Chinese Journal of Polar Science, Vol. 15, No. 2, 137－142, December 2004

Definition of Arctic and Antarctic Sea Ice Variation Index

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Received September 6, 2004

Abstract It is well known that varying of the sea ice not only in the Antarctic but also in the Arctic has an active influence on the globe atmosphere and ocean. In order to understand the sea ice variation in detail, for the first time, an objective index of the Arctic and Antarctic sea ice variation is defined by projecting the monthly sea ice concentration anomalies poleward of 20°N or 20°S onto the EOF (empirical orthogonal function)-1 spatial pattern. Comparing with some work in former studies of polar sea ice, the index has the potential for clarifying the variability of sea ice in northern and southern high latitudes.

Key words Arctic sea ice, Antarctic sea ice, variation index.

1 Introduction

It is well known that sea ice in the polar region plays an important role in the global climate changes as a part of climate system (Carleton 1989, Yuan and Martinson 2000, 2001; Cheng and Bian 2002, Liu and Martinson 2002, Liu and Zhang 2004, Gigor and Wallace 2002 *et al*). In fact, numerous modeling studies suggest an important influence through the sea ice fields alone (Grumbine 1994, Meehl 1990, Rind *et al.* 1995). In order to understand the variability of Arctic and Antarctic sea ice along with the possible connections with climatic anomalies in detail, it's necessary to define an objective index. But, up to now, there is no any index to describe the polar sea ice variability although Cheng defined ASO (Antarctic sea ice oscillation) as the EOF (empirical orthogonal function)-1 mode of sea ice concentration anomalies in the sea area around Antarctic. In the present paper, we will give the sea ice spatial variation index not only in the Antarctic sea area but also in Arctic in the light of the definition of AOI (Arctic Oscillation Index) and AAOI (Antarctic Oscillation Index) and based on the work of Chen (2002).

Here we demonstrated the prominent features of Arctic and Antarctic sea ice variability revealed by empirical orthogonal function analysis firstly, and then a numerical definition of the spatial variability index will be given.

2 Data

Monthly mean sea ice concentration data on 1 degree grids are used in the study. It is got from the GICE dataset which describes data derived from Walsh Sea-Ice Concentration data and provided by The British Atmospheric Data Centre (BADC) (*http://badc.nerc.ac.uk/home/*). The dataset used here spans a 36-year period from January 1966 to December 2001. In addition, monthly sea ice concentration anomalies are produced by first creating the monthly means, removing the monthly climatology and then detrending the time series at each sample. The datasets used here all span a 23-yr period from 1981 to 2003.

3 The spatial variation of the polar sea ice

In this section, the spatial structure of Arctic and Antarctic sea ice variation is investigated and the empirical orthogonal function is applied. To extract the representative modes, all 432 months are used as continuous time series for EOF analysis. The EOF-1 pattern weighted monthly sea ice concentration deviation in southern hemispheric area from 50°S to 90°S is illustrated in Fig. 1a. This mode accounts for 27% variance. From the figure we can see that there are two high deviation poles centered in the Weddell Sea and in the southern of Indian Ocean along 75°S. Except for the high centers, there is also a stronger low one centered in the northern of Ross Sea along 60°S and a weaker low deviation pole in the southern of Indian Ocean with the same latitude to the stronger low one. So, in Antarctic the sea ice oscillation is prominent, which is the same to the form studies. With the same data analysis process the EOF-1 spatial pattern of the high latitudes area in the northern hemisphere from 50°N to 90°N is showed in Fig. 1b. It contains 25% of the total variance. Comparing with the spatial pattern of the southern high-latitude sea ice it doesn't bear out the evident feature of standing wave in Arctic. Most striking of the figure is that there is an evident high deviation pole centered in Hudson Bay along the latitude of 57°N. As for low deviation, there are no evident poles. But the figure show such a pattern that the high deviation area exists in the high-latitude Arctic Ocean and in the most area of the north Pacific Ocean and the north Atlantic Ocean are the low deviation ones.

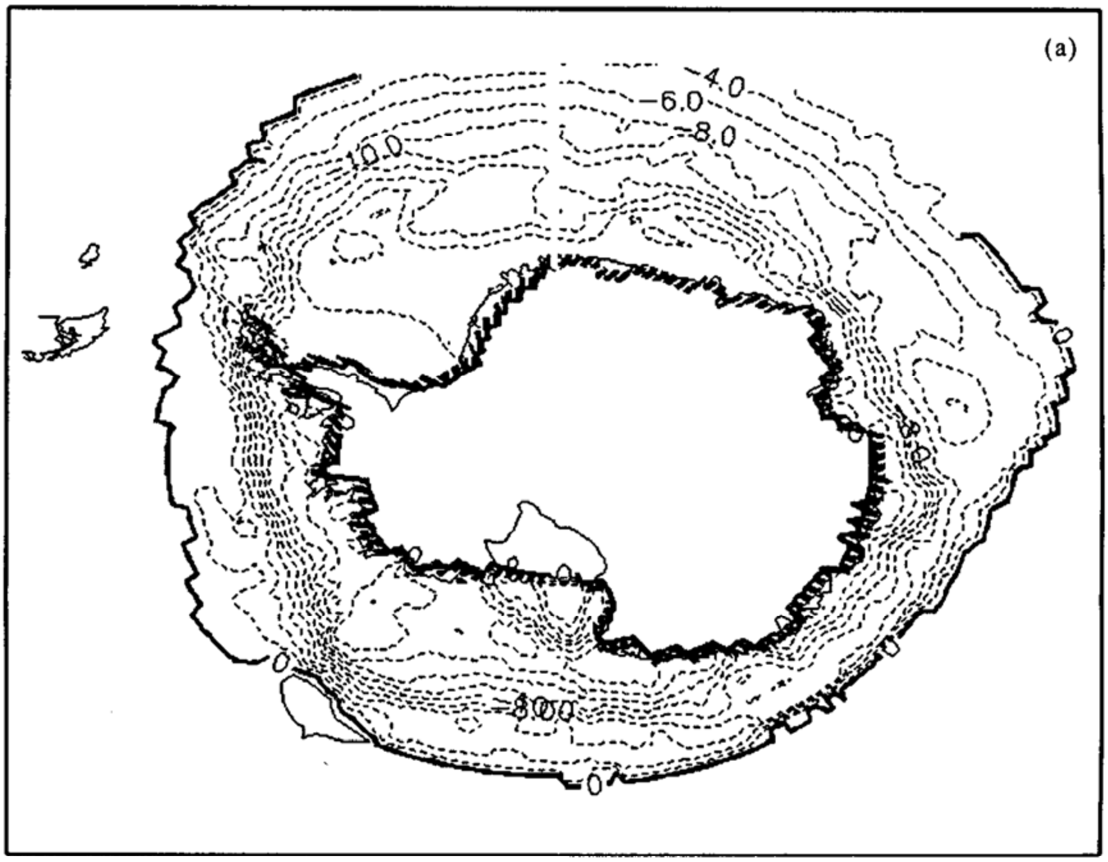

Fig 1a The eigenvector of the first EOF mode of the sea ice concentration anomaly from 1/66 to 12/01 containing 27% of the total variance from 50°S to 90°S in the Southern Hemisphere

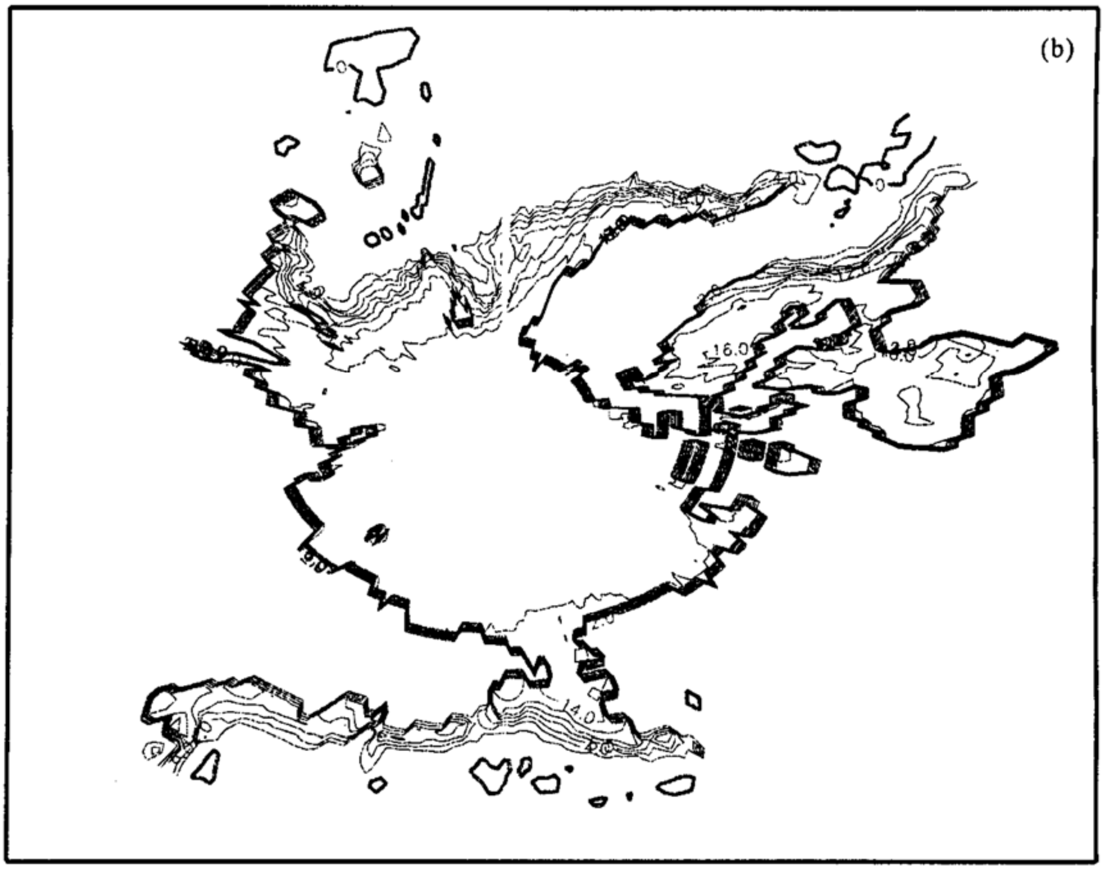

Fig 1b The eigenvector of the first EOF mode of the sea ice concentration anomaly from 1/66 to 12/01 containing 25% of the total variance from 50°N to 90°N in the Northern Hemisphere

4 Definition of Arctic and Antarctic sea ice variation index

The above analysis suggests that the sea ice variation from 50°S and 90°S and from 50°N to 90°N both have high and low deviation areas. The spatial variability of sea ice is evident. Then in the light of definition of monthly AAO index and AO index in the National Weather Service Climate Prediction Center, the variability can be objectively expressed just by the projecting the monthly sea ice concentration anomalies poleward of 50°S and poleward of 50°N onto the EOF_1 spatial pattern. They are defined as the EOF_1 time variation index. Fig. 2 shows the sea ice concentration variance explained by the Antarctic and Arctic sea ice variation index. The High (Low) index corresponds to sea ice increase (decrease) in high deviation areas and sea ice decrease (increase) in low deviation areas.

From the former studies it has been known that sea ice extent has a decreasing trend of $-2.7 \pm 0.5\%$ (10^6 km^2) in Arctic and an increasing trend of $1.09 \pm 0.37\%$ (10^6 km^2) in Antarctic (Cavalieri 2003; Vyas 2003; Watkins and Simmonds 2000). The decreasing and increasing trend in Arctic and Antarctic sea ice can be embodied from sea ice variation index well.

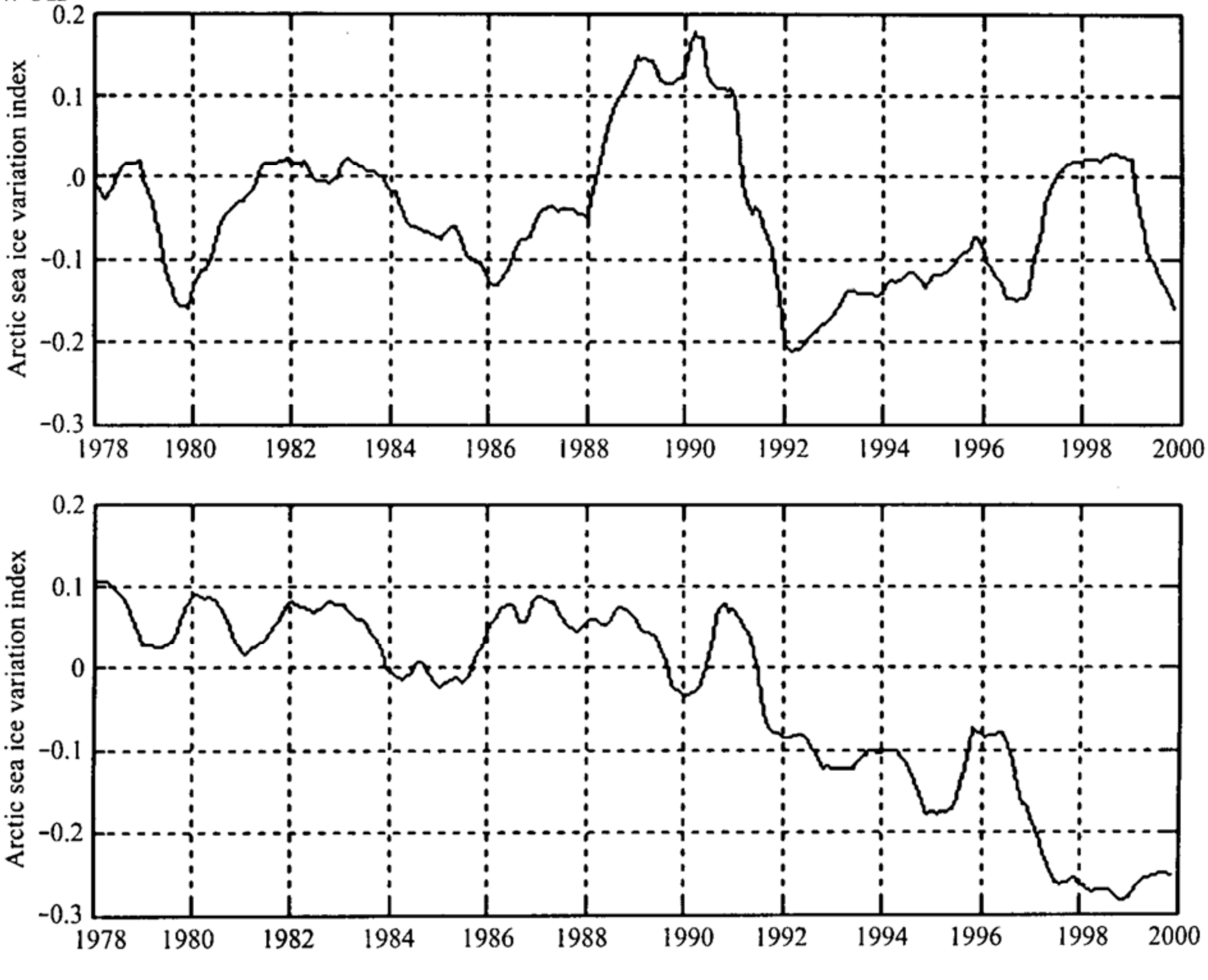

Fig. 2 Upper: The Antarctic sea ice concentration variation index from 1/78 to 12/00 from 50°S to 90°S in the Southern Hemisphere. Lower: The Arctic sea ice concentration variation index from 1/78 to 12/00 from 50°N to 90°N in the Northern Hemisphere.

5 Conclusions and discussion

In this paper, we defined the varying index of the Arctic and Antarctic sea ice by projecting the monthly sea ice concentration anomalies poleward of 20°N or 20°S onto the EOF (empirical orthogonal function)-1 spatial pattern. Basic fact shows that it has the potential for clarifying the variability of sea ice in northern and southern high latitudes. A question must to clear up is that the study is primary and attempting, so much work must be done to verify it.

The ENSO signal has been found in the southern and northern high latitude from analyzing sea ice data (Gloersen 1995; Simmods and Jacka 1995; Kwok and Comiso 2002). Statistically significant polar-extropolar (tropics and midlatitudes) and circumpolar teleconnection patterns were also recently quantified by investigating the relationship between the Antarctic sea ice edge and global surface air temperature (SAT) as well as other climate indices (Yuan and Martinson 2000). An important science question about the mechanism between the sea ice variations in the polar region has not been clear. This new index definition about Arctic and Antarctic sea ice variability given in this article will be necessary and helpful for clarifying the teleconnection between sea ice and other atmospheric or oceanic physical phenomenon which is the work we are going to do in the future.

Acknowledgements This work is finished in the key Lab. of Marine Science and Numerical Modeling, First Institute of Oceanography. It is supported by the National Natural Science Foundation of China (Grant No. 40231013).

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