

Trends in Free Tropospheric Ozone from Homogenized Ground-based and Profile Datasets (1995-2020): The TOAR II/HEGIFTOM Project

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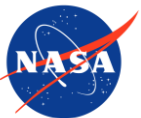
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Thompson & HEGIFTOM Team, AMS, 29-1-24



- **WHAT is IGAC/TOAR II?**
- **WHY Is HEGIFTOM (Harmonization and Evaluation of Ground-based Instruments for Free Tropospheric Ozone Measurements) so important in Ozone (TOAR II) & Climate Assessments?**
- **HEGIFTOM: WHAT, HOW, WHERE. Data Status.**
- **Preliminary Global ozonesonde FT column trends (4-8 km) for TOAR II by two statistical methods (QR and MLR)**
- *Summary: Trends to date (Sonde) for 1998-2021 show:*
 - *Zero-moderate changes globally, independent of statistical method*
 - *Mid-latitude trends include both FT O_3 losses & increases*
 - *In cases of FT O_3 increases, rates are typically higher in tropics than mid-latitudes*



WHAT IS IGAC/TOAR II?

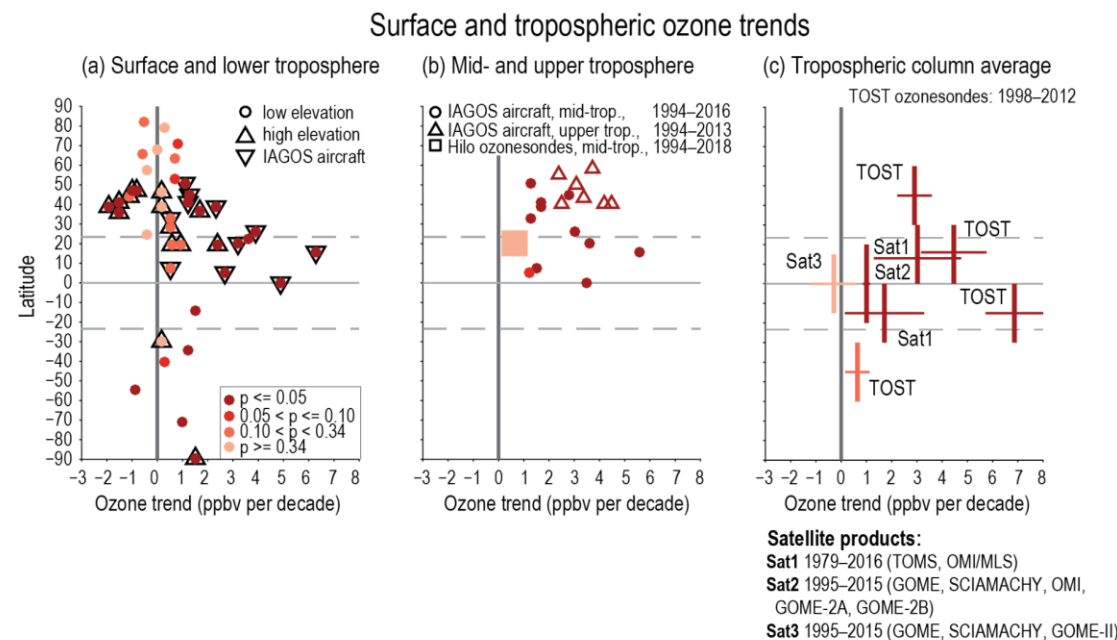


- Unlike more formal UNEP/WMO Ozone Assessments, based on a government-defined process, the TOAR (Tropospheric Ozone Assessment Report) began as a grass-roots volunteer activity in 2011 under the Intl Global Atmospheric Chemistry project (IGAC)
- The first TOAR (2012-2016) issued its "Report" as 6 papers in *Elementa*, 2017-2020. Topics included: Trends, uncertainties, vegetative impacts, health impacts
- TOAR II kicked off in 2021. Aims to deliver its Reports in late 2024/early 2025.
 - Reports based on papers in Copernicus journals completed by April 2024
 - Statistical approach and figure formats prescribed

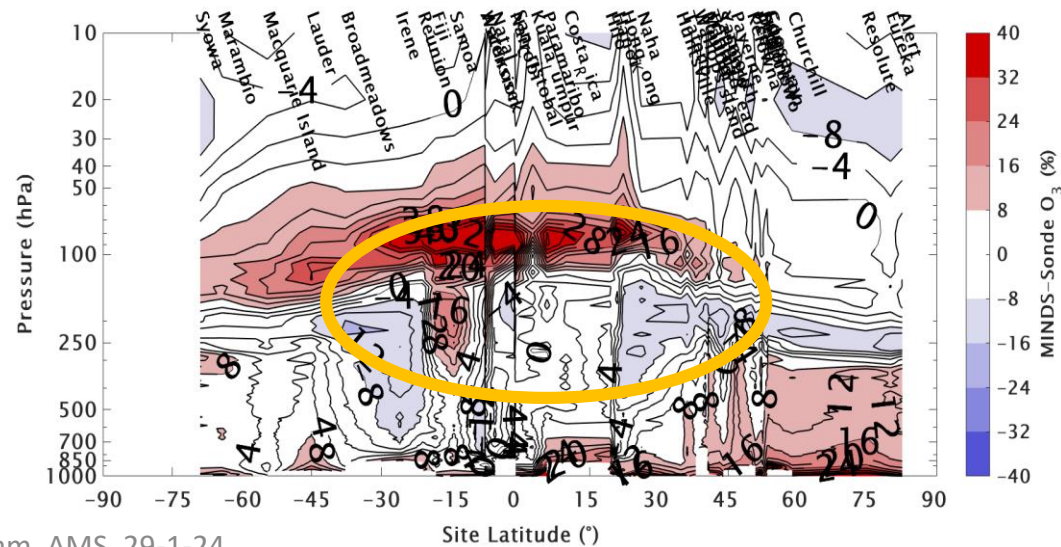
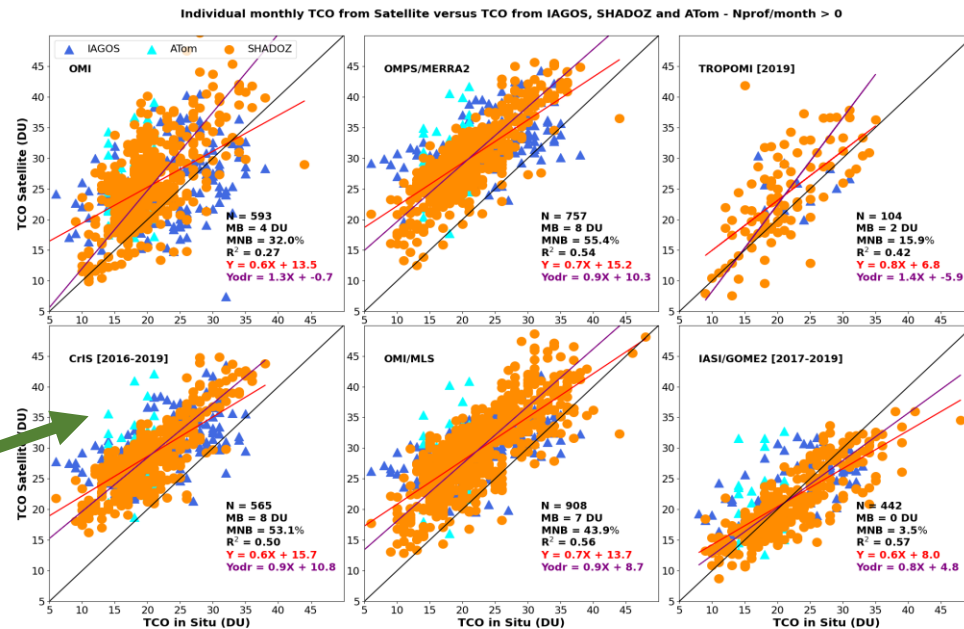
Tropospheric Ozone Assessment Report: Present-day distribution and trends of tropospheric ozone relevant to climate and global atmospheric chemistry model evaluation

Collections: [Knowledge Domain: Atmospheric Science](#), [Special Feature: Tropospheric Ozone Assessment Report \(TOAR\)](#)

A. Gaudel, O. R. Cooper, G. Ancellet, 53 others



- **Free Tropospheric (FT) O_3 is Radiative Forcer, amplifying impact of increasing methane emissions**
- **Satellite Tropospheric Column Ozone (TrOC) too limited in duration & quality for trends. Poor correlation, large offsets & uncertainty compared to tropical IAGOS & ATom aircraft profiles and to SHADOZ sondes (Upper from Gaudel et al., 2023)**
- **Typical model O_3 simulations relatively poor in FT: 10-20% discrepancy over range of latitudes, altitudes (gold in Lower, updated from Stauffer et al., 2019)**



HEGIFTOM: IGAC/TOAR II Activity, Co-Leads: R. Van Malderen & H. G. J. Smit

Alternative to still-evolving satellite TrOC (tropospheric ozone column) products:

- FT ozone from 5 ground-based instrument types, most from NDACC & related networks: **in-service aircraft [IAGOS], ozonesondes, FTIR, Brewer/Dobson Umkehr, Lidar (Photos, Right)**
- All instrument types have been used in HEGIFTOM. Reprocessed data based on rigorous protocols and absolute standards, thus ensuring harmonized time-series, with artifacts removed. Contributing networks
- Each measurement is delivered with uncertainty and a quality flag
- ***This Study: Preliminary Report on O_3 trends with FT TrOC, 4-8 km, extracted from ozonesondes***



IAGOS



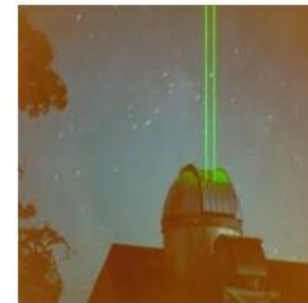
Ozonesondes



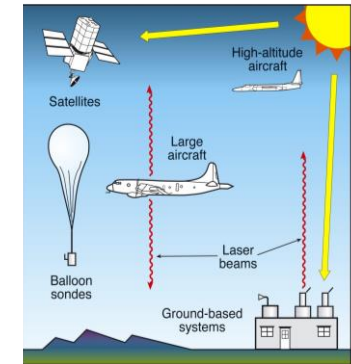
Brewer/Dobson Umkehr



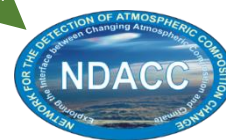
FTIR



Lidar



FT,
4-8 km



<http://hegiftom.meteo.be/datasets>

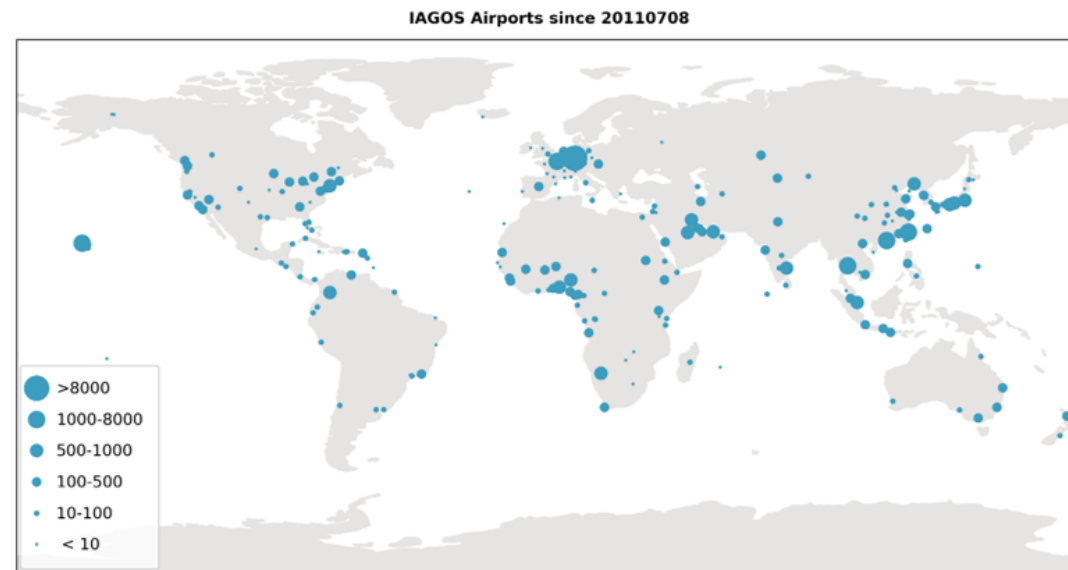
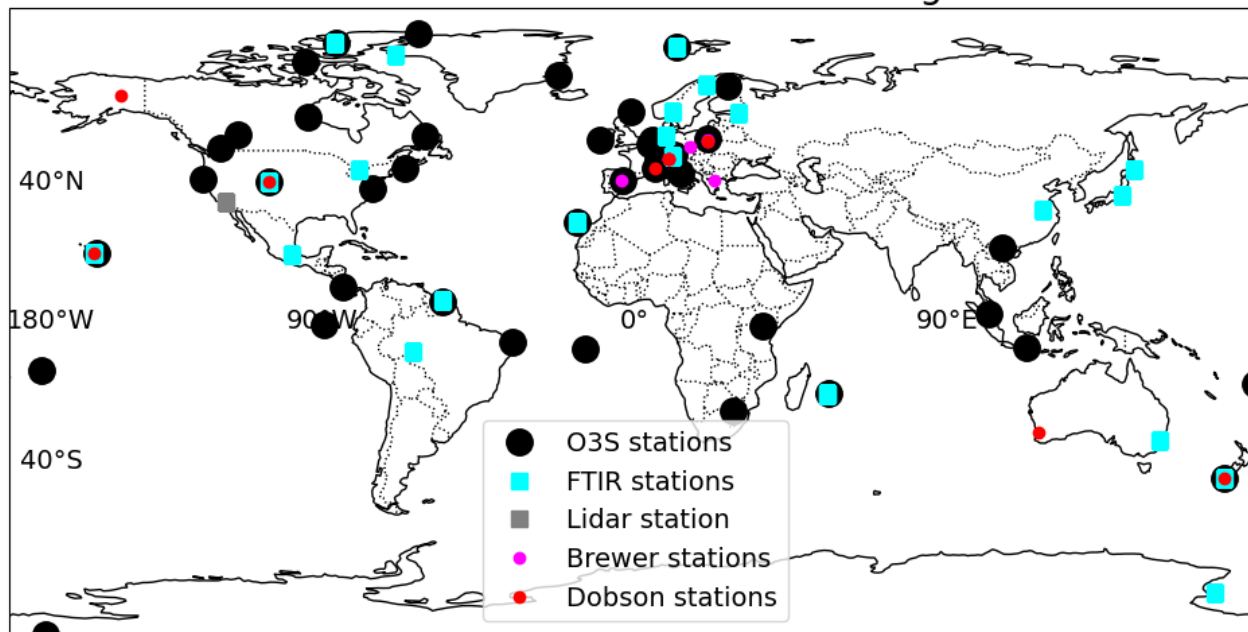




WHERE: HEGIFTOM Data from NDACC & Affiliated Networks (SHADOZ, WMO/GAW, IAGOS)



Global Observation Network Sites Contributing to HEGIFTOM

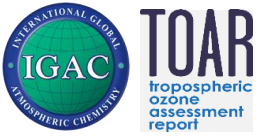


Credit: Left, D. Kollonige; Right, IAGOS

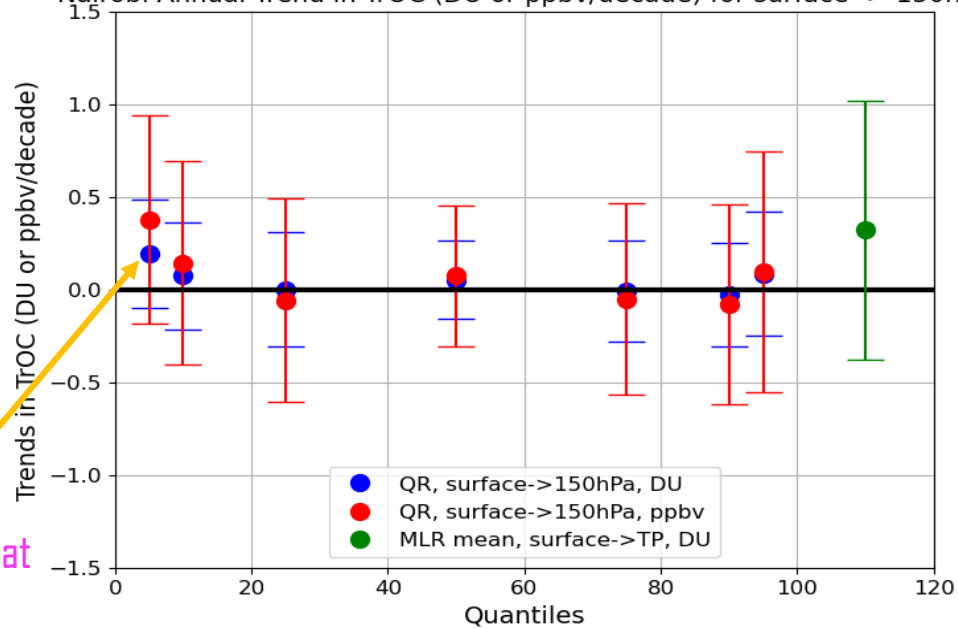
- Many FTIR stations (**Left**) coincide with ozonesondes, some have Dobson or Brewer: “super sites”. Trends consistency among multi-site instruments to be evaluated
- In tropics, sonde, IAGOS (**Right**) trends & satellite comparisons underway (Gaudel et al., submitted, 2023; [Kollonige et al., Poster #355 Tues, 30 Jan, 3 pm](#))
- Sonde-IAGOS co-located profiles evaluated (Tarasick et al., 2019; @ IAGOS Users, 11/23)



HEGIFTOM Trends. Input & Guidelines

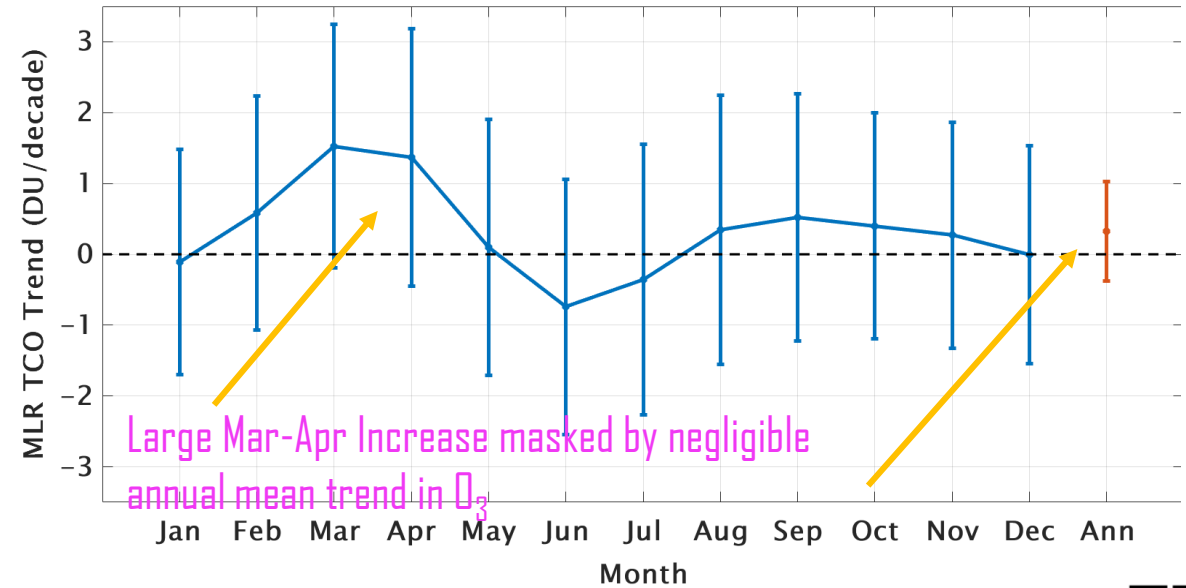


Nairobi Annual Trend in TrOC (DU or ppbv/decade) for surface -> 150hPa



Largest Increase at Low O_3

Nairobi Tropospheric Column MLR Trends (1998–2021)



Large Mar-Apr Increase masked by negligible annual mean trend in O_3

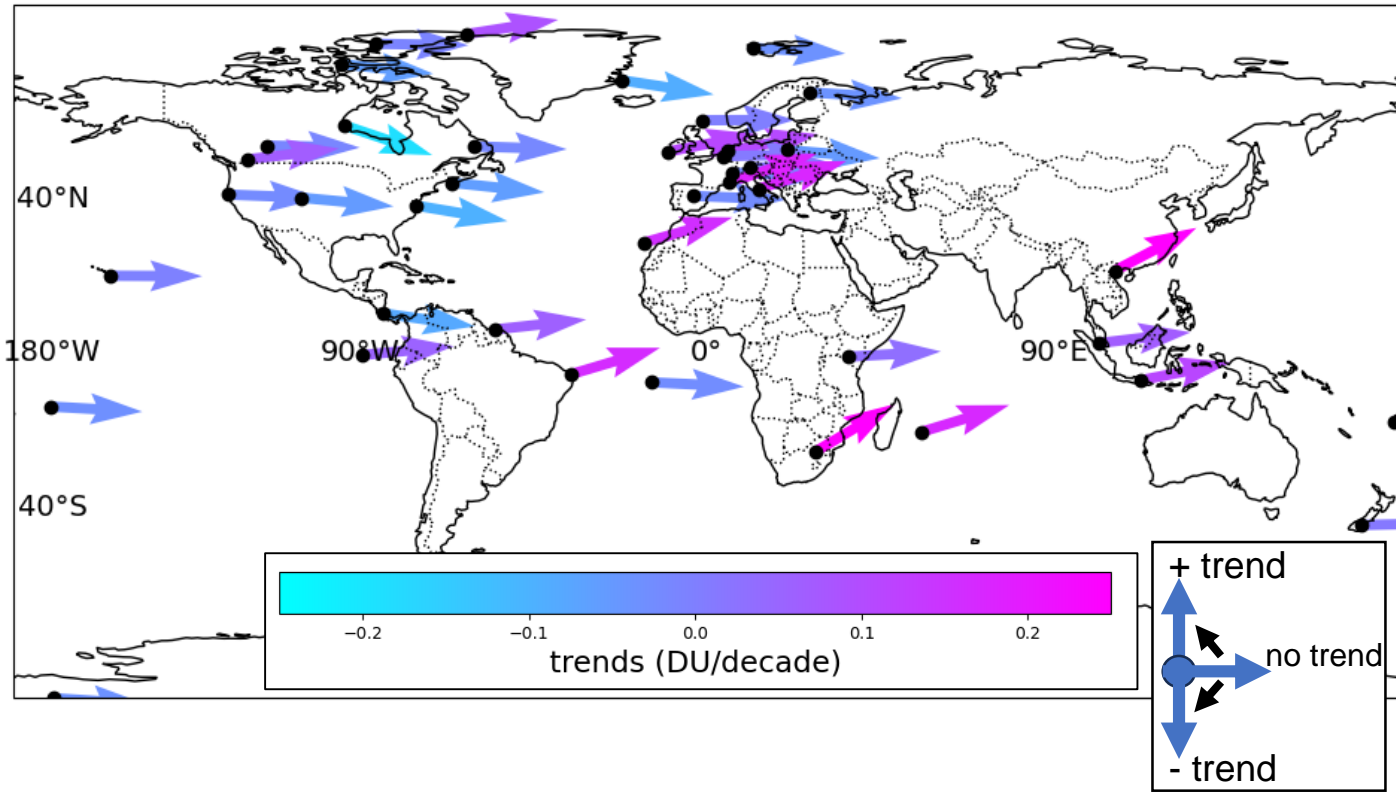
- Recommended TOAR II statistical approach is Quantile Regression (QR) with NOAA-provided test code, e.g., K-L Ch et al., (2023; JGR; 10.1029/2022JD038090)
- Multiple-Linear Regression (MLR), standard of Stratospheric O_3 community, used in Thompson et al. (2021) & Stauffer et al., ACP, 2023; [Poster #612 Wed, 31 Jan, 3 pm](#)
- Above example for a SHADOZ Nairobi station shows merits of each approach. QR gives insights into low-mid-ozone- O_3 profiles. Monthly means from MLR give insight into meteorological or chemical signatures responsible for O_3 trends



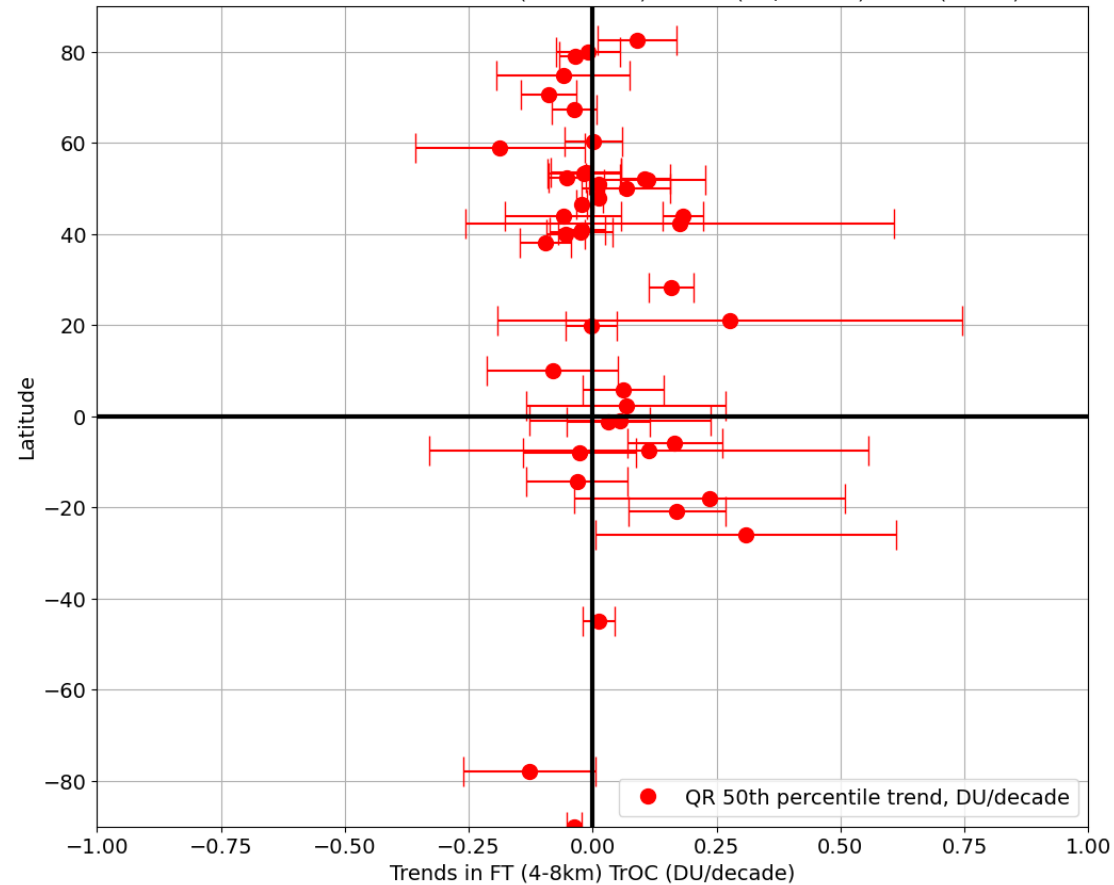
TREND RESULT 1. MEDIAN TRENDS WITH QR

- Sonde (black points), 50-%ile median profiles, analyzed with QR over 24 yrs, 1998-2021
- Mid-upper FT segment, 4-8 km, negative- \rightarrow no trend in blue colors on map.
- **Changes are < 0.50 DU/dec, positive OR negative, all latitudes**

Global Ozonesonde QR Median Trend (1998-2021) in TrOC (DU/decade) for FT (4-8km)



Global Ozonesonde Median Trend (1998-2021) in TrOC (DU/decade) for FT (4-8km)

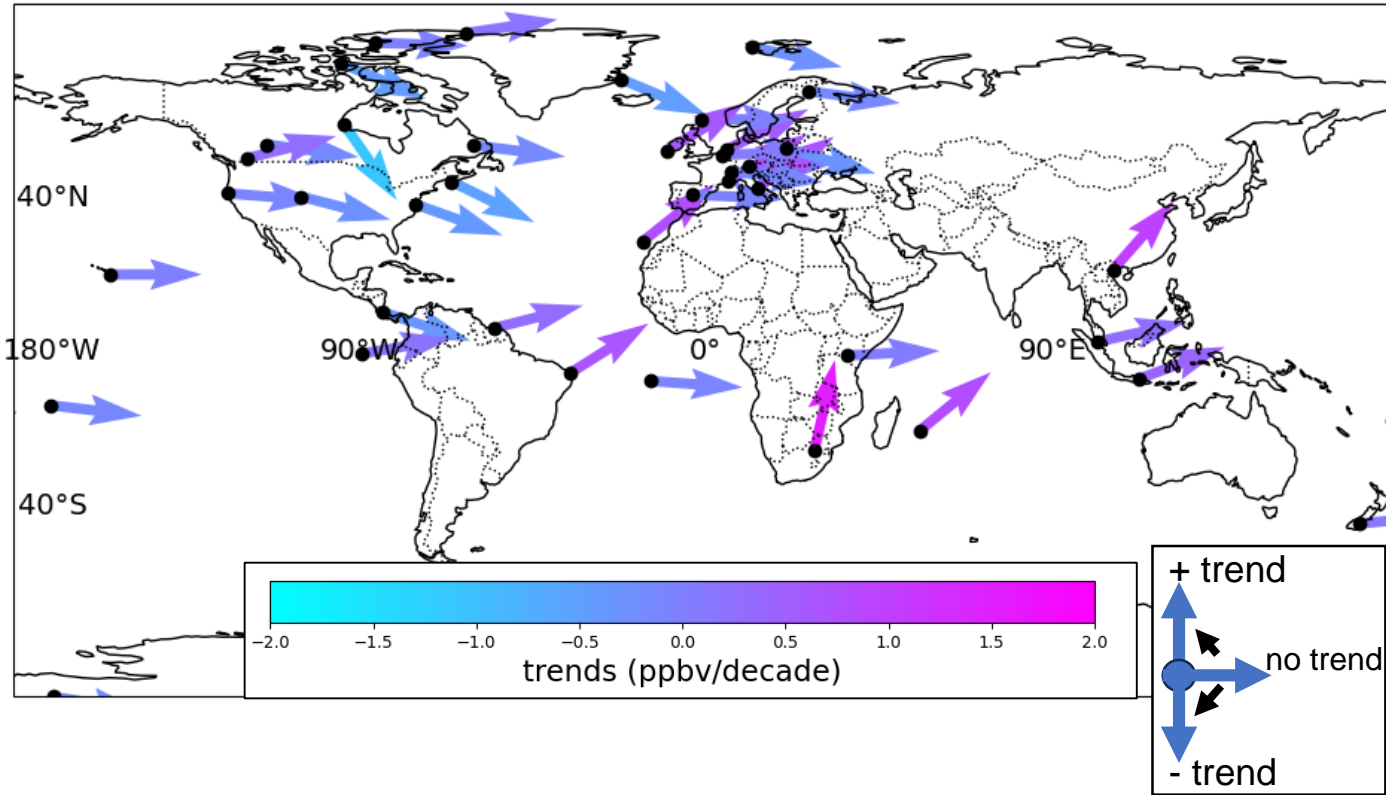


- 41 sonde sites (>70%) in HEGIFTOM database

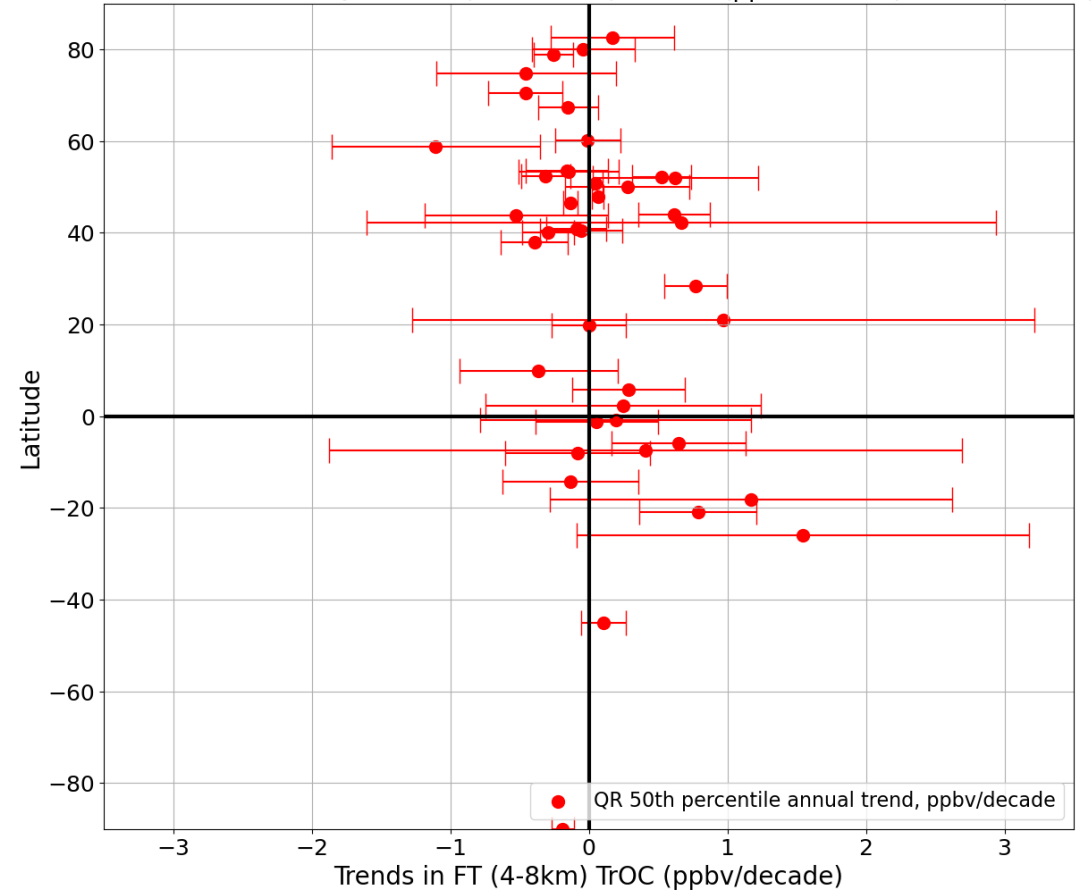
TREND RESULT 1. MEDIAN TRENDS WITH QR

- Sonde (black points), **50-%ile median** profiles, analyzed with QR over 24 yrs, 1998-2021
- Mid-upper FT segment, 4-8 km, negative- \rightarrow no trend in blue colors on map.
- **Changes are < 2 ppbv/dec, most < 1 ppbv/dec, positive QR negative, all latitudes**

Global Ozonesonde QR Median Trend (1998-2021) in TrOC (ppbv/decade) for FT (4-8km)

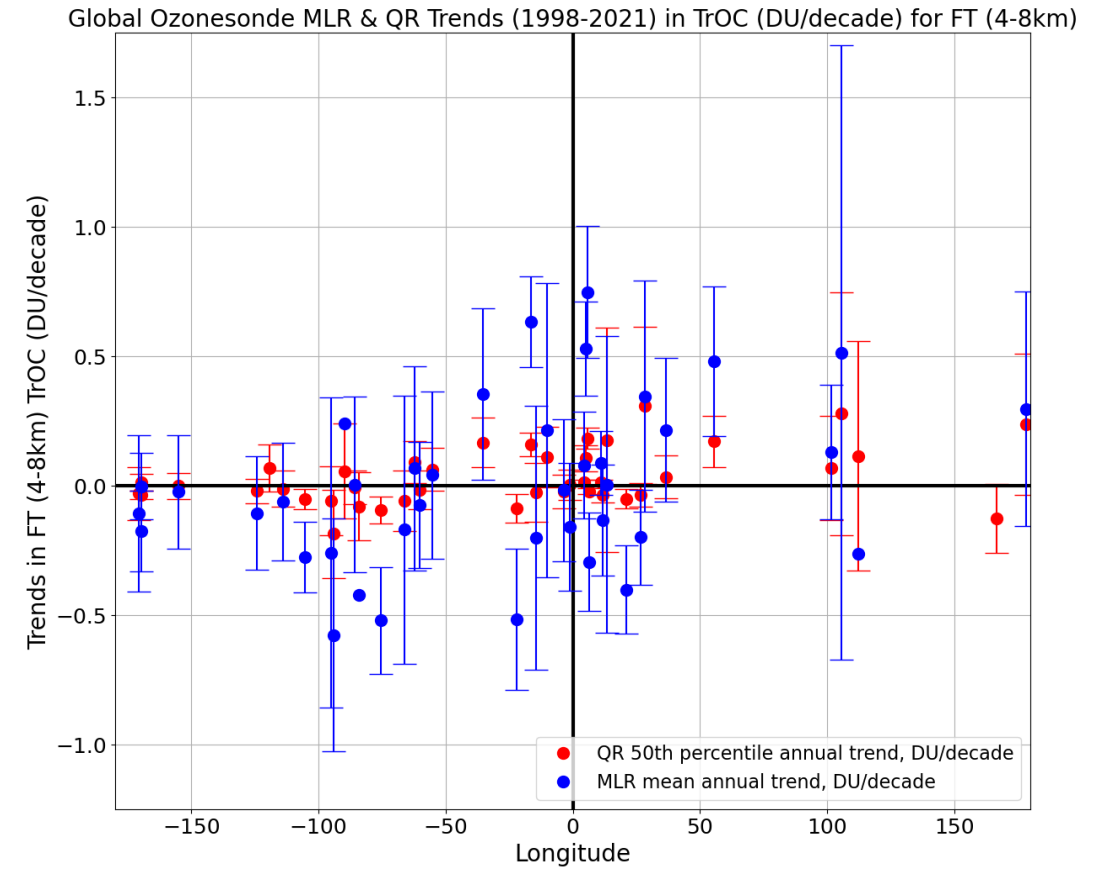
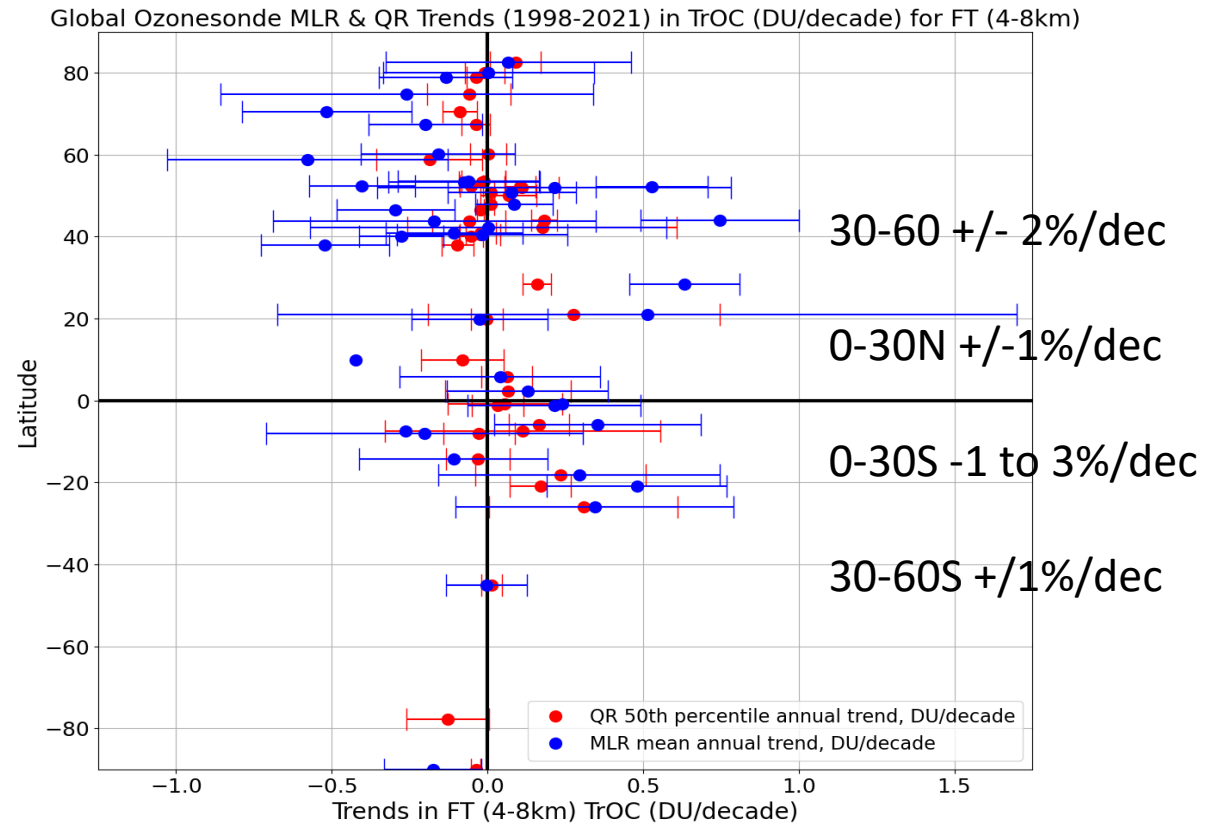


Global Ozonesonde QR Trends (1998-2021) in TrOC (ppbv/decade) for FT (4-8km)



- 41 sonde sites ($>70\%$) in HEGIFTOM database

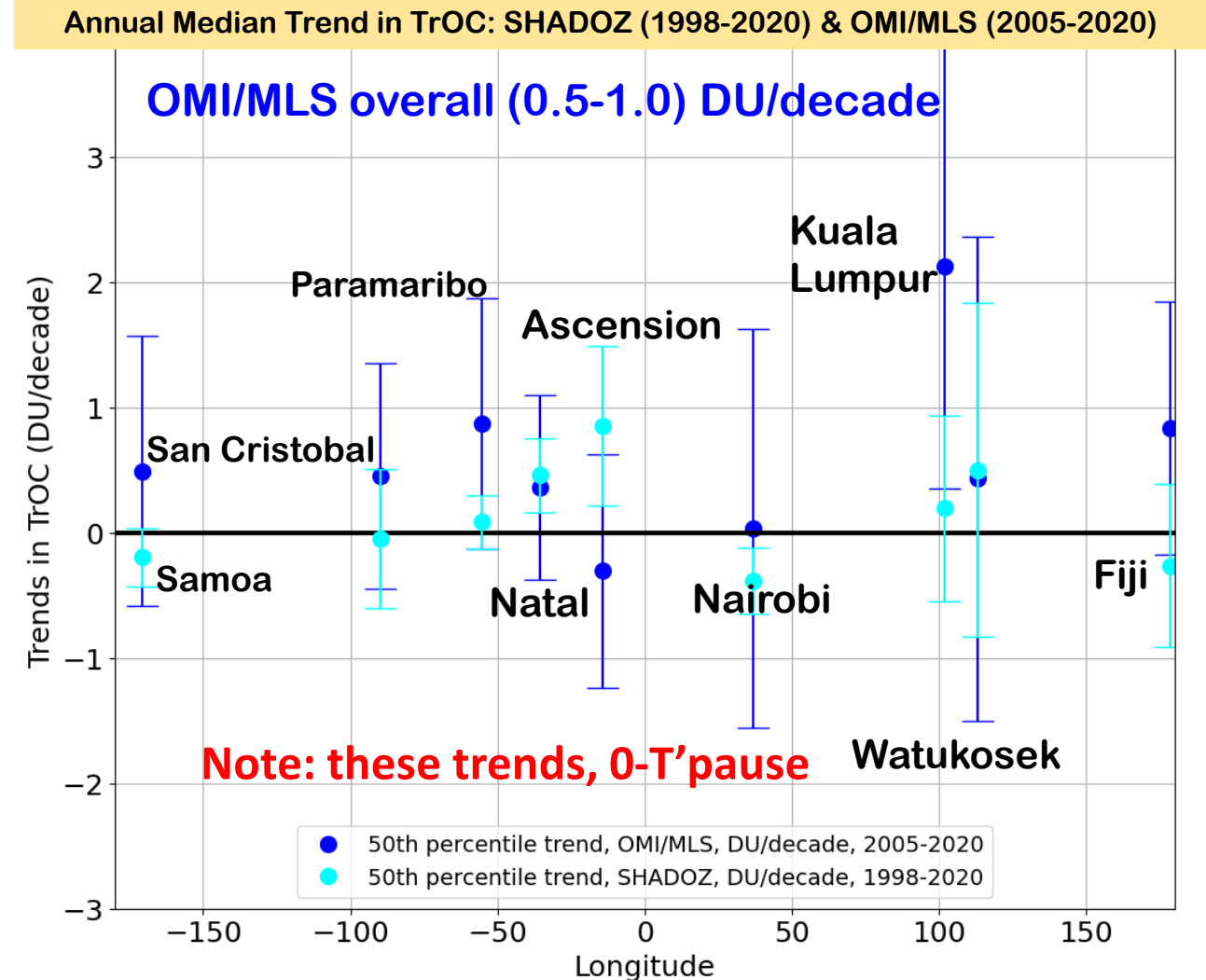
TREND RESULT 2. MLR & QR TRENDS SIMILAR



- **Preliminary results** show magnitude of trends with MLR is larger than QR for some stations. Work ongoing to be sure comparable trend values are being obtained from each method.
- Equivalent changes for FT amounts (~7-12 DU) range from **-2% to + 2%/dec (Left)**. Exceptions include Izana, Hanoi, OHP and several tropical sites. E. Pacific/Americas display smaller increases than over Europe/Africa or Asia/W. Pacific **(Right)**.

TREND RESULT 3. WAY FORWARD

- **HEGIFTOM data provide essential TOAR II reference to evaluate models, satellite products!** *Expect High Impact on TOAR II Report. Example Right: OMI/MLS Total TrOC trend compared to HEGIFTOM (SHADOZ) trends*
- **SUMMARY.** Results with 4-8 km FT O_3 :
 - > Mostly small trends, both positive and negative, over all latitudes, regions. Tropical increases typically larger than at mid-latitudes
 - > Trend direction similar using QR and MLR, but MLR magnitude is larger
- **Next steps** for TrOC:
 - > Compute trends from other 4-8 km HEGIFTOM segments, e.g. FTIR
 - > Determine trends for other O_3 columns, e.g. surface to 300 hPa



Thank you! Acknowledgments. Bibliography

- **Acknowledgments: Dozens of funding organizations. Hundreds of researchers who have operated and collected ozone ground-based data over the past 30 years!**

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