# The stratospheric QBO affects Southern Ocean sea ice through the tropical convection in early austral winter

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The quasi-biennial oscillation (QBO) is quasi-periodic oscillation of the tropical zonal wind in the stratosphere with 2-2.5-year period. Recently, it has been recognized that the QBO affects the extratropical circulation through tropical convection by modifying tropical tropopause temperature (Martin et al., 2019; Peña-Ortiz et al., 2019; Yamazaki et al., 2020). We examined the QBO effect on Southern Ocean sea ice concentration (SIC) and found clear QBO signals in early austral winter.

The atmospheric dataset we used is the ERA-Interim reanalysis data for 40 years (1979-2018). In this study, the phase of the QBO (easterly or westerly) is defined by the zonal-mean zonal wind near the equator [5S-5N] at 50 hPa in June. The years were classified as WQBO or EQBO years when the absolute values of the wind anomalies exceeded 3 m $s^{-1}$. As a result, we selected 14 EQBO winters and 20 WQBO winters. For SIC, HadISST_version2 dataset was used for the same period. Outgoing longwave radiation (OLR) data from NOAA is also used as a proxy of tropical convection.

SIC differences between EQBO and WQBO show the enhancement of SIC off the Ross Sea, Weddell Sea, and Princess Elizabeth Land in EQBO winters and dominant wave-3 pattern (Fig. 1). This pattern is clearly seen in June and July, and it decays in August. The enhanced SIC regions correspond to anomalous offshore wind regions, and the reduced SIC regions correspond to on shore wind regions. It demonstrates the atmospheric circulation anomaly associated with the QBO produces the SIC anomaly. The surface atmospheric circulation is closely related with the upper atmospheric flow. The upper circulation anomaly associated with the QBO shows a wave train propagating from Indian Ocean to the Ross Sea (Fig. 2).

Seeking for the origin of the wave train, we examined the QBO signal of OLR, i.e., tropical convection. Tropical convection in June shows the enhancement over Indian Ocean in the EQBO composite (Fig. 3). Using a linear baroclinic model (LBM; Watanabe and Kimoto, 2000), it is confirmed that the convective heat source over Indian Ocean can produce the wave train (Fig. 4).

In summary, the stratospheric QBO affects the tropical convection, in this case, over Indian Ocean, then generating the wave train which propagates into high southern latitude. The resultant circulation anomaly affects Southern Ocean sea ice concentration. Because the QBO is a quasi-regular oscillation, the present result gives a possibility that winter sea ice can be predicted in one-year advance.

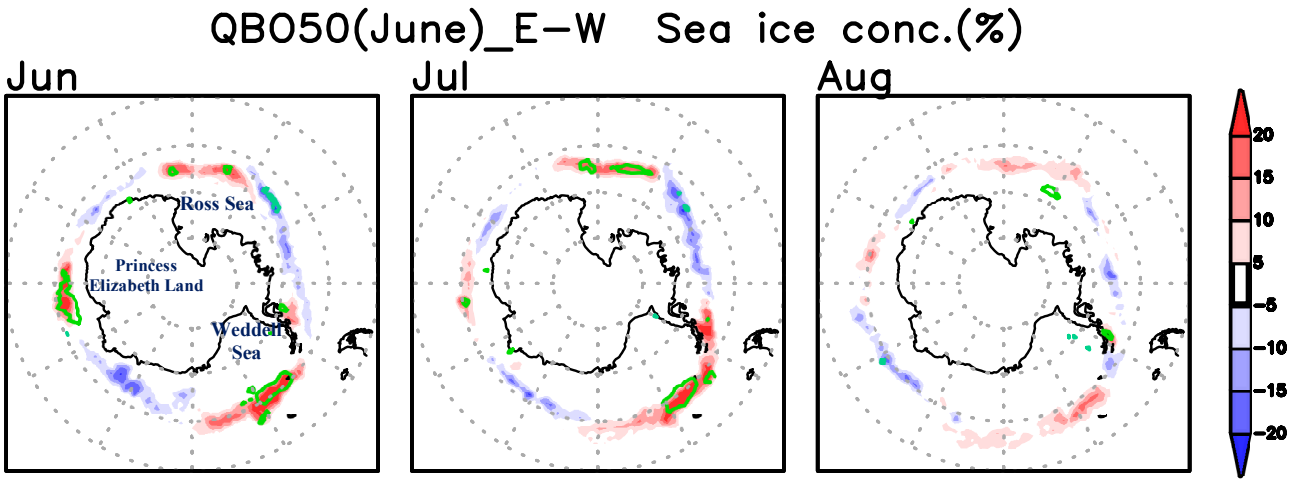


Figure 1. June (left), July (middle), and August (right) sea ice concentration differences between EQBO years and WQBO years (Red and blue shades). Unit is % (color bar). Green (Blue-green) solid (dashed) line shows the area statistically significant at 95% confident level.

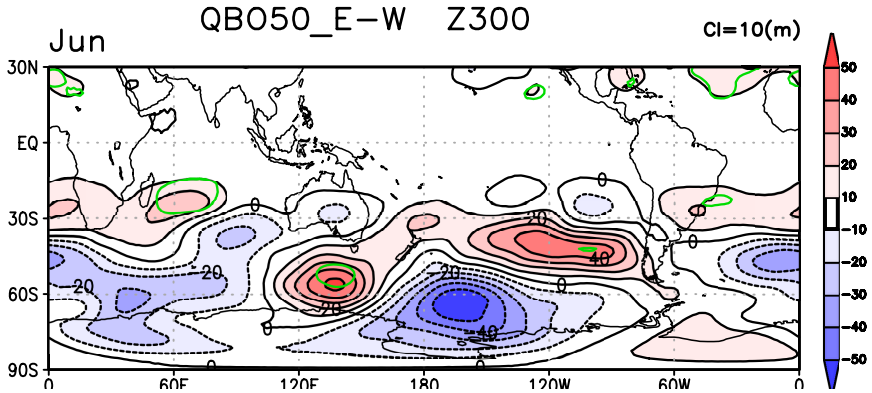


Figure 2. June geopotential difference at 300 hPa between EQBO years and WQBO years. Unit is m. Green (Blue-green) solid (dashed) line shows the area statistically significant at 95% confident level.

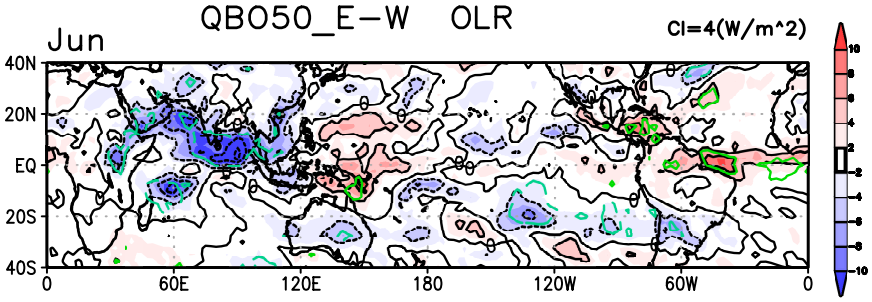


Figure 3. June OLR difference between EQBO years and WQBO years. Unit is W/m$^2$. Generally, the negative value means enhanced convection. Green (Blue-green) solid (dashed) line shows the area statistically significant at 95% confident level.

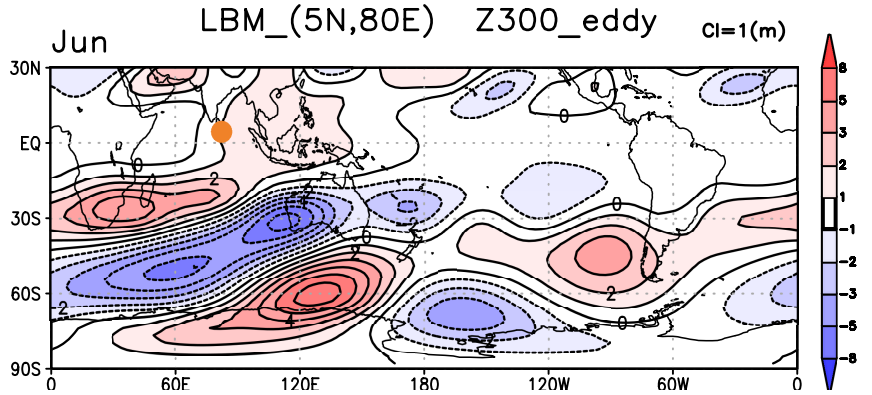


Figure 4. Geopotential height response at 300 hPa upon the heat source centered at [5N, 80E] (shown by orange circle) under climatological June background field. Calculation is based on the LBM. The deviation from the zonal mean is shown.

**References**

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