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Aleutian-Icelandic Low Seesaw and its Relationship with the Arctic Oscillation (Extended Abstract)

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1. Introduction

Recent studies have revealed that a seesaw-like oscillation is dominant in the wintertime Northern Hemisphere (NH) lower stratosphere between the polar vortex and its surroundings, coupled with the tropospheric variability reminiscent of the well-known North Atlantic Oscillation (NAO). Thompson and Wallace (1998) called this pattern "Arctic Oscillation (AO)". Unlike the conventionally defined NAO, however, this pattern with a high degree of zonal symmetry is characterized by significant pressure anomalies with a particular sign that cover the entire Arctic region. They postulated the concept of "annular mode", to describe essential dynamics common in the AO and its Southern Hemisphere counterpart. Wallace (2000) argued that the NAO is merely a regional expression of the NH annular mode or AO. Deser (2000) showed that the annularity of the AO is owing to the dominance of the associated Arctic anomalies rather than to the midlatitude inter-basin link between the NA and North Pacific (NP). These studies emphasize a meridional linkage between the Arctic and NA, which accounts for a larger fraction of the interannual variance in the sea-level pressure (SLP) over the extratropical NH than any other anomaly patterns. It is thus implied that the Icelandic low (IL) tends to vary with the Arctic polar vortex and represented well in the leading empirical orthogonal function (EOF) of SLP over the extratropical NH.

It was suggested previously, however, that a seesaw-like interannual oscillation tends to occur in winter between the IL and Aleutian Low (AL ; van Loon and Rogers 1978 ; Wallace and Gutzler 1981). The seesaw signature was apparently imprinted in the leading EOF pattern of monthly SLP anomalies. In our recent paper (Honda *et al.* 2001), we found that the seesaw tends to be apparent particularly during late winter (February to mid-March). The seesaw appears to form in association with the propagation of wave activity accumulated from early to midwinter over the NP into the NA in the form of stationary Rossby wave trains across North America and the northern NA. The seesaw formation is completed in late winter after the anomalies over the NA formed as a part of the wave train become matured and maintained through the feedback forcing from high-frequency transients along the Atlantic storm track, while the NP anomalies are also kept maintained through the feedback from the Pacific storm track.

With the particular seasonal dependence of the seesaw formation between the IL and AL, both of which reside where the interannual variability is strongest in the extratropical NH, one may wonder what impact the seesaw formation may possibly exert upon the structure of the leading NH tropospheric variability especially in late winter. Bearing this issue in mind, we perform the following statistical analyses by using atmospheric circulation data over the 22 recent years (1973-1994), during which the seesaw signature was more apparent than before. We utilized the daily data based on the National Meteorological Center (NMC, currently the U.S. National Centers for Environmental Prediction : NCEP) analyses and the NCEP reanalyses. A more complete description is found in Honda and Nakamura (2001).

2. Results

In order to show the significant influence of the formation of the AL-IL seesaw upon the seasonality of the leading interannual variability in a straightforward manner, an EOF analysis was applied to the monthly extratropical anomalies in SLP, 250- and 50-hPa height for the November-December-January (NDJ) and February-March-April (FMA) periods, separately (Fig. 1). It is apparent that the seesaw formation significantly modifies the characteristics of the leading tropospheric EOFs. he tropospheric "annular mode" is present at the surface throughout the cold season (Figs. 1a ands 1d), and it is indeed identified as the leading interannual variability in early winter both in the lower and upper troposphere (Figs. 1a and 1b). After the seesaw formation in February, however, the annular mode is no longer identified as the leading variability in the upper troposphere (Fig. 1e). Rather, it is masked by the predominant combined signature of the so-called Pacific/North American pattern and a meridional dipole over the Northwestern Atlantic as an upper-level manifestation of the seesaw. Though somewhat less pronounced, the pattern of the near-surface leading variability is modified accordingly in late winter by the superposition of the distinct signature of the seesaw upon the annular mode (Fig. 1d). In the stratosphere, in contrast, the annular mode is unambiguously identified as the leading interannual variability throughout winter (Figs. 1c and 1f), suggesting that the AL-IL seesaw is essentially a tropospheric phenomenon. The above result based on monthly anomalies has been confirmed by applying an EOF analysis separately to anomalies averaged over each of the nine overlapping 45-day periods staggered with 15-day intervals.

As shown in Fig. 2a, the correlation between the leading upper- and lower-tropospheric PCs is strongly positive in all the nine sub-seasonal periods throughout winter, indicating the strong vertical coupling of the leading interannual variability within the troposphere. In contrast, the correlation between the leading tropospheric and stratospheric PCs exhibits a notable late-winter minimum. It may be the case, however, that the annular mode are still significant in late winter but captured in higher-order EOFs. So, as another indicator of the mode, we averaged anomalies over the Arctic region to the north of 80°N. These "polar cap anomalies" could capture the AO-related variability even if its midlatitude anomalies were masked by other teleconnection patterns. As shown in Fig. 2b, the correlation between the tropospheric and stratospheric polar-cap anomalies is highly significant throughout winter, indicating that the vertical coupling of interannual anomalies remains strong within the polar vortex associated with the annular mode. Therefore, the apparent late-winter reduction in the coherence between the tropospheric and stratospheric leading variability is not due to the disappearance of the annular mode. Rather, it must be attributed primarily to the tendency that the signal of the AL-IL seesaw dominates over the signature of the annular mode in the troposphere during late winter.

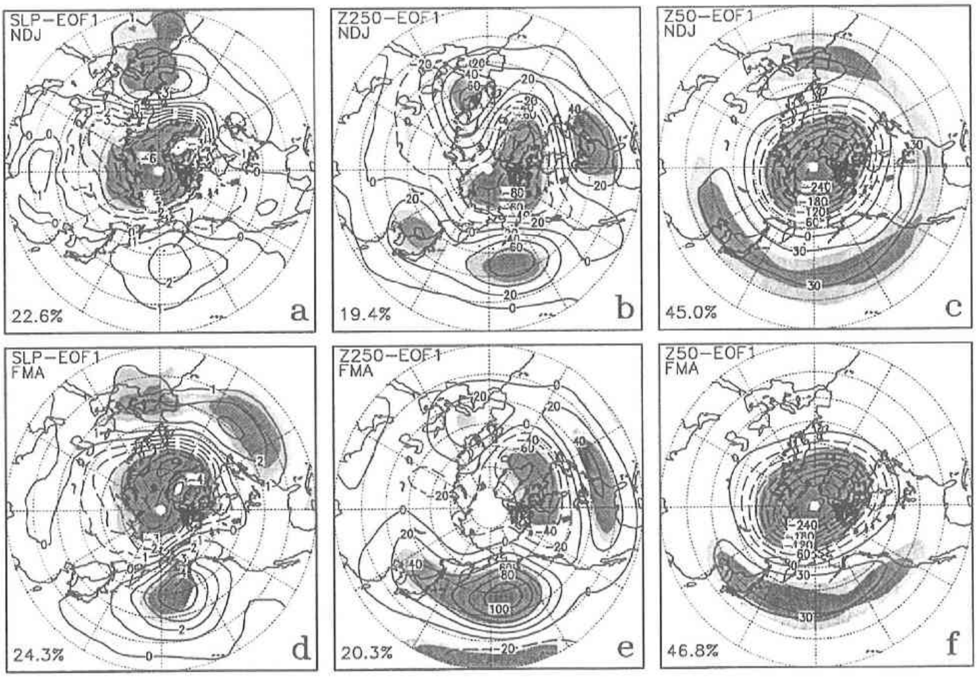

Fig. 1 The first EOFs of monthly (a) SLP, (b) 250-hPa and (c) 50-hPa height anomalies over the domain poleward of 20°N only for November, December and January over the period of 1973–1994. (d), (e) and (f) : are the counterparts of (a), (b) and (c), respectively, for February, March and April. Plotted in each panel is the linear regression coefficient between a local monthly anomaly of a given variable and the leading principal component (PC) of the variable. The coefficient corresponds to a local change in a particular variable when a given PC increases by its unit standard deviation. Areas of light and heavy shading indicate the correlation between the anomalies and PC is significant with the 90% and 95% confidence levels, respectively. Contour interval : 1 hPa (a and d), 20 m (b and e), 30 m (c and f). Negative contours are dashed.

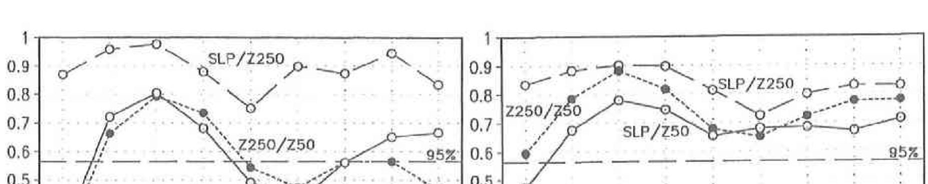

Fig. 2(a) Simultaneous correlation coefficients among the leading PCs of the mean SLP, 250-hPa and 50-hPa height anomalies for each of the nine 45-day periods from early December to early April over the 1973–1994 period. The 95% confidence level is indicated. (b) As in (a), but for 45-day mean "polar cap anomalies" of the three variables defined as their averages over the area to the north of 80°N.

3. Concluding remarks

The present study has revealed that the late-winter formation of the AL-IL seesaw exerts a substantial impact on the structure of the leading interannual variability in the troposphere. Despite the zonally-symmetric anomalies associated with the annular mode are significant throughout the cold season, the zonally-asymmetric anomalies associated with the AL-IL seesaw are superimposed on the annular mode signature in the lower troposphere and they even overwhelm it in the upper troposphere. The annularity of the tropospheric leading variability is thus reduced in late winter especially at the upper troposphere. Nevertheless, because of a particular geographical alignment between the anomalous IL and AL, zonal wind anomalies associated with their late-winter seesaw yield a strong projection on the meridional plane, whose latitudinal profile is almost indistinguishable from the counterpart of the annular mode. Therefore, any dynamical interpretation of the NH annular mode (or AO) based on zonal averaging of the observed anomalies requires some caution, as long as the analysis period includes late winter. It is argued that the AO, defined as the leading SLP variability for the entire cold season, may be interpreted as a mixture of the annular mode and the AL-IL seesaw. It is also argued that the late-winter tropospheric variability over the NA may not necessarily be associated with the annular mode (or AO), since as much as 50% of it, particularly in the vicinity of the climatological-mean IL, is found covariant with the NP variability for the data period considered.

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