Development of Trend-Quality Ozonesonde Profile Data through 30 Years of Laboratory and Field Experiments

Ryan M. Stauffer*, Anne M. Thompson, Herman G. J. Smit, Debra E. Kollonige, Roeland Van Malderen, David W. Tarasick, Jonathan Davies, Holger Vömel, Peter von der Gathen, Richard Querel, Gary A. Morris, Bryan J. Johnson, and Patrick D. Cullis

*NASA/GSFC; Greenbelt, MD, USA; **All Authors = ASOPOS 2.0

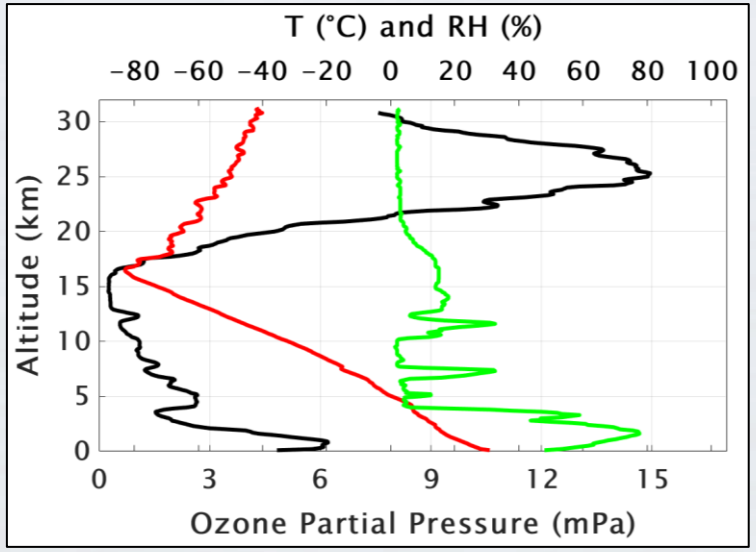
iCACGP-IGAC Kuala Lumpur, 12 September 2024 14:50

Roadmap: 30 Years of O_3Sonde DQA Effort

- What is an ozonesonde? How does it work?
- Preparation disparity leads to large ozonesonde biases
- Solving the problem with JOSIE Experiments & ASOPOS
- Success! Deriving ozonesonde trends with confidence
- What is there left to do?

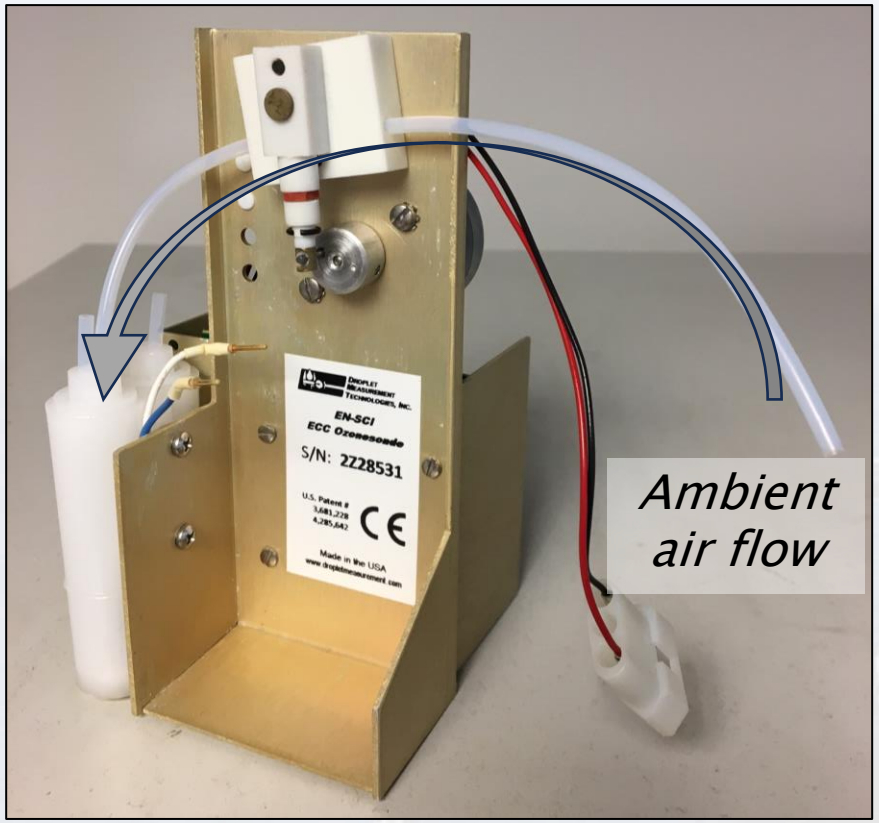
What is an ECC Ozonesonde?

Kuala Lumpur SHADOZ ozonesonde+radiosonde launch



Ozone**, **temperature**, and **humidity

1. During balloon flight, ambient air is pumped into cells containing a KI solution
2. Ozone reacts with solution, causing **two electrons** to flow in the external circuit per O_3 molecule
3. Measure the resulting electrical current and convert into ozone partial pressure

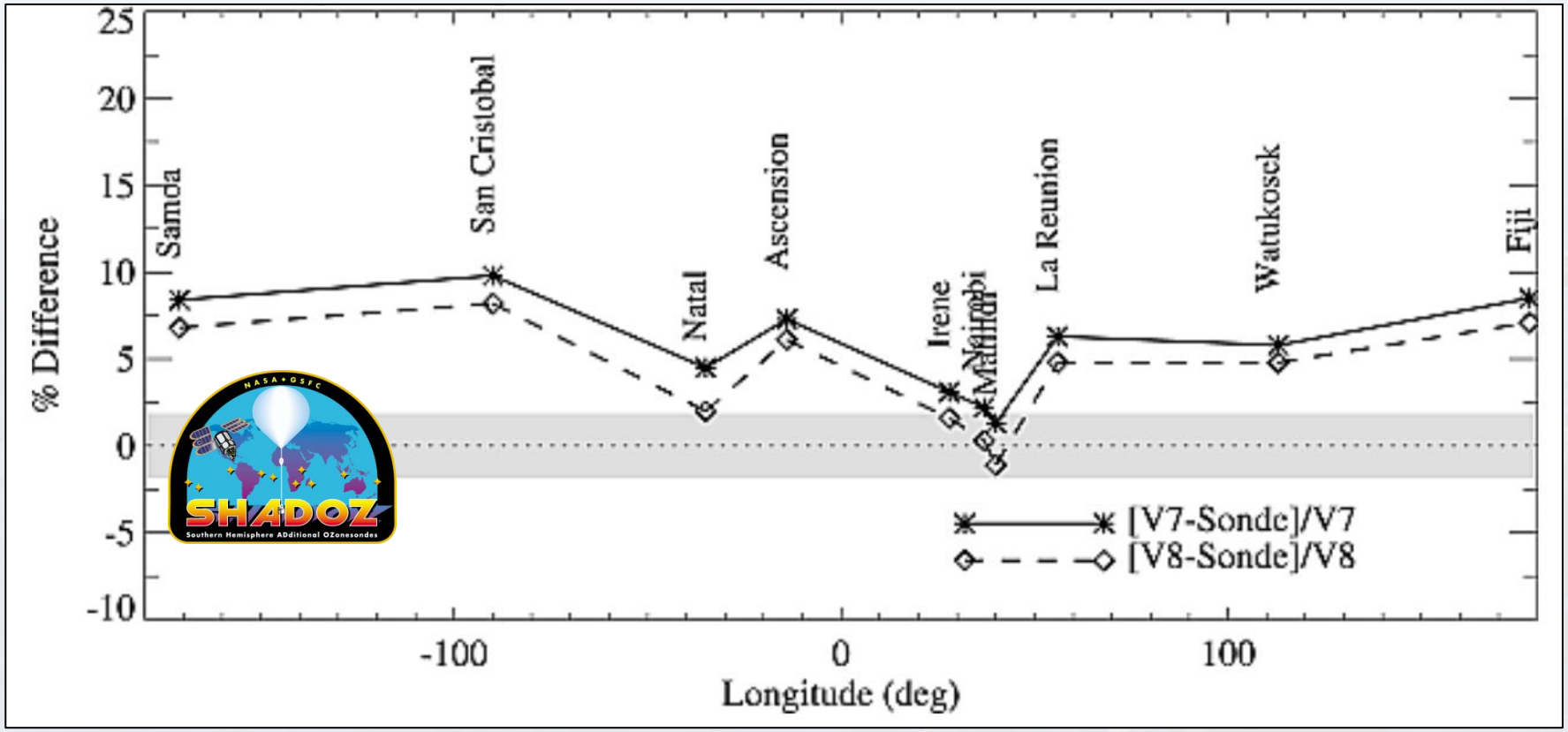


ECC ozonesonde outside of its protective Styrofoam box

Ozonesonde Biases of >10% Were Common

- Ozonesonde stations used differing sonde types, preparation techniques, KI solutions, data processing…
- These all led to differences in measurements
- *How to remedy the station-to-station disparity and biases?*

Southern Hemisphere Additional Ozonesondes (SHADOZ) TCO Biases Compared to TOMS (1998-2001)



From Thompson et al. (2007; JGR)

JOSIE Ozonesonde Experiments & ASOPOS

- Jülich OzoneSonde Intercomparison Experiments held at the World Calibration Centre for Ozonesondes (WCCOS) chamber →

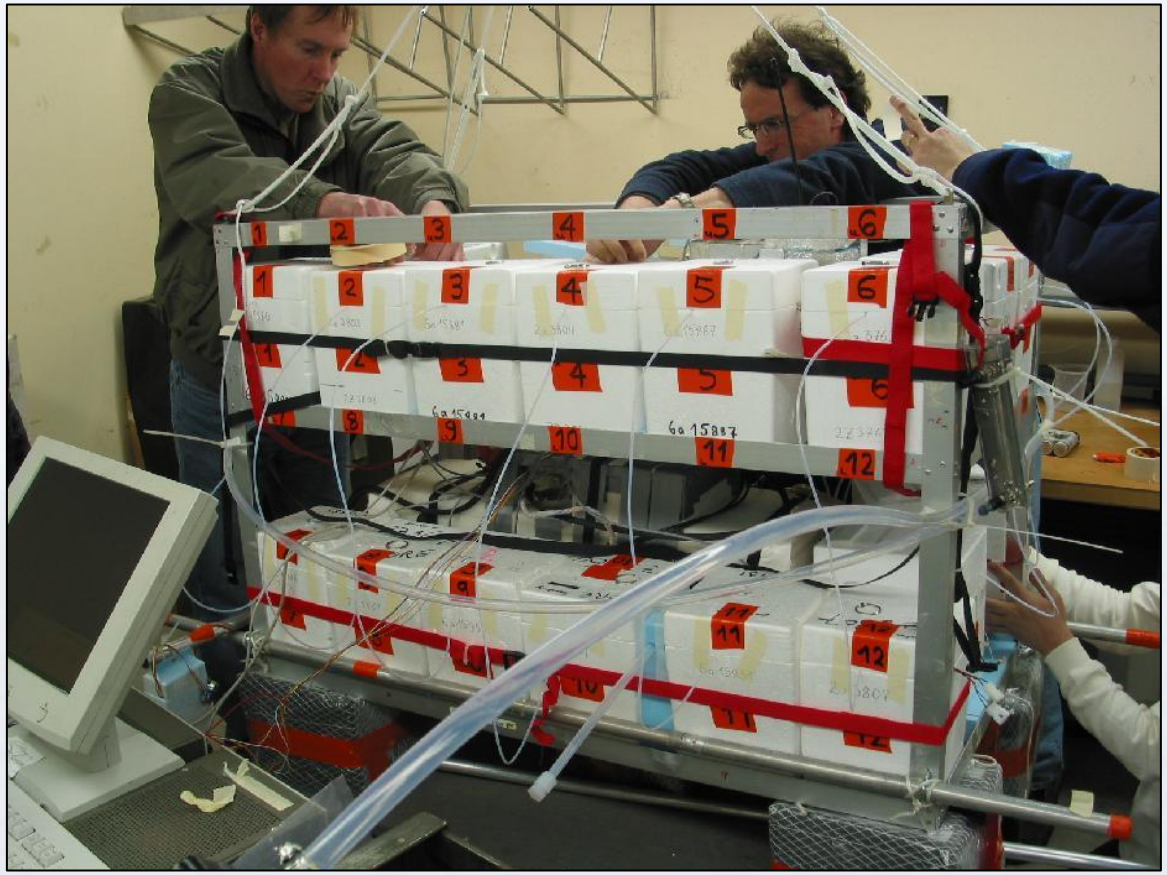
- JOSIEs (first in 1996) tested the combinations of sondes and preparation procedures that existed in the network at that time

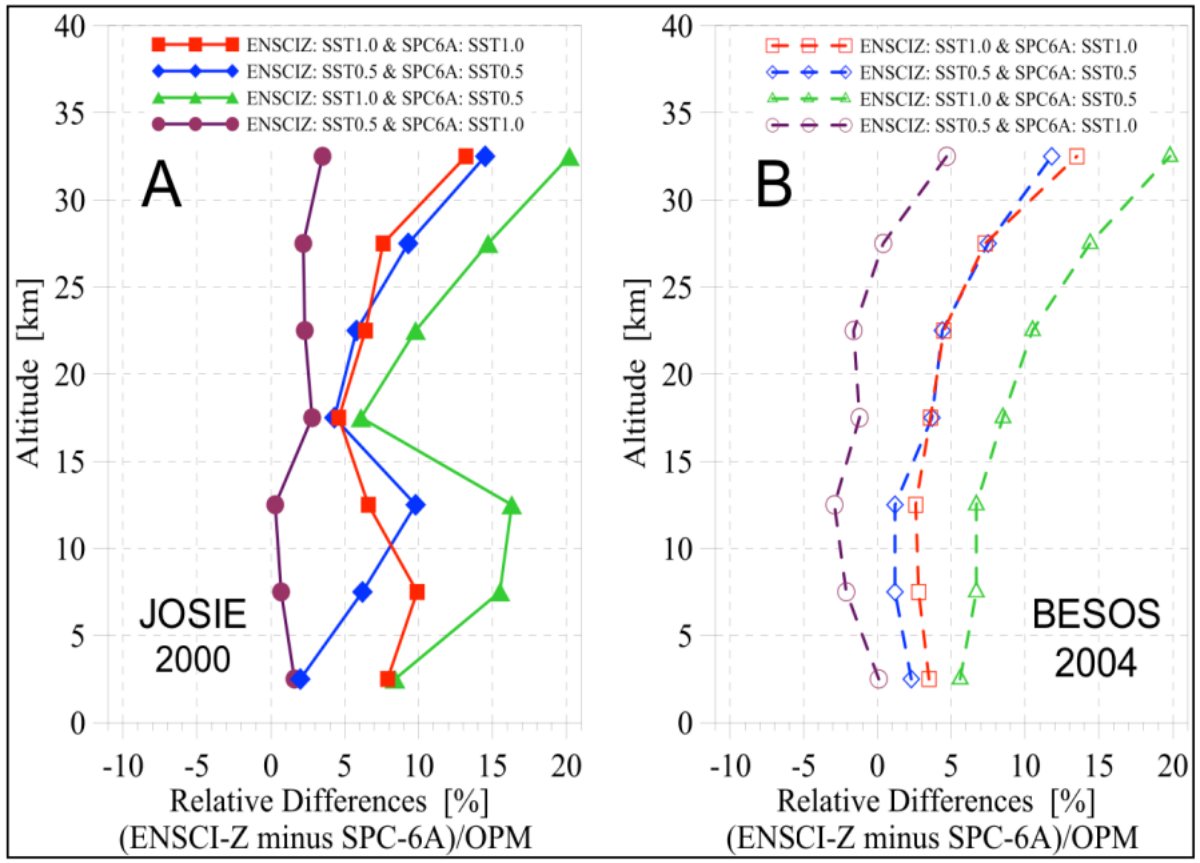
Placeholder for ASOPOS 1.0 group photo

- ECC ozonesondes proved superior. Future JOSIEs focused on ECCs only

- Assessment of Standard Operating Procedures for Ozonesondes (ASOPOS) Expert Panel developed the first preliminary SOPs

Field Measurements Confirm JOSIE Results

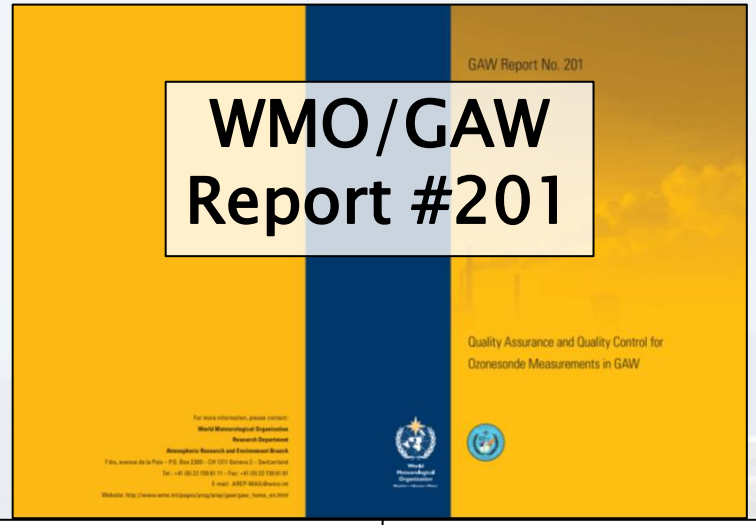


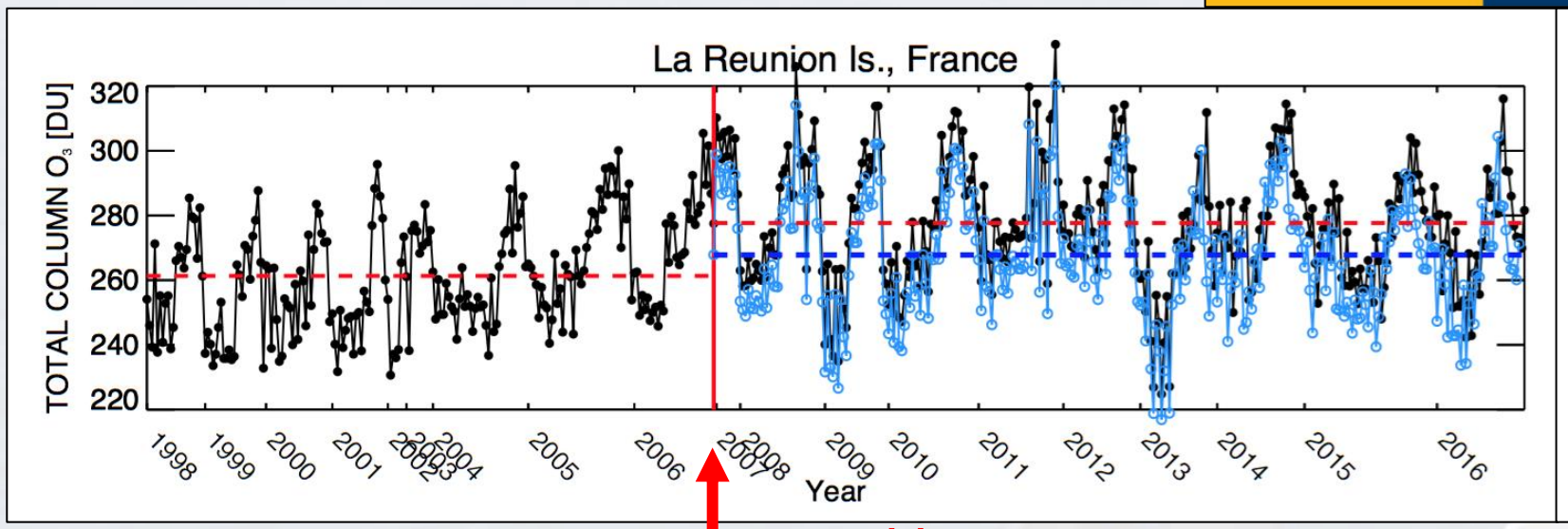


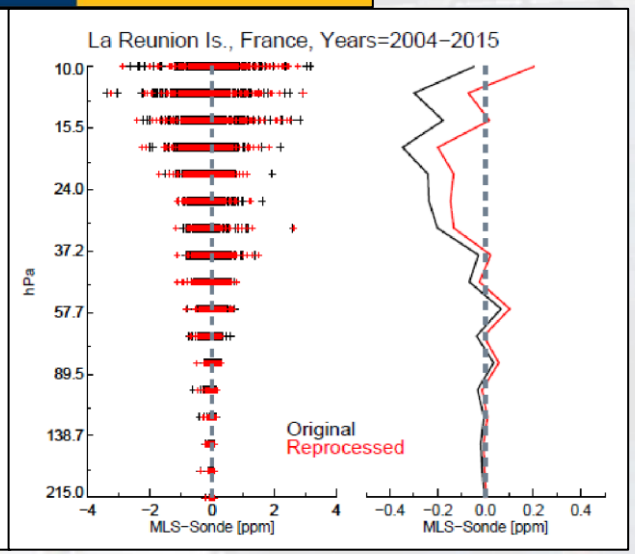
The 2004 BESOS experiment (Laramie, WY, USA; **left**) confirmed results from the JOSIE laboratory experiments (**right**). These indicated that each of the two ECC manufacturers should be paired with a different KI solution strength (shown in **purple** at right)

Data Reprocessing: "Homogenization"

- ASOPOS published the first ozonesonde SOPs from JOSIE and BESOS results in WMO/GAW no. 201 →
- Also prescribed data reprocessing procedures to homogenize data based on differing operational practices. Example from La Réunion SHADOZ shown below (*inadvertent KI solution change in 2007!)*







261 ± 17 DU

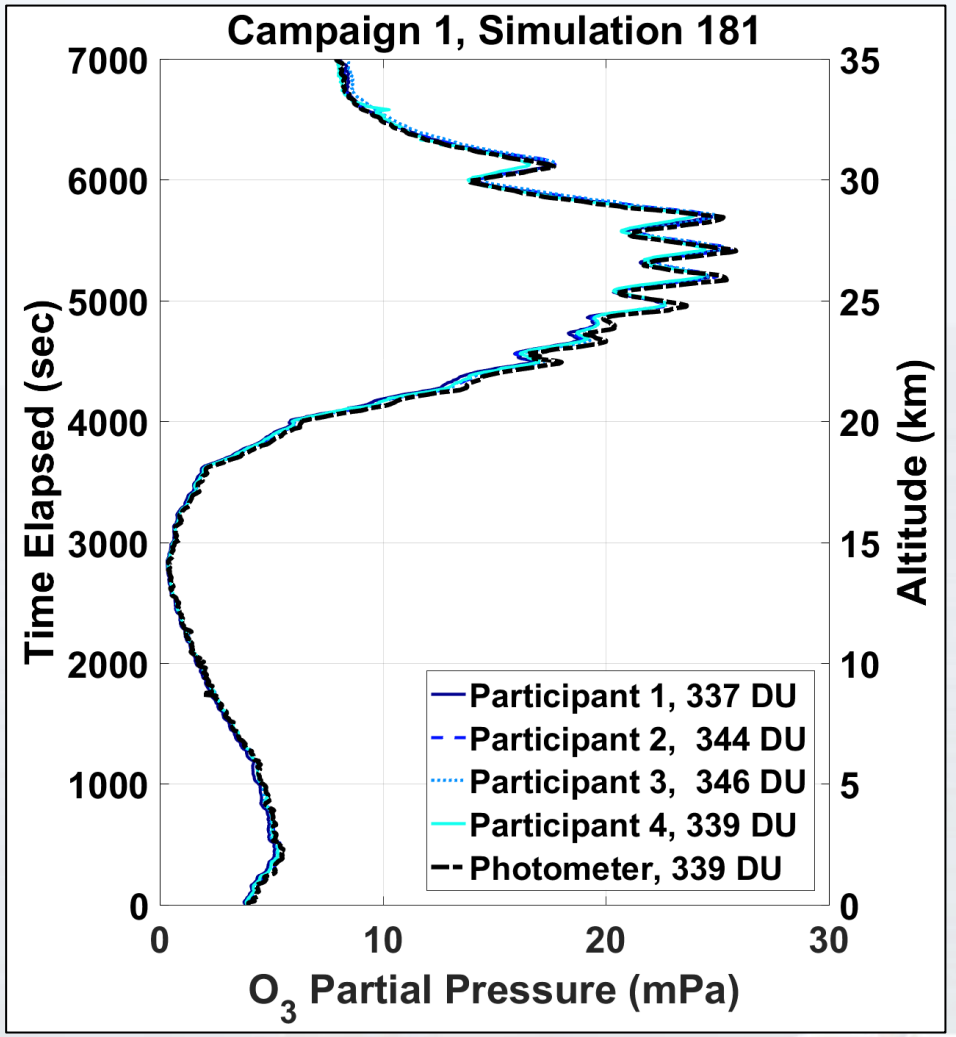
Old: 278 ± 19 DU

New: 268 ± 18 DU

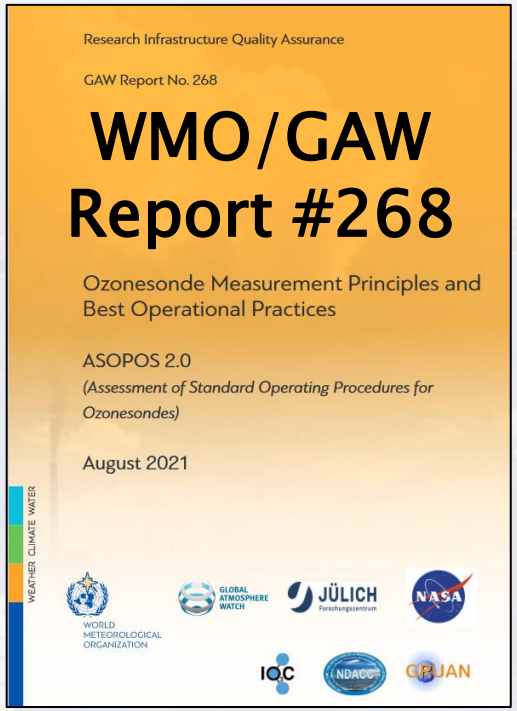
ASOPOS 2.0 Refines SOPs

- ASOPOS 2.0 formed at QOS 2016 in Edinburgh. *What was missing?*
- Uncertainties, recommendations on data quality assurance, prescription of required metadata
- JOSIE-SHADOZ 2017 focused on tropical profiles and confirmed past results → WMO/GAW #268

ASOPOS 2.0 in Brussels, Sep 2019

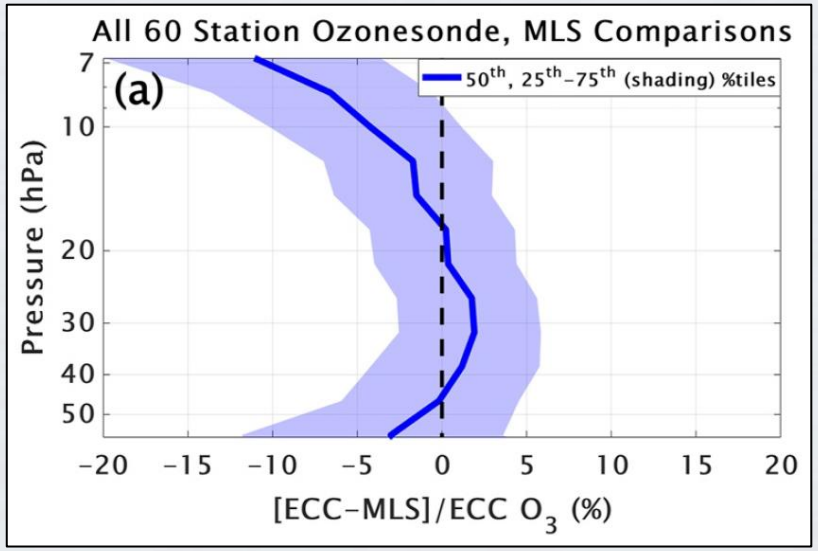


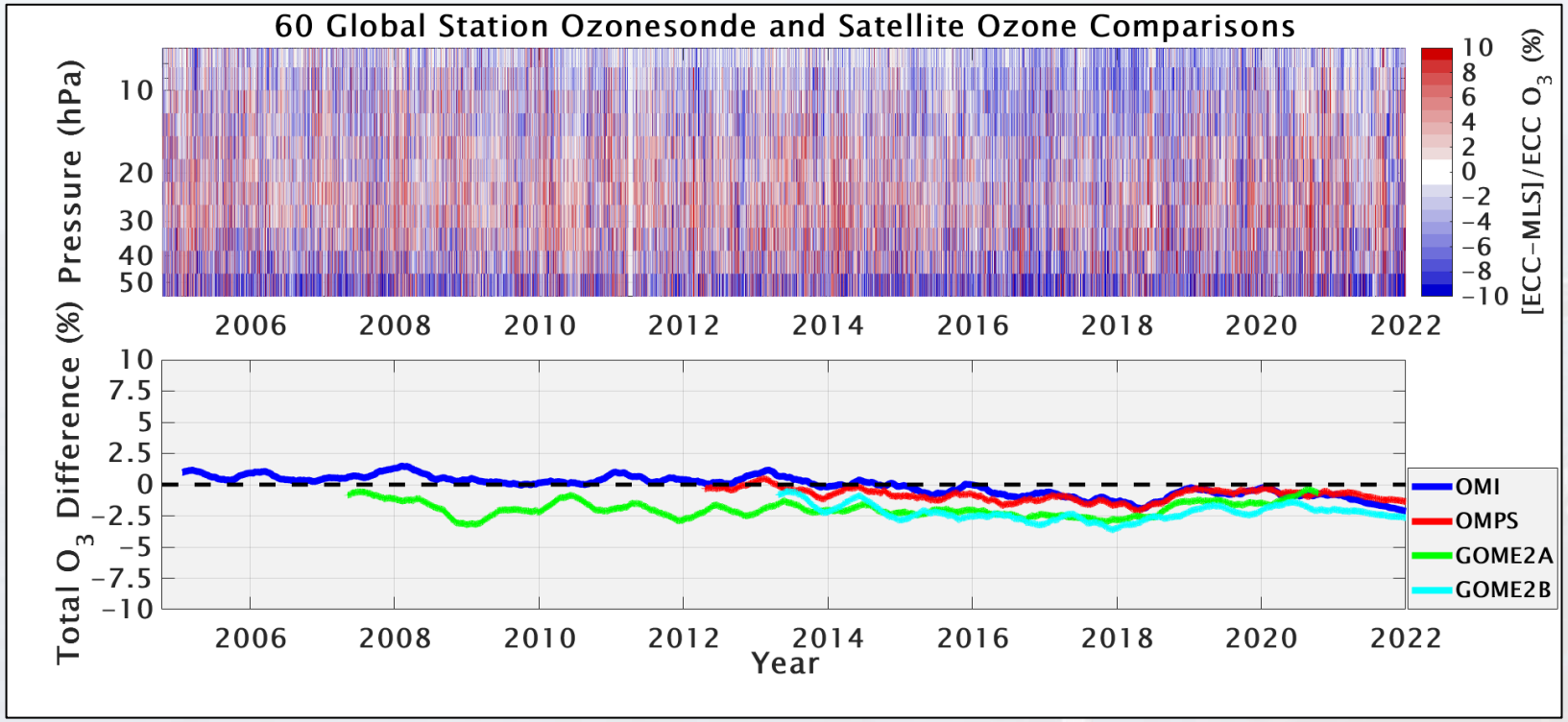
Four Ozonesondes Compared to WCCOS UV Photometer



The Fruits of Our Labor: ±2% Agreement!

- Global survey of 60 stations in Stauffer et al., (2022) showed total column ozone agreement with satellites of ±2%. Agreement with Aura MLS profiles is ±5%
- Uncertainties reduced from ~20% in the 1990s to near 5% today

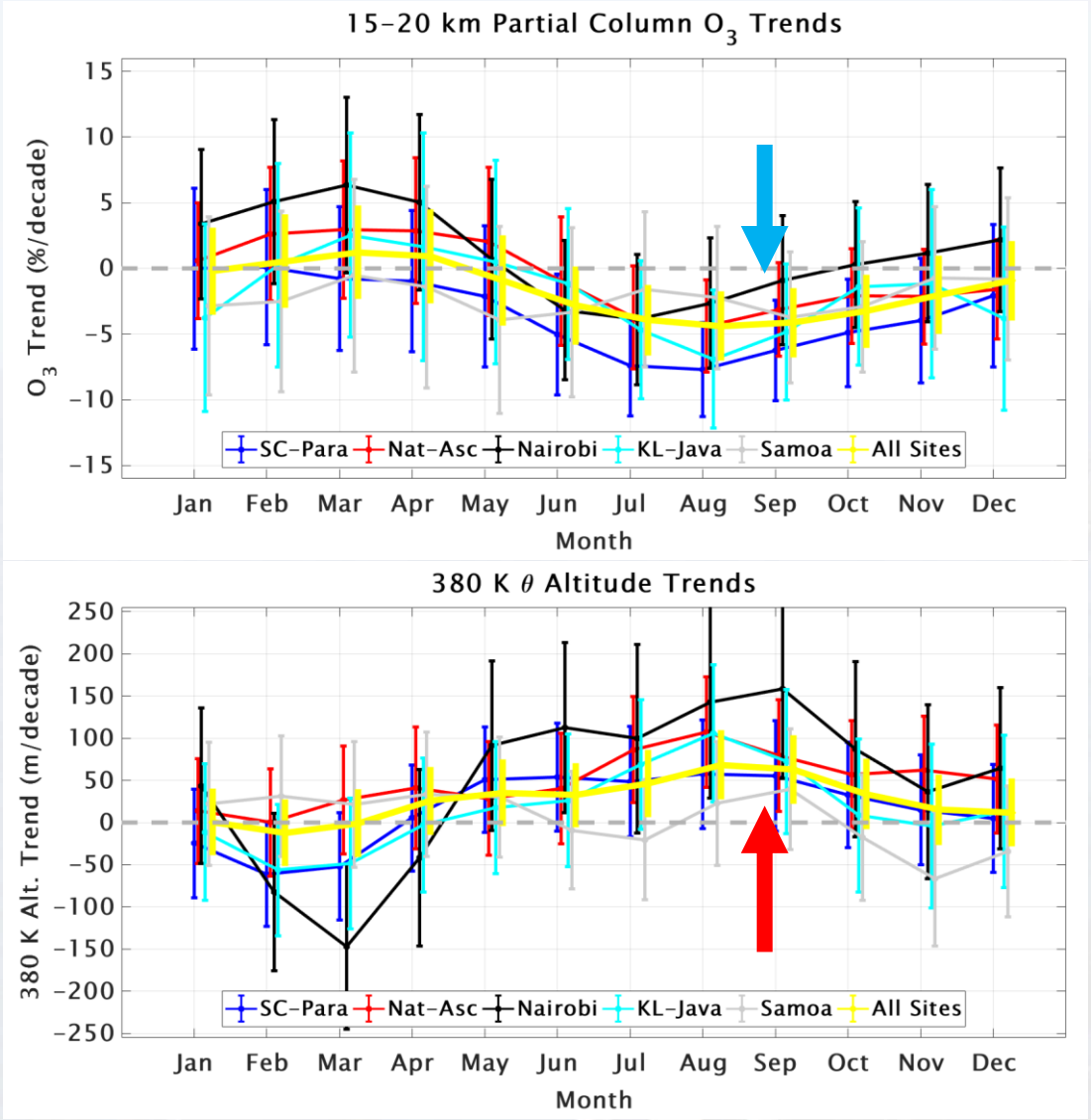




- Global ozonesonde data are accurate enough to detect a drift in OMI total column ozone (see above), which has since been corrected

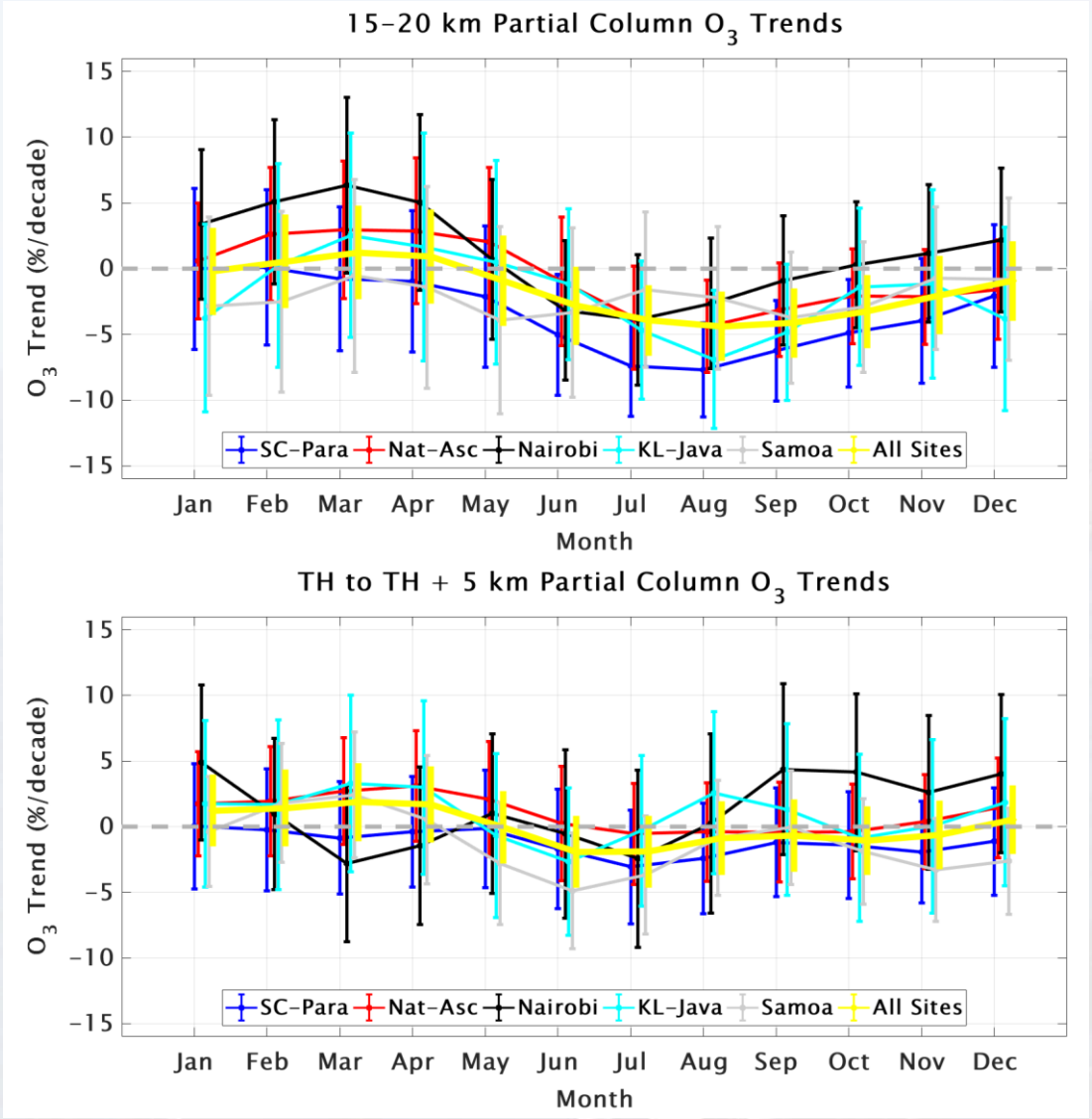
Computing Trends with Confidence

- Use the data for ***attribution*** of ozone trends!
- Update of Thompson et al. (2021; JGR). 1998–2022 O_3 trends →
- 15–20 km SHADOZ ozone trends from 8 stations (combined in yellow) are negative in 2nd half of year (**top**)
- Radiosonde PTU are key ancillary SHADOZ data. Tropopause height is increasing (**bottom**)!

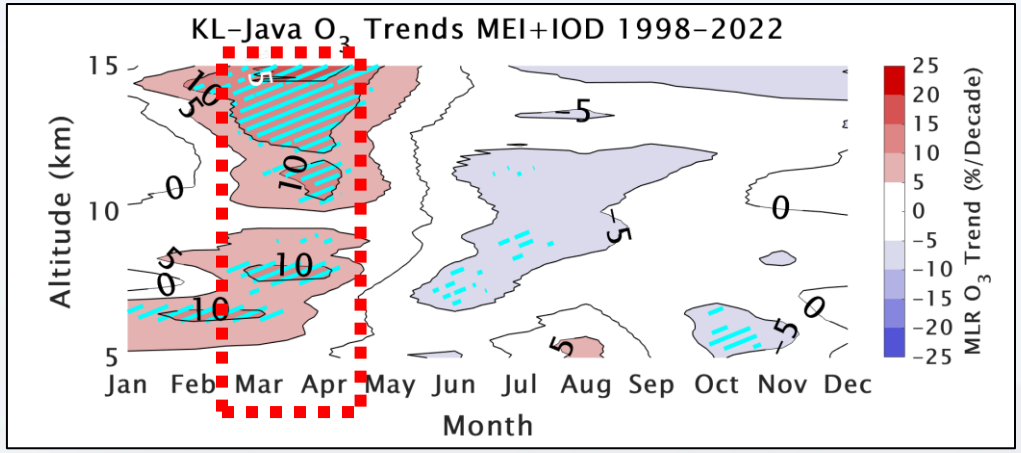


Computing Trends with Confidence

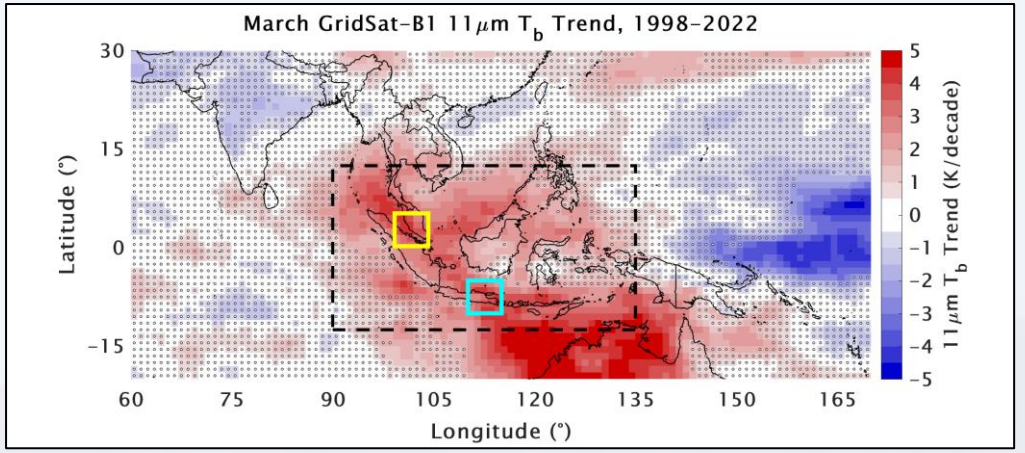
- Reference the ozone profiles to the tropopause height
- The trends disappear (**bottom**)!
- Dynamics and climate change signal, not ozone loss, is the cause
- Important for activities such as LOTUS



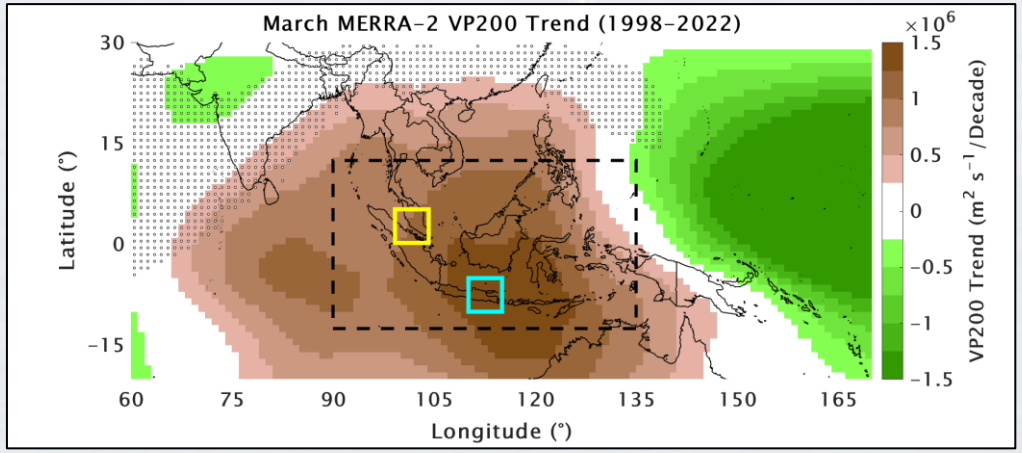
Computing Trends with Confidence



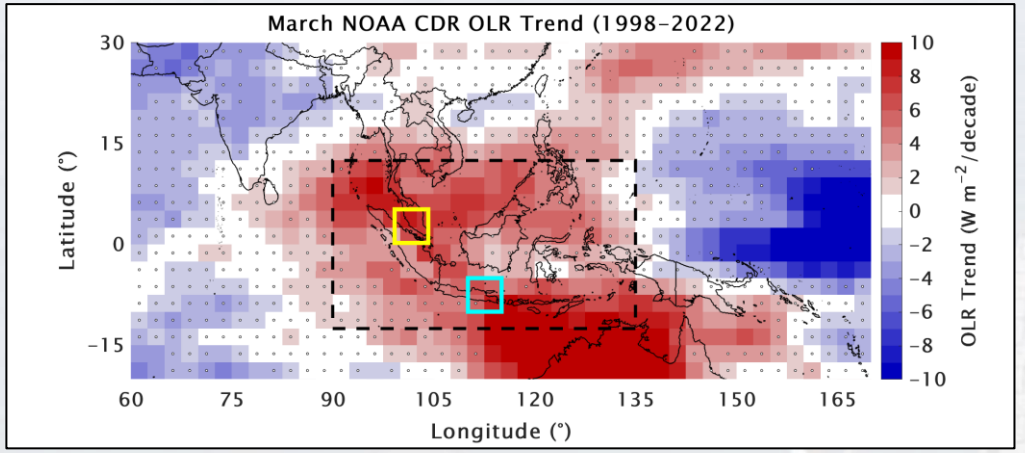
Large early-year FT positive ozone trends 1998-2022



Warming cloud tops = less convection



Increasing wind convergence= less convection

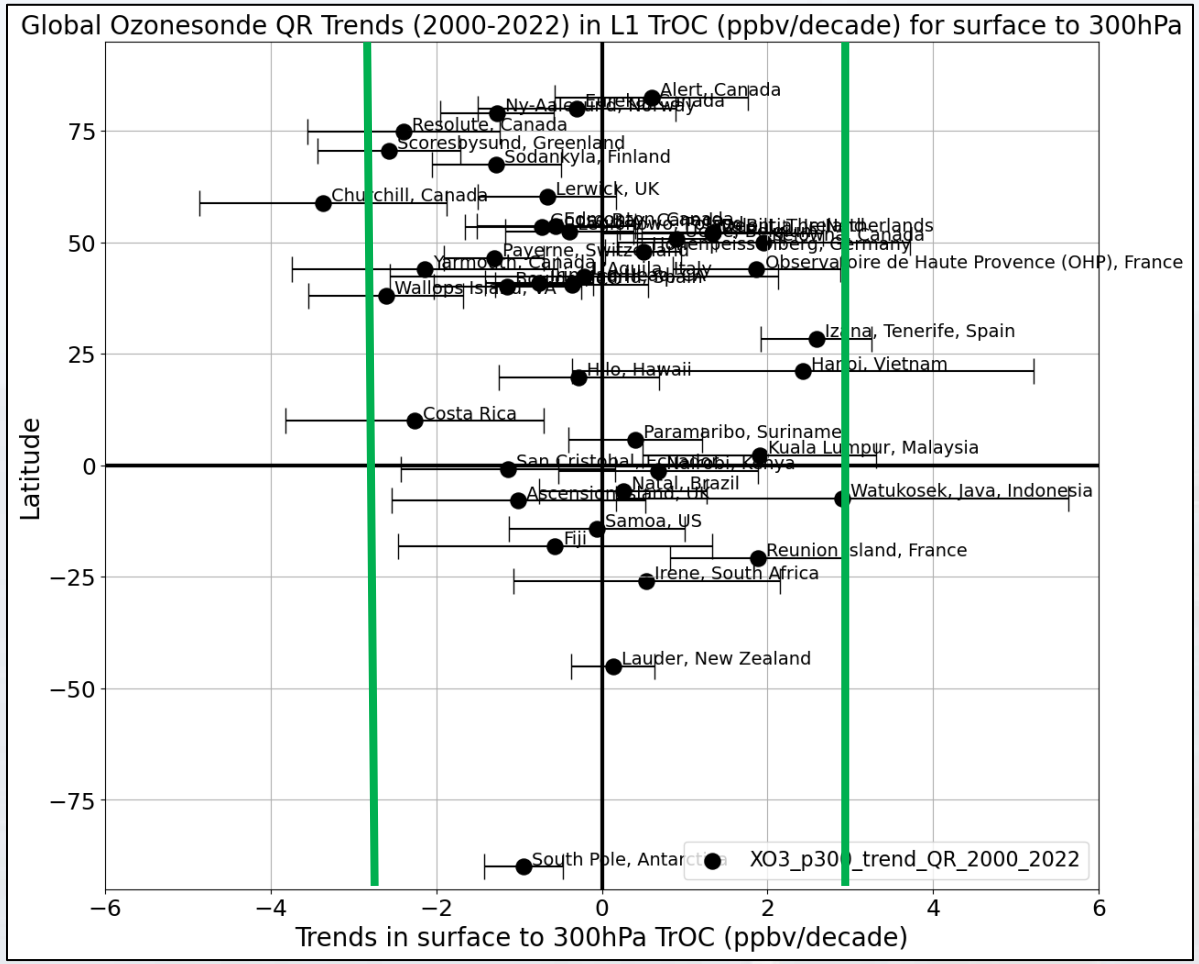


Increasing OLR= less convection

- Use the data for ***attribution*** of ozone trends!
- Decreasing convection → Large FT O_3 trends
- Stauffer et al. (2024; ACP, TOAR-II SI)

Computing Trends with Confidence

- Global tropospheric ozone trends computed within the TOAR-II (IGAC) HEGIFTOM Working Group
- Also includes FTIR, Dobson Umkehr, Lidar, IAGOS aircraft profiles
- Modest trends from surface-300 hPa, with largest increases in SE Asia
- A reference for models and satellites!

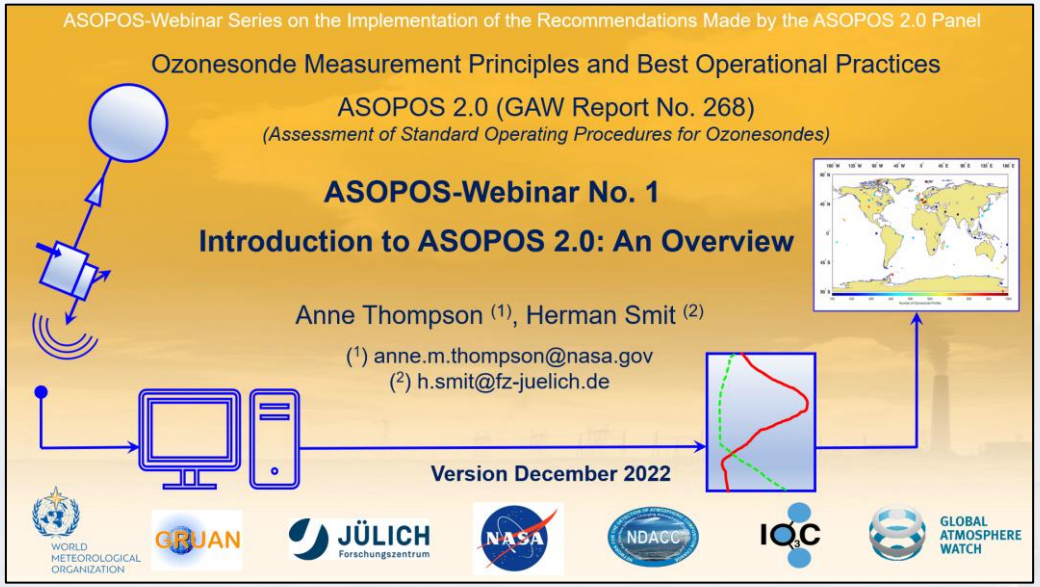


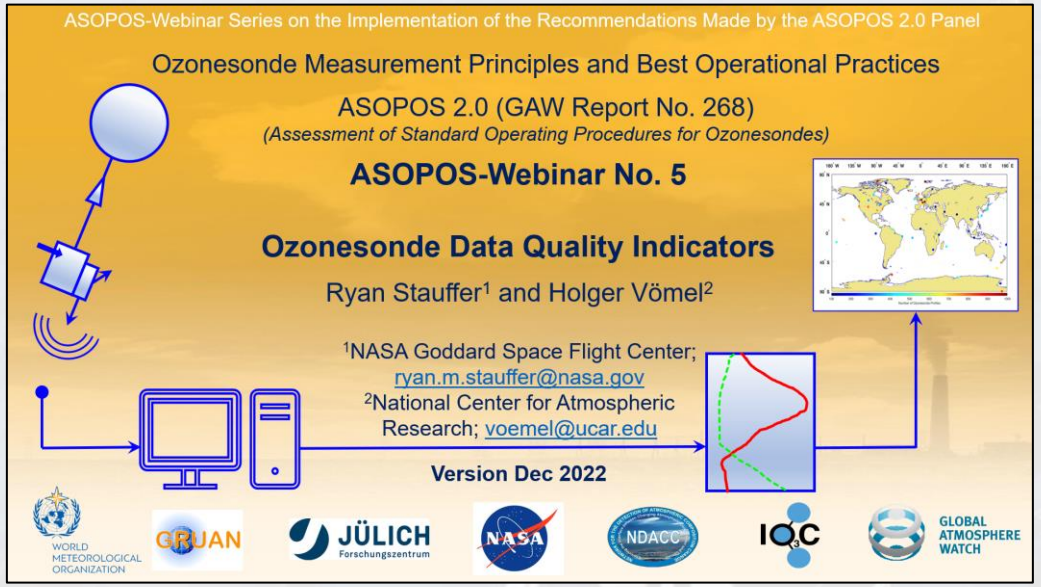
Global tropospheric ozonesonde trends from TOAR-II HEGIFTOM WG. ***Within ±3 ppbv/decade!***

DAQ is an Ongoing Process…

- Remaining Issues (**ASOPOS 2.1**):
  1. Handling/existence of the ECC "background current"
  2. Time response correction (Vömel et al., 2020; Smit et al., 2024)
  3. Bias found in one of two ECC manufactures
  4. Near-real time QA procedures?
  5. Capacity building

- **#5**: WMO/GAW Report no. 268 webinars now online. Holding virtual regional meetings with *all* global ozonesonde stations

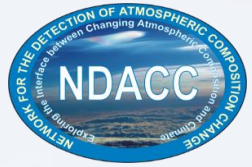




Summarizing 30+ Years of Success

- Lack of ozonesonde SOPs and differing procedures within the network led to large biases
- JOSIE and BESOS Experiments→ASOPOS Prescribes SOPs
- Homogenized data show excellent agreement with satellites
- Ozonesonde trends can be computed with confidence:
  - Tropical lower stratospheric ozone declines are a result of a rising tropopause
  - SE Asia positive free-tropospheric trends linked to declining convection
  - Overall global tropospheric trends are modest, but highest in SE Asia

References



Thank you to NASA HQ for its continued support of SHADOZ, to local PIs and station operators, and to the hundreds of ozone community members for using ozonesonde network data for exciting science!

Stauffer, R. M., et al., *Atmos. Chem. Phys.*, doi: https://doi.org/10.5194/acp-24-5221-2024, 2024
Stauffer, R. M., et al., *Earth Space Sci.*, 9, doi: 10.1029/2022EA002459, 2022
Smit, H. & A. M. Thompson, Editors, ASOPOS 2.0 WMO/GAW Report #268, 2021
Thompson, A. M., et al., *J. Geophys. Res* ,126, doi: 10.1029/2021JD034691, 2021
Tarasick, D. W. et al., *Earth Space Sci.,* doi: 10.1002/2019EA000914, 2021
Stauffer, R. M., et al., *Geophys. Res. Lett.,* doi: 10.1029/2019/GL086791, 2020
Vömel, H., et al., *Atmos. Meas. Tech.,* https://doi.org/10.5194/amt-13-5667-2020, 2020
Thompson, A. M., et al., *Bull. Am. Meteor. Society,* doi.org/10.1175/BAMS-17-0311, 2019
Witte, J. C., et al., *J. Geophys. Res.,* 124, doi: 10.1002/2018JD030090, 2019
Sterling, C. W., et al., *Atmos. Meas. Tech.,* amt-2017-397, 2018
Witte, J. C., et al., *J. Geophys. Res.,* 123, doi: 10.1002/2017JD027791, 2018
Thompson, A. M., et al., J. Geophys. Res., 122, 13000-13025, doi: 10.1002/2017JD027406, 2017
Witte, J. C., et al., *J. Geophys. Res.,* 122, 6611-6636, doi: 10.1002/2016JD026403, 2017