Recent understanding of AO and its predictability in the NWP models

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The Arctic Oscillation (AO) is a noticeable variation pattern in boreal winter and one of the most important aspects for winter seasonal forecasts in East Asia. While the AO has been actively studied over the last decade, its mechanism has not been clarified completely. In the presentation, overview of recent studies on the AO and its predictability by the numerical weather prediction (NWP) models will be introduced from the seasonal forecaster's viewpoint.

The AO is defined as the leading mode of Empirical Orthogonal Function (EOF) analysis of sea level pressure in winter and characterized by the contrast of sea-level pressure anomalies between the Arctic and mid-latitudes. This "annular" pattern can been found from the troposphere to the lower stratosphere. Therefore, the AO has a barotropic pattern. The AO index is defined as a component of the leading mode of the EOF of 500 hPa height anomalies in winter (DJF) in JMA. If the AO index is positive, the polar vortex shrinks and strengthens and the westerlies tend to flow zonally. On the other hand, in case of the negative AO index, the westerlies tend to meander and cold air mass tends to inflow from high latitudes to East Asia.

The AO pattern is found even in a long-range integration experiment of an atmospheric general circulation model (AGCM) with fixed climatological conditions of SST. This means that the AO is an internal variability of the atmosphere in mid-high latitudes. Recent studies indicate that the AO is sustained mainly by the interaction between zonally asymmetric waves and zonal mean flow (zonal-eddy coupling).

According to the hindcast (22 years from 1984 to 2005) of the JMA's seasonal prediction model, forecast skill of the AO is low. This issue is common to all of the NWP models because the AO is the internal variability of the atmosphere in the mid-high latitudes even if the AO is affected by the forcing from the tropical ocean. (Generally, forecast skill in mid-high latitudes is lower than that in the tropics.)

Nevertheless, some interesting studies have been reported about the AO. In the Northern Atlantic, many studies on the North Atlantic Oscillation (NAO) have been carried out. The NAO is the dominant mode of winter climate variability in the North Atlantic and pressure gradient variation between the Icelandic Low and the Azores High. Therefore, the anomalies pattern of NAO is similar to that of AO in the North Atlantic. It is known that the NAO has high correlation with the meridional "tripole" pattern of SST anomalies in the Atlantic, which is the main mode of decadal-scale variability. Some studies show that the tripole pattern of SST anomalies forces the NAO pattern, as the El Niño-like SST anomalies force the Pacific/North American (PNA) pattern. One of the reasons why the NAO attracts attention recently is that some studies have pointed out the relationship between the NAO/AO index and global warming. The NAO/AO index has an upward trend since 1960s, and it will be positive in the global warming hypothesis experiment. According to this view, the warming will accelerate in the mid-latitudes such as East Asia. However, the upward trend of the NAO/AO index becomes unclear in the recent years. The relation between the AO/NAO and global warming will be discussed as a future issue.

On the other hand, there is some research showing inverse relationship between snow coverage in the eastern Eurasia in fall and the AO index in the subsequent winter. Meanwhile, in the stratosphere-troposphere interaction, the Polar-night Jet Oscillation (PJO), which is a prominent mode in the winter stratosphere, can promote the AO pattern in the troposphere. Such studies may offer new views of the predictability of the AO.

Finally, some model products by the recent the JMA's seasonal numerical ensemble prediction for 2008/2009 winter, which was used for one of the prognostic tools for the JMA's operational cold season outlook issued on 23 October 2008, will be introduced. The initial date is 17 October 2008 and the ensemble size is 51. Figure 1 shows the ensemble mean of 500hPa height anomalies at 500 hPa during this winter (DJF in 2008/09). Figure 2 shows the leading mode of 500 hPa anomalies in this winter by each ensemble member. Figure 3 shows prediction skill of the AO index by the hindcast (22 years from 1984 to 2005) for DJF with the initial date in October. The results of figures 1 and 2 indicate positive phase of the AO. However, forecasters need to consider the low prediction skill of AO according to the hindcast (Figure 3).

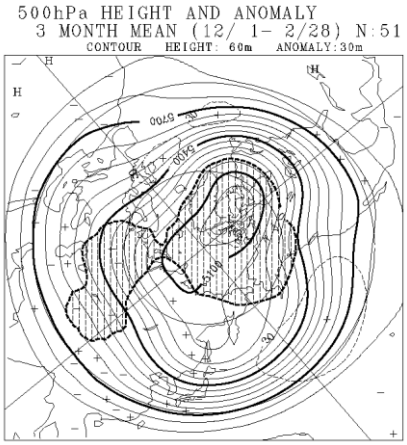

Figure 1 Ensemble mean of 500hPa height anomalies at 500 hPa during this winter (DJF in 2008/09)

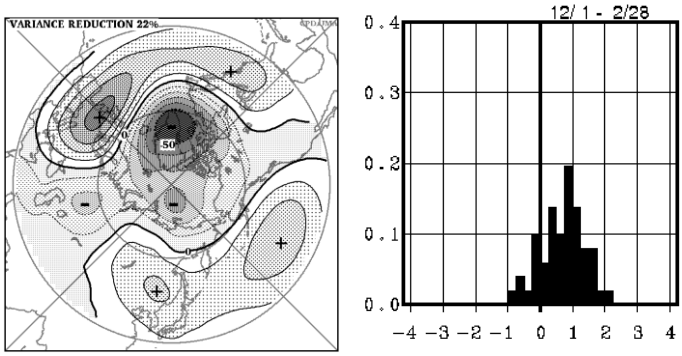

Figure 2 EOF-1 mode of 500 hPa height anomalies in winter (DJF) (left) and the histogram of the predicted AO index (component of EOF-1 mode of 500 hPa anomalies in winter) by each ensemble member (right)

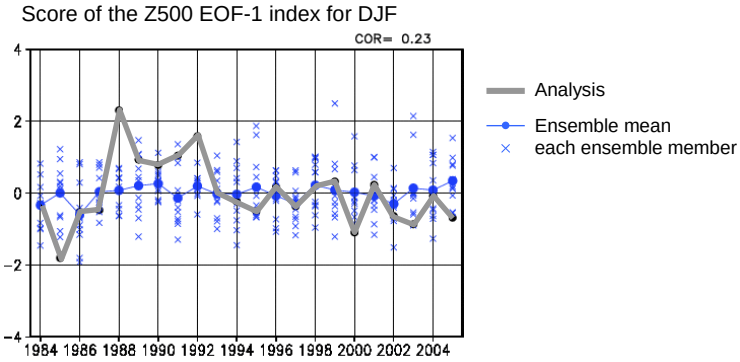

Figure 3 Prediction skill of the AO index by the hindcast (22 years from 1984 to 2005) for DJF with the initial date in October