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Supplement of

Examining ENSO-related variability in tropical tropospheric ozone in the RAQMS-Aura chemical reanalysis

Maggie Bruckner et al.

Correspondence to: Maggie Bruckner (mebruckner@wisc.edu)

S1. Influence of the QBO on RAQMS-Aura upper tropospheric ozone

It has been suggested by prior studies (eg. Chandra et al., 2002; Lee et al., 2010; Oman et al., 2013; Ziemke and Chandra, 2012) that tropical upper troposphere ozone is impacted by the QBO. Here we 1) confirm the presence of a QBO in RAQMS-Aura, 2) evaluate the response of the tropical ozone profile to the QBO, and 3) compare the magnitude of the tropospheric ozone QBO response to the tropospheric ozone ENSO response.

Due to the re-initialization of RAQMS-Aura meteorology with archived NCEP GDAS analyses at 6 hour intervals, a QBO signature is present in the analysis (figure S1) in spite of the relatively coarse vertical resolution in the stratosphere. A similar ozone QBO feature is present in RAQMS-Aura due to the assimilation of Microwave Limb Sounder (MLS) stratospheric ozone profiles. We calculate QBO EOFs from the monthly mean zonal winds over Singapore (1˚N, 104˚E) from 70 to 10hPa (Wallace et al., 1993). The RAQMS-Aura QBO PCs are compared to QBO coefficients available from the NASA Atmospheric Chemistry and Dynamics Laboratory QBO website ((https://acd-ext.gsfc.nasa.gov/Data_services/met/qbo/qbo.html) (figure S2). The RAQMS-Aura QBO PCs and NASA QBO coefficients agree well, signifying that RAQMS-Aura has a realistic QBO zonal mean zonal wind signature.

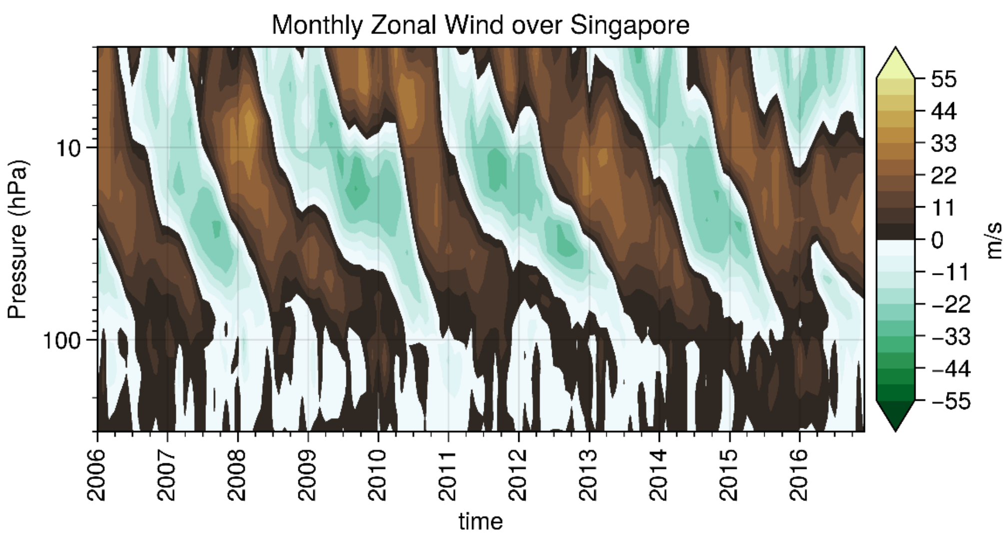

Figure S1. Deseasonalized RAQMS-Aura monthly zonal wind over Singapore.

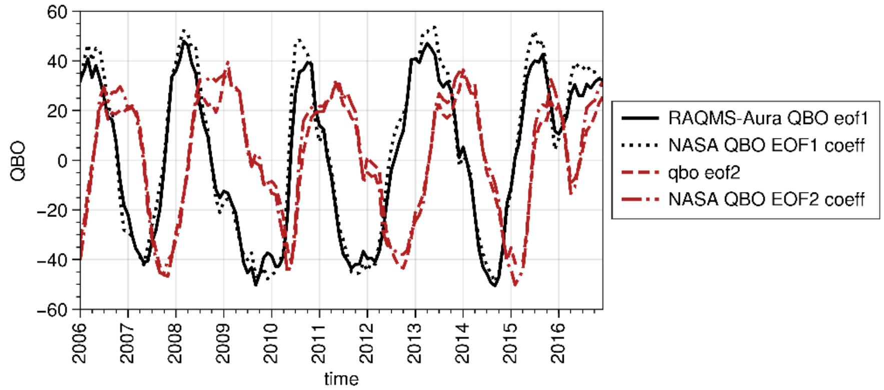

Figure S2. Time series of the first (black) and second (red) QBO EOFs from 2006-2016 from RAQMS-Aura (solid) and NASA Atmospheric Chemistry and Dynamics Laboratory QBO website (https://acd-ext.gsfc.nasa.gov/Data_services/met/qbo/qbo.html) (dashed).

Following Oman et al. 2013 we fit the multiple linear regression $\boldsymbol{\Delta O_3}(t) = \sum \boldsymbol{w_{x_j} \Delta X_j(t) + \epsilon(t)}$ for the 2006-2016 period. $X_{\boldsymbol{j}}$ are the Nino 3.4 index, QBO $PC_{\mathbf{1}}$, and QBO $PC_{\mathbf{2}}$; $\boldsymbol{\Delta O_3}$ is the deseasonalized RAQMS-Aura ozone mixing ratio at 100 hPa over the equator averaged over 180°W - 110°W; $\boldsymbol{w_{x_j}}$ and $\boldsymbol{\epsilon}$ are the regression coefficients. The regression fit is shown in Figure S3a and should be compared to Figure 2 in Oman et al. 2013. The individual contributions to the regression in Figure S3b. The obtained fit is not directly comparable to that obtained from MLS data by Oman et al. 2013 as our regression is fit over a different time period. Despite these differences, we find the magnitude of the QBO contributions to the regression fit relatively small compared to the ENSO contribution as found by Oman et a 2013. From this, we conclude that the QBO has a slight impact on interannual variability in the tropical upper troposphere but this impact is generally small relative to the ENSO impact on the region.

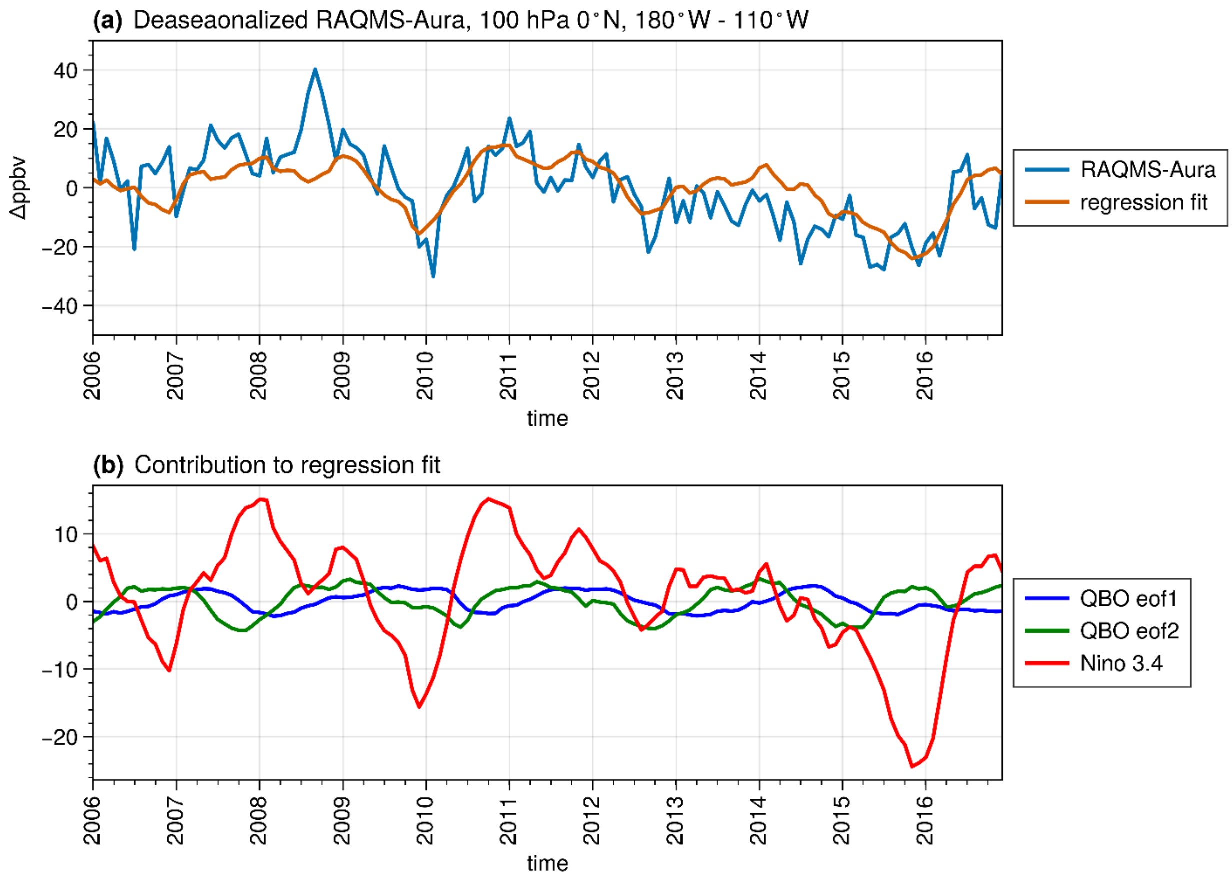

Figure S3. a) Deseasonalized RAQMS-Aura ozone anomaly at 100 hPa over the equator averaged over 180°W - 110°W and reconstructed from multiple linear regression. b) Contribution to the regression of the Nino 3.4 index, RAQMS-Aura QBO PC_1, and RAQMS-Aura QBO PC_2.

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