Chinese Journal of Polar Science, Vol. 17, No. 2, 136-141, December 2006

Research on changes and circulations of sea-ice in Eurasian in recent 50 years

Dong Xinning(董新宁)[1] and Fang Dexian(方德贤)[2,3]

1. Chongqing Climate Center, Chongqing 401147, China;

2. Key Laboratory of Mesoscale Severe Weather Ministry of Education, Nanjing University, Nanjing 210093, China;

3. Chongqing Meteorological Office, Chongqing 401147, China

Received September 25, 2006

Abstract Using the monthly 1°×1° sea-ice concentration data of Hadley center and the monthly NCEP geopotential height data from January 1953 to February 2003, temporal and spatial changing characters of sea-ice are examined. The results show almost all of the sea-ice of eight regions was decreasing, especially all seasons in Europe. But in Asia part, those display some increasing trends in spring and winter. Abrupt times of sea-ice in Europe were at end of 1970's and in Asia the times in summer/fall(spring/winter) were at end of 1980's.

Key words sea-ice; trend; Mann-Kendall; difference height field

1 Introduction

Polar region in north is the large source of arctic mass. As an important member of climatic system, sea-ice and its variation impact on intensity and extent of northern cold air. With the stronger influence of greenhouse-effect in latest 50 years, much more studies indicate there comes significant warming in NH. Extent and intensity of sea-ice in arctic pole has changed and they must deeply influence the climate of NH, even the whole globe.

Holloway(Holloway and Sou 2002) observed that Arctic sea-ice has decreased by half in latest 10 years; using sonic sounding data Gloersen(Gloersen *et al.* 1999) considered that there is a small and significant negative trend of Arctic ice-cap during 1978-1987, and Arctic sea ice is decreasing in each season while the largest trend is in spring and the small one in fall. The regional characteristic is the sharpest decreasing in European. Maslanik (Maslanik *et al.* 1996) pointed out that Arctic sea ice has the negative trend since 1979, especially in summer. Deser(Deser *et al.* 1996) considered Arctic sea ice shows apparent trend of decreasing and has influenced the number of cyclone in North Atlantic. Using the stream water data of Japan Hokkaido which is described the ice condition in northwestward of North Pacific, Chen(Chen *et al.* 2001; 2003) etc. draw the conclusion that there is an out-of-phase variation between two sides of Greenland. Zhao(Zhao *et al.* 2000) indicated that Artic sea ice of most regions is decreasing in three seasons, namely, spring, summer

and autumn, however there is no apparent trend of sea ice changing in winter.

The purpose of this paper is to show the details of sea ice changing in Eurasian.

2 Data and Methods

The monthly sea ice concentration (SIC) data during 1953.1-2003.2 were offered by Hadley Center and the monthly geopotential height data we used were obtained from NCEP/NCAR for the period of the same one with SIC.

Q indexes are the time series which are the sums of each grid value in the sea region. The area of $1° \times 1°$ decreases with the increasing of latitude because there is relationship between sea ice concentration and the area. Correction factor of latitude (α) is adopted for minimum the discrepancy from data, $a = \cos(\alpha\pi/180)$, α is the corresponding latitude of the grid. DO index is the normalized Q one.

Linear tendency estimation method: regression equation is constructed which is between the variable x_i (sample: n) and the corresponding time t_i: $\hat{x}_i = a + bt_i$, ($i = 1, 2, \cdots, n$), a (b) is regression constant (coefficient) separately. Mark of b explains the tendency and rate of variable, namely, positive (negative) b indicates the increasing (decreasing) trend. Whether the tendency is significant can be estimated based on the relationship between b and r (correlation coefficient). Given a certain significant level α, if $|r| > r_\alpha$, indicates that the trend of x serial is apparent with the changing of t, vise versa.

Mann-Kendall method (MK) defines a statistic $S_k = \sum_{i=1}^{n} r_i (k = 2, 3, \cdots, n)$, for a serial x (sample size: n), S_k is the accumulated sum when value of sample i is bigger than that of sample j ($1 \leqslant j \leqslant i$). Supposed the former serial is random and independent, $U(S_k)$ $1 \leqslant k \leqslant n$, the normalized S_k serial will construct a curve UF, repeating the steps for inverse serial of x and make $ub_k = -uf_k$, $k = n, n-1, \cdots, 1$ and $ub_1 = 0$, then get the curve UB. Positive/negative UF means raising/falling tendency which is significant when UF is beyond the threshold. There is node, UF with UB, between two thresholds, it is called abrupt point and the corresponding time is the time which means that the abrupt changing is beginning.

3 Linear Tendency Estimation Analysis

Considering the format of data and geographical reasons, Eurasia sea is divided into eight regions: 1) the Norweigian Sea (NOR, 0°–20°E, 70°–90°N), 2) the Barents Sea (BAR, 20°–55°E, 65°–90°N), 3) the Kara Sea (KAR, 55°–100°E, 65°–90°N), 4) the Laptev Sea (LAP, 100°–150°E, 70°–90°N), 5) the East Siberian Sea (ES, 150°E–180°, 65°–90°N), 6) the Chukchi Sea (CHU, 180°–160°W, 65°–80°N), 7) the Bering Sea (BER, 160°E–160°W, 50°–65°N), 8) the Sea of Okhotsk (OKH, 135°–160°E, 40°–65°N).

The overall characteristic of sea ice changing is decreasing in recent years. From Fig.1, sea ice in Europe decreased sharply and the trend has passed the 0.5 confidence level test. The parts of Asia sea ice are softer than European one, furthermore, there does comes increasing trend in the Sea of Okhotsk in lower latitude.

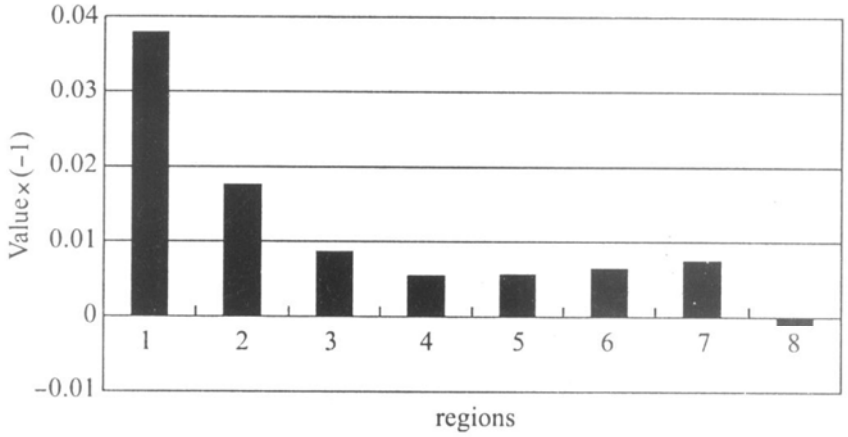

Fig 1 Average trends of sea-ice of eight regions in Eurasian
(1-8 indicates eight regions in Eurasian from west to east)

The changing has different facet not only in space but also in season. Table1 showed Eurasia sea ice are all negative trends in summer and the sea ice in most regions of Asian displayed the increasing trends in spring and winter. In the table, the trends of summer, fall and winter passed the 0.5 confidence level test. And sea ice in Asian has the significant increasing trend in spring. In one word, 1) European sea ice has coincidental decreasing trend in each season and the trend in spring is relative weak. 2) The sea ice in Asian decreased chiefly in summer and fall (i.e. melting periods) while it increased obviously in winter and spring. 3) The sea ice in the middle (two sides) of the continents showed slower (faster) decreasing.

Table 1 The tendency value (TD) of Eurasia sea ice in each season (In blanket, corresponding correlation coefficient, the black passed 0.5% confidence level)

TD	Spring	Summer	Fall	Winter
NOR	-0.0473 (-0.7552)	-0.0270 (-0.7445)	-0.0312 (-0.7292)	-0.0464 (-0.7097)
BAR	-0.0247 (-0.05988)	-0.0188 (-0.7093)	-0.0122 (-0.5392)	-0.0147 (-0.5055)
KAR	-0.0022 (-0.3513)	-0.0193 (-0.6907)	-0.0115 (-0.4169)	-0.0022 (-0.4066)
LAP	0.0039 (0.6056)	-0.0243 (-0.6791)	-0.0068 (-0.2899)	0.0048 (0.6368)
ES	0.0074 (0.6352)	-0.0247 (-0.5264)	-0.0163 (-0.4358)	0.0103 (0.7276)
CHU	0.0039 (0.5982)	-0.0129 (-0.5763)	-0.0198 (-0.591)	0.0029 (0.5040)
BER	-0.0159 (-0.4782)	-0.0016 (-0.5014)	-0.0016 (-0.4732)	-0.0114 (-0.4837)
OKH	0.0013 (0.0511)	-0.0068 (-0.8294)	-0.0007 (-0.7857)	0.0111 (0.3784)

4 Abrupt Change Analysis and Testing

Many researches displayed sea ice of Eurasian not only decreased in the long-term scale but also had the different characteristics in different regions and seasons. Sea ice in NOR/ES is on behalf of European/Asian part for examining the abrupt changing. To be noted, the else have almost the same characteristics with their examples in every season.

In Fig2, sea ice in NOR in spring showed the consistent wave motion before 1970's and then decreased sharply. From the position of node, the decreasing phenomenon was the abrupt changing from 1974. The condition in summer increased slowly before 1970's, then decreased and became significantly after 1980's, its abrupt time is 1978. Sea ice in fall and winter were more before 1970's, then decreased sharply. 1977/1981 was the abrupt time of fall/winter.

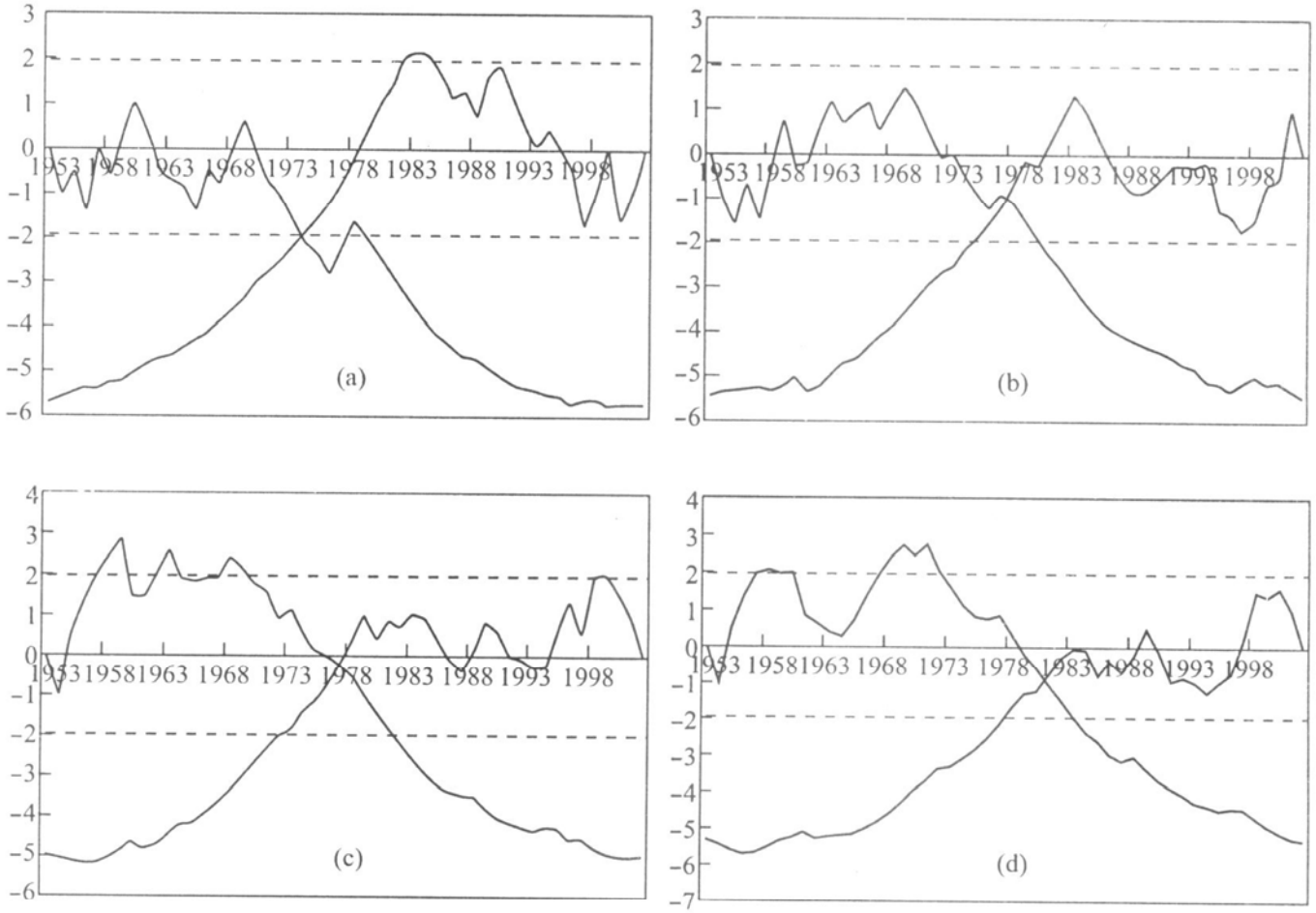

Fig 2 Abrupt changes analysis of DQ index of Nor (x: year; y: MK statistic value; black line: UF; grey line: UB; dashed line: the 95% confidence level).

In Fig3 (a), UF which was upon zero, displayed there was increasing trend of sea ice in ES, and the significant increasing occurred during 1960's and mid-1980's to nowadays, the abrupt time was 1980. (b) and (c) showed the situations in summer and fall, which were near zero and after 1970's the decreasing tendency were apparent, the abrupt time in summer and fall were 1985 and 1987 respectively. (d) is similar to the spring but its significant periods were longer (mid-1950's to mid-1970's and mid-1980's to nowadays re-

spectively), the abrupt time is 1984.

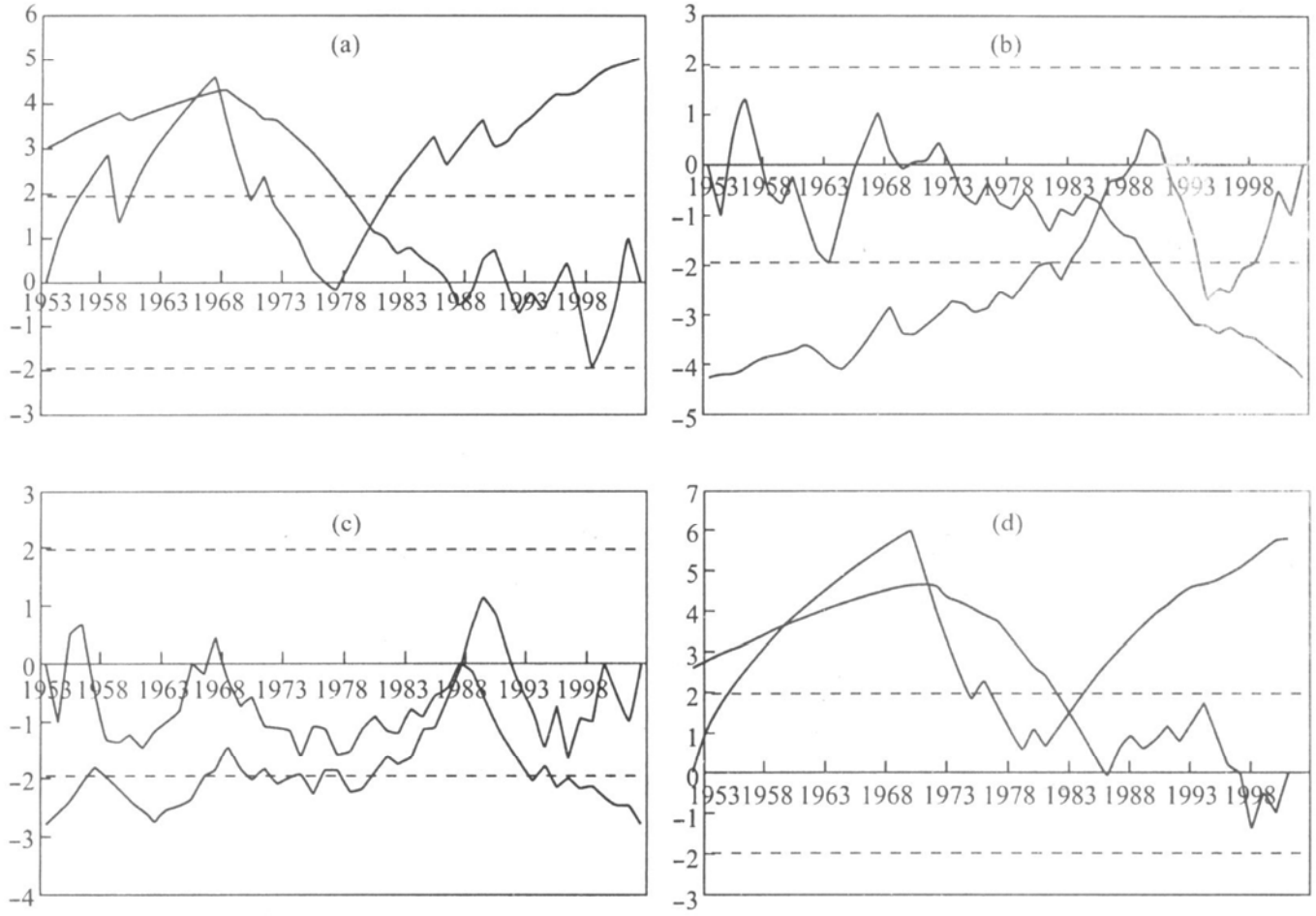

Fig 3 Abrupt changes analysis of DQ index of ES(same to Fig2).

All in one, there were unanimous decreasing in European regions in each season and significant decreasing in latest 20 years, the abrupt time was mostly at the end of 1970's and the beginning of 1980's. Meanwhile, there were different in Asian, there was almost no significant tendency, the main characteristic is increasing in winter and spring and decreasing in summer and fall. The abrupt times of them are basically in late of 1980's which were much later than the abrupt times of Europe.

5 Conclusions

(1) Sea ice showed unanimous decreasing trends with sharply in summer/fall and slowly in the others. In winter, there is increasing phenomenon in some regions.

(2) In the whole, Sea ice in Europe decreased cutely than that in Asia.

(3) The results of MK stated three regions in Europe displayed almost same decreasing change which maintained in a certain level before 1970's and then decreased rapidly. the abrupt time mostly at the end of 1970's. Asia parts presented the trait of increasing—decreasing—increasing variation, sea ice in summer and fall were always decreasing in any time. The abrupt times of Asia regions were in the late of 1980's which was later than those of Europe.

References

Chen M X, Xu H M, Guan Z Y (2001): Relationship of spring Greenland sea ice with summer surface air temperature and rainfall in China. Journal of Nanjing Institute of Meteorology, 24(4): 483-490.

Chen M X, Guan Z Y, Xu H M (2003): A simple study on relation of winter-spring Greenland sea ice change with air temperature /precipitation in early summer of China. Journal of Nanjing Institute of Meteorology, 22 (1): 6-13.

Deser C *et al.* (2000): Arctic ice variability in the context of recent atmospheric circulation trends. J Climate, 13: 617-623.

Gloersen P, Parkinson C L, Cavalieri D J, *et al.* (1999): Spatial distribution of trends and seasonality in the hemisphere sea ice cover. J Geophys Res, 104(c9): 20827-20835.

Holloway G, Sou T (2002): Has Arctic sea ice rapidly thinned? J Climate, 60(50): 1691-1701.

Maslanik J A, Serreze M C, Barry R G (1996): Recent decrease in arctic summer ice cover and linkages to atmospheric circulation anomalies. J Geophys Res, 23(67): 1677-1680.

Zhao Y C, Sun Z B, Hong N D (2000): The variations of the Arctic and Antarctic sea ice. Journal of Nanjing Institute of Meteorology, 23(3): 330-337.