TRENDS IN TROPICAL LMS OZONE (1998-2019) FROM SHADOZ V06 PROFILES: REFERENCE FOR SAGE-BASED SATELLITE PRODUCTS

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OUTLINE

- Background: Tropical LMS (lowermost stratosphere, 15-20 km) ozone trends are important! Context from Pre-ISS/SAGEIII studies
- Climatology of FT (free tropospheric) & LMS $O_3$ at 5 SHADOZ sites
  - Tropopause Height (“TH,” 380K level) from SHADOZ radiosonde
  - “Convective Proxy” = Gravity-wave (GWI) from in $O_3$, PT laminae
- Results: Regional and seasonally dependent LMS $O_3$ trends that can be compared to models and satellite “products.”
**Background: LMS Ozone Trends with SHADOZ and SAGE-based Merged Satellite Products**

- **LEFT.** Merged SAGE II-SHADOZ profiles with 1998-2009 from SHADOZ. MLR with MEI for ENSO variability, Randel & Thompson (2011) yields a negative trend, $\sim -4\%$/decade at 18 km.

- **RIGHT.** Tropical strat. O$_3$ “merged products,” three with SAGE II => -(2-4)$\%$/dec. 1998-2016 (Ball et al., 2018). Compare MERRA trend, $+\sim 5\%$/decade (Wargan et al., 2018, not shown).
• Use 22-yr SHADOZ data (1998-2019) to determine trends in O₃ and 2 dynamical indicators derived from radiosondes.
• **Sonde advantages over satellite data**
  (1) More precise O₃ than satellite data in LMS
  (2) Regular fixed site sampling at ~100-150 m resolution gives Free Tropos. (FT) and LMS trends
  (3) In-situ profile data, full zonal coverage
• Data presented from 5 “sites” (Right)
• Seasonal O₃ to 20 km (Below)

“Seasonal” transitions, marked by sharp O₃ gradients (white vertical lines), represent alternations in dominant dynamic influences, ie convection vs advected pollution (Thompson et al., 2012)
Seasonal Transitions in FT \( O_3 \) & Convective Proxy (GWF) Align. TH Annual Cycles Vary Annually (16.5 – 17.3 km)

- Sharp \( O_3 \) seasonal gradients (prior slide), coincide with GWF transitions. Convective activity seen in FT \( O_3 \), but the waves appear in the LMS (Thompson et al., 2011).

- One station displays significant annual trend

- **Compute Trends in monthly mean \( O_3 \), GWF (0.1 km intervals) and TH using GSFC MLR model with typical QBO, ENSO, IOD terms.**

- **Table (Right) lists 5 station locations, profile #, and terms for best model fit. Last column is annually averaged trend**

<table>
<thead>
<tr>
<th>Site</th>
<th>Lat, Lon (*)</th>
<th>Profiles</th>
<th>MLR Terms</th>
<th>Ann</th>
</tr>
</thead>
<tbody>
<tr>
<td>SC+Para</td>
<td>5.8, -55.21/-0.92, -89.62</td>
<td>1227 ENSO+QBO</td>
<td></td>
<td>-2.6%/dec</td>
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<tr>
<td>Natal+Ascen</td>
<td>-5.42, -35.38/-7.58, 14.24</td>
<td>1436 ENSO+QBO</td>
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<td>0.9</td>
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<tr>
<td>Nairobi</td>
<td>-1.27, 36.8</td>
<td>941 ENSO+QBO</td>
<td></td>
<td>1.2</td>
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<tr>
<td>KL+Java</td>
<td>2.73, 101.27/-7.5, 112.6</td>
<td>786 ENSO+QBO+IOD</td>
<td></td>
<td>-2.7</td>
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<tr>
<td>Samoa</td>
<td>-14.23, -170.56</td>
<td>795 ENSO+QBO</td>
<td></td>
<td>-2.9</td>
</tr>
</tbody>
</table>
LMS Ozone Trends (%/decade; cyan significant)

- LMS ozone displays a negative trend but mostly during latter part of year
- Magnitude of LMS ozone losses (blue circles) is 5-10%/decade
Positive Trends in Tropopause Height Coincide with LMS Ozone Loss

- **Mid-late year:** Tropopause Height (380K altitude) increases, ~150-175 m, occur when LMS O$_3$ decreases ~5%/dec. LMS O$_3$-TH anti-correlated (0.7-0.9)
- Connection to GW change (not shown) less clear
- **Next:** Examine other data, re-analyses for evidence of TH & convective trends
SIGNIFICANCE OF SHADOZ TRENDS. Context from LMS Ozone & TH Cycles (Anomaly from Means)

- Significant LMS O$_3$ losses coincide with O$_3$ maximum, July – Sept/Oct. A decreasing maximum with little change in Jan-May O$_3$ minimum signifies a “flattening” of the annual cycle (due to BDC, Randel et al. 2007)
- Tropopause Height increase coincides with LMS O$_3$ loss. Small decrease in TH Jan.-May (TH max) means that mean TH is increasing and the annual cycle will flatten out
Summary: SHADOZ LMS Trends

- **Ozone Trends:** Only 1 of 5 SHADOZ stations exhibits “robust” annual change, ~3%/dec LMS O₃ loss at SC-Para during 1998-2019. From Jun/Jul to Nov/Dec, 3 stations display significant O₃ losses in isolated months
  - Our results do not readily “match up” with zonally averaged satellite trends. The trends of Szlag et al. (2020) with 4 merged products using SAGE II (one with SAGE III) show maximum LMS O₃ losses in M-A-M, not J-J-A as in sondes
  - SHADOZ O₃, TH data & model fits over 22 yrs will be available for satellite and model comparisons – Reference for ongoing Assessments (LOTUS, etc)?

- **Dynamical Influences on LMS Ozone Trends?**
  - LMS O₃ losses are strongly correlated with TH increases (mid-late year)
  - In both cases, LMS O₃ (maximum) and TH (minimum), the direction of change during this time flattens the annual cycle
  - More study of links among LMS O₃ TH, convective activity is needed. Look at independent data, re-analyses and output from suitable Chem-Climate models.
THANK YOU FOR ATTENTION!

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EARLY SAGE & SHADOZ ARTICLES

RECENT SATELLITE PRODUCT TRENDS

SHADOZ V06 OZONE ARTICLES