Stratosphere-Troposphere Coupling: The Influence of the Quasi-Biennial Oscillation on the Arctic Polar Vortex and Troposphere in Perpetual Winter WACCM Runs

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Introduction

- QBO is the dominant mode of interannual variability in the tropical stratosphere, but is not well represented by the vast majority of GCMs.
- Here we study how an imposed QBO influences the circulation outside the tropical stratosphere

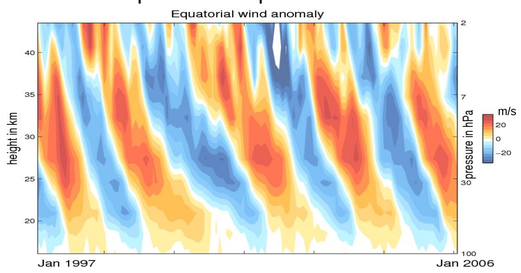


Figure 1: Zonal wind anomalies in reanalysis data

Focus on the effect of the QBO in two regions: extratropical troposphere and stratospheric polar vortex.

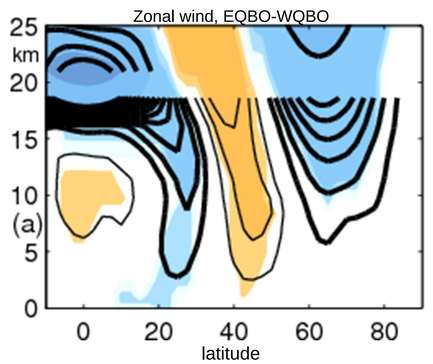


Figure 2:Monthly averaged zonally averaged zonal wind Easterly QBO(EQBO)-Westerly QBO(WQBO), Reanalysis, NDJF C.I.=0.5m/s in troposphere and 5m/s in stratosphere

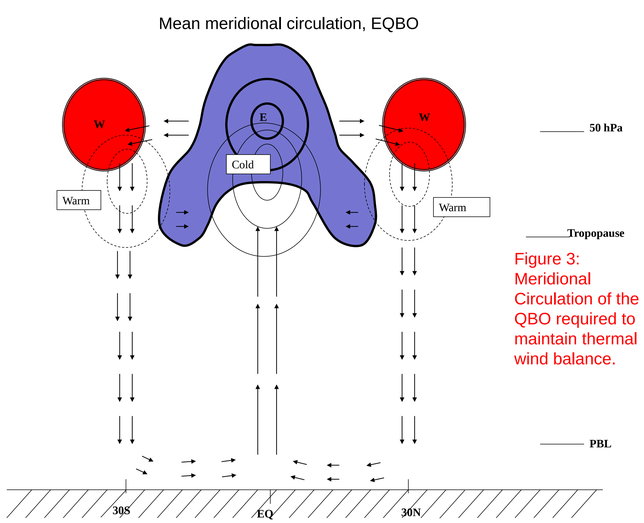
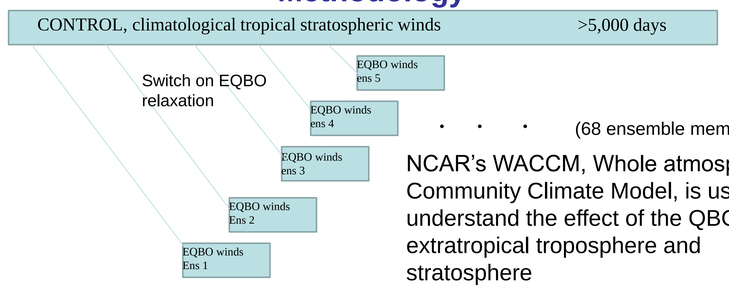


Figure 3: Meridional Circulation of the QBO required to maintain thermal wind balance.

Methodology



NCAR's WACCM, Whole atmosphere Community Climate Model, is used to understand the effect of the QBO in the extratropical troposphere and stratosphere

Response in Troposphere

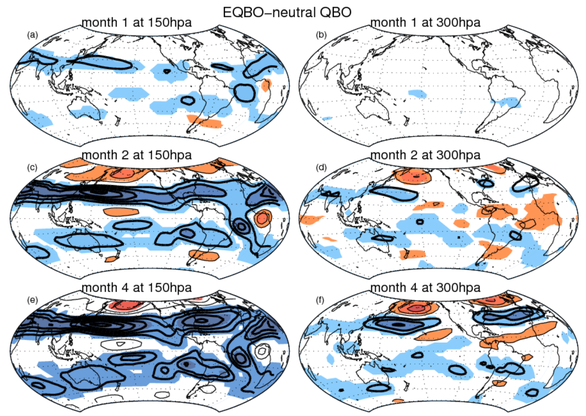


Figure 5: Zonal wind anomalies in the lower stratosphere and upper troposphere after branching with EQBO winds. Anomalies significant at the 95% level are shaded. Contour interval is 1m/s

Strong and significant effect on zonal wind in North Pacific sector. Present in reanalysis as well. OLR decreases, implying more high clouds. Changes in convective precipitation much more regional.

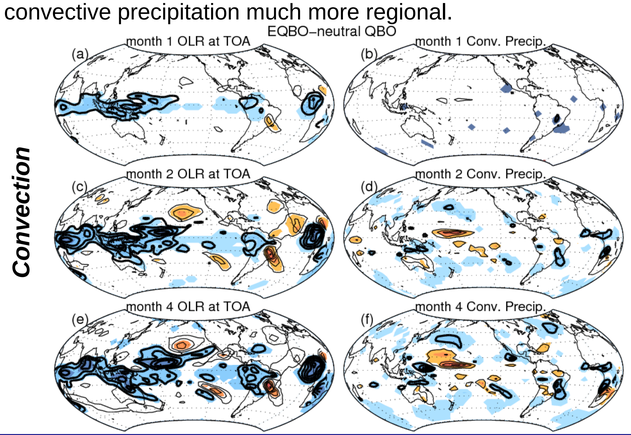


Figure 5: OLR at TOA and convective precipitation anomalies after branching with EQBO winds. Anomalies significant at the 95% level are shaded. Contour interval is 0.5mm/day and 4W/m^2.

References

Garfinkel, C.I. and D.L. Hartmann(2011), The Influence of the Quasi-Biennial Oscillation on the Troposphere in Wintertime in a Hierarchy of Models, Part 2-Perpetual Winter WACCM runs, JAS, 68, doi: 10.1175/2011JAS3702.1.

Garfinkel, C.I., T.A. Shaw, D.L. Hartmann, and D.W. Waugh(submitted), Does the Holton-Tan Mechanism Explain How the Quasi-Biennial Oscillation Modulates the Arctic Polar Vortex?, JAS

Response in Stratosphere

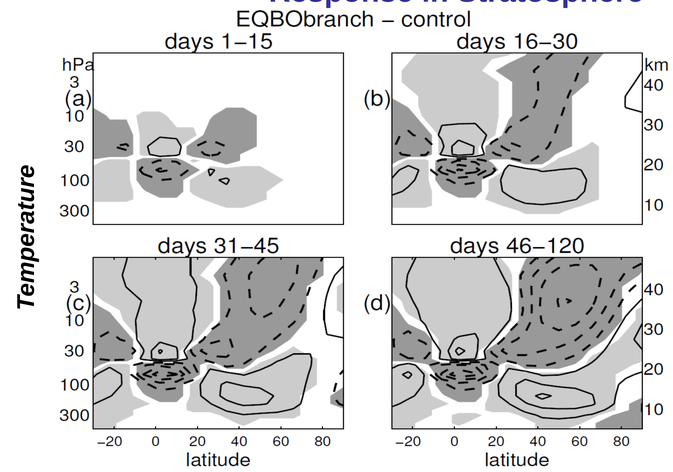


Figure 6: Temperature anomalies after branching with EQBO winds. Anomalies significant at the 95% level are shaded. Contours shown at ±1, ±3, ±5, ±7,and ±9K. Negative contours are dashed

Effect in both the subtropical lower stratosphere and by the polar vortex. Enhanced EP flux convergence in both of these regions. Effect by polar vortex starts in midlatitude upper stratosphere and propagates polewards and downwards.

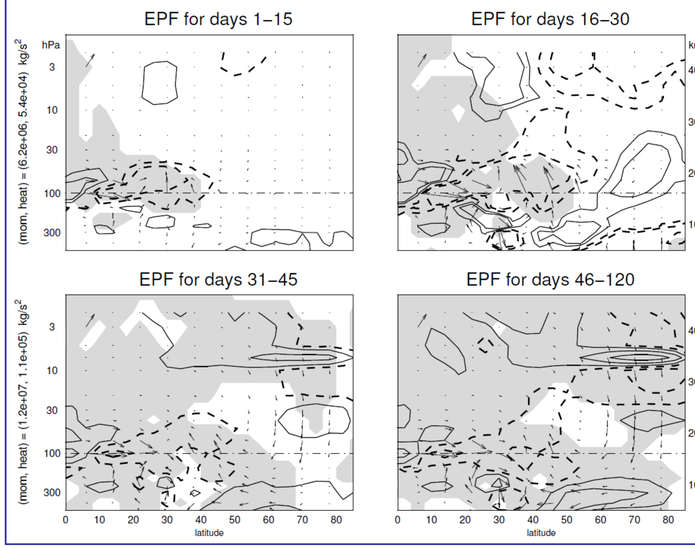


Figure 7:Eliassen Palm Flux anomalies after branching with EQBO winds (EQBO-neutQBO). Contours of the divergence of the EPF are shown at ± 0.12, ±0.25, ± 1, ± 2ms^{-1}d^{-1} in the top row; in the bottom row, the 0.12ms^{-1}d^{-1} contour is omitted. A reference arrow for the stratosphere is located in the top left hand corner of the plots, and its magnitude is on the far left. In the troposphere, arrow length denote anomalies five times larger. Significant anomalies at the 95% level are shaded.

Concluding remarks

Easterly QBO winds
1) Cause enhanced Eliassen-Palm Flux (EPF) convergence in the subtropics from 150hPa to 50hPa, which leads to the subtropical critical line moving poleward into the midlatitudes in the lower stratosphere.
2) Create a barrier to wave propagation from subpolar latitudes to midlatitudes in the middle and upper stratosphere, which leads to enhanced wave convergence in the polar vortex region.
3) Affect high frequency eddies throughout the extratropical troposphere, with the influence strongest and most robust in the North Pacific, leading to a weakened North Pacific jet.
4) Lead to an increase in tropical high clouds and decreased OLR. It is unclear why anomalies in tropical deep convection have the spatial pattern they appear to have.
These effects are mechanistically distinct; while (1) is related to the subtropical critical line, (2)-(4) are due to different aspects of the mean meridional circulation of the QBO. See papers for details.

Overall Conclusion – Modern GCMs should attempt to include the QBO!!