Analytical and theoretical study for seasonal variation of the Arctic Oscillation

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The Arctic Oscillation (AO) is a notable atmospheric phenomenon in the Northern Hemisphere in winter, which is a north-south seesaw of the atmospheric mass between the Arctic region poleward of 60N and a surrounding zonal ring in the mid-latitude. The AO is defined as the primary mode of the emprical orthogonal functions (EOF-1) for the wintertime sea level pressure (SLP) anomaly in the Northern Hemisphere. It is generally agreed that the AO is essentially a mode internal to the atmosphere. However, the realization as to whether the AO is a physical mode of a linearized dynamical system, or a simple statistical illusion of independent multiple teleconnections, is an open question under active debate.

The purpose of this study is to investigate the seasonal variation of the AO by applying EOF analyses for each month. Moreover, compared with the theoretical AO mode obtained by SVD analysis using the barotropic S-model, we investigate whether the AO in each season is a physical mode of a dynamical system for the global atmosphere or not.

The EOF analyses are conducted for the barotropic component of the atmosphere, 500hPa height and SLP. The AO in winter appears for every atmospheric field, negative anomaly over the Arctic and positive anomalies over the North Atlantic and North Pacific. The AO in summer obtained from SLP is different from that in other seasons, which shows only positive anomaly over the Eurasian Continent. The AO in summer obtained by the barotropic component is different from SV-NAM obtained by Ogi et al. (2004). In fall, the structures derived by EOF-1 appear in synoptic-scale pattern, which is not similar to the AO in winter. The AO in summer appears to be sensitive to the analysis period and EOF analysis area.

Next, the SVD analyses, based on the neutral mode theory, are conducted for each season to compare with the EOF-1 for each season. It is found that the AO-like structure appears robustly in DJF when the viscosity is parameterized by the scale-dependent hyperdiffsion. However, in other seasons, the dynamical SVD-1 mode is different from the observed EOF-1. Therefore, the viscosity is changed to the bi-harmonic diffusion. It is found that the dynamical SVD-1 mode is different from the observed EOF-1.

From these results, it is found that the structure of the AO in summer is not an annular pattern due to the influence of baroclinic component. Moreover, in reference to the result of the nonlinear simulation of the AO using the same barotropic model, it is concluded that the AO in winter is a physical mode of a dynamical system for the global atmosphere, however, the AO in summer is a not physical mode.