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

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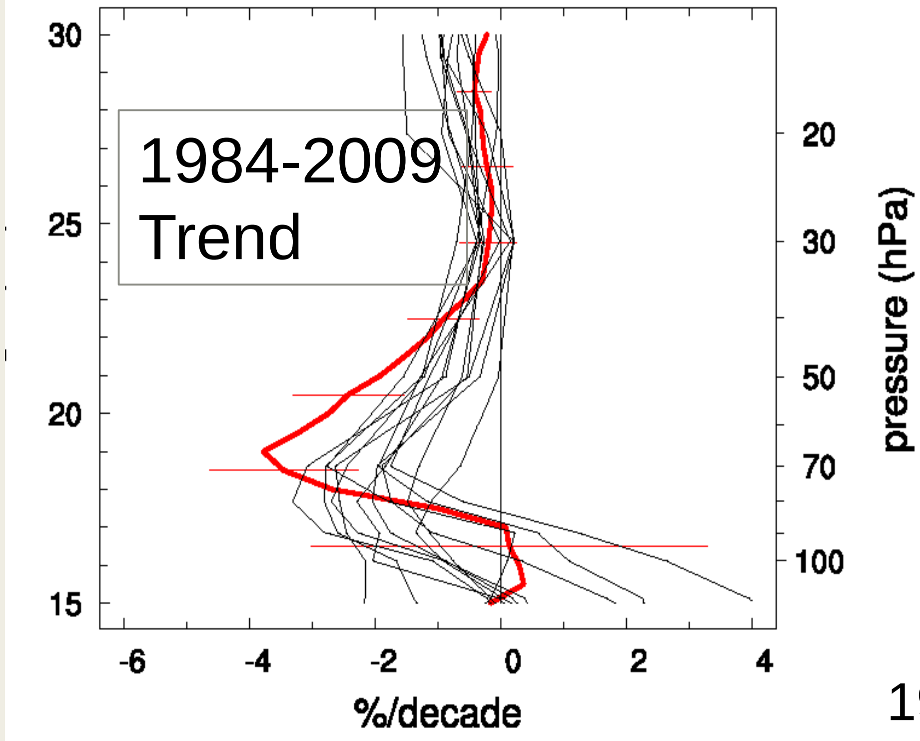
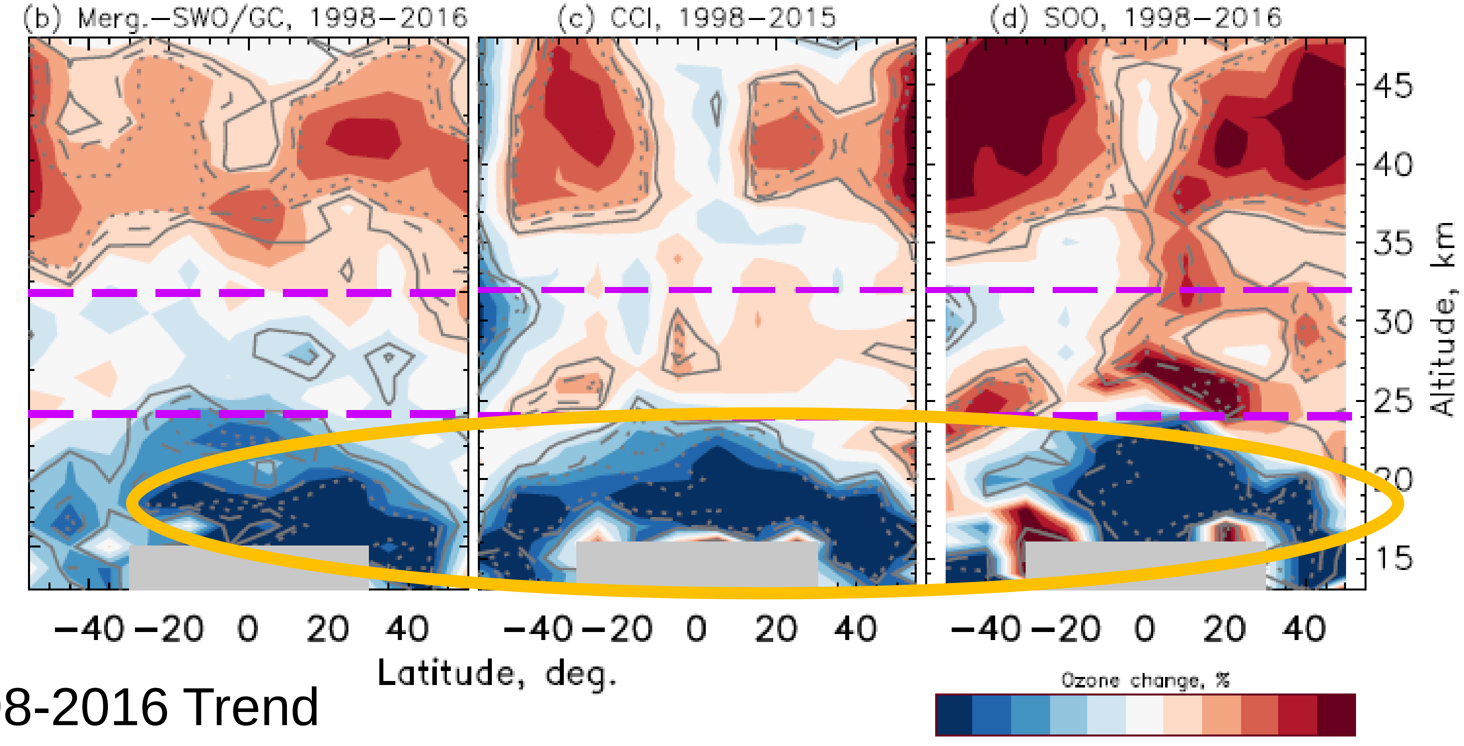
OUTLINE

- 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
- Trends (1998-2019) in O_3, GWI, Tropopause Height computed with MLR. Assume QBO, ENSO, IOD oscillations, annual & seasonal cycles
- Results: <u>Regional and seasonally</u> 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





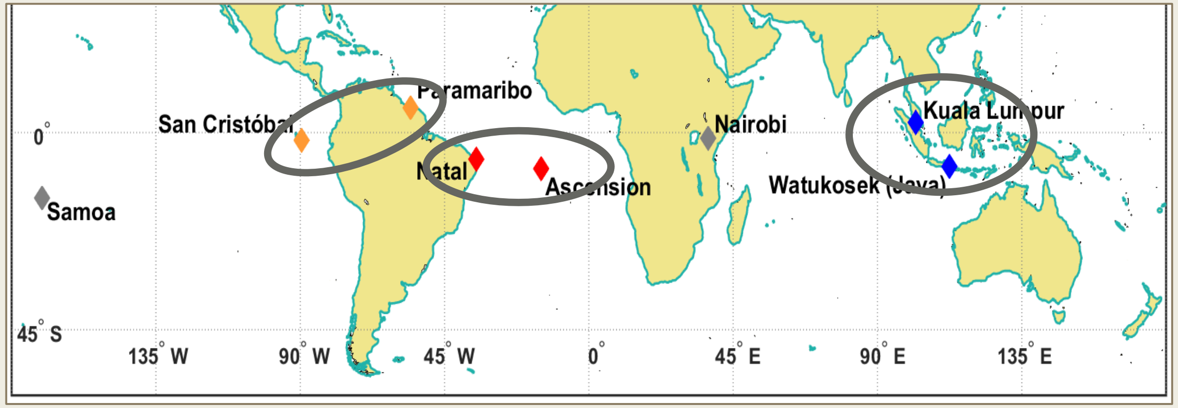
1998-2016 Trend

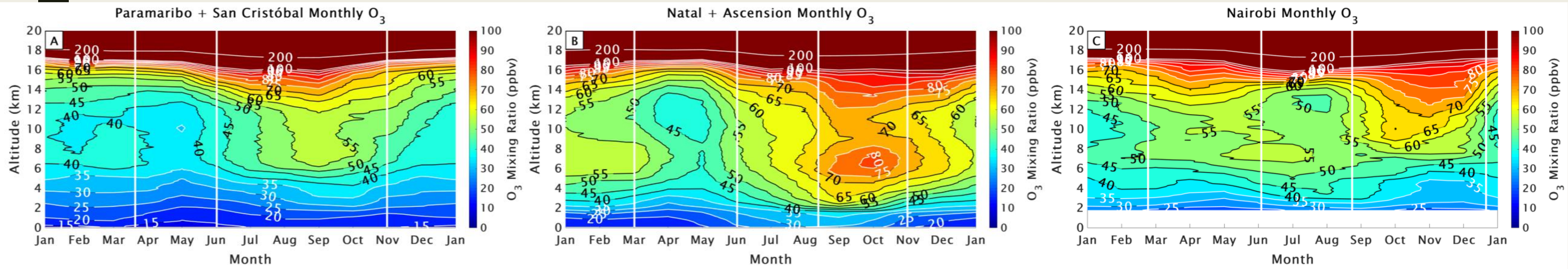
- **LEFT.** Merged SAGE II-SHADOZ profiles with 1998-2009 from SHADOZ. MLR with MEI for ENSO variability, Randel & Thompson (2011) yields a negative trend, ***~-4%/decade*** at 18 km
- **RIGHT.** Tropical strat. O_3 "merged products," three with SAGE II => **-(*<u>2-4)%/dec,</u>*** 1998-2016 (Ball et al., 2018). Compare MERRA trend, ***<u>+~5%/decade</u>*** (Wargan et al., 2018, <u>not shown</u>)

SHADOZ Climatology: O_3 Seasonal & Regional Variability

- **Use 22-yr SHADOZ data (1998-2019) to** determine trends in O_3 and 2 dynamical indicators derived from radiosondes.
- **Sonde advantages over satellite data**
  (1) More precise O_3 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 O_3 to 20 km (Below)**

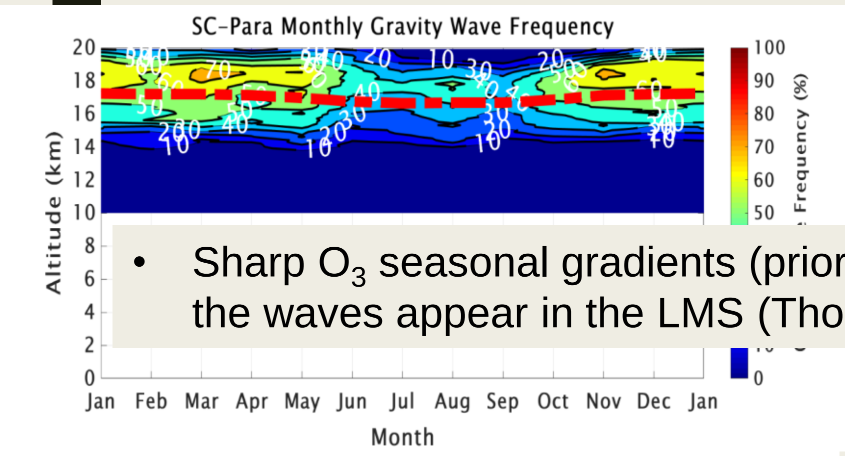
SC-Para Nat-Asc KL-Java

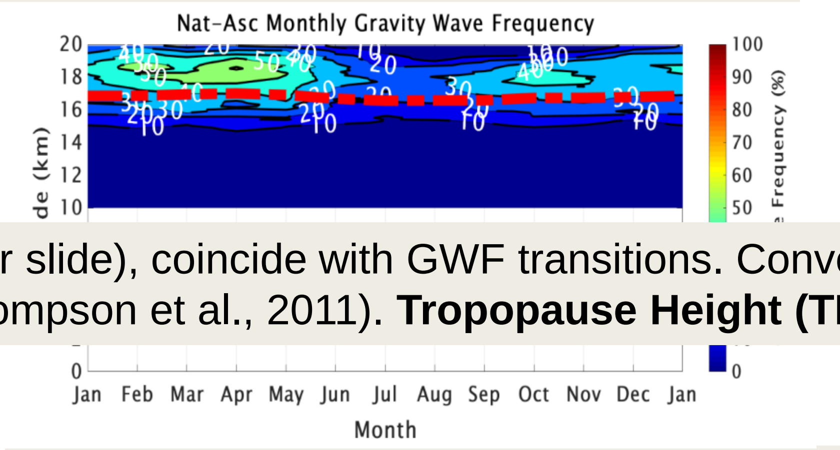


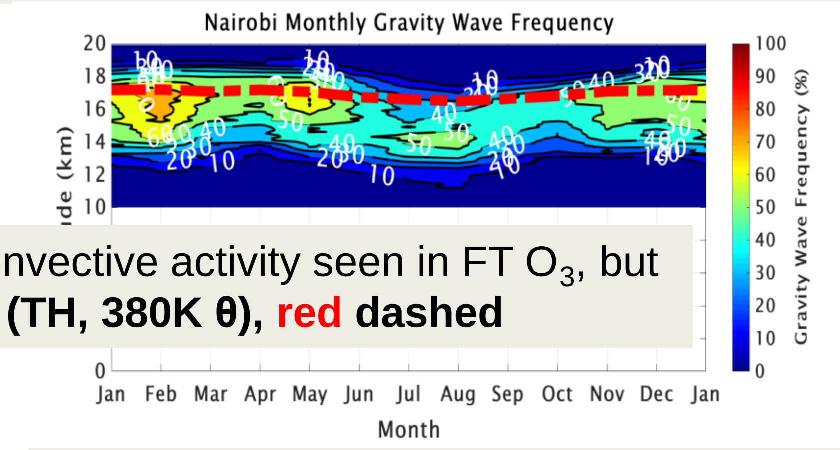


"Seasonal" transitions, marked by sharp O_3 gradients (white vertical lines), represent alternations in dominant dynamic influences, ie convection vs advected pollution (Thompson et al., 2012)

Seasonal Transitions in FT O_3 & Convective Proxy (GWF) Align. TH Annual Cycles Vary Annually (16.5 – 17.3 km)





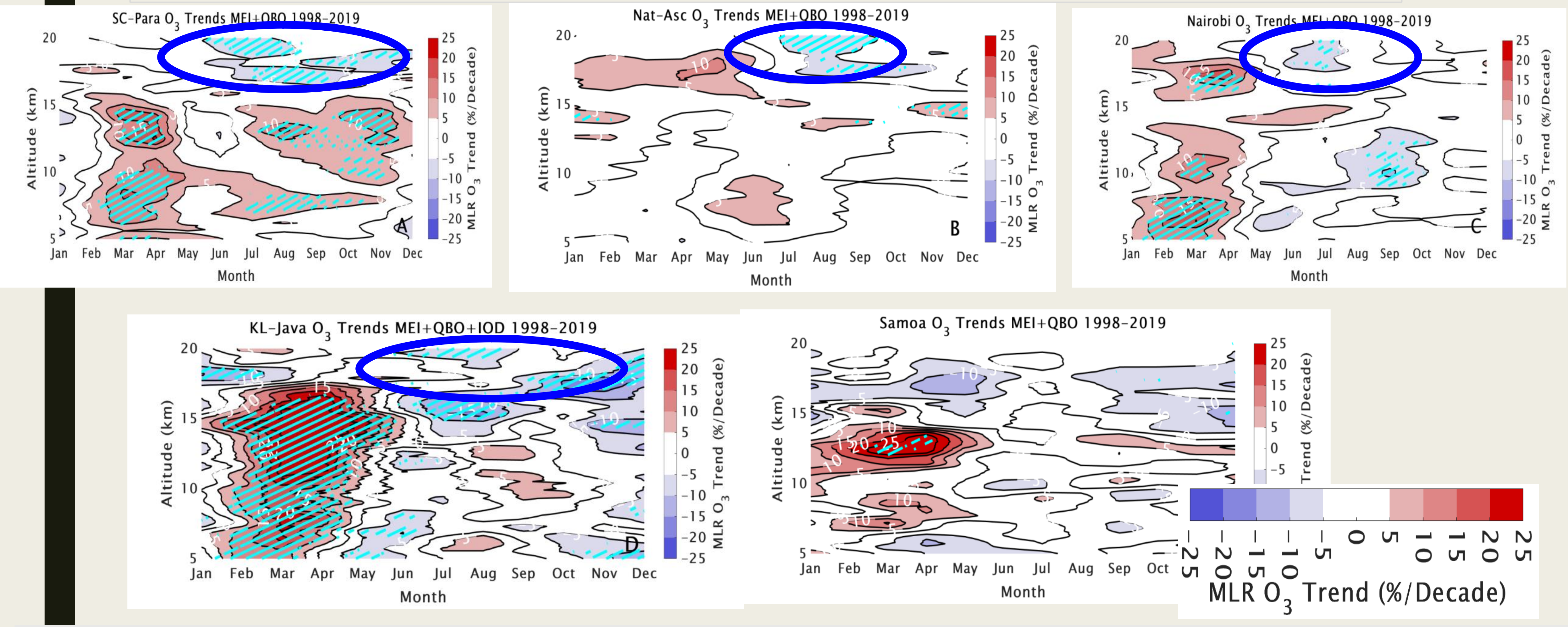


- Sharp O_3 seasonal gradients (prior slide), coincide with GWF transitions. Convective activity seen in FT O_3, but the waves appear in the LMS (Thompson et al., 2011). **Tropopause Height (TH, 380K θ), red dashed**

- **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**
- **One station displays significant annual trend**

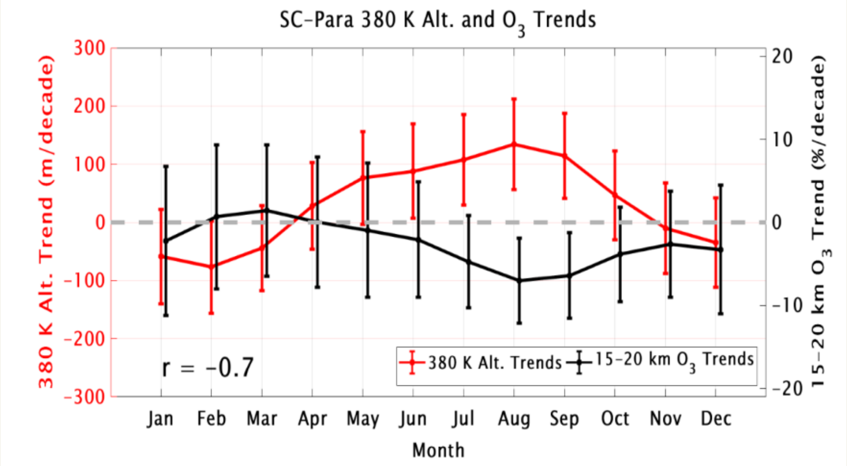
Site	Lat, Lon (°)	Profiles	MLR Terms	Ann
SC+Para	5.8, -55.21/-0.92, -89.62	1227	ENSO+QBO	
15-20 km			%/dec	-2.6
Natal+Ascen	-5.42, -35.38/-7.58, 14.24	1436	ENSO+QBO	
15-20 km				0.9
Nairobi	-1.27, 36.8	941	ENSO+QBO	
15-20 km				1.2
KL+Java	2.73, 101.27/-7.5, 112.6	786	ENSO+QBO+IOD	
15-20 km				-2.7
Samoa	-14.23, -170.56	795	ENSO+QBO	
15-20 km				-2.9

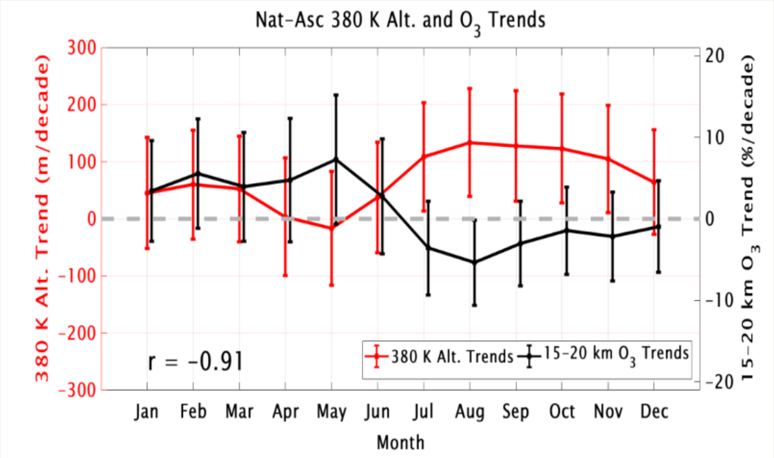
LMS Ozone Trends (%/decade; cyan significant)

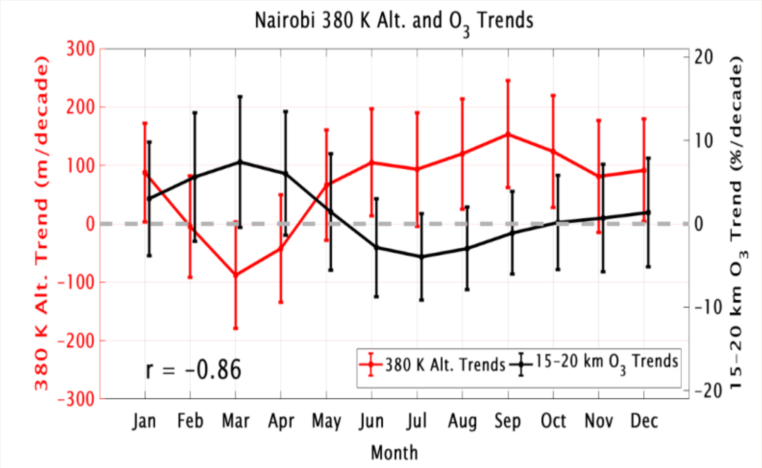


- LMS ozone displays a negative trend but mostly during latter part of year
- Magnitude of LMS ozone losses (blue circles) is 5-10%/decade

Positive Trends in Tropopause Height Coincide with LMS Ozone Loss





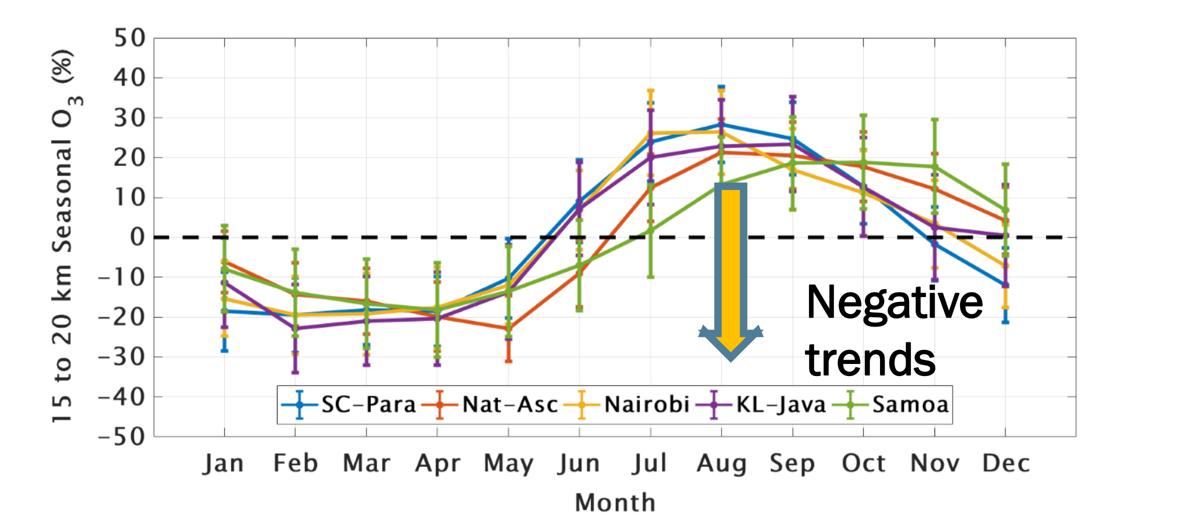


LMS O_3 trend TH (380K) trend

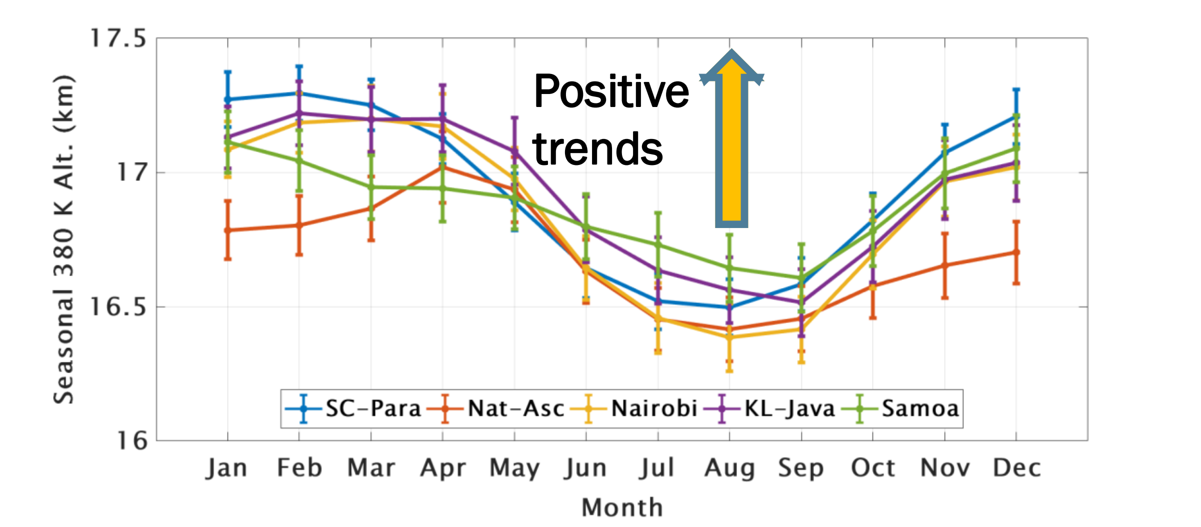
- **Mid-late year**: Tropopause Height (380K altitude) increases, ~150-175 m, occur when LMS O_3 decreases ~5%/dec. LMS O_3-TH anti-correlated (0.7-0.9)
- Connection to GW change (not shown) less clear
- **Next:** Examine other data, re-analyses for evidence of TH & convective trends

SIGNIFICANCE OF SHADOZ TRENDS. Context from LMS Ozone & TH Cycles (Anomaly from Means)

Monthly LMS Ozone Anomaly



Tropopause Height Anomaly



- **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

- <u>**Ozone Trends:**</u> Only 1 of 5 SHADOZ stations exhibits "robust" annual change, ~3%/dec **LMS O_3 loss at SC-Para** during 1998-2019. *From <u>Jun/Jul to Nov/Dec</u>, 3 stations display significant O_3 losses in <u>isolated</u> months*
  - Our results do not readily "match up" with zonally averaged satellite trends. The trends of Szelag et al. (2020) with 4 merged products using SAGE II (one with SAGE III) show maximum LMS O_3 losses in M-A-M, <u>not</u> J-J-A as in sondes
  - SHADOZ O_3, TH data & model fits over 22 yrs will be available for satellite and model comparisons – ***Reference*** for ongoing Assessments (LOTUS, etc)?
- <u>**Dynamical Influences on LMS Ozone Trends?**</u>
  - LMS O_3 losses are strongly correlated with TH increases (mid-late year)
  - In both cases, LMS O_3 (maximum) and TH (minimum), the direction of change during this time flattens the annual cycle
  - More study of links among LMS O_3 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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