Independent Component Analysis Applied to Arctic Oscillation

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1. Introduction

The Independent Component Analysis (ICA) has an advantage to the Principal Component Analysis(PCA). The ICA is able to resolve a signal into statistically independent components which construct the original signal. Although cross correlation of the principal components is zero, each principal component may be a mixed signal of independent components. The ICA is an analysis which extracts independent signals from a mixture.

2. Application of ICA to meteorology

Arctic Oscillation(AO) is defined on the basis of the PCA using the atmospheric surface pressure of the Northern Hemisphere. Recently, arguments about the substance of AO are taken place. In this research, ICA is applied to this problem; the result shows clear difference between PCA and ICA. Purpose of the study is to extract some modes which are considered to be physically meaningful.

The model of ICA is expressed as X=AS. Each rows of X is observed signal, each row of S is the independent component, and A is a system function. It is possible to extract both the system function A and the independent signals S, under the assumption of independence among observed signals.

3. Data

We used the monthly averaged atmospheric pressure data (NCEP/NCAR re-analysis data) of northern hemisphere.

4. Two methods of the analysis

We have tried two methods for the AO problem. In the method(1), the spatial pattern of surface pressure is considered. The feature in the spatial patterns can be extracted. Monthly atmospheric pressure for dozens of years is drawn. The data at a point will be considered as pixel data of a picture, and features of the picture will be extracted. The method(2) is extracting independent modes from the time series data.

5. The procedure of analysis

First, we find all principal components by PCA. Secondly,we choose the leading principal component in the sense that the sum of the variance of which exceeds 90% of the total variance. Thirdly, by using the leading principal components, we can re-construct them by the sum of the independent components using the system function A.

6. Results

We have successfully reproduced the AO characteristics by the analysis method(2); similar spatial pattern has been obtained by method(1). It is shown that the diversity of the each principal components is considerably large from November to March. Moreover, all the principal components were able to be expressed as the sum of an independent components. Although the first principal component shows annular pattern centering on the North Pole, they were able to be expressed as the sum of 38 independent components. Those independent components have the spatial structure featured by locally limited energy. The result of the analysis method(2) strongly suggests that AO is mainly composed of three independent components.