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Maintaining High Quality Ozonesonde Datasets for O_3 Trends Studies: Using NASA Wallops Flight Facility and SHADOZ Dual Soundings and Long-term Records for Demonstration

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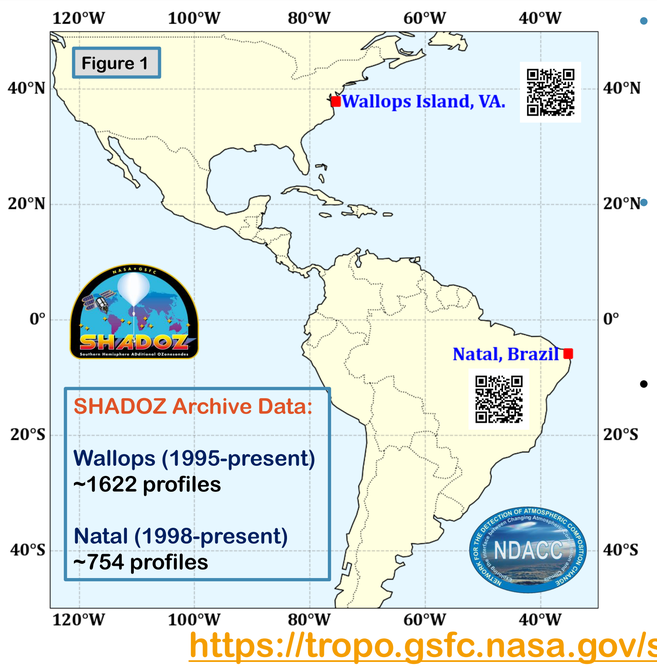
Wallops and Natal Ozone Measurements



- NASA Wallops Flight Facility (WFF; Wallops Island, VA.; 37.9N, 75.5W) is longest continuously operating ozonesonde station in continental US (since 1970; Figure 1).
- SHADOZ Natal station (Natal, Brazil; 5.4S, 35.4W) is longest running ozonesonde measurement station in tropics (since 1978; Figure 1).
- Both stations use similar instrumentation for their soundings including Science Pump Corporation (SPC) electrochemical concentration cell (ECC) ozone sensors; both also have long-term Dobson records.

https://tropo.gsfc.nasa.gov/shadoz/Wallops.html
https://tropo.gsfc.nasa.gov/shadoz/Natal.html

- Dating back to digital measurement era (since 1995 for WFF), WFF and Natal ozone profiles are reprocessed and homogenized based on WMO GAW guidelines (*Smit et al.*, 2021) to remove known biases, improve overall accuracy, and provide uncertainties for each profile (*Witte et al.*, 2018; *Witte et al.,* 2019; available in SHADOZ V06 format (link above).
- WFF has legacy of evaluating ozonesondes w/ dual sonde launches testing Standard Operating Procedures (SOPs), radiosonde/ozonesonde systems and various combinations of ECC sensors and sensing solution type (SST) formulae.
- Both stations are part of Network for Detection of Atmospheric Composition Change (NDACC) and data can be found at NDACC Data Housing Facility (DHF).
- Non-homogenized data for pre-digital era can be found at WOUDC. Digital era record (current data) is in SHADOZ V06 format on the SHADOZ archive.

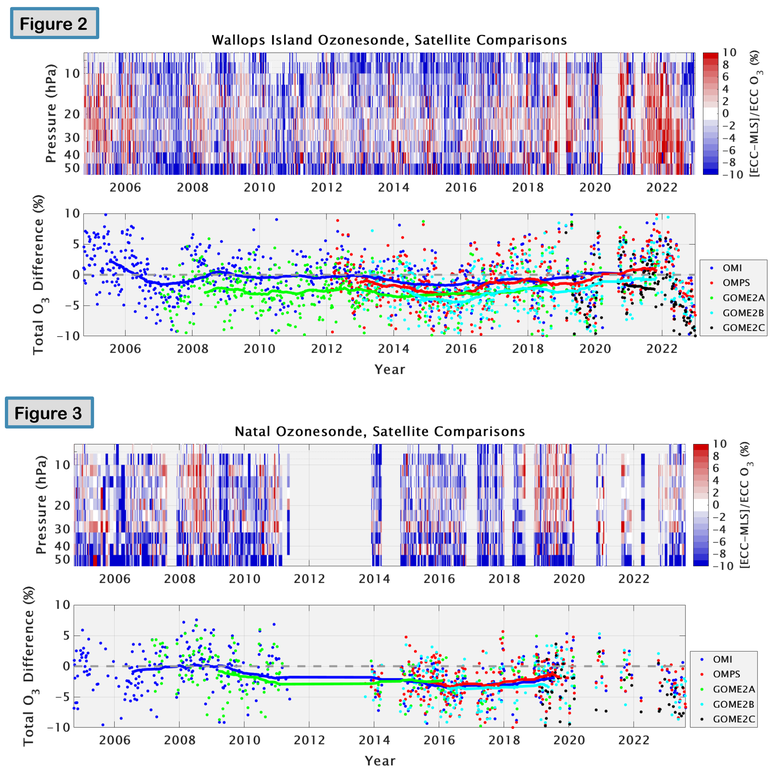
Wallops and Natal Ozone Teams and Measurements

NASA GSFC Greenbelt and WFF Team:
Row 1 (left-to-right): Dr. Anne Thompson, Rhonie Wolff, and Dr. Debra Kollonige.
Row 2 (left-to-right): Dr. Ryan Stauffer, Dr. Niko Fedkin, Chris Wright, and Tom Northam.

INPE Natal Brazil Team (left-to-right):
Edmilson Silva, Tercio Penha, Renan Gadelha, and Dr. Francisco Raimundo.
Not shown are Dr. Maria Paulete Pereira Martins and Joao Vitor Batista.

- The well-established WFF and Natal ozonesonde systems are comprised of SPC ECC sensors filled with a 1% KI - full buffer SST, interfaced with a Lockheed Martin Sippican (LMS) radiosonde.
- WFF and Natal ozone timeseries below shows the long-standing stability and high-quality nature of these ozone datasets.
- Radiosonde systems were upgraded to new state-of-the-art Vaisala systems and operational radiosondes switched to RS-41 in 2022 for WFF and 2024 for Natal.

Figure 2



- Ozonesonde: SPC
- Radiosonde: LMS
- Solution: 1% KI - full buffer SST
- Background current: Before launch
- Pump efficiency corr: WFFAVG
- Flowrate corr: Temp. only-based

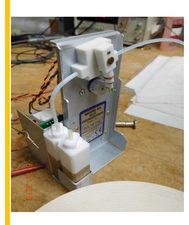


Figure 3

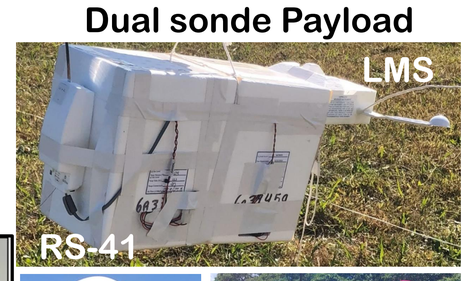
- Ozonesonde: SPC
- Radiosonde: Vaisala RS-41
- Solution: 1% KI - full buffer SST
- Background current: Before launch
- Pump efficiency corr: WFFAVG
- Flowrate corr: Temp. only-based

Time-series of Wallops (Figure 2) and Natal (Figure 3) ECC ozonesonde and satellite comparisons. Top panel in each compares ECC ozonesondes and Aura MLS stratospheric O_3 profiles (%); bottom panels compare sondes with satellite TCO. Colors on top panels indicate where ECC O_3 is greater (red shades) or less (blue) than MLS.

Dual Sonde Launches: Testing New Vaisala Systems

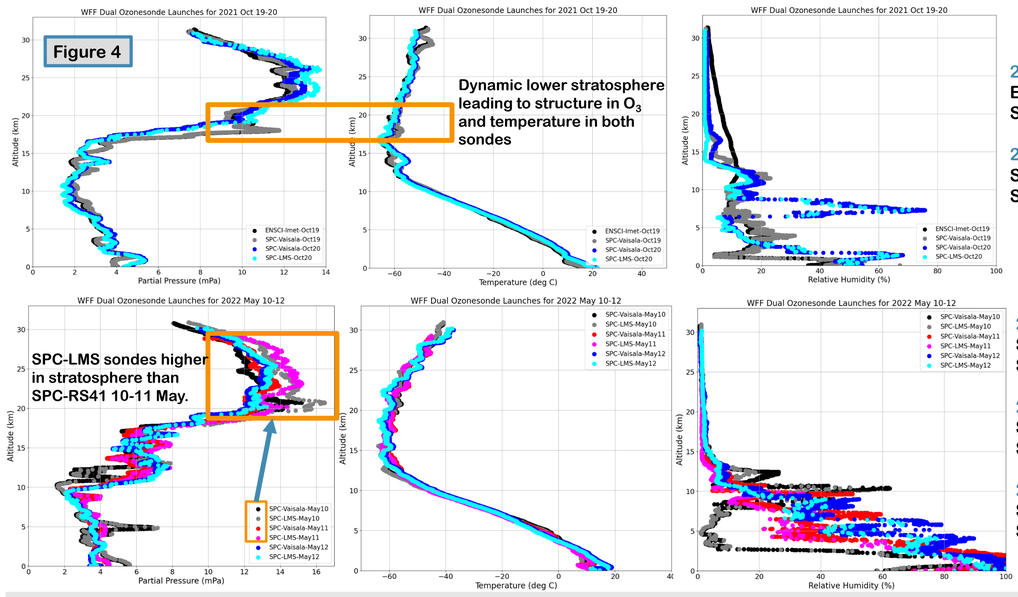
- Goals for testing the two radiosondes:
  - (1) Maintain consistency in data before and after change to Vaisala RS-41.
  - (2) Create SOPs for new Vaisala ground system while keeping standard practices.

Dual sonde Payload



Results of Dual Sonde Launches: Wallops and Natal

- Greenbelt Team visited the WFF team in Oct 2021/May 2022 and the Natal Team in March 2024 to prepare and launch multiple dual sondes (LMS & RS-41 w/ SPC). The profiles (Figure 4 and 5) and comparisons of total column ozone (TCO; Figure 6) are below.



2021-Oct-19
ENSCI-IMet #2Z33310
SPC-RS41 #6A37295

2021-Oct-20
SPC-RS41 #6A37294
SPC-LMS #6A39459

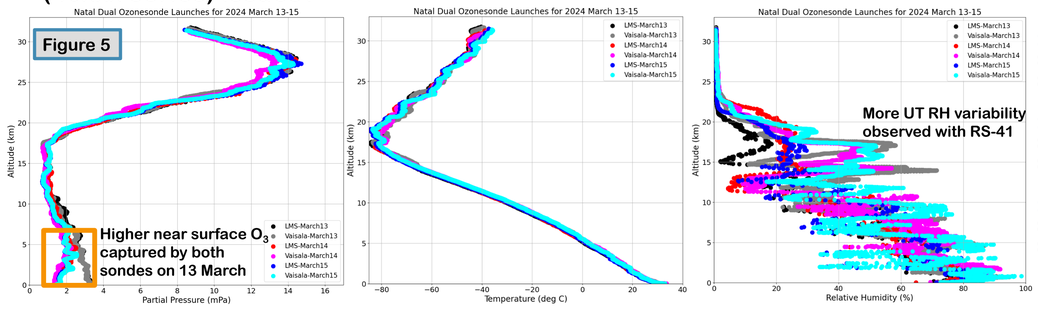
2022-May-10
SPC-RS41 #6A40274
SPC-LMS #6A40273

2022-May-11
SPC-RS41 #6A40276
SPC-LMS #6A40275

2022-May-12
SPC-RS41 #6A37286
SPC-LMS #6A37285

Figure 4: Partial pressure (mPa), temperature (deg C), and relative humidity (%) profiles from each dual sonde launch Oct 2021 and May 2022 at Wallops.

- Oct 2021 profiles have ~1% TCO diff b/w sondes and w/ satellites or Dobson.
- 10-11 May 2022 profiles have larger differences ranging from 3-7%. Perhaps SPC ozonesonde (40xxx series) issues?

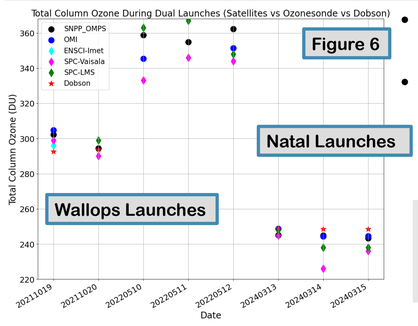


2024-March-13
SPC-RS41 #6A41257
SPC-LMS #6A41320

2024-March-14
SPC-RS41 #6A41258
SPC-LMS #6A41322

2024-March-15
SPC-RS41 #6A41259
SPC-LMS #6A41323

Figure 5: Partial pressure (mPa), temperature (deg C), and relative humidity (%) profiles from each dual sonde launch 13-15 March 2024 at Natal.



- On 13 March, ozonesonde comparisons ranged b/w 0-2% difference with Dobson and satellite TCO.
- On 14-15 March, LMS and Vaisala sondes were lower than Dobson TCO by ~4% and 5-9%, respectively; differences ranged between 4-7% with satellites. Vaisala sondes observed lower stratospheric ozone than LMS b/w 25-30 km.

Figure 6: TCO comparisons b/w ozonesondes, Dobson (red), SNPP OMPS (black) , and OMI (blue) during dual sonde launches at Wallops and Natal.

Wallops and Natal Tropospheric Ozone Trends

- WFF and Natal high-quality O_3 datasets are the "gold standard" for trends studies.
- WFF has negative TrOC (surface to 300 hPa) O_3 trends (-2.5 ppbv/dec while Natal has slightly positive (0.3 ppbv/dec) trends in Figure 7 (*Van Malderen et al.* 2024).

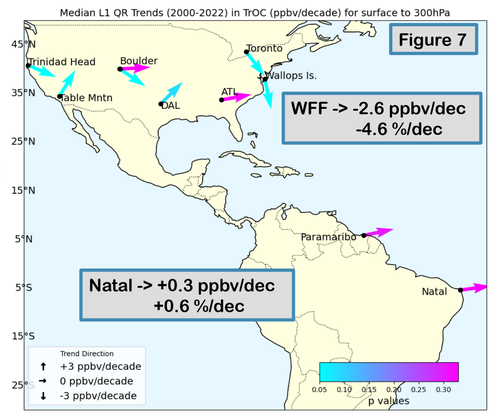


Figure 7: QR 50th percentile trends (ppbv/decade) for 2000-2022 column-avg tropospheric ozone for surface to 300hPa. Color map ranges +/- 3 ppbv/dec and arrow direction shows increase (up), decrease (down) or no trend (rightward). P-values show confidence in trends with blue colors indicating high confidence ($p<0.05$) trends.

Future Work and References

- Apply *Smit et al.* (2024) time response correction + calibration (TRCC) for fast and slow response of the ECC ozonesonde to the WFF and Natal datasets.
- Compare with conventional approach (along with their estimated uncertainties).

[1] J. C. Witte et al., The NASA Wallops Flight Facility digital ozonesonde record: Reprocessing, uncertainties, and dual launches, JGR: Atmospheres, 124, 3565–3582, https://doi.org/10.1029/2018JD030098, 2019.
[2] J. C. Witte, et al., First Reprocessing of Southern Hemisphere ADditional OZonesondes Profile Records: 3. Uncertainty in Ozone Profile and Total Column, JGR: Atmospheres, 123, 6, 3243-3268, https://doi.org/10.1002/2017JD027791, 2018.
[3] H. G. J. Smit, D. Poyraz, R. Van Malderen, A. M. Thompson, D. W. Tarasick, R. M. Stauffer, B. J. Johnson, and D. E. Kollonige, New insights from the Jülich Ozone Sonde Intercomparison Experiment: calibration functions traceable to one ozone reference instrument, Atmos. Meas. Tech., 17, 73–112, https://doi.org/10.5194/amt-17-73-2024, 2024.
[4] Smit, H. G. J., Thompson, A. M., and the ASOPOS 2.0 Panel: Ozonesonde Measurement Principles and Best Operational Practices, WMO Global Atmosphere Watch Report Series, No. 268, World Meteorological Organization, Geneva, https://library.wmo.int/idurl/4/57720 (last access: 10 December 2023), 2021.
[5] Van Malderen, R., Thompson, A. M., Kollonige, D. E. et al. Global Ground-based Tropospheric Ozone Measurements: Reference data and trends from individual sites (2000-2022) from the HEGIFTOM homogenized ground-based profile ozone data sets, Atmos. Chem., Phys., submitted, 2024.