Dynamics and Predictability of Downward Propagation of Stratospheric Planetary Waves Promoting Blocking Formation over the North Pacific: A Case study for March 2007

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The atmospheric blocking is one of the most important circulation features in the troposphere causing anomalous weather in the extratropics. Recent theoretical studies have revealed that the blocking is basically maintained against dissipative processes through the selective absorption of synoptic anticyclones due to vortex-vortex interactions. On the other hand, its formation mechanism still remains controversial, but our recent observational studies indicate that downward propagating planetary waves from the stratosphere into the troposphere is a key to promote the blocking formation, especially over the North Pacific. However, the dynamics and predictability of the downward propagation of stratospheric planetary waves have not been revealed as yet.

In this study, predictability of a downward propagating event of planetary waves in the lower stratosphere observed in early March 2007 is examined by conducting ensemble forecasts using an AGCM. It is detected that the predictable period of this event is about 7 days. Regression analysis using all members of an ensemble forecast also reveals that the downward propagation is significantly related to an amplifying quasi-stationary planetary-scale anomaly with barotropic structure in polar regions of the upper stratosphere. Moreover, the anomaly is 90° out of phase with the ensemble mean field. Hence, the upper stratospheric anomaly determines the subsequent vertical propagating direction of incoming planetary waves from the troposphere by changing their vertical phase tilt, which depends on its polarity. Furthermore, the regressed anomaly is found to have similar horizontal structure to the pattern of greatest spread among members for predicted upper-stratospheric height field, and the spread growth rate becomes maximum prior to the occurrence of the downward propagation. Hence, we propose a working hypothesis that the regressed anomaly emerges due to the barotropic instability inherent to the upper stratospheric circulation.

In fact, the stability analysis for basic states comprised of the ensemble-mean forecasted upper-stratospheric streamfunction field using a non-divergent barotropic vorticity equation on a sphere supports our hypothesis. Thus, the barotropic instability inherent to the distorted polar vortex in the upper stratosphere forced by incoming planetary waves from the troposphere determines whether the planetary waves are eventually absorbed in the stratosphere or emitted downward into the troposphere.

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