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Anomalous high-frequency wave activity flux preceding anomalous changes in the Northern polar jet

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Anomalous forcing by quasi-geostrophic (QG) waves has been reported as an important forcing factor in the Northern Annular Mode (NAM) in recent literatures. In order to shed a light on the dynamics of the NAM from a different angle, we have examined anomalous behavior of the winter jets in the upper troposphere and stratosphere by focusing our diagnosis on not the anomalous geopotential height (Z) itself, but on the anomalous change in the Z (dZ) between two successive months and preceding transient QG wave activity flux during the cold season.

We calculated EOFs of dZ between two successive months at 150hPa for a 46-year period, from 1958 to 2003, using the monthly mean NCEP reanalysis data. We then formed anomaly composites of changes in Z and the zonal velocity (U), as well as the preceding and following wave activity flux, Z, U, and temperature at various heights, for both positive and negative phases of the first EOF.

For the wave forcing fields, we adopted the diagnostic system for the three-dimensional QG transient wave activity flux in the zonally-varying three-dimensional mean flow developed by Plumb (1986) with a slight modification in its application to the data. Our choice of the Plumb86 is based on the fact that the winter mean flow in the Northern Hemisphere is characterized by noticeable zonal asymmetry, and has a symbiotic relationship with waves in the extra-tropics. The Plumb86 flux was calculated for high-frequency (period of 2 to 7 days) and low-frequency (period of 10 to 20 days) waves with the ultra-low-frequency (period of 30 days or longer) flow as the reference state for each time frame of the 6 hourly NCEP reanalysis data from 1958 to 2003. By replacing the mean flow with the ultra-low-frequency flow in the application of the Plumb86 formula, the flux fields were calculated as time series at 6 hour intervals. The time series of the wave activity flux was then averaged for each month.

The patterns of composited anomalous dZ and dU clearly show anomalous acceleration or deceleration of U in the polar region, accompanied by anomalies of the opposite sign in the subtropics throughout the troposphere and stratosphere. The anomalies are conspicuously large in the polar stratosphere. The composited anomalous Z and U in the preceding and following months indicate that these large anomalies in dZ and dU occur when the polar troposphere and stratosphere are relaxing back toward the climatology from strongly anomalous states that closely resemble the positive and negative phases of the NAM. In this process of relaxation, the atmosphere actually overshoots the climatology and develops anomalies of the sign opposite to those existed initially.

The anomalous wave activity flux exhibit strong signals of anomalous upward (downward) propagation of high-frequency waves in the North Atlantic storm track from the bottom of the atmosphere, penetrating up to the stratosphere, when the polar jet is anomalously strong (weak) in the preceding month. The anomalous horizontal wave activity flux shows anomalous eastward (westward) flux emanating from the North Atlantic storm track when the polar jet is anomalously strong (weak) in the preceding month. These patterns suggest that anomalous high-frequency waves originating from the North Atlantic storm track in the lower troposphere contribute to the destruction of both phases of the NAM. However, the anomalous flux divergence is very noisy everywhere due to the noisiness of the advective horizontal flux, making it difficult to ascertain the role of the high-frequency transients in the destruction of the NAM.