Aerosols and Ocean Science Expeditions (AEROSE) in Support of NOAA Satellite Cal/Val

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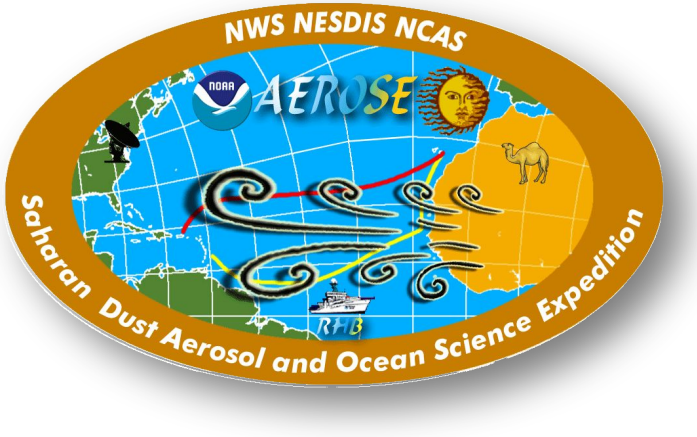


2021 PIRATA-24/TAV Meeting (Virtual)
May 2021

Acknowledgments

- The **NOAA Joint Polar Satellite System (JPSS-STAR) Office** (*L. Zhou, M. D. Goldberg*), and the **NESDIS/STAR Satellite Meteorology and Climatology Division** (*S. Kalluri, I. Csiszar*)
- The **Howard University NOAA Center for Atmospheric Sciences (NCAS)** supported by
  - The NOAA Minority Serving Institutions Educational Partnership Program (EPP)
  - National Science Foundation Career Grant (ATM-9703167)
  - NASA Grant (NG-1224)
- The **NOAA PIRATA Northeast Extension (PNE)** (*R. Perez, R. Lumpkin, G. Foltz, C. Schmid,* NOAA/AOML)
- **NOAA/PSL** (*D. Wolfe, L. Bariteau*)
- **UM/RSMAS** (*P. Minnett, M. Szczodrak, M. Izaguirre*)
- **Sounder validation** (*C. Barnet, B. Sun, M. Divakarla, A.K. Sharma, W. Wolf, et al.*)
- The numerous students, officers and crew, who participated in, and contributed to, the campaigns over the years…

Outline

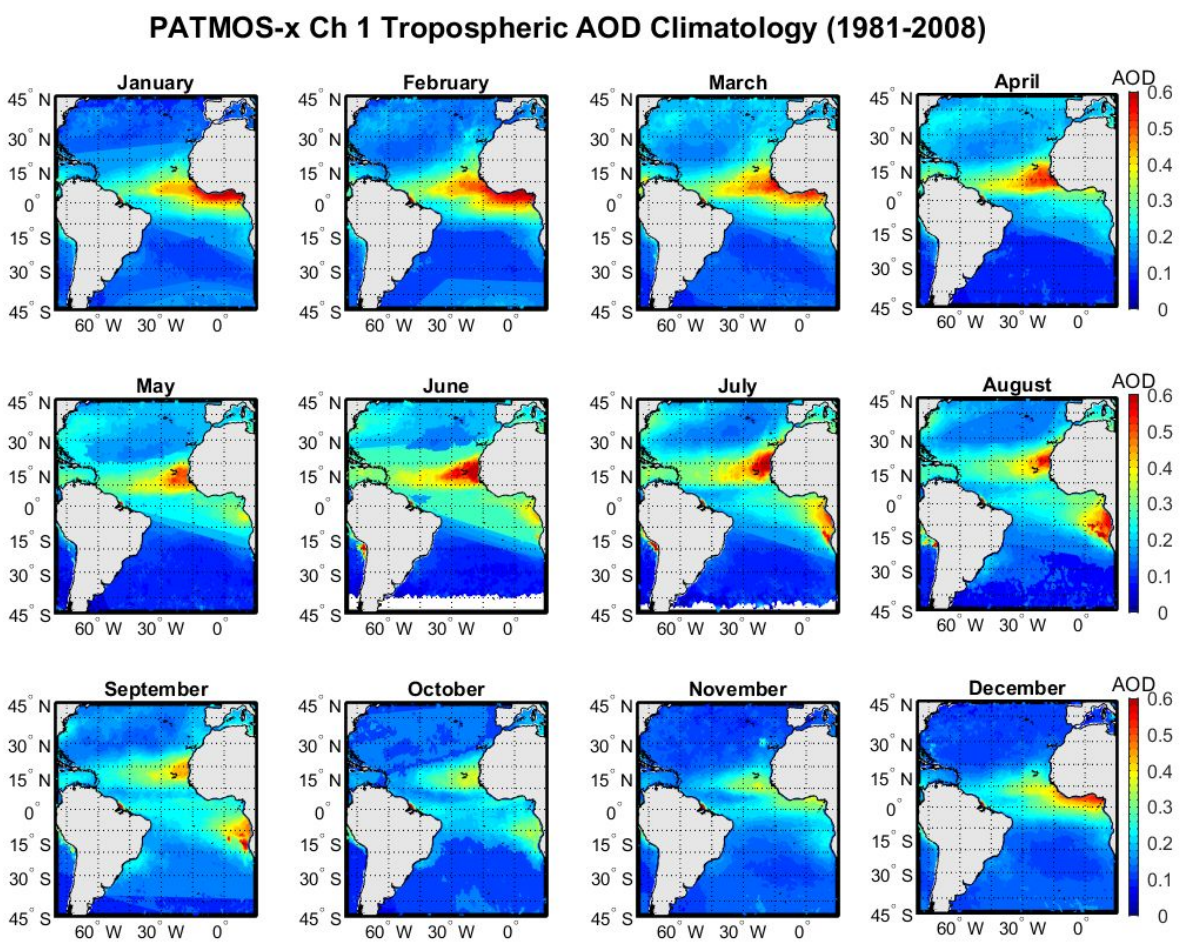
- **PNE/AEROSE Overview**
  - AEROSE campaigns
  - AEROSE support of NOAA satellite remote sensing
- **NOAA Satellite Calibration/Validation (Cal/Val)**
  - Validation of the NOAA operational sounders
    - Temperature (*T*) profile
    - Moisture (H_2O) profile
    - Ozone (O_3)profile
- **2019 PNE/AEROSE Campaign Highlights**
  - Campaign overview
  - Observation of the March 2019 Saharan Dust outflow event
  - Exercising the use of NUCAPS for underway guidance
- **Summary and Future Work**

Aerosols and Ocean Science Expeditions (AEROSE)
in Support of NOAA Satellite Cal/Val

NOAA PNE/AEROSE OVERVIEW

NOAA PNE/AEROSE Overview

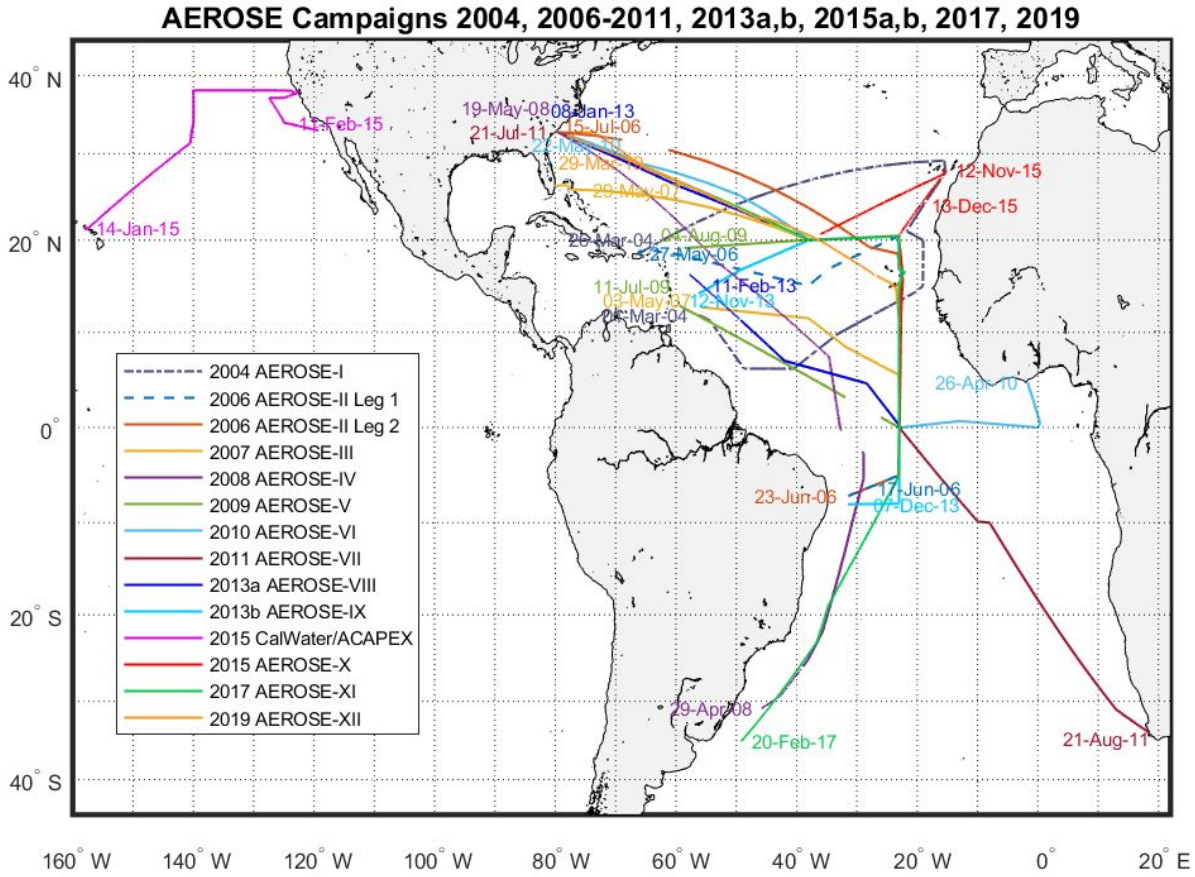
- **NOAA Aerosols and Ocean Science Expeditions (AEROSE)** are ship-based intensive field campaigns conducted since 2004 in collaboration with
  - **Howard University NOAA Center for Atmospheric Sciences (NCAS)** and **NOAA/NESDIS/STAR**
  - NOAA **PIRATA Northeast Extension (PNE)** buoy project
  - **NOAA/PSL** (formerly ESRL/PSD) and **UM/RSMAS**
- The **PNE main mission** is charged with servicing moored TAO buoys in the tropical Atlantic
- The PIRATA buoy region is of interest in terms of **meteorology** (over multiple space-time scales) as well as **air-quality**
  - **Saharan air layers (SAL)** and **dust aerosol** outflows
  - Main development area for **Atlantic tropical cyclones**
  - **Anthropogenic biomass burning** aerosols and trace gases, including tropospheric ozone



AEROSE Campaigns to Date

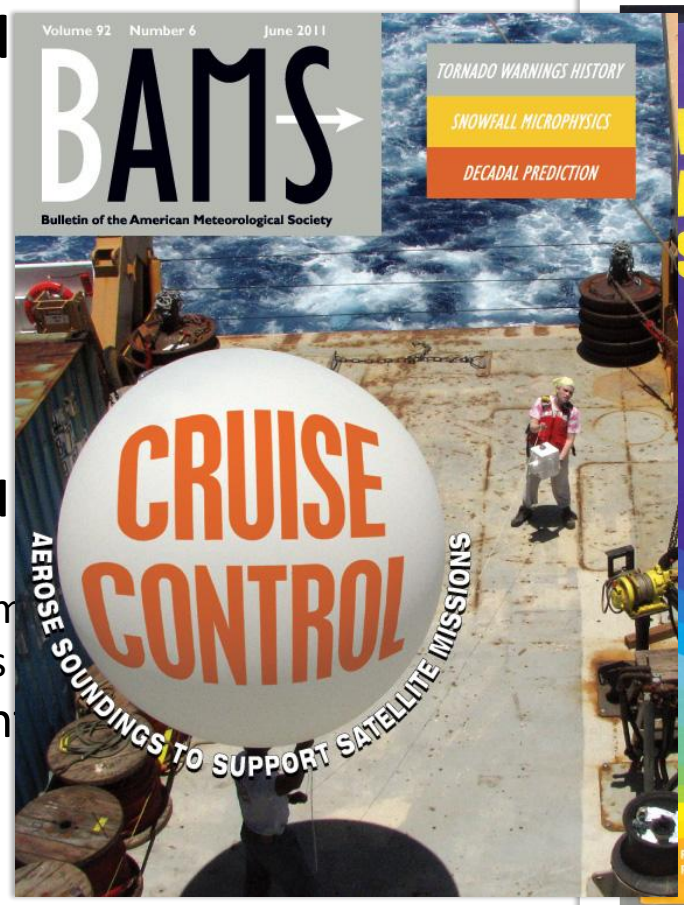
- **Multi-year ship-based intensive field campaigns** (*Morris et al.* 2006):
  - AEROSE-I (March 2004)
  - PNE/AMMA/AEROSE-II (Jun-Jul 2006)
  - PNE/AEROSE-III (May 200)
  - AEROSE-IV (Apr-May 2008)
  - PNE/AEROSE-V (Jul-Aug 2009)
  - PNE/AEROSE-VI (Apr-May 2010)
  - PNE/AEROSE-VII (Jul-Aug 2011)
  - PNE/AEROSE-VIII (Jan-Feb 2013)
  - PNE/AEROSE-IX (Nov-Dec 2013)
  - CalWater/ACAPEX (Jan-Feb 2015)
  - PNE/AEROSE-X (Nov-Dec 2015)
  - PNE/AEROSE-XI (Feb-Mar 2017)
  - PNE/AEROSE-XII (Mar 2019)
- **AEROSE** has yielded an unprecedented collection of *in situ* measurements of the Saharan air layer (SAL) and associated African dust and smoke outflows over the tropical Atlantic Ocean
  - Transport, microphysical evolution and regional impacts
  - Regional atmospheric chemistry and marine meteorology

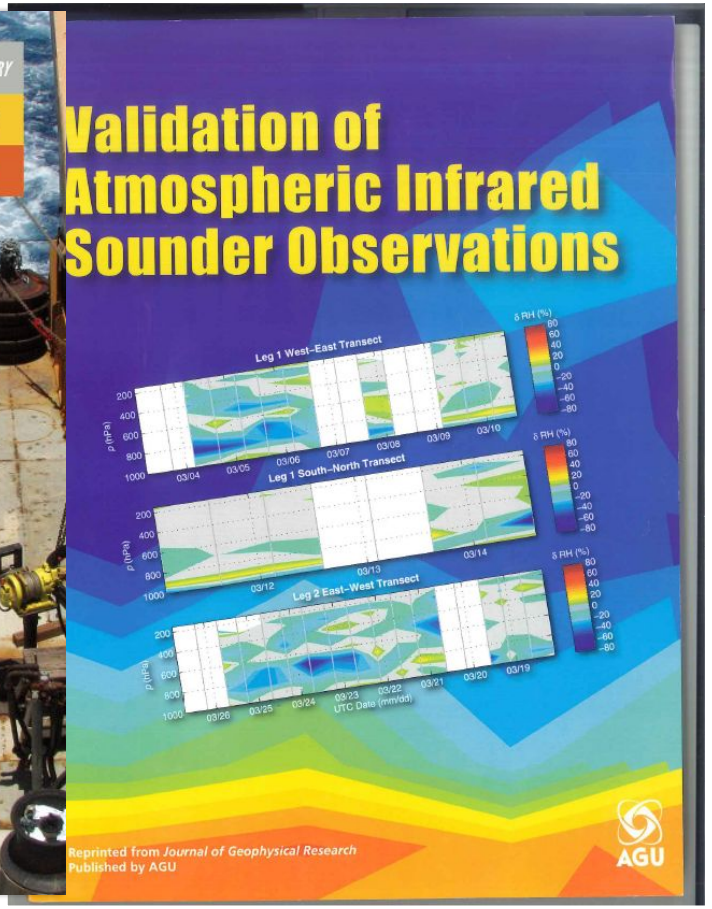
AEROSE Cruise Tracks (2004 to present)



AEROSE Support of NOAA Satellite Remote Sensing

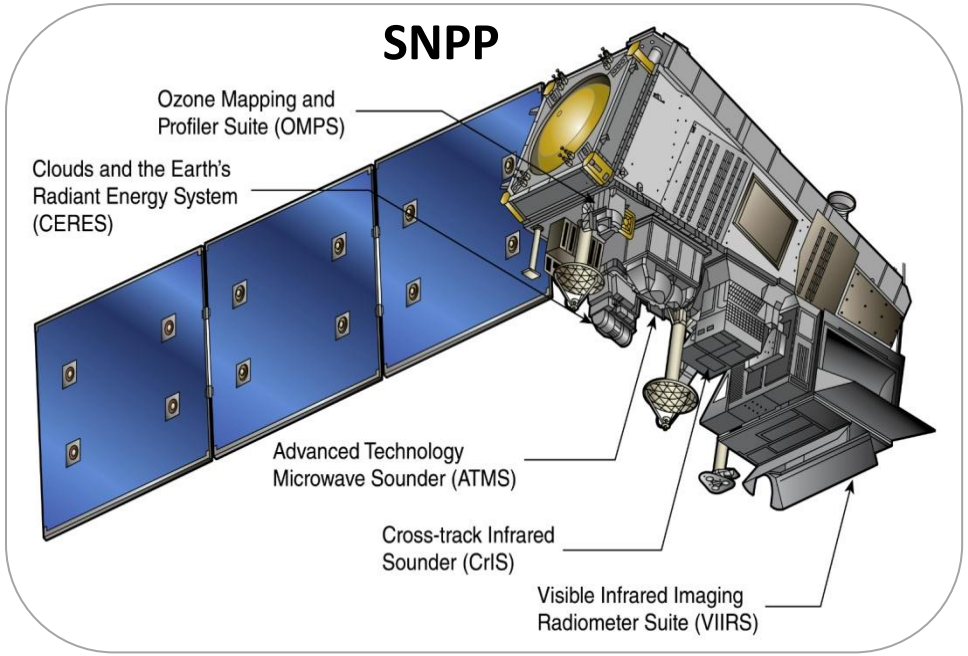
- **AEROSE** has been **extensively leveraged in support of NOAA satellite remote sensing**
  - Because the region is of meteorological interest, it is germane to **satellite sounder mesoscale-synoptic observing missions** (e.g., operational Advanced Weather Interactive Processing System, AWIPS)
  - **Ocean-based campaigns** are **gold standard** for satellite cal/val
    - Ocean surface is well-characterized and uniform
    - Largest impact of satellite data are over oceans
  - Data from AEROSE has formed an important component of the overall JPSS Intensive Cal/Val effort (*Nalli et al.* 2011, 2013, 2018a,b)





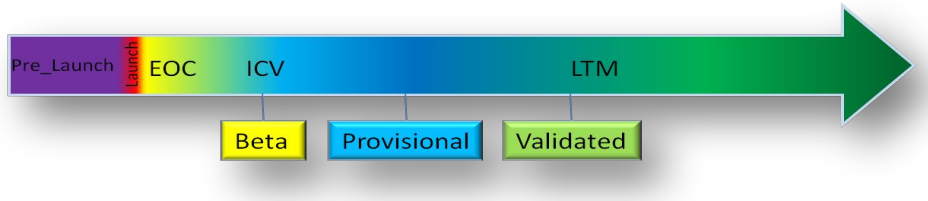
Aerosols and Ocean Science Expeditions (AEROSE)
in Support of NOAA Satellite Cal/Val

NOAA SATELLITE CALIBRATION/VALIDATION (CAL/VAL)



JSTAR Cal/Val Program and Sounder Validation Hierarchy

- **Calibration/Validation (Cal/Val)** is "the process of ascribing uncertainties to these radiances and retrieved quantities through comparison with correlative observations" (*Fetzer et al.,* 2003)
  - Validation enables development/improvement of algorithms
- **JSTAR Cal/Val Phases** (*Zhou etal.* 2016)
  - Pre-Launch ⟶ Early Orbit Checkout (EOC)
  - **Intensive Cal/Val (ICV)**
    - Validation of EDRs against multiple correlative datasets
  - **Long-Term Monitoring (LTM)**
    - Routine characterization of all EDR products and long-term demonstration of performance



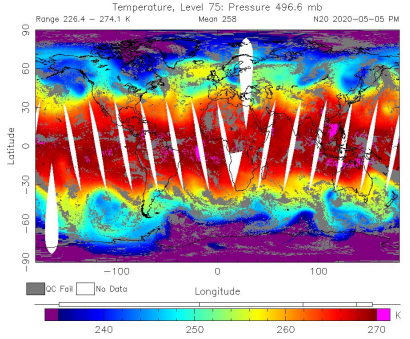
$T/H_2O/O_3$ Profile Validation Hiearchy
(e.g., *Nalli et al., JGR Special Section,* 2013)

1. **Numerical Model (e.g., ECMWF, NCEP/GFS) Global *Comparisons***
   - Large, global samples acquired from Focus Days
2. **Satellite Sounder EDR (e.g., AIRS, ATOVS, COSMIC) *Intercomparisons***
   - Global samples acquired from Focus Days (e.g., AIRS)
3. **Conventional PTU/O3 Sonde Matchup *Assessments***
   - WMO/GTS operational sondes or O3-sonde network (e.g., SHADOZ)
4. **Dedicated/Reference PTU/O3 Sonde Matchup *Assessments***
   - *Dedicated* for the purpose of satellite validation
   - Reference sondes: CFH, **GRUAN** corrected RS92/RS41
   - **ARM sites** (e.g., *Tobin et al.,* 2006), **AEROSE**, **CalWater/ACAPEX**, BCCSO, PMRF
5. **Intensive Field Campaign Closure-Experiment *Dissections***
   - Include dedicated sondes, ideally *not* assimilated into NWP models
   - Include ancillary datasets, ideally funded aircraft campaign(s)
   - **SNAP, AEROSE, RIVAL, CalWater**, JAIVEX, AWEX-G, EAQUATE

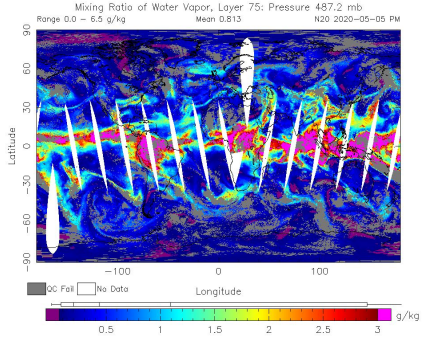
NOAA Unique Combined Atmospheric Processing System (NUCAPS) Algorithm

- **Operational algorithm**
  - **NOAA Enterprise Algorithm** for CrIS/IASI/AIRS (AST v5.9; after *Susskind, Barnet & Blaisdell,* 2003; *Susskind et al.,* 2011)
  - Global non-precipitating conditions
  - Atmospheric Vertical Temperature and Moisture Profiles (AVTP, AVMP)
  - **Trace gases: O_3, CO, CO_2, CH_4**
  - cf. *Divakarla et al.*, this session
- **Users**
  - **Weather Forecast Offices (AWIPS)**
    - Nowcasting / severe weather
    - Alaska (cold core)
  - NOAA/CPC (OLR)
  - NOAA/ARL (IR ozone, trace gases)
  - NOAA TOAST product (IR ozone EDR)
  - Basic and applied science research (e.g., *Pagano et al.,* 2014)

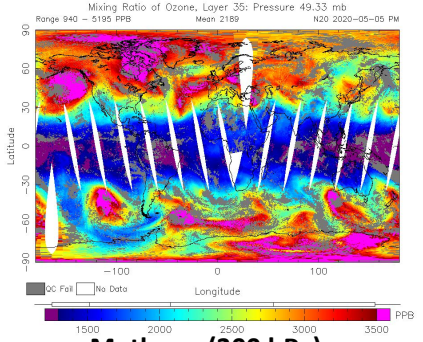
AVTP (500 hPa)



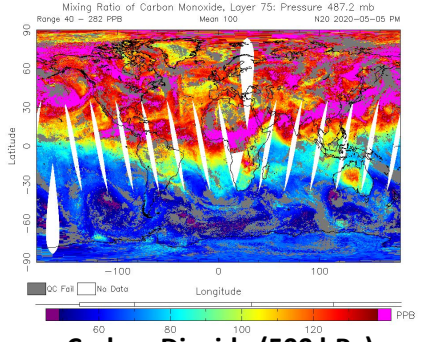
AVMP (500 hPa)



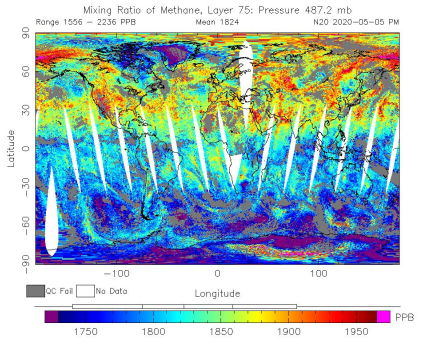
Ozone (50 hPa)



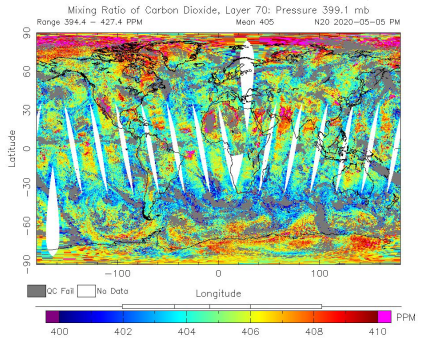
Carbon Monoxide (500 hPa)



Methane (300 hPa)



Carbon Dioxide (500 hPa)



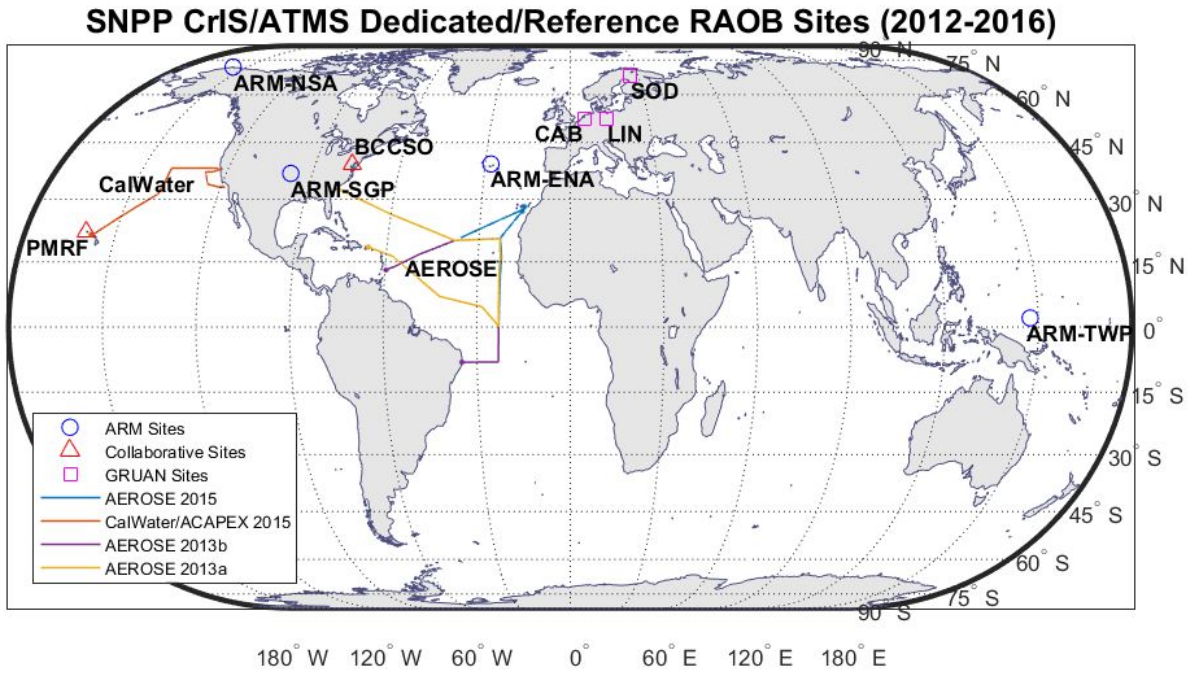
https://www.star.nesdis.noaa.gov/jpss/EDRs/products_Soundings_2018.php
http://www.ospo.noaa.gov/Products/atmosphere/soundings/nucaps/index.html

AEROSE Data for NOAA Operational Satellite Cal/Val

- **Cal/Val truth datasets** typically include:
  - Vaisala RS92 and RS41 radiosondes
  - ECC Ozonesondes (HU/NCAS)
  - MAERI (U-Miami)
  - Microtops sunphotometers
  - Vaisala ceilometer
- **Dedicated radiosondes and ozonesondes** are launched timed for LEO satellite overpasses
  - JPSS-Series NOAA-20 or SNPP
  - Metop-B or Metop-C (about 50/50)
  - NASA Aqua AIRS
- AEROSE RAOBs provide **fully independent truth** data
  - Not assimilated
  - Decoupled from land-based sites

SNPP Dedicated/Reference Radiosonde Collocation Sample

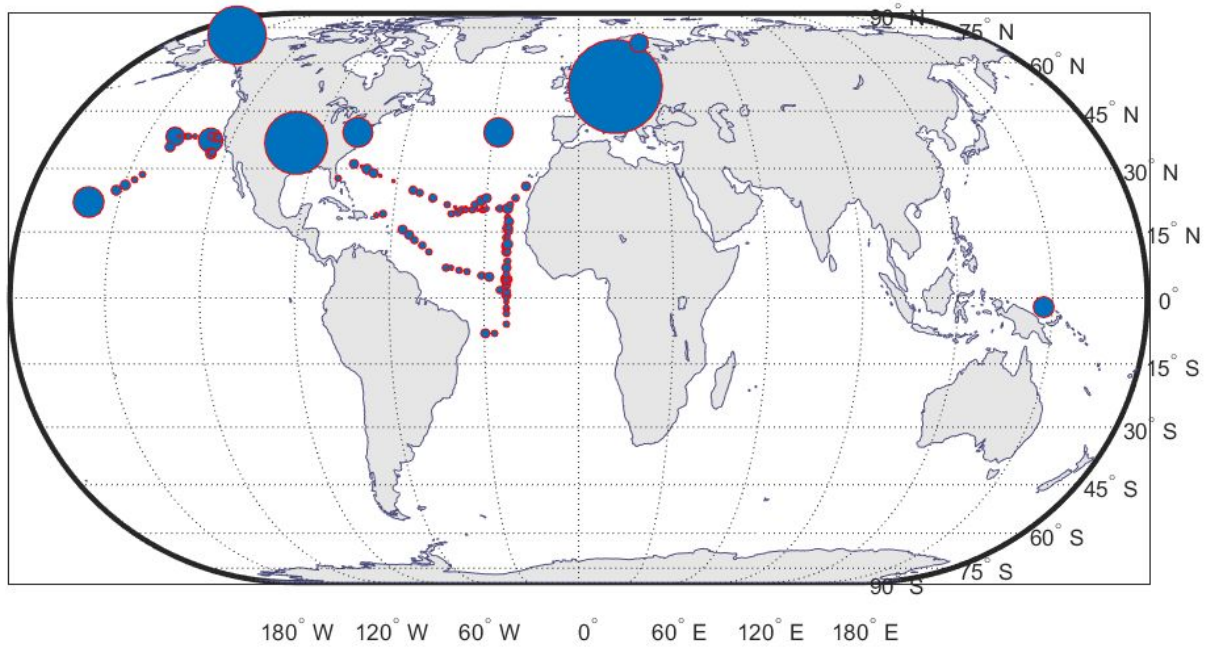
JPSS SNPP-Dedicated and GRUAN Reference RAOB Sites



Geographic Histogram

FOR Collocation Criteria

$\delta x \leq 75$ km, $-60 < \delta t < 0$ min



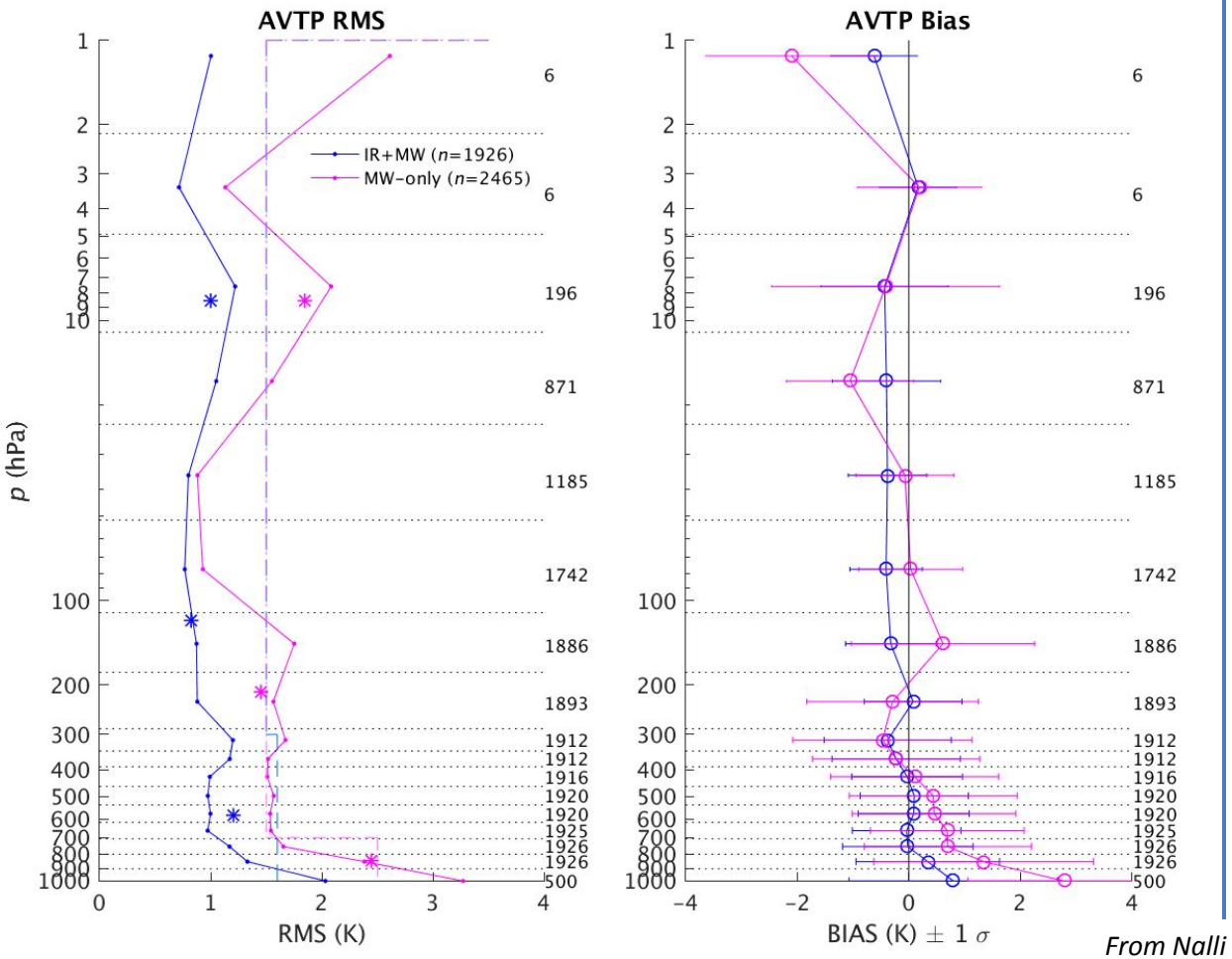
From Nalli et al. (2018)

SNPP NUCAPS Temperature and Moisture Profile Statistics

AVTP Versus RAOB

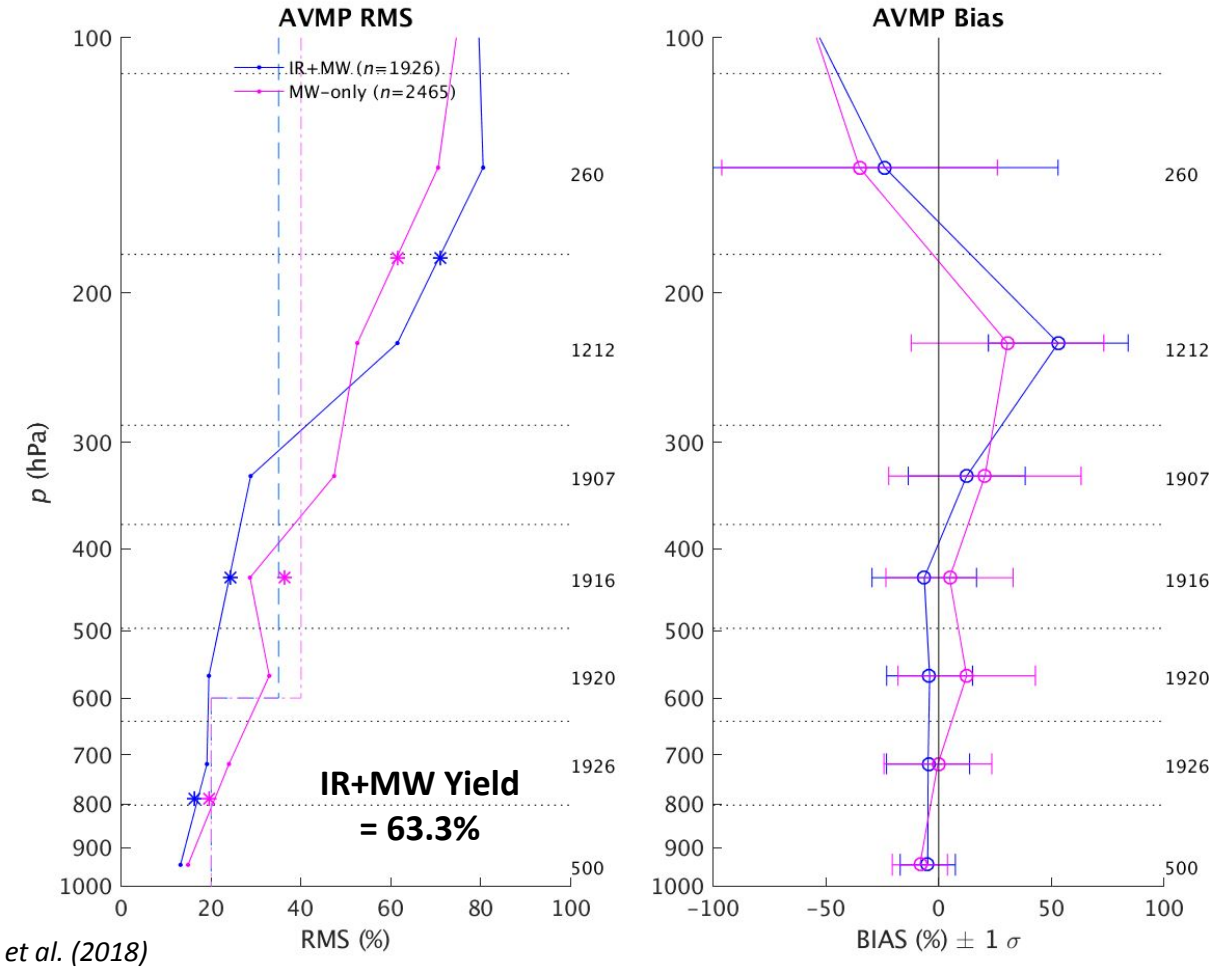
** Broad-Layer Stats (Per JPSS Level 1 Requirements)

IR+MW
MW-Only **



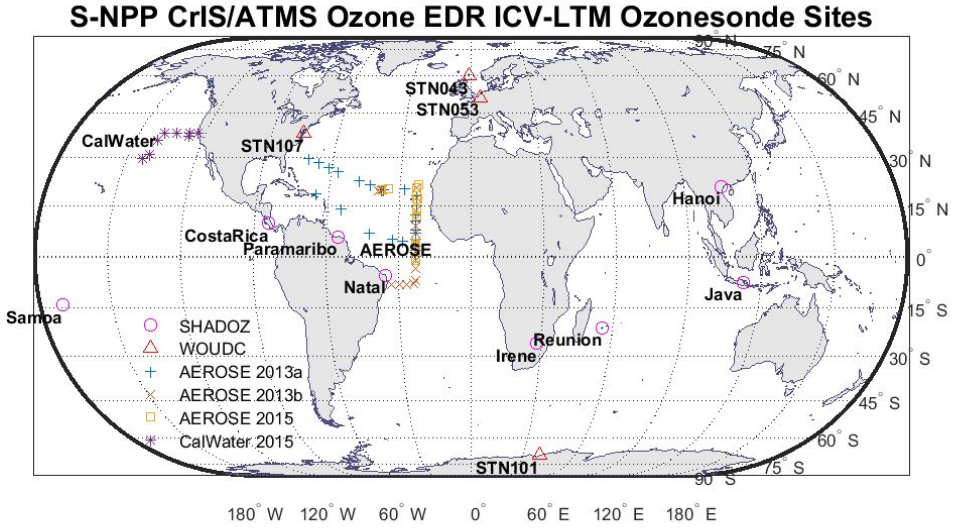
AVMP Versus RAOB

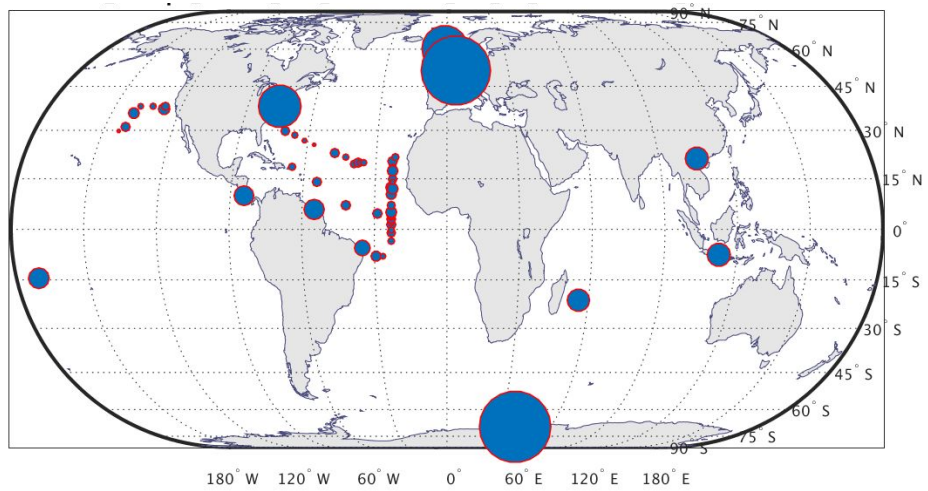
Broad Layer Stats (Per JPSS Level 1 Requirements)



From Nalli et al. (2018)

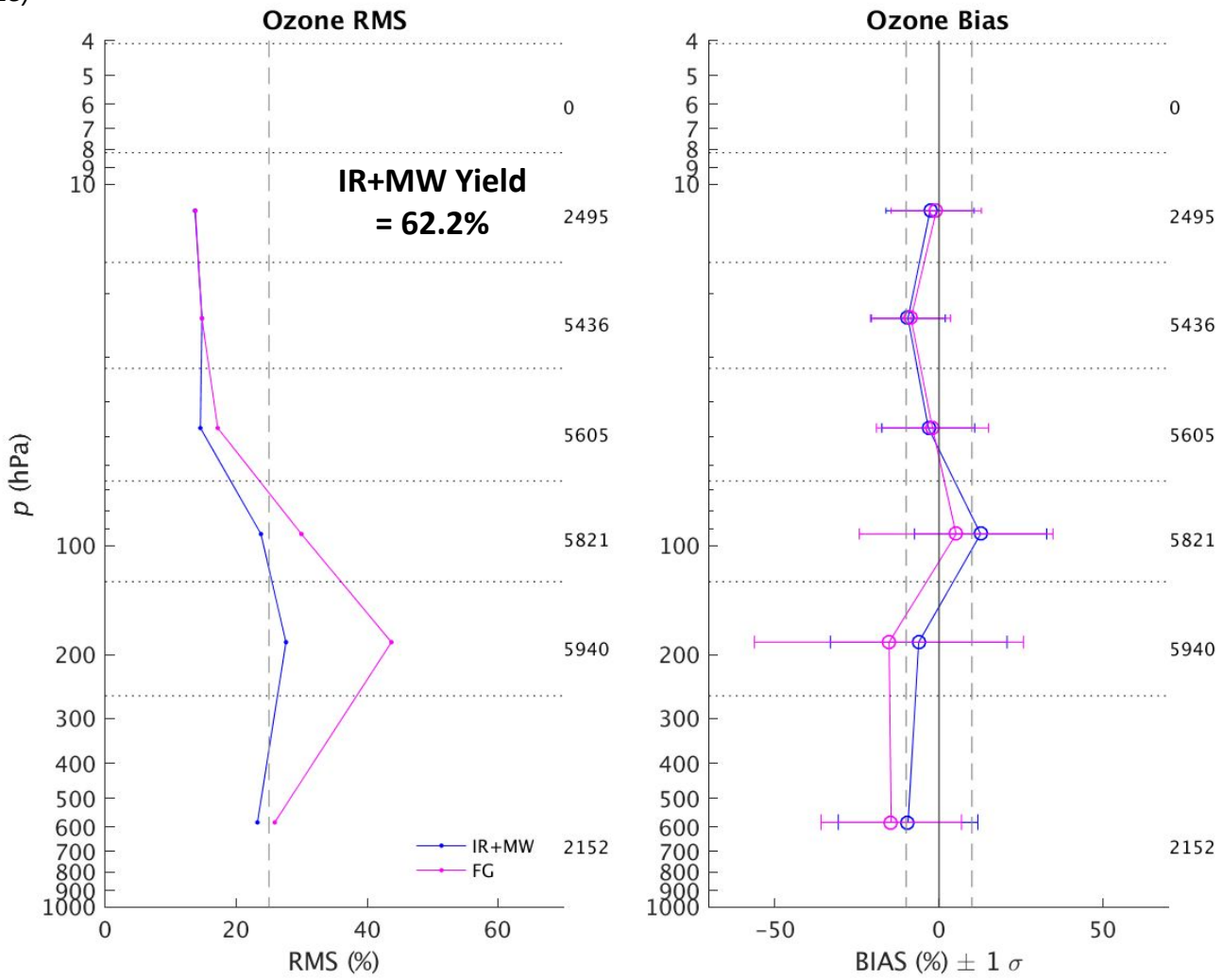
SNPP NUCAPS IR Ozone Profile EDR Validation





From Nalli et al. (2018)

Retrieval and *A Priori*



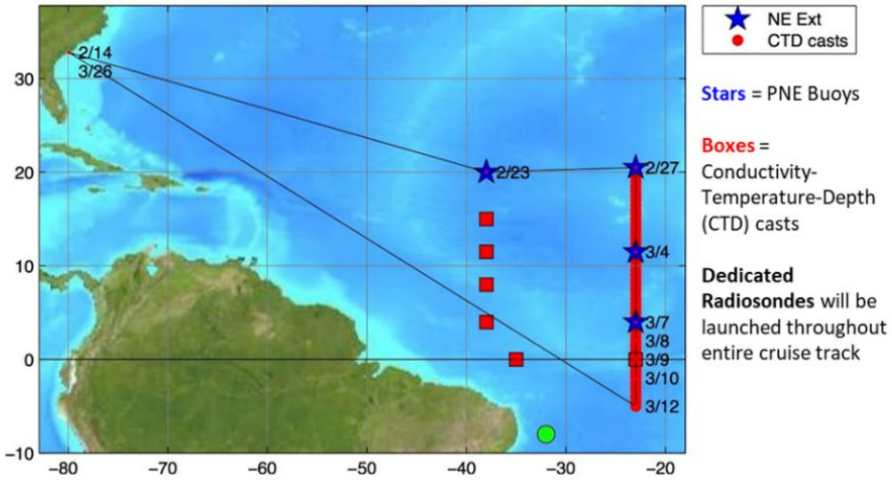
Aerosols and Ocean Science Expeditions (AEROSE)
in Support of NOAA Satellite Cal/Val

2019 PNE/AEROSE CAMPAIGN HIGHLIGHTS

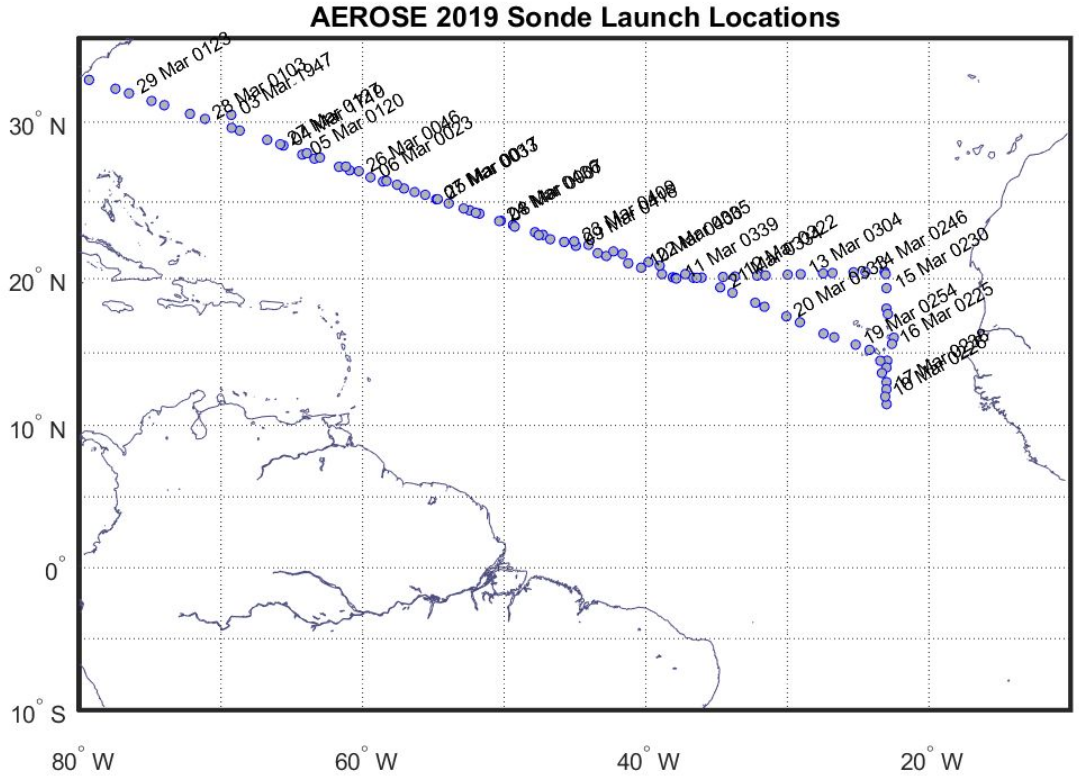
2019 AEROSE Campaign Summary

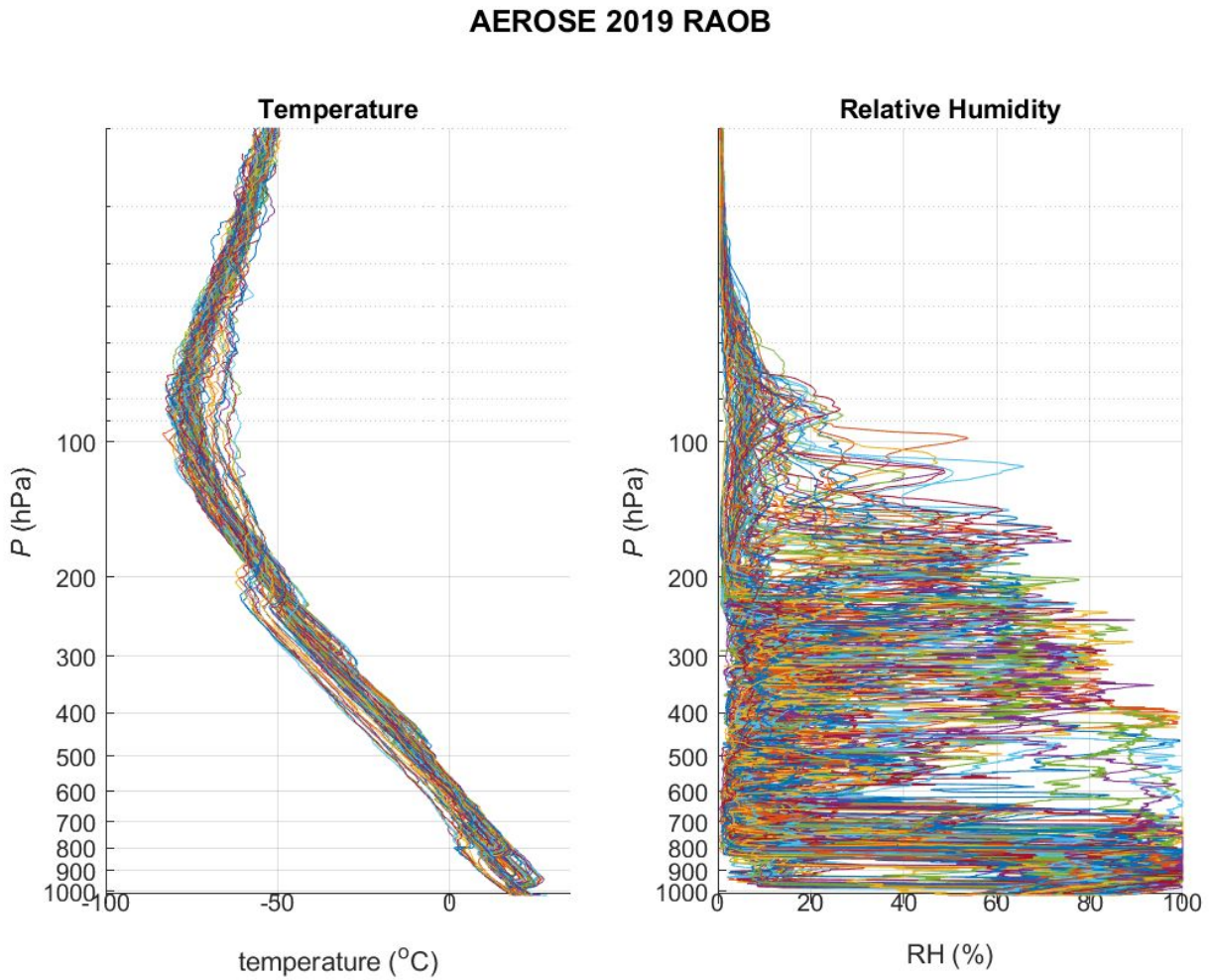
- The **2019 NOAA PNE/AEROSE** campaign was completed onboard the NOAA Ship *Ronald H. Brown*
  - **1–29 March 2019,** Charleston, SC to Charleston, SC
  - The cruise departure was delayed by 7 days due to engine problems
  - Return was 2 days earlier due to a sick crewman and “Barrel Man”
  - In spite of these setbacks, the cruise track took us within a significant **Saharan dust outflow plume**

2019 PNE/AEROSE Planned Cruise Track

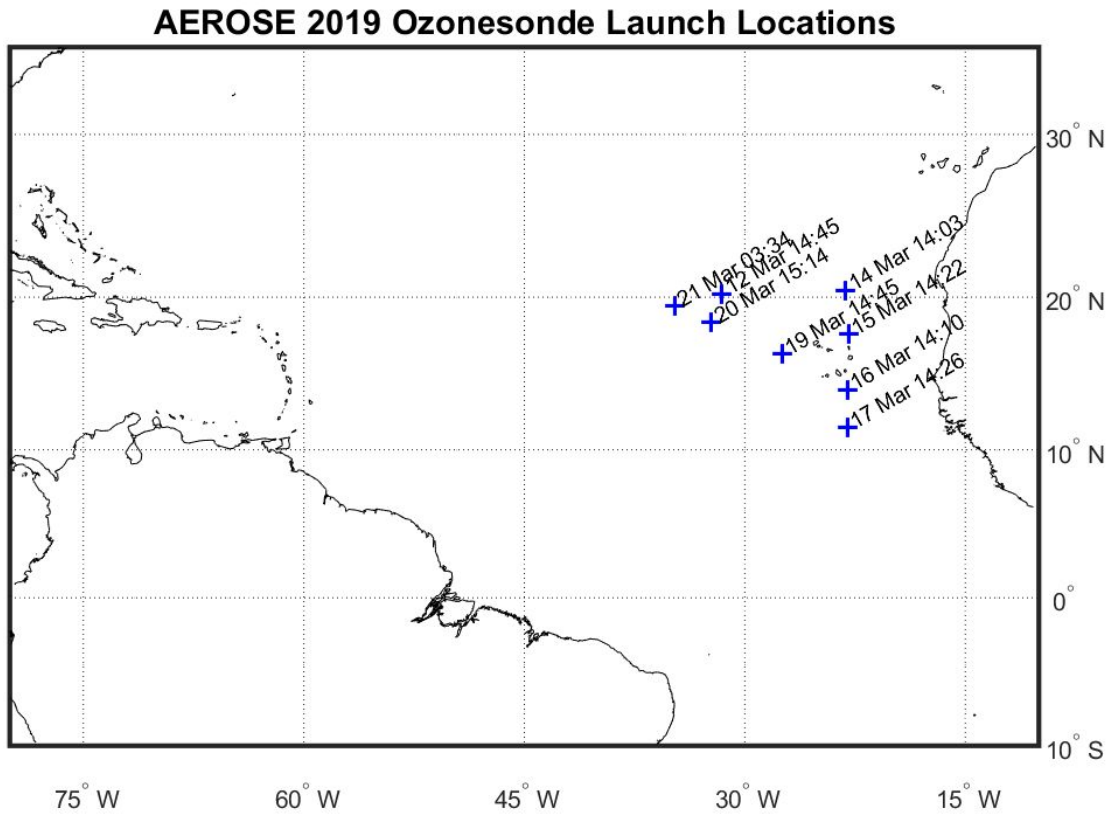


2019 AEROSE RAOB Quick View

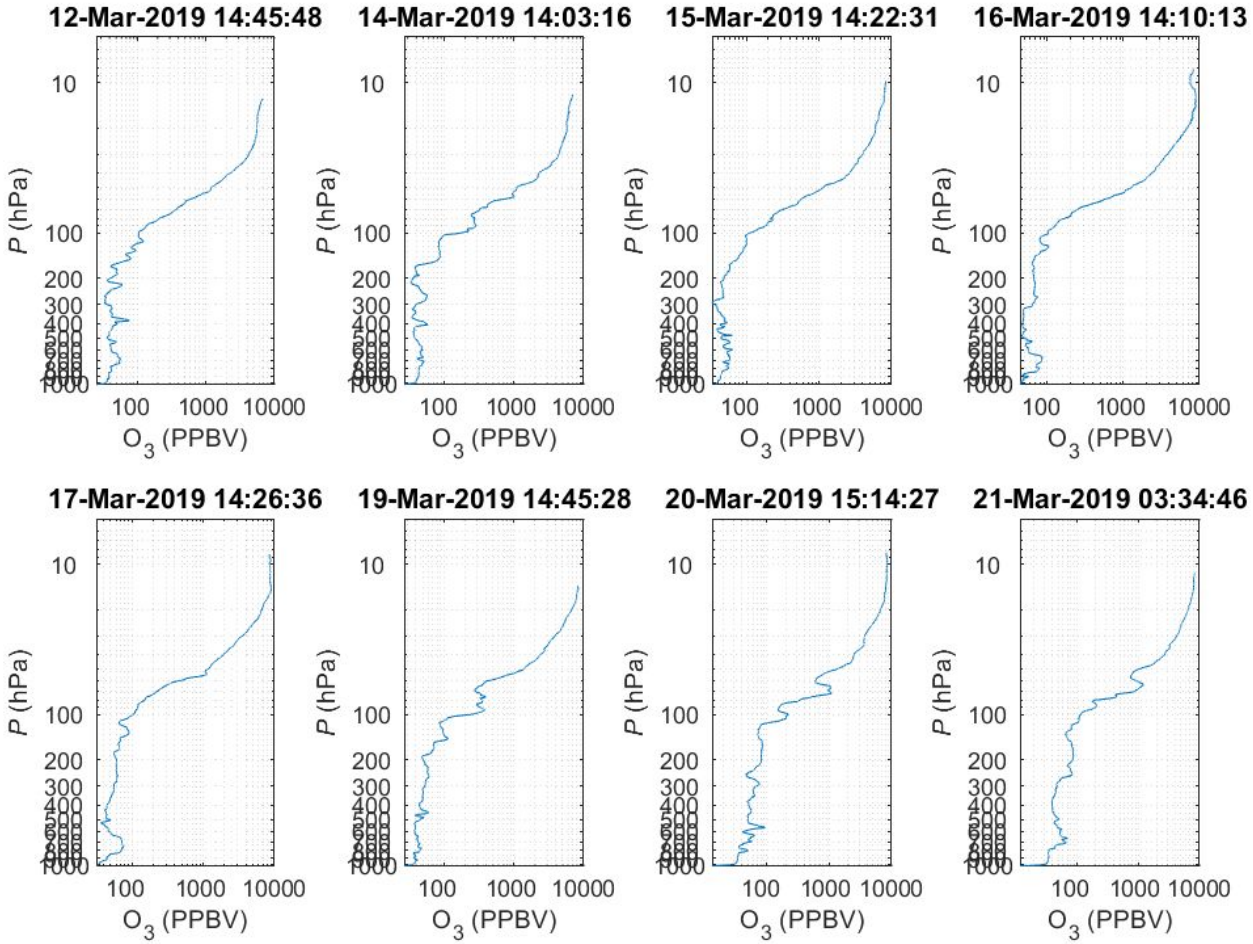




2019 AEROSE Ozone Quick View

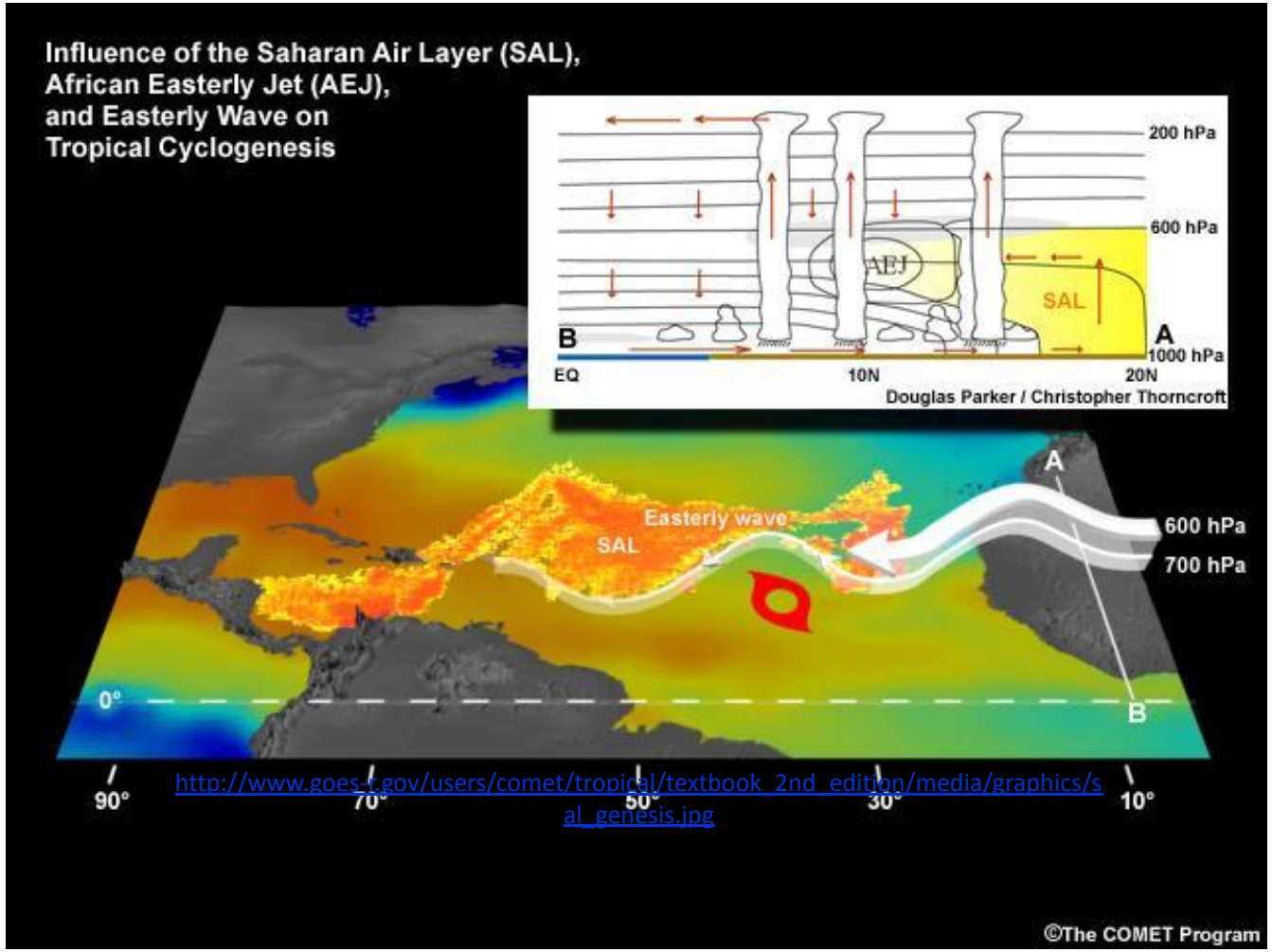


AEROSE Full-Column Ozone Profiles



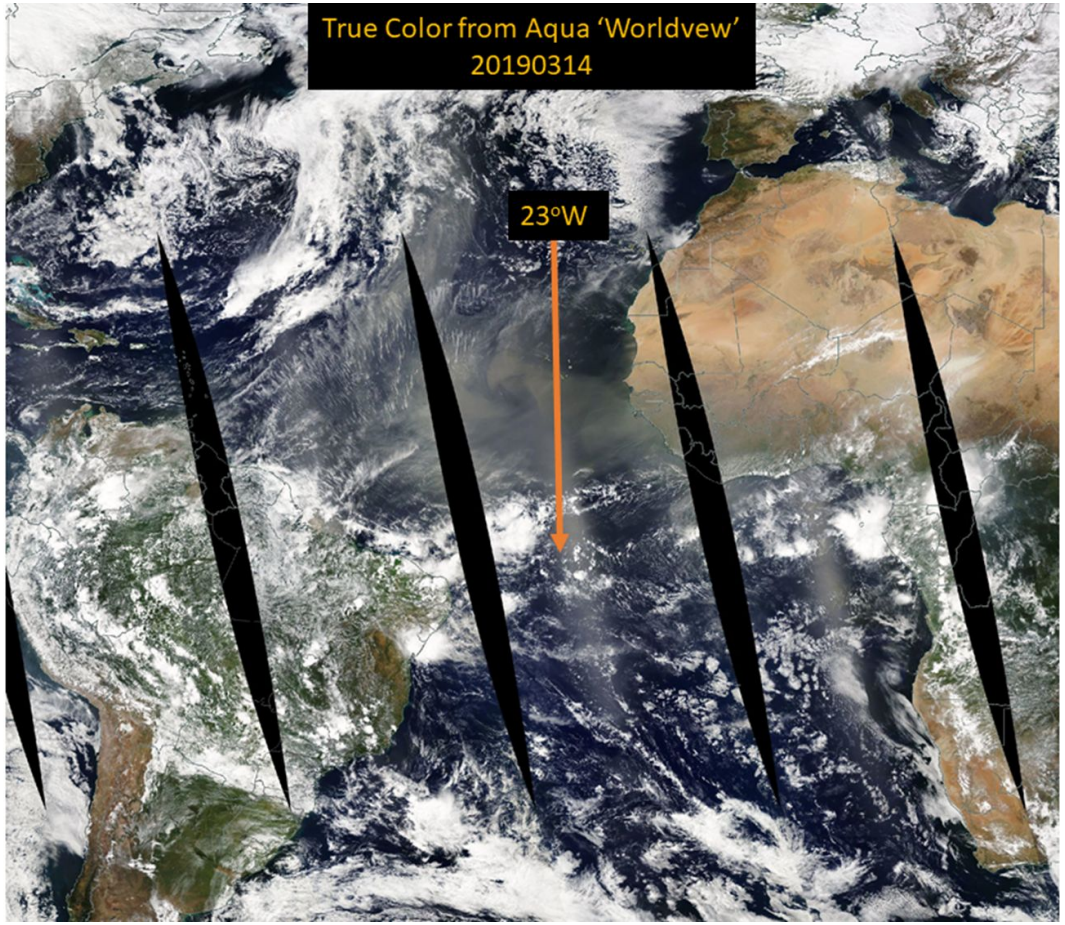
Saharan Air Layers (SAL)

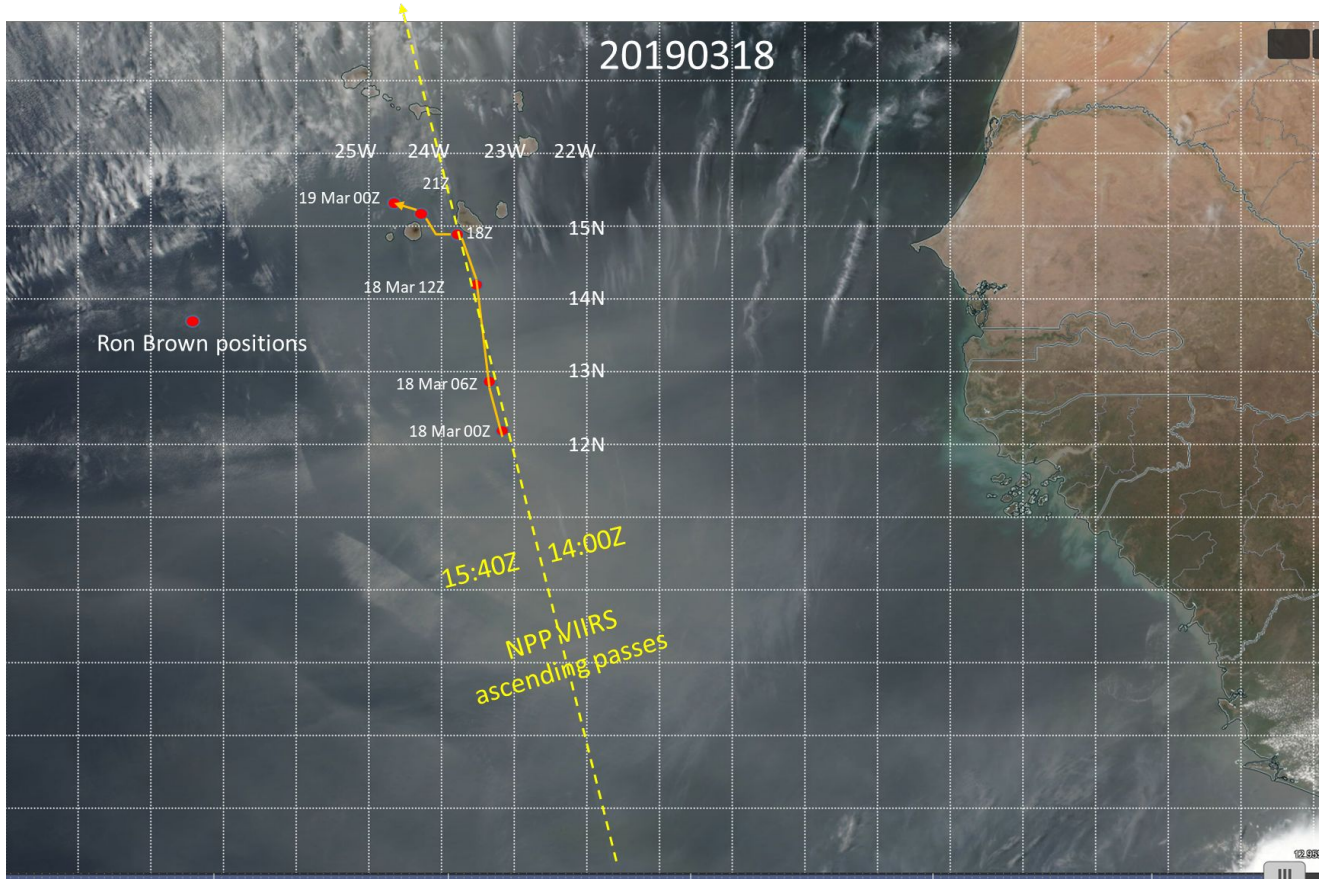
- **Saharan air layers (SALs)** are synoptic to mesoscale stable layers of dry, warm air of desert origin (Carlson and Prospero 1972)
  - **Advect across the Atlantic Ocean,** often accompanying **high levels of Saharan dust aerosols** (*Carlson and Prospero* 1972).
  - These **stabilizing conditions** are thought to suppress hurricane activity over the Atlantic (e.g., *Karyampudi & Pierce* 2002; *Dunion & Velden* 2004; *Wong & Dessler* 2005; *Sun et al.* 2008), and may also be self-sustaining as a result of reduced radiative cooling in the layer
  - Based upon AEROSE SAL cross-sectional observations (e.g., *Nalli et al.* 2005), **the SAL appears to be a persistent special case of a dry air tongue or dry filament phenomenon** (*Nalli et al.* 2011)



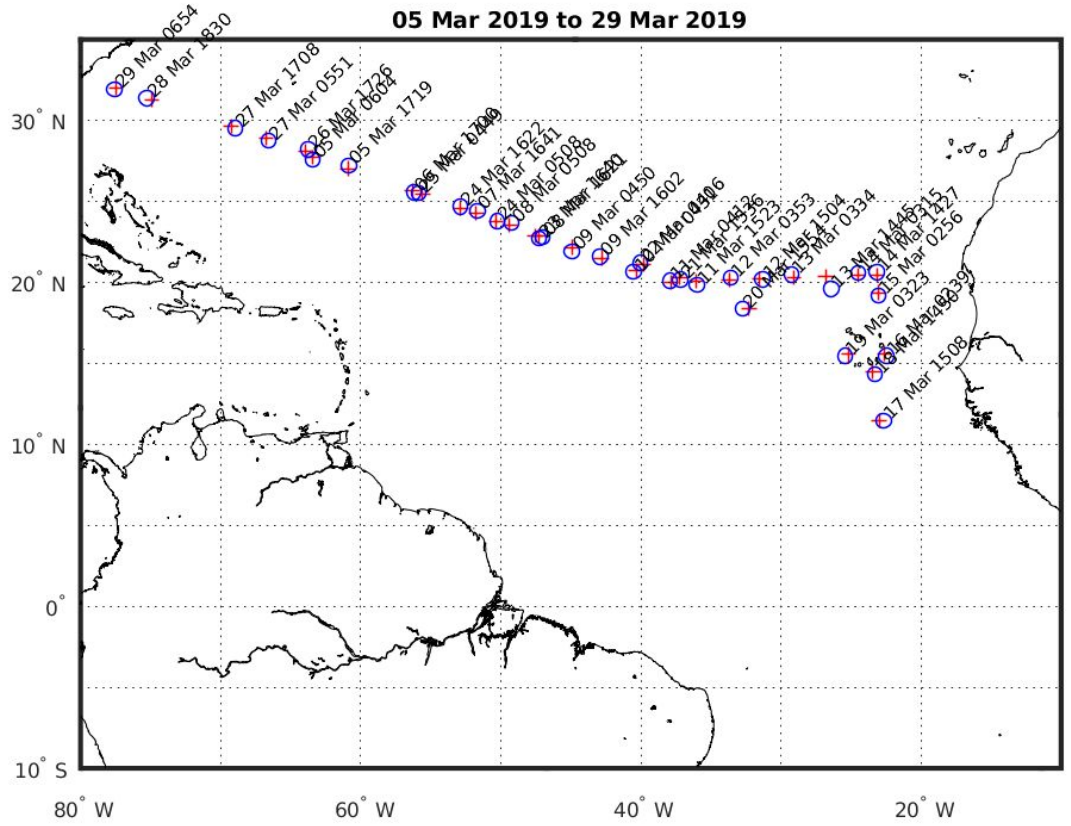
March 2019 AEROSE Saharan Dust Outflow Event

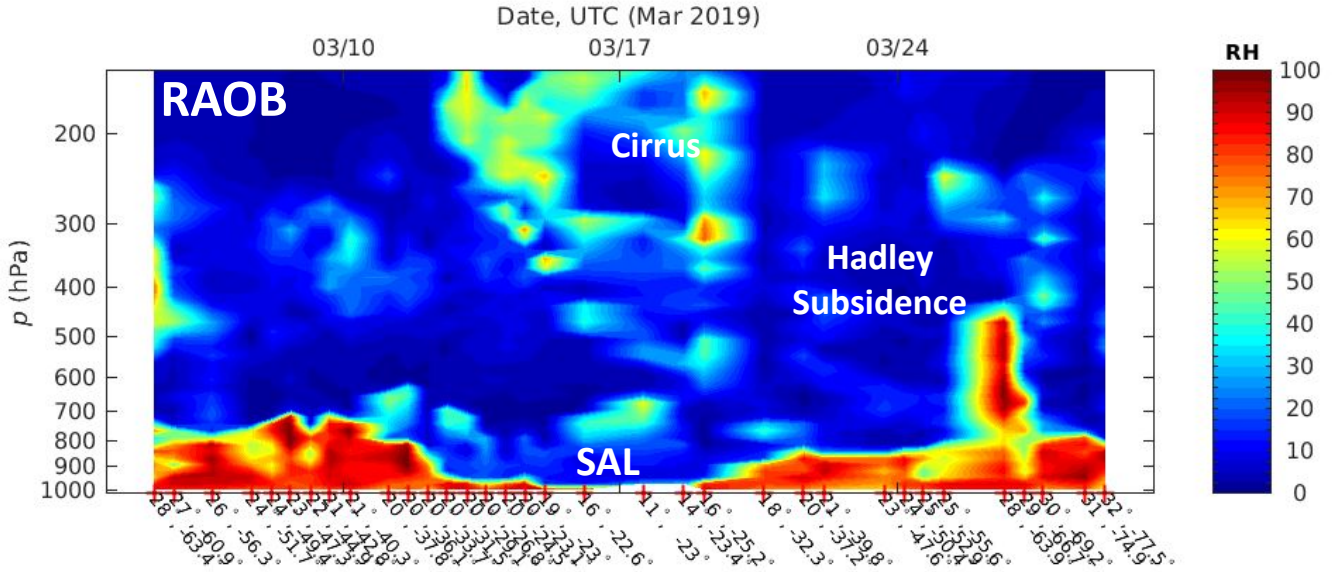
Images provided to us while underway courtesy of Arunas Kuciauskas (NRL)

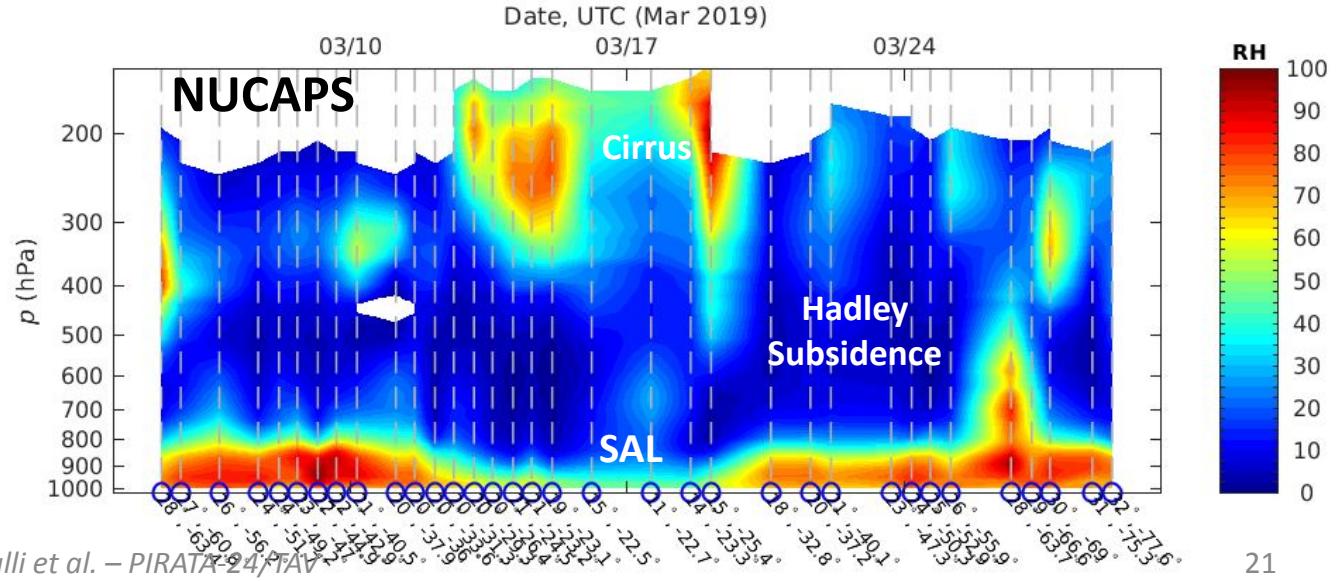




NOAA-20 NUCAPS Cross-Sectional Observation of the SAL

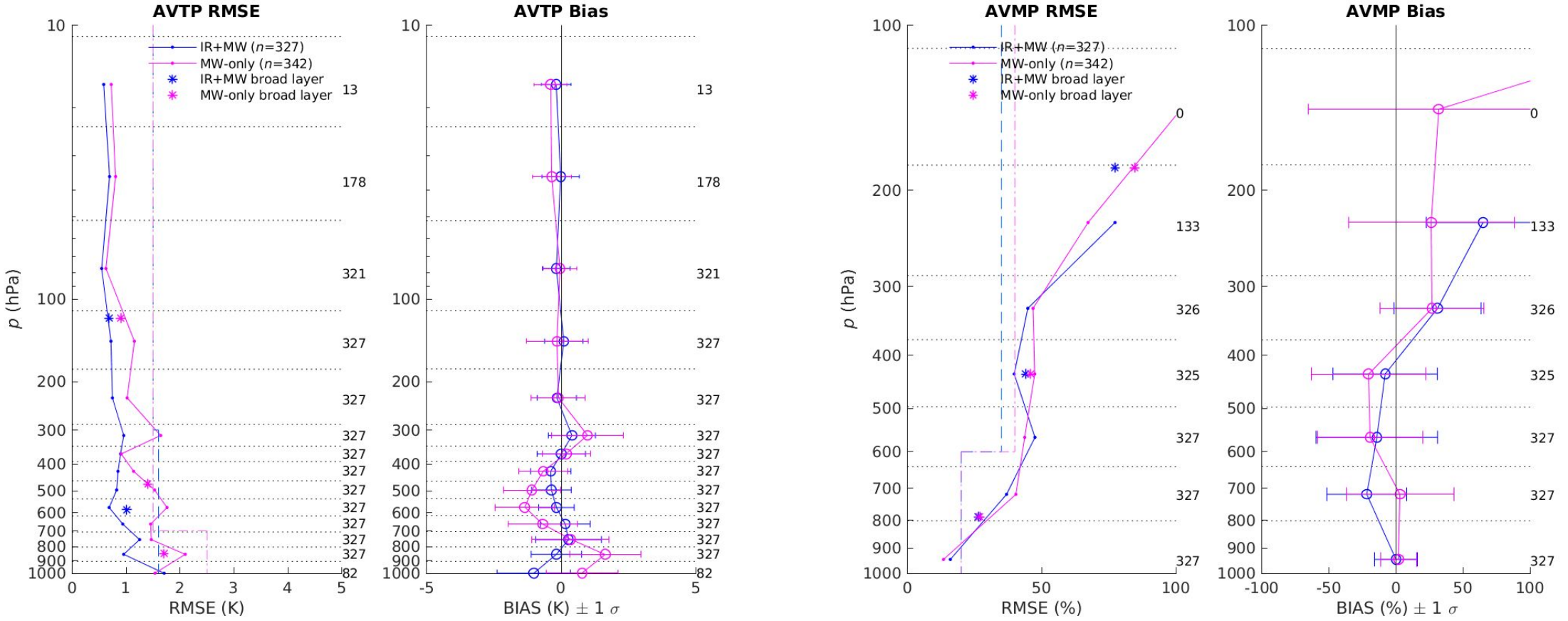






NUCAPS Profile Statistics versus AEROSE Dedicated RAOB (including SAL conditions)

IR+MW
MW-Only

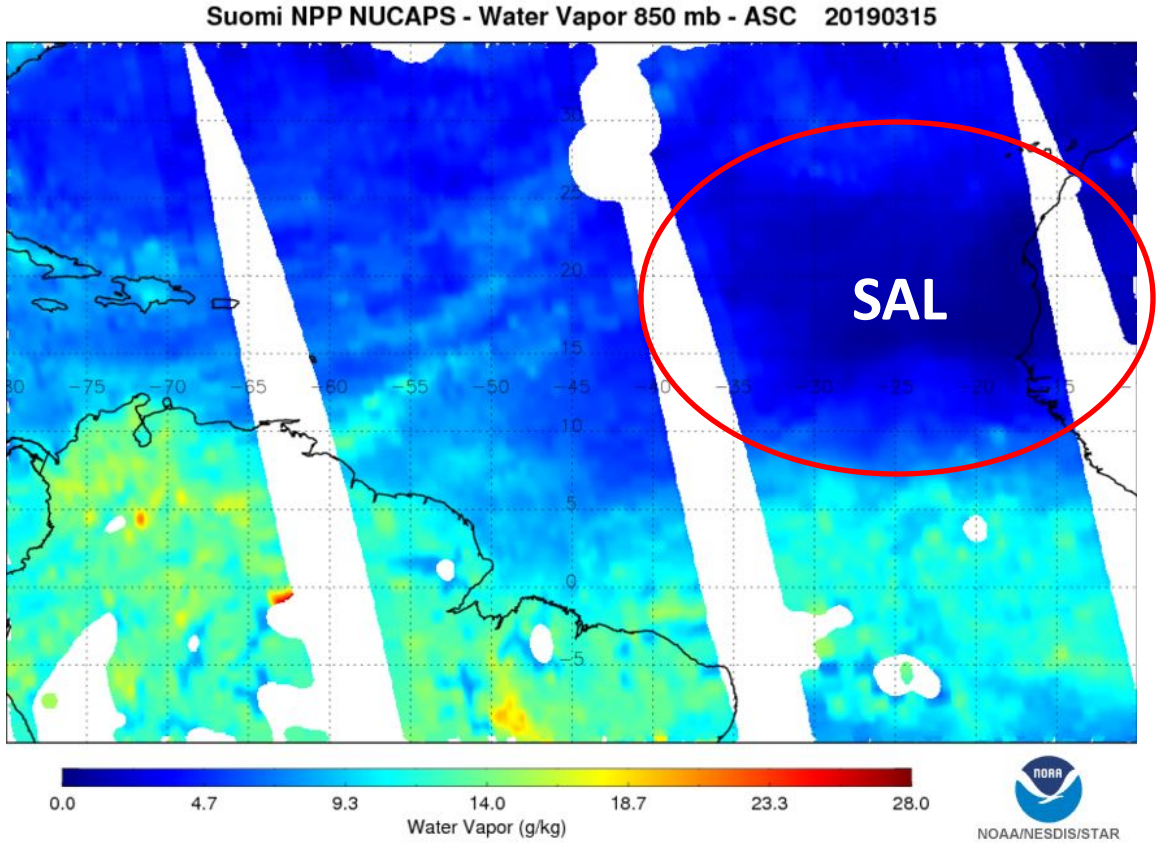


Exercising the use of NUCAPS for underway guidance

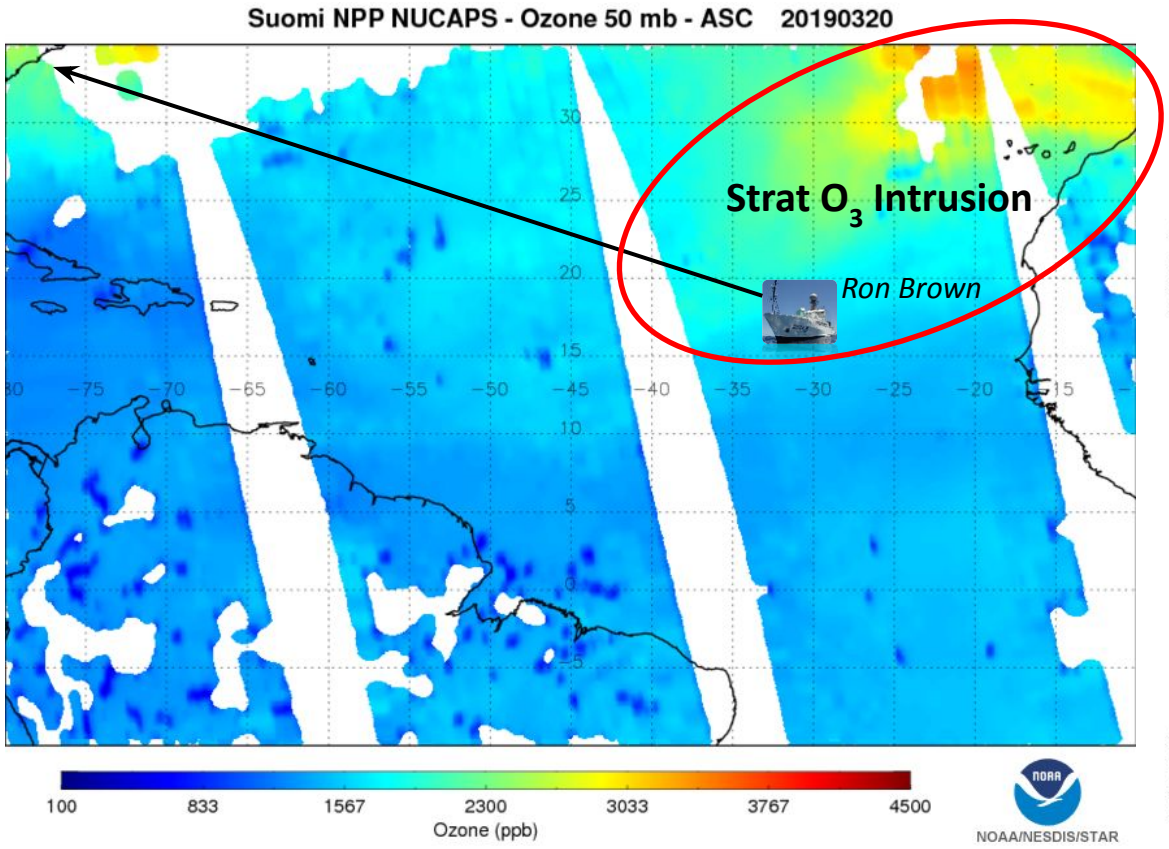
- AEROSE campaigns have previously been "one-way" in that they acquired data in support of NUCAPS validation: **AEROSE → NUCAPS**
- JPSS has supported **Proving Ground and Risk Reduction Initiatives (PGRR)** to engage the user community, including the support of intensive campaigns (e.g., the 2016 ENRR campaign): **AEROSE ↔ NUCAPS**
  - However, unlike land-based (aircraft) campaigns, **bandwidth (and time)** has been **extremely limited** onboard a ship
- Thus, while underway we worked with the **JSTAR Mapper** team (Charlie Brown, Ryan Smith, Tom Atkins) to arrange the provision of tailored **compressed images**
  - AEROSE domain only
  - Proper units and colormap limits
  - Lat/Lon grids
  - EDRs relevant to the campaign
  - More recommendations: RH and potential temperature
  - **https://www.star.nesdis.noaa.gov/jpss/mapper**

NUCAPS EDRs (compressed images) useful for AEROSE

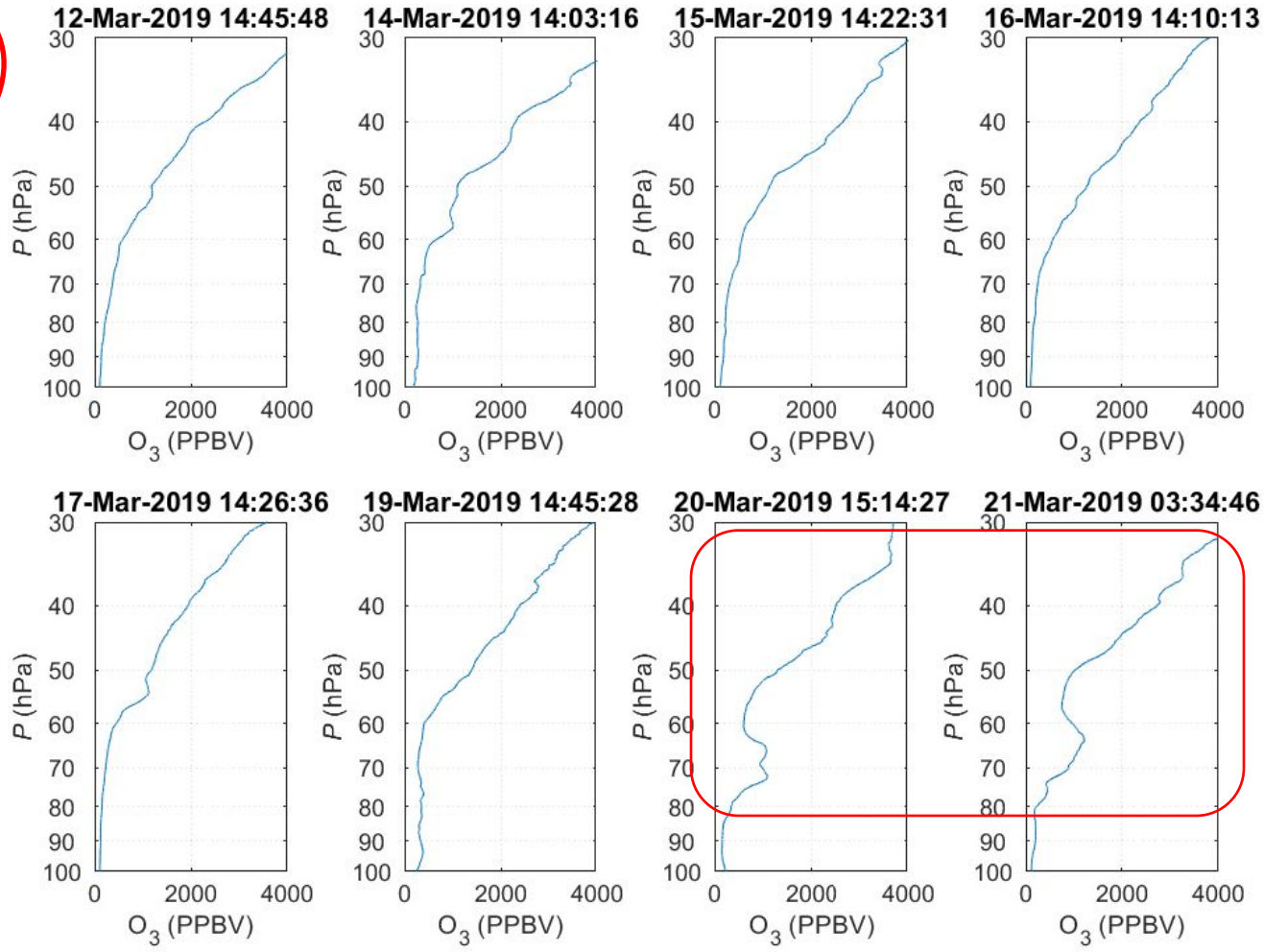
- For **SAL** detection
  - **Water vapor** at 700, 850 hPa
  - **Temperature** at 700, 850 hPa
- For **biomass burning** detection
  - **Carbon monoxide** at 850, 700, 500 hPa
- For **strat intrusion/tropopause folding** detection
  - **Ozone** at 100, 50, 20, 10 hPa
- For general atm chemistry interest
  - **Methane** at 500 hPa



NUCAPS Guidance Example: Ozone

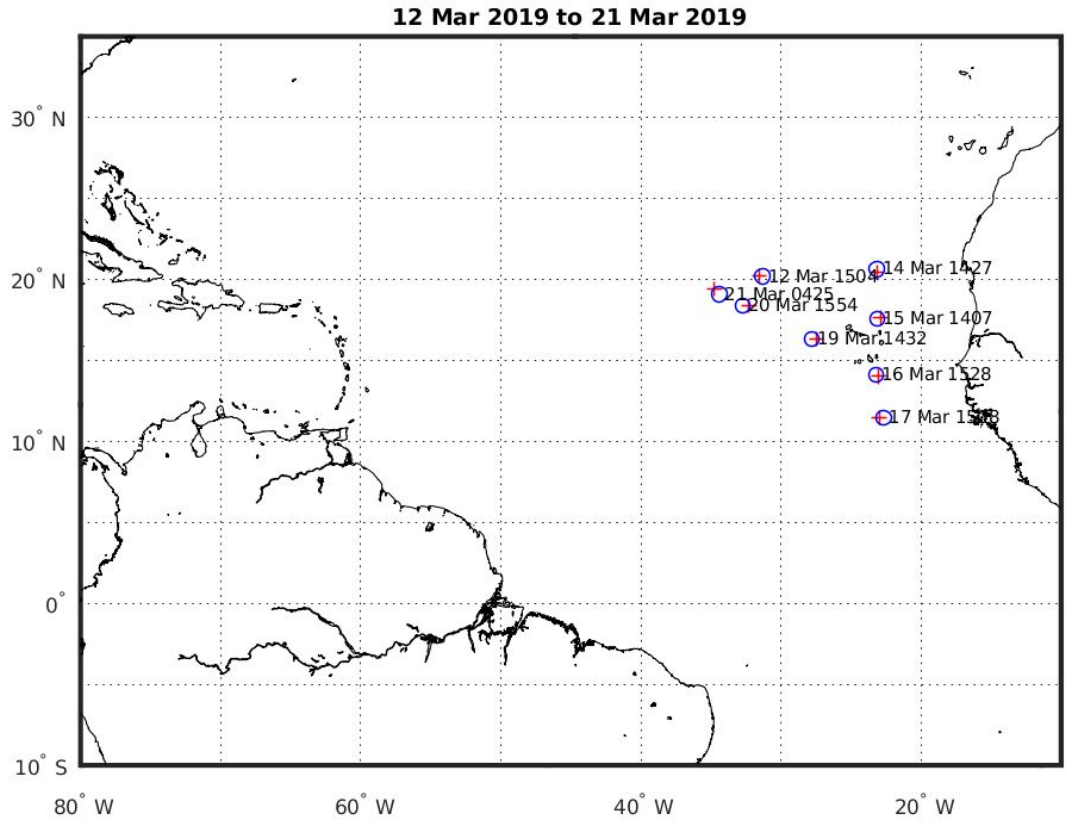


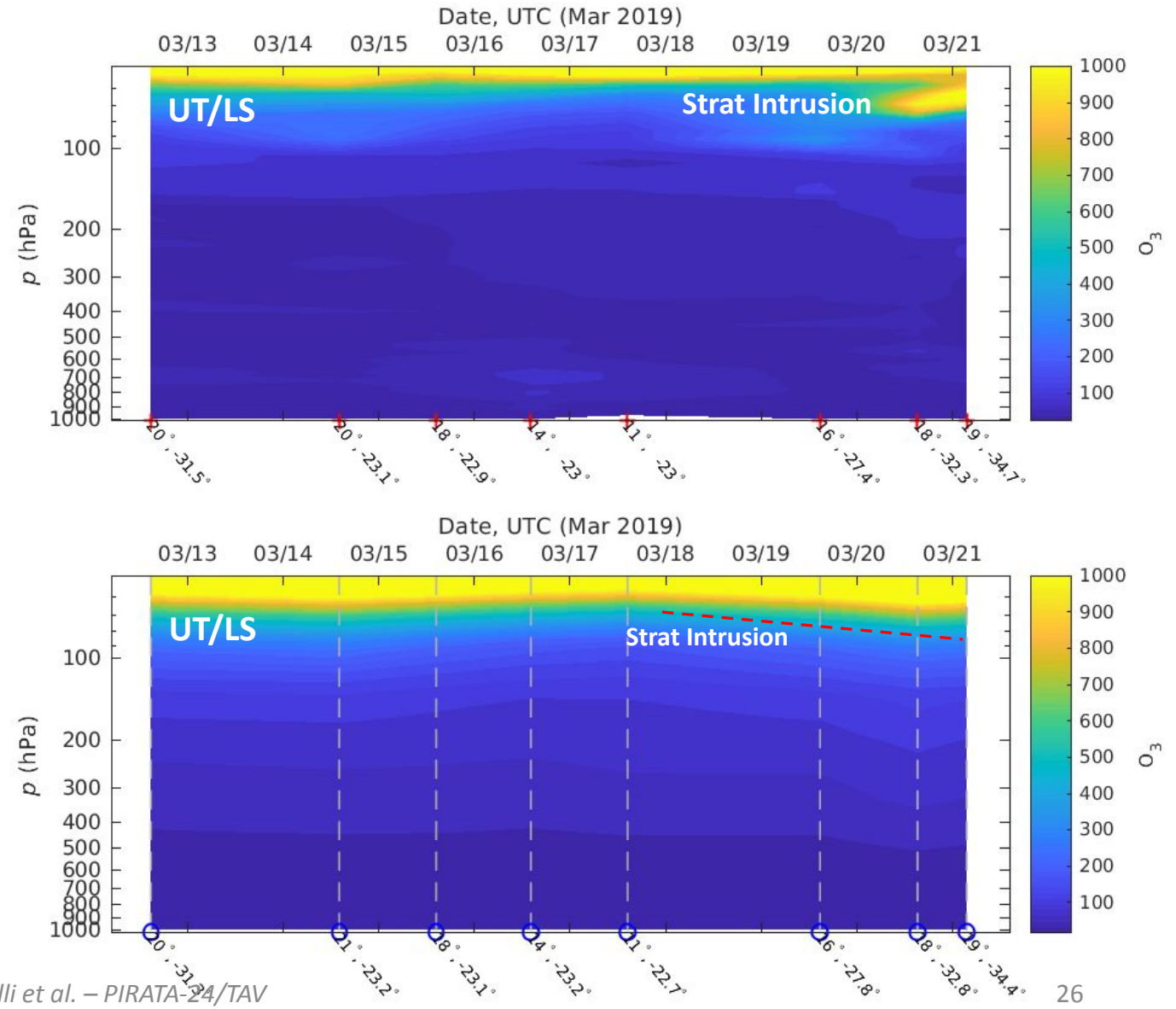
2019 AEROSE UT/LS Ozone



Based on the NUCAPS ozone product and the 20 March ozonesonde, we decided to launch another ozonesonde on 21 March. **Elevated UT/LS ozone** was observed in both soundings.

NUCAPS Ozone Cross-Section on Edge of Strat Intrusion





Summary and Future Work

- **AEROSE** has compiled a multiyear set of ship-based, marine *in situ* cross-sectional **truth measurements** over the tropical Atlantic Ocean.
  - The cruise domains span **a region of meteorological interest**
    - **Atlantic region**: SAL, tropical storm formation, and tropospheric ozone/carbon/aerosol chemistry and transport.
    - The tropical-ocean is an important under-sampled region
  - As highlighted here, there are numerous interdisciplinary applications of these data

- **AEROSE contribution** to **satellite cal/val**
  - Oceans cover ~70% of Earth surface; satellite data over oceans have biggest impact on NWP
  - Ocean-based truth data have unique value because the ocean surface is easier to characterize radiatively
  - AEROSE data have comprised an important component of the overall JPSS cal/val effort
  - Ancillary data (MAERI, ozone, etc.) enable the possibility of cal/val and **closure-experiment**-type “dissections”

Future Work

- Unfortunately, only a truncated AEROSE was possible in the January 2021 PNE cruise due to COVID-19 and scheduling conflicts with the AMS Annual Meeting
- Thus, we are keeping our fingers crossed for the **next PNE** cruise opportunity, tentatively **Nov-Dec 2021**
- The PNE and AEROSE groups (along with several other groups) are in the process of contributing to an edited book project, entitled ***Field Measurements for Passive Environmental Remote Sensing: Instrumentation, Intensive Campaigns, and Satellite Applications***, to be published by **Elsevier** later this year

Aerosols and Ocean Science Expeditions (AEROSE)
in Support of NOAA Satellite Cal/Val

THANK YOU! QUESTIONS?