson Bay region increases dynamic and thermodynamic ice growth

Figure 4. 1973, 1983, 1992 NDJFM z500 composite (1968-1996 climatology)

PNA Event: '72

z500 NDJFM (m)



- negative PNA pattern dominates
- anomalous low heights (opposite to 1998) reflects a more southerly position of the polar front

Figure 3. 1972 NDJFM 500mb height anomaly field (1968-1996 climatology)

ArcticNet

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ENSO, NAO & PNA: 1972-2002

(a) PNA

Figure 6. Loading pattern of the North Atlantic Oscillation (NAO), derived from EOF analysis of monthly mean 500mb height (1950-2000). Figure from NOAA/CPC

- positive PNA index phase features anomalous high heights over the Aleutian islands and southeastern U.S. and anomalous low heights over Hawaii and central Canada
- 1972: strongest negative index

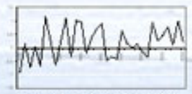


Figure 7. Time-series of NDJFM averaged PNA index. Data from NOAA/CPC

(b) NAO

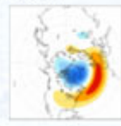


Figure 8. Loading pattern of the North Atlantic Oscillation (NAO), derived from EOF analysis of monthly mean 500mb height (1950-2000). Figure from NOAA/CPC

- positive NAO index phase features a stronger than normal subtropical high pressure center and a n intensified Icelandic low
- 1973, 1983, 1992: positive NAO
- 1998: neutral NAO

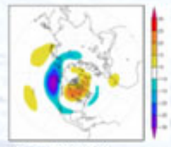
Figure 9. Time-series of NDJFM averaged NAO index. Data from NOAA/CPC.

(c) ENSO

YEAR	NDJ	DJF	JFM
1972	-0.5	-0.7	-0.7
1973	0.1	1.4	1.2
1974	-.2	1.0	1.5
1975	-0.7	-0.5	-0.5
1976	-1.4	-1.5	-1.2
1977	0.8	0.5	0.3
1978	0.8	0.7	0.4
1979	0.1	0.1	0
1980	0.1	0.1	0.1
1981	0.1	0.3	0.4
1982	0.3	0	0.1
1983	2.3	2.1	2
1984	-0.4	-0.3	-0.3
1985	-1.1	-1	-0.8
1986	0.3	0.4	0.4
1987	1.2	1.1	1.2
1988	1.1	0.8	0.5
1989	-1.0	-1.2	-1.3
1990	0.1	0.1	0.2
1991	0.4	0.5	0.6
1992	1.7	1.6	1.7
1993	0.1	0.3	0.4
1994	0.2	0.2	0.1
1995	1.3	1.2	0.9
1996	-0.8	-0.8	-0.7
1997	0.4	0.4	0.3
1998	2.5	2.4	2
1999	-1.1	-1.0	-1.2
2000	-1.0	-1.0	-1.0
2001	-0.7	-0.7	-0.5
2002	0.2	0.1	0.1

Table 1. Cold and Warm ENSO Episodes by Season. Warm (red) and cold (blue) based on a threshold of +/- 0.5C for SST anomalies in the Niño 3.4 region. Source: Climate Prediction Center, National Weather Service (NOAA)

Strongest El Nino Events: 72/73; 82/83; 91/92; 97/98



- 500mb heights anomaly features anomalous low heights over the northeast Pacific and anomalous high heights over central Canada

Figure 10. 500mb geopotential height (m) composite for El Nino events: 1958, 1966, 1969, 1973, 1977, 1983, 1987, 1988, 1992, 1995, 1998, 2003; using 1968-1996 climatology

The PNA and NAO are the dominant patterns of large-scale atmospheric variability over the Pacific basin/North America and the Atlantic basin/Europe, respectively. The El Nino Southern Oscillation is the leading model of global inter-annual climate variability.

Proposed Forecasting Tool

At the end of March, a spring/summer sea ice forecast can be made based on NDJFM averaged indices of the PNA, NAO and ENSO.
(a) coincident strong El Nino and positive NAO: heavy ice conditions
(b) strong El Nino and neutral NAO: light ice conditions
(c) strong negative PNA: heavy ice conditions

DATA SOURCES

Sea ice data is from the Canadian Ice Service Digital Ice Chart Database (Crocker, 2000) and is publicly available from Environment Canada. For the spring break-up period in Hudson Bay (June 25 to September 10) weekly ice charts are available beginning in 1972.

Northern hemisphere 500mb height anomalies are calculated from the NCEP/NCAR reanalysis: data (1950-present, 2.5-degree grid, Kalnay et al., 1996) using a 1968-1996 climatology.

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