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Tropical tropopause layer structure during QBO disruptions and the roles of waves

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The tropical tropopause layer (TTL) is an important region where air enters from the tropical troposphere to the stratosphere. The cold point tropopause (CPT) within the TTL determines how much water vapor can enter the tropical stratosphere. The water vapor will then be transported to higher latitudes via the Brewer-Dobson circulation and further influences the stratospheric chemistry and the radiation budget around the globe.
A dominant mode of variability in the tropical stratosphere – the quasi-biennial oscillation (QBO) – can influence the TTL and related processes through thermal wind balance and secondary circulation. The QBO consists of downward propagating easterlies and westerlies, alternating with a period of about 27–28 months. But twice since its discovery – first in 2015/16 and then again in 2019/20 – the QBO was disrupted — both in the past decade. During these anomalous years, easterlies developed at around 40–50 hPa within the westerly regime, while the westerly regime ascended and halted for about 6 months. There was also stronger tropical upwelling during QBO disruptions that favored the development of anomalous easterly wind.
Here we focus on how the QBO disruptions can influence the TTL structure and water vapor using GPS-RO data, MLS observations, and ERA-5 reanalysis. We analyze temperature, water vapor, and tropical upwelling fields between QBO disruptions and the westerly QBO composite. We find there tends to be a colder zonal mean CPT temperature but relatively more water vapor during QBO disruptions. The increased water vapor relates to the regional pattern of the CPT temperature. During QBO disruptions, CPT temperature tends to be warmer over the western Pacific and colder over the eastern Pacific where the western Pacific is usually called the “cold trap” region and the air gets final dehydrated. Since both tropical and extratropical waves can influence the QBO and the tropical upwelling, we also investigate the roles of waves during QBO disruptions by analyzing the EP flux and its divergence and the momentum equation. We find that tropical waves and midlatitude Rossby waves both influence the zonal wind in the tropical lower stratosphere, but the stronger tropical upwelling is mainly caused by the midlatitude Rossby waves. Studying the influences of QBO on the TTL structure and roles of waves during QBO disruptions sheds light on a better understanding of the mechanisms causing QBO disruptions and their potential influences on the climate.