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Review

ENSO-LIKE PERIODICITIES IN THE ARCTIC CRYOSPHERE

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Abstract: Attempts have been made to associate periodicities of interannual variations in the Arctic cryosphere with periodic phenomena occurring in other regions of the world such as the cycle of El Niño Southern Oscillation (ENSO). ENSO-like periodicities are recognized in interannual variations of sea-ice extent in subarctic seas and of net mass balance of glaciers in the Arctic. A large-scale seesaw phenomenon is found between two groups of subarctic seas separated by a line drawn from the Kamchatka Peninsula to the southernmost cape of Greenland. The net mass balances of two glaciers in Svalbard have a similar cycle in interannual variations with the ENSO cycle. It is noticeable that there is an apparent correlation involving four major ENSO events and little time-lag between the year of less net mass balance of glaciers in Svalbard and the ENSO year.

1. Introduction

The Arctic is considered as one of the most sensitive and early responsive regions of global climatic changes in the world. Results of GCM simulation predict that the most apparent enhancement of global warming will occur in the Arctic (Wetherald and Manabe, 1986). However, amplitudes of long-term and year-to-year variations of zonal-mean temperature in the northern hemisphere increase with increasing latitude in both temperatures observed at weather stations and computed by a global atmosphere-ocean model (WMO-ICSU, 1990). If a weak sign of global warming appears in the Arctic, it will be difficult to find in the surface air temperature because of masking by large noise of the year-to-year fluctuation.

As the mass balance of the cryosphere (snow and ice) reflects the integral of changing air temperature, it is expected that interannual variations of the Arctic cryosphere will reveal a trend of global change, if it exists, more clearly than those of surface air temperature.

An examination was carried out to associate periodicities of year-to-year variations in the Arctic cryosphere with periodic phenomena observed in other parts of the world such as the cycle of El Niño Southern Oscillation (ENSO). An apparent correlation is recognized between the variation of net mass balance of Arctic glaciers and the ENSO cycle.

2. ENSO Cycle in Year-to-year Variations

ENSO is a phenomenon which was first discovered in the tropical Pacific. About once in several years, the prevailing trade winds weaken so that warm surface waters, which are normally driven westward by the winds, move eastward to overlie the cold waters of the Peru Current mostly in winter near the Christmas season. The spatial mean sea surface temperature (SST) in the quadrilateral bounded by 4°N and 4°S, 150°W and 90°W is taken as an index of El Niño, called Niño-3. The Southern Oscillation is a fluctuation of inter-tropical atmospheric circulation which is strongly linked to El Niño. An indicator of the Southern Oscillation is the difference of sea level atmospheric pressures between Tahiti and Darwin, Australia, and is called the Southern Oscillation Index (SOI). Year-to-year changes of ENSO indices, the Niño-3 SST and the SOI, are shown in Fig. 1 (1950–1988), and later in Fig. 4 (1966–1994).

Apparent ENSO events occurred in 1972–73, 1976–77, 1982–83, 1986–87 and 1991–93, indicated as a large positive anomaly of Niño-3 SST and a large negative anomaly of SOI.

3. Large Scale Oscillations of Winter Maximum Sea-ice Extent in Subarctic Seas

An attempt was made by Niebauer (1988) to examine the relations among ENSO, the north Pacific weather patterns and interannual variability of sea-ice extent in the Bering Sea. However, he did not find a strong correlation between ENSO indices and

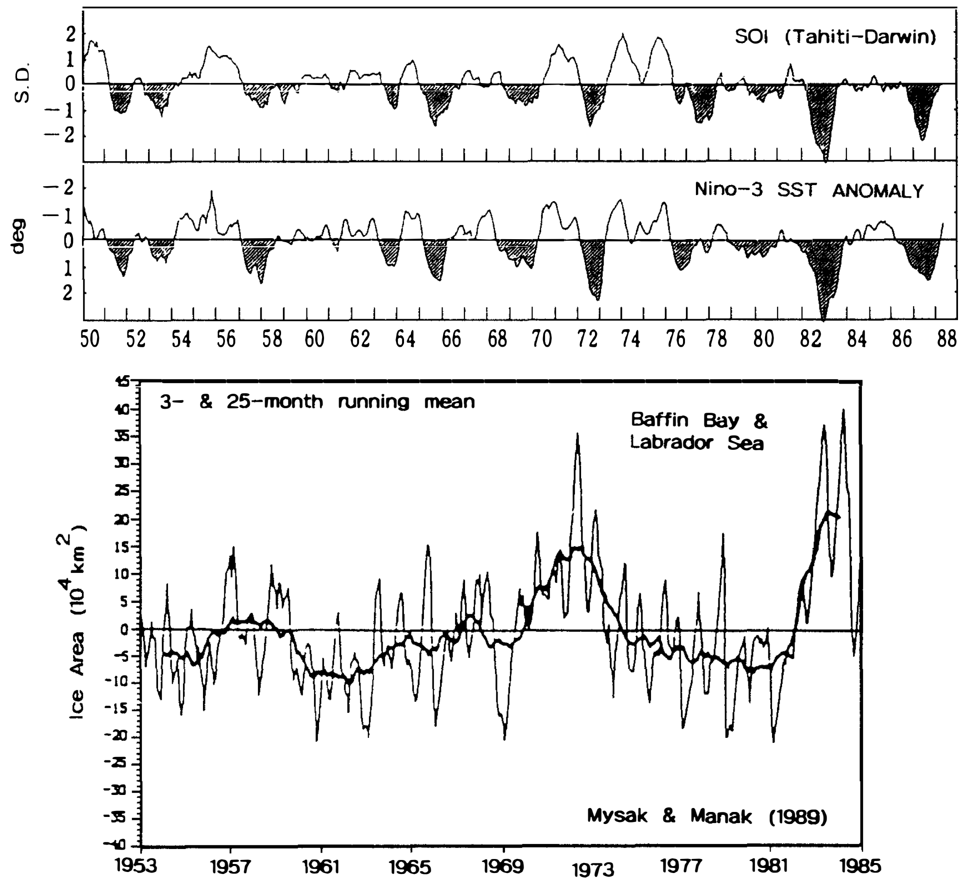

Fig. 1. Sea-ice area anomaly in Baffin Bay and Labrador Sea (after Mysak and Manak, 1989) compared with ENSO indices, the SOI and the Niño-3 SST anomaly.

parameters in the Bering Sea, such as ice cover, sea surface temperature, air temperature, the Aleutian Low Index and the North American Index. Recently GLOERSEN (1995) showed statistically significant quasi-biennial and quasi-quadrennial periodicities of the Arctic and Antarctic sea-ice cover that agree well with variations in ENSO indices.

MYSAK and MANAK (1989) studied interannual variabilities of Arctic sea-ice extent over the 32-year period 1953–84. They showed 3- and 25-month running mean anomalies of ice extent in the Bering Sea, Beaufort and Chukchi Seas, Hudson Bay, Baffin Bay and Labrador Sea, Greenland Sea, Barents and Kara Seas, and East Siberian and Laptev Seas. They found that the anomaly fluctuation varies from region to region and exhibits an approximately 4–6 year cycle in the western Arctic. They described the very strong ENSO event of 1982–83, however, they did not find that the fluctuation of ice extent of any subarctic sea was linked with the ENSO cycle.

ONO (1993a) pointed out that there is a correspondence between interannual fluctuation of sea-ice extent in Baffin Bay and the Labrador Sea, shown as a figure by MYSAK and MANAK (1989), and variations of ENSO indices, as illustrated in Fig. 1. In the strong ENSO years 1972–73 and 1982–83, apparent increases of ice extent are recognized in Baffin Bay and the Labrador Sea. Some peaks of the 3-month running mean correspond to weak ENSO events such as 1956–58, 1963, 1965, 1976 and 1979.

ONO (1993b) found that interannual variations of winter maximum ice extent in each subarctic sea can be classified into three groups using SMMR data from 1979 to 1987, as shown in Fig. 2. The Arctic Ocean, Canadian Arctic and Hudson Bay are completely covered with ice every winter. The Barents, Greenland and Okhotsk Seas had

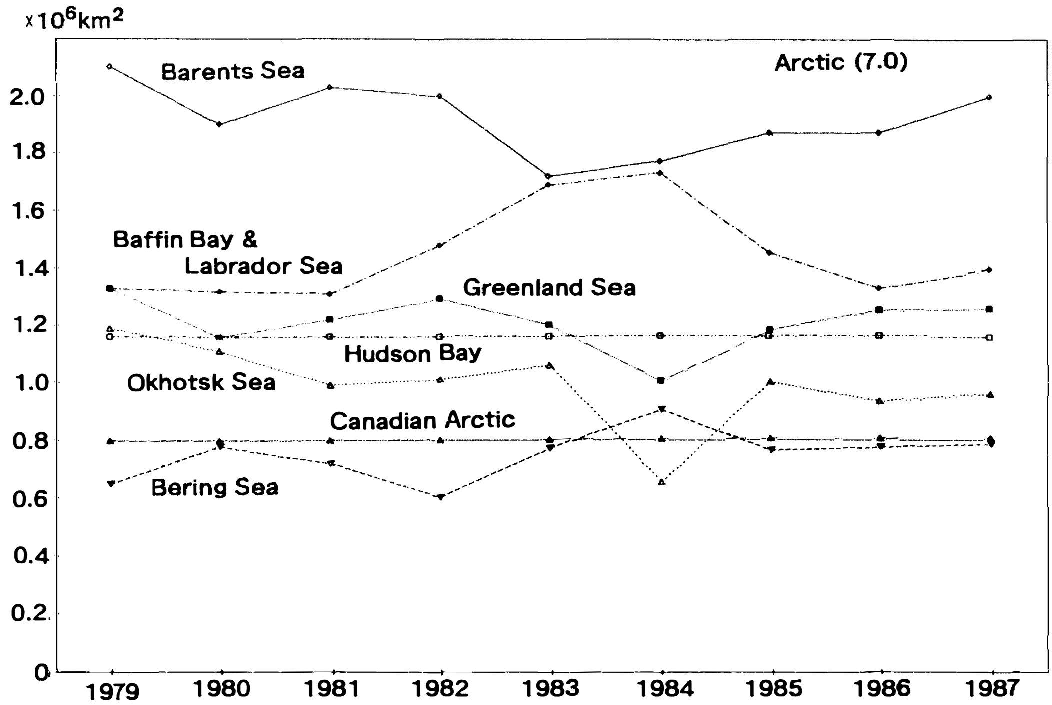

Fig. 2. Year-to-year variations of maximum sea-ice extent of each frozen sea in the northern hemisphere. The Arctic Ocean is completely covered with ice every year and has an area of 7.0×10^6 km^2.

Fig. 3. A large-scale seesaw found between the maximum sea-ice extent of 1979 and of 1984.

large ice extent in 1979 and small extent in 1984, and conversely the Baffin Bay-Labrador Sea and Bering Sea had small extent in 1979 and large extent in 1984. These two groups of subarctic seas are separated by a line drawn from Kamchatka to the southernmost cape of Greenland, as shown in Fig. 3. The same seesaw features are obtained in combinations of 1973/1976 and 1989/1991.

The seesaw sea-ice extent in the northern hemisphere has an uncertain periodicity of several years. The seesaw makes the interannual variation of the whole ice extent in the northern hemisphere smaller than that of each subarctic sea. It is therefore expected that a large anomaly of sea-ice extent in some subarctic sea is useful for a detector of global climate change.

An attempt was made to relate the ice extent anomaly in the Barents Sea to the ENSO cycle. Seasonal maximum ice extent in the Barents Sea appears smaller in winter after a strong ENSO. It seems reasonable that if the Gulf Stream transports additional heat into the Barents Sea in an ENSO period, the ice extent in the Barents Sea decreases the next winter.

4. ENSO-like Periodicity in the Mass Balance of Arctic Glaciers

It is well known that small glaciers in the northern hemisphere have been shrinking during the past hundred years. The growth or retreat of a glacier is related sensitively to climatic conditions, so features of glaciers may serve as climate change indicators.

The Arctic Environment Research Center of the National Institute of Polar Research started field observations at Ny-Ålesund, Svalbard in 1991, under a cooperative research agreement with the Norwegian Polar Research Institute (NP). Two glaciers near Ny-Ålesund named Austre Brøggerbreen and Midtre Lovenbreen have been studied by the NP's glaciology group for more than 20 years. Sizes of the glaciers are about 8 by 4 km for the Austre Brøgger glacier and about 3.5 by 1.5 km for the Midtre Loven glacier. HAGEN and RIESTEL (1990) and LEFAUCONNIER and HAGEN (1990) showed interannual variations of the mass balance of these glaciers and pointed out that the prevailing negative mass balance, that means melting of the glaciers, has decreased as a long-term trend, that is in the opposite sense expected from global warming.

Their data have a large year-to-year fluctuation around this long-term trend of decreasing negative mass balance. ONO (1995) pointed out that good correspondence is recognized between the fluctuation of net mass balance and the variation of ENSO indices. As shown in Fig. 4 for Austre Brøgger and Midtre Loven glaciers, the fluctuation of the yearly net mass balance bn, including the recent data provided by Dr. HAGEN, shows

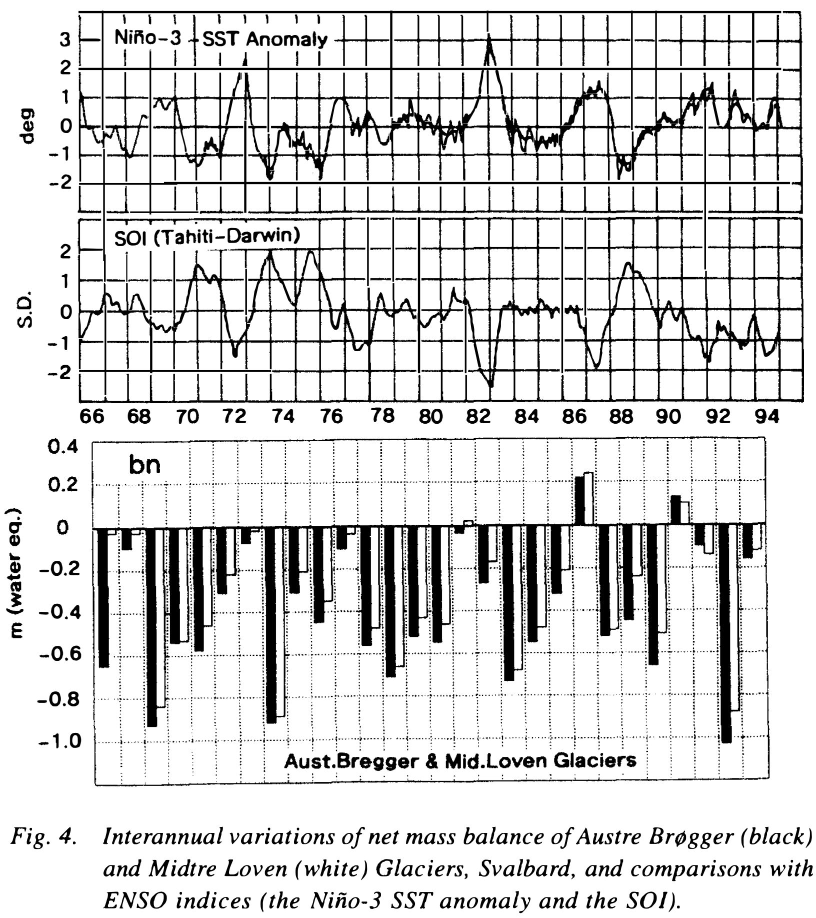

Fig. 4. Interannual variations of net mass balance of Austre Brøgger (black) and Midtre Loven (white) Glaciers, Svalbard, and comparisons with ENSO indices (the Niño-3 SST anomaly and the SOI).

an apparent correlation involving four major ENSO events with little time-lag between the year of less net mass balance of these glaciers and the ENSO year. According to the original data set, the interannual variation of winter precipitation **bw** has only a small anomaly compared with that of summer melting **bs**, and then the annual net mass balance **bn** depends more on the variation of summer melting **bs**.

It is expected from Fig. 4 that in an ENSO year less melting or a cool summer will appear in Svalbard. This result suggests that ENSO-cycle phenomena occur not only in the tropics but also in the Arctic through some global-scale atmospheric oscillation.

5. Conclusions

A large scale seesaw in the winter maximum sea-ice extent in the northern hemisphere is recognized between two groups of subarctic seas separated by a line between the Kamchatka Peninsula and the southernmost cape of Greenland.

Significant relationships are found between interannual variations in the Arctic cryosphere and the ENSO cycle. ENSO is a remarkable phenomenon in the tropics recognized in both the atmosphere and the ocean as interannual and decadal time scale variations. ENSO-related phenomena appear in the interannual variability of sea-ice extent in some subarctic seas, and in the mass balance of glaciers in Svalbard.

Moreover, unlike the anomaly of sea-ice extent in the subarctic seas, there is little lag between the periodicity of net mass balance of some Arctic glaciers and the ENSO cycle. This result suggests that the ENSO-cycle phenomenon is not only initiated from the tropics, but also started in the Arctic through some global-scale atmospheric oscillation.

We will continue to investigate the global scale ENSO phenomenon and their predictability, in parallel with global warming.

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