



*Supplement of*

## **Disentangling the chemistry and transport impacts of the quasi-biennial oscillation on stratospheric ozone**

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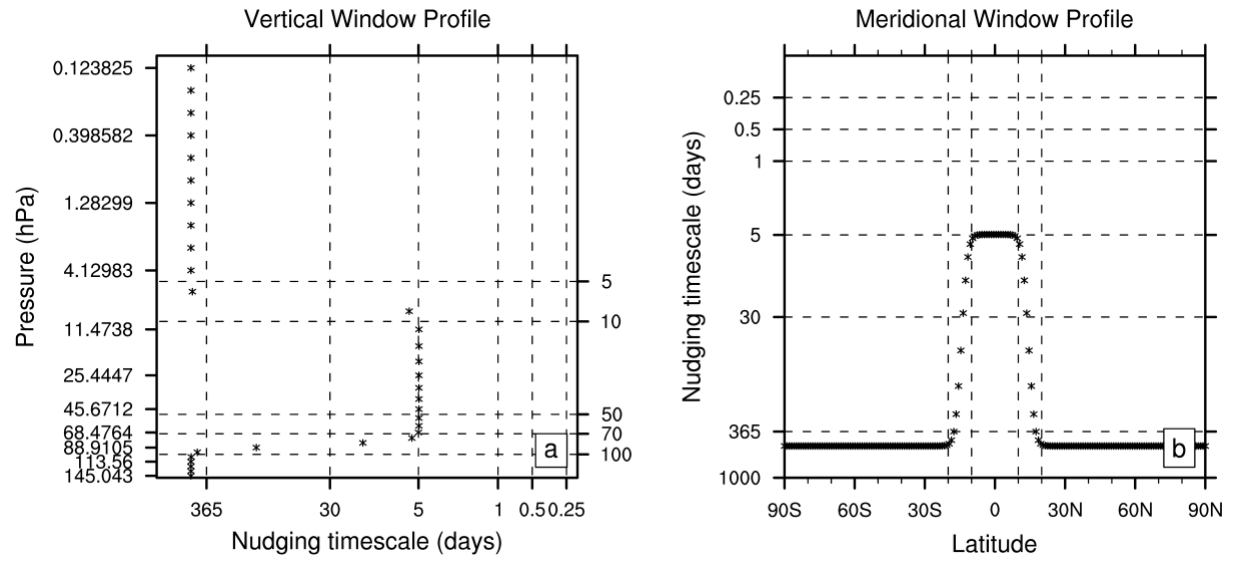


Figure S1 Spatial dependence of nudging timescale in the (a) vertical and (b) meridional directions for E3SMv2.

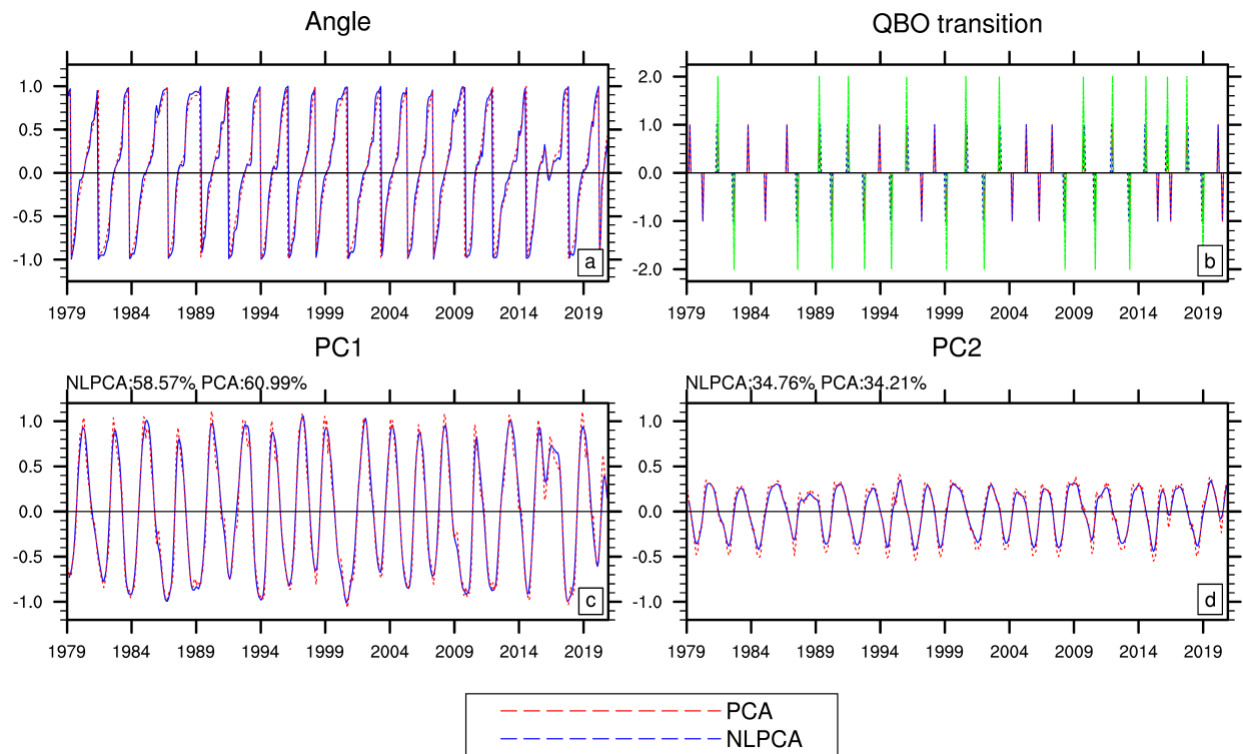


Figure S2 (a) normalized QBO phase angle derived from NLPCA/PCA (red/blue), and (b) NLPCA/PCA representation of the QBO phase transition (1 denotes QBOw->QBOe, -1 denotes QBOe->QBOw, green denotes regions where NLPCA/PCA-derived QBO transition is different), (c) mode 1 and (d) mode 2 principal component. The angle is normalized by  $\pi$ , and 0 and 1 indicate QBO phase transitions (QBOe -> QBOw or QBOw -> QBOe). For showing purpose, PCA1 and PCA2 are divided by 1500 and 1000, respectively.

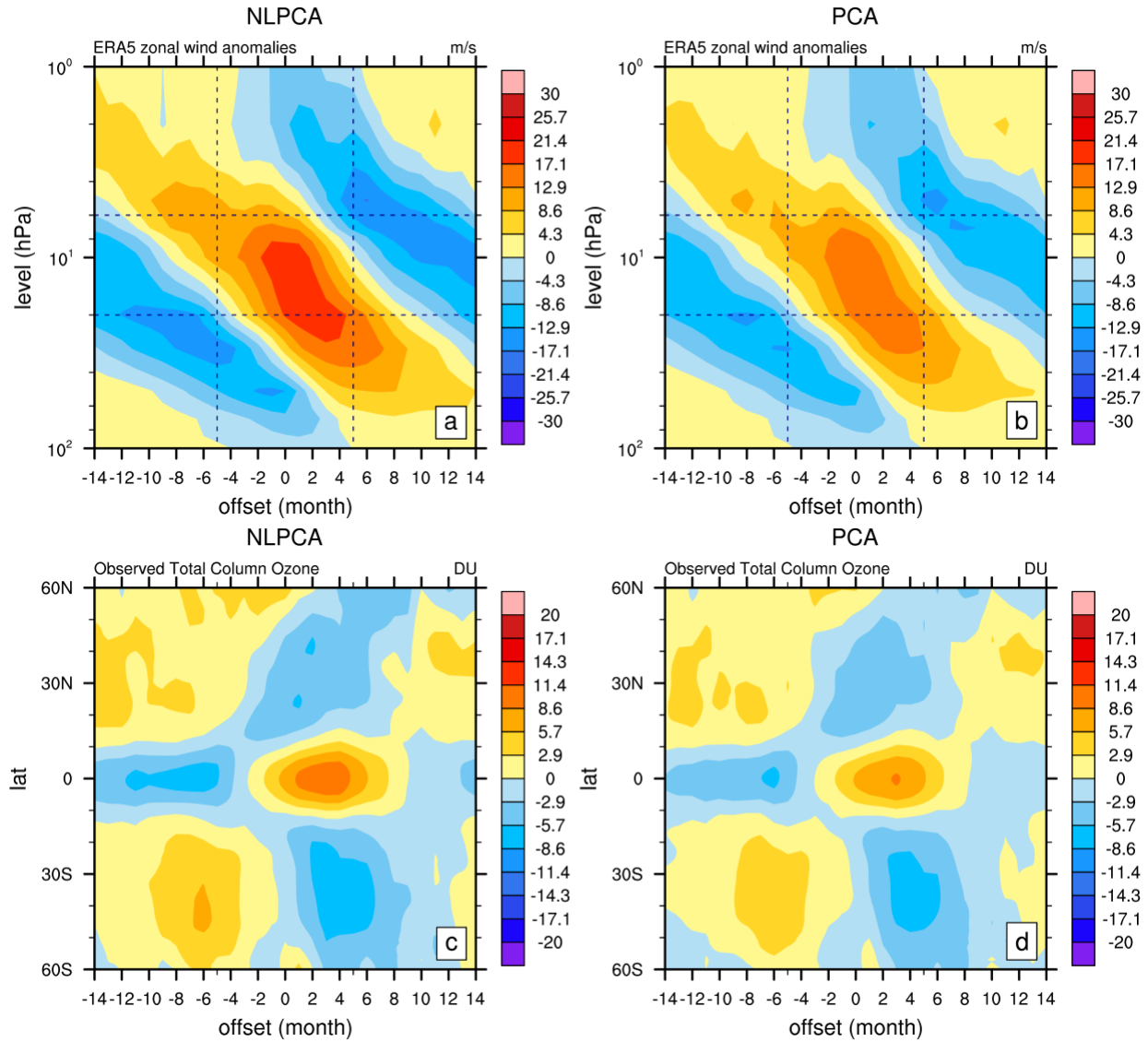


Figure S3 ERA5 tropical zonal wind anomalies (15S-15N, m/s) for 1979-2020 and observed total column ozone (DU) as a function of QBO phase based on index derived from (a, c) NLP, (b, d) PCA.

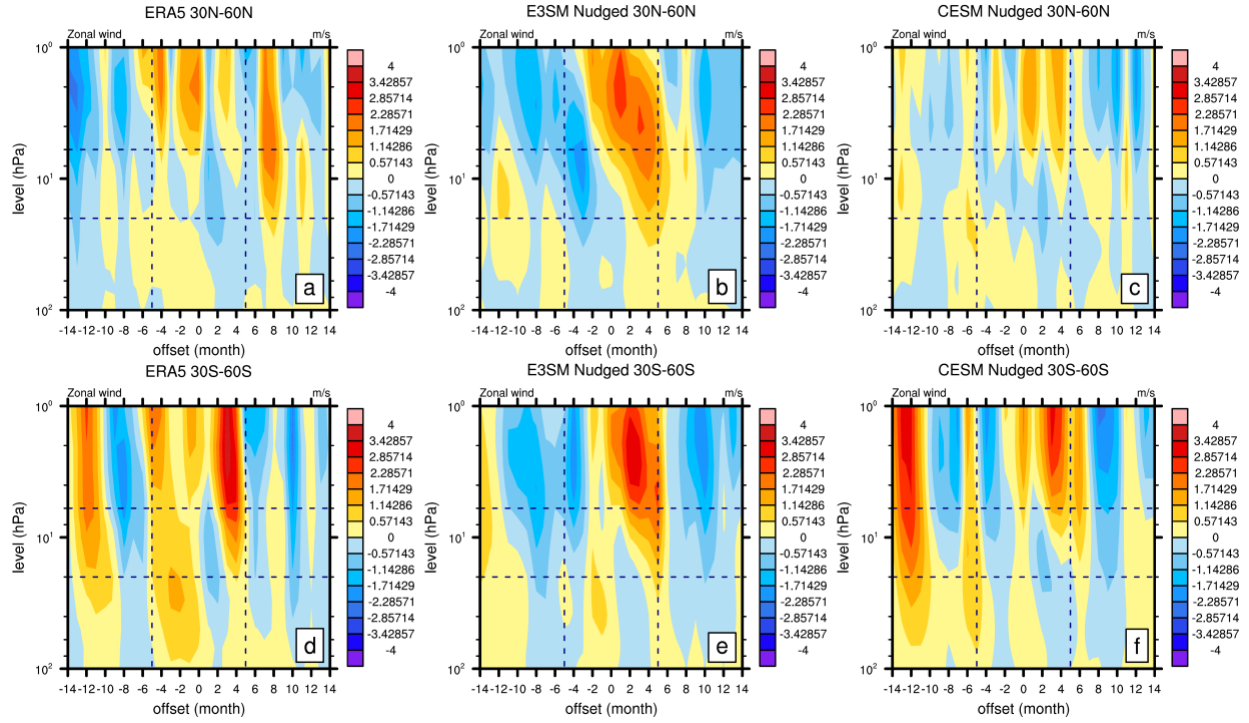


Figure S4 Pressure-time cross-section of the extratropical (30°N-60°N/30°S-60°S) zonal wind (m/s) as function of QBO for (a, d) ERA5, (b, e) E3SMv2 nudged, (c, f) CESM2 nudged for 1979-2020. 0 is centered on the month when QBO index shifts from QBO<sub>e</sub> to QBO<sub>w</sub> (determined by when current QBO index < 0 and next QBO index > 0). The QBO phase is determined by 5S-5N average of the zonal wind.

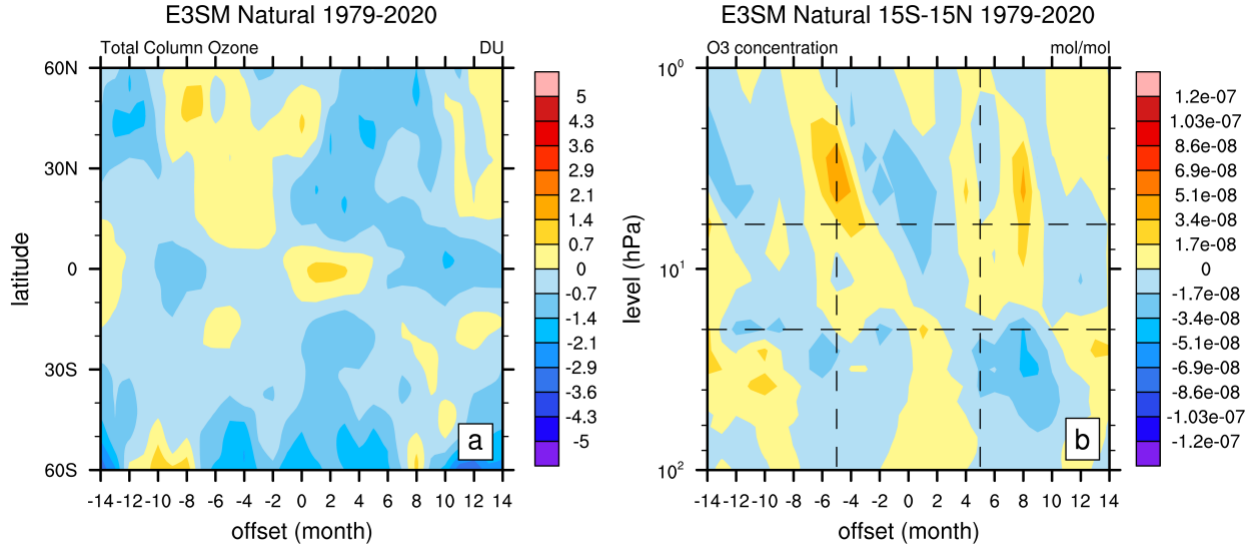


Figure S5 (a) Total column ozone (TCO, Dobson Unit) anomaly (relative to 1979-2020 mean) and (b) pressure-time cross-section of the tropical (15°S-15°N) anomalous ozone concentration (mol/mol) as function of QBO phase (determined by NLPKA QBO index) for E3SMv2 natural simulation for 1979-2020. 0 is centered on the month when QBO index shifts from QBOe to QBOw (determined by when current QBO index < 0 and next QBO index > 0). The QBO phase is determined by 5S-5N average of the zonal wind.

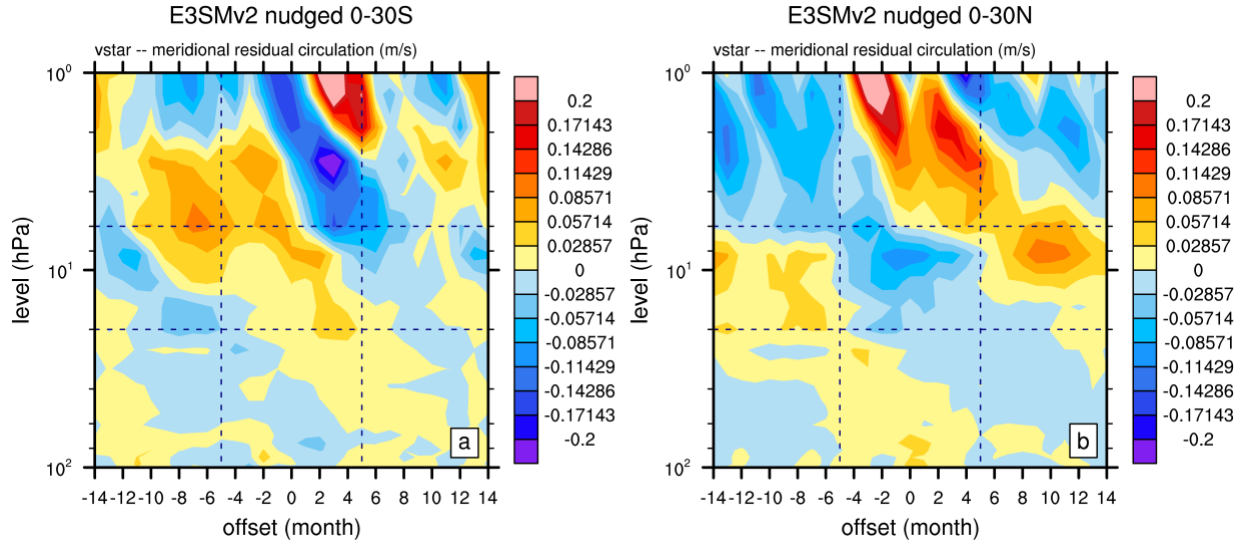


Figure S6 Pressure-time cross-section of the northern and southern hemisphere ( $0^{\circ}$ - $30^{\circ}$ N/ $0^{\circ}$ - $30^{\circ}$ S) anomalous transformed eulerian mean  $v^*$  (m/s) as function of QBO phase (determined by NLPCA QBO index) for E3SMv2 nudged simulation for 1979-2020. 0 is centered on the month when QBO index shifts from QBOe to QBOw (determined by when current QBO index  $< 0$  and next QBO index  $> 0$ ). The QBO phase is determined by 5S-5N average of the zonal wind.

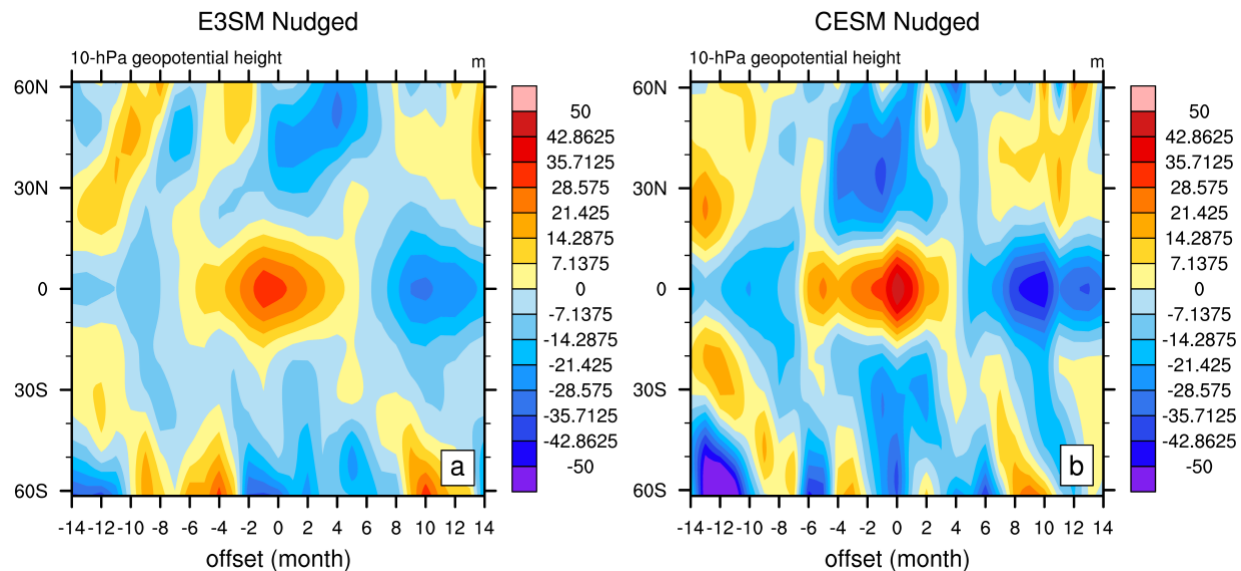


Figure S7 10-hPa geopotential height (m) for (a) E3SMv2 Nudged, (b) CESM2 Nudged. 0 is centered on the month when QBO transits from QBOe to QBOw (determined by when current QBO index < 0 and next QBO index > 0). The QBO phase is determined by 5S-5N average of the zonal wind.



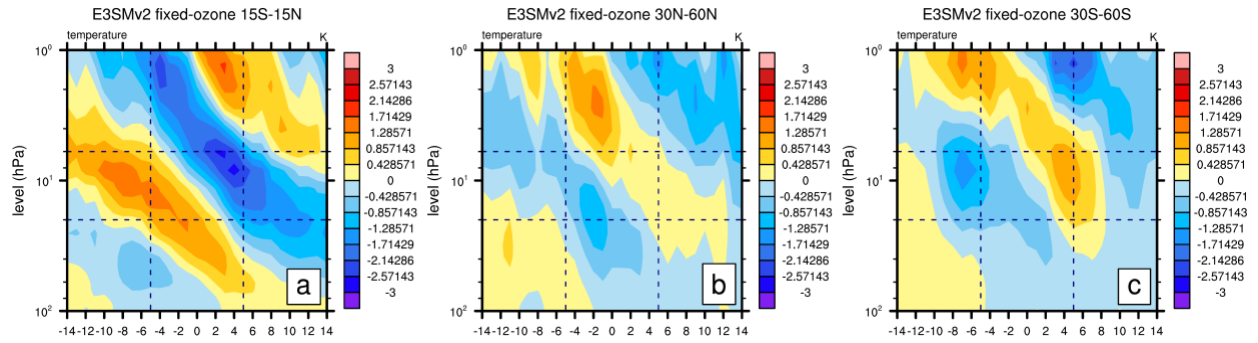


Figure S8 Pressure-time cross-section of the tropical/extratropical (15°S-15°N/30°N-60°N/30°S-60°S) 1979-2020 temperature (K) as function of QBO for (a, b, c) E3SMv2 fixed-ozone. 0 is centered on the month when QBO index shifts from QBOe to QBOw (determined by when current QBO index < 0 and next QBO index > 0). The QBO phase is determined by 5S-5N average of the zonal wind.