

SEASONAL AND REGIONAL PERSPECTIVES OF ARCTIC SEA ICE OSCILLATION: WAVELET ANALYSIS

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Abstract

Variability of the sea-ice cover (extent) in the Northern Hemisphere (Arctic and subpolar regions) associated with AO (Arctic Oscillation) is investigated using historical data from 1901 to 1997. A principal component analysis (empirical orthogonal functions, EOFs) was applied to sea ice area (SIA) anomalies for the period 1953-95. The leading EOF mode for the SIA anomaly shows an in-phase fluctuation in response to AO and is named ASIO (Arctic sea ice oscillation). Arctic sea ice experiences seasonal variations of different types in timing and magnitude. Four types of seasonal variations are identified in the Arctic sea ice, superimposed on long-term interannual to decadal variability. Consistent with the total Arctic SIA anomaly, eight regional SIA anomalies have shown significant in-phase decrease (downward trend) since 1970, possibly part of a very long-term (century) cycle. Thus, it is recommended that SIA anomalies in the sensitive seasons be used to better capture interannual, interdecadal, and longer (century) variability. Major decadal and interdecadal time scales of SIA anomalies are found 7-11 and 16-20 years. In the Sea of Okhotsk, a century time scale is evident. The reduction rate (negative trend) of the total Arctic sea ice cover in the last three decades is -4.5% per decade with the summer rate being the highest (-10.2% per decade). The contribution to this total reduction varies from region to region, among which sea-ice cover in the Greenland and Norwegian Seas experiences the highest reduction rate of -20.2% per decade.

Introduction

The Arctic sea ice oscillation (ASIO) is defined as an in-phase fluctuation of the Arctic SIA anomalies (Wang and Ikeda 2000a, b) in response to the AO, i.e., the AO-related SAT (surface air temperature) and SLP anomalies. The in-phase (or spatially uniform) decline of Arctic sea ice cover in the last three decades is the major feature of the ASIO. The ASIO can be discretely described to be hypersensitive decadal oscillations in the Arctic/subarctic climate (atmosphere-ice-ocean) system (Ikeda 1990). The remarkable decadal oscillations in the last 30 years are attributable to a reduction of sea-ice thickness (and/or sea-ice cover) in the Arctic (Ikeda et al. 2000). Therefore, the Arctic sea-ice cover anomaly should not be considered as a passive player in the Arctic climate system (Wu et al. 1999).

To follow up the ASIO idea, this study aims to identify the regional signatures of the ASIO by providing a regional perspective of the SIA anomalies. This study will also investigate the following questions:

- 1) What are the regional character and seasonality of sea ice extent in different regions?

- 2) What seasons better reflect interannual variability and decadal oscillations in different regions?
- 3) What are the decline rates in sea ice cover in the last three decades in different seasons and different regions?
- 4) What are the major cycles of SIA anomalies?

Results

Figure 1 shows annual time series of SIA anomalies for the most sensitive seasons (spring and summer) in all eight regions and the entire Arctic Ocean. The trends since 1970 are remarkable, varying from region to region, superimposed by the interannual and decadal variability.

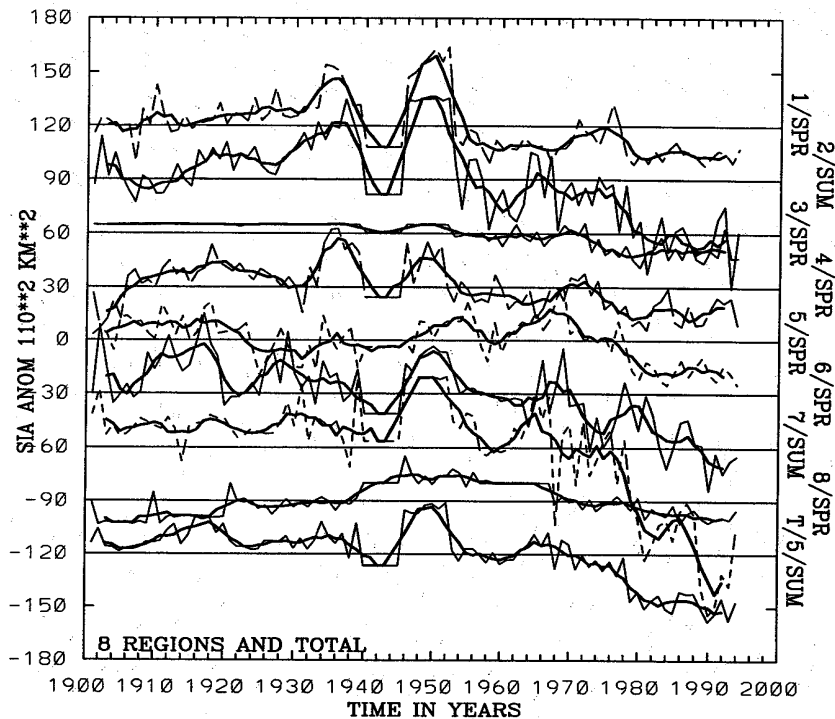


Fig. 1. Annual time series of SIA anomalies of most sensitive seasons for region 1 (Bering Sea), 2 (Beaufort and Chukchi Seas), 3 (Hudson Bay), 4 (Baffin Bay-Labrador Sea), 5 (Greenland and Noweigian Seas), 6 (Barents and Kara Seas), 7 (East Siberian and Laptev Seas), 8 (Sea of Okhotsk), and total Arctic Ocean divided by 5.

Table 1 depicts the decadal trends and relatively regional contribution to the total Arctic sea ice change. In the last three decades (1970-1994), the negative trend of the total Arctic sea ice extent is -4.5% per decade. This negative trend can be simulated by a coupled ice-ocean model (-4% per decade, Hilmer and Lemke 2000). The negative trends vary from region to region. The relatively regional contribution to the total Arctic trend can be, in the order of magnitude, listed as following regions: regions 5 (-20.2%), 6 (-6.2%), 7 (-1.9%), 3 (-6.8%), and 2 (-1.2%), in terms of relative reduction rate (percentage per decade), although the large absolute reduction rate occurs in regions 1 (-13.2%) and 8 (-5.6%). The regional reduction rate of -20.0% per decade is largest in the Greenland and Norwegian Seas (region 5).

Table 1. Annual trends from 1970 to 1994, and the relatively regional contribution to the total Arctic sea ice trend of -4.5% per decade. Units are 110 km.

Region	1	2	3	4	5	6	7	8	Total
Trend Decade ⁻¹	-13.2	-1.6	-6.8	-8.8	-20.2	-6.2	-1.9	-5.6	-4.5%

To detect the periods of ASIO, we applied wavelet analysis to sea-ice area anomalies of all eight regions (with only region 4, Baffin Bay-Labrador Sea, being shown in Fig. 2). The significant period shows a decadal (7-11 year centered at eight years) to 16-20 years.

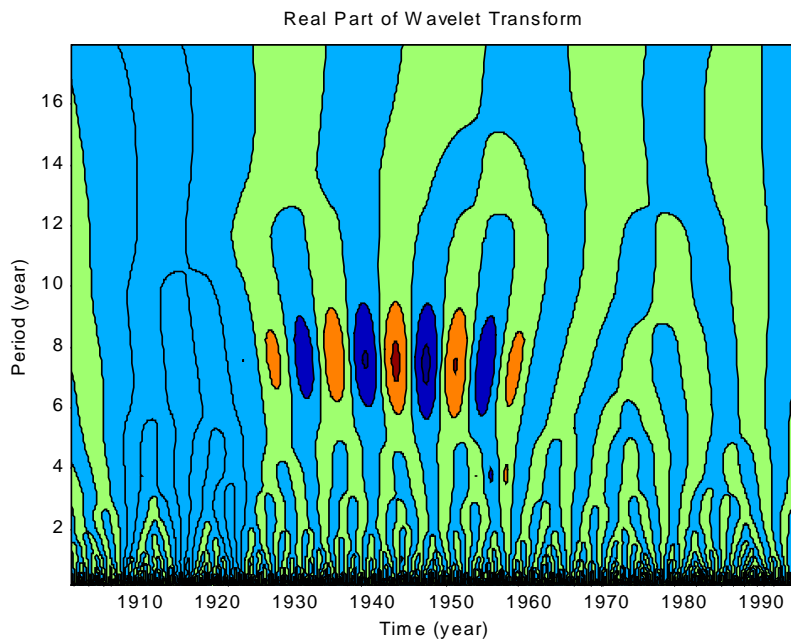


Fig. 2. Real part of wavelet transform of sea-ice area anomaly in region 4.

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