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SENSING THE CORRELATION BETWEEN ATMOSPHERE TELECONNECTION PATTERNS AND SEA ICE EXTENT: MICROSYSTEM TECHNOLOGY "GEOMATH"

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Abstract

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It is developed a microsystem technology of the data processing and sensing the correlation between atmosphere teleconnection patterns and sea ice extent. It is based on using the satellite and other observation data and PC complex of the wavelet-analysis program "GeoMath".

Keywords: microsystem technology "GeoMath", atmosphere teleconnection patterns, sea ice extent.

Анотація

ДЕТЕКТУВАННЯ КОРЕЛЯЦІЇ МІЖ АТМОСФЕРНИМИ ТЕЛЕКОННЕКЦІЙНИМИ ПАТТЕРНАМИ ТА КРИЖАНИМ ПОКРИТТЯМ: МІКРОСИСТЕМНА ТЕХНОЛОГІЯ "GEOMATH"

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Розвивається мікросистемна технологія обробки даних та детектування кореляції між атмосферними телекоммунікаційними паттернами і величиною крижаного морського покриття, яка базується на використанні даних спутникових та інших спостережень і ПК комплексі програм вейвлет-аналізу "GeoMath".

Ключові слова: мікросистемна технологія "GeoMath", атмосферні телекоммунікаційні паттерни, крижані покриття

Аннотация

ДЕТЕКТИРОВАНИЕ КОРЕЛЛЯЦИИ МЕЖДУ АТМОСФЕРНЫМИ ТЕЛЕКОННЕКЦИОННЫМИ ПАТТЕРНАМИ И ЛЕДОВЫМ ПОКРЫТИЕМ: МИКРОСИСТЕМНАЯ ТЕХНОЛОГИЯ "GEOMATH"

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Развивается микросистемная технология обработки данных и детектирования кореляции между атмосферными телеконнекционными паттернами и величиной ледового морского покрытия, базирующаяся на использовании данных спутниковых и других наблюдений и ПК комплексе программ вэйвлет-анализа "GeoMath".

Ключевые слова: микросистемная технология "GeoMath", атмосферные телеконнекционные паттерны, ледовые покрытия

1. Introduction

Carrying out new advanced sensors and effective microsystem technologies for the needs of the environmental and atmosphere physics is on of the important problems (c.f.[1-11]). First of all, speech is about the natural, environmental data and its processing. Surely, there is a great necessity in the developing an effective technology for processing the satellite and other observation data.

The present work goes on our investigations on developing a new, advanced microsystem technology "GeoMath" [1-9]. Earlier it has been used in solving a whole number of tasks of the modern environmental and atmosphere physics. In particular, speech is about such problems as [1-9]: sensing the kinetical features of energy exchange in mixture CO_2-N_2-H_20 of atmospheric gases under interacting with laser radiation, sensing the nonlinear interaction between global teleconnection patterns, atmospheric teleconnection patterns and eddy kinetic energy content, temporal variability of the atmosphere ozone content and prediction of the effect of North-Atlantic oscillation, using meteorological data for reconstruction of annual runoff series over an ungauged area within the empirical orthogonal functions approach, using non-decimated wavelet decomposition to analyze time variations of North Atlantic Oscillation, eddy kinetic energy, and precipitation, sensing the nonlinear interaction between global teleconnection patterns and at last, firstly a prediction of the possible genesis of fractal dimensions in the turbulent pulsations of cosmic plasma — galactic-origin rays — turbulent pulsation in planetary atmosphere system. In ref.[1] the preliminary data regarding the correlation between atmospheric teleconnection patterns and sea ice extent were presented.

Here we develop a microsystem technology of the data processing and present the final results regarding sensing the correlation between atmosphere teleconnection patterns and sea ice extent. We use the satellite and other observation data and PC complex of the wavelet-analysis program "GeoMath".To reveal the atmospheric forcing of the sea ice extent (SI) in some Arctic seas we use approach based on the wavelet decomposition which allows to solve some questions by extracting the common characteristics of variability in the time frequency space. This method was successfully applied to many geophysical signals, including the time series of atmospheric teleconnection patterns and sea ice (see Grinsted et al., 2004; Jevrejeva et al, 2003; Khokhlov et al., 2004).

In ref.[1] it has been noted that the climate model projections of a future climate change due to increased greenhouse gas concentrations show a maximum annual mean warming near the surface in the high northern latitudes. This warming is aligned with a retreat of sea ice. Numerical experiments, which were performed by Hilmer and Lemke (2000), show that a net reduction of Arctic sea ice volume amounts to the 4% per decade for the period starting with the 1961, the decrease within the 1987-1998 was three to six times larger than within the previous periods.

Some sensitivity experiments with a sophisticated sea ice model have revealed that the sea ice cover is most strongly affected by the surface air temperature and the surface wind field whereas other forcing parameters play a minor role. On the other hand, both aforementioned parameters are strongly affected by the atmospheric teleconnection patterns. The Arctic Oscillation, the North Atlantic Oscillation (NAO), and the Pacific/North American (PNA) can be considered as the dominant atmospheric modes of variability in the Arctic.

The joint analysis for the variability of atmospheric circulation and sea ice extent (SI) in the Arctic seems as attractive but for the case of observational time series there are some difficulties. First from theirs consists in the comparatively short monthly time series of ice conditions for most seas in the Arctic basin since reliable data appeared at the satellite era. Other difficulty lies in the fact that the SI is characterized by pronounced annual variations with the summer minima and the winter maxima. Against these variations the low-frequency atmospheric influence is hard evolved.

2. Methods and data

Main approach used in the current study is cross wavelet transform which was in detail described in ref. [1-4]. Here we give only the key features. Wavelets are the fundamental building block functions, analogous to the trigonometric sine and cosine functions. The particular wavelet can be characterized by how it is localized in time and frequency (for details see Daubechies, 1992). When using wavelets for feature extraction purposes the Morlet wavelet is a good choice, since it provides a good balance between time and frequency localization. The idea behind the continuous wavelet transform (CWT) is to apply the wavelet as a bandpass filter to the time series. The wavelet is stretched in time by varying its scale and normalizing it to have unit energy. The CWT of a time series with uniform time step is defined as the convolution of this series with the scaled and normalized wavelet. The cross wavelet transform of two time series is defined as complex conjugation of two particular CWT. This approach allows to define the cross wavelet power (CWP) and the local relative phase (LRP) between two tome series in time frequency domain.

Here, we consider monthly indices for the NAO and the PNA as well as the monthly ice extents in the Bering Sea, the Baffin Bay, the Greenland Sea, and the Kara-Barents seas from November 1978 to December 2002. The sea ice extent dataset is derived from brightness temperatures by the bootstrap algorithm (Comiso, 2002). Except for the Bering Sea, which is ice-free during August, other seas are ice-covered during all seasons. It is naturally that sea ice conditions in the Bering Sea are affected by the PNA rather than the NAO whereas for other three seas the influence of the NAO should be dominant. The choice for the three seas in the Atlantic sector is conditioned by the different trends in the ice thickness during the last decades of twenty century (Hilmer and Lemke, 2000). We standardize all time series and, since the monthly sea ice extent is far from normally distributed, transform indices for the SIs into a record of percentiles (in terms of its cumulative distribution function).

3. Results

It is naturally that for the case of two particular seas the cross wavelet power with the 5% significance level (SL5) has maxima in the 8-16 month band which are caused by the annual variations of the SI. On the other hand, in such time band the local relative phases of sea ice extent in the Atlantic basin lead slightly that in the Bering Sea. Figure 1 [1] showing the CWP and LRP of SIs in the Bering Sea and the Greenland Sea can be considered as the example of such behaviour. Also, the comparatively large CWP outside the SL5 is registered for these seas only. Other interesting feature of cross wavelet relationship in Fig. 1 is the fact that on the time scale with the 3-4-year period the LRP is antiphase. Moreover, the 3-4 year band is characterized by the significant wavelet coherence calculated as proposed by Torrence and Compo (1998). To a certain extent, this behaviour can be analogous to the Antarctic Dipole in the Southern Ocean (Simmonds and Jacka, 1995; Yuan and Martinson, 2001) though the CWP is not significant.

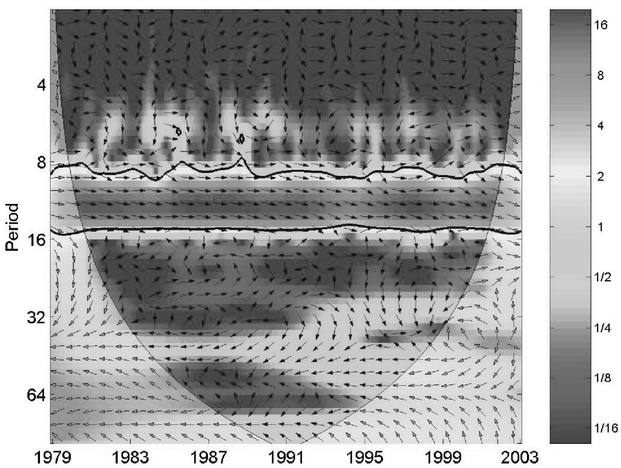

Figure 1. The CWP of the SIs time series in the Bering Sea (BSI) and the Greenland Sea (GSI). The SL5 against red noise is shown as a thick contour and cone of influence where edge effects might distort the picture is shown as a lighter shade. The LRP is shown as arrows (with in-phase pointing right, anti-phase pointing left, and GSI leading BSI by 90є pointing straight down)

Consider the CWP of the teleconnection patterns and sea ice extents (Fig. 2). As for the previous case, one can be noted that there almost always is significant common wavelet power in the 8-16 month band for whole period under consideration. However, the NAO and the GSI are in-phase, whereas the PNA and the BSI are anti-phase. At the same time, less significant, but comparatively large, CWP is registered in the case of the NAO and GSI with the 3-5-year period (with leading NAO). The last finding is also confirmed by the experiments of Hilmer and Jung (2000).

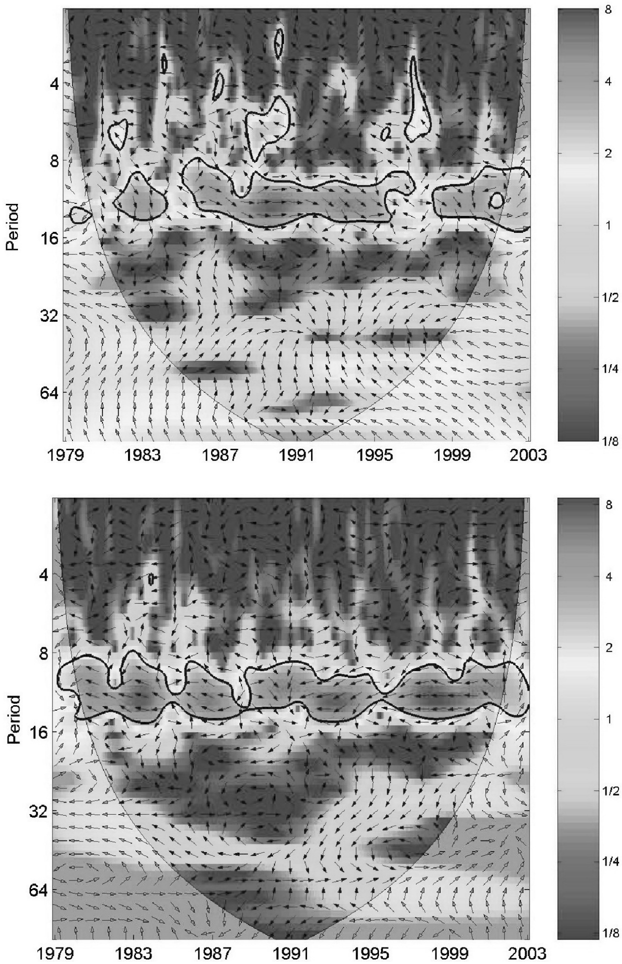

Figure 2. The CWP of the NAO and GSI (left), and the PNA and BSI (right) time series. All parameters are the same as in Figure 1

4. Conclusions

Therefore, we developed a microsystem technology of the data processing and presented the final results regarding sensing the correlation between atmosphere teleconnection patterns and sea ice extent. In particular, we have used the wavelet analysis to reveal coherence in the variability of atmospheric circulation and ice conditions in the Arctic seas. This analysis allows decomposing time series as well as estimating common wavelet power. Using the CWP we uncovered that there is the significant anti-phase relationship between the ice extent in the Bering and the Greenland seas. To a certain extent, this relationship can be analogous to the Antarctic Dipole in the Southern Ocean. So, the presented paper demonstrates an effectiveness of the PC complex of the wavelet-analysis program "GeoMath" [1-10].

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