Southern Hemisphere Additional Ozonesondes (SHADOZ) Network: Satellite Validation Standard & UT/LS Trends

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Roadmap: High-Quality Profiles for Validation & Trends

- **SHADOZ Network Status and Archive Updates**

- **Ozonesonde Data Quality Assurance Activities – How we know our data are of excellent quality**

- **Global Perspective: ±2% Total Column Ozone Agreement w/Satellites!**

- **Setting the Standard for Ozone Trends**
  - SHADOZ tropical trends from surface to UT/LS: Climate signal at tropopause (update of Thompson et al., 2021; JGR "T21")
  - Tropics show overall modest trends except SE Asia where dynamics are a factor (Stauffer et al., 2024; ACP TOAR-II Special Issue)
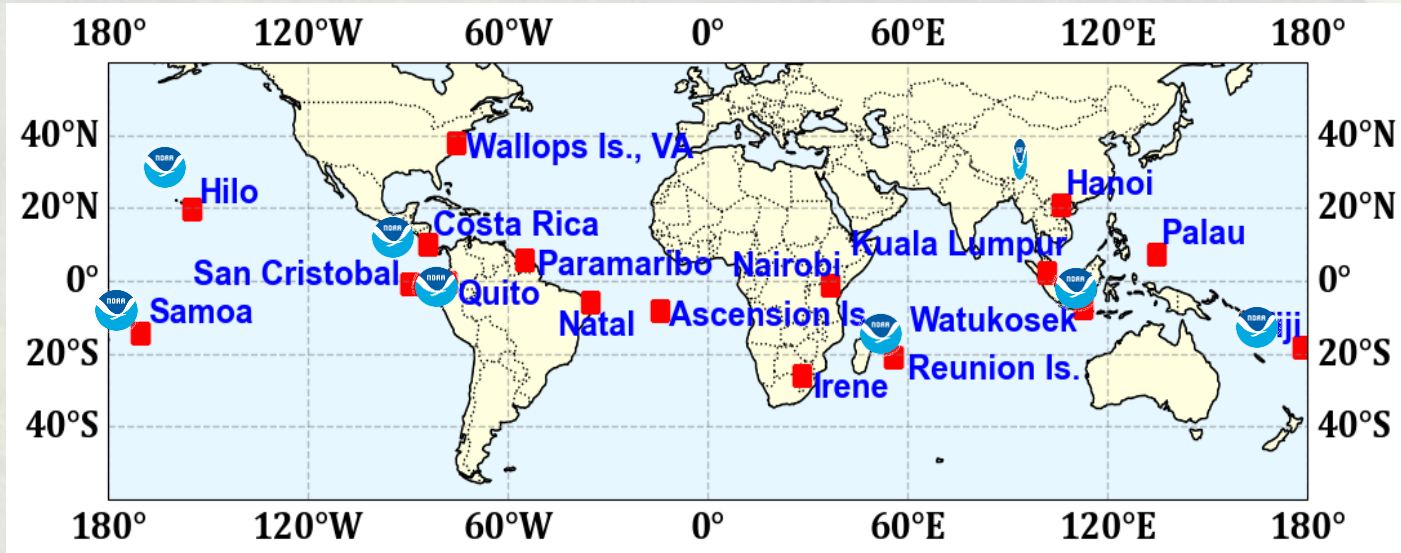
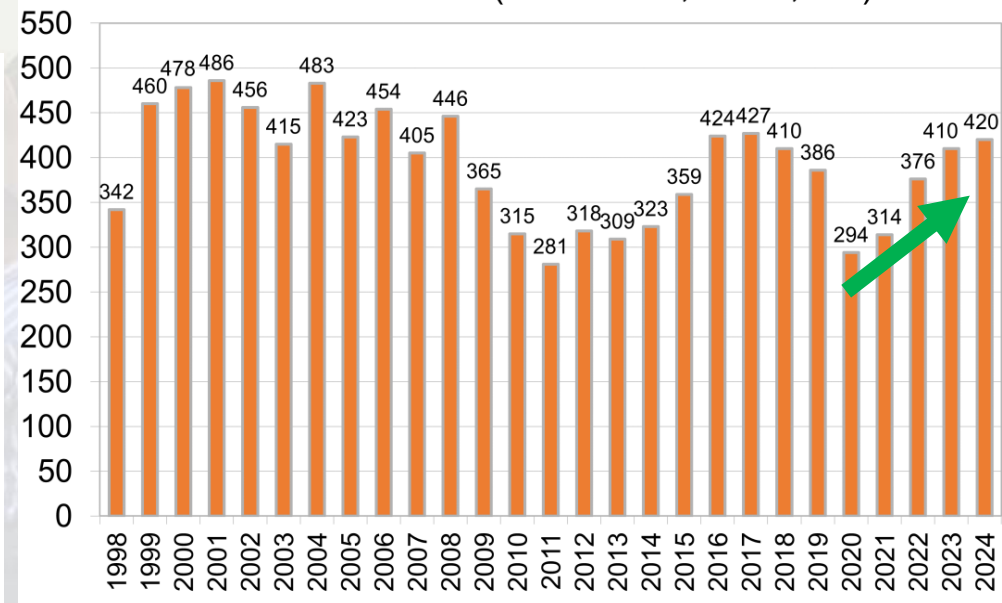# SHADOZ: >25 Years and >10,000 Profiles

- 14 stations with >10-year records. Launches (2-4/mo) from > 20 sponsors, organizations
- 2024: **Palau** and **Quito** join SHADOZ – V06 data will be @ archive soon!
- >10,000 O_3-PTU profiles archived on SHADOZ website
- SHADOZ v6 data DOI: https://doi.org/10.57721/SHADOZ-V06
- NASA/GSFC includes 50+ yr Wallops (WFF) record

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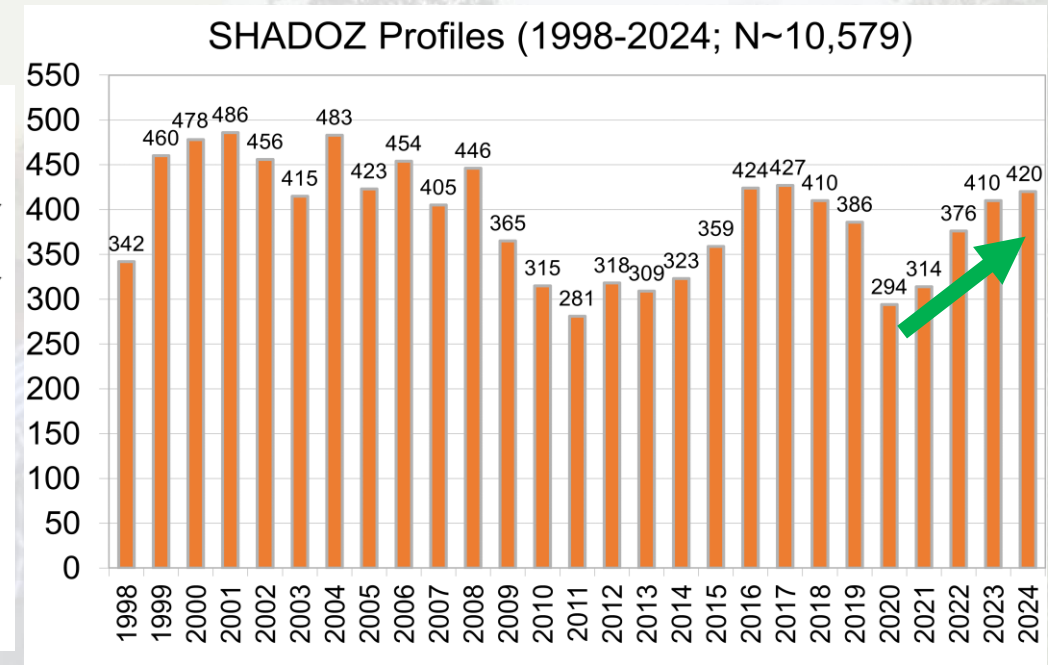

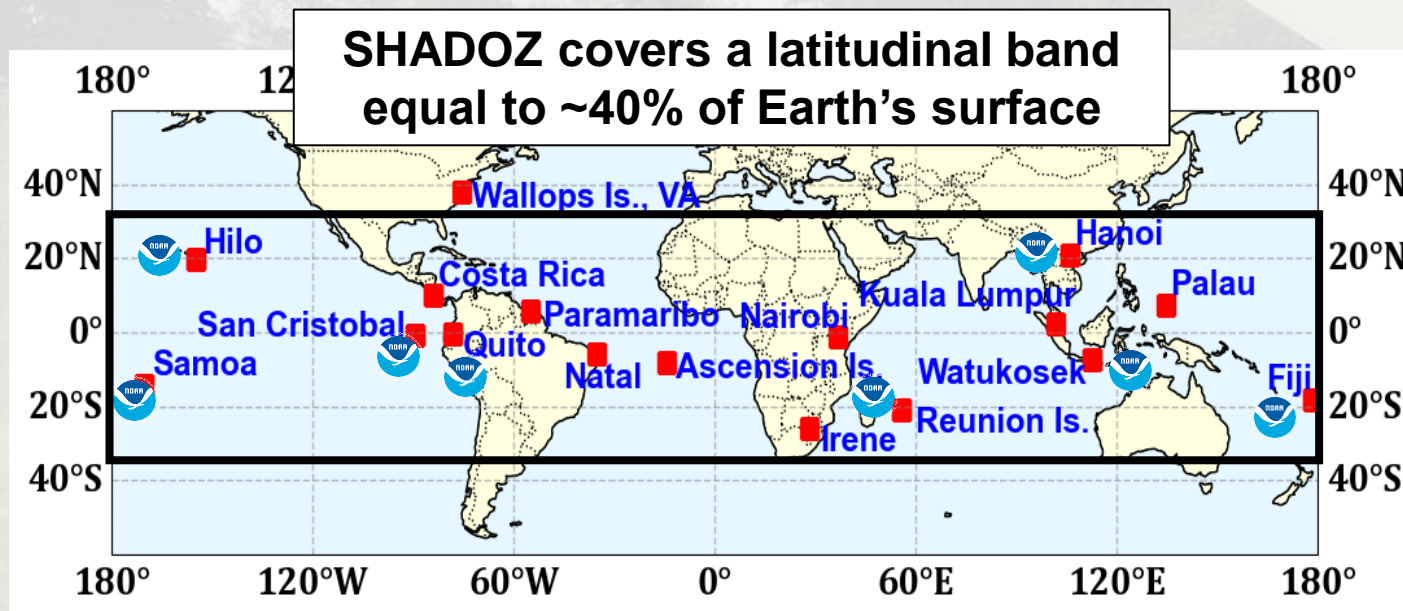SHADOZ Profiles (1998-2024; N~10,579)
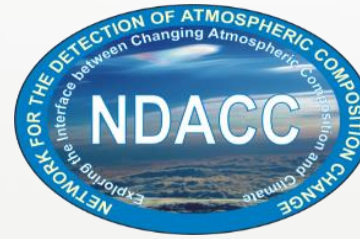
NOAA station/logistical support

SHADOZ Data Archive Status

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SHADOZ covers a latitudinal band equal to ~40% of Earth's surface

NOAA station/logistical support

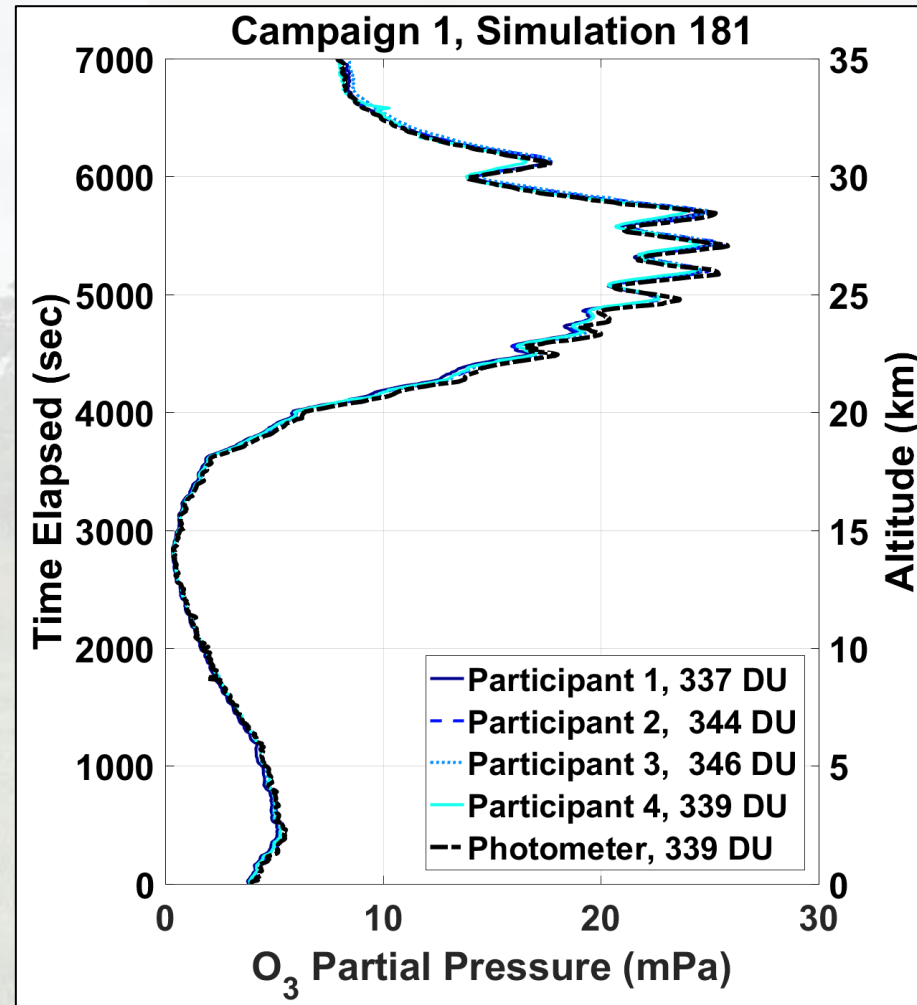# SHADOZ Data Quality Assurance and Recent Science
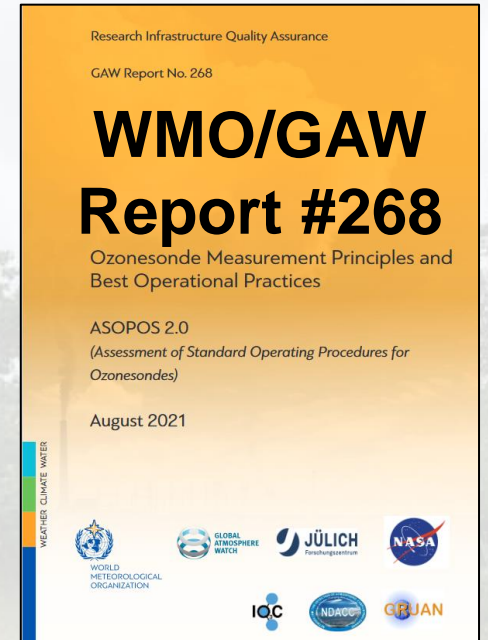
Data Quality Assurance: ASOPOS Panel

- Assessment of Standard Operating Procedures for OzoneSondes v2.0 (ASOPOS 2.0) prescribes SOPs for global network

- Field and WCCOS chamber tests at FZJ, Germany, inform guidelines and steps to reprocess or "homogenize" data → **5% uncertainty goal for satellite validation**

World Calibration Centre for OzoneSondes (WCCOS) environmental chamber

Campaign 1, Simulation 181

Participant 1, 337 DU
Participant 2, 344 DU
Participant 3, 346 DU
Participant 4, 339 DU
Photometer, 339 DU

Four Ozonesondes Compared to WCCOS UV Photometer

Research Infrastructure Quality Assurance

GAW Report No. 268

WMO/GAW Report #268

Ozonesonde Measurement Principles and Best Operational Practices

ASOPOS 2.0 (Assessment of Standard Operating Procedures for Ozonesondes)

August 2021

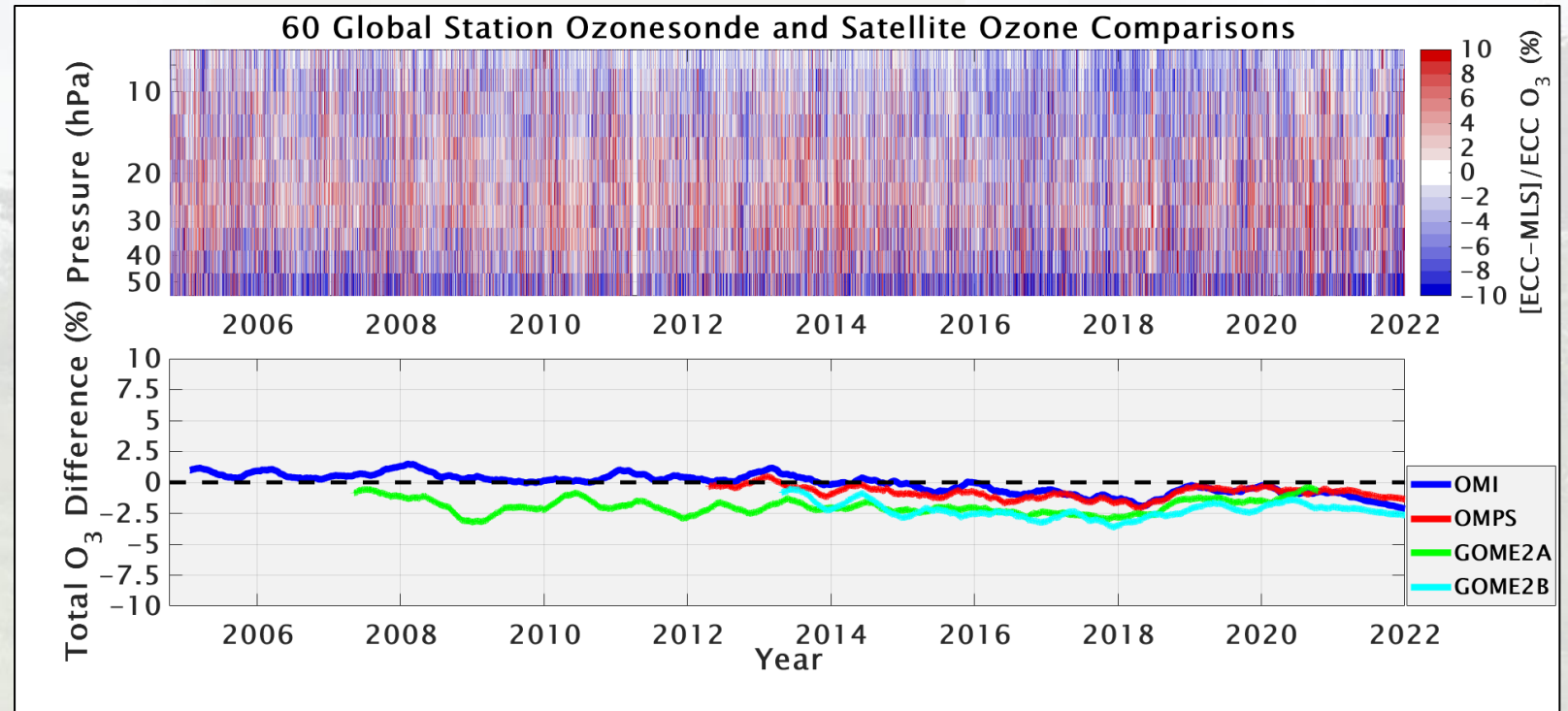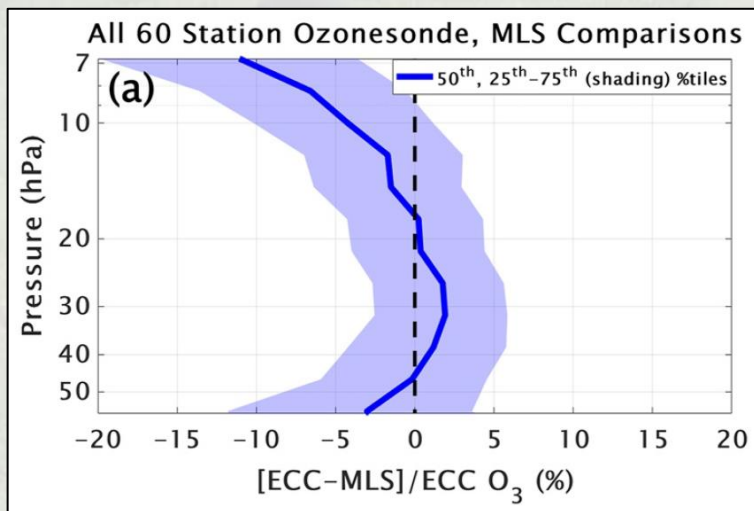*ASOPOS 2.0, Brussels, Sep 2019*

Fruits of Our Labor: ±2% Agreement!

- Global survey of 60 stations in **Stauffer et al., (2022)** showed total column ozone stability with satellites of ±2%. Agreement with Aura MLS profiles is ±5%

- Data reprocessing has been highly successful!

- Uncertainties reduced from ~20% in the 1990s to near 5% today

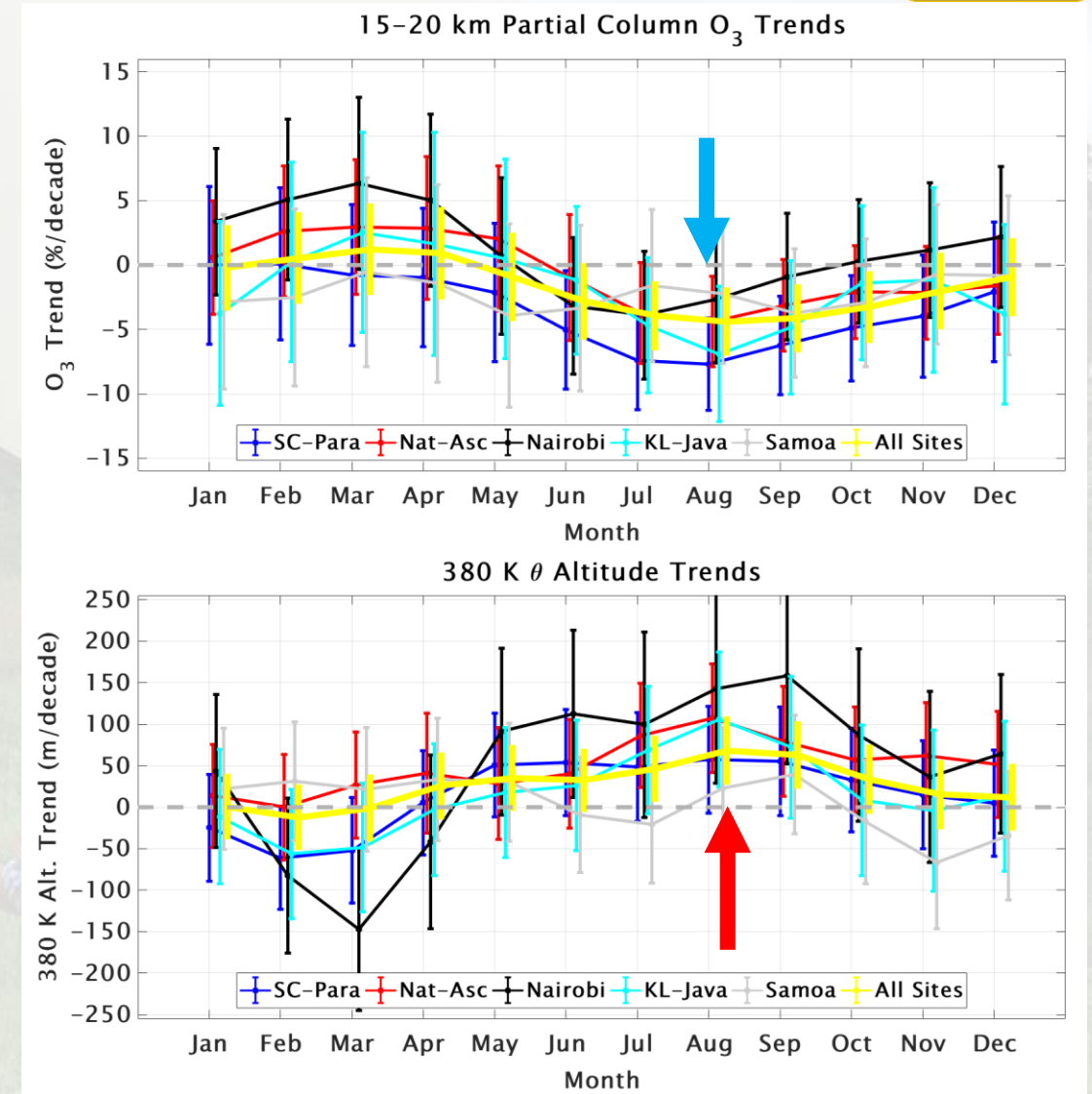All 60 Station Ozonesonde, MLS Comparisons

- Global ozonesonde data are accurate enough to detect a drift in **OMI** v8.5 total column ozone (see above), which has since been corrected.

- ***We compute ozonesonde profile trends with added confidence!***
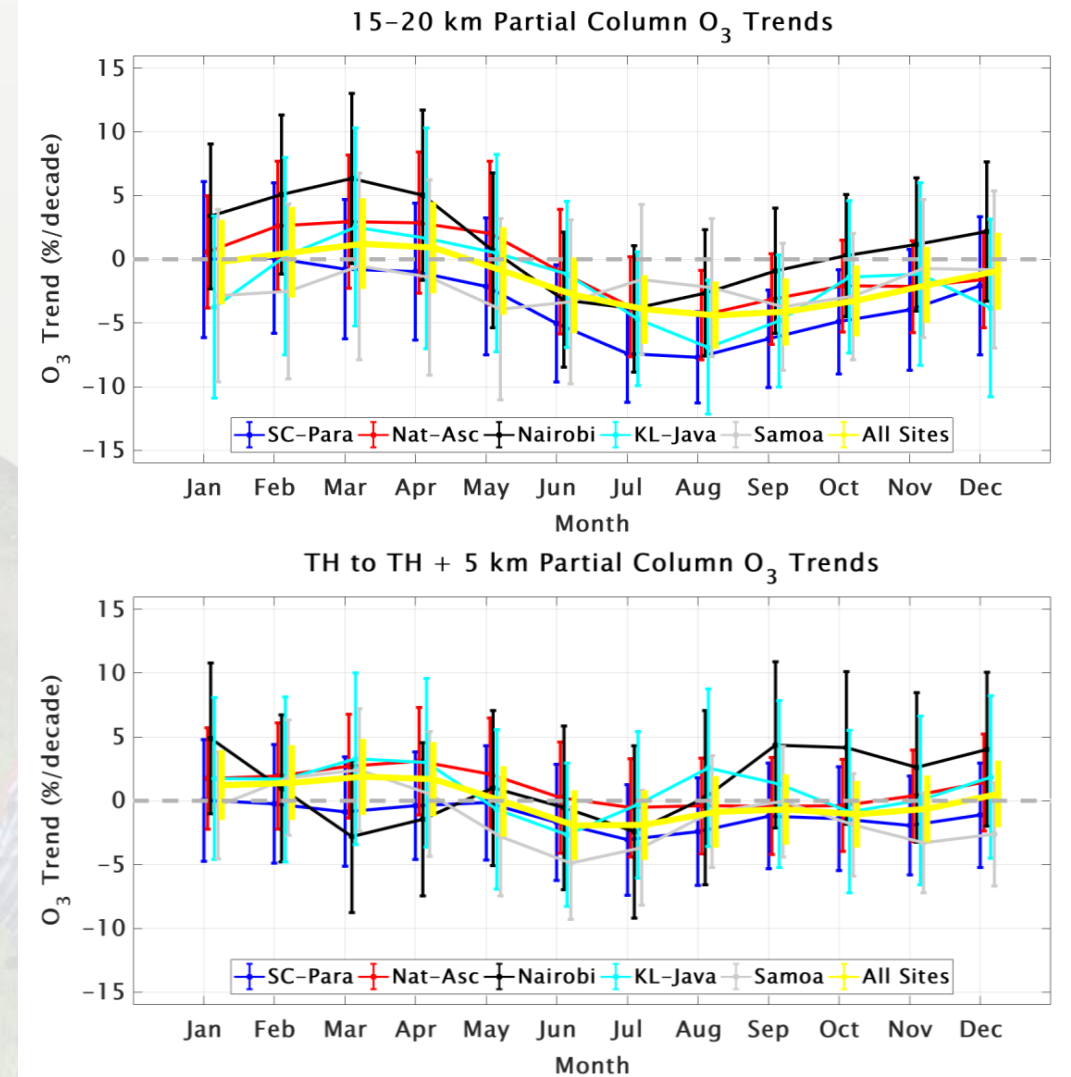
SHADOZ Science: O₃ Profile Trends

- SHADOZ ozonesonde profile trends updated from *Thompson et al., 2021* ("T21"). **1998-2023** trends calculated with multiple linear regression (MLR) model at five stations (8 total individual sites) *and* **all sites combined in yellow**)

- In the 15-20 km layer, significant negative trends of -5 to -7 %/decade occur in several months during the second half of the year (**top**)

- This is coincident with significant positive trends in the tropopause height at the stations (**bottom**)

- *Are SHADOZ lower stratospheric ozone trends an artifact of tropopause height changes?*

Update from Thompson et al. (2021)
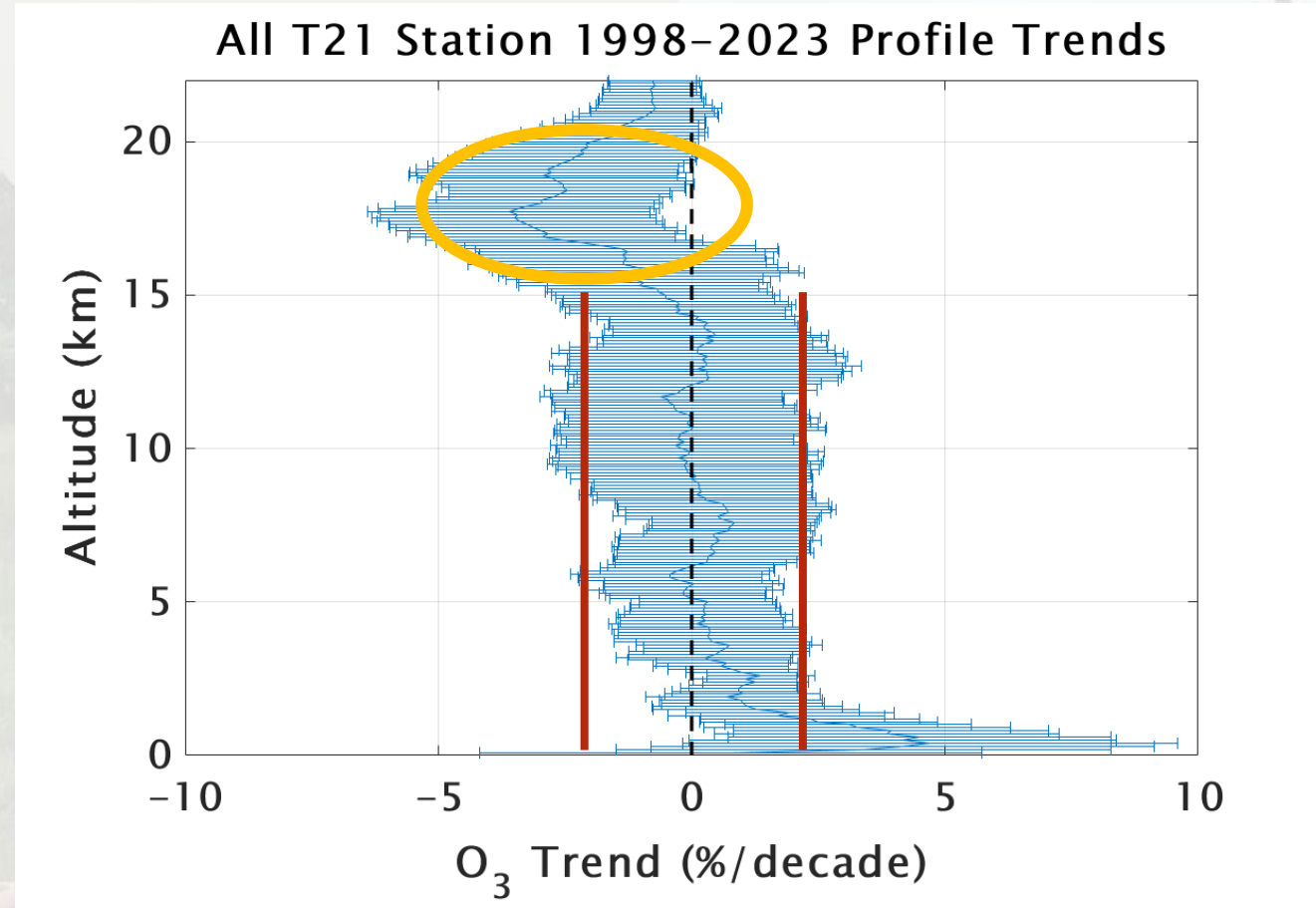
SHADOZ Science: O$_3$ Profile Trends

- Referencing the ozonesonde profiles to the tropopause height and re-calculating trends shows that the trends largely "disappear"! (**bottom**)

- **Climate signal in tropopause height increases are leading to negative ozone trends in the lower stratosphere**

- Trends output from *Thompson et al., (2021; JGR)* are found at: https://tropo.gsfc.nasa.gov/shadoz/SHADOZ_PubsList.html.

- **Use the output to evaluate satellite and model-based trends calculations!**

15–20 km Partial Column O$_3$ Trends

TH to TH + 5 km Partial Column O$_3$ Trends
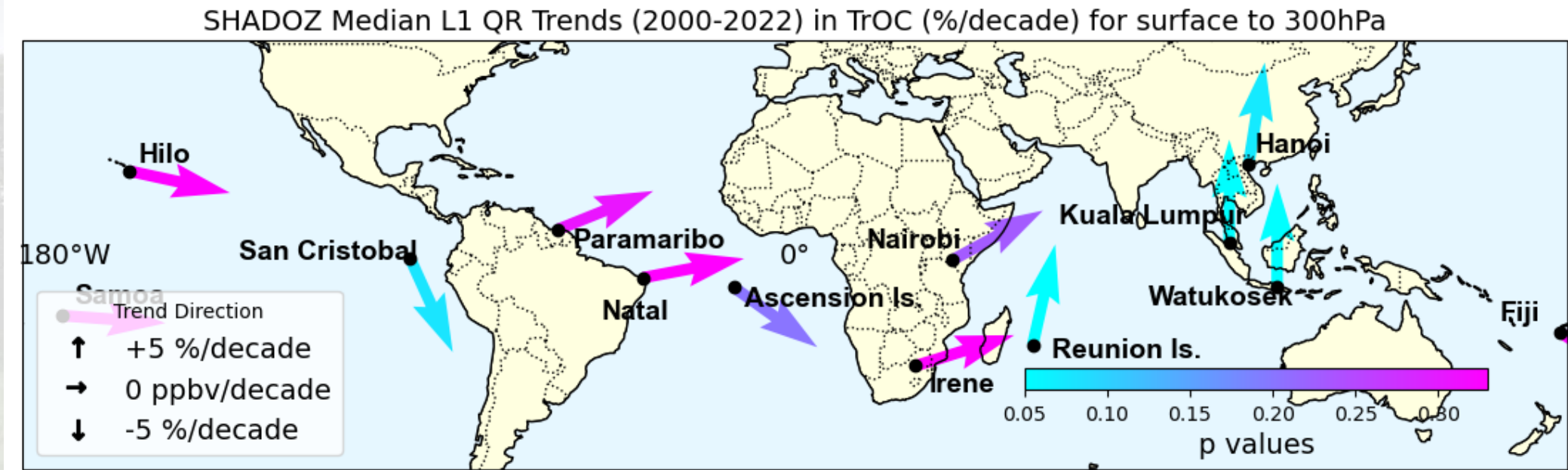
Update from Thompson et al. (2021)

SHADOZ Science: O₃ Profile Trends

- Profile trends **1998-2023** from all 8 tropical SHADOZ stations used in T21 **combined** →

- Mean UT/LS trends to -4 %/decade (significant with 95% confidence) across 8 tropical stations. More re-processing in NDACC, ASOPOS 2.1 will cut UT/LS uncertainty further – stay tuned

- ***Seasonal/monthly*** *trends contain important information. Not always uniform.*

- **Note**: **No** Free Troposphere trend above ~2 km altitude! Boundary layer positive trends are driven only by Kuala Lumpur & Watukosek Equatorial SE Asia stations

All T21 Station 1998–2023 Profile Trends

SHADOZ Science: Tropospheric O$_3$ Trends

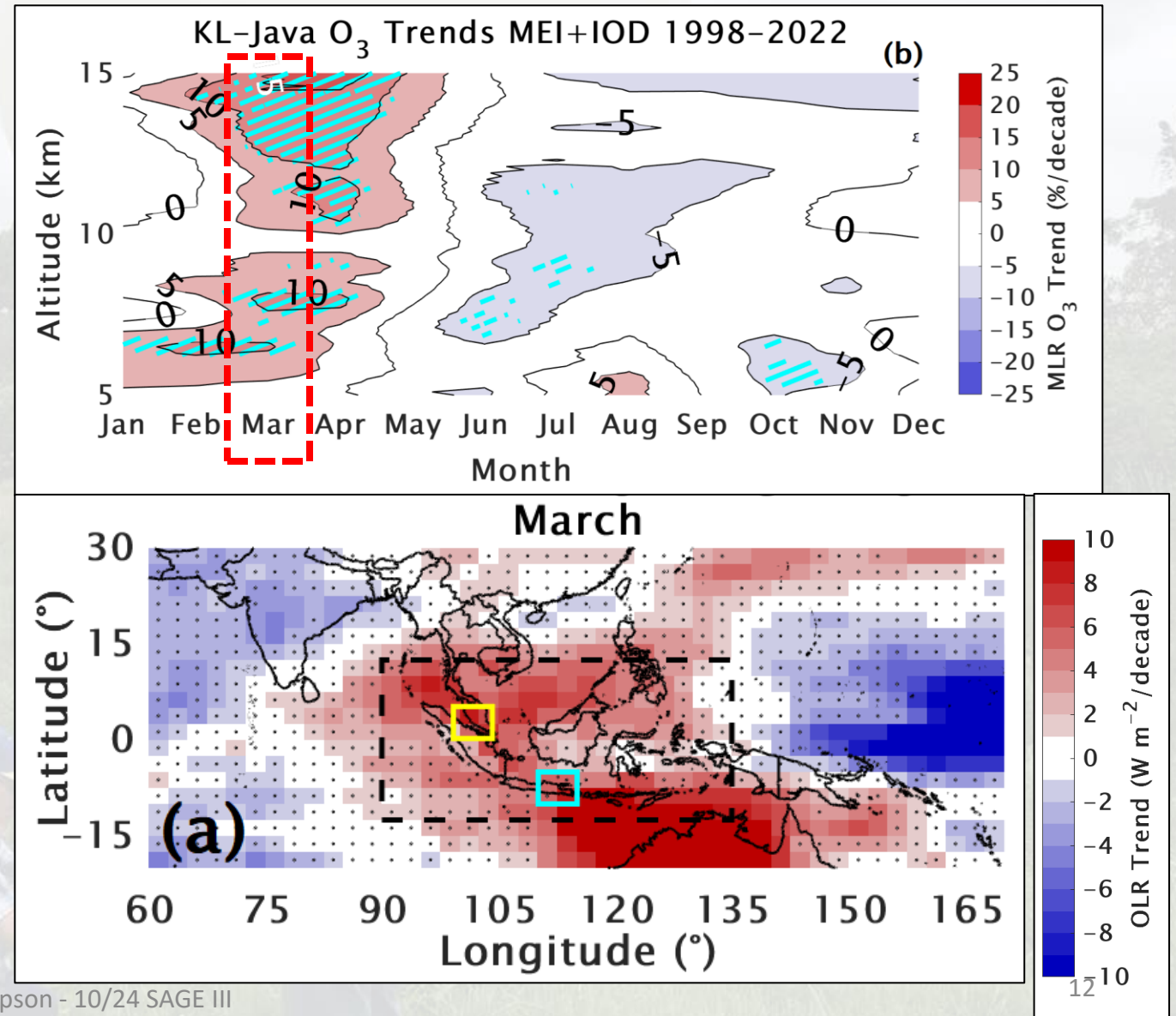SHADOZ Median L1 QR Trends (2000-2022) in TrOC (%/decade) for surface to 300hPa

- **Contribution to TOAR II/HEGIFTOM Tropospheric column (surface to 300 hPa) trends** calculated using Quantile Regression (QR) show overall modest increases across the tropics

- Largest (**~5%/decade**) positive trends over 2000-2022 are found in SE Asia (Hanoi, KL, Watukosek)

- *Are increases driven entirely by anthropogenic emissions, or is there also a dynamics story to the tropospheric trends in SE Asia?*

SHADOZ Science: O₃ Profile Trends

- *Stauffer et al.,* (2024; ACP TOAR-II SI) shows that **Feb-Apr large positive ozone trends** over Southeast Asia (**top**; KL and Java SHADOZ stations) are associated with a significant decrease in convection (**bottom**) **1998-2022**

- Decrease in convection reduces the lofting and redistribution of near-surface ozone poor air, and tropospheric ozone accumulates

- **This is a *dynamics* signal only identified using monthly-resolved trends in ozone and meteorological parameters, e.g. cloud brightness T, VP$_{200}$, PWAT, OLR →**

Summary

- SHADOZ fills an otherwise **huge gap** in ozone profile data in the tropics. **More than 10,000 profiles archived.**

- *How do we know our data are of high-quality?* Lab and field tests inform reprocessing efforts that have helped us achieve high accuracy and close to a ~5% uncertainty goal for ozonesonde data

- **SHADOZ ozone data and trends set standard for SAGE III and SAGE-derived satellite products (GOZCARDS, SWOOSH) evaluation, activities like LOTUS and TOAR-II/HEGIFTOM!**

Thanks to our partners, collaborators, and NASA HQ Program Manager K. Jucks for support