Winter Wind Stress Curl field in the North Atlantic and their relation to atmospheric teleconnection patterns

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In the past works, nine teleconnection patters are detected in the Northern Hemisphere: North Atlantic Oscillation (NAO), East Atlantic pattern (EA), West Pacific pattern, East Pacific/North Pacific pattern, Pacific/North American pattern (PNA), East Atlantic/West Russian pattern, Scandinavia pattern, Tropical/Northern Hemisphere pattern (TNH), Polar/Eurasia pattern, and Pacific Transition pattern. In the North Atlantic, the NAO is primary mode of the atmospheric teleconnection pattern, and numerous authors have described oceanic variations associated with the NAO. However, except NAO, it is not clear how other teleconnection patterns give an impact on the oceanic variations. In this study, we focus on the wind stress curl (WSC), since the WSC is regarded as the driving source for the oceanic gyre. The purpose of the present study is to clarify the features of WSC field and to reveal their relation to atmospheric teleconnection pattern.

We use two reanalysis datasets of WSC: NCEP/NCAR (Kalnay et al. 1996) and ERA-40 (Uppala et al. 2005). Since the WSC is calculated by the spatial derivative of wind stress, small-scale features tend to be relatively exaggerated. In order to highlight the large-scale variations, we use WSC field smoothed by a 1-2-1 filter in zonal and directions four times and a half power point at about 20 degree. We also use two 500 hPa geopotential height (Z500) dataset and sea level pressure (SLP) dataset: NCEP/NCAR and ERA-40. Although two datasets have different grid scales and data periods, we did not unify. In the present study, we focus on winter (December to February). In the following description, we show only the results using the dataset of NCEP/NCAR reanalysis, since we could get almost the same results of the ERA-40 dataset. The winter indices of atmospheric teleconnection patterns derived by Barnston and Livezey (1987) are used. The analysis area is the North Atlantic sector [10°N-80°N, 90°W-30°E], which includes both subtropical and subpolar gyres. Analysis period is 56 years from 1950 to 2005.

We perform a rotated empirical orthogonal function (REOF) analysis for the WSC anomaly field (Fig. 1). The first mode shows a tripole pattern at the eastern part of the target area (Fig. 1a), the second mode represents a die-pole pattern at the eastern part (Fig. 1b), the third mode exhibits a die-pole pattern at the central part (Fig. 1c), and the fourth mode is dominated only at the western part (Fig. 1d). After adopting a correlation analysis between the REOF modes and teleconnection pattern indices, it is clearly found that each mode has one-to-one relations with specific teleconnection pattern: NAO for the first mode, EA pattern for the second mode, TNH pattern for the third mode, and PNA pattern for the fourth mode. The same relations are obtained from a Maximum Covariance analysis (MCA) applied to WSC anomaly field in the North Atlantic sector and Z500 anomaly field in the Northern Hemisphere north of 10°N.

Next, we investigate an impact of teleconnection patterns on the oceanic gyre, in terms of behaviors of Sverdrup transport (SVT). The SVT can be regarded as values showing the current of wind driven circulation under the assumption of linear-barotropic response of the ocean to WSC. In the real ocean, there are delayed ocean adjustment processes due to the baroclinic Rossby wave propagation. However, we cannot expect this kind of response. We focus on the NAO and EA pattern, because these two patterns are extracted as the leading two modes by REOF analysis and MCA. As a result, it is found that the NAO forcing makes the both subtropical and subpolar gyres spin-up or spin-down simultaneously, and EA forcing controls the latitudinal shift of gyre boundary designated by the SVT zero line.

Finally, it is suggested that it is necessary to evaluate not only the roles of NAO but also those of EA, TNH, and PNA for the further understanding of air-sea coupled system.

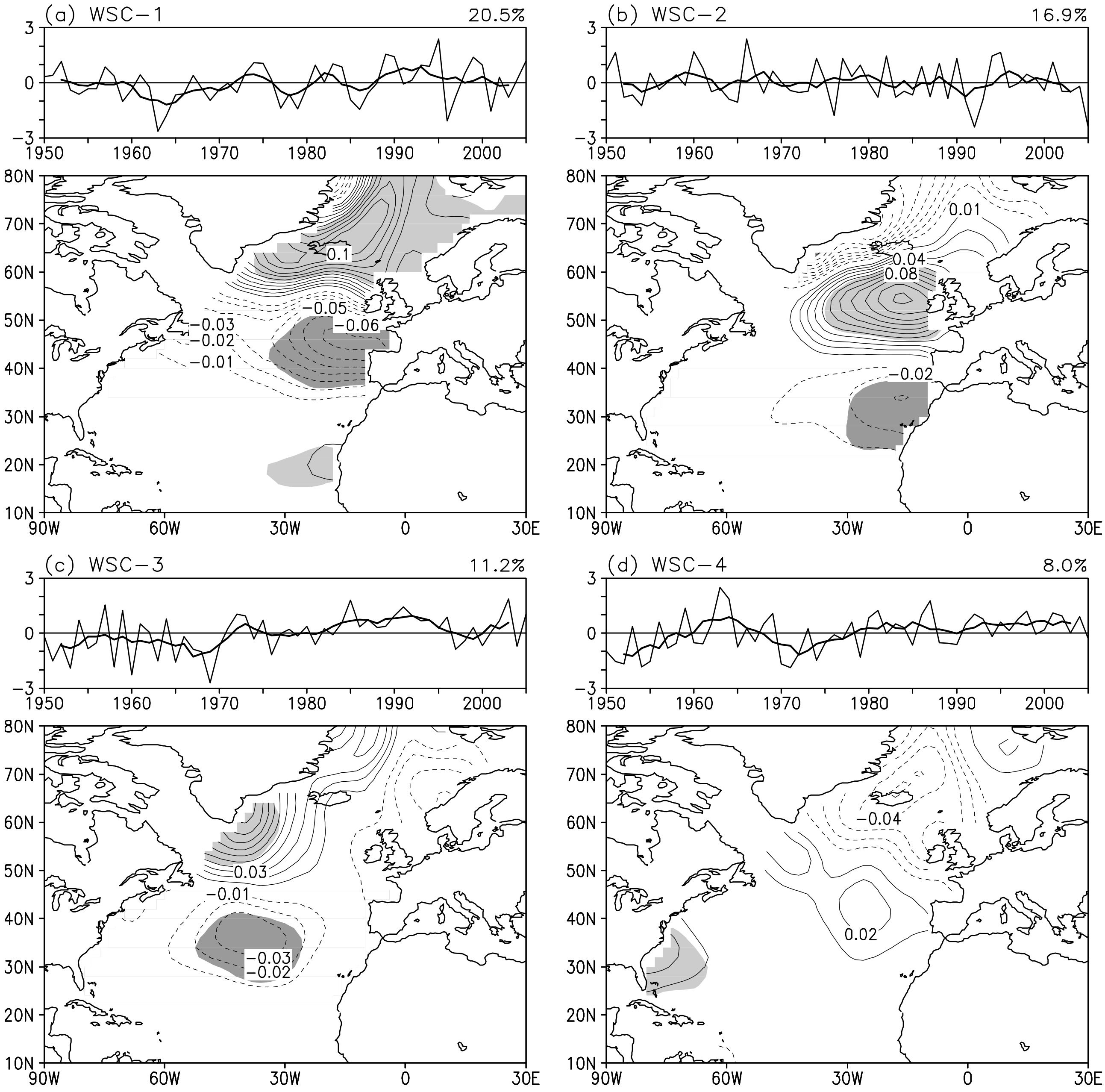

Fig. 1. REOF modes of WSC anomaly field: (a) WSC-1, (b) WSC-2, (c) WSC-3, and (d) WSC-4. (Upper panels) Time coefficient. Thick line denotes 5-year running mean. (Lower panels) Regression coefficient of WSC. Contour interval is 0.01. Unit is 10^{-6} kg m^{-2} s^{-2}. Shading denotes regions exceeding a significance level of 1%. Percent of explained variance is shown in the upper right of each panel.

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