



# NOAA Aerosols and Ocean Science Expeditions (AEROSE) and Satellite Sounder EDR Validation

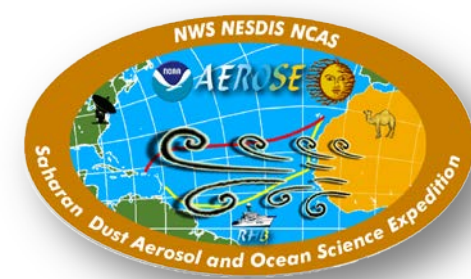
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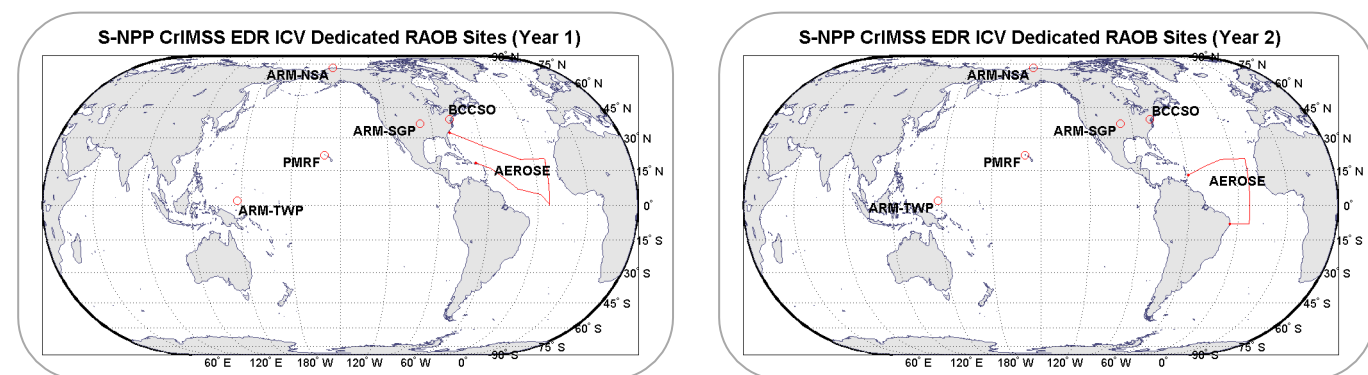


## AEROSE

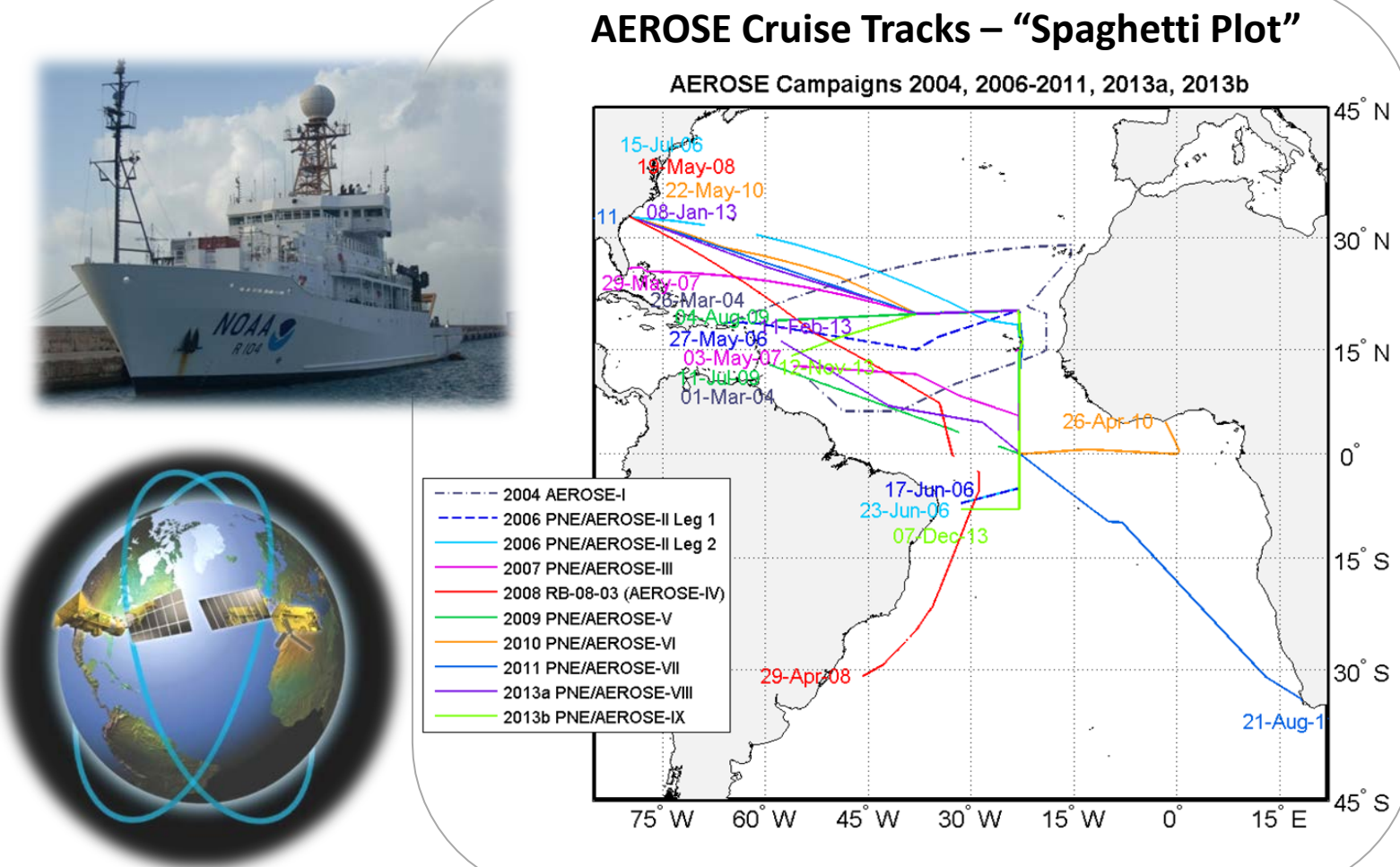


### NOAA Aerosols and Ocean Science Expeditions (AEROSE)

- Trans-Atlantic intensive field campaigns conducted aboard the NOAA Ship *Ronald H. Brown* (Morris et al. 2006; Nalli et al. 2011):
  - AEROSE-I (March 2004; 4 weeks)
  - PNE/AMMA/AEROSE-II (Jun-Jul 2006; two legs, 8 weeks)
  - PNE/AEROSE-III (May 2007; 4 weeks)
  - AEROSE-IV (Apr-May 2008; 3.5 weeks)
  - PNE/AEROSE-V (Jul-Aug 2009; 4 wks)
  - PNE/AEROSE-VI (Apr-May 2010; 4 wks)
  - PNE/AEROSE-VII (Jul-Aug 2011; 5 wks)
  - PNE/AEROSE-VIII (Jan-Feb 2013; 5.5 wks)
  - PNE/AEROSE-IX (Nov-Dec 2013; 4 wks)
- 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
- Ocean-based truth data (e.g., dedicated RAOBs) from AEROSE forms an important component of the overall JPSS Intensive Cal/Val (ICV) effort (Nalli et al. 2006, 2011, 2013; Xie et al. 2013)



- The AEROSE domain is germane to satellite sounder mesoscale-synoptic observing missions (e.g., operational user Advanced Weather Interactive Processing System, AWIPS)
  - Saharan air layer (SAL) and distribution of tropical water vapor
  - Dust and biomass burning aerosols
  - Tropospheric ozone dynamics



## PNE/AEROSE Partnership

- Participating Institutions
  - Howard University NOAA Center for Atmospheric Sciences (HU/NCAS)
  - NOAA/NESDIS/STAR
  - University of Miami/RSMAS
  - NOAA/ESRL/PSD
  - NOAA/OAR Atlantic Oceanographic and Meteorological Laboratory (AOML)
  - NOAA Pacific Marine Environmental Laboratory (PMEL)
- Synergism
  - Low Cost - Low Risk
  - Engages broader science community on specific problems.
  - All parties gain access to all data.
  - AEROSE is a key component of the PNE cruises. NOAA's allocation of ship time on the *Ronald H. Brown* for PNE/AEROSE cruises is fully optimized.

NAME	INSTITUTION	COLLABORATION
N. Nalli, C. Barnet, T. Reale, A. Gambacorta, T. King, H. Xie, B. Sun, W. Wolf, et al.	NOAA/NESDIS/STAR	RAOBs, Radiosondes, CrIMS/GES-R EDR Cal/Val, IASI, AIRS, CAI/Val, IR Radiative Transfer, NPROVS
E. Joseph, V. Morris, M. Oyola, E. Roper, C. Spells, A. Flores, et al.	HU/NCAS, Hampton U.	Aerosol and Chemistry Radiation Measurements, Ozone, Helium
R. Lumpkin, G. Foltz, C. Schmidt	NOAA/NOML	PNE Chief Scientists, TAC Meetings, CTDS, XRTS
P. Minnett, M. Szczodrak, M. Iturbide	UM/RSMAS	M-AERI, MW Radiometer, All-sky camera
D. Wolfe et al.	NOAA/OAR/ESRL/PSD	Vaisala Sounding System, Surface Flux Measurements, Vaisala ceilometer

## AEROSE Truth Datasets

### Dedicated Radiosonde Observations (RAOBs)

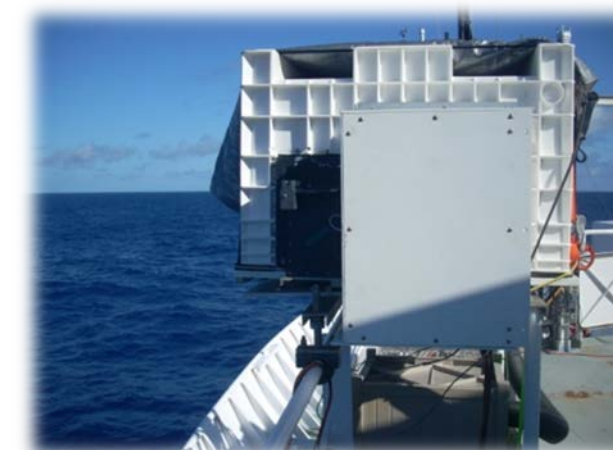
- Vaisala RS92 GPS rawinsondes
  - Launched coinciding LEOS satellite overpasses
  - Suomi NPP (CrIMSS)
  - MetOp-A and -B (IASI)
  - Aqua, A-Train (AIRS)
  - Pressure, temperature, humidity, PTU(z)
  - GPS Winds, u(z), v(z), and altitude, z(t)
  - Not uploaded into GTS (i.e., *not assimilated*)
  - 892 total RAOBs to date
    - 110 PTU soundings in Jan-Feb 2013
    - 96 PTU soundings in Nov-Dec 2013



- ECC Ozone sondes interfaced with RS92
  - Measure O<sub>3</sub>(z) partial pressure
  - ~1/day during S-NPP and MetOp overpasses
  - 156 O<sub>3</sub> soundings to date
    - 24 O<sub>3</sub> soundings in Jan-Feb 2013
    - 19 O<sub>3</sub> soundings in Nov-Dec 2013

### Marine Atmospheric Emitted Radiance Interferometer (M-AERI)

- Ship-based FTS that measures downwelling and upwelling calibrated IR spectra (Minnett et al. 2001)
- High accuracy calibration using 2 NIST-traceable blackbodies
- Derived (EDR) products
  - High accuracy skin SST derived from semi-opaque spectral region (~7.7 μm) (Smith et al. 1996)
    - Skin SST is an important state parameter and "ground truth"
  - Retrievals of lower tropospheric profiles at turbulent time scales (e.g., Szczodrak et al. 2007)
  - Ocean surface spectral emissivity (e.g., Hanafin and Minnett 2005; Nalli et al. 2008b)



### Other Shipboard Data

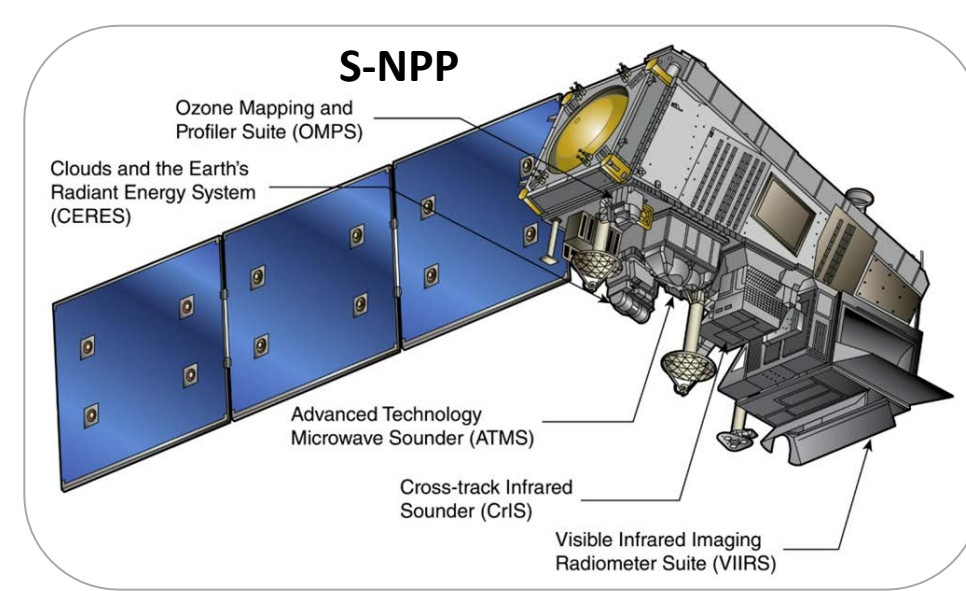
- Microtops Sunphotometer
  - Multi-channel raw data provides information on changes in total column aerosols
  - Since 2009, the AEROSE Team collaborated with the NASA/GSFC AERONET Maritime Aerosol Network (Sminov et al. 2011).
- Vaisala Ceilometer (low power lidar) attenuated backscatter for aerosol vertical distribution
- Broadband pyranometers and pyrgeometers (downwelling LW and SW Fluxes)
- In situ gas & particle measurements
- Meteorological and oceanographic surface measurements



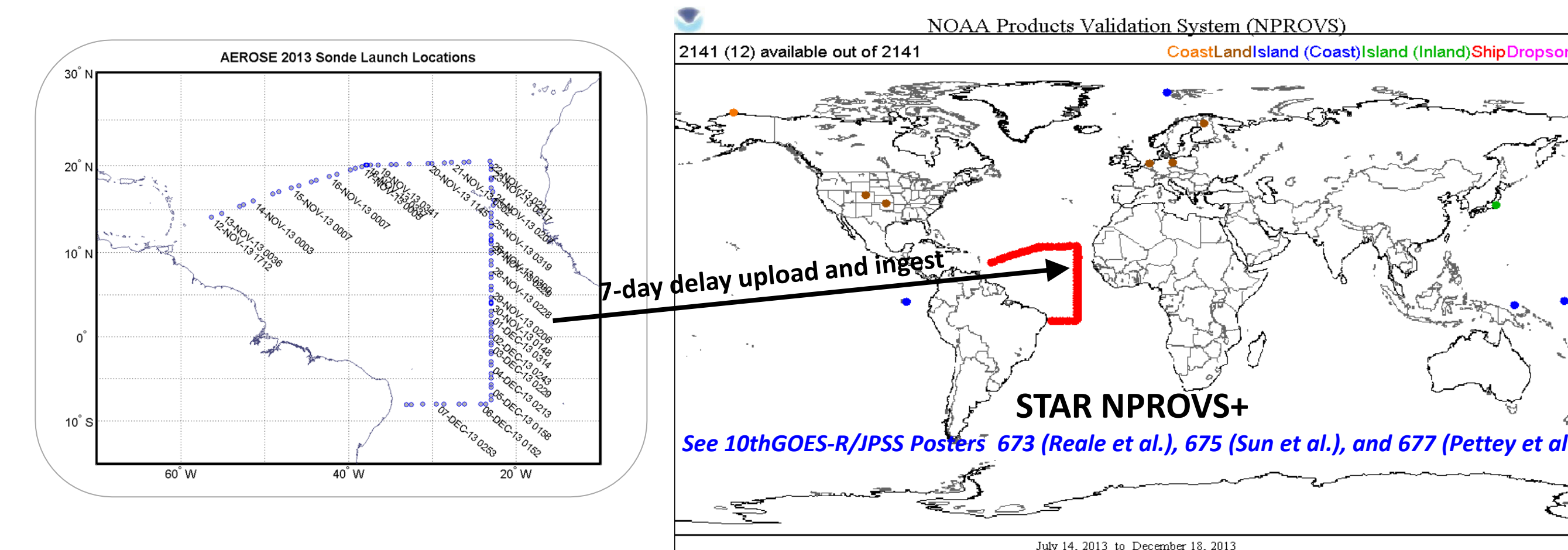
## Satellite Sounder Environmental Data Record (EDR) Validation Over Open Ocean

### Satellite Sounder EDRs

- S-NPP Cross-track Infrared Microwave Sounder Suite (CrIMSS)
  - NOAA-Unique CrIS/ATMS Processing System (NUCAPS) EDR
    - See 10thGOES-R/JPSS Oral 9.1, Gambacorta et al.
  - Original CrIMSS IDPS EDR
- MetOp-A,-B NOAA-Unique IASI EDR
- Aqua AIRS Science Team EDR (dedicated RAOBs for S-NPP)



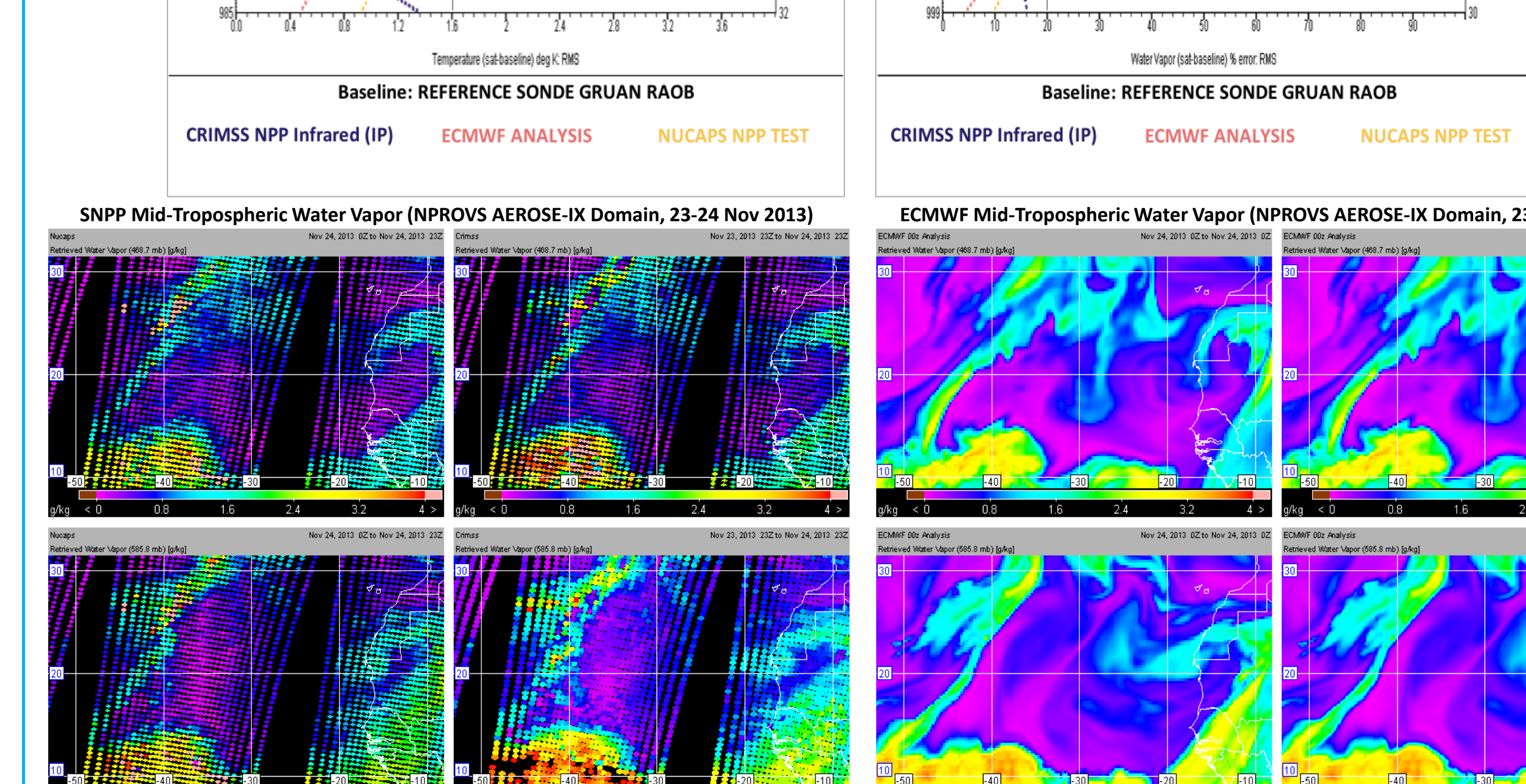
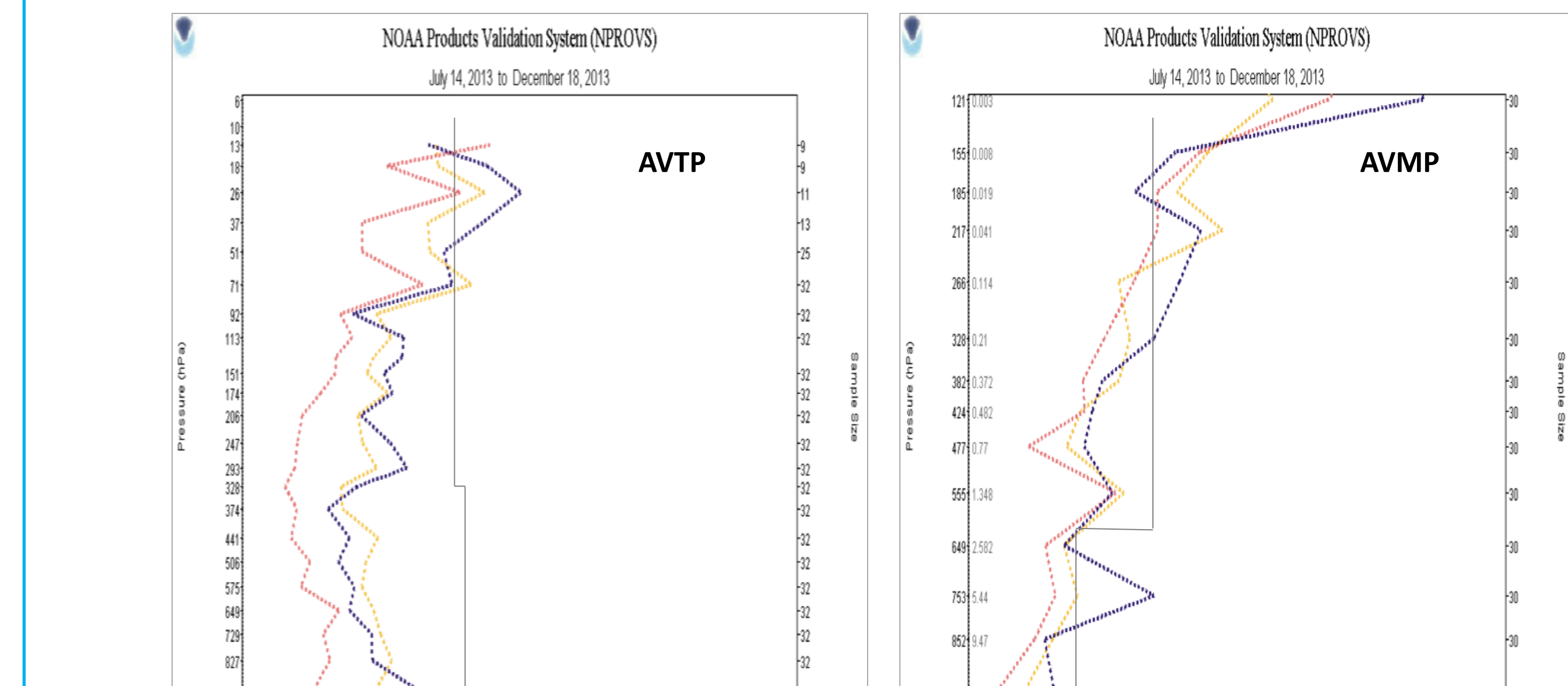
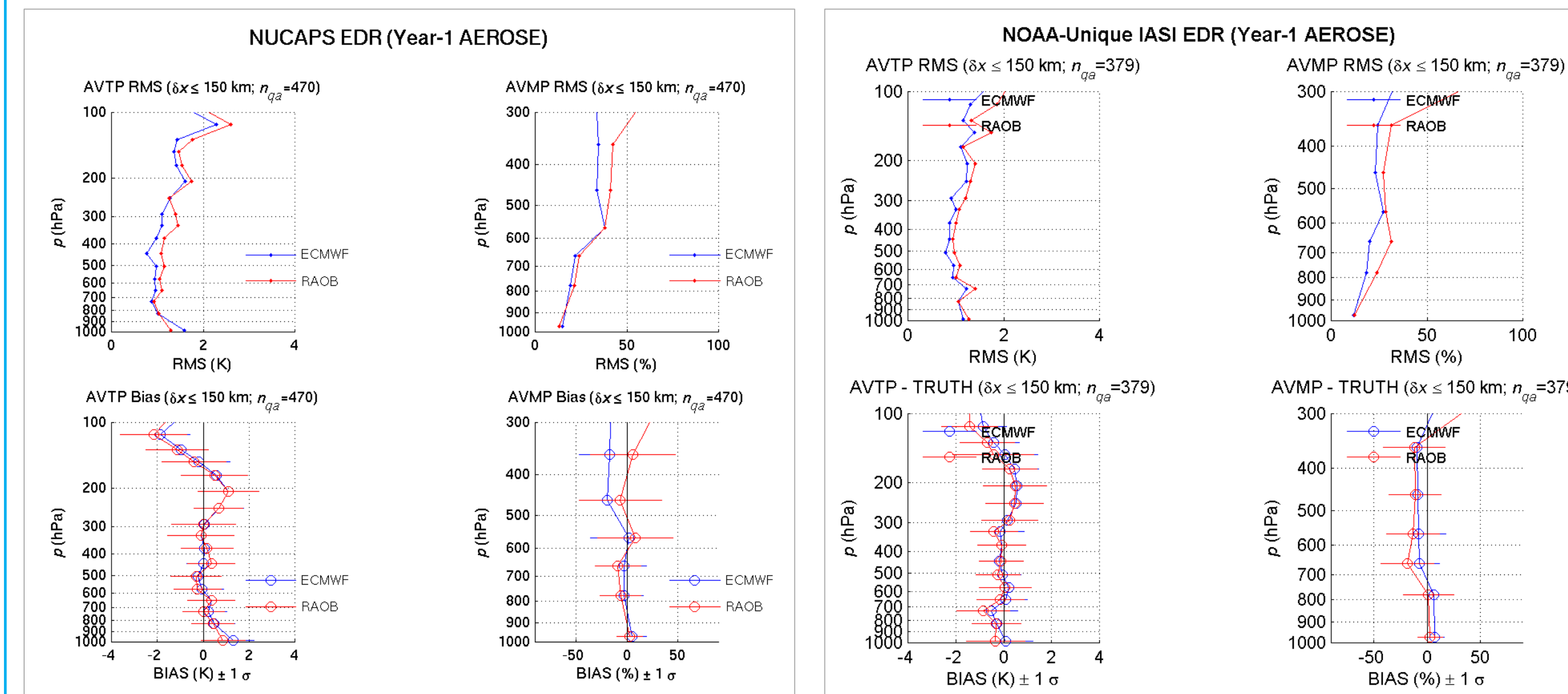
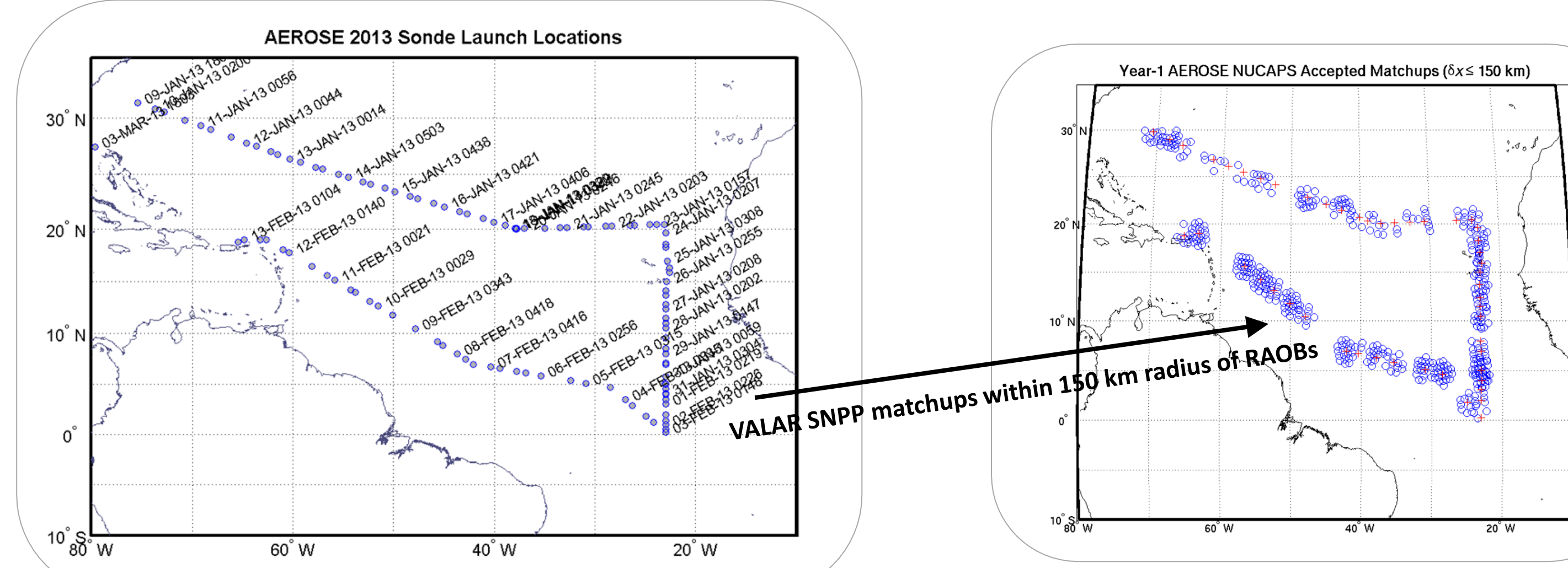
### 2013b AEROSE-IX (Year-2)



### 2013a AEROSE-VIII (Year-1)

#### STAR EDR Validation Archive (VALAR) and Methodology

See 10thGOES-R/JPSS Oral 9.3, Nalli et al.



## Summary

- 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 in terms of the SAL, tropical storm formation, and tropospheric ozone/carbon/aerosol chemistry and transport.
  - Numerous interdisciplinary applications of these data
- AEROSE contribution to satellite sounder EDR intensive cal/val includes (e.g., Nalli et al., 2011)
  - AEROSE domain is an important region for observations from satellite sounder missions, thus validation is desirable.
  - Oceans cover ~70% of Earth surface area and it is the satellite data over oceans that have the biggest impact on NWP.
  - Ocean-based truth data carries unique value for cal/val given that the ocean surface is far easier to characterize radiatively.
  - Ancillary data (M-AERI, ozone, etc.) enable the possibility of cal/val "dissections" (Nalli et al., 2013).
- SNPP CrIMSS NUCAPS EDRs (and IASI EDRs) meet performance specifications versus AEROSE dedicated RAOB data.

## Future Work

- SNPP CrIMSS NUCAPS Stages 1-3 Validated Maturities
  - AVTP, AVMP validation over open ocean, within and without Saharan air layer, dust, smoke
    - Dusty scene risk reduction
    - SAL detection
  - Ozone, carbon monoxide trace gas profile validation
  - Skin SST validation
  - Apply averaging kernels in error analysis (e.g., see 10thGOES-R/JPSS Oral 9.3, Nalli et al.)
  - NUCAPS EDR algorithm development
- The next AEROSE is on hold until a suitable replacement is found for the *Ronald H. Brown*, which NOAA is deploying to the Pacific Ocean for the next several years.

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- The Howard University NOAA Center for Atmospheric Sciences (NCAS), Serving Institutions Educational Partnership Programs supported by
  - The NOAA Minority Serving Institutions Educational Partnership Program
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- Frank Tilley, Michael Pettey, W. W. Wolf, (NOAA/NESDIS/STAR)
- CrIMSS EDR cal/val team, especially Xu Liu (LaRC), Bill Smith (Hampton U.)
- T. Pagano (JPL) and the NASA Sounder Science Team
- The many students, who participated in, and contributed to, the campaigns over the years
- The officers and crew of the *Ronald H. Brown*

The views, opinions and findings contained in this report are those of the authors and should not be construed as an official NOAA or U.S. Government position, policy or decision.

## Selected References

Morris, V., P. Clemente-Colón, N. R. Nalli, E. Joseph, R. A. Armstrong, Y. Detrés, M. D. Goldberg, P. J. Minnett and R. Lumpkin, 2006: Measuring trans-Atlantic aerosol transport from Africa. *Eos Trans. AGU*, 87(50), 565-571.

Nalli, N. R., et al., 2005: Profile observations of the Saharan air layer during AEROSE 2004. *Geophys. Res. Lett.*, 32, L05815, doi:10.1029/2004GL022028.

Nalli, N. R., et al., 2006: Ship-based measurements for infrared sensor validation during Aerosol and Ocean Science Expedition 2004. *J. Geophys. Res.*, 111, D09S04, doi:10.1029/2005JD006385.

Nalli, N. R., P. J. Minnett, E. Maddy, W. W. McMillan, and M. D. Goldberg, 2008: Emissivity and reflection model for calculating unpolarized isotropic water surface leaving radiance in the infrared. 2: Validation using Fourier transform spectrometers. *Appl. Optics*, 47(25), 4649-4671.

Nalli, N. R., et al., 2011: Multi-year observations of the tropical Atlantic atmosphere: Multidisciplinary applications of the NOAA Aerosols and Ocean Science Expeditions (AEROSE). *Bull. Amer. Meteorol. Soc.*, 92, 765-789, doi: 10.1175/2011BAMS2997.1.

Nalli, N. R., et al., 2013: Validation of satellite sounder Environmental Data Records: Application to the Cross-track Infrared Microwave Sounder Suite. *J. Geophys. Res.*, Atmos., 118, doi:10.1002/2013JD020436.

Szczodrak, M., P. J. Minnett, N. R. Nalli, and W. F. Feltz, 2007: Profiling the lower troposphere over the ocean with infrared hyperspectral measurements of the Marine-Atmosphere Emitted Radiance Interferometer. *J. Atmos. Oceanic Technol.*, 24, 390-402. DOI: 10.1175/JTECH1961.1.

Xie, H., N. R. Nalli, et al., 2013: Integration and ocean-based prelaunch validation of GOES-R Advanced Baseline Imager legacy atmospheric products. *J. Atmos. Oceanic Technol.*, 30(8), 1743-1756. DOI: 10.1175/JTECH-D-12-00120.1.

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