



## **Modulation of the connection between ENSO and the South China Sea Summer Monsoon Onset by the stratospheric QBO**

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The El Niño–Southern Oscillation(ENSO) can exert significant impact on the onset of South China Sea Summer Monsoon(SCSSM). We investigate the modulation effects and mechanisms of the stratospheric quasi-biennial oscillation(QBO) on the link between ENSO and the SCSSM onset. The connection between the ENSO and the SCSSM onset is shown to depend on the QBO phase. During the westerly shear phase (WS phase), the correlation between the ENSO and SCSSM onset is not significant. While in the easterly shear phase (ES phase), ENSO events can exert a significant impact on the onset dates of SCSSM with late (early) onsets of SCSSM in the El Niño (La Niña) decay years.

During the ES phase, the tropical tropopause is higher over Maritime continent(MC), stratification near tropical tropopause layer(TTL) is more stable due to the temperature anomalies, and the wind shear at TTL is stronger. Therefore, the deep convection in MC is depressed and the effects of QBO strengthen and maintain the El Niño event through Walker Circulation. The effects of the WS phase is contrary. The modulation of the QBO results in the periods of El Niño events is shorter in the WS phase and cannot be sustained until the outbreak of SCSSM. Therefore, during the WS phase the link between the El Niño and the onset of SCSSM is weak.

During La Niña events, the main difference in the modulations between two QBO phases on the SCSSM onset is the spatial distribution of wind anomalies. In the ES phase, the warm anomalies near 20°N, associated with the cold anomalies near equator, generate strong easterly thermal wind south of 20°N. It leads an intensification of the easterly anomalies at upper troposphere over the South China Sea(SCS), which is favorable to the early onset of SCSSM. While in the WS phase, the offsetting effect between QBO and La Niña event results in weak wind anomalies in upper troposphere over SCS. In addition, during the La Niña event years in the WS phase, cold anomalies of SST in tropical northwestern Pacific lead to sinking anomalies and low-level divergence. These effects resulting in low-level easterly anomalies over Indo-China Peninsula and SCS and cutting off the westerly anomalies from Indian Ocean. All of the impacts in WS phase decrease the correlations of the La Niña event and the onset of SCSSM.