Hierarchy of numerical model simulations on the equatorial QBO-like oscillations in the stratosphere-troposphere coupled system

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Dynamical features of the vertical coupling between the stratosphere and troposphere in the tropics are quite different from those in the extratropics. In the extratropics, large-scale atmospheric motions are largely constrained by the conservation law of potential vorticity (PV), and winds are induced by PV anomaly field. In the tropics, on the other hand, the Coriolis parameter is so small that geostrophic or gradient wind balance cannot be well applied to large-scale motions. In other words, the quasi-geostrophic constraint is not very strong in the tropics. The predominant source to drive the atmospheric motions is moist convection in the tropics, whereas it is baroclinic instability of the zonally symmetric flow field in the extratropics. Horizontal scale of moist convection is O(l km), and it is much smaller than that of the most unstable baroclinic disturbance in mid-latitudes, O(1000 km), over three orders or so.

In the last decade or two, some observational, numerical, and theoretical studies have revealed multifaceted aspects of the two-way dynamical coupling in the tropics, not only upward influence but also downward one, associated with the equatorial Quasi-Biennial Oscillation (QBO), which is considered to be driven through the wave-mean flow interactions of equatorial waves and gravity waves generated in the troposphere and propagating upward into the stratosphere. Recently, it was shown by analyses of global data over three decades that the QBO modulation of the activity of Madden Julian Oscillation (MJO), which is a predominant intraseasonal oscillation of organized super cloud clusters along the equator, was statistically significant during boreal winter, and that the MJO amplitude is larger in the easterly phase of the QBO than in the westerly phase, with slower eastward propagation and longer life-time of active convection (Yoo and Son, 2016; Nishimoto and Yoden, 2017).

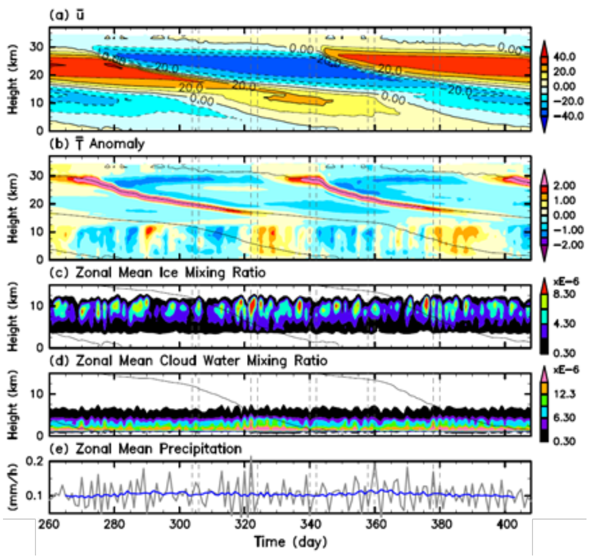

Fig. 1 QBO-like oscillation in a minimal model (Nishimoto et al., 2016).

In this talk, research progress on stratosphere-troposphere two-way dynamical coupling in the tropics is systematically reviewed, and contributions of my group to this research subject based on hierarchy of numerical model simulations on the equatorial QBO-like oscillations in the stratosphere-troposphere coupled system are compactly summarized.

Yoden et al. (2014) used a two-dimensional cloud-system-resolving regional model with explicit stratosphere and troposphere under a periodic lateral boundary condition, and obtained a QBO-like oscillation in a radiative-moist-convective quasi-equilibrium state (Fig.1). It is a self-sustained oscillation in the minimal model of the QBO in a stratosphere-troposphere coupled system. The QBO-oscillation in the minimal model also shows modulation of the zonal mean precipitation in accordance with the oscillation in the troposphere. This could be a good test bed to understand the fundamental characteristics of moist convection and its aggregation depending on the environmental flow and thermodynamic fields.

References

Bui, H.-H., E. Nishimoto, and S. Yoden, 2017: Downward influence of QBO-like oscillation on moist convection in a two-dimensional minimal model framework. *J. Atmos. Sci.*, **74**, 3635-3655, https://doi.org/10.1175/JAS-D-17-0095.1

Nishimoto, E., and S. Yoden, 2017: Influence of the stratospheric quasi-biennial oscillation on the Madden–Julian oscillation during austral summer. *J. Atmos. Sci.*, **74**, 1105-1125, https://doi.org/10.1175/JAS-D-16-0205.1

Nishimoto, E., S. Yoden, and H.-H. Bui, 2016: Vertical momentum transports associated with moist convection and gravity waves in a minimal model of QBO-like oscillation. *J. Atmos. Sci.*, **73**, 2935-2957, https://doi.org/10.1175/JAS-D-15- 0265.1

Yoden, S., H.-H. Bui, and E. Nishimoto, 2014: A minimal model of QBO-like oscillation in a stratosphere-troposphere coupled system under a radiative-moist convective quasi-equilibrium state. *SOLA*, 10, 112-116, https://doi.org/10.2151/sola.2014-023

Yoo, C., and S.-W. Son, 2016: Modulation of the boreal wintertime Madden–Julian oscillation by the stratospheric quasi-biennial oscillation. *Geophys. Res. Lett.*, **43**, 1392–1398, doi:10.1002/2016GL 067762