The Extratropical Response to the Quasi-Biennial Oscillation (QBO) in the NH winter in QBOi experiments

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The quasi-biennial oscillation (QBO) dominates the variability of the equatorial stratosphere and its influence extends extratropical circulation during winter in both hemispheres. One intrigue feature of the Northern Hemisphere (NH) is a phenomenon known as known as a Holton-Tan (HT) effect, whereby the polar vortex tends to be stronger, colder, and less disturbed from its circumpolar circulation in its westerly phase in the equatorial lower stratosphere. Many previous studies have supported the extratropical response to the QBO (HT relationship) in NH winter. However, the mechanism behind the HT effect is still under debate. Here, we examine modulation of planetary wave activities associated with the HT effect, by using the internal-QBO driven Meteorological Research Institute Earth System Model version 2 (MRI-ESM2; updated version) and its former version, under the auspices of the SPARC QBO initiative (QBOi) activity which designed a set of coordinated experiments. Diagnostic tools used here are composite differences in zonal wind, temperature and EP-flux to understand how Rossby wave propagation changes in the presence of equatorial QBO winds.

The conventional HT explanation (or hypothesis) was that the QBO involves the width of the extratropical waveguide as a result of latitudinal shift in the subtropical critical line. In the easterly QBO (E-QBO) phase (~50hPa), the waveguide to the planetary wave propagation should be narrower, which would refract the planetary waves as they propagate out of the troposphere. However, the QBO-composite differences show EP flux anomalies directed just equatorward (i.e., enhanced equatorward flux) in the midlatitude lower stratosphere during 50 hPa E-QBO during NH winter in the model as well as ERAi datasets. This means that the conventional HT hypothesis cannot explain EP-flux composite directions. Overall, our analyses of the composite differences in zonal wind and temperature in the set of coordinated experiments show that the HT effect tend to be large when the QBO-induced mean meridional circulation is strong especially in the upper vicinity of subtropical jet. This result suggests that the QBO-induced mean meridional circulation causes a poleward shift of the subtropical jet, which triggers more waves to propagate into the stratosphere from the troposphere.

Key words: quasi-biennial oscillation (QBO), Holton-Tan effect, extratropical circulation in the Northern Hemisphere

References

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