ESTIMATION OF MONSOON ACTIVITY OVER THE JAPAN SEA

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Introduction

Japan Sea is located on the boundary between the Asian continent and Pacific Ocean with the seasonal distinction of thermal circulation and wind regimes. The monsoon character of a wind regime over the Sea is the reflection of seasonal change of dominant circulation systems over the Asian continent and the North Pacific Ocean. Main goal of this research was the estimation of the monsoon activity over the Japan Sea.

Data

Next main sources of meteorological data were used:

- Ship weather observations in the Japan Sea for the period 1960-1990 (WDC-B, Obninsk, Russia, *http://www.meteo.ru/rfund/mormet/int.htm*). The database of ship weather observations contains the information about the weather characteristics at fixed hours.
- The analysis data of the ECMWF for the period 1991-1998 for four main synoptic times with 6-hour discreteness on the 0.5625 degree grid (ECMWF, 1995).
- Monthly mean Sea level pressure (SLP) prepared by National Center of Atmospheric Research (NCAR) (Trenberth & Paolino, 1980).

Total volume of the ship weather observations data in the Japan Sea for every meteorological element was about seven hundred thousands. Approximately 210 thousands or 30% from the total number of observations over the Japan Sea correspond to the northeastern part of the Sea (limited from the west by 140°E). Up to 48% of observations (334 thousands) were in the northern part (above the 40°N, without northeast area), and about 21% of observations (139 thousands) were in the southern part of the Sea (below the 40°N).

Number of observations near the coast of the Korean peninsula (limited from the east by 130°E) was about 1% (5 thousands of observations) from a total number of observations over the Sea. The number of observations over the Japan Sea in summer, except the northeast area, is about 60-70% from number of observations in winter. Over the northeast area of the Japan Sea with the Tatar Strait, on the contrary, the maximum of observations accounts on the warm period. One of the reasons is that in winter practically the whole Tatar Strait, especially in northern part, is covered with a stable ice cover (except some warm winters).

The data control was done with use of synoptical and statistical methods of the analysis. After the checking the volume of sample data decreased almost by 10%.

Results

Seasonal baric fields over the Asian-Pacific Region at Sea level are characterized by change of synoptic atmospheric action centers. In winter they are: the Asian (Siberian) High over the continent with a ridge directed to Kolyma and north of Kamchatka, and Aleutian Low over the northern part of Pacific ocean. In summer over the Asian continent the Asian Low dominates. North Pacific is under the effect of the permanent North-Pacific of High (Hawaiian High). The influence of North-Pacific High is extended to the Far Eastern Seas with formation High over the Okhotsk Sea.

The seasonal intensity of barometric fields over the Asian-Pacific region is determined by macro-scale barometric gradient as the difference of air pressure at centers of climatic baric systems divided to a longitudinal distance between them. Fig. 1 shows the long-term series of macro-scale barometric gradients in winter and in summer.

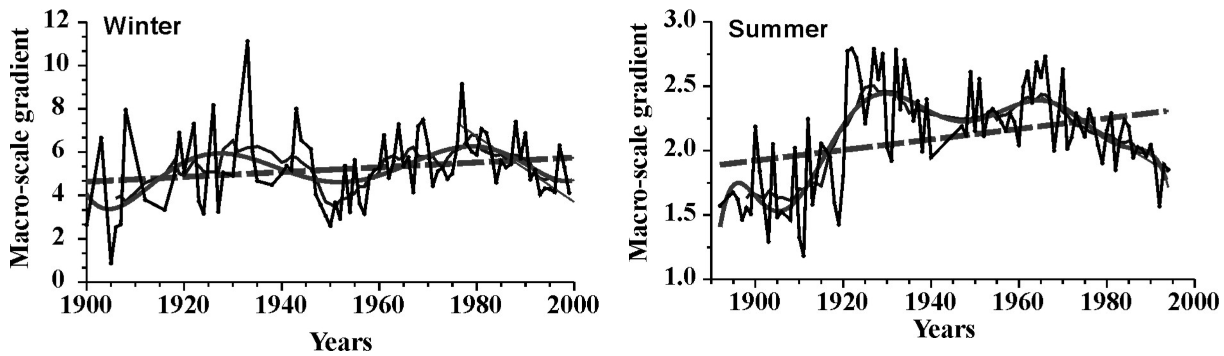

Fig. 1. Macro-scale barometric gradient (hPa/10°L) for the centers of climatic baric systems in January and July with running 11-year average and trends

Winter's macro-scale barometric gradient is the difference between air pressure in centers of the Asian High and the Aleutian Low to the longitudinal distance between them. Summer macro-scale barometric is the difference between air pressure in centers the North Pacific High and the Asian Low to the longitudinal distance between them.

The long-term course of macro-scale barometric gradients in winter and in summer has the wave character. Time series of the winter macro-scale barometric gradient of the significant secular trend for the whole of analyzed period do not show, but some time periods by increase or decrease of the gradient are characterized. For example, the last 20 years the significant tendency for decrease in a gradient was observed. It reached -1.5 hPa/10° of longitude per 10 year, with determination factor R^2=0.49 when 95% significance level R^2=0.010.

Summer macro-scale barometric gradient shows the significant positive secular trend equal to 0.04 hPa/10° of longitude per 10 year. During the last 30-40 years the summer macro-scale barometric gradient decreases approximately by -0.2 hPa/10° of longitude per 10 year, R^2=0.86).

The seasonal features of baric fields define the wind regime over the Japan Sea. The monsoon character of a wind regime over the Japan Sea is reflected in the distribution of the predominant winds – from the continent in winter, and from the Pacific Ocean in summer. It is possible to assume that during last decades the tendency for decrease in the winter macro-scale barometric gradient could cause a weakening of an intensity of the winter Far Eastern monsoon.

Winter Far Eastern monsoon (or continental monsoon with NW, W and N wind directions) is formed under the influence of an interaction of the Asian High and Aleutian Low. The air masses of winter continental monsoon are dry and very cold. They are formed in the central part of the Asian High. The continental air becomes more warm and humid when moves over the Japan Sea and its takes some features of an unstable air mass.

The summer Far Eastern monsoon (or Pacific monsoon with SE, S, SW wind directions) is a result of interaction of the North-Pacific High and South-Asian Low. The air masses of summer monsoon are humid. They are formed over the Pacific Ocean in North-Pacific High.

The total frequency of winter monsoon winds direction over the Japan Sea varies from 60-65% in the western part of Sea to 70-80% in the east part. Total frequency of summer monsoon winds is about 40-50% increasing up to 60% in the Tatar Strait.

The winter Far Eastern monsoon is expressed more strongly than summer monsoon. The analysis of zonal and meridional components of winter wind system over the Japan Sea with component- analysis showed that in January the first three modes of decomposition determine 29.5%, 24.1% and 13.4% of a total variability of a wind fields over the Japan Sea (67%). The similar analysis for a winter season in whole shows the stability of chosen typical fields (first three modes of EOF decomposition of seasonal characteristics of a wind determine 31%, 18% and 14% of a total variability of a winter wind fields – 63%) and possibility of using for an evaluation of seasonal monsoon activity over the Japan Sea.

The structure of first and second modes of the EOF-decomposition of wind fields is connected with a variability of intensity winter monsoon, and can be used for an estimation of monsoon activity over the Japan Sea. The fields of EOF-1, EOF-2, EOF-3 are possible to be used as typical fields (patterns) of winter monsoon variability over the Japan Sea in January.

The first mode (EOF-1) shows the anomality of intensity meridional component of winter monsoon winds over the Japan Sea. The positive values show an increase in northern component winter monsoon, negative-it slacking (Fig. 2, EOF-1). The second mode (EOF-2) shows the anomality of intensity zonal component. The positive values show an increase in western component of winter monsoon, negative-it slacking (increase in east component, Fig. 2, EOF-2). The third mode (EOF-3) shows the contribution of winter cyclonic activity over the Japan Sea (Fig. 2, EOF-3).

The typical fields of a variability winter monsoon over the Japan Sea for first three modes of EOF decomposition of a wind fields indicating the anomality of winter monsoon, were projected to the actual fields of a wind for each term. The contribution of each typical field to an actual field represented as time coefficients sequentially for EOF-1, EOF-2, EOF-3 was estimated.

The average field of pressure corresponds to average typical field of winter monsoon winds (see Fig. 2, Resulting wind). The anomaly that winter monsoon winds could be related with anomaly of an air pressure is possible to assume. The anomalies of a field pressure at Sea level determine the intensity of anomalies winter monsoon concerning to an average typical field monsoon.

The Fig. 3 shows areas, where the anomalies of baric fields are related to the intensity of an appropriate component of wind fields variability. Changes of a sign at centers of these areas result in changes of monsoon intensity.

The direction of winter monsoon over the Japan Sea depends on the interaction of the Asian anticyclone and Aleutian Low. The intensity of winter monsoon depends on a local distribution of baric fields in region of the Japan Sea and adjacent areas.

By the estimates of the contribution of each typical correlation field in real daily baric fields were the indexes of a monsoon activity (IMA)–meridional, zonal and vortex indexes of a monsoonal activity. They were represented as time coefficients of a decomposition of baric field anomalies on the typical correlation fields for the whole period (Fig. 4). Correlation coefficients of temporary factors of typical fields component winter monsoon with anomalies of pressure in the centers of maximum influence amount to 0.6-0.8, that testifies to significant stability of chosen regions.

The increase in positive meridional and zonal indexes shows the increase in intensity of winter monsoon. The increase in negative meridional and zonal indexes shows the decrease in intensity of winter monsoon. The positive vortex index shows the cyclonic circulation over the Japan Sea and increase of northern winds in the western part of the Japan Sea. When a sign of the vortex index is changed to the opposite, the northern winds will increase over the Tatar Strait and in the East part of the Japan Sea.

The time march of meridional index monsoon activity shows an absence of significant secular trend in period from the beginning to the end of the 20th century. But after 1970^{s} significant tendency of a decrease in the meridional index is observed (-0.6 units per 10 years, R=0.15).

The similar tendency was observed for the winter macro-scale barometric gradient. The significant secular tendency of an increase is observed for the zonal index of the monsoon activity (0.12 units per 10 years, R=0.12). The vortex index shows the negative significant secular trend (-0.10 units per 10 years, R=0.18). The changes of zonal and vortex indexes are in an antiphase.

Though the intensity of monsoon and its variability depend on the distribution of a local barometric field over the Japan Sea and adjacent regions of continent and ocean, the relation between the meridional (zonal) index of monsoon activity and macro-scale barometric gradient is significant at the 0.1% level (correlation coefficients are 0.32 and 0.44). The vortex index relates to the macro-scale barometric gradient in the greater degree (-0.55).

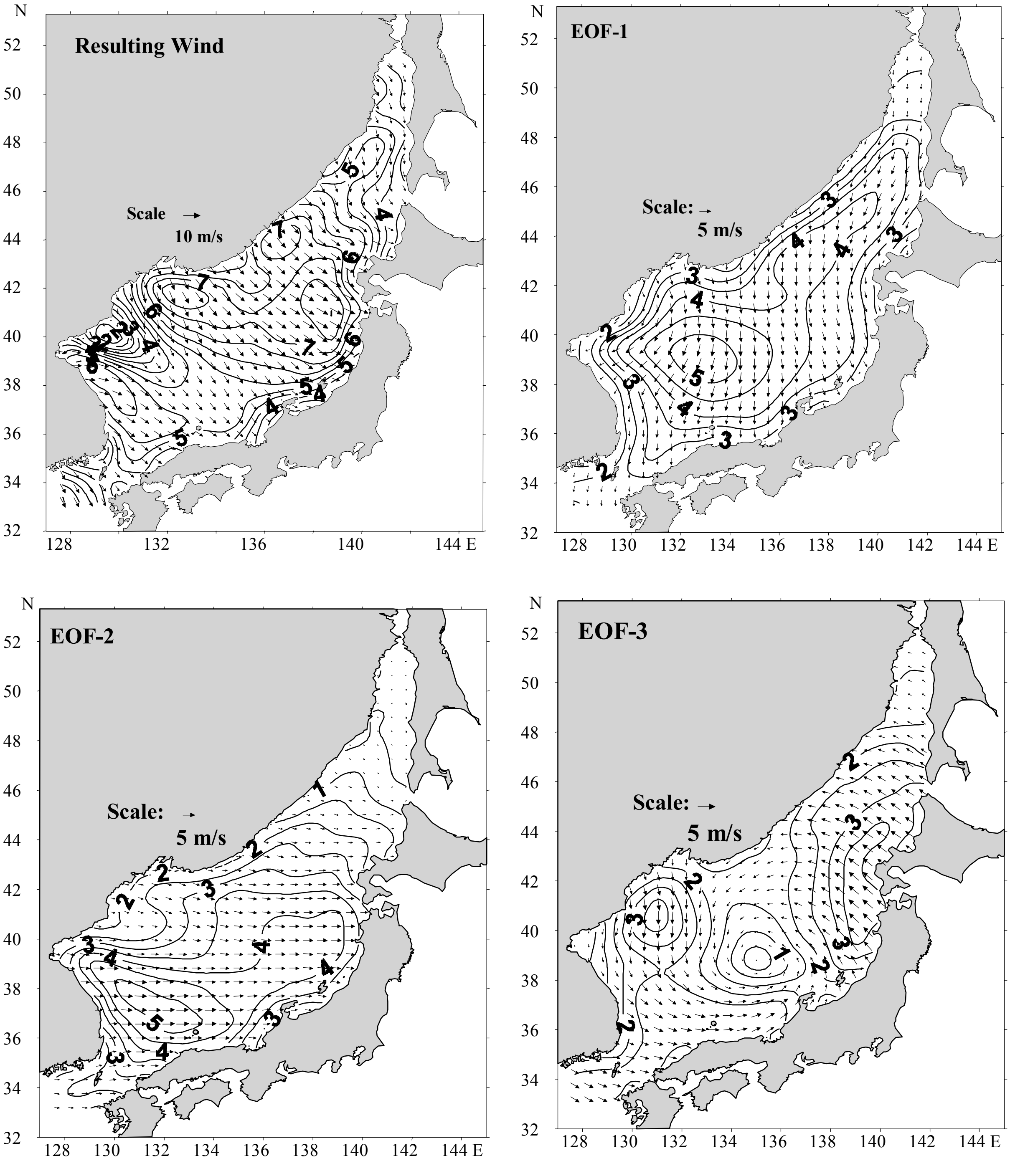

Fig. 2. Resulting wind in January over the Japan Sea and the main components of a wind vector variability (lines show the wind module)

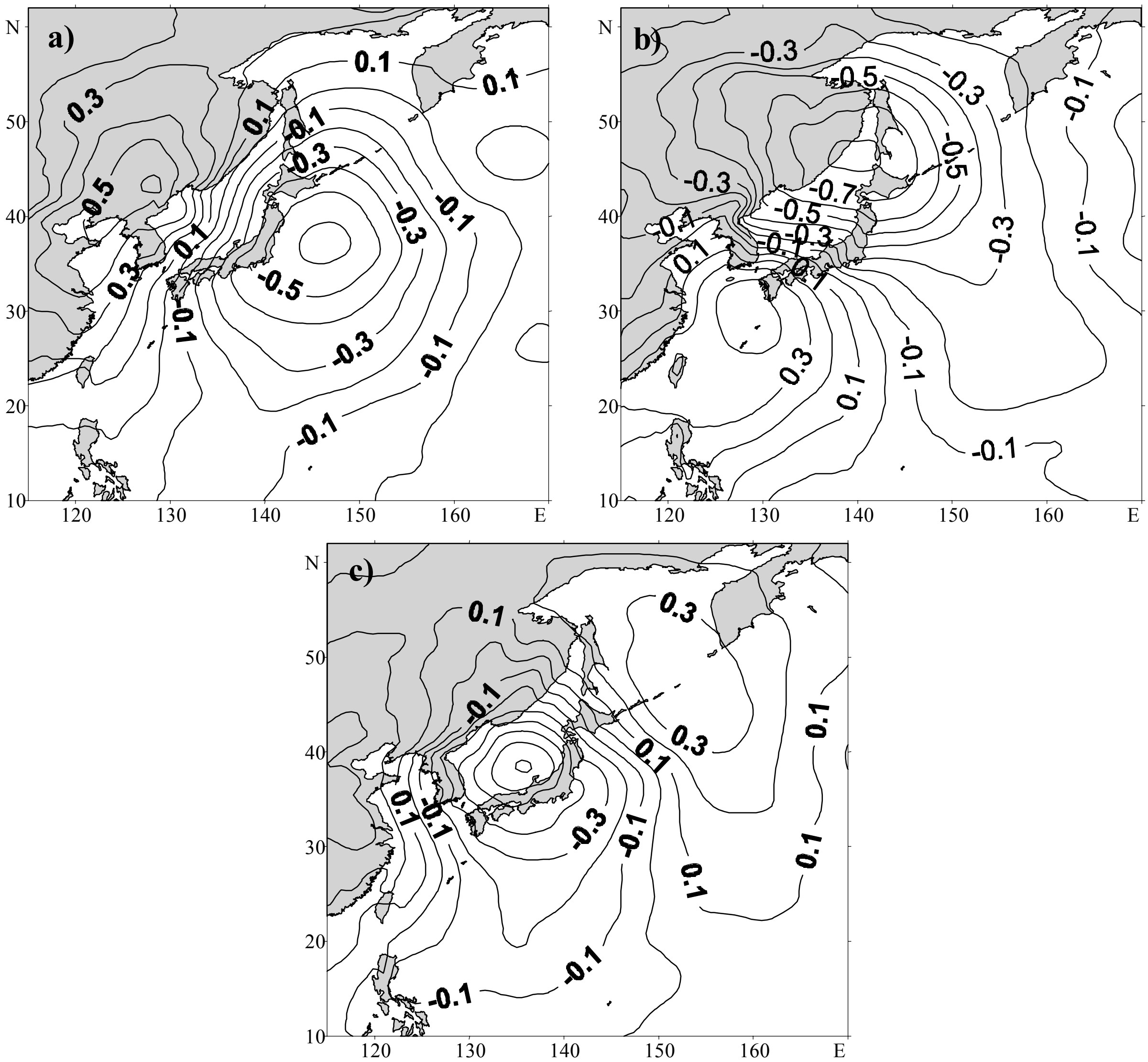

Fig. 3. Typical correlation fields of air pressure at SL for EOF-1, EOF-2 and EOF-3 of a wind over the Japan Sea in January

Conclusion

The monsoon regime of winds over the Japan Sea depends on the interaction of the seasonal climatic baric systems. The intensity of the monsoon depends on a local distribution of air pressure over the Japan Sea and adjacent areas of Asian continent and Pacific Ocean. Significant tendency for increase in the zonal index is observed. After the 1970^{s} significant tendency for decrease in the meridional index is observed. The vortex index has the negative significant secular trend. The changes of zonal and vortex indexes are in an antiphase.

With the use of the indexes of monsoon activity it is possible to evaluate a climatic variability connected with the dynamics of atmospheric processes and to restore the monthly wind fields over the Japan Sea and to analyse monsoon intensity in any year.

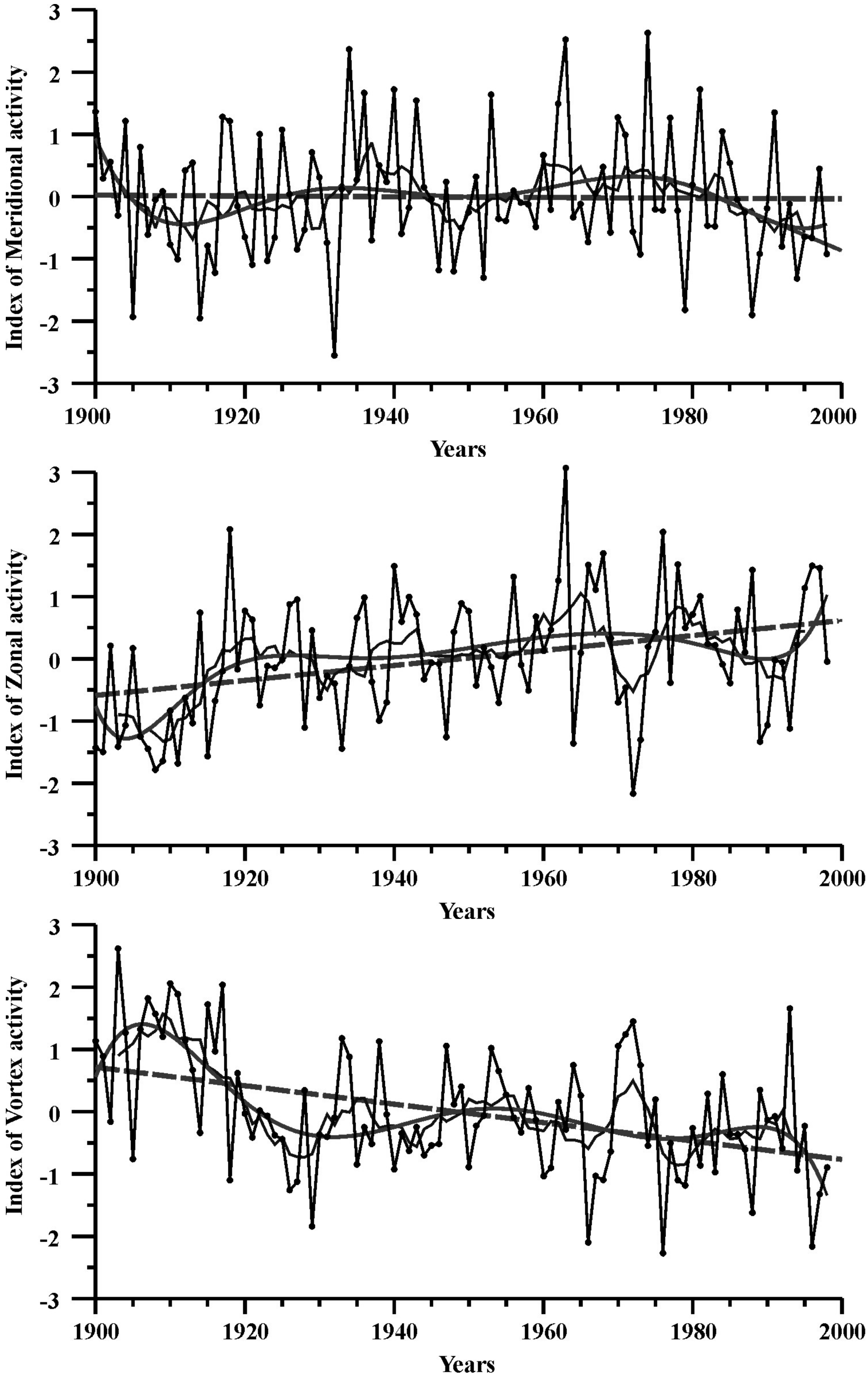

Fig. 4. Indexes of monsoon activity over the Japan Sea

References

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2. Trenberth K.E. & Paolino D.A. 1980. The Northern Hemisphere sea level pressure data set: Trends errors and discontinuities // Mon. Wea. Rev. Vol. 108. P. 855-872.