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

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Outline

- **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***

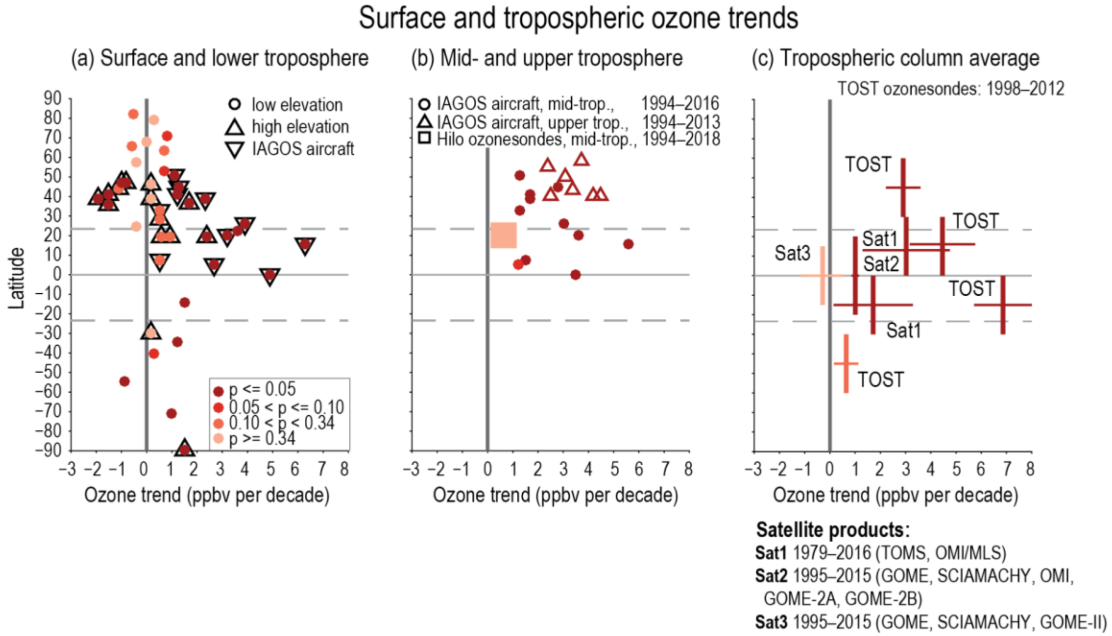
WHAT IS IGAC/TOAR II?

- **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

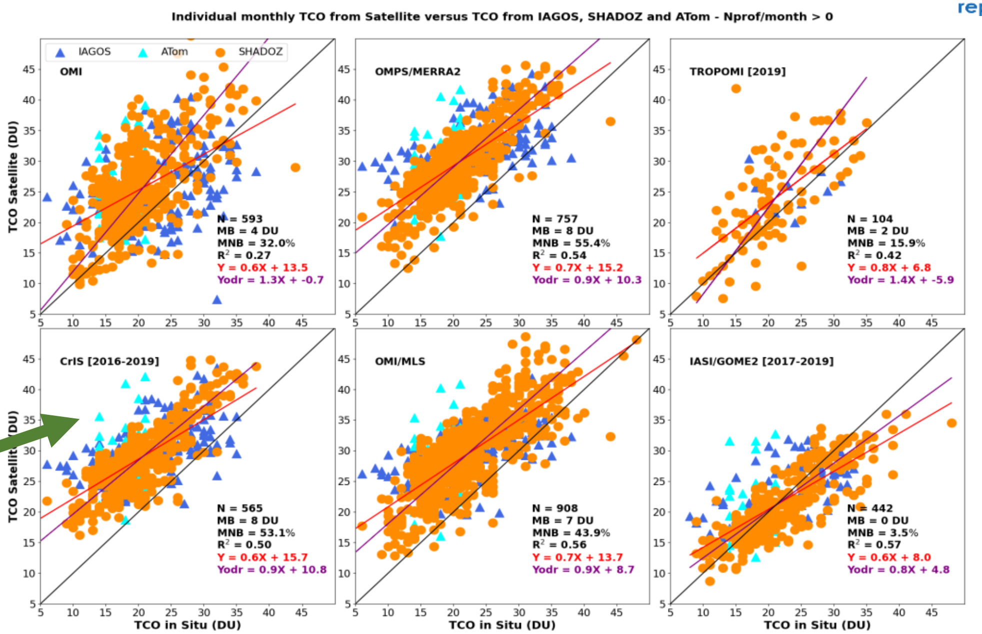


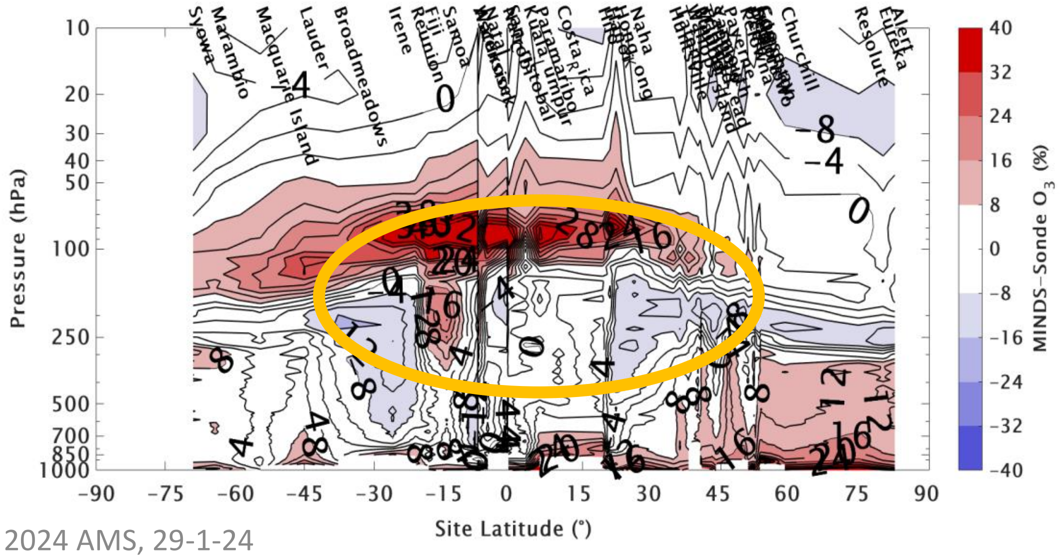
WHY HEGIFTOM?

- 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)





WHAT & HOW: HEGIFTOM Data to the Rescue!

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***

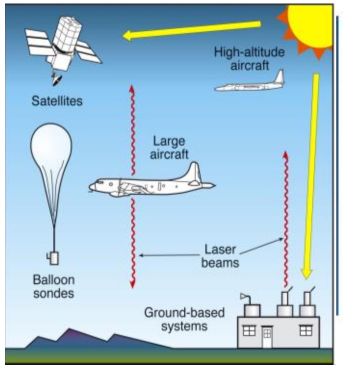
IAGOS


Ozonesondes


Brewer/Dobson Umkehr


FTIR


Lidar

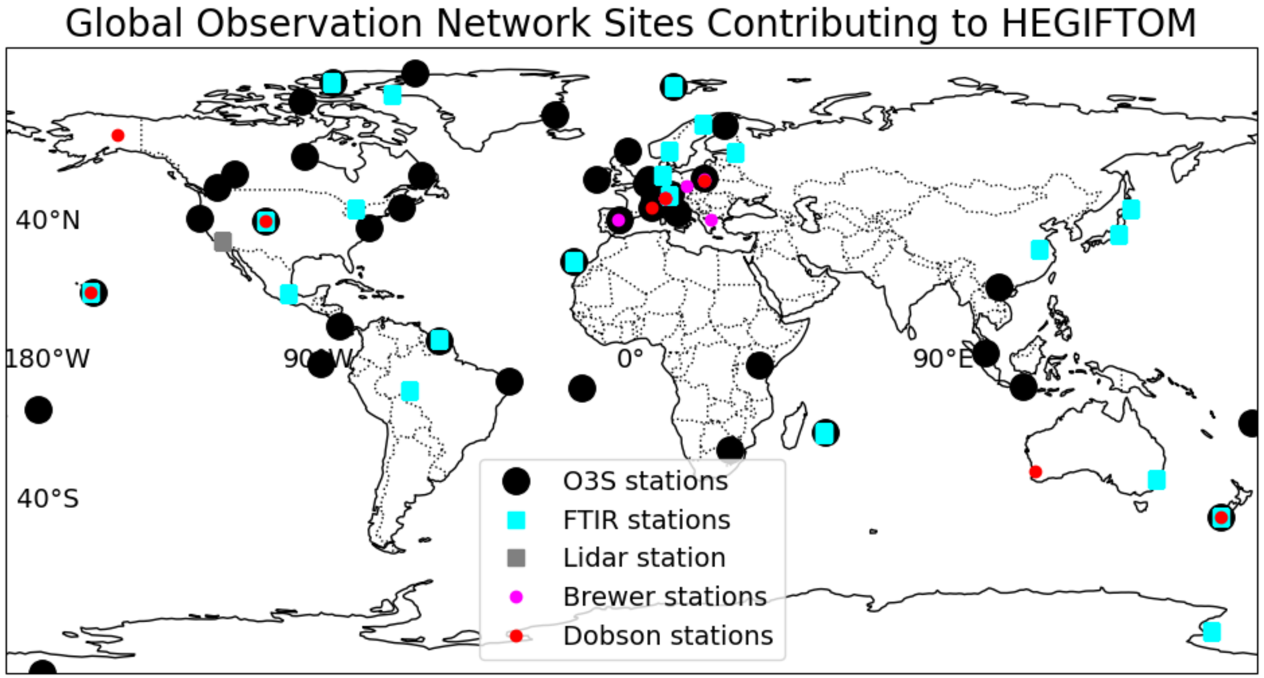


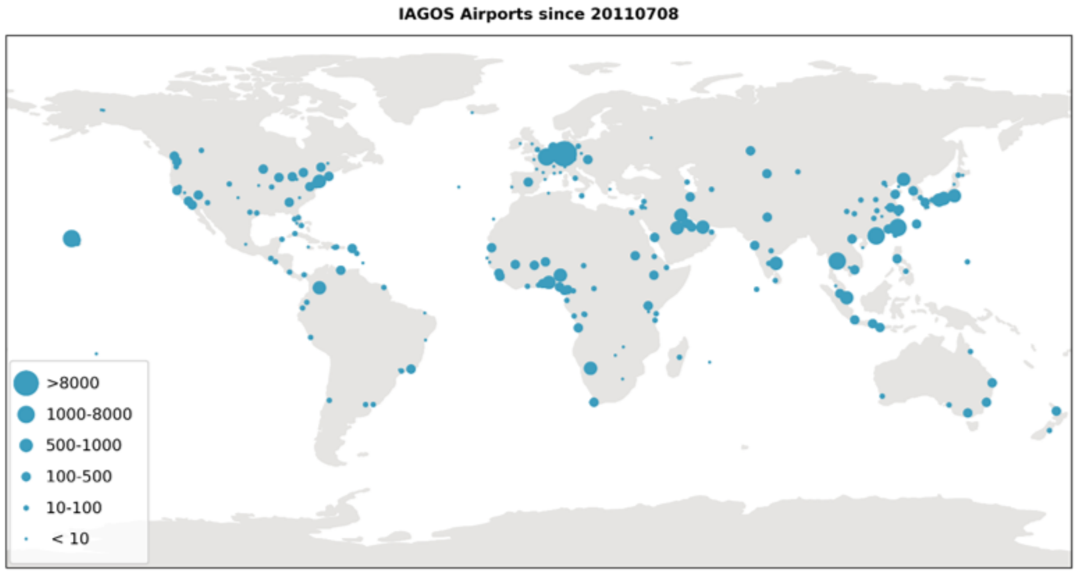
FT, 4-8 km

NDACC GAW SHADOZ

http://hegiftom.meteo.be/datasets

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



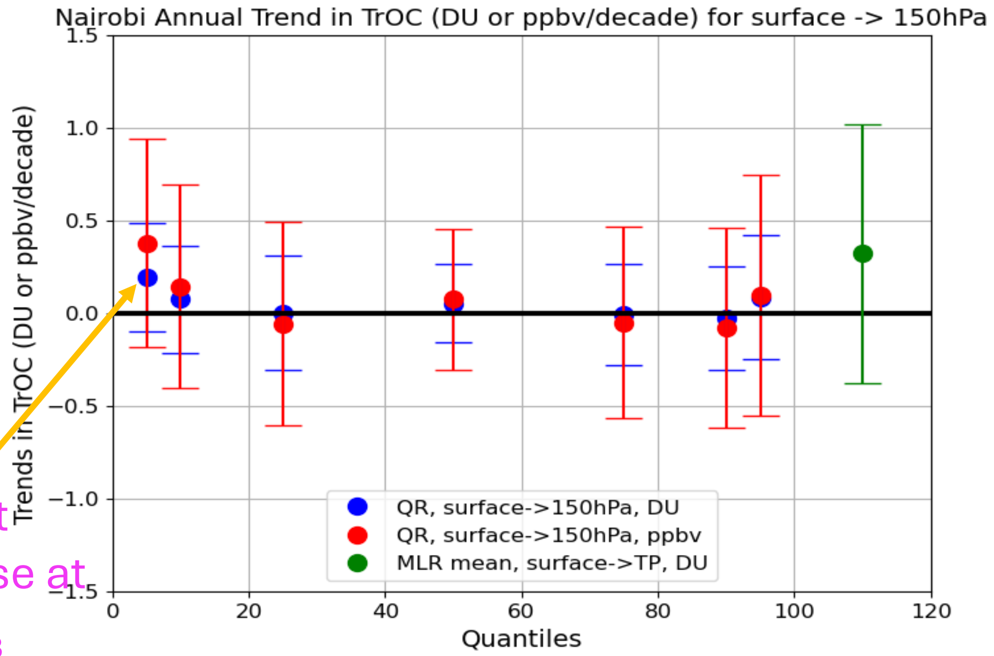


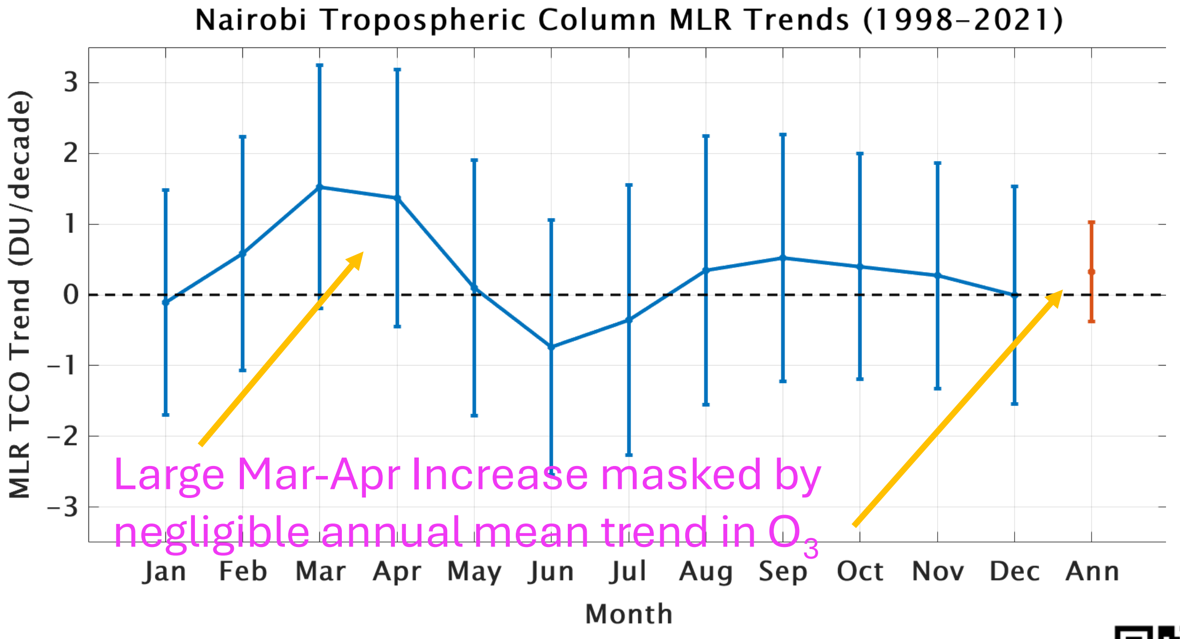
Credit: Left, D. Kollonige; Right, IAGOS

- **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

Largest Increase at Low O_3



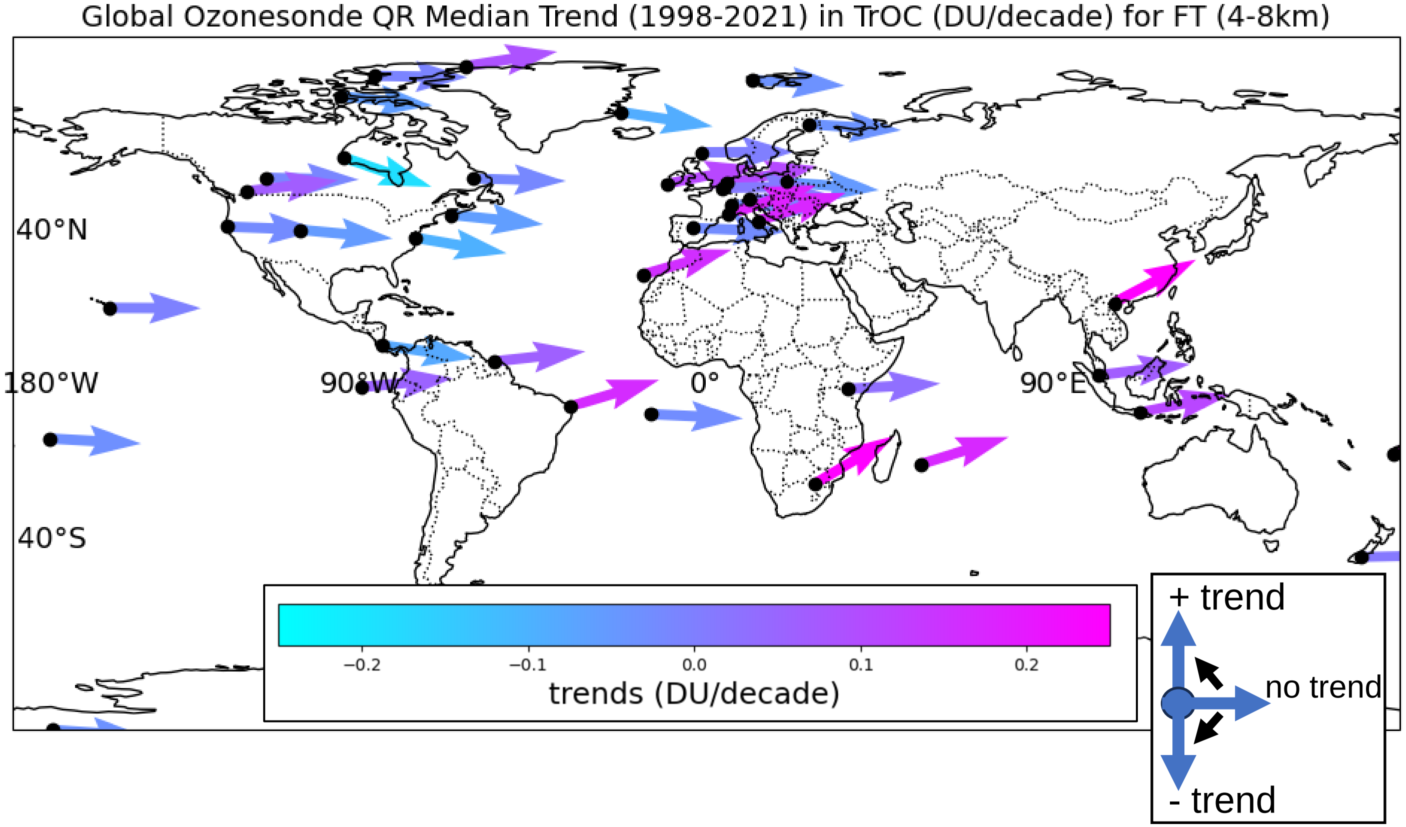


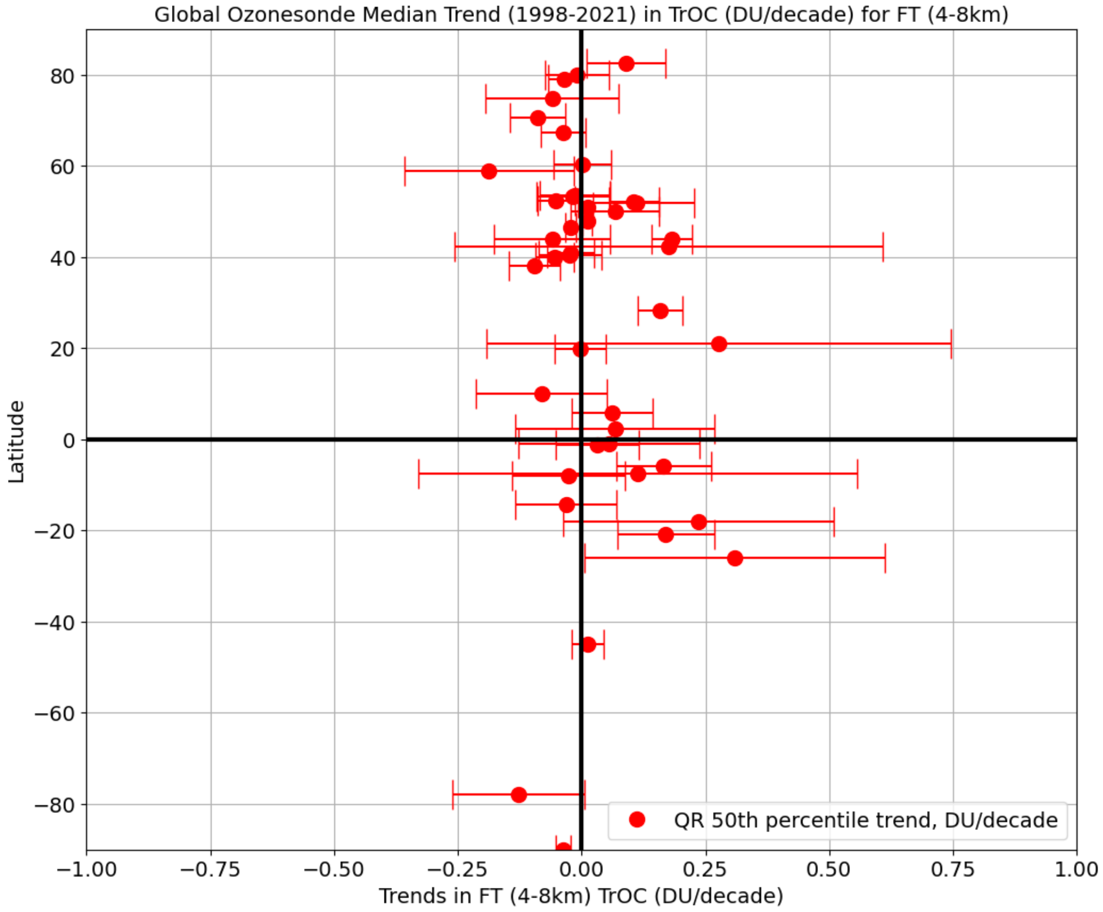
Large Mar-Apr Increase masked by negligible annual mean trend in O_3

- **Recommended TOAR II statistical approach is Quantile Regression (QR) with NOAA-provided test code, e.g., K-L Chang et al., (2023; JGR; 10.1029/2022JD038090)**
- **Alternative: Multiple-Linear Regression (MLR) as used in Thompson et al., 2021 & Stauffer et al., ACP, in review. MLR is standard of stratospheric ozone Assessment community**
- **Above example for a typical SHADOZ 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-> no trend in blue colors on map.
- **Changes are < 0.50 DU/dec, positive OR negative, *all latitudes***

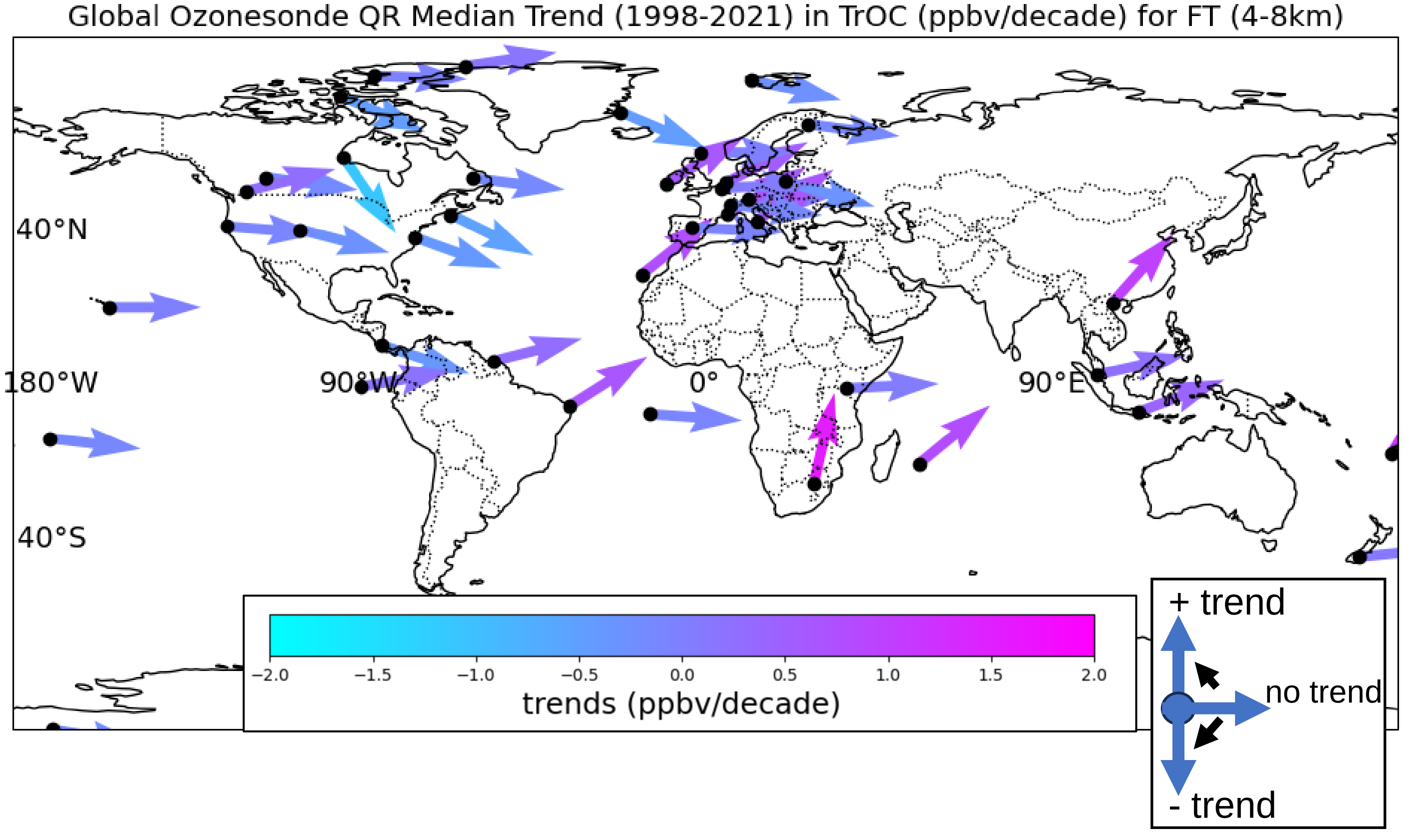


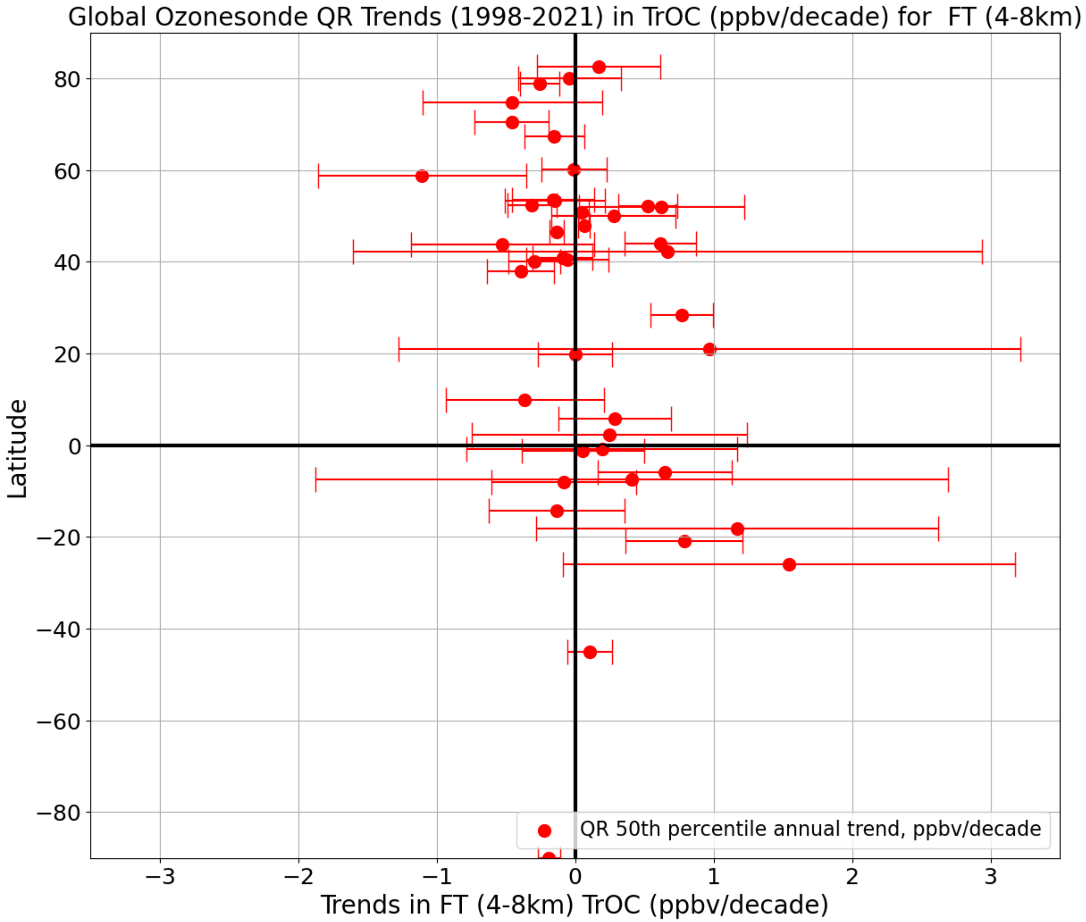


- 41 sonde sites (>70%) in HEGIFTOM database

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-> no trend in blue colors on map.
- **Changes are < 2 ppbv/dec, positive OR negative, *all latitudes***





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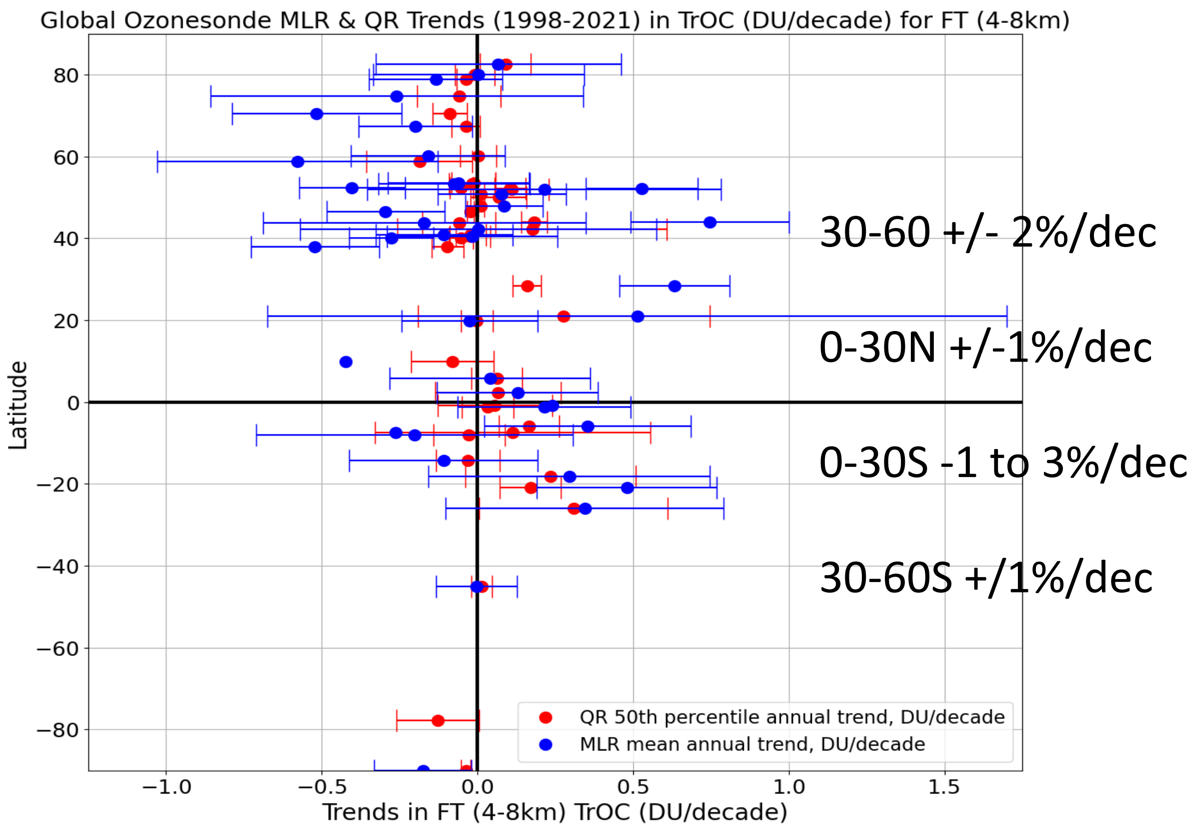
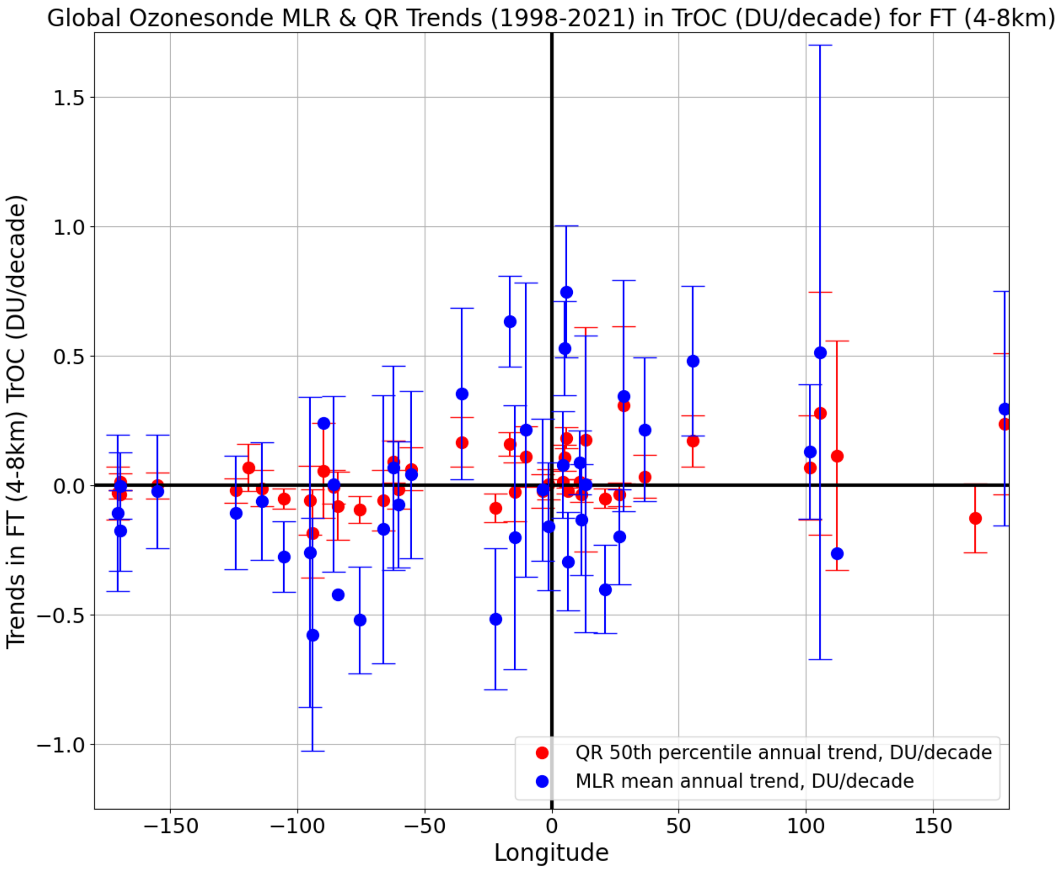
TREND RESULT 2. MLR & QR TRENDS SIMILAR





- **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 - Right!***
- Preliminary results with sonde-based 4-8 km FT O_3 columns show:

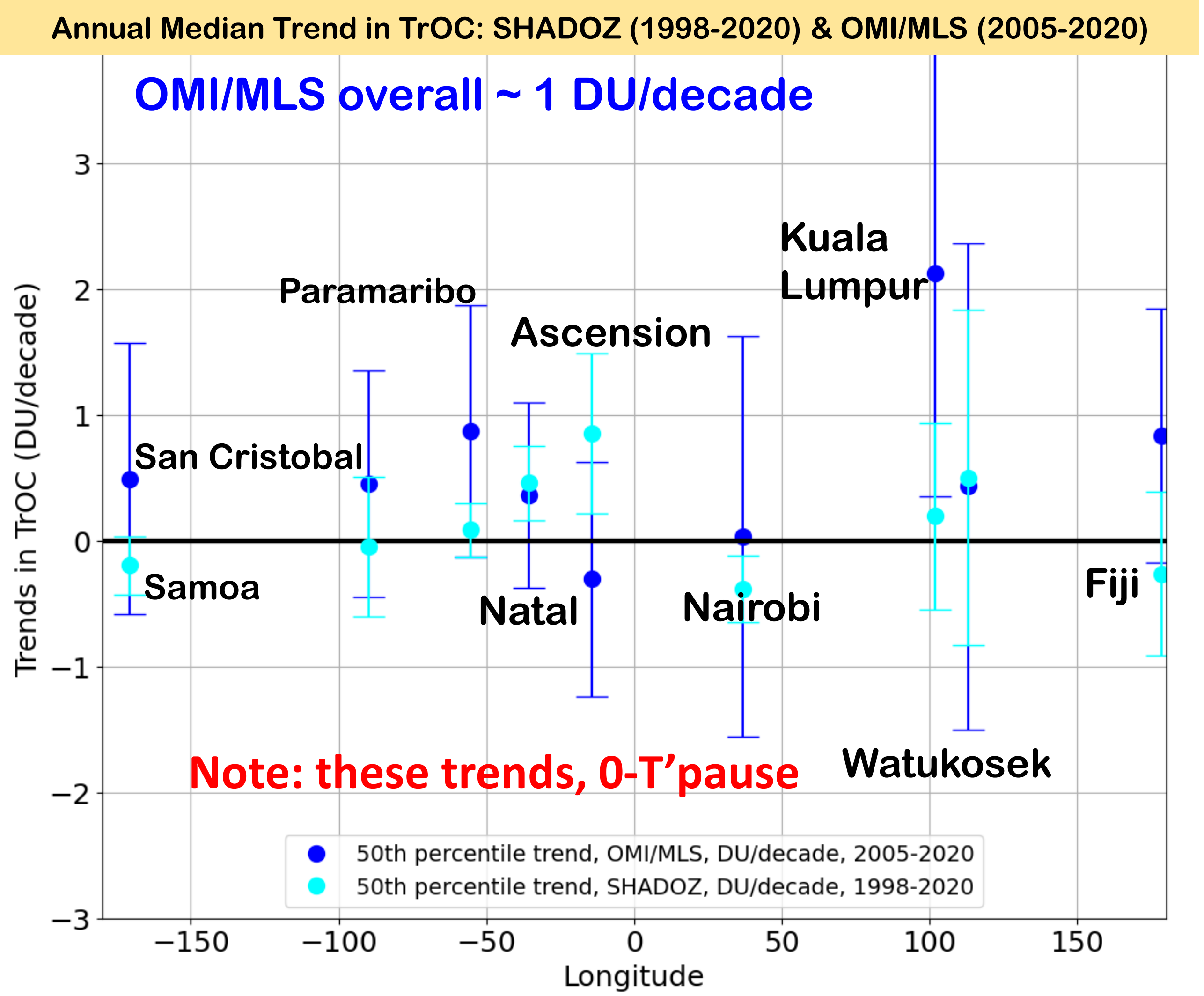
  -> Mostly small trends, both positive and negative, over all latitudes, regions

  -> Tropical increases tend to be larger than at mid-latitudes

  -> Trend direction similar using QR and MLR, but MLR magnitude is larger
- **Next steps** for TrOC:

  -> Continue using HEGIFTOM to evaluate models, satellite trends, ie beyond tropics.

  -> Compute trends from other HEGIFTOM data (e.g. FTIR), various column segments, 5 and 95 quantiles (50% shown here)



Kollonige et al. Poster #355

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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