

**BACKGROUND, GOALS & SUMMARY**

- IGAC Tropospheric O<sub>3</sub> Assessment Report (TOAR II) is supplying ground-based measurements by 5 methods that will be used as input for next IPCC Report
- HEGIFTOM (Harmonization & Evaluation of Ground-based Instruments for FT Ozone Measurements) is establishing trends from data supplied by WOUDC, NOAA, NDACC, SHADOZ\*, IAGOS with uncertainties. Trends emphasize free tropospheric (FT) & total tropospheric columns TrOC in ppbv/decade

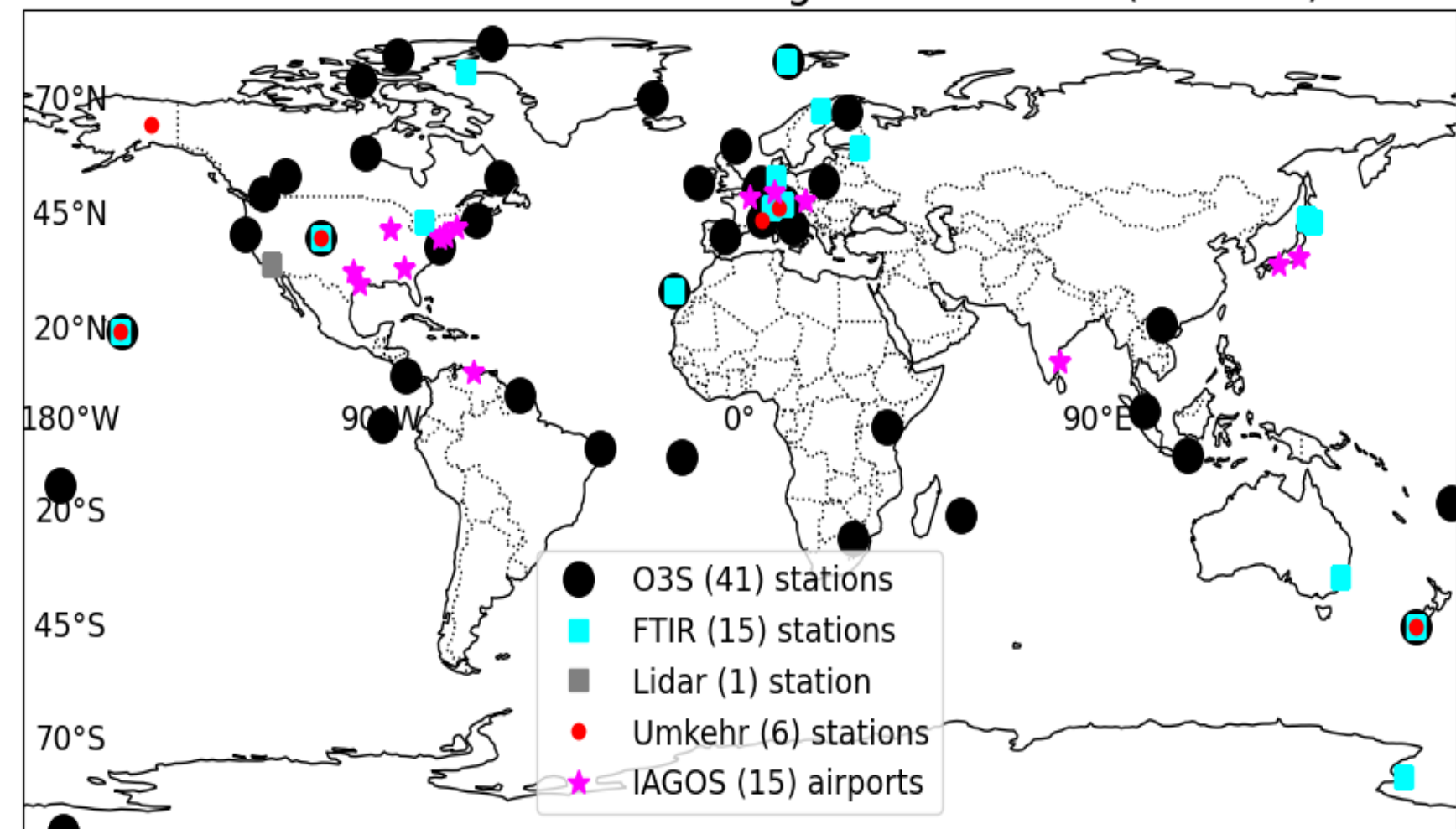


- Data at: <http://hegiftom.meteo.be/datasets>
- Trends determined for nominal:
  - 1) TrOC – Tropospheric column, Surface to 300 hPa
  - 2) FT – Free tropospheric column, 300 hPa < p < 700 hPa
- \*See 1450 Thursday Talk from R. Stauffer and poster from D. Kollonige (#B133)



**OZONE SITES - STATION STATISTICS USED IN ANALYSES**

Global Observation Sites Contributing to HEGIFTOM (L1 Data) Trends



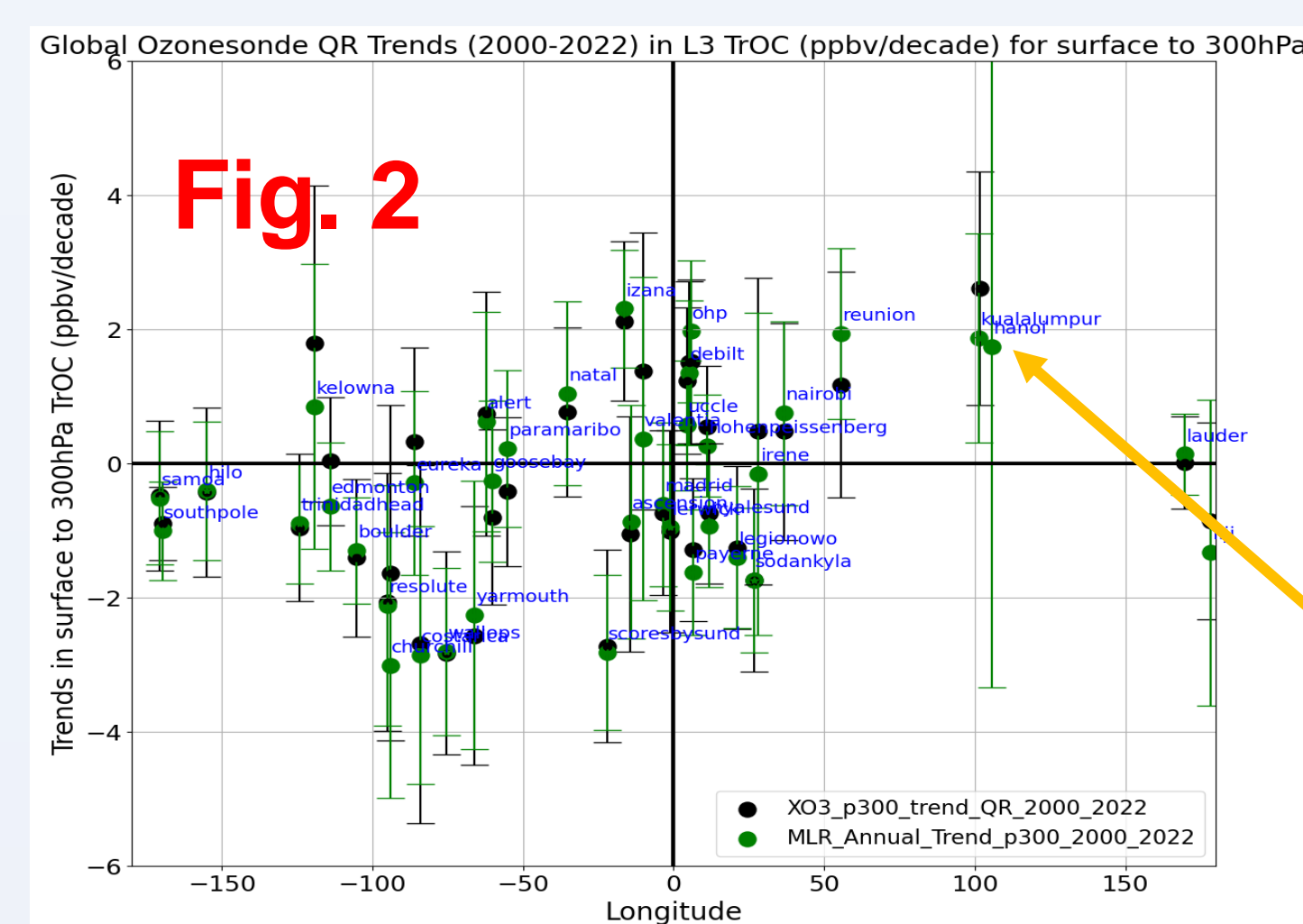
- L1 QR Data Trends (78):**
  - O3Sonde (41)
  - FTIR (15)
  - IAGOS (15)
  - Umkehr (6; Lidar (1))
- L3 QR Data Trends (68):**
  - O3Sonde (37)
  - FTIR (14): no Boulder
  - IAGOS (10)
  - Umkehr (6; Lidar (1))
- L3 MLR Data Trends (62):**
  - O3Sonde (38)
  - FTIR (14)
  - IAGOS (3)
  - Umkehr (6; Lidar (1))

**Fig. 1:** Stations, instruments color-coded, some with 2-3 types

**TREND QUESTIONS ANSWERED BY HEGIFTOM DATA**

1. How do TrOC (surface to 300 hPa) trends (2000-2022) compare computed with QR and MLR? *Answer with analysis of L3 (monthly mean) TrOC from ozonesondes - Figure 2*
2. How do TrOC trends vary by region? *Examine ozonesonde trends longitudinally & with Global Map Figures 3, 4*
3. How do FT (Free Tropospheric) and TrOC trends compare? Why do they differ? *Determine FT ozone trends (700-300 hPa column). Compare lower trop, FT, TrOC for sondes Figures 5, 6*
4. How do TrOC trends from sondes compare to those from other instruments (IAGOS, FTIR, Dobson Umkehr, Lidar)? *Compare trends at co-located stations Figures 7-9*

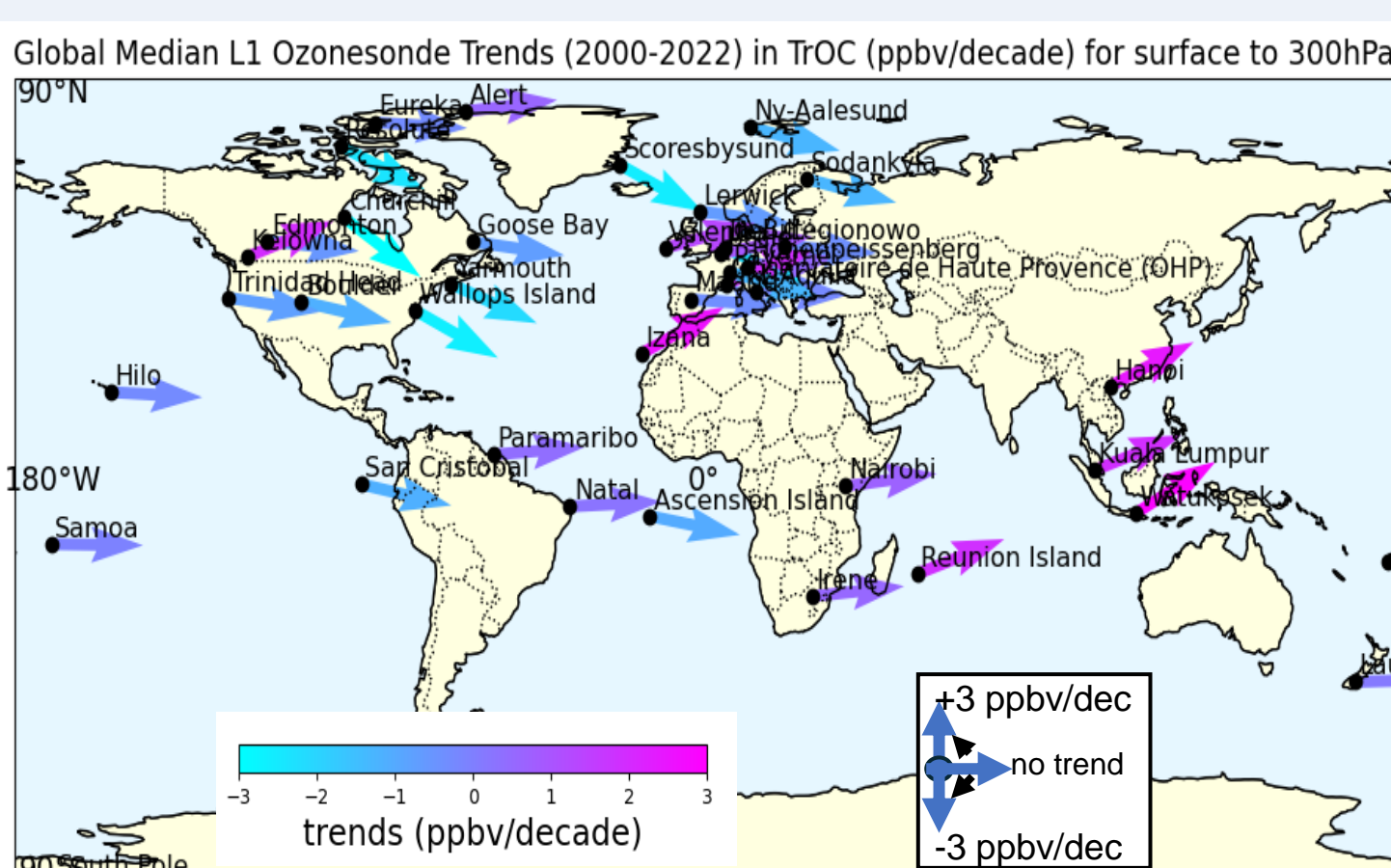
**QUES 1: OZONESONDE TRENDS WITH QR & MLR METHODS**



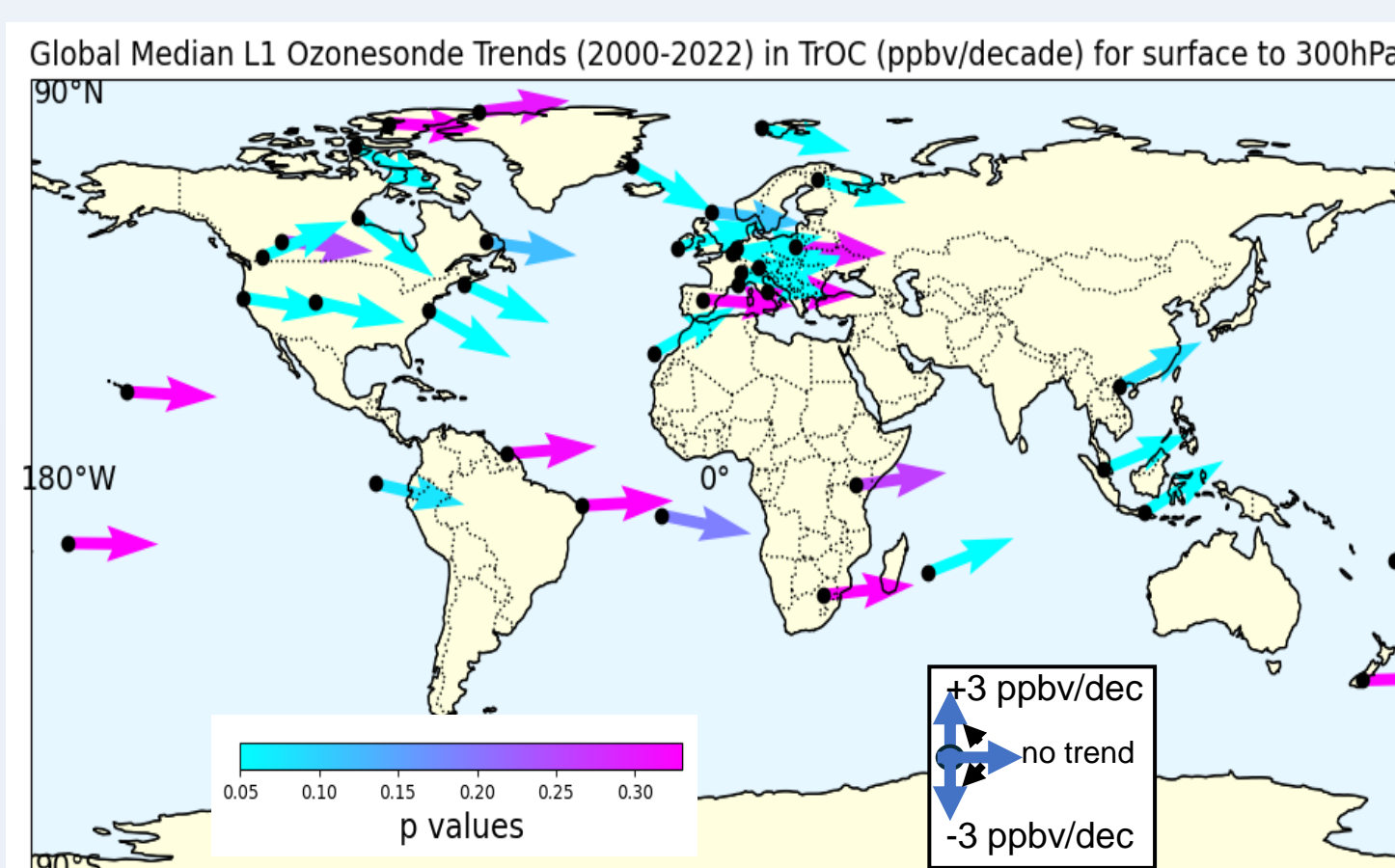
Tropics -> ± 1-2% /dec  
 SE Asia -> + 5-8% /dec  
 N. America -> ± 1-2% /dec  
 W. Europe -> ± 1-2% /dec

QR & MLR trends approx. the same. All areas except SE Asia (Kuala Lumpur, Hanoi) have similar numbers of sites with positive & negative trends

**QUES 2: TrOC TRENDS (QR), UNCERTAINTIES BY REGION**



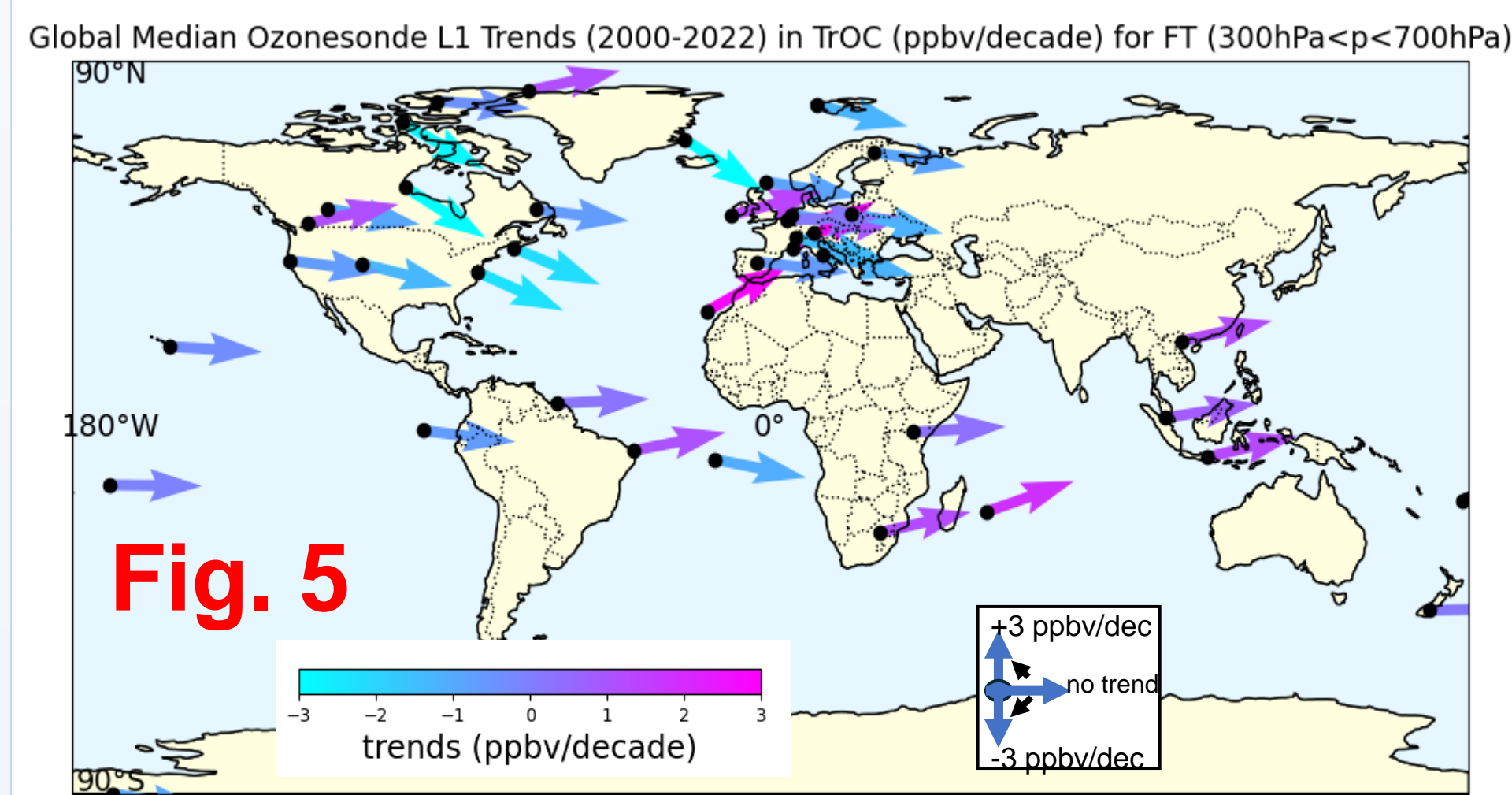
**Fig. 3**



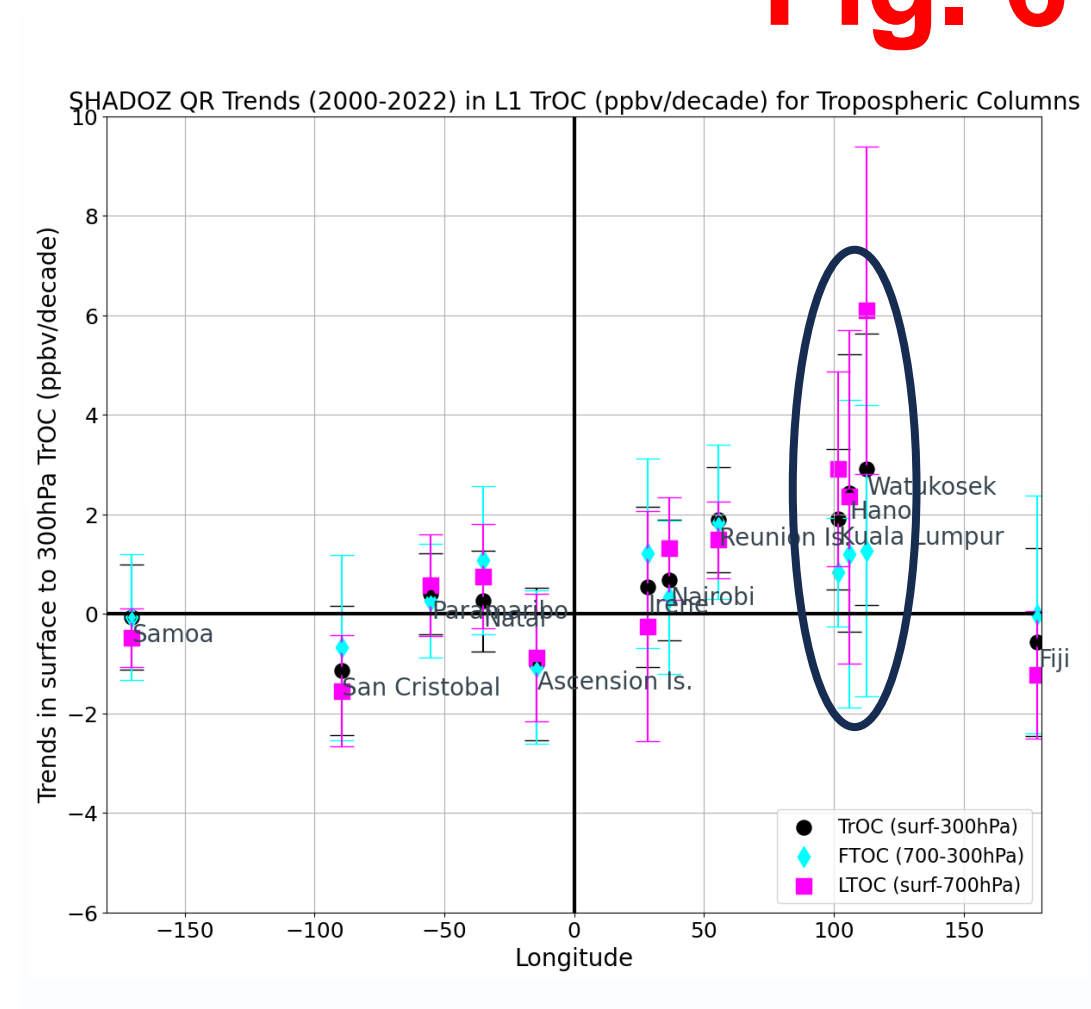
**Fig. 4**

**QUES 3: FTOC TRENDS (QR) FOR OZONESONDE PROFILES**

Recall that FT ozone is the important climate forcer. We determine FT trends with QR (50%-ile) for ozonesonde profiles between 300 and 700 hPa (Figure 5). Examples where FTOC trends are greater than TrOC (cf Figure 4) suggest most increases are from imported FT ozone. Where TrOC trends are larger, e.g., in tropical urban regions like Hanoi, Kuala Lumpur, trends in the LT (lowest troposphere) exceed those in FT and TrOC (Figure 6; details in Poster #B133).

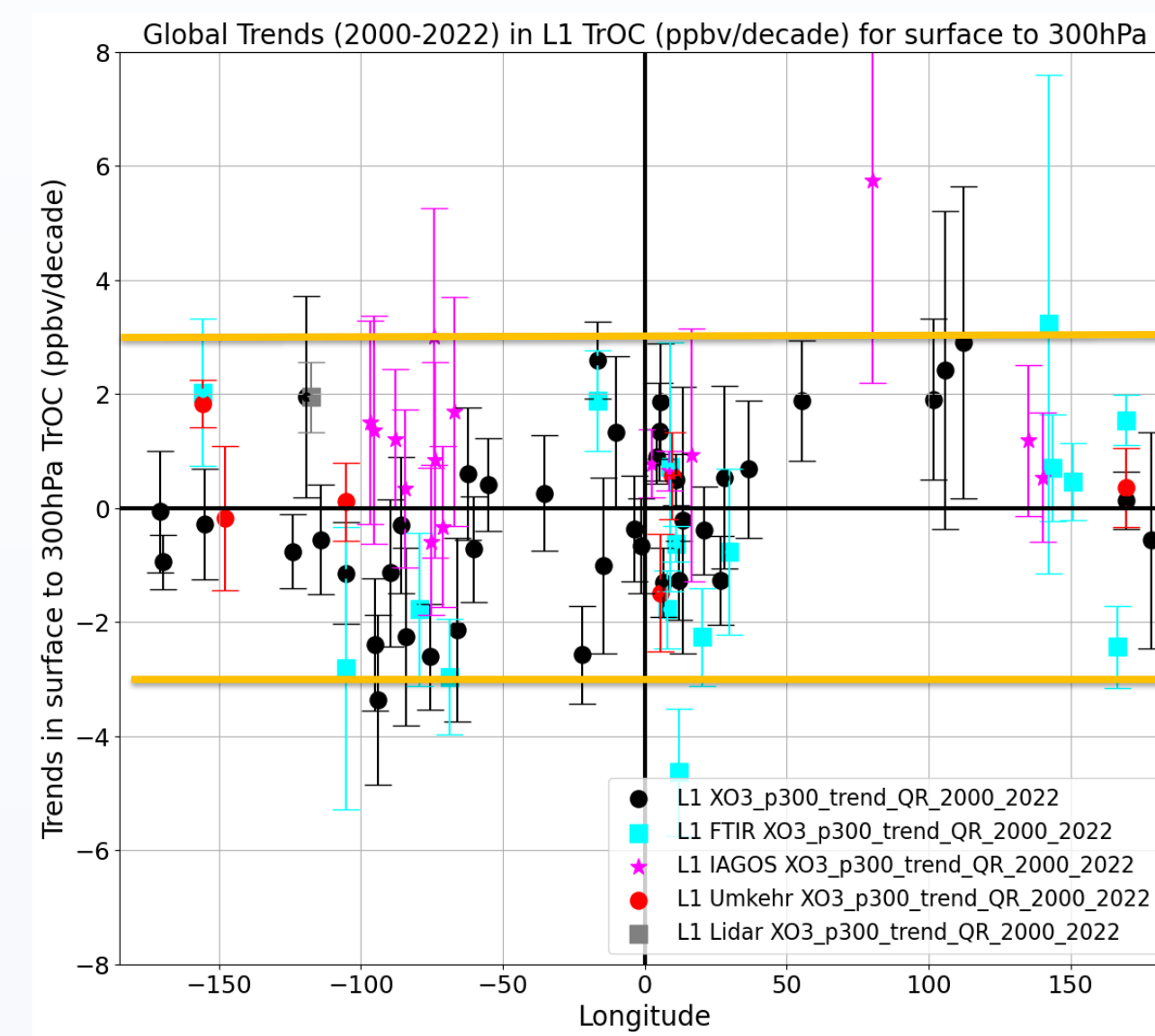


**Fig. 5**

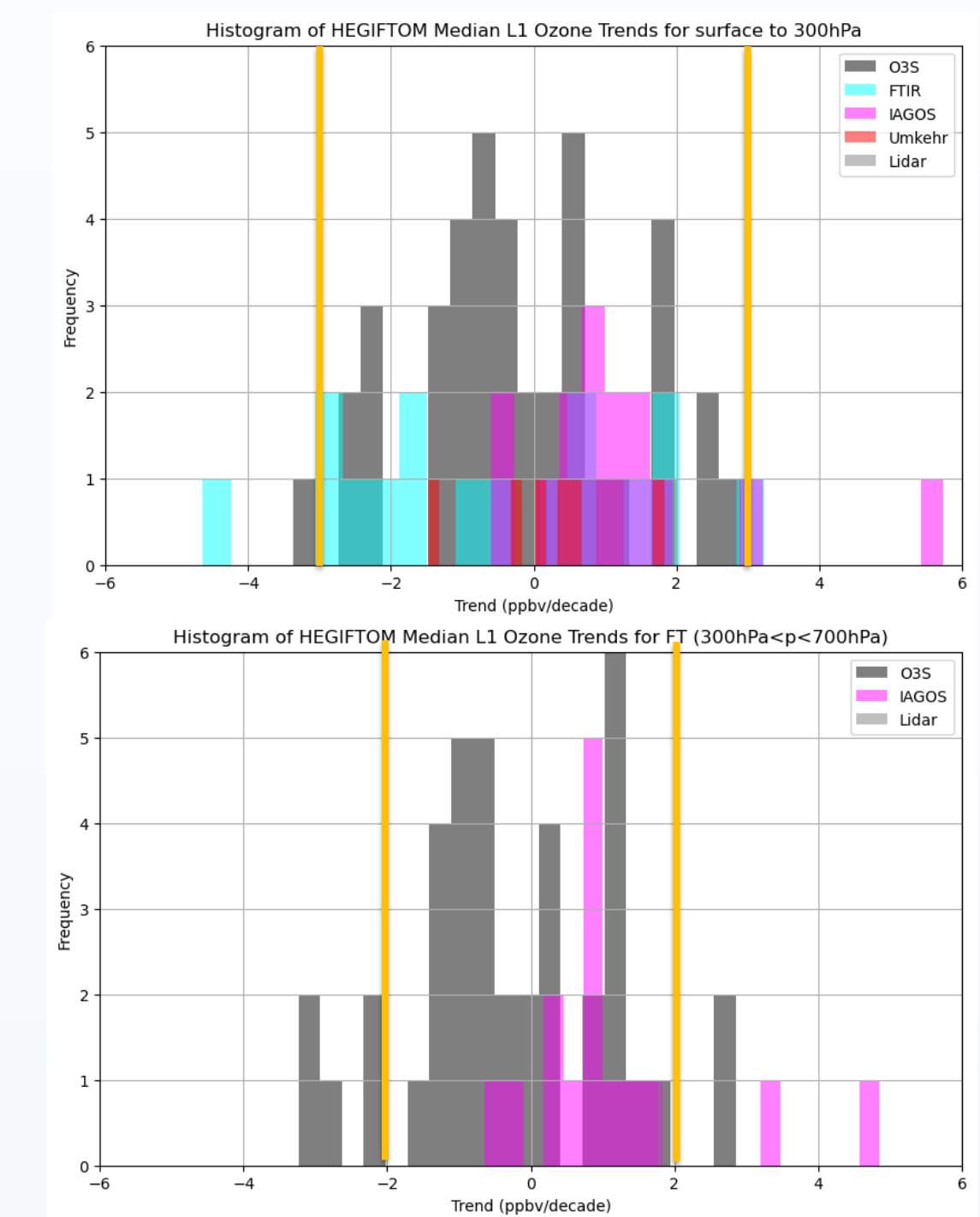


**Fig. 6**

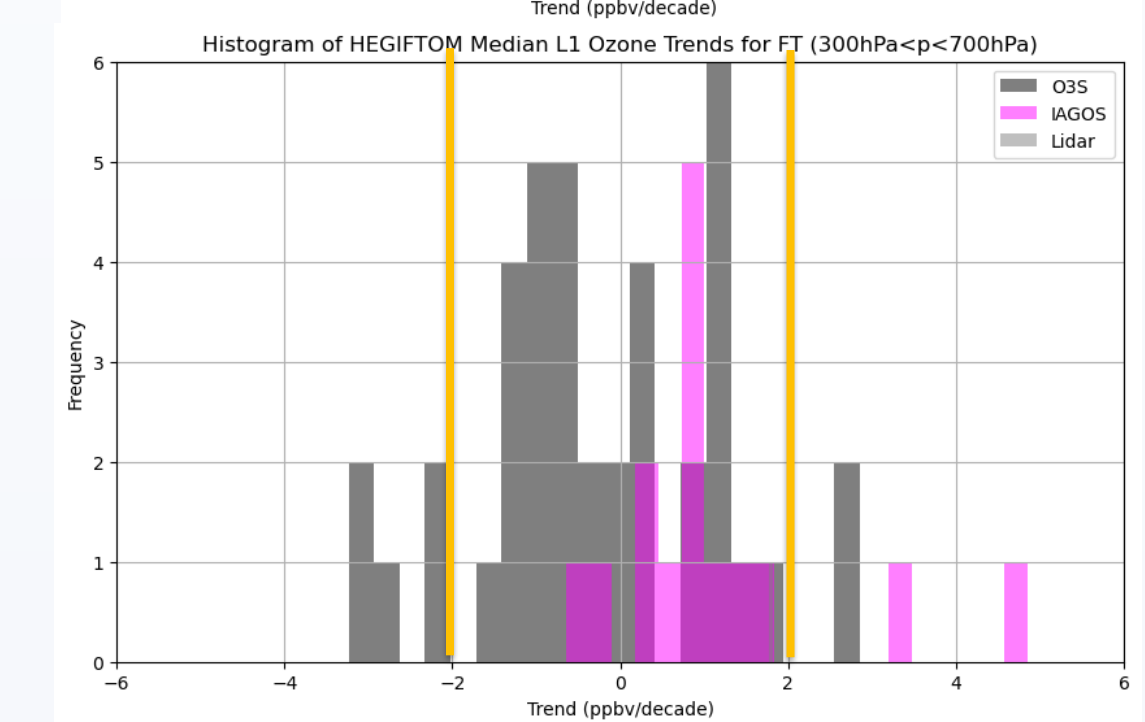
**QUES 4: TRENDS ACROSS ALL 5 HEGIFTOM INSTRUMENTS**



**Fig. 7**



**Fig. 8**



**Fig. 9**

Figure 7 shows that within uncertainty nearly TrOC trends from all instrument types fall within ± 3 ppbv ozone/decade. The TrOC trends histogram in Figure 8 indicates some bias in FTIR; a few IAGOS airports in urban regions have the largest increases. For FTOC, the corresponding trends are within ± 2 ppbv/decade (Figure 9). Note that there is no FTIR and Umkehr information for the FTOC.

**Summary: HEGIFTOM RESULTS FOR TOAR II**

- Ground-based data from 5 instrument types in the TOAR II/ HEGIFTOM database display relatively modest trends in a nominal tropospheric column (surface to 300 hPa).
- Nearly all TrOC trends fall within ± 3 ppbv O<sub>3</sub>/decade which corresponds to within ± (1-2) %/ decade except in SE Asia where trends in the lowest troposphere may exceed 5-8%/decade.
- The same trends for the FTOC (300 < p < 700 hPa) range fall within ± 2 ppbv O<sub>3</sub>/decade. These trends are largely independent of instrument type and the statistical trends method used.
- It is not possible to generalize these modest trends globally because freely available homogenized data are lacking for most of Asia and the southern hemisphere (Australia, Africa, So. America).
- **FOR TOAR II, HIGH-QUALITY HEGIFTOM DATA & TRENDS PROVIDE CONSTRAINTS FOR CHEMISTRY-CLIMATE MODELS AND EVOLVING TROPOSPHERIC OZONE SATELLITE PRODUCTS!**

**Relevant References, Acknowledgments**

Chang, K. L., et al. (2022). Impact of the COVID-19 economic downturn on tropospheric ozone trends: An uncertainty weighted data for quantifying regional anomalies Above western North America and Europe, *AGU Advances*, 3(2), <https://doi.org/10.1029/2021AV000542>.

Kollonige, D. E., et al. (2024). Southern Hemisphere Additional Ozonesondes (SHADOZ) 2024 Project Updates: Archive News and Tropospheric Ozone Data Trends. (poster #B133) ICACGP-IGAC2024 conference, Kuala Lumpur.

Stauffer, R. M., et al. Talk, 1450, 12 Sept, IGAC, Development of Trend-Quality Ozonesonde Profile Data through 30 Years of Laboratory and Field Experiments

Stauffer, R. M., et al. (2024) Dynamical drivers of free-tropospheric ozone increases over equatorial Southeast Asia, *Atmos. Chem. Phys.* <https://doi.org/10.5194/acp-24-5221-2024>.

Thompson, A. M., Stauffer, R. M., Wargan, K., Witte, J. C., Kollonige, D. E., & Ziemke, J. R. (2021). Regional and seasonal trends in tropical ozone from SHADOZ profiles: Reference for models and satellite products, *J. Geophys. Research: Atmospheres*, 126, <https://doi.org/10.1029/2021JD034691>

Van Malderen, R., Thompson, A. M., et al in prep, 2024.. Global ground-based tropospheric ozone measurements: Reference trends (2000-2022) from the TOAR-II/HEGIFTOM project, for *Atmos. Chem. Phys.*

**Acknowledgments:** Support for SHADOZ and our analyses: thanks to NASA (UACO, K. Jucks) & ISS/SAGE III (R. Eckman) and to the NOAA/GML Ozone & Water Vapor Group (G. Morris).