Tropospheric ozone column trends from homogenized ground-based profile ozone datasets from the TOAR-II HEGIFTOM Focus Working Group

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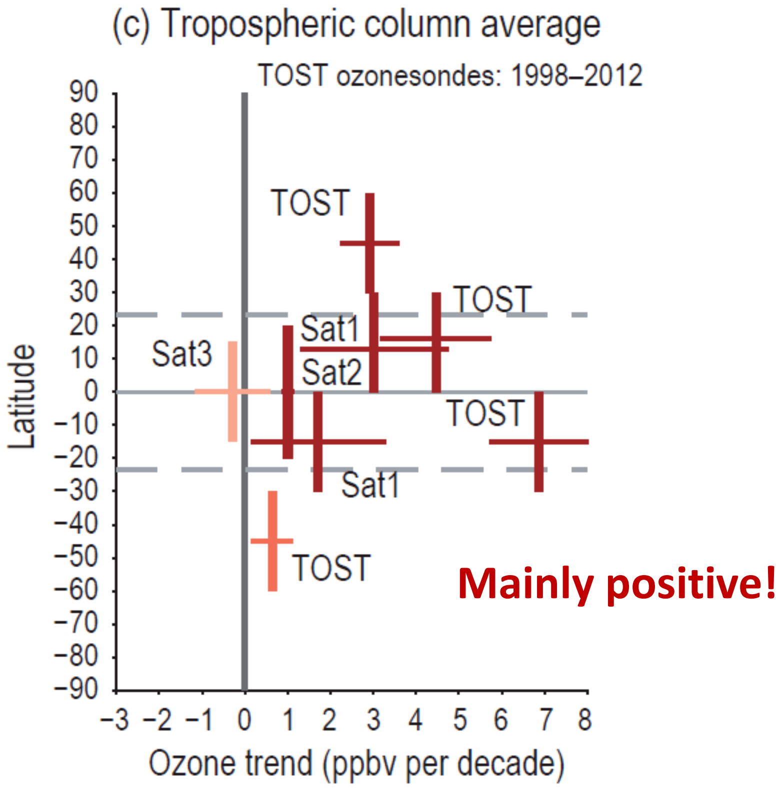
http://hegiftom.meteo.be/

Motivation

- TOAR-II: tropospheric ozone **trends** assessment
- In literature:

Fig. 2.8 of
IPCC AR6, 2021.



Satellite products:
Sat1 1979–2016 (TOMS, OMI/MLS)
Sat2 1995–2015 (GOME, SCIAMACHY, OMI, GOME-2A, GOME-2B)
Sat3 1995–2015 (GOME, SCIAMACHY, GOME-II)

✓ **Here**: focus on high-quality **ground-based** and **in-situ** measurements (individual sites + “merged”)

✓ Consistency in tropospheric ozone column metric (**here**: surface to 300 hPa)

✓ Consistency in used trend estimation tools (QR vs. MLR)

✓ Consistency in time ranges (here: 2000-2002 till 2019-2022)

✓ Consistency in units (ppbv/dec)

Introduction to TOAR-II Focus Working Group: HEGIFTOM

Harmonization and Evaluation of Ground-based Instruments for Free Tropospheric Ozone Measurements, *chairs: Herman Smit & Roeland Van Malderen*

Key Objective:

Evaluation and harmonization of the different free tropospheric ozone profiling datasets of the established measuring platforms (in-service aircraft, ozonesondes, Brewer/Dobson Umkehr, FTIR, Lidar).

Major Deliverable:

Quality assessed ozone data sets, whereby each measurement gets also an ***uncertainty*** and a ***quality flag***. Thereby, ***representativeness*** and ***instrumental drifts*** will be characterized and evaluated.

IAGOS

Ozonesondes

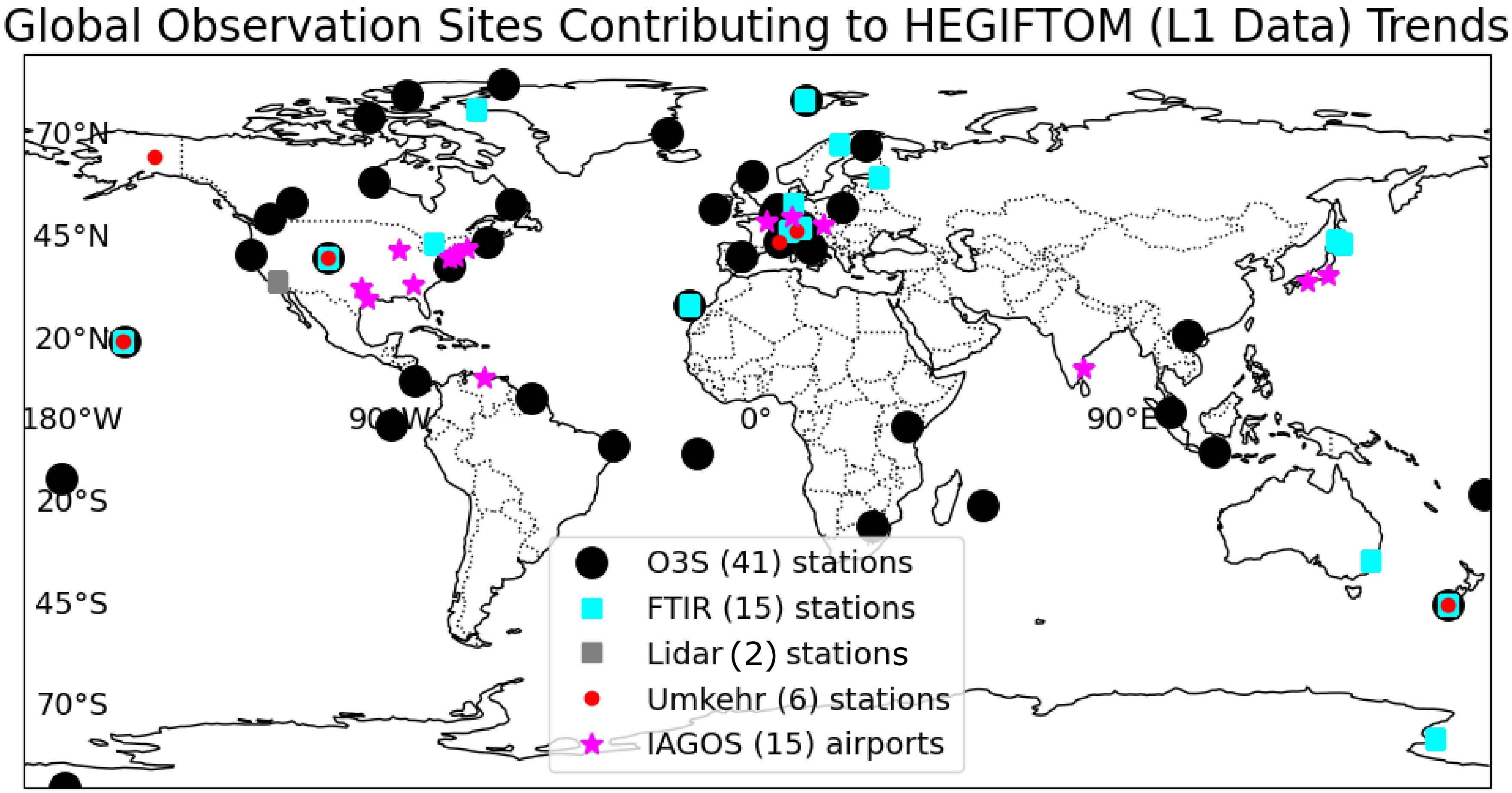
Brewer/Dobson Umkehr

FTIR

Lidar

http://hegiftom.meteo.be/datasets

HEGIFTOM sample for distribution & trends

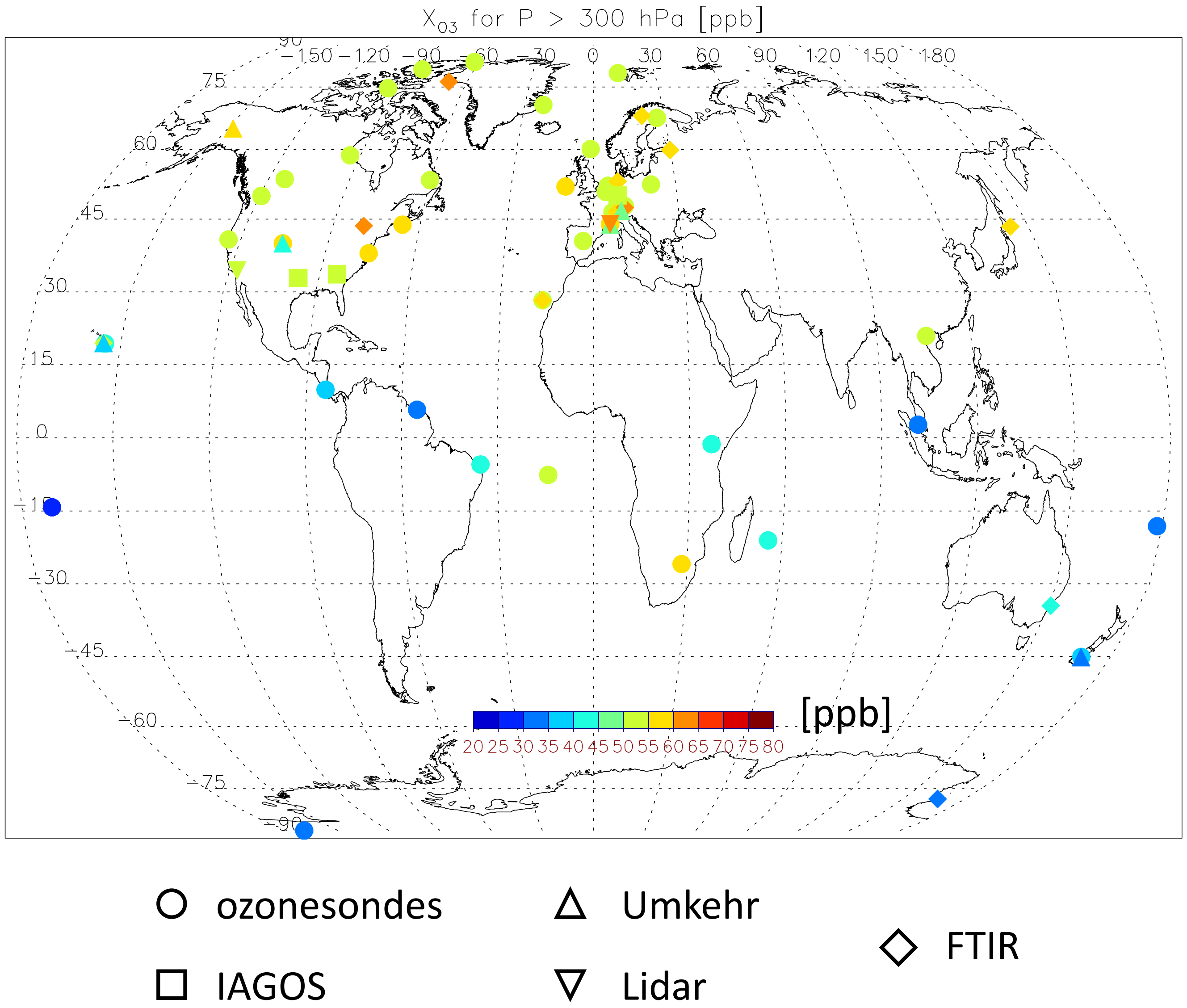


\+

= 79 sites

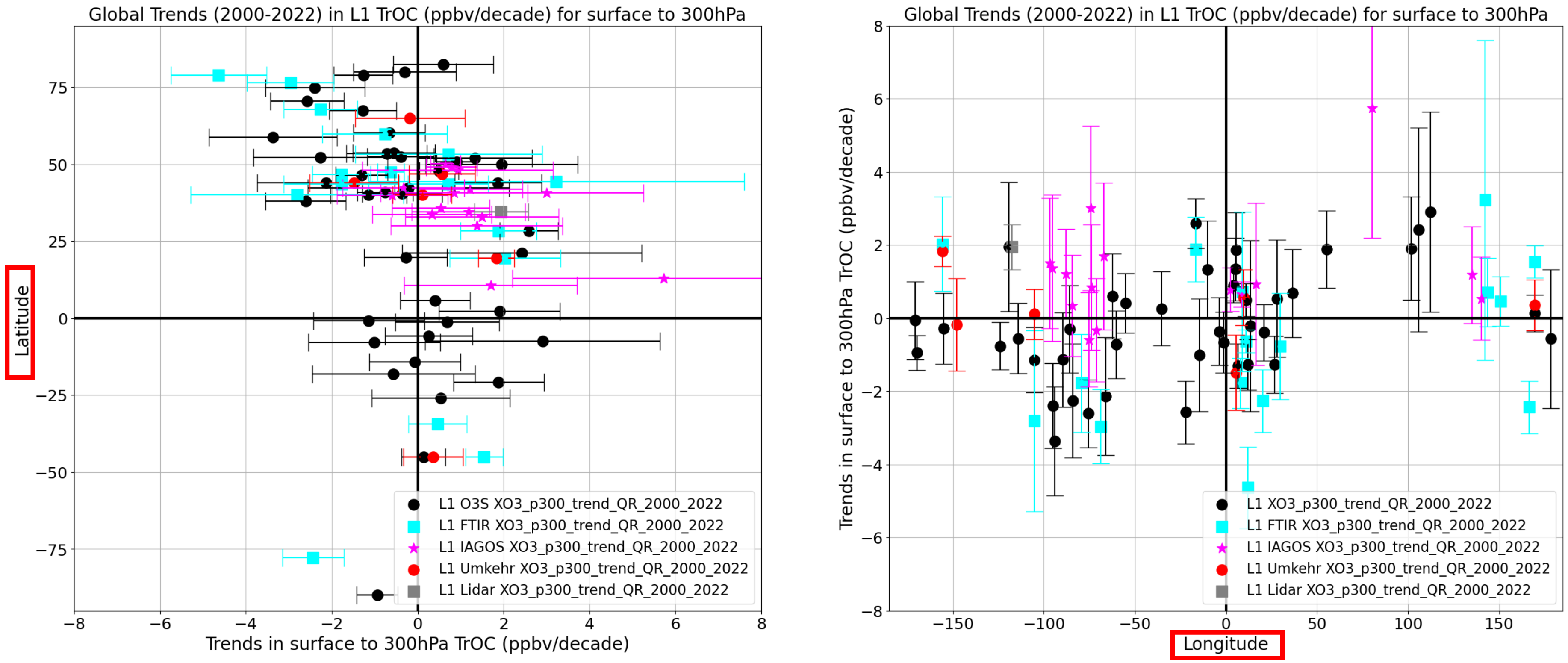
- Sampling and gaps put constraints
- Some sites with different techniques (Boulder, Hawaii, Lauder, OHP, Ny Ålesund, Izaña, …) ➔ intercomparisons

Tropospheric ozone column distribution



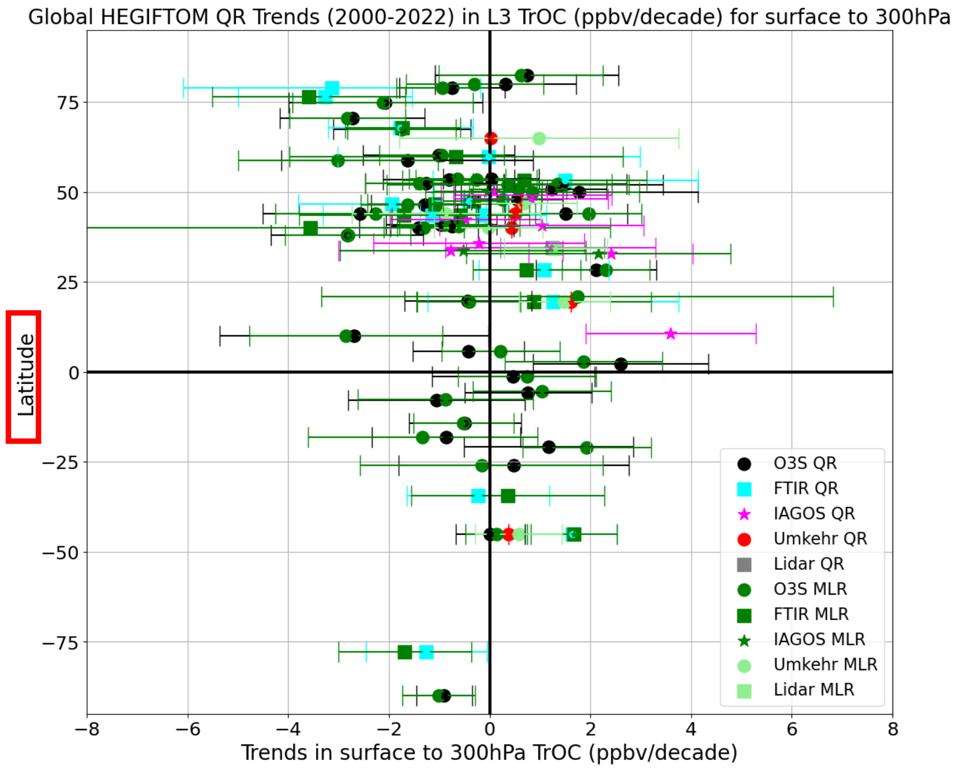
- Mean column-averaged tropospheric ozone distribution (TrOC) from **surface – 300 hPa** for **2000-2022**
- **Lowest**: tropics (< ±15°) and SH; **Highest**: NH (spring & summer!)
- **Reason**: ozone production from enhanced anthropogenic emissions in the NH and higher rates of stratospheric downwelling (e.g. Griffiths et al., 2021).

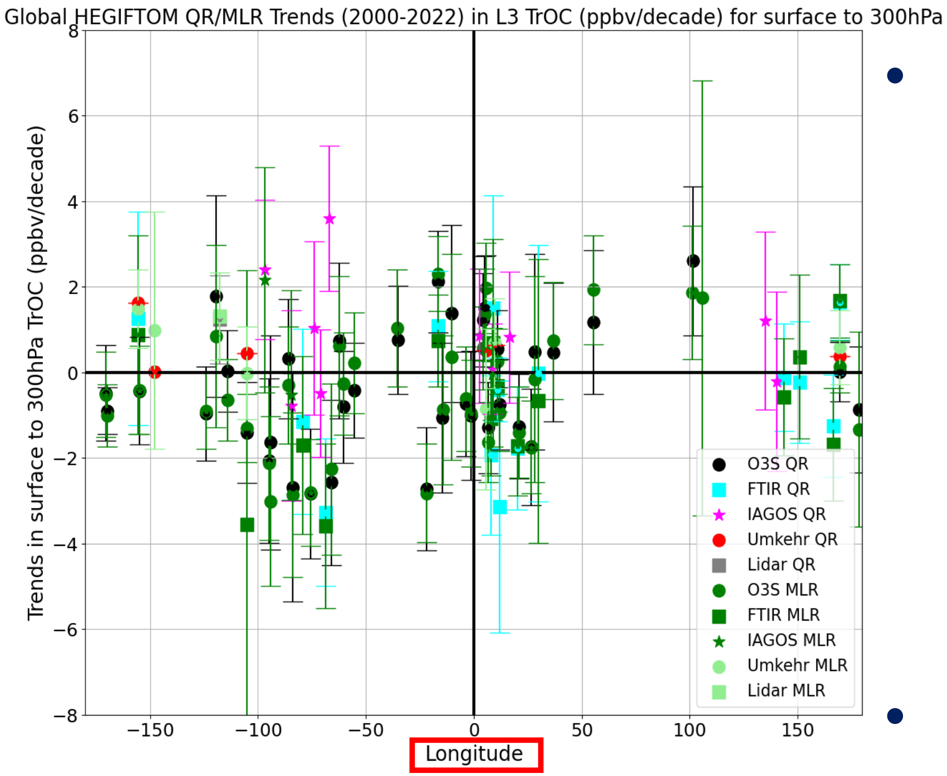
Trend results: median trends with Quantile Regression



- HEGIFTOM multi-site, multi-instrument data show TrOC trends ±3 ppbv/dec globally

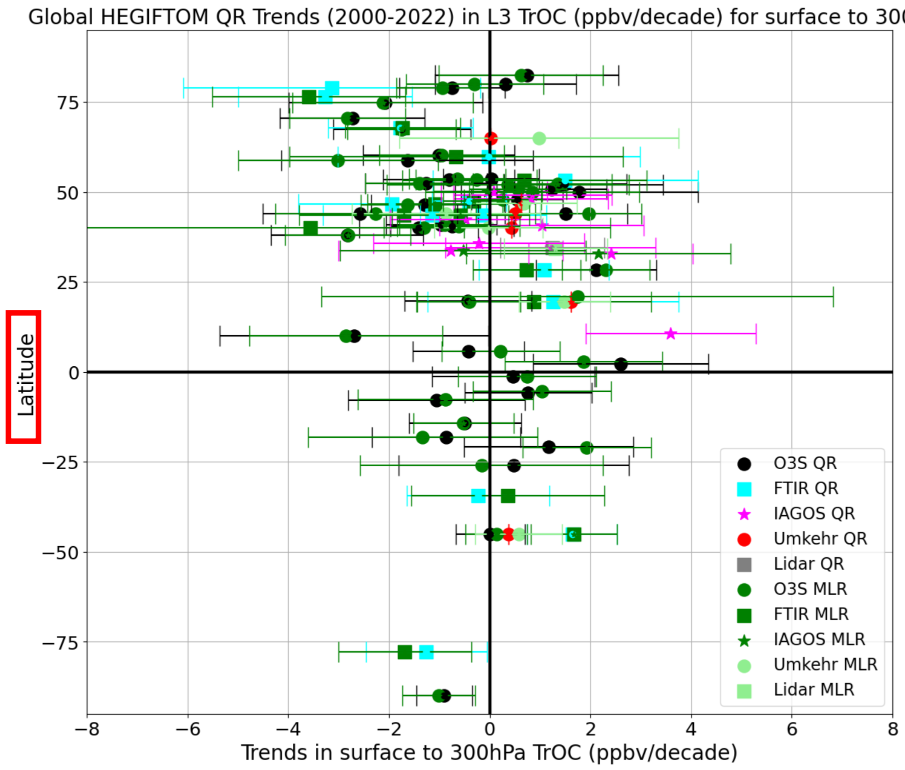
Trend results: QR & MLR trends

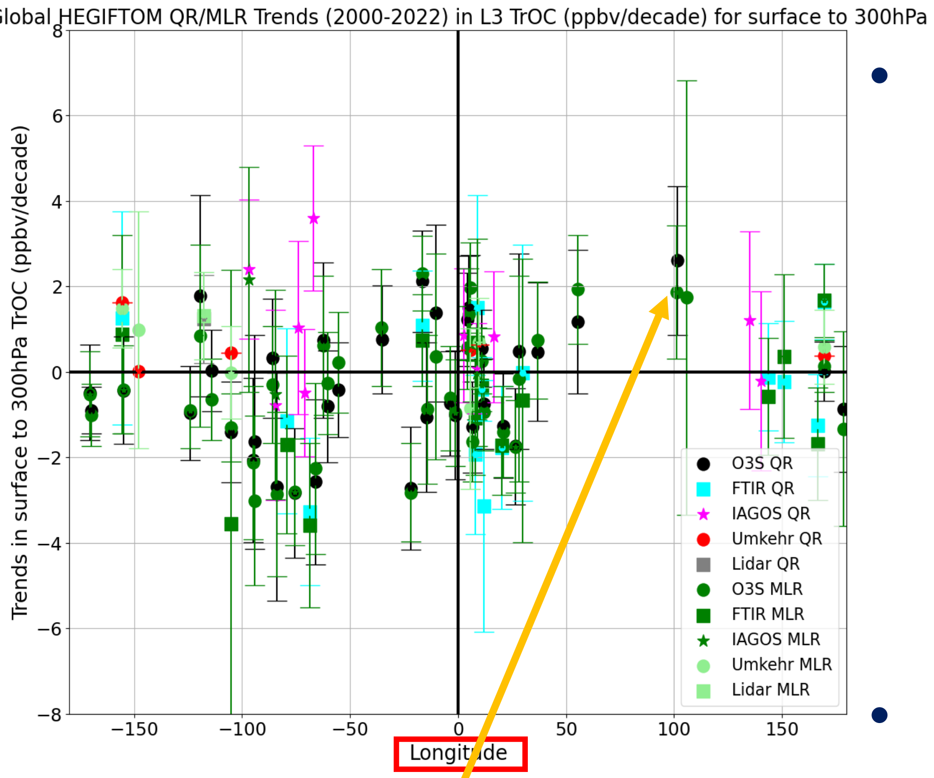




- HEGIFTOM multi-site, multi-instrument data show TrOC trends ±3 ppbv/dec globally, independent of used statistical method (MLR in green)
- Trend estimates provide constraints for satellite and model products!

Trend results: QR & MLR trends

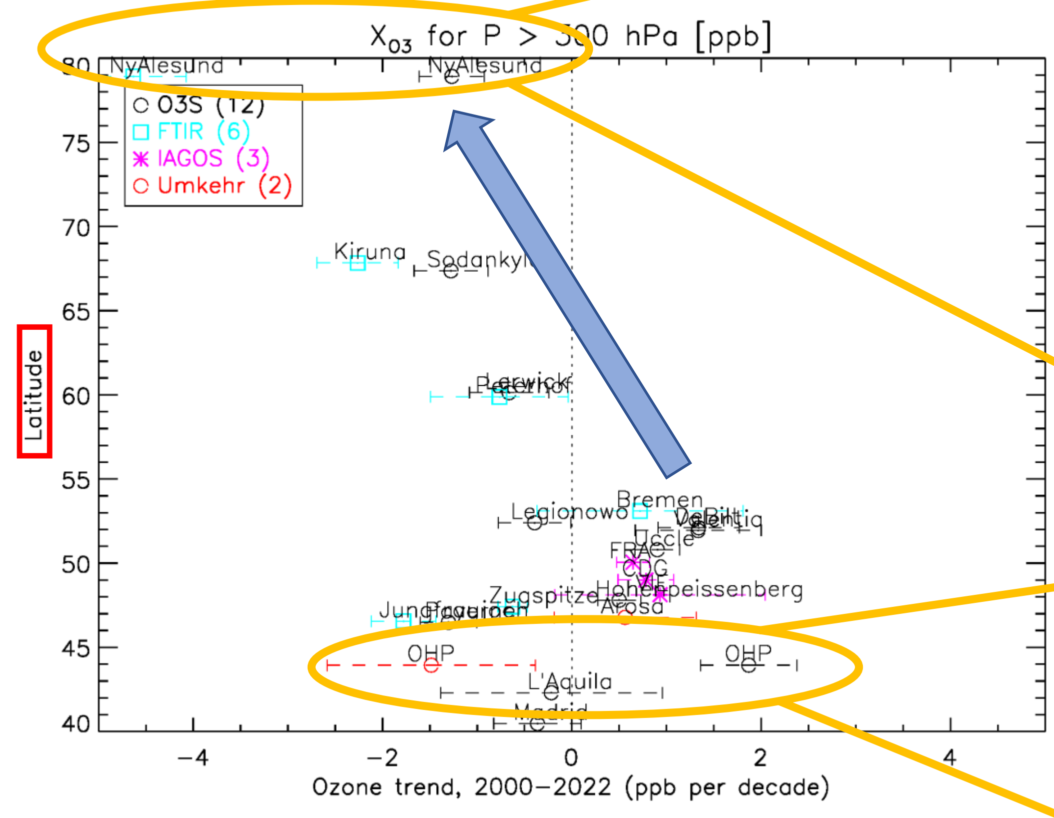


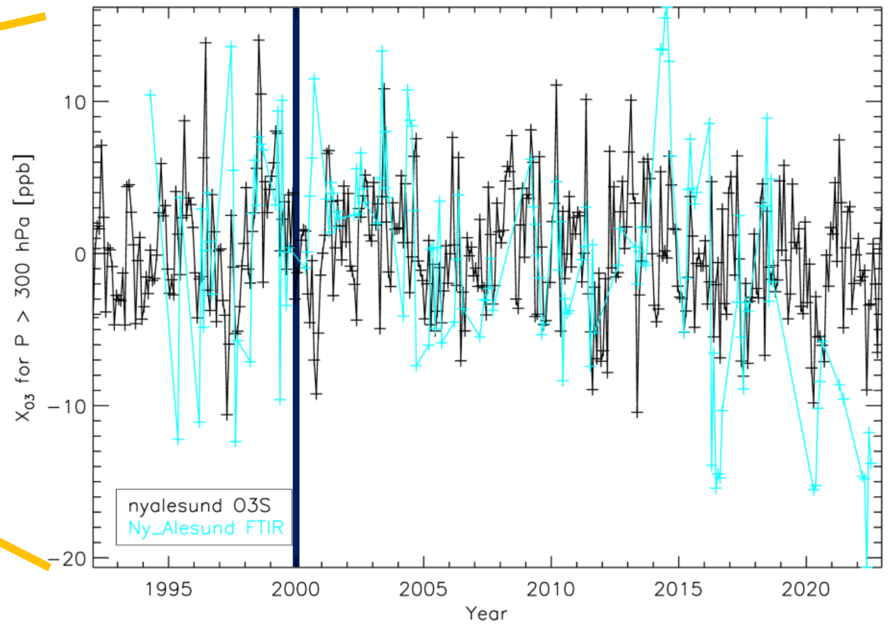


- HEGIFTOM multi-site, multi-instrument data show TrOC trends ±3 ppbv/dec globally, independent of used statistical method (MLR in green)
- Trend estimates provide constraints for satellite and model products!
- Regional trends? (gap filling, sampling rate ↗)

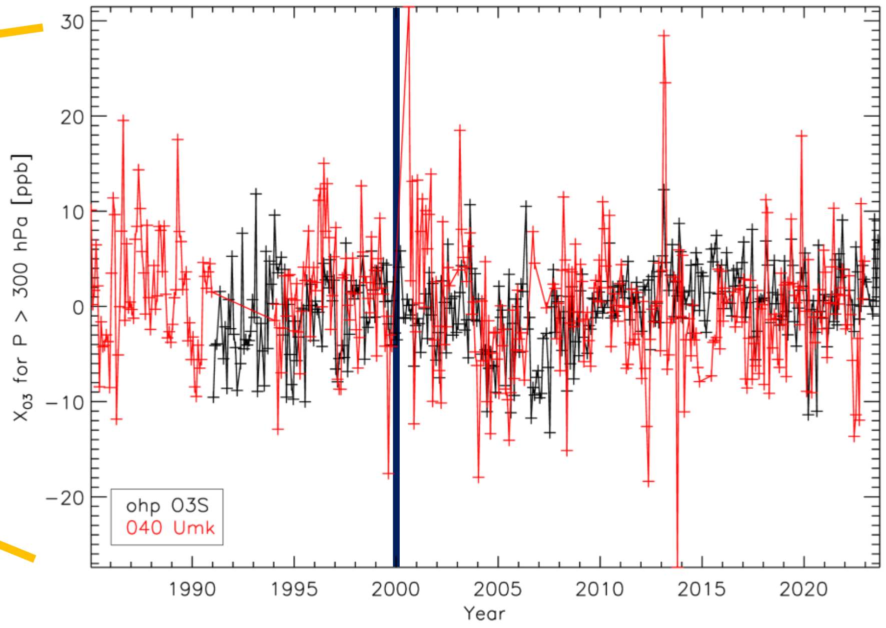
Tropics -> ± 1-2% /dec
SE Asia -> + 5-8% /dec
N. America -> ± 1-2% /dec
W. Europe -> ± 1-2% /dec

Trend results: focus on Europe & supersites





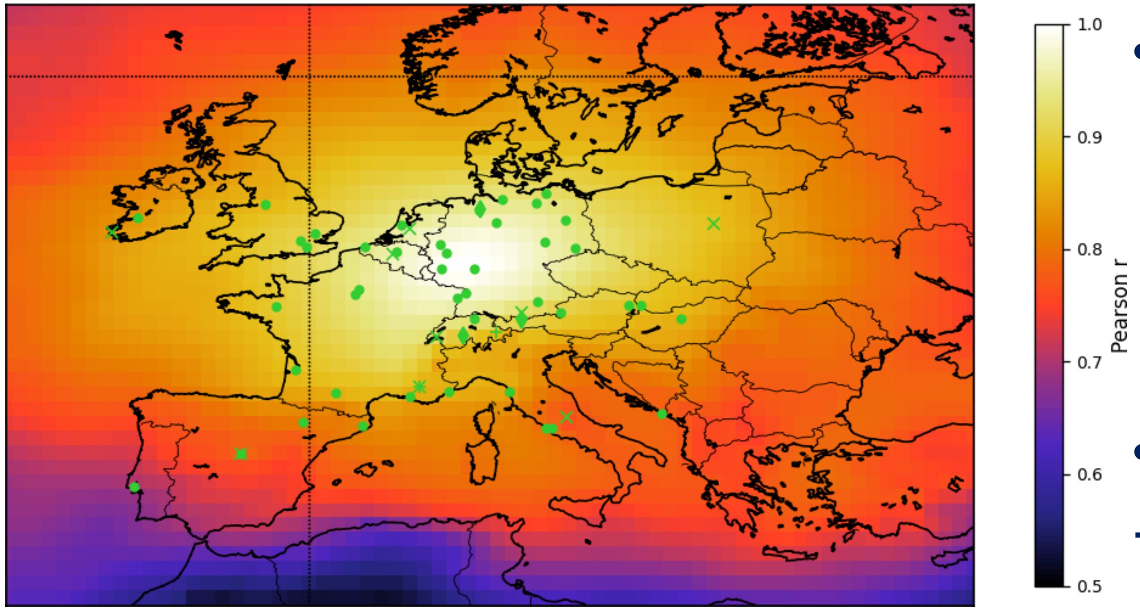
OZONESONDE
FTIR



OZONESONDE
UMKEHR

- visual inspection of the time series!
- negative trends for higher latitude sites?
- European regional TrOC trend meaningful?

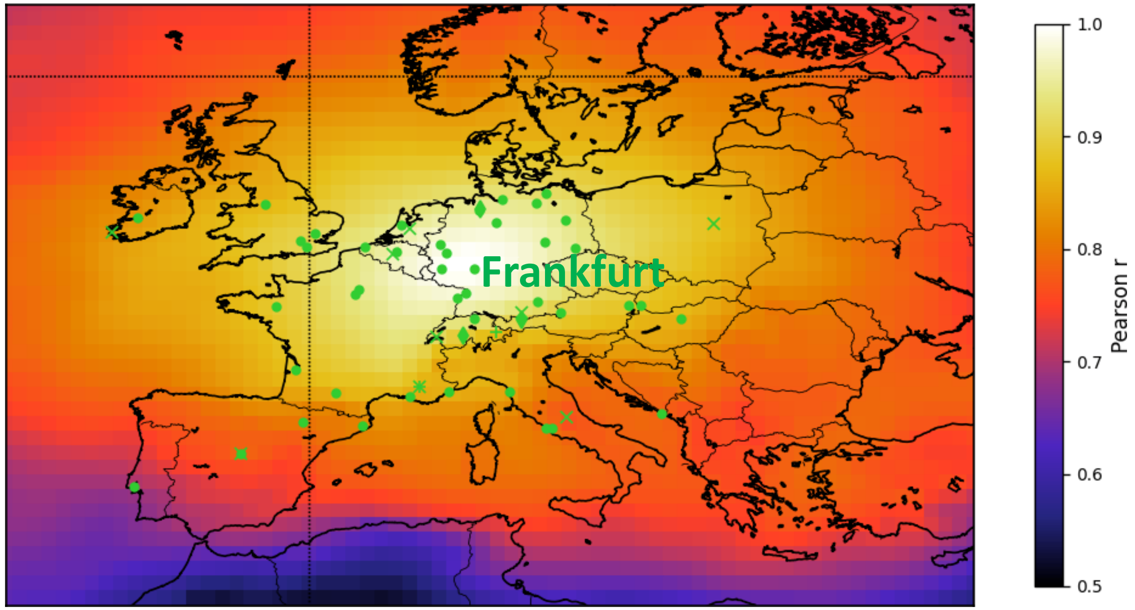
Trend results: strategy for regionalized trends



- Correlation maps between CAMS TrOC (sfc – 300 hPa) monthly anomalies at HEGIFTOM sites (here: Frankfurt, IAGOS)
- r > 0.7!

→ talk by Björklund on Mon PM

Trend results: strategy for regionalized trends



1. regions

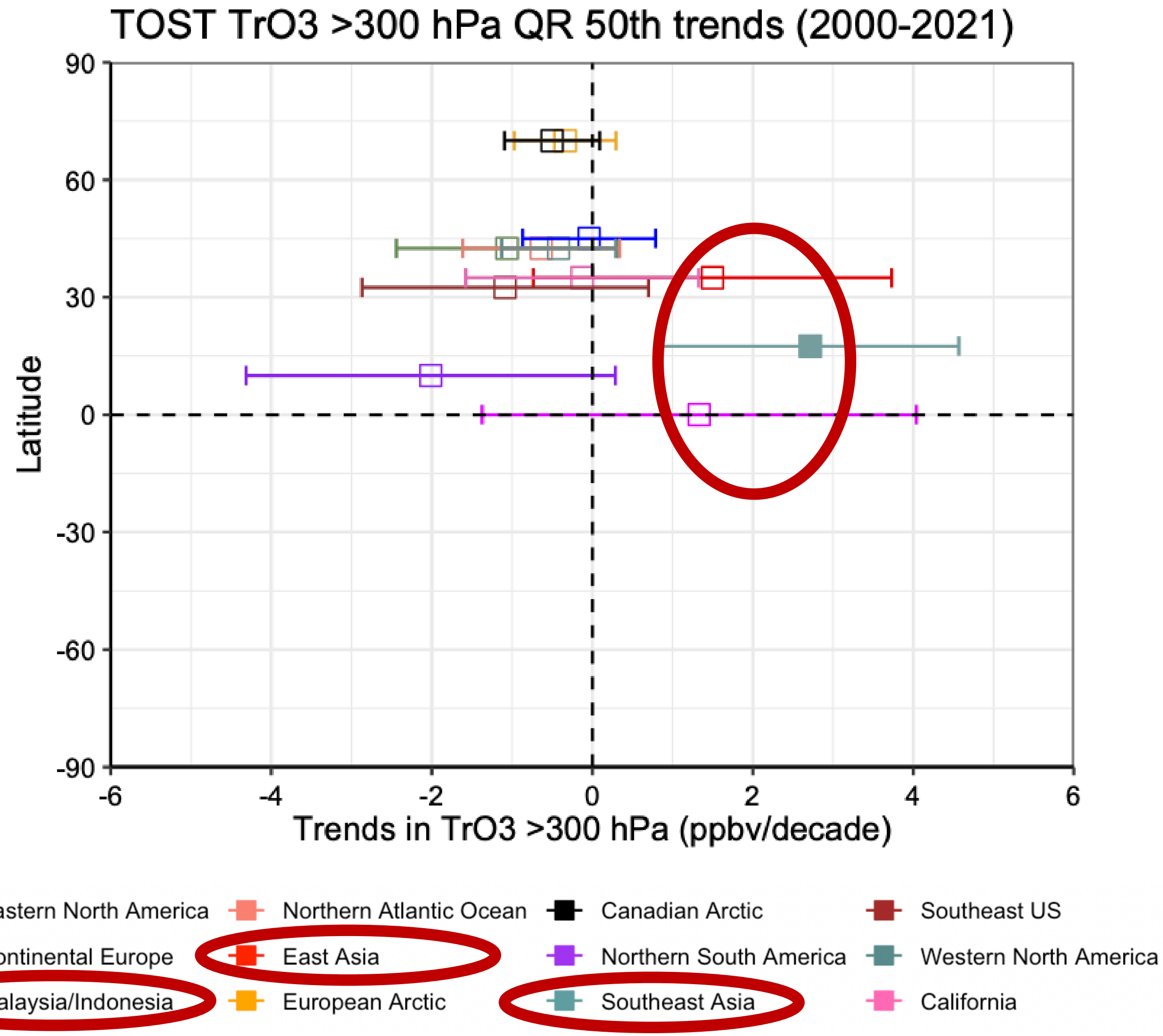
2. sites

Trends in defined regions with TOST (Trajectory-mapped Ozonesonde dataset for the Stratosphere and Troposphere): **ozonesondes only**!

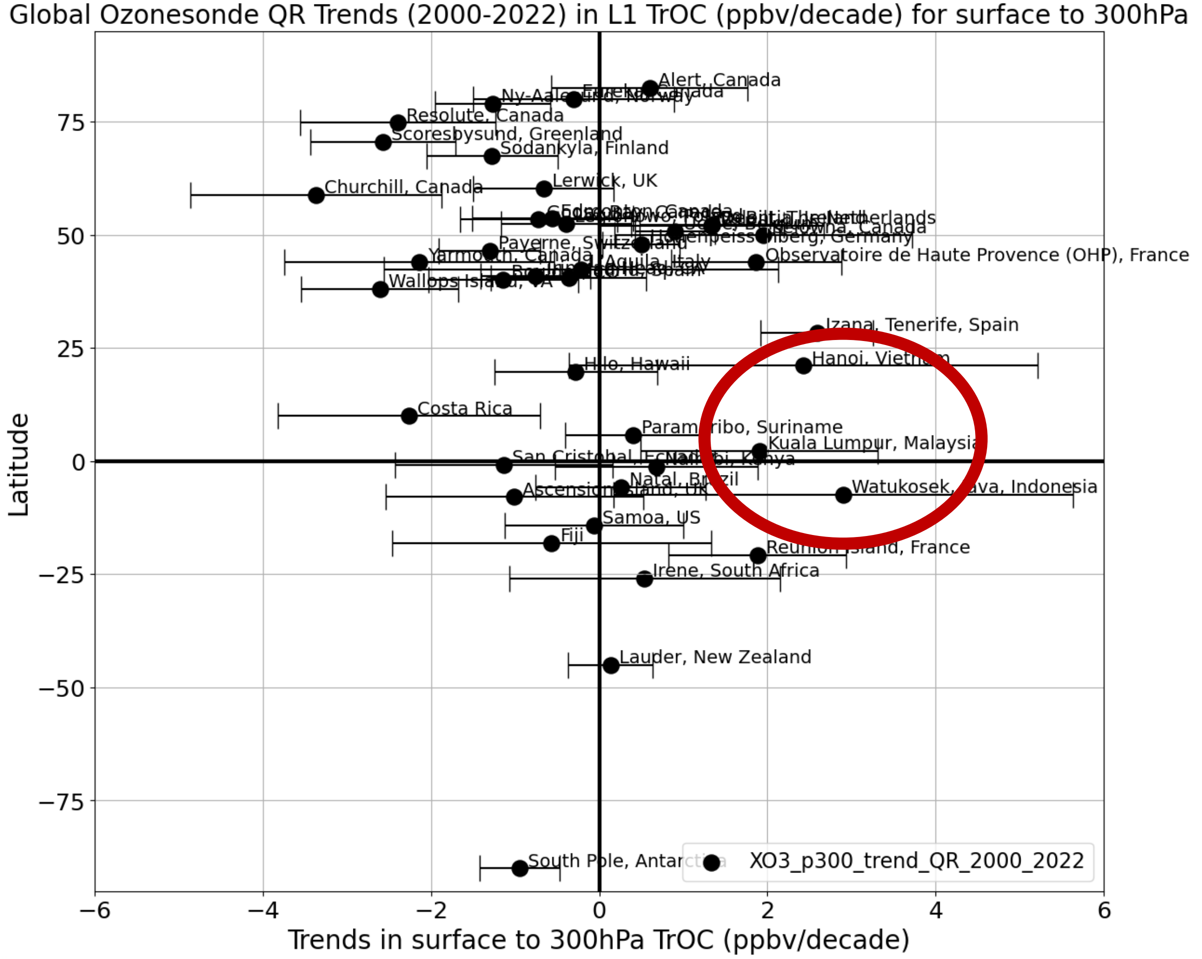
→ Zang et al., EGUsphere, 2024

Statistical method for calculating synthetized trends from **well-correlated individual time series for all instruments**, allowing an intercept and a slope to adjust the difference from each individual trend against the overall trends: WORK IN PROGRESS!

Trend results: strategy for regionalized trends



+ ~2.7 ppbv/decade



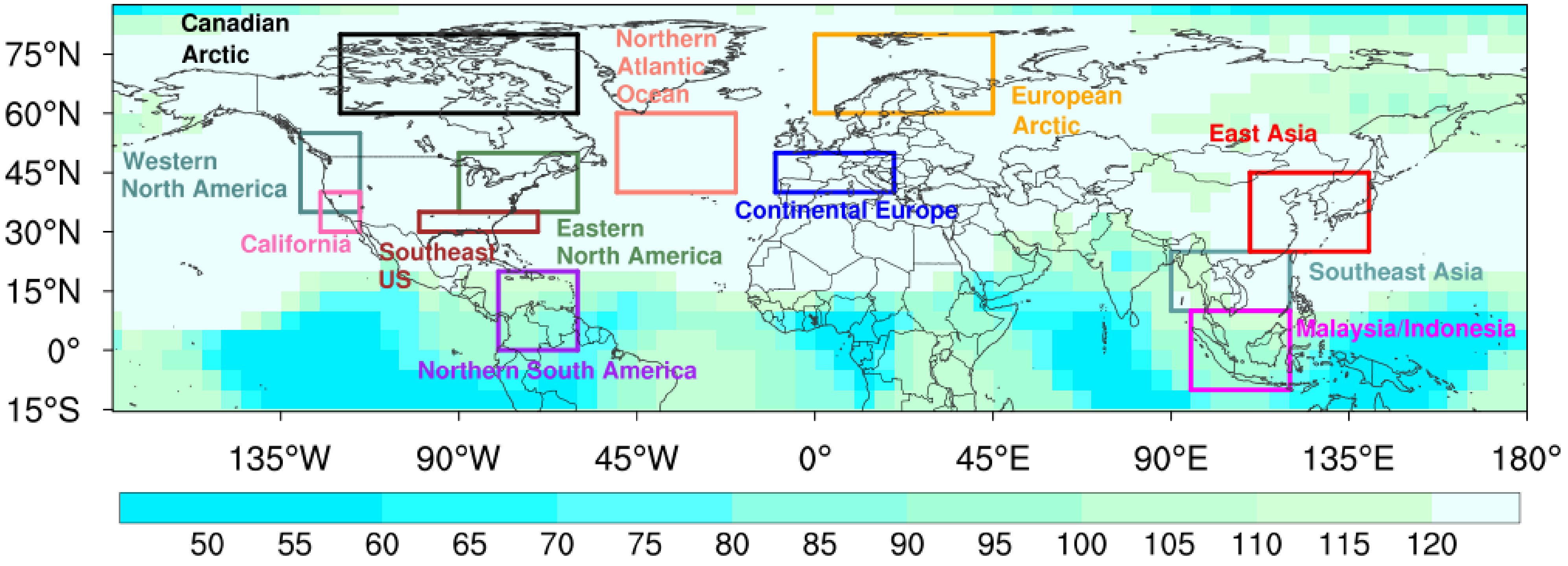
Highly consistent!

Conclusions and outlook

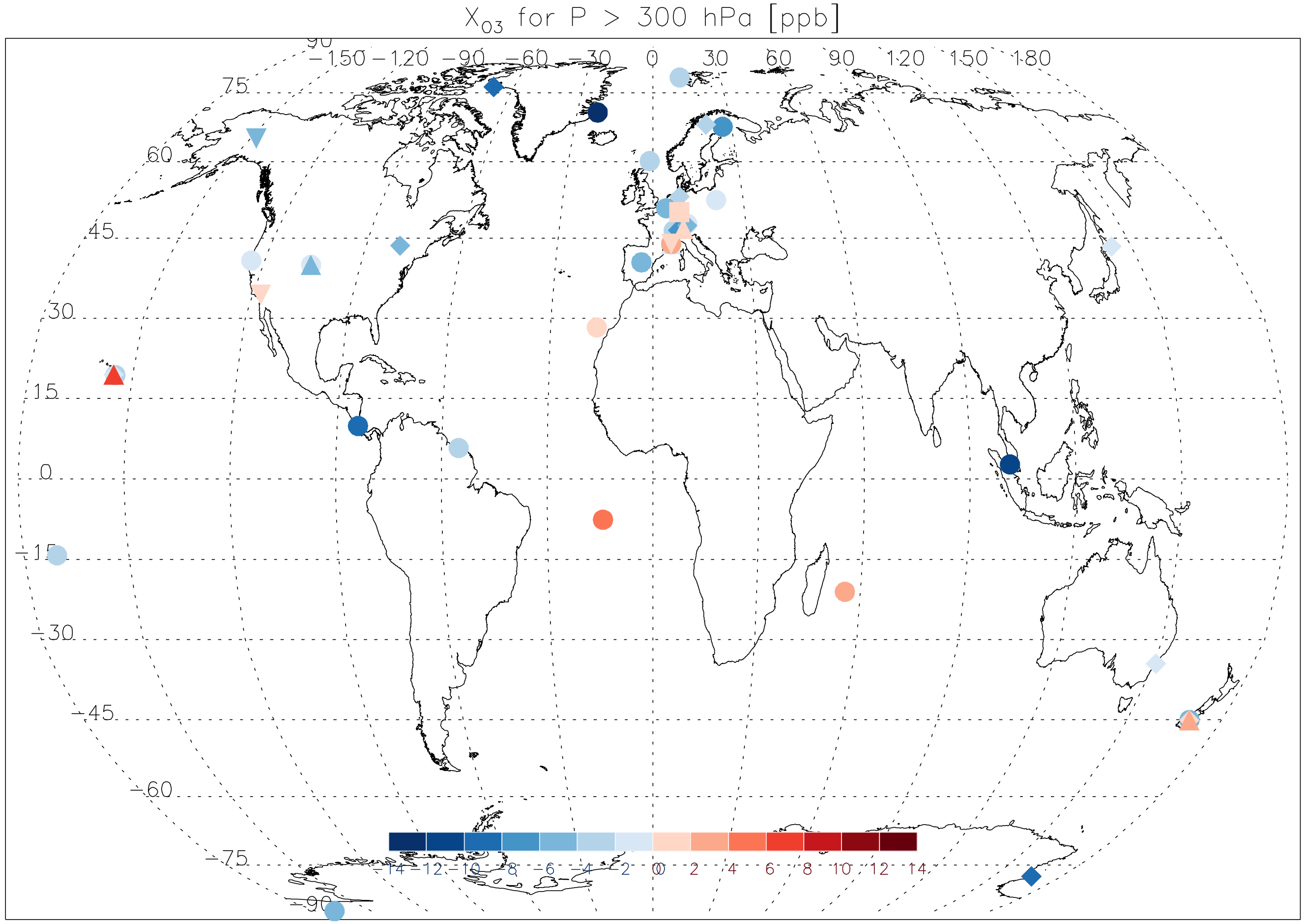
- Quality-assessed, ground-based observations reveal TrOC trends between ±3 ppbv/dec globally, for the 2000-2022 time period.
- Only in SE Asia distinctly positive, other "regions": positive and negative
- Individual site trends vs. regional trends: complementary
  - ✓ **Merging datasets** for regional trends to cope with gaps (IAGOS) and temporal sampling (IAGOS, ozonesondes)
  - ✓ Provides information about spatial and temporal **representativeness** of individual time series (in both directions!)
- Not shown here: free-tropospheric and lower-tropospheric ozone trends!
- To be submitted to TOAR-II SI (Copernicus Journals)

Trend results: strategy for regionalized trends

Number of samples (1990-2021, 4 seasons per year): TrO3 >300 hPa



Tropospheric ozone column distribution: COVID impact

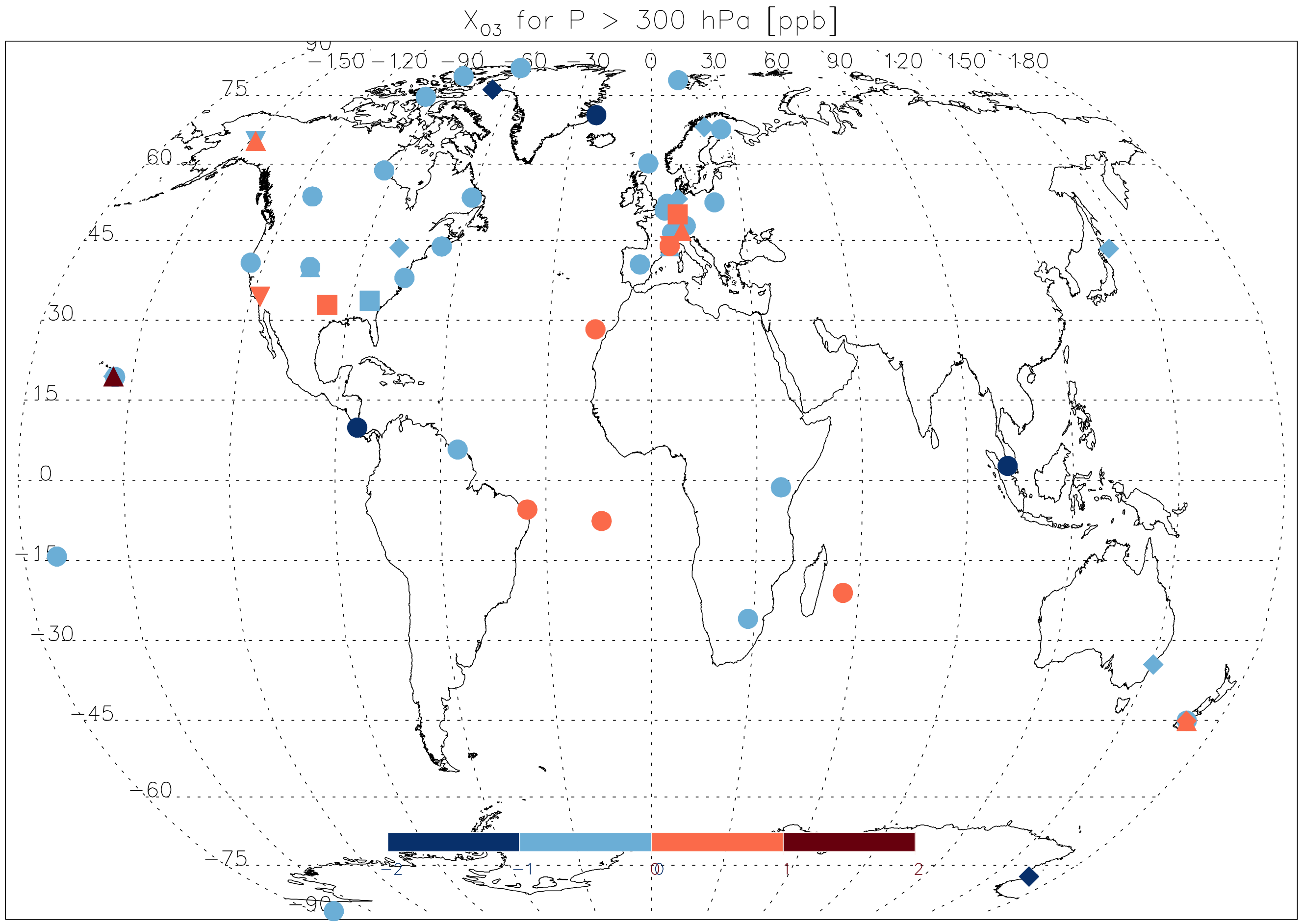


○ ozonesondes △ Umkehr ◇ FTIR

□ IAGOS ▽ Lidar

- Relative change of mean TrOC for the time period 2020-2022 vs. 2000-2019
  Blue: 2020-2022 < 2000-2019
  Red: 2020-2022 > 2000-2019
- Decline in 75% of the sites, on average -2.5% prominent in NH (spring + summer), stronger in FT.
- See talk by J. Ziemke
- Impact on trends!

Tropospheric ozone column distribution: COVID impact



ozonesondes
IAGOS
Umkehr
Lidar
FTIR

- Relative change of mean TrOC for the time period 2000-2022 vs. 2000-2019
  Blue: 2000-2022 < 2000-2019
  Red: 2000-2022 > 2000-2019
- Decline in 75% of the sites,
  on average -0.3%
  prominent in NH (spring + summer),
  stronger in FT.
- See talk by J. Ziemke
- Impact on trends!