UPDATES ON TROPICAL SHADOZ SONDE DATA QUALITY ASSURANCE & TRENDS

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OUTLINE

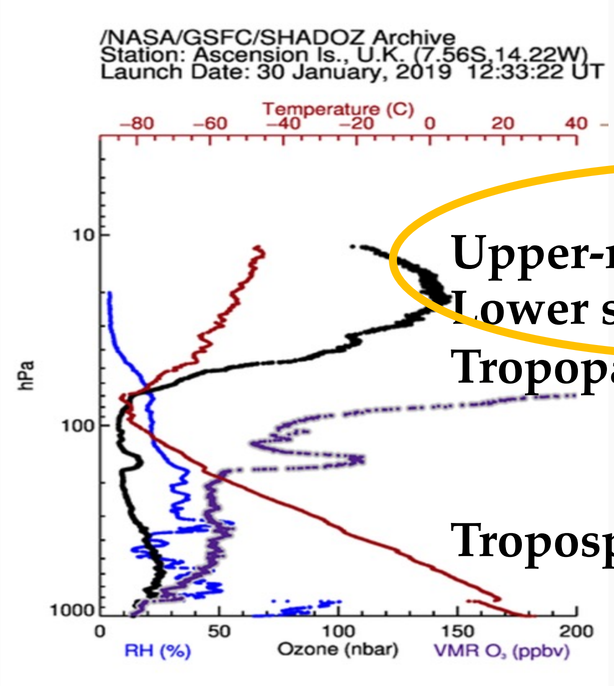
- **Introduction: (1) Ozonesonde instrument & profiles; (2) SHADOZ network**

- **SHADOZ Quality Assurance (QA) – Recap of 2022 Status**
  - **QA Criteria – Sonde Stability (Stauffer et al., *ESS*, 2022)**
  - **"Dropoff" in Ensci sonde Total Column Ozone (TCO) solved – data correction being implemented**

- **Updated LMS (Lowermost Stratosphere) and Free Tropospheric (FT) ozone trends (Thompson et al., *JGR*, 2021; Stauffer et al., *ACP, in prep.*, 2023)**

OZONESONDE INSTRUMENT & OZONE PROFILE

- **Ozonesonde: a small instrument attached to a radiosonde & flown on a weather balloon to measure O_3 concentration (black in Figure --- ->) from surface to 35 km with ~100-m resolution**
- **Ozonesondes have achieved 5% uncertainty goal! With 2 instrument types & 3 types of sensing solution (SST), each instrument must be calibrated & data processed following SOP**

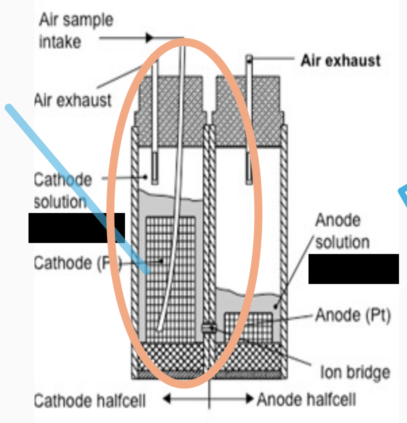


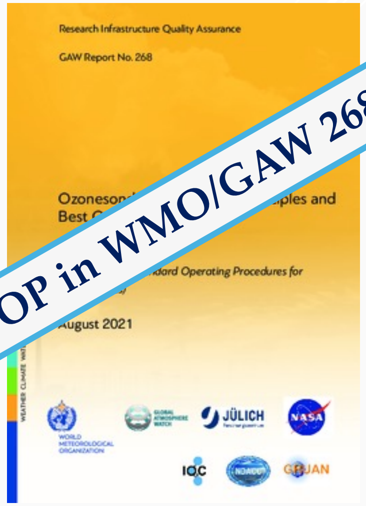
Electrochemical Concentration Cell (ECC) Ozonesonde – ***Two manufacturers, SPC & En-Sci***

3 KI Sensing Solution Types SST

Air Intake

Pump Motor

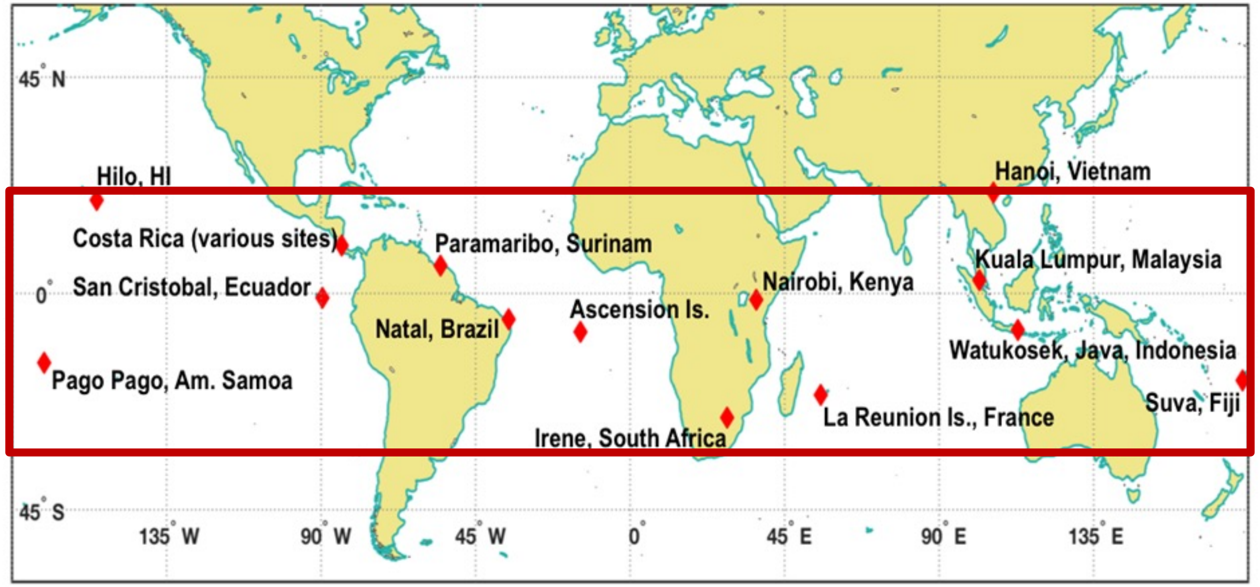




$$2\,KI + O_3 + H_2O \rightarrow I_2 + O_2 + 2\,KOH$$

SHADOZ NETWORK AND STATIONS

- Operations from 1998-present, with 14 active stations, each with over 10 years of data.
- Ozonesonde-radiosonde profiles collected 2-4x/ month. >35% Earth!
- Shared support from ~20 organizations leverages resources, sustains operations
- Now >9900 profiles! Will pass 10,000 profiles 10/23!
- Some data @ WOUDC, NDACC *but use SHADOZ*
- SHADOZ has data DOIs now!

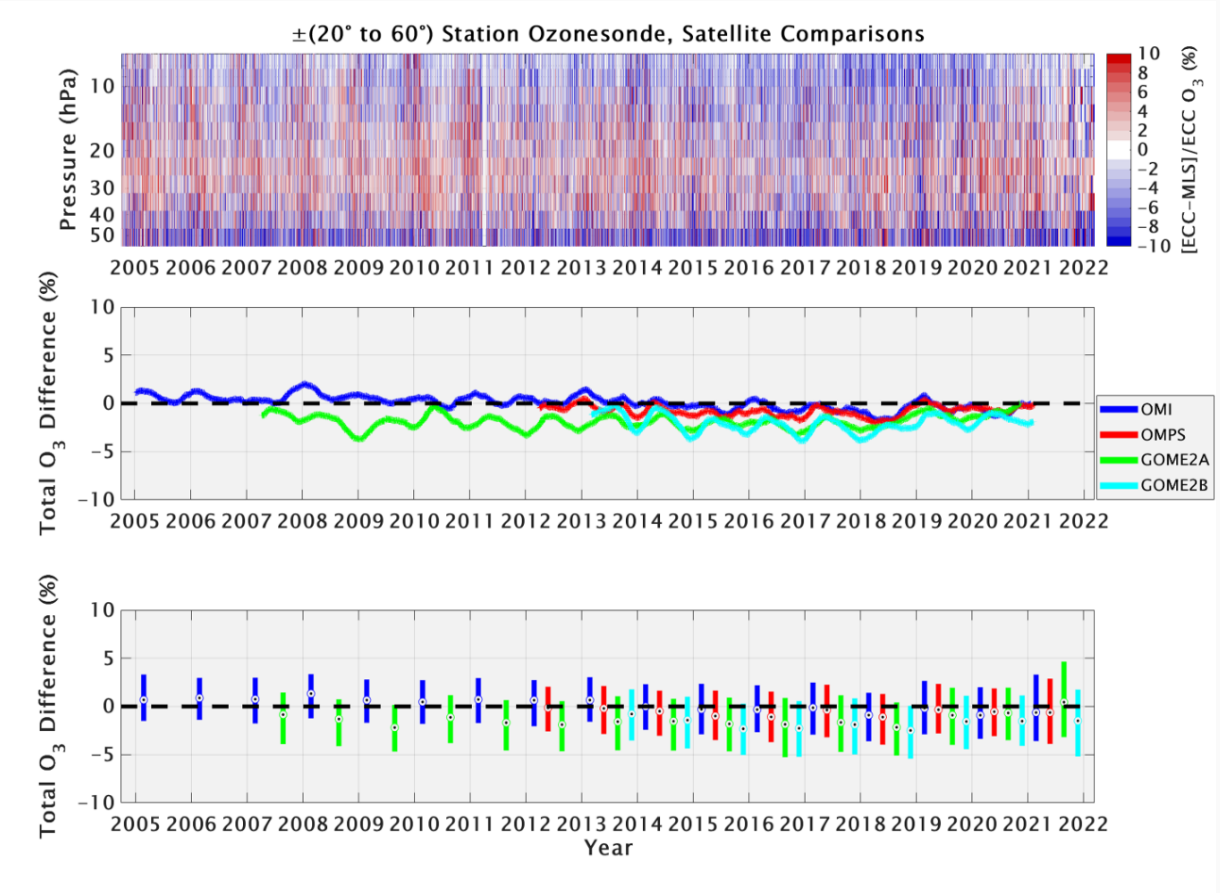


https://doi.org/10.57721/SHADOZ-V06
https://doi.org/10.57721/SHADOZ-V01-UNC

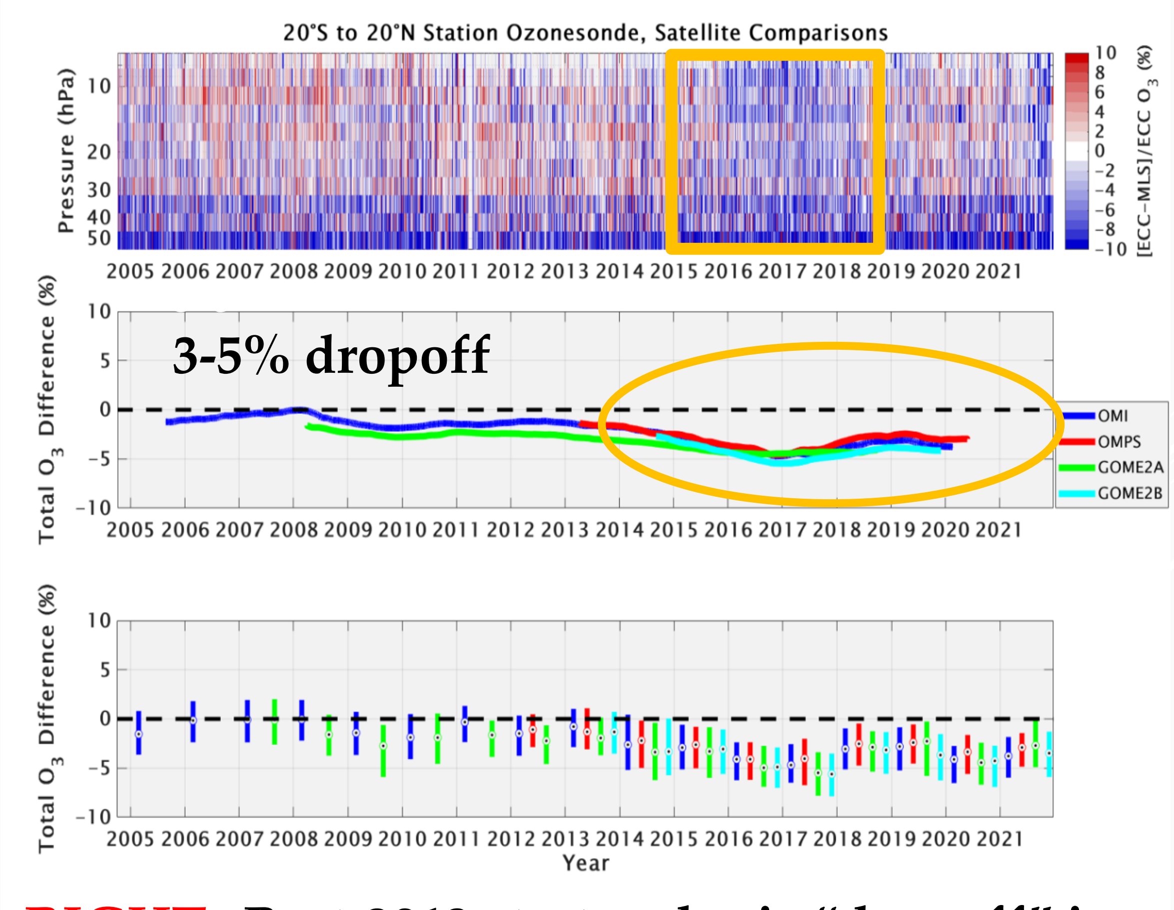
SHADOZ Webpage: https://tropo.gsfc.nasa.gov/shadoz

REGIONAL DIFFERENCES IN OVERALL QUALITY – MID-LATITUDE VS TROPICAL SONDES IN GSFC 60-STATION UPDATE (*STAUFFER ET AL.*, 2022)

NH and SH Mid-latitude Stations



SHADOZ Stations

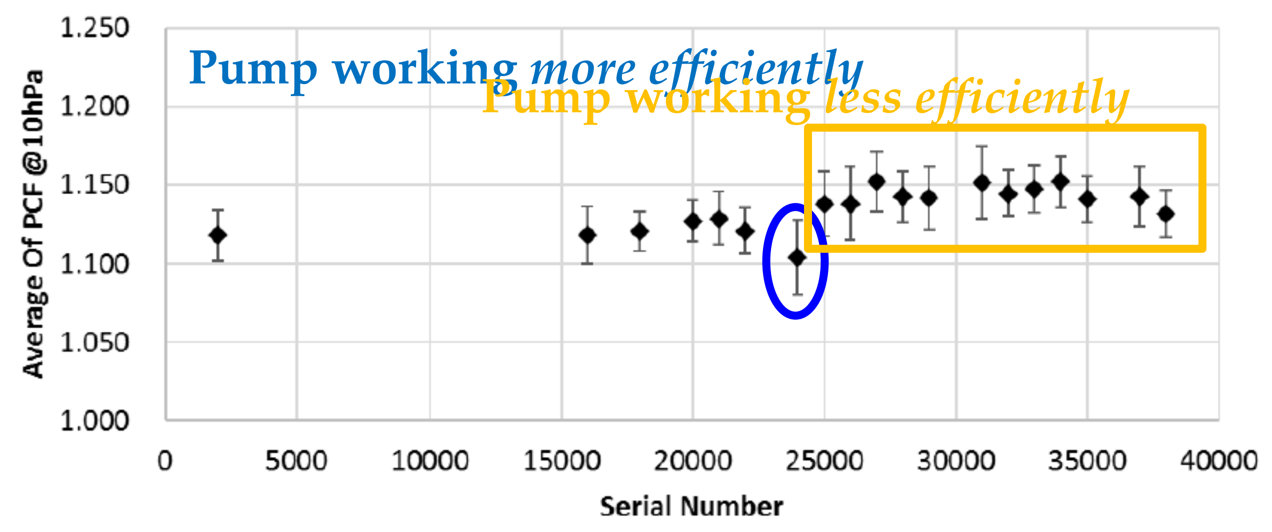


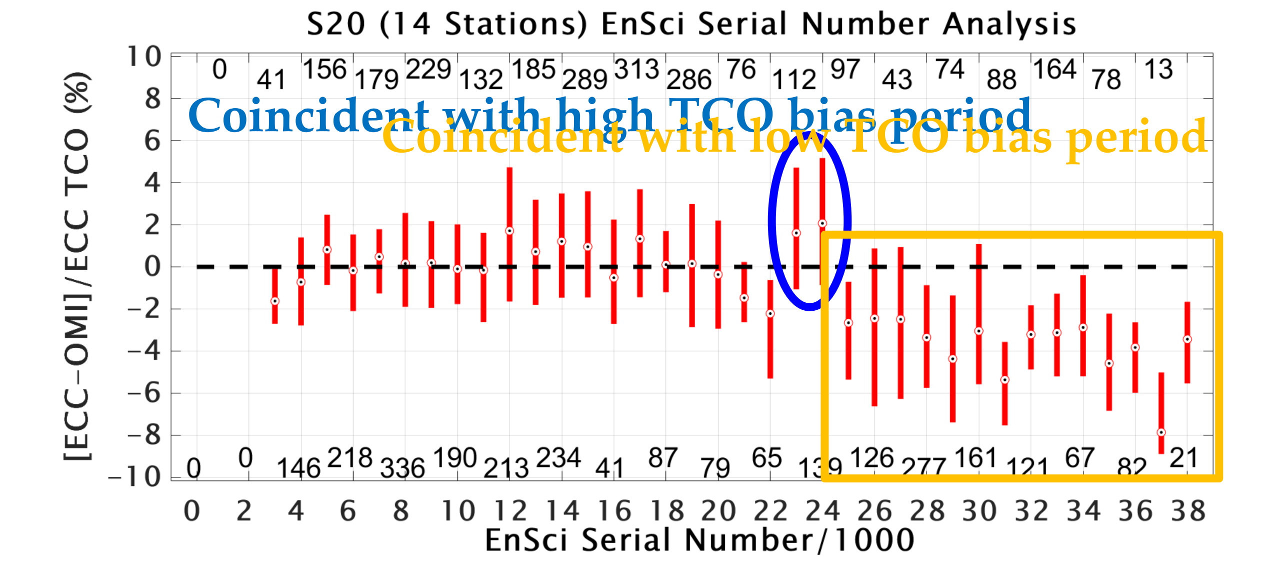
LEFT: Stable ozone measurements in Aura/MLS stratospheric layers (upper) *and* 4 polar-orbiting uv-vis TCO satellites (lower) *and* Brewer/Dobsons

RIGHT: Post-2013 stratospheric "dropoff" in strat. O_3 (Upper). Lower: up to 5% less TCO than satellite TCO *for 1/2 of SHADOZ sites*

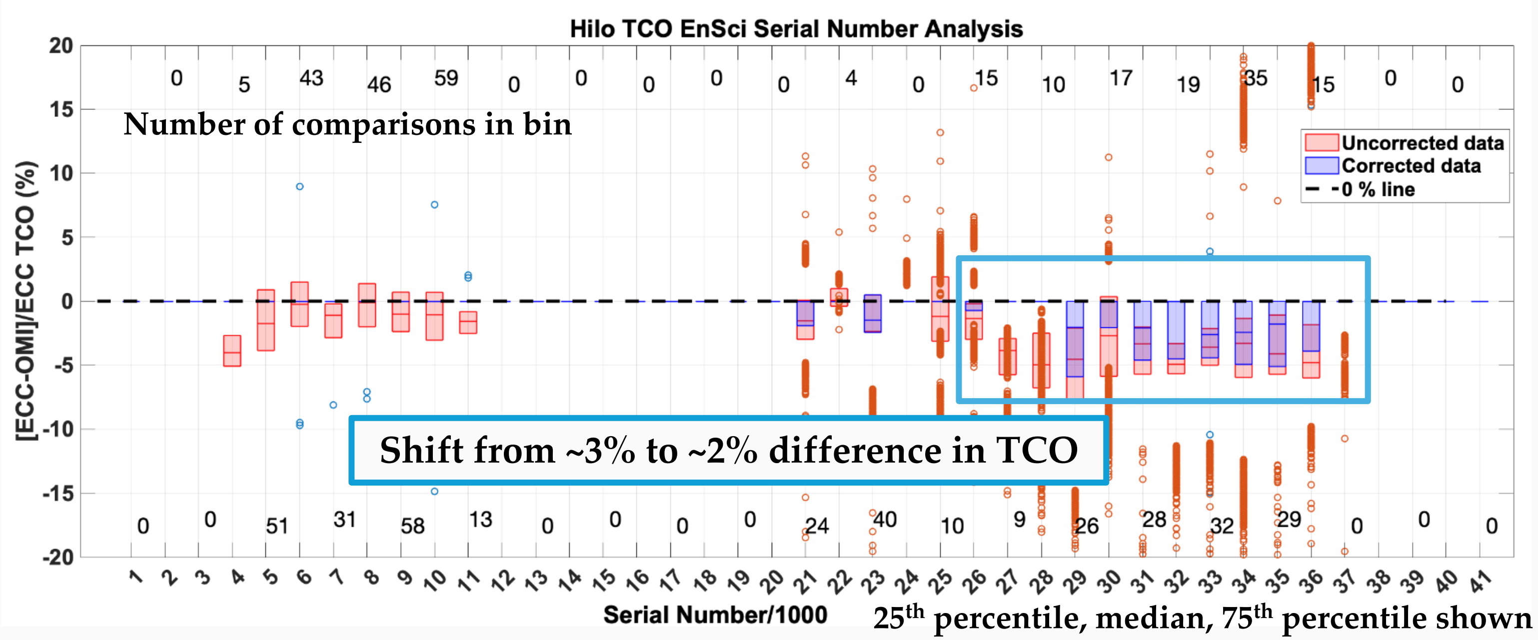
"DROPOFF" CAUSE: EN-SCI PUMP EFFICIENCY PROBLEMS

- Ozonesonde data are processed using average values to account for a decrease of pump efficiency at stratospheric pressures
- New Nakano and Morofuji (*AMT*, 2023) shows changes to En-Sci sonde pump efficiencies ➔ average values are not sufficient. These changes are coincident with the En-Sci TCO drop En-Sci Serial Numbers
- Reprocessing ozonesonde data using new pump efficiencies will reduce magnitude of the TCO drop
- *Expect 100% sonde TCO sonde-satellite* $\underline{+}$*2%_ agreement*

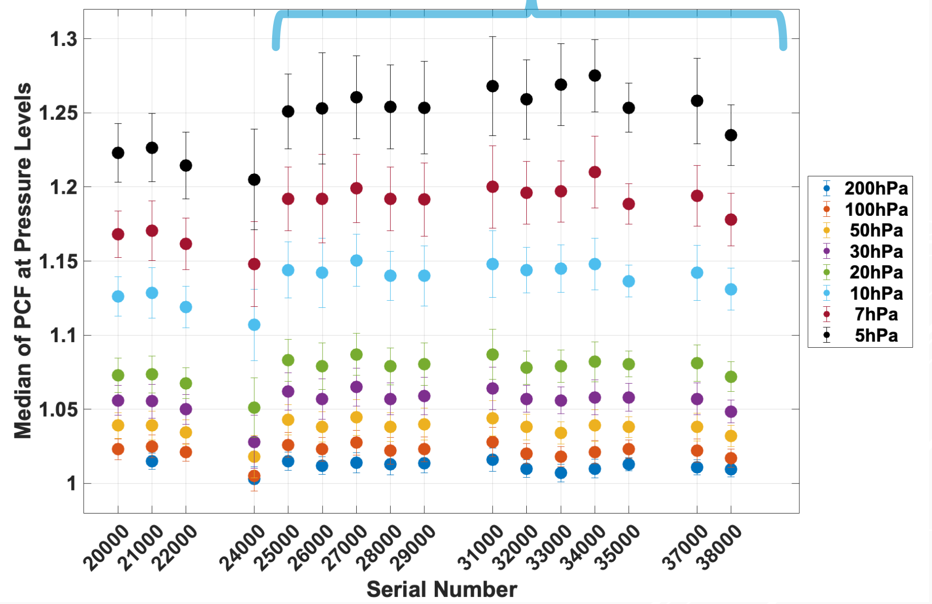




IMPLEMENTATION OF NEW PUMP EFFICIENCIES



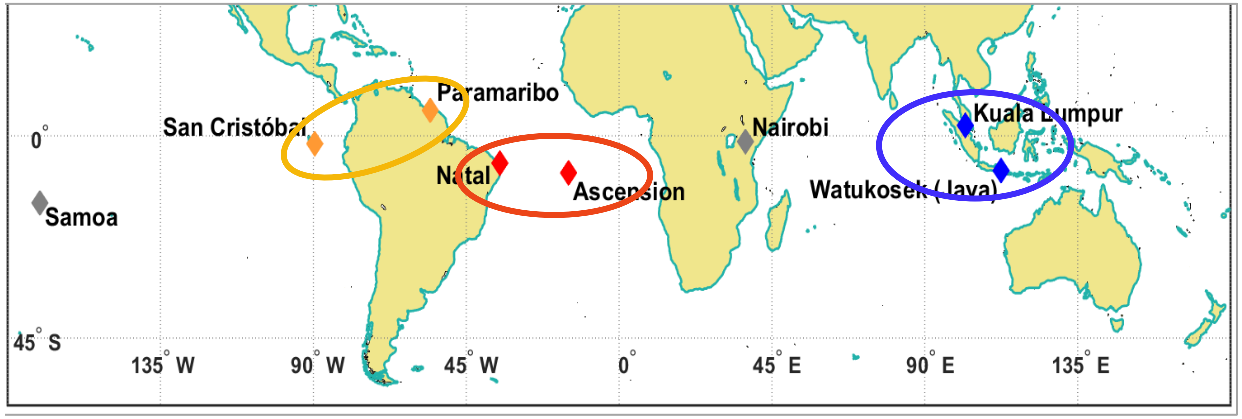
Ozonesonde low bias coincident with worse than avg pump performance for pressure levels < 200hPa



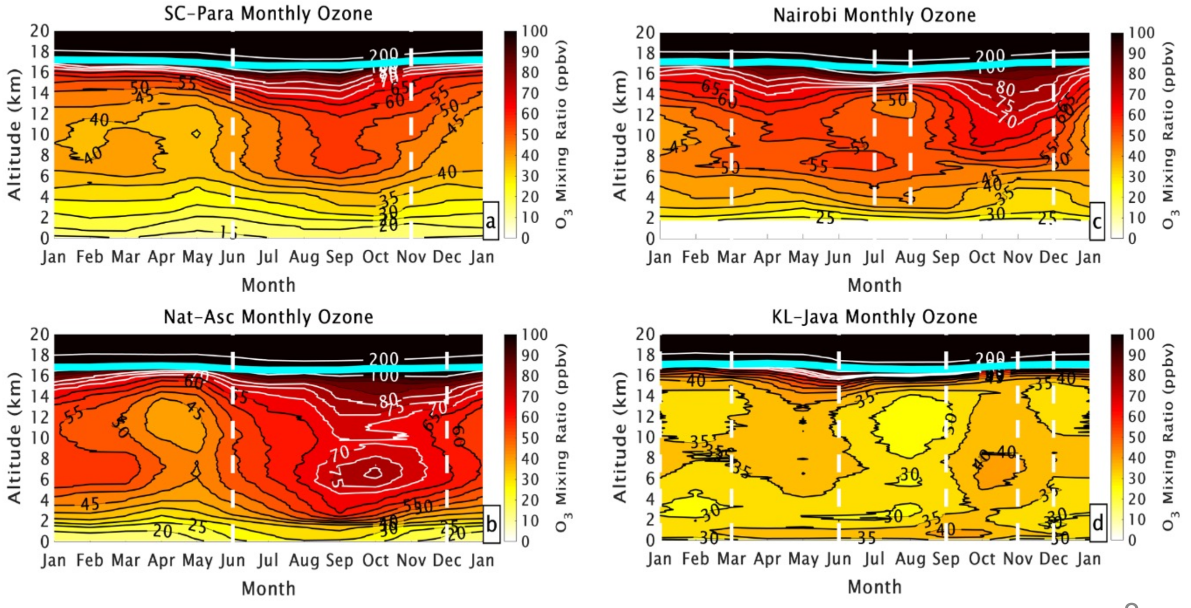
- Efforts are underway for reprocessing ozonesonde data based on *Nakano & Morofuji* (2023) results, which will reduce errors at impacted stations (e.g. shown is Hilo).
- Initial corrections show improvement from ~3% to ~2% difference as compared to OMI TCO values for serial numbers >20000 for the Hilo station. More updates to come on other station corrections in the next few months!

SHADOZ Trends Study: O_3 Seasonal & Regional Variability

- **Challenge in Satellite O_3 Trends:** Below 50hPa (20 km) satellite O_3 data is most uncertain
- **Use 22-yr SHADOZ data (1998-2019)** to compute trends in O_3. **Sonde advantages**
  (1) More precise O_3 than satellites
  (2) 100-150-m resolution at fixed sites=> FT <u>and</u> LMS trends in 1 dataset
  (3) Regional sondes avoid zonal means
  (4) Radiosondes give tropopause height (TH)
- **Data used from 5 "sites," 3 combo** for better statistics; > 5100 total profiles **(Upper)**
- **Seasonal O_3 (Below). TH annual cycle in cyan**
- TH annual cycle is ~ 1km, minimum mid-year
- "Seasonal" O_3 transitions (white vertical lines), represent alternations in dominant dynamic influences, ie convection vs advected pollution (Thompson et al., *JGR*, 2012; *JGR*, 2021 = "T21")

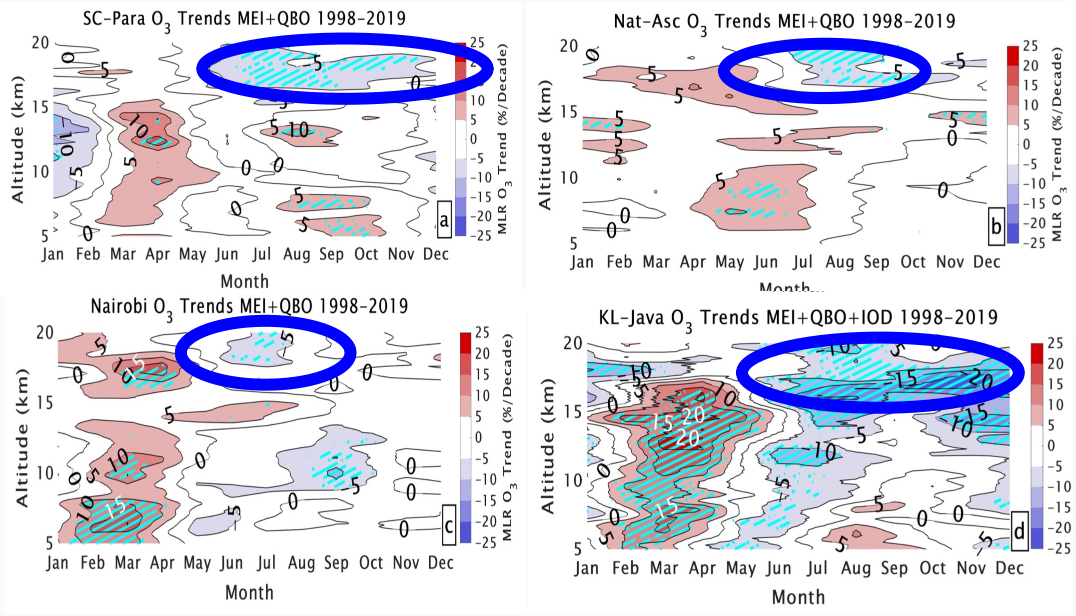


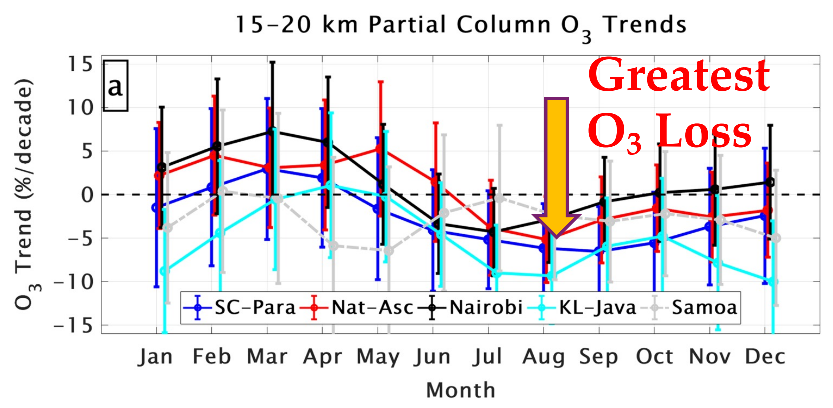
SC-Para Nat-Asc KL-Java

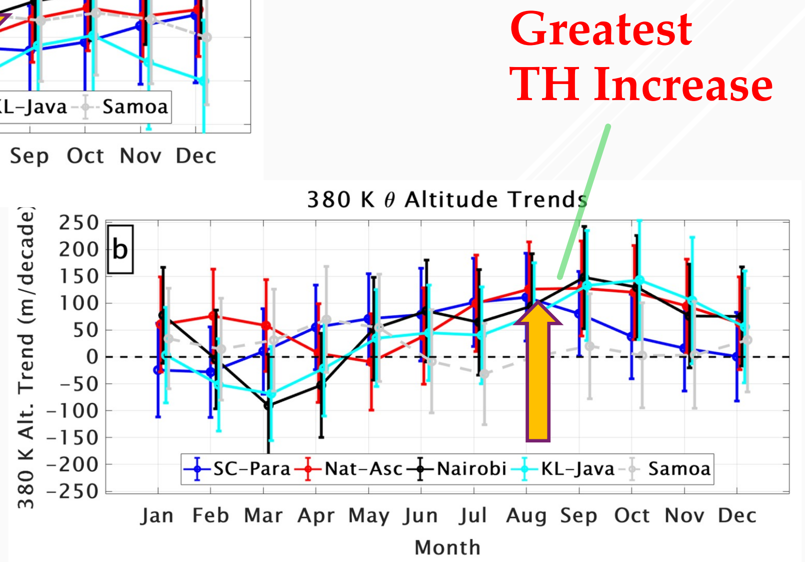


SHADOZ OZONE TRENDS STUDY – 1998-2019 (*T21*)

- **LMS (15-20 km) O_3 trends for 1998-2019 presented at 2021 SAGE STM (Thompson, Stauffer et al., *JGR,* 2021; T21) have been updated by analyzing 1998-2022 SHADOZ profiles.**
- **Recall - T21 (below) found small *O_3 LMS losses* (blue) after June coinciding with O_3 annual maximum and seasonal *increase in tropopause height (TH)*, seasonal maximum**
- **When trends recomputed with LMS = TH+ 5km, trends disappeared**

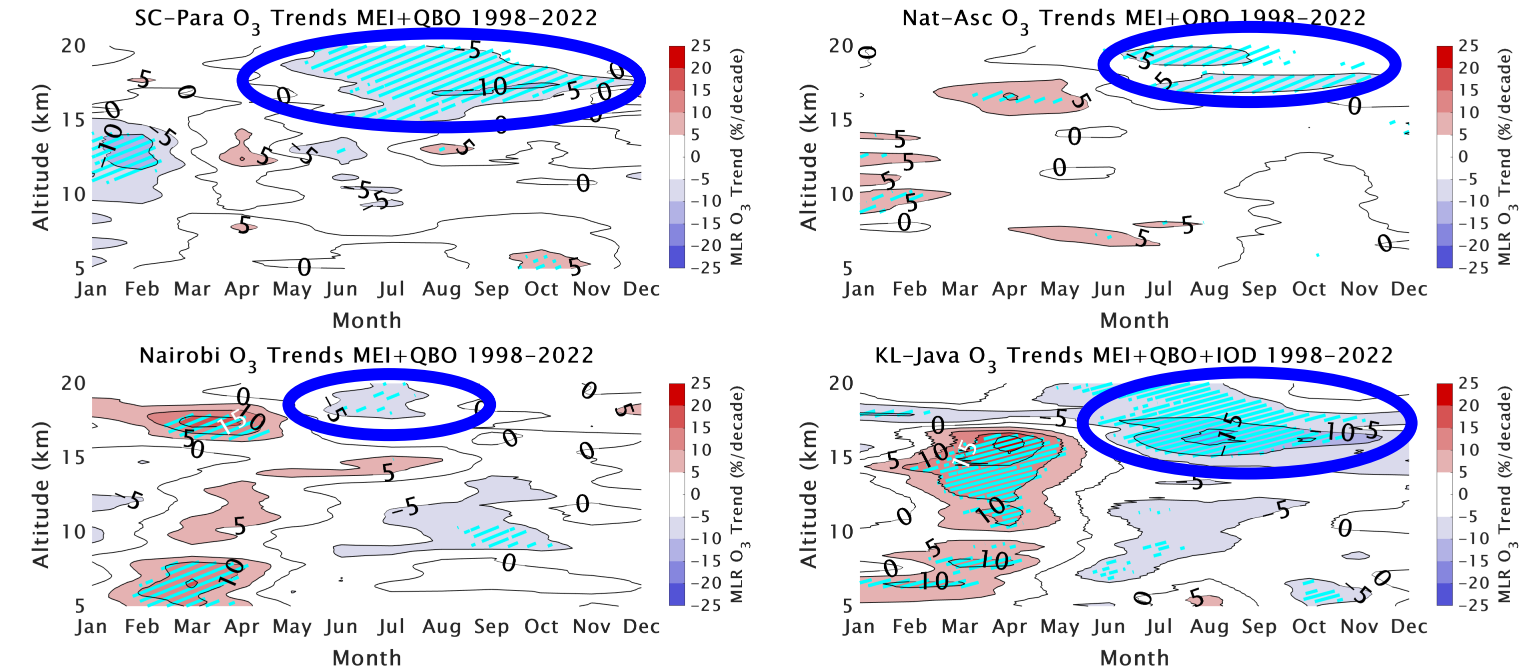


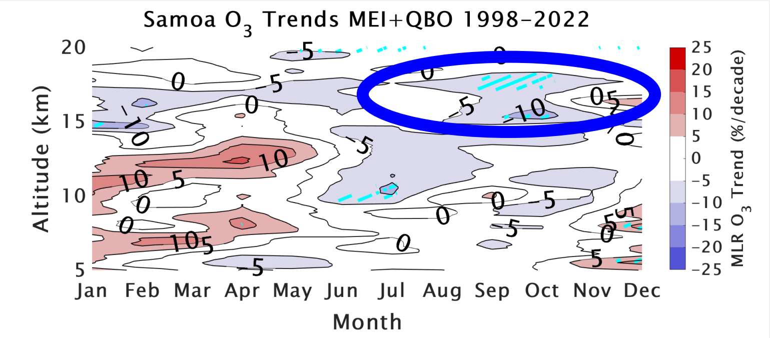


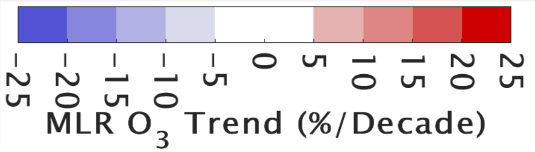


Updated (25-Yr, 1998-2022) LMS Ozone Trends

- **Trends in monthly mean O_3 & TH (alt. of 380K θ) computed by Goddard Multiple Linear Regression (MLR) model with QBO, ENSO as MEI, IOD terms, seasonal, annual cycles**
- **LMS ozone = 15-20 km. Contours from monthly means, 100-150 m-resolution calculations. *Trends in %/decade change, 1998-2022.* Red shades indicate ozone increase. Blue shades indicate ozone loss. Cyan shading significant at 95%**
- **LMS O_3 losses greatest after May, slight rate decrease @ KL-Java, SC-Para, Samoa increase**

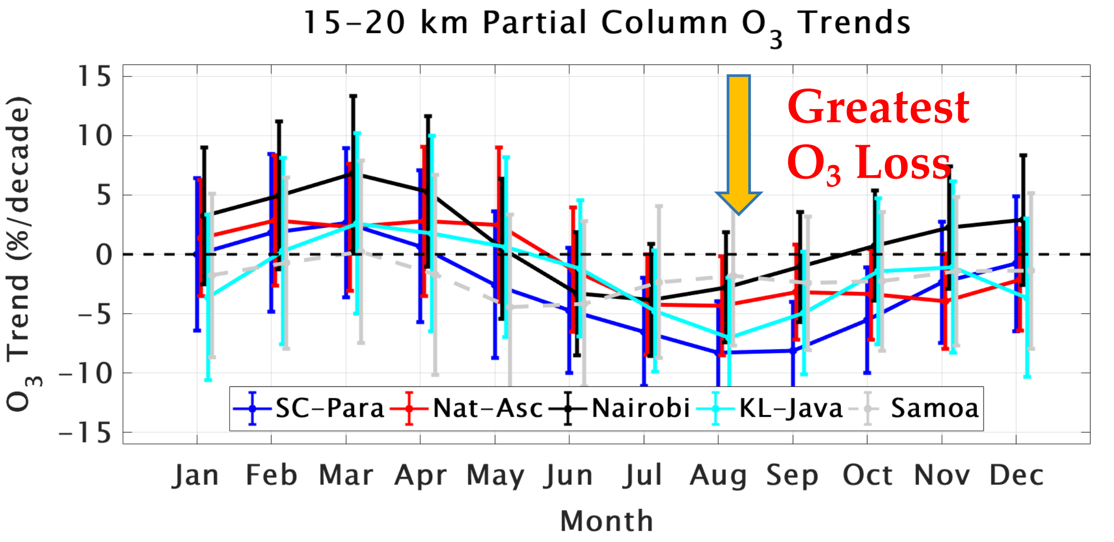


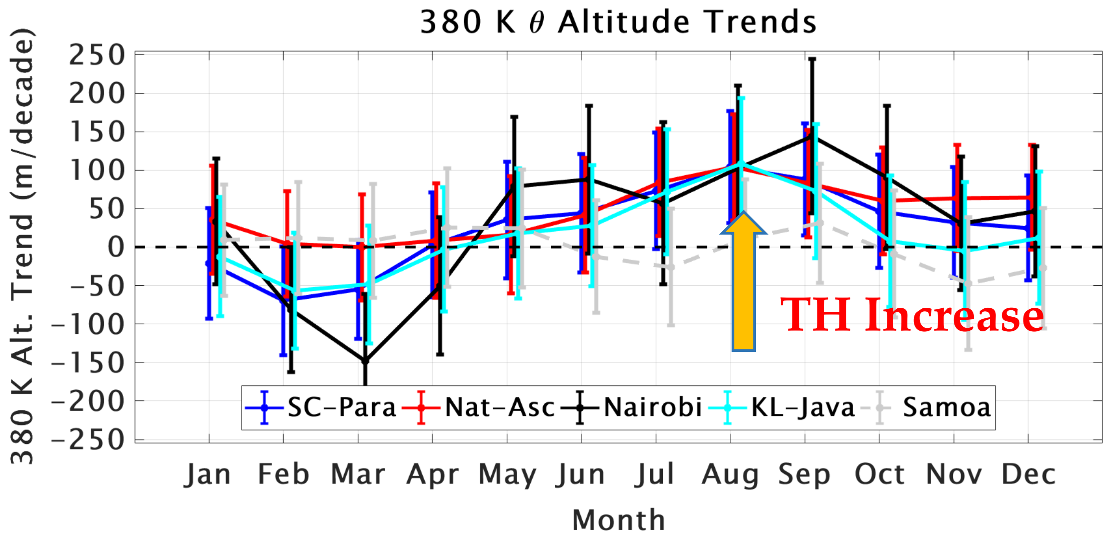




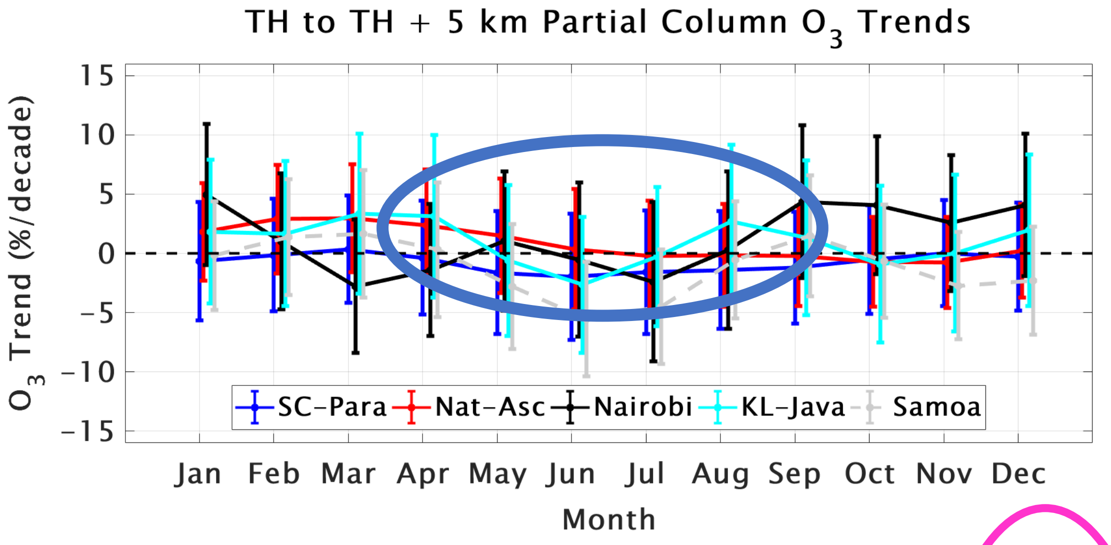
Positive TH Trend Coincides with LMS O_3 Loss Similar to T21 (Left)
Re-computed O_3 Trends – Stronger O_3-TH Change Anti-correlation (Right)

Altitude-defined LMS O_3, TH Trend (95% CI)





TH+5 km LMS- Mid-Year Trends Disappear



SITE	# PROFS	MLR TERMS	LMS (15-20 KM) (%/dec)	TH-REF LMS (%/dec)
SC-PARA	1302	MEI+QBO	**-3.5**	-0.8
NAT-ASC	1565	MEI+QBO	-1.3	+0.8
NAIROBI	976	MEI+QBO	+0.8	+1.2
KL-JAVA	870	MEI+QBO+IOD	-2.2	+0.9
SAMOA	876	MEI+QBO	-2.0	-1.3

SUMMARY & LOOKING AHEAD

SHADOZ (and other sonde) QA Update

- SHADOZ continues to lead the ozonesonde community in setting new Standard Operating Procedures (SOP). Expect a new version of SHADOZ by end of 2023 that (1) corrects for 'dropoff' in pump efficiency in stratosphere; (2) Artifact 'low' ozone in Tropopause Transition Layer. The latter will follow new *Smit et al.,* (2023) paper recommendations based on JOSIE-SHADOZ-2017 (*Thompson et al.,* 2019)
- **Practical implication for SAGE III users. All SHADOZ station stratospheric profiles are now valid for comparisons**
- Reprocessing of global sonde record continues in sonde community – 100% goal with 3-5% accuracy and precision is in sight

SHADOZ Tropical LMS Trends (update of T21)

- LMS trends with 2019-2022 data added (25-yr total) resemble 22-yr trend (*Thompson et al.,* 2021)
- *Not Shown:* Free tropospheric (FT) trends at 25 yrs are similar to T21 but ozone increases moderated slightly, perhaps due to COVID impacts. In-depth study of KL-Java trends implicates changes in convection (*Stauffer et al., in prep,* 2023)

ACKNOWLEDGMENTS. SONDE QA & TRENDS PAPERS

As SHADOZ PIs and SAGE STM members we thank Richard Eckman and Ken Jucks for support.

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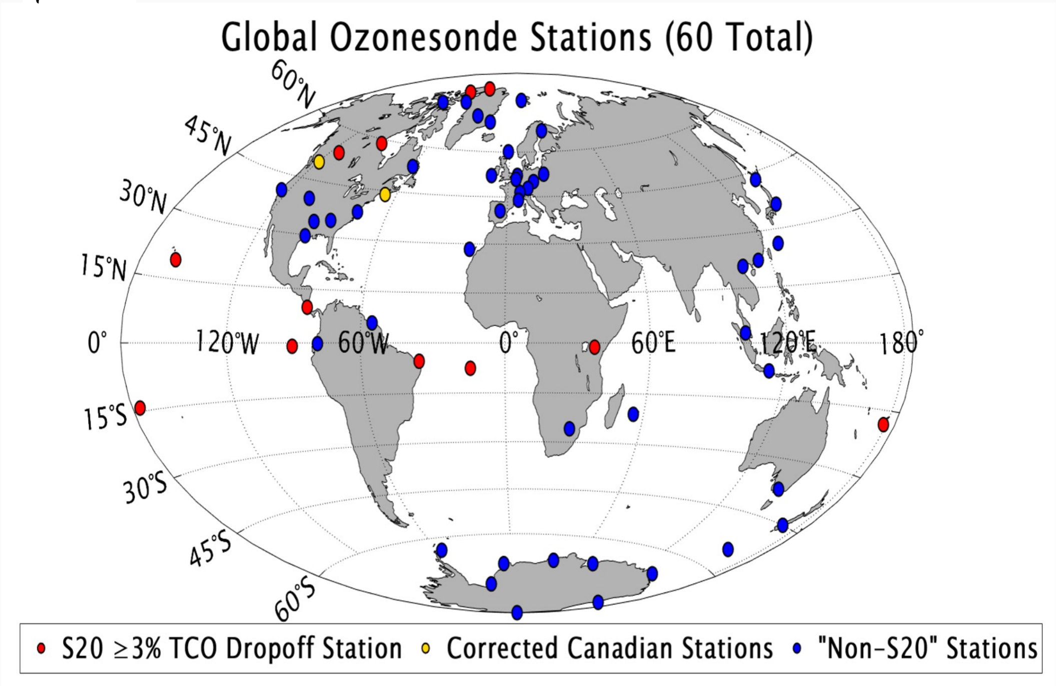
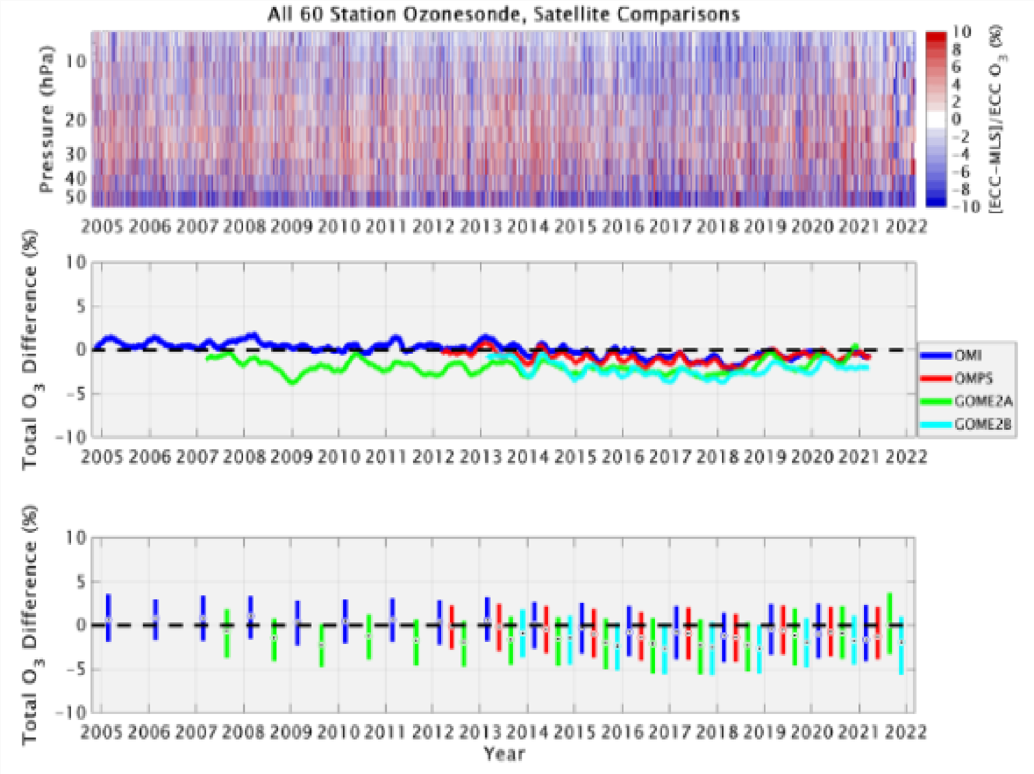
OZONESONDE STABILITY UPDATE





Stauffer et al., 2022

- **Good News!** Now more than 70% of 60 global stations have reprocessed data! Stauffer et al. (2022) examined > 40K profiles, 2005-2021. Only a handful of Canadian & SHADOZ sites (**Red, Left**) display TCO drop ≥ 3%. Similar comparisons with Dobsons, Brewers, SAOZ. Globally > 80% of sonde profiles agree within TCO by ± 2%!! (**Right**).
- **Best News!** Study of Nakano & Morifuji (2023) reported instrument "EnSci dropoff" cause and how to reprocess a correction (next slide). Expect 100% stability in 2023!