Stratospheric transport and ozone fluxes resulting from different QBO widths in WACCM

N$_2$O Composites during westerly QBO shear

\{Westerly QBO Shear = easterlies at 50hPa with westerlies at 25hPa\}

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**MLS**

**WACCM-SD**

**WACCM-FR**

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CESM WAWG Meeting | Breckenridge | June 21, 2016 | Sasha Glanville, Doug Kinnison, and Jessica Neu
Zonal Winds at 30 hPa

WACCM-FR

WACCM-SD
Zonal Winds at 30 hPa

WACCM-FR

WACCM-FR (modQBO)

WACCM-SD

QBO nudged winds

10 deg half-width

5 deg half-width

MERRA
$N_2O$ Composites during westerly QBO shear

{Westerly QBO Shear = easterlies at 50hPa with westerlies at 25hPa}
Tropical w* composites during ENSO/QBO Combinations

- **Westerly QBO Shear** = dotted
- **Easterly QBO Shear** = solid

**El Nino**
**La Nina**

- **Easterly QBO Shear** = easterlies above westerlies (stronger BDC)
- **Westerly QBO Shear** = westerlies above easterlies (weaker BDC)
Residual Circ. (vertical advection)

1997-2013

w* 25-50 hPa 10S-10N Lag +1 mo

QBO U50-U25 Shear

ENSO MEI Index

- Easterly QBO Shear = easterlies above westerlies (stronger BDC)
- Westerly QBO Shear = westerlies above easterlies (weaker BDC)

modQBO slopes are much more like SD
Measuring Vertical and Horizontal Mixing

1. Advect the base of the tape recorder (time) using $w^*$ (time, z) from the model...get a synthetic tape recorder

2. Calculate the RMS of the actual tape recorder (time, z) minus the synthetic tape recorder (time, z) ...get a RMSE

3. This gives you the ppmv of water vapor that got into a region because of other factors...in other words, a “mixing metric”

{Note: Start the advection at 70mb so you are way above the cold point and you don’t carry up any mixing from the TTL}
WACCM-SD

WACCM-SD H₂O

Synthetic H₂O (input WACCM-SD w* only)

WACCM-SD Actual minus Synthetic H₂O

WACCM-FR

WACCM-FR H₂O

Synthetic H₂O (input WACCM-FR w* only)

WACCM-FR Actual minus Synthetic H₂O

Actual

Synthetic (w* only)

Difference (aka amount due to vertical and horizontal mixing)
• **RMSE taken between 25-50hPa, 10S-10N**
• The “mixing metric” appears to depend more on QBO, however it has a weak correlation with ENSO (note: El Nino forces westerlies in lower stratosphere [Jian Lu, 2008]).
• The “mixing metric” peaks when westerlies occur.
• The (U,V,T) nudging placed on SD perhaps explains the lower correlations.
H$_2$O changes in the 25-50hPa region accomplished by vertical AND horizontal mixing
H₂O changes in the 25-50hPa region accomplished by vertical AND horizontal mixing

H₂O changes in the 25-50hPa region accomplished by vertical mixing only
Now that we’ve removed the projection of water vapor onto the vertical-plane, which added/subtracted from real vertical motion, we can now use the wTR (2-level, lag correlation) method to truly calculate upwelling speed.
Upwelling (vertical advection + vertical mixing)

1997-2013
Upwelling
25-50 hPa
10S-10N
Lag +1 mo

QBO
U50-U25 Shear

ENSO
MEI Index

- Easterly QBO Shear = easterlies above westerlies (stronger BDC)
- Westerly QBO Shear = westerlies above easterlies (weaker BDC)
{Although the O3 mass flux looks slightly different in modQBO, the midlatitude STE has not changed in the NH or SH.}
Conclusions

1. Regarding stratospheric transport (upwelling anomalies and relationships with QBO/ENSO), WACCM-SD and the new WACCM-FR (modQBO) better match observations.

2. By shrinking the width of the QBO in WACCM-FR, it better matches SD/observations in the stratosphere with minor changes to the midlatitude ozone correlations.
   - Less RWB. Does this allow for greater influence by ENSO? Does midlatitude ozone variability depend more on ENSO? Less on QBO?
   - Polar night jet benefits from larger width (Hansen et al., 2013).

3. By decreasing Rossby wave drag in the tropics, the convection-related gravity wave drag begins to play a larger role in the lower/middle stratosphere (compared to original WACCM-FR).
   - Downward control calculations show increased shallow branch speed and decreased deep branch speed.

4. Although these versions of WACCM do not have an interactive QBO, the circulations induced by different QBO widths in our study may offer insight into the spatial reach imposed on gravity waves in newer models.
Easterly zonal winds are contoured with black lines.

EP-Flux Divergence is contoured with colors.
Midlatitude Ozone Flux (STE)

**WACCM-SD**

<table>
<thead>
<tr>
<th>40N-50N 150 hPa O\textsubscript{3} vs 30N-50N 510 hPa O\textsubscript{3}</th>
</tr>
</thead>
<tbody>
<tr>
<td>R = 0.18 ± 0.13</td>
</tr>
<tr>
<td>slope = 0.04 ± 0.03</td>
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</tbody>
</table>

**WACCM-FR**

<table>
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<tbody>
<tr>
<td>R = 0.25 ± 0.12</td>
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<tr>
<td>slope = 0.06 ± 0.03</td>
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**WACCM-FR (modQBO)**

<table>
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<th>40N-50N 150 hPa O\textsubscript{3} vs 30N-50N 510 hPa O\textsubscript{3}</th>
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<tbody>
<tr>
<td>R = 0.30 ± 0.12</td>
</tr>
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<td>slope = 0.06 ± 0.03</td>
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</table>

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**Northern Hem**

**WACCM-SD**

<table>
<thead>
<tr>
<th>40S-50S 150 hPa O\textsubscript{3} vs 30S-50S 510 hPa O\textsubscript{3}</th>
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</thead>
<tbody>
<tr>
<td>R = -0.09 ± 0.14</td>
</tr>
<tr>
<td>slope = -0.06 ± 0.08</td>
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**WACCM-FR**

<table>
<thead>
<tr>
<th>40S-50S 150 hPa O\textsubscript{3} vs 30S-50S 510 hPa O\textsubscript{3}</th>
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</thead>
<tbody>
<tr>
<td>R = 0.21 ± 0.13</td>
</tr>
<tr>
<td>slope = 0.06 ± 0.06</td>
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**WACCM-FR (modQBO)**

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<tr>
<td>slope = 0.13 ± 0.06</td>
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**Southern Hem**