TRENDS IN TROPICAL OZONE & CONVECTION (1998-2018) BASED ON V06 SHADOZ PROFILES

Anne Thompson (anne.m.thompson@nasa.gov)

with Ryan Stauffer, J. C. Witte,* D. E. Kollonige, K. Wargan, J. R. Ziemke

*@ NCAR/EOL; all others at NASA-Goddard, Greenbelt, MD

NOAA e-GMAC Session, 17-7-2020

GRL, submitted, June 2020. https://www.essoar.org/doi/10.1002/essoar.10503415.1

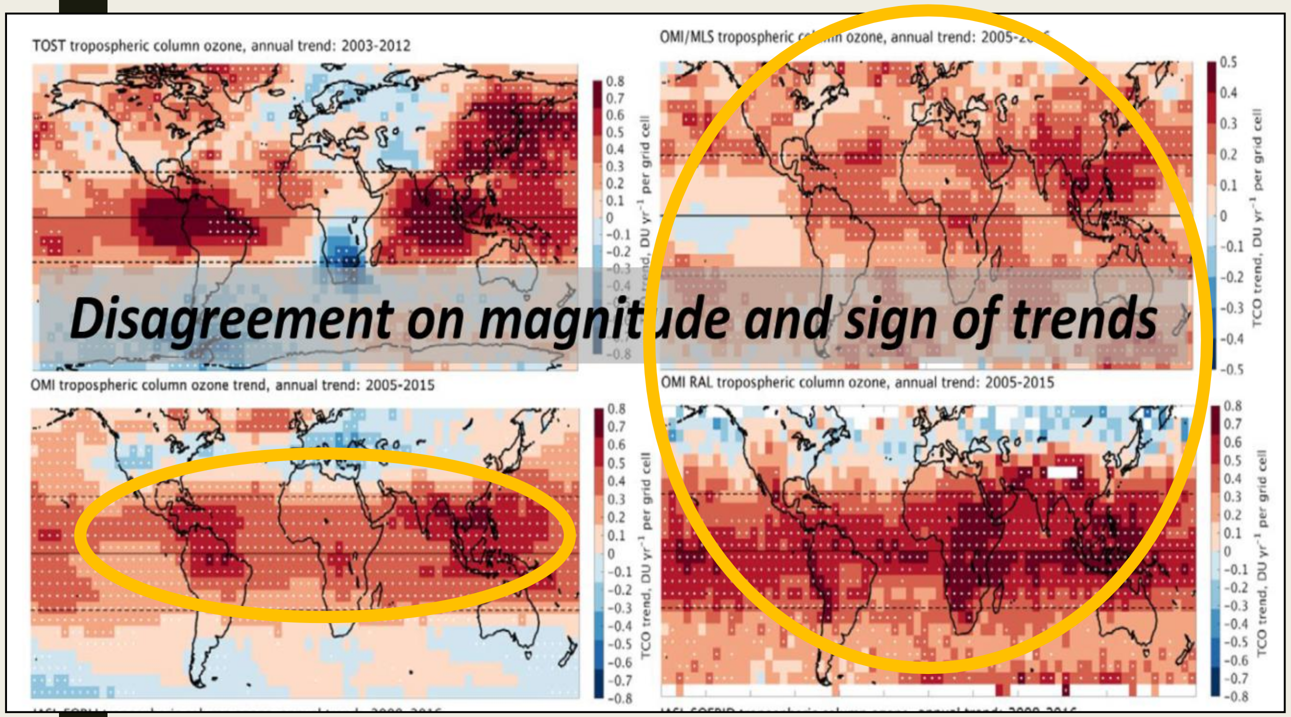
OUTLINE

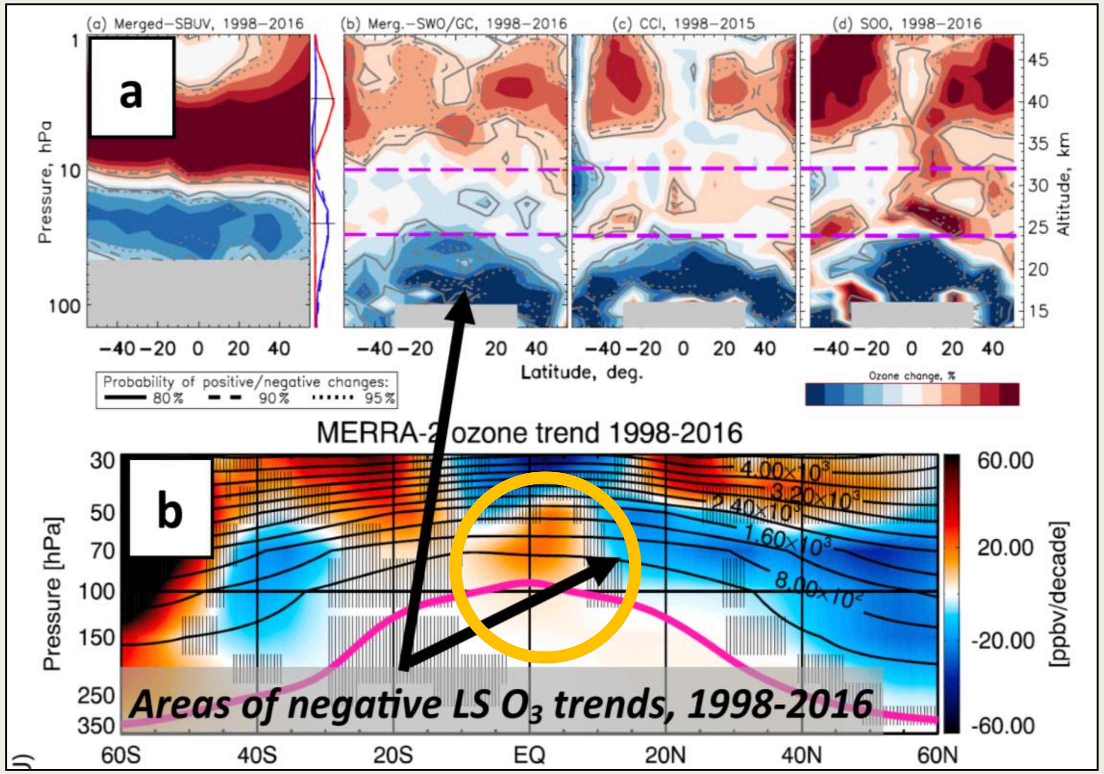
- Background: Why look at tropical FT (free troposphere, 5-15 km) and LMS (lowermost stratosphere, 15-20 km) ozone trends?

- Climatology of FT & LMS Ozone & Convection at 5 SHADOZ sites
  - Seasonal O_3 variations correlate with convective variations
  - “Convective Proxy” = Gravity-wave (GWI) signal in O_3, PT laminae

- Trends (1998-2018) in O_3, GWI, tropopause height computed with MLR, assuming QBO, ENSO, IOD oscillations, annual cycle, solar cycle

Background 1:– Motivating Uncertainties

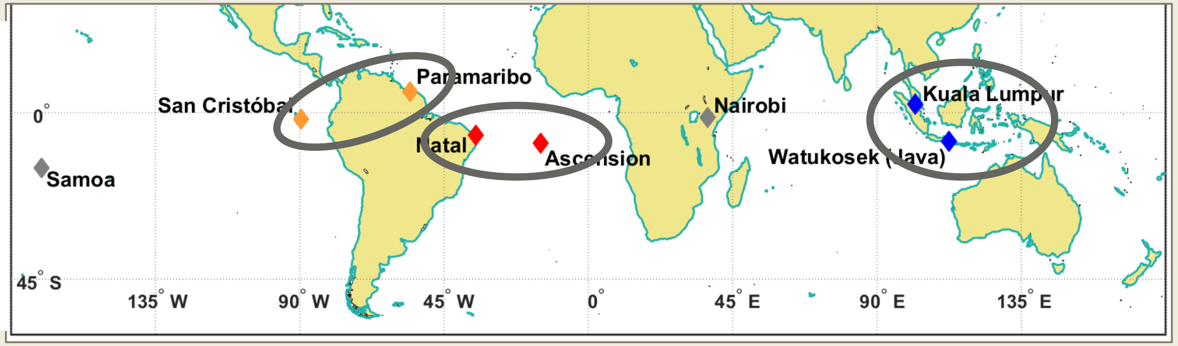




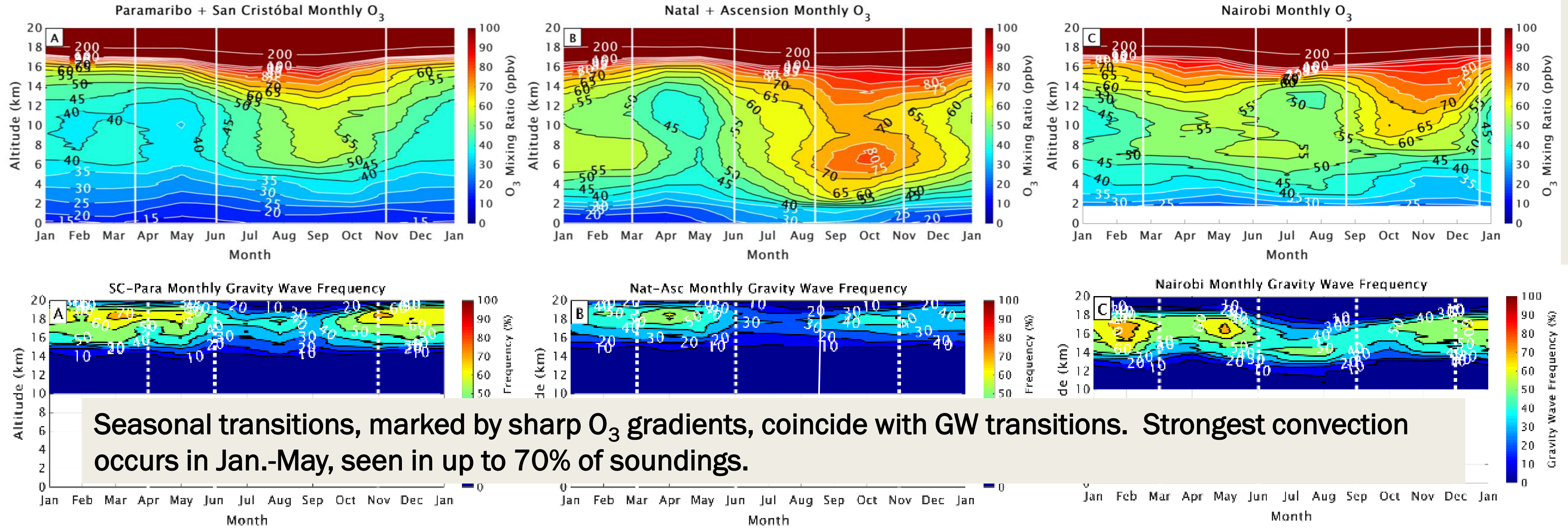
- **LEFT.** "Validated satellite" FT O_3 products (Gaudel et al., 2018). Trends diverge in region, magnitude, sign. POSITIVE tropical trends: ***OMI based: ~10-25%/ decade, ~2005-2017***
- **RIGHT.** Tropical LMS O_3 Satellite "products," Ball et al. (2018) => ***-5%/decade,*** 1998-2017 (upper) or MERRA trend, ***+~5%/decade*** (Wargan et al., 2018, lower).

Background 2: Role of Convection

SC-Para Nat-Asc KL-Java



- **Use SHADOZ sonde profiles to evaluate FT & LMS "tropical trends"** with QC-ed, high-resolution data over 1998-2018 period (750-1360 sondes/station)
- Determine if trends are related to seasonal processes, ie convection (D-J-F-M-A) inferred by O_3/PT laminae



Seasonal transitions, marked by sharp O_3 gradients, coincide with GW transitions. Strongest convection occurs in Jan.-May, seen in up to 70% of soundings.

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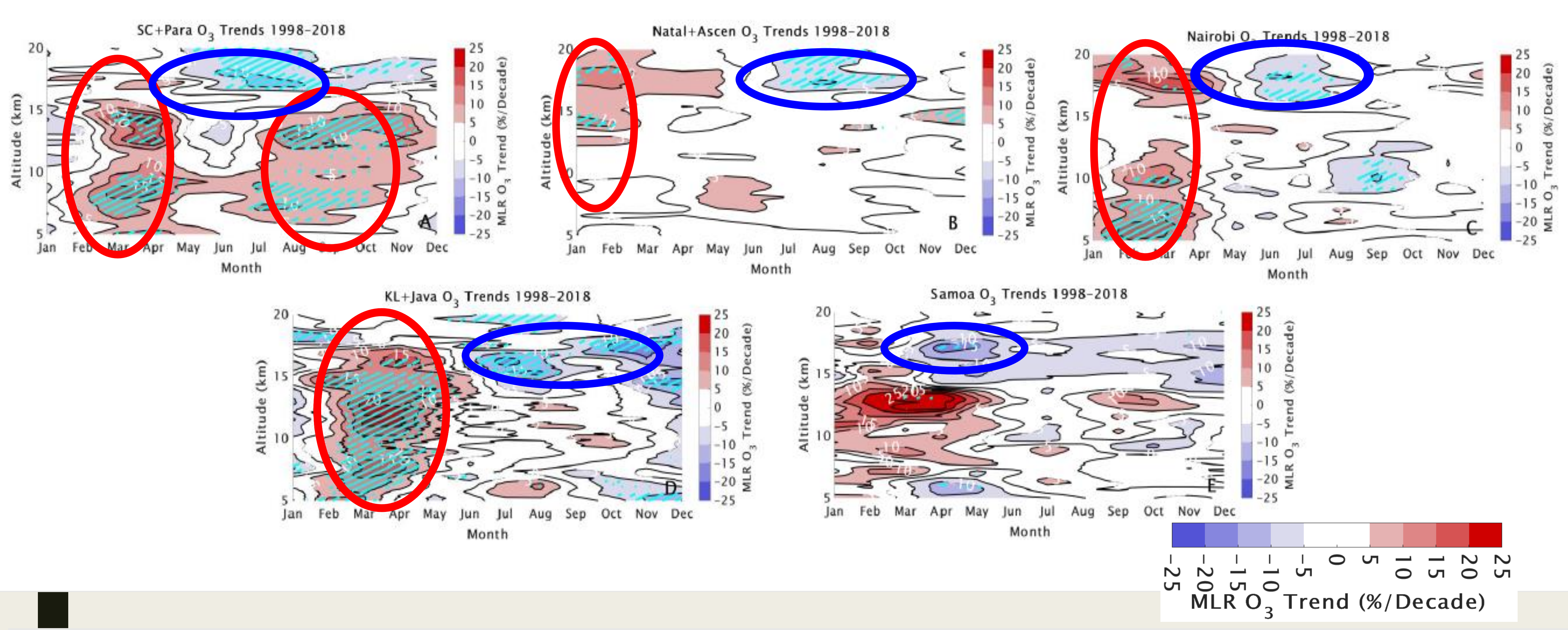
FT & LMS Ozone Trends (%/decade; cyan significant)



First part of year (most convective), trends positive in FT and LMS. Except for SC-Para, FT mid-latter part of year is slightly negative. LMS negative latter part of year except Samoa.

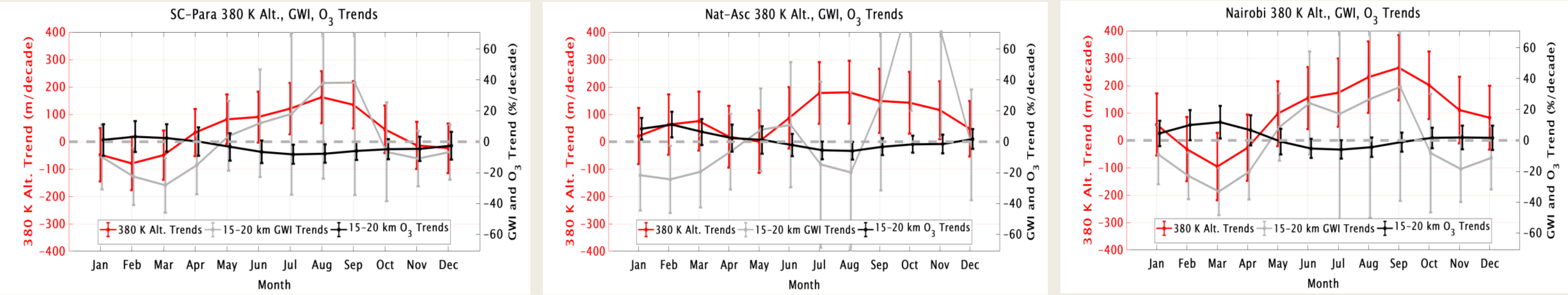
Trends in MFT (5-10 km), UFT (10-15 km), LMS (15-20 km) Ozone: %/decade, bold significant

Site	Lat, Lon (°)	N	MLR Terms	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
SC-Para	5.8, -55.21/ -0.92, -89.62	1190	ENSO+QBO													
5-10 km				-2.1	6.4	**12.3**	**9.7**	4.3	4.3	7.1	7.0	5.2	4.8	2.6	-2.0	**5.0**
10-15 km				-7.8	-4.1	12.6	**17.9**	1.1	-4.3	4.3	**12.4**	**11.2**	**11.0**	**11.5**	2.9	**5.7**
15-20 km				1.2	3.3	2.5	0.1	-3.3	-6.6	**-8.1**	**-7.7**	**-5.9**	-4.8	-4.6	-2.6	**-3.0**
Nat-Asc	-5.42, -35.38/ -7.58, 14.24	1363	ENSO+QBO													
5-10 km				-1.1	0.1	1.0	1.1	2.3	4.0	3.5	0.9	-0.7	-0.3	0.1	-0.7	0.8
10-15 km				7.9	7.7	3.3	1.5	2.8	3.4	4.2	5.5	4.3	1.5	0.3	3.3	**3.8**
15-20 km				**8.4**	**11.1**	6.3	2.3	1.2	-2.1	-5.6	**-5.9**	-3.2	-1.6	-1.5	1.7	0.9
Nairobi	-1.27, 36.8	905	ENSO+QBO													
5-10 km				4.3	**12.6**	**13.7**	4.8	-3.3	-3.8	-0.4	1.5	1.2	1.1	0.7	0.4	2.7
10-15 km				-1.1	4.4	6.9	4.4	1.3	2.2	3.2	-1.9	-6.1	-5.2	-2.6	-1.9	0.3
15-20 km				4.5	**10.0**	**11.8**	6.5	-0.8	-5.2	**-5.9**	-4.3	-1.1	1.6	1.9	1.7	1.7
KL-Java	2.73, 101.27/ -7.5, 112.6	770	ENSO+QBO +DMI													
5-10 km				-3.0	**9.5**	**14.0**	4.4	-1.1	1.8	3.2	-1.5	-1.0	3.7	2.1	-4.7	2.3
10-15 km				-6.2	3.9	**12.2**	**11.7**	6.9	2.4	-0.5	-1.3	0.5	0.9	-3.2	-8.2	1.6
15-20 km				-2.1	1.2	1.0	1.2	2.2	-0.6	-5.6	**-7.4**	-4.7	-2.7	-4.0	-4.9	-2.2
Samoa	-14.23, -170.56	752	ENSO+QBO													
5-10 km				3.7	6.4	6.4	-1.5	-5.6	-1.1	4.1	0.9	-4.7	-4.3	0.4	3.0	0.6
10-15 km				12.4	19.6	16.2	11.3	3.1	-3.5	-5.3	0.1	4.4	-0.5	-5.9	-1.4	4.2
15-20 km				0.3	6.8	3.8	-4.2	-5.3	-1.7	-1.3	-2.3	-0.7	0.8	-1.8	-4.0	-0.8

No Trends!

Only one station – SC + Para has significant FT & LMS Annual trend! All others in isolated, seasons, layers!!

Trends in Convection, Tropopause Height Are Consistent with Ozone Trends



LMS O_3 trend TH (380K) trend Convective (GWI) trend

- Suppressed Jan-Apr. convection leads to lower tropopause, **FT ozone increase ~5%/decade.** With less mixing, detrainment, FT ozone builds up.
- Mid-year: increases in convection, "tropopause height" (380 K) ~100-250 m, **decreases LMS ozone ~5%/decade.** LMS O_3-TH anti-correlated (.7-.9)

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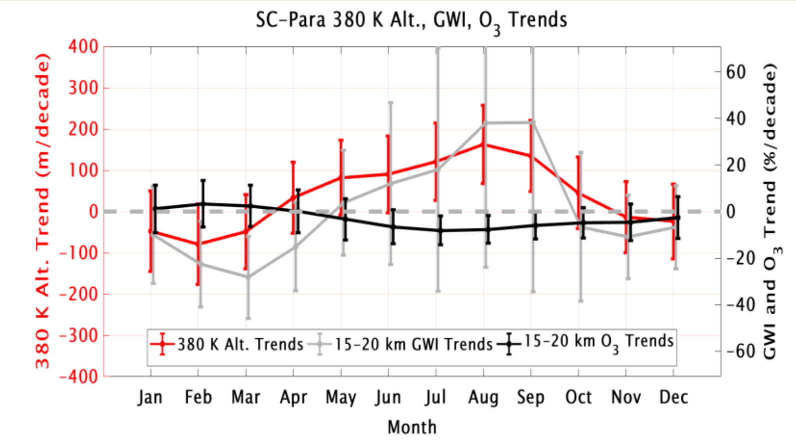

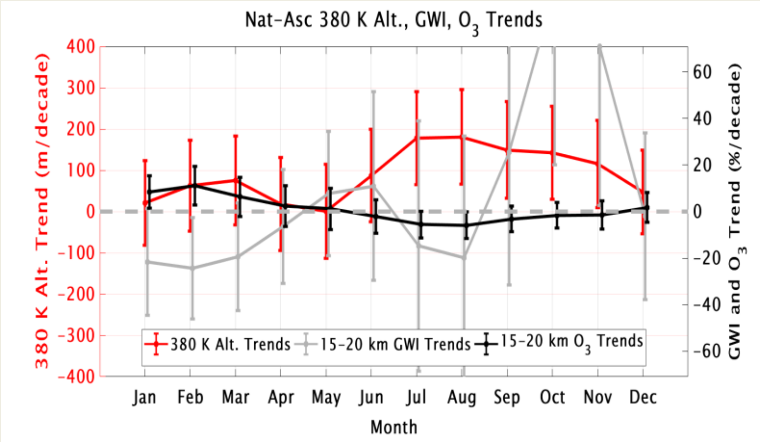

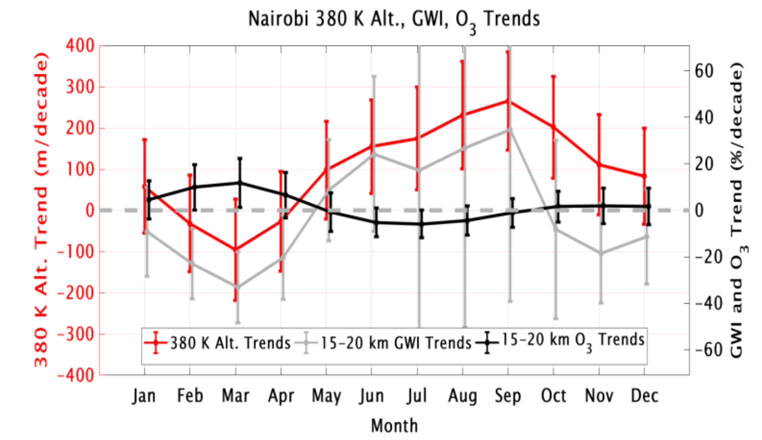

LMS O_3 trend — TH (380K) trend — Convective (GWI) trend

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Summary

- **Ozone Trends:** Only 1 of 5 SHADOZ stations has "robust" annual changes, ~5%/dec **FT O_3 increase** and ~3%/dec **LMS O_3 loss**. *Seasonal & regional trends from SHADOZ – **gold standard** for satellite, model trend evaluation*

- **Convective Influences?** Seasonality of FT ozone increases, LMS losses coincide with changes in convection but mechanisms require further study. Do mid-year tropopause height increases stem from more convection?

- **FT Ozone Results:** **(1)** Jan.-April is annual FT O_3 minimum, so *convective changes could be modifying O_3 profile distribution.* **(2)** Zonal distribution of SHADOZ sites suggests that dynamical factors are perturbing O_3 across the tropics. *Such changes could underlie widespread O_3 growth due to emissions*

THANK YOU FOR ATTENTION!

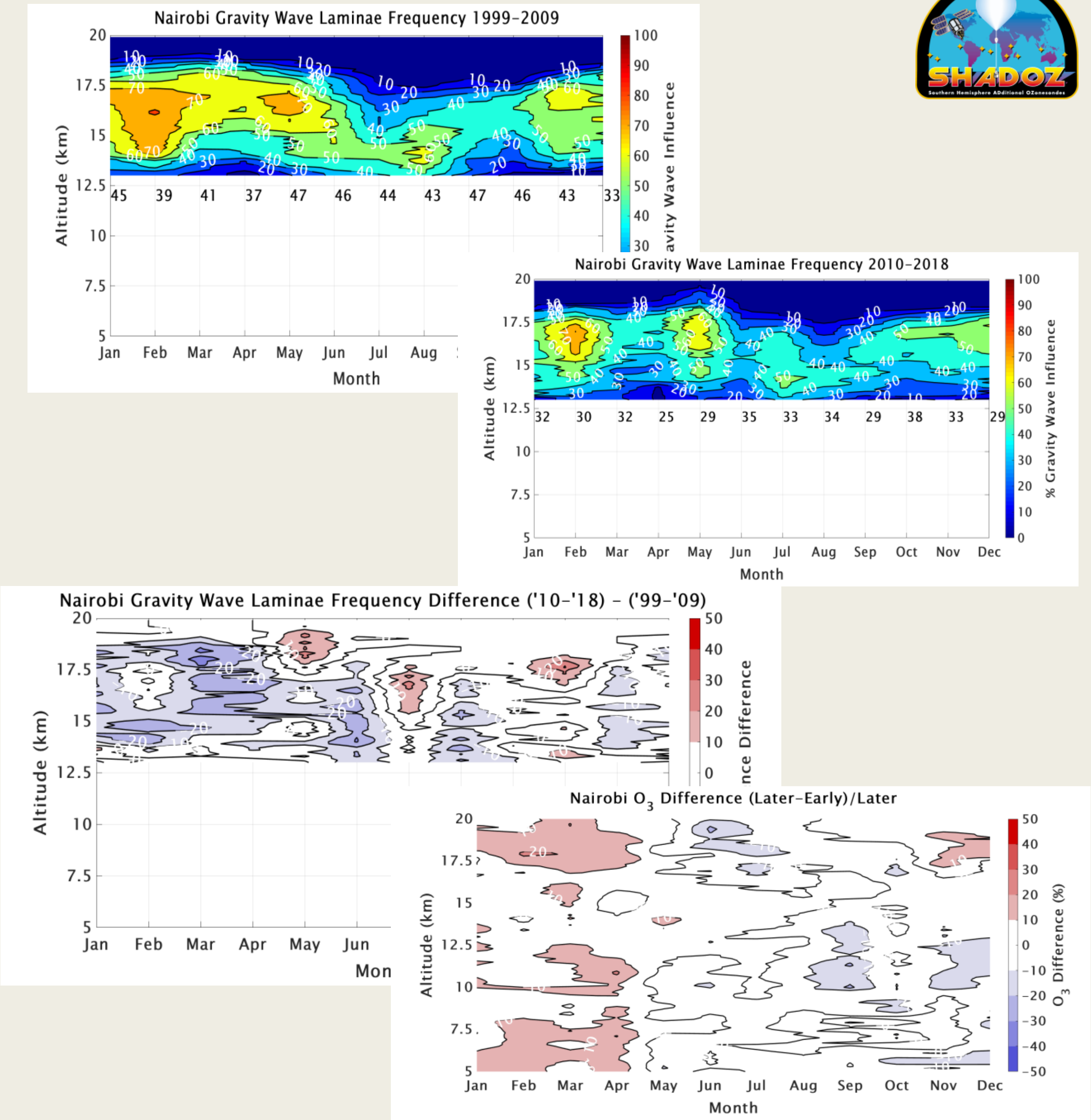
- **NASA SUPPORT:** Upper Atmospheric Composition Observations Program (Ken Jucks, HQ) for SHADOZ support. Additional funding from USRA/NPP to RMS, ISS/SAGE III to AMT, GMAO to KW

- **NOAA SHADOZ PARTNERSHIP:** Ozone & WV Group: B. Johnson, P. Cullis, I. Petropavlovskikh (LOTUS Report)

- **COMMENTS:** O. Cooper (NOAA/CSD), W. Randel (NCAR)

CI Trends?

- GWI – computed from amount of O_3 in segments affected by GW as determined from PT, O_3 laminae (LID method). TTL laminae assumed to be proxy for convective impacts in troposphere. (Nairobi examples)
- Possible decline in GWI? Does this mean less convection and more ozone (pollution) buildup in Jan-April in FT and TTL?
- Other sites less clear... *Needs more study*



FT Ozone – Convection (GWF) Link Based on Self-Organizing Maps (SOM)