2009 PNE/AEROSE-V
Marine Validation Campaign Summary

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and

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Sounder Science Team Meeting
Greenbelt, Maryland, USA
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AEROSE Overview

- The **Aerosol and Ocean Science Expeditions (AEROSE)** are a series of trans-Atlantic intensive atmospheric field campaigns conducted aboard the NOAA Ship *Ronald H. Brown (RHB)* (*Morris et al.* 2006).
  - AEROSE-I (March 2004; 4 weeks)
  - PNE*/AMMA*/AEROSE-II (June-July 2006)
    - Leg 1 (4 weeks)
    - Leg 2 (4 weeks)
  - PNE/AEROSE-III (May 2007; 4 weeks)
  - RB-08-03 Interhemispheric Transit descoped mission (Apr-May 2008; 3 weeks)
  - **PNE/AEROSE-V** (July-August 2009; 4 weeks)

- As part of the NOAA/PNE mission, the AEROSE campaigns have grown to become one of the most extensive collections of *in situ* measurements of the Saharan air layer (SAL) and associated African dust and smoke outflows over the tropical Atlantic Ocean, including
  - Transport, microphysical evolution and regional impacts
  - Regional atmospheric chemistry and marine meteorology

*AMMA – African Monsoon Multidisciplinary Analysis

*PNE – PIRATA Northeast Extension

Key Contributors

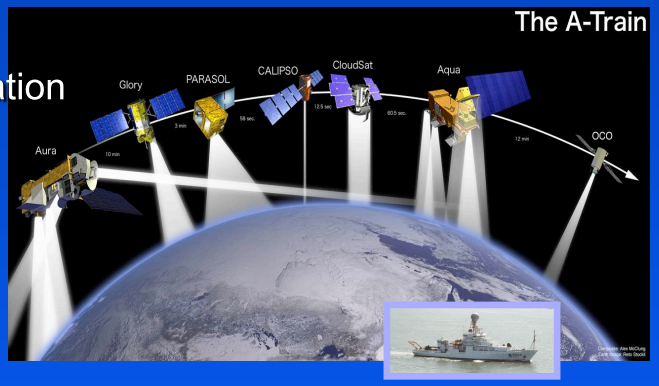
NAME	INSTITUTION	COLLABORATION
N. Nalli, C. Barnet, H. Xie M. Goldberg, W. Wolf M. Divakarla, G. Guo, T. Reale J. Wei, E. Maddy, et al.	NOAA/NESDIS/STAR	RS92 Rawinsondes; CrIMSS/GOES-R Proxy Data and Pre-Launch EDR Validation; NPROVS
E. Joseph, V. Morris Grad Students	HU/NCAS	Aerosols; Chemistry; Radiation Budget; Ozonesondes; Helium
R. Lumpkin C. Schmid	NOAA/AOML	PNE Chief Scientists; TAO Moorings; CTD, XBTs
P. Minnett **M. Szczodrak,** M. Izaguirre	UM/RSMAS	M-AERI Measurements; MW Radiometer; All-sky camera
D. Wolfe B. Otto	NOAA/OAR/ESRL/PSD (formerly NOAA/ETL)	Vaisala sounding system; Surface Flux Measurements; C-Band Radar; Wind Profiler; Sea Space Satellite Uplink
T. Pagano, E. Fetzer **AIRS Science Team** W. Feltz, R. Knuteson	JPL UW/CIMSS	AIRS/IASI validation rawinsonde support ('07,'08) AIRS validation rawinsonde support ('04,'06)

Validation Schemes

- **Validation** of satellite products is the process of assessing the retrieved quantities against a set of independent measurements (e.g., *in situ*)
  - Particularly important to monitor for systematic errors associated with a small number of sensors

- **Satellite validation schemes**
  - **Operational** *in situ* matchup data (usually **NOAA**)
    - Statistical significance: large matchup data samples can be obtained using (e.g., operational radiosondes over land, and moored buoys); "global" scale
  - **Intensive campaigns (e.g., AEROSE, START, JAIVEx)**
    - Simultaneous complementary measurements that can be used to specify key aspects of the atmospheric state
    - Allows focused case studies, including interesting, but more difficult, smaller scale meteorological phenomena (e.g., SAL, aerosols); ships/airplanes only ways to sample over open ocean
  - **Dedicated sites (e.g., GRUAN, ARM)**
    - Research-quality data acquired during overpass times

- **Measurements over the open ocean** are valuable for validation
  - Surface is far simpler to specify and better characterized
  - Oceans are where satellites are expected to make a significant impact (where there is no *in situ* data)



AEROSE Campaigns to Date
Marine-SAL Validation Data

- **March 2004: AEROSE-I**
  - Primary mission onboard *Ronald H. Brown*
  - 3-hourly RAOBs (RS80/90), including EOS-Aqua AIRS overpasses (156 total)
  - Marine Atmospheric Emitted Radiance Interferometer (M-AERI)
    - Up and downwelling IR spectra
    - Sea surface skin temperature
  - Microtops sun photometer
  - CIRIMS (skin SST)
  - Surface pyranometers

- **Jun-Jul 2006: PNE/AMMA/AEROSE-II**
  - 2/day RAOBs (RS92) during A-Train AIRS overpasses (42 + 54 = 96 total)
  - Ozonesondes (6 + 14 = 20 total)
  - M-AERI
  - Microtops sun photometer
  - Micropulse Lidar (MPL)
  - Multifilter Rotating Shadowband Radiometer (MFRSR)
  - Ceilometer
  - Surface pyranometers

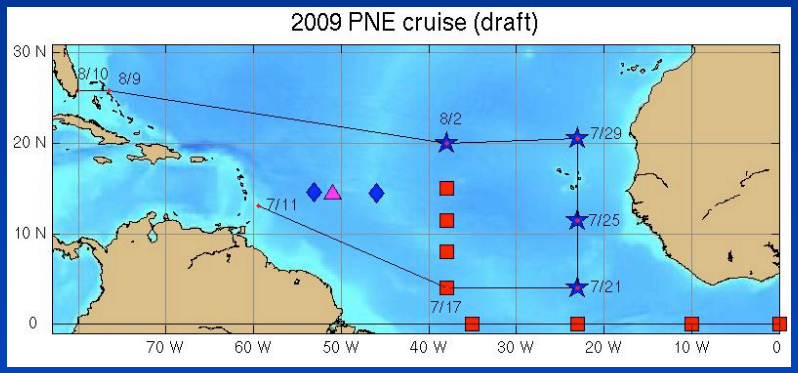
- **May 2007: PNE/AEROSE-III**
  - 4/day RAOBs (RS92) during A-Train and METOP-A IASI overpasses (96 total)
  - Ozonesondes (17 total)
  - M-AERI (onboard, but QA data not yet available due to instrument failures)
  - Microtops
  - MPL, MFRSR, Ceilometer, pyranometers

- **Apr-May 2008: RB-08-03 Interhemispheric Transit**
  - Cruise radically descoped by NOAA/OMAO due to severe ship mechanical problems
  - 4/day RAOBs (RS92) during A-Train and METOP-A IASI overpasses (75 total)
  - Ozonesondes (16 total)
  - M-AERI
  - Microtops
  - MPL, MFRSR, Ceilometer, pyranometers

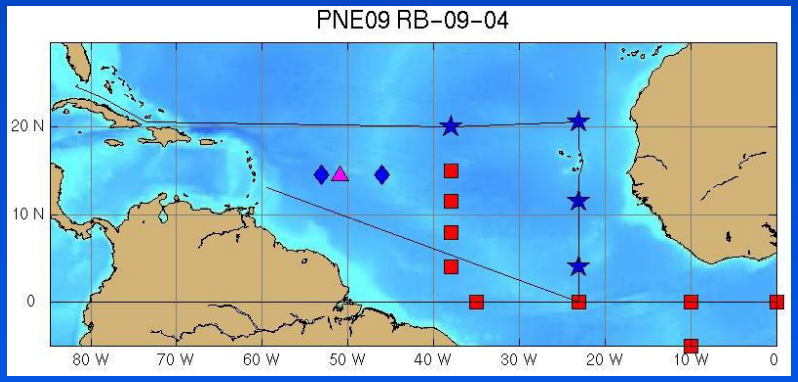
- **Jul-Aug 2009: PNE/AEROSE-V**
  - 4-6/day RAOBs (RS92) during A-Train and METOP-A IASI overpasses (81 total)
  - Ozonesondes (17 total)
  - M-AERI (onboard, but QA data not available due to high noise)
  - Microtops (calibrated and uploaded to Maritime Aerosol Network)
  - Ceilometer, pyranometers

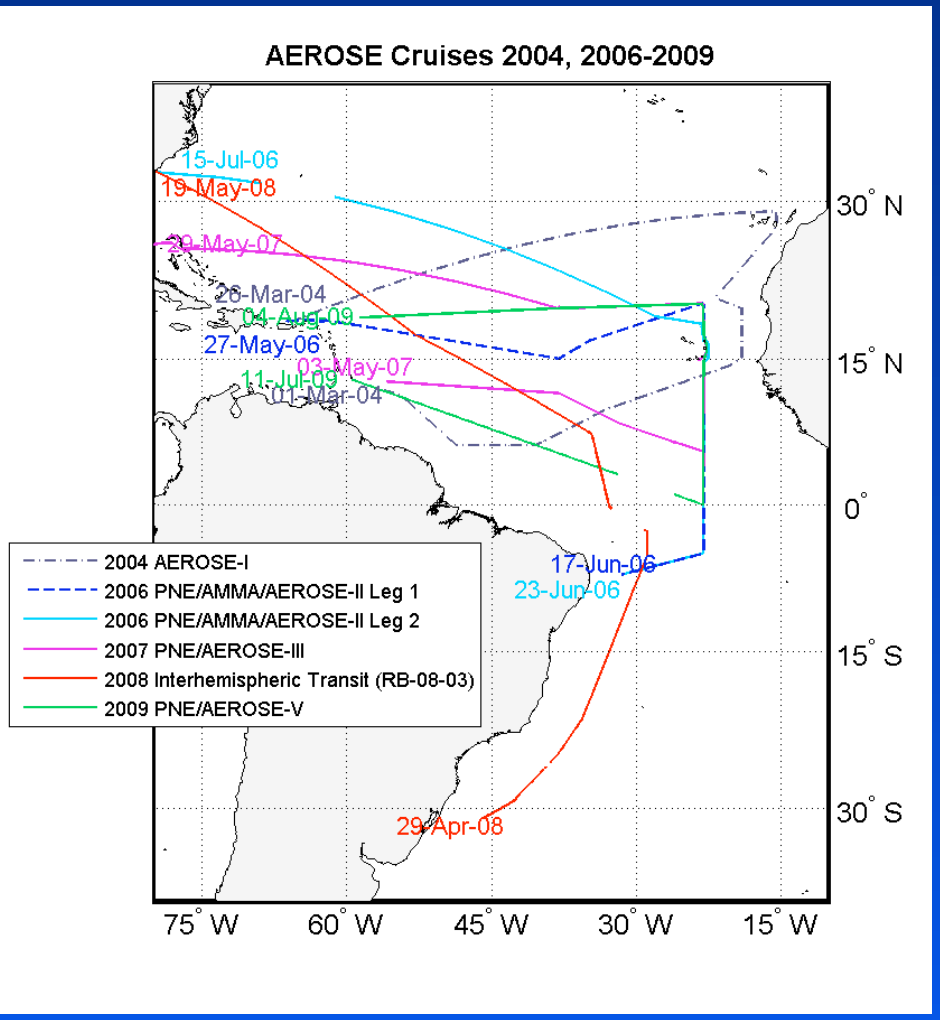
Cruise Tracks 2004, 2006–2009

2009 proposed track



2009 modified track





Dedicated Radiosonde Observations (*PTU*, *v*, *z*(*t*), O_3)

- **Vaisala RS92 GPS rawinsondes** (RS80/90 in 2004) launched coinciding with AIRS and IASI overpasses
  - Sondes typically 4/day at ~01:30, 09:30, 13:30, 21:30
  - 81 successful '09 launches
  - **504 PTU soundings** to date
  - **GPS altitude,** *z*(*t*), from RS92 sondes
- **Ozonesondes** ~1/day during AIRS/IASI overpasses
  - **17** successful '09 launches
  - **70 O_3 soundings** to date

Marine Atmospheric Emitted Radiance Interferometer (M-AERI)

(P. Minnett *et al.*)

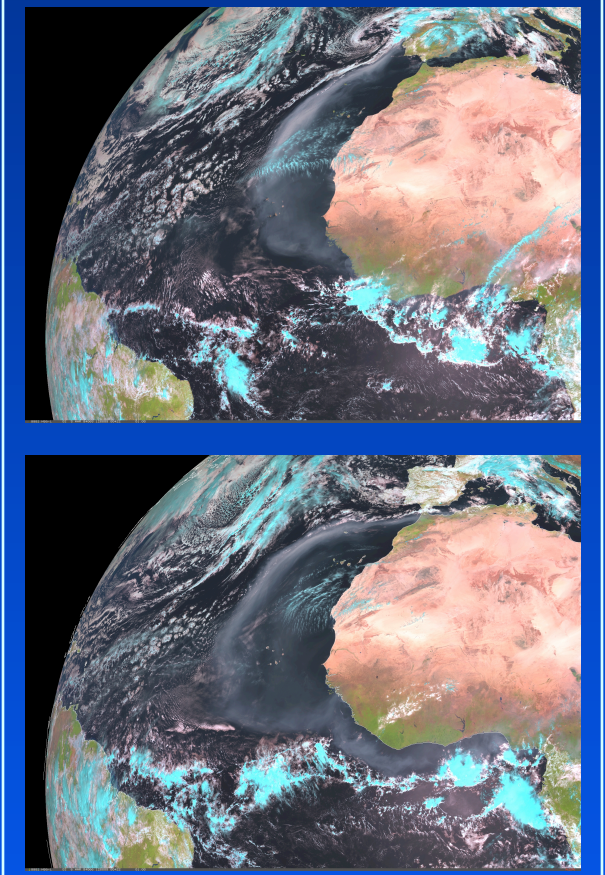
- Ship-based **FTS** designed to sample downwelling and upwelling calibrated IR spectra near the surface (*Minnett et al.* 2001)
- High accuracy **calibration** is achieved using 2 **NIST-traceable blackbodies** (e.g., *Revercomb et al.* 1988)
- Derived products
  - High accuracy skin SST derived from semi-opaque spectral region (~7.7 μm) (*Smith et al.* 1996)
  - Continuous retrievals of lower tropospheric profiles at turbulent time scales (e.g., *Szczodrak et al.* 2007)
  - Retrieval of ocean surface spectral emissivity (e.g., *Hanafin and Minnett* 2005; *Nalli et al.* 2008b)
- Unfortunately, M-AERI encountered technical problems (e.g., high noise) during the 2009 campaign; the issue was not resolved underway; data has not been released

Of Meteorological Interest for Satellite Sounding…

Saharan Dust Aerosols

- 2 billion metric tons of mineral dust are injected into the atmosphere from the Sahara annually
  - Peaks during NH summer and springtime
- These coarse-mode aerosols are often transported within easterly trade winds well across the Atlantic north of the ITCZ
  - This westward flow accounts for the 30–50% of the dust output
  - Significant impact on the meteorology and climate dynamics of the tropical North Atlantic (e.g., radiation balance)
- Due to absorption/scattering, they also impact infrared radiances, and thus geophysical retrievals

Dust outflow during **AEROSE-I**
6-7 Mar 04, Meteosat SEVIRI



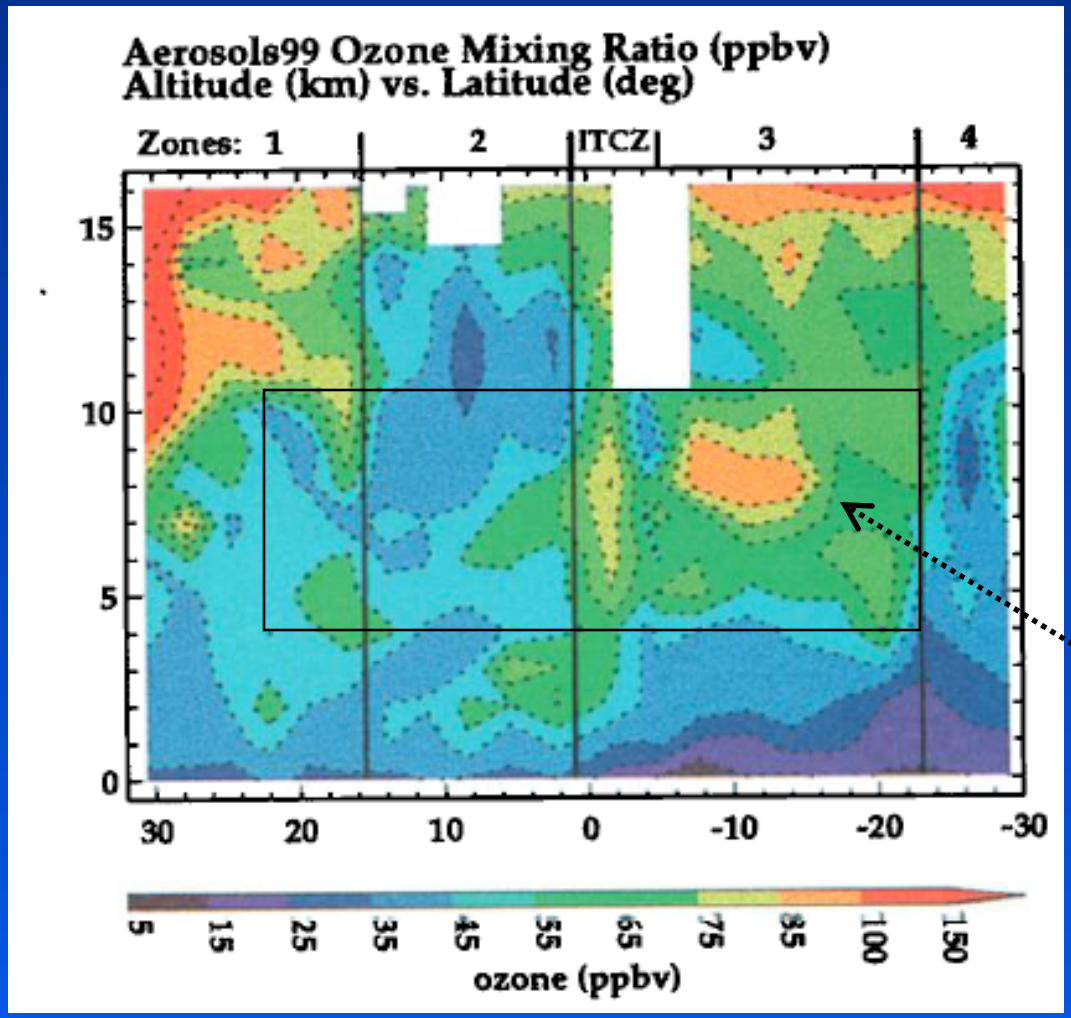
Saharan Air Layer (SAL) and Tropical Cyclogenesis

- Dry, warm stable, desert air advects over Atlantic
  - Enhanced low level temperature inversion
  - Enhanced vertical wind shear associated with midlevel easterly jet
  - Sometimes contains significant levels of Saharan dust
  - SAL cross-sections obtained during AEROSE 2004 (*Nalli et al.* 2005), and PNE/AEROSE 2006, 2007 and 2009
- These conditions hypothetically act to suppress hurricane formation over the Atlantic (e.g., *Dunion and Velden* 2004; *Evan et al.* 2006)
- LEO and GEO satellite sounders and imagers are tools whereby the SAL can be observed synoptically; therefore, **validation in this region is desirable**

Atmospheric Chemistry

- **Tropospheric Ozone dynamics** over the Tropical Atlantic
  - Smoke aerosol precursors from African and South American **biomass burning**
    - Horizontal advection via easterlies
    - Vertical transport via tropical deep convection
  - **Lightning** in deep convection – NO_x formation
  - **Stratospheric intrusions**

Tropical Atlantic Tropospheric Ozone Dynamics

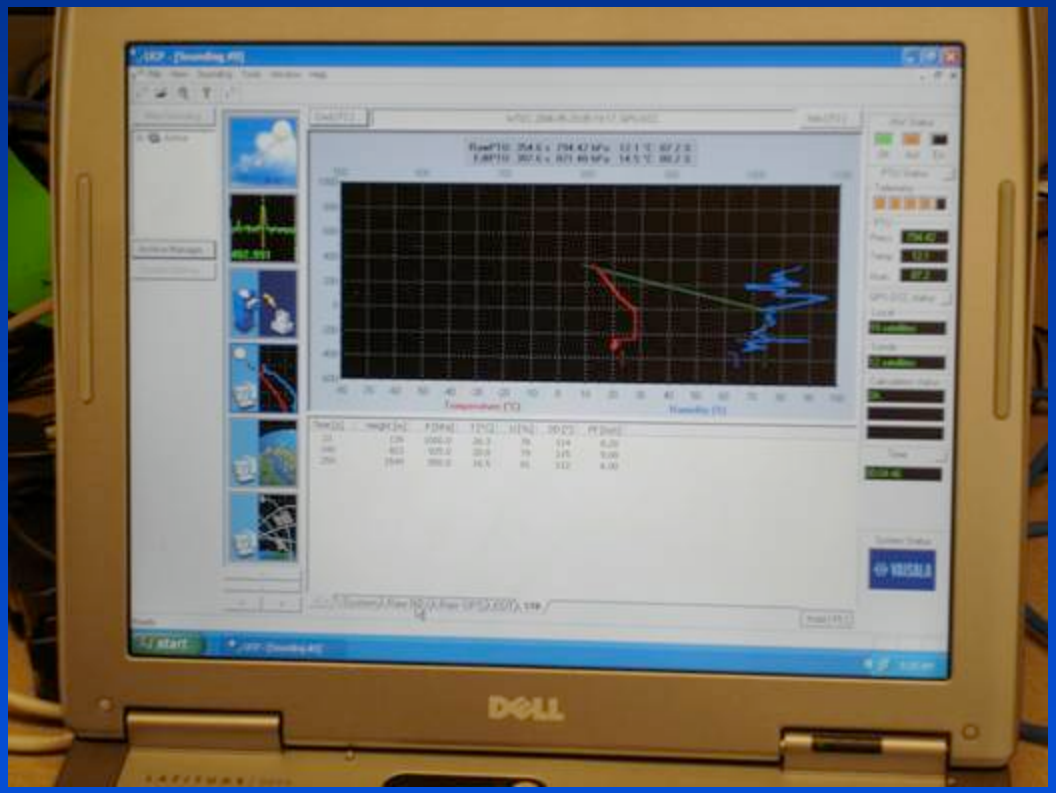


Cf. Aerosols99 Cruise (*Thompson et al.* 2000)

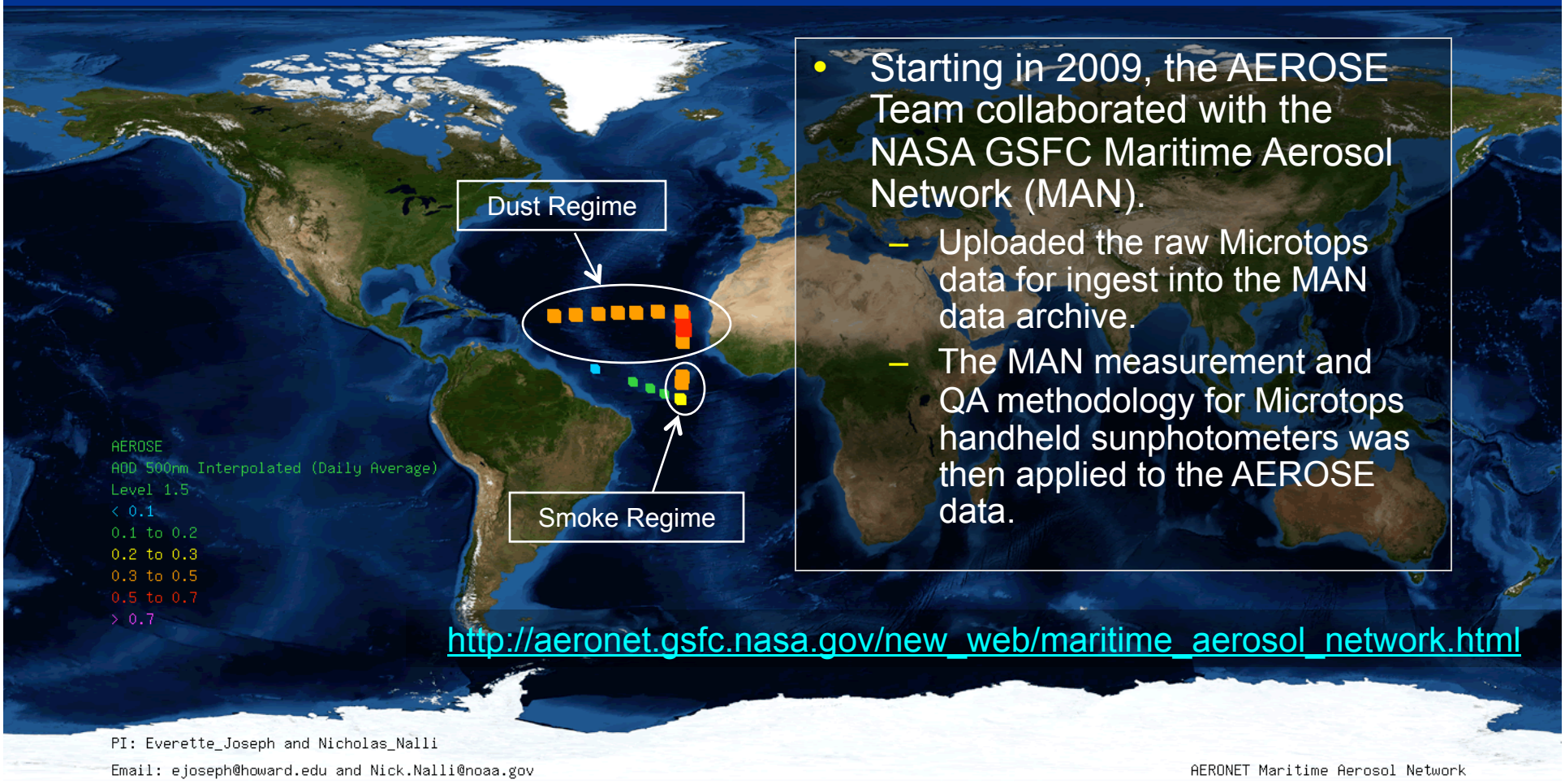
Interhemispheric Tropospheric Ozone

"Tropical Atlantic Paradox"

2009 Data Highlights



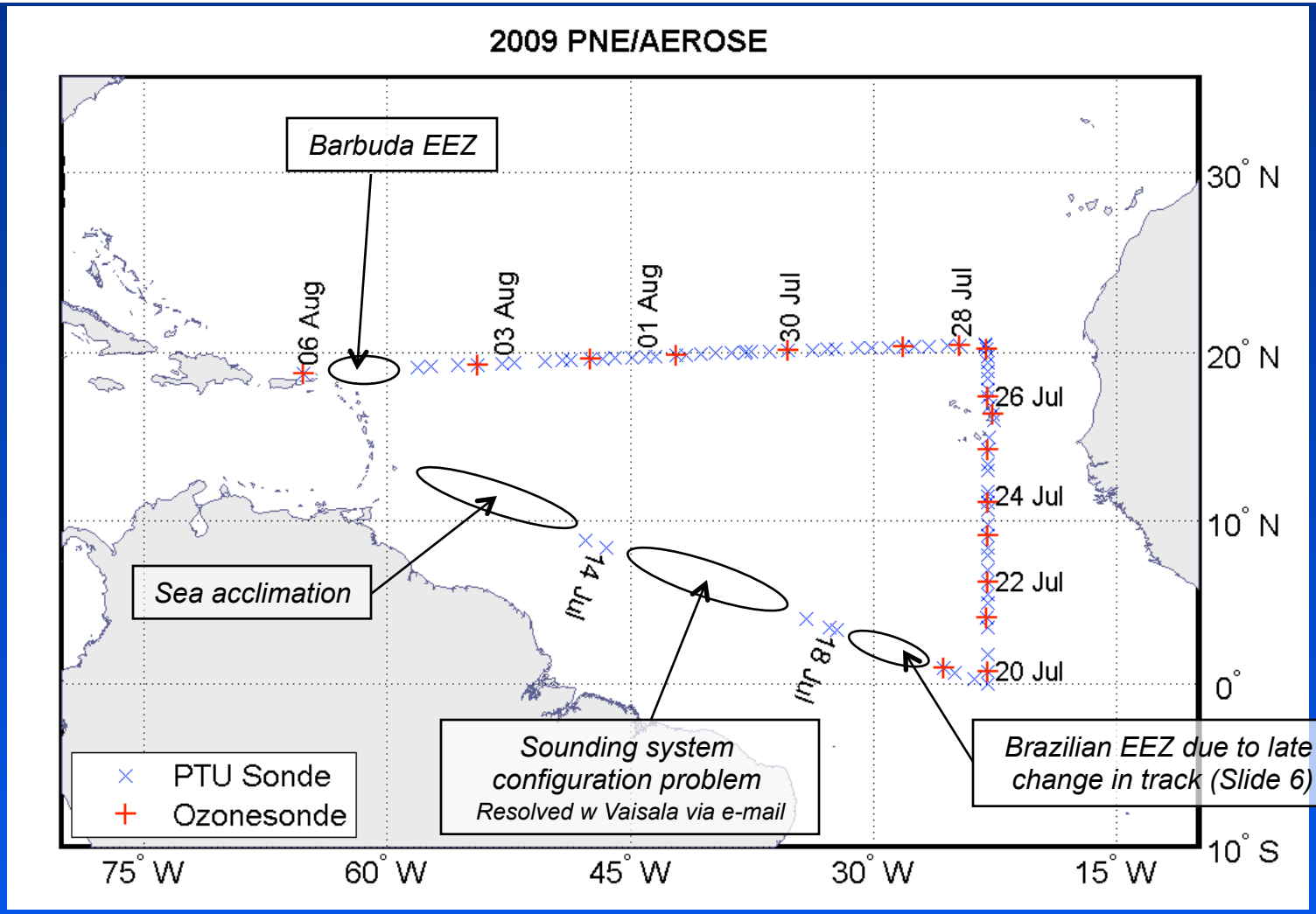
Microtops Aerosols
GSFC Maritime Aerosol Network



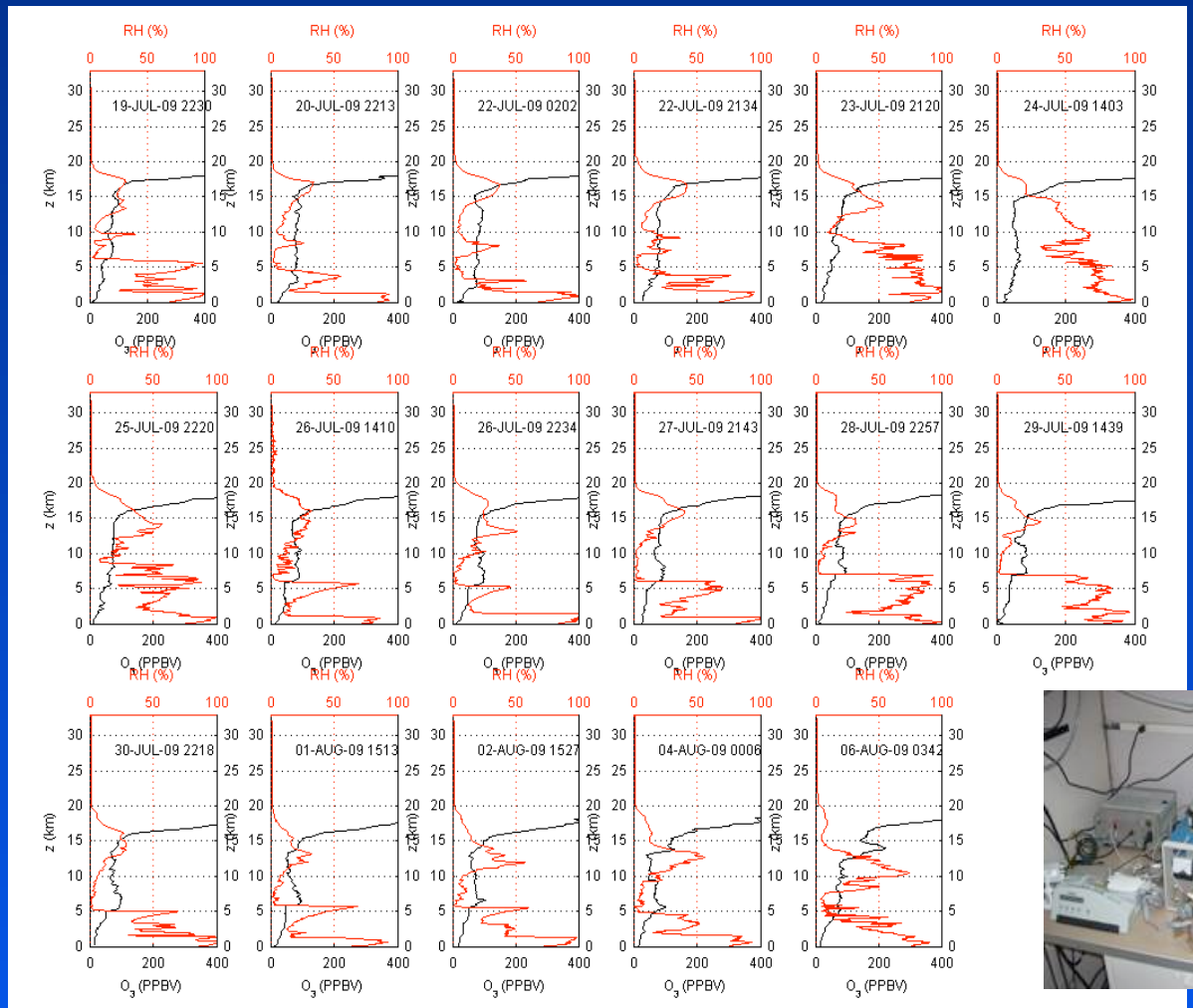
- Starting in 2009, the AEROSE Team collaborated with the NASA GSFC Maritime Aerosol Network (MAN).
  - Uploaded the raw Microtops data for ingest into the MAN data archive.
  - The MAN measurement and QA methodology for Microtops handheld sunphotometers was then applied to the AEROSE data.

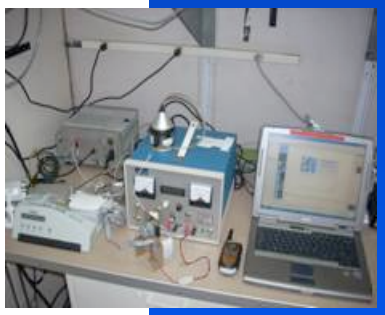
http://aeronet.gsfc.nasa.gov/new_web/maritime_aerosol_network.html

North Atlantic RAOB Cross-Sections

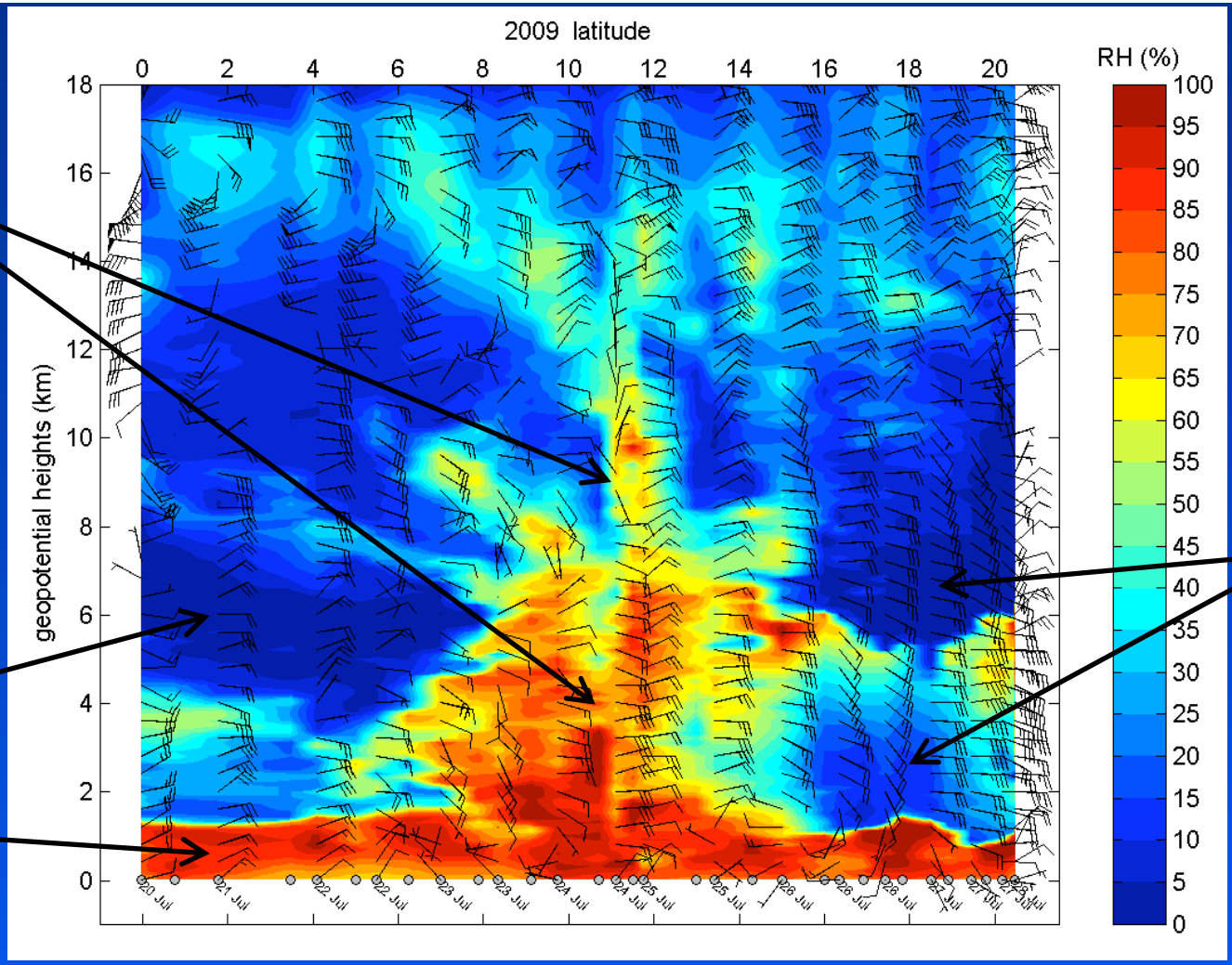


Ozone Profiles





Tropospheric RH Longitudinal (S-N) Cross-Section



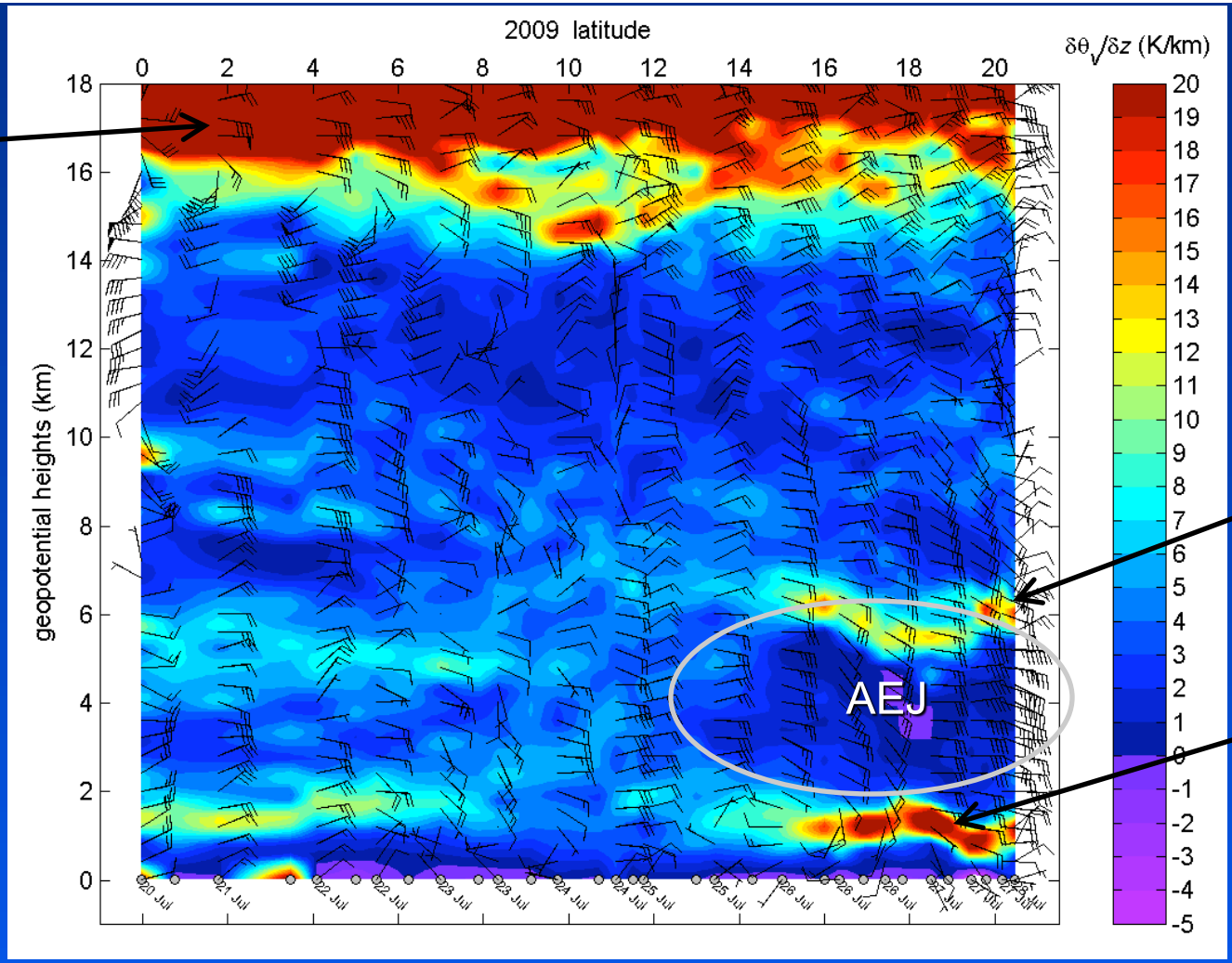
ITCZ

Non-SAL African airmass

Marine BL

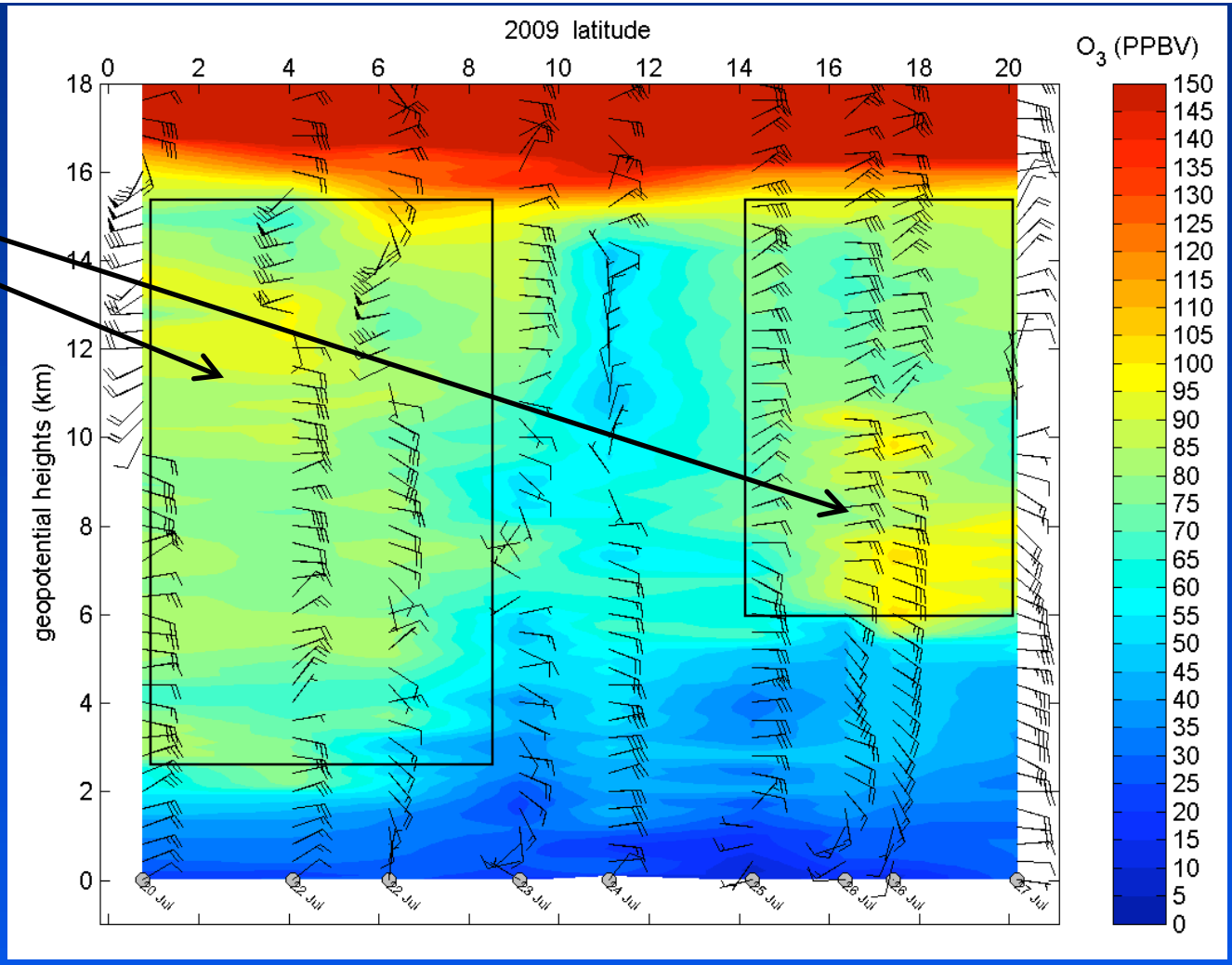
SAL

Tropospheric VPTLR Longitudinal (S-N) Cross-Section

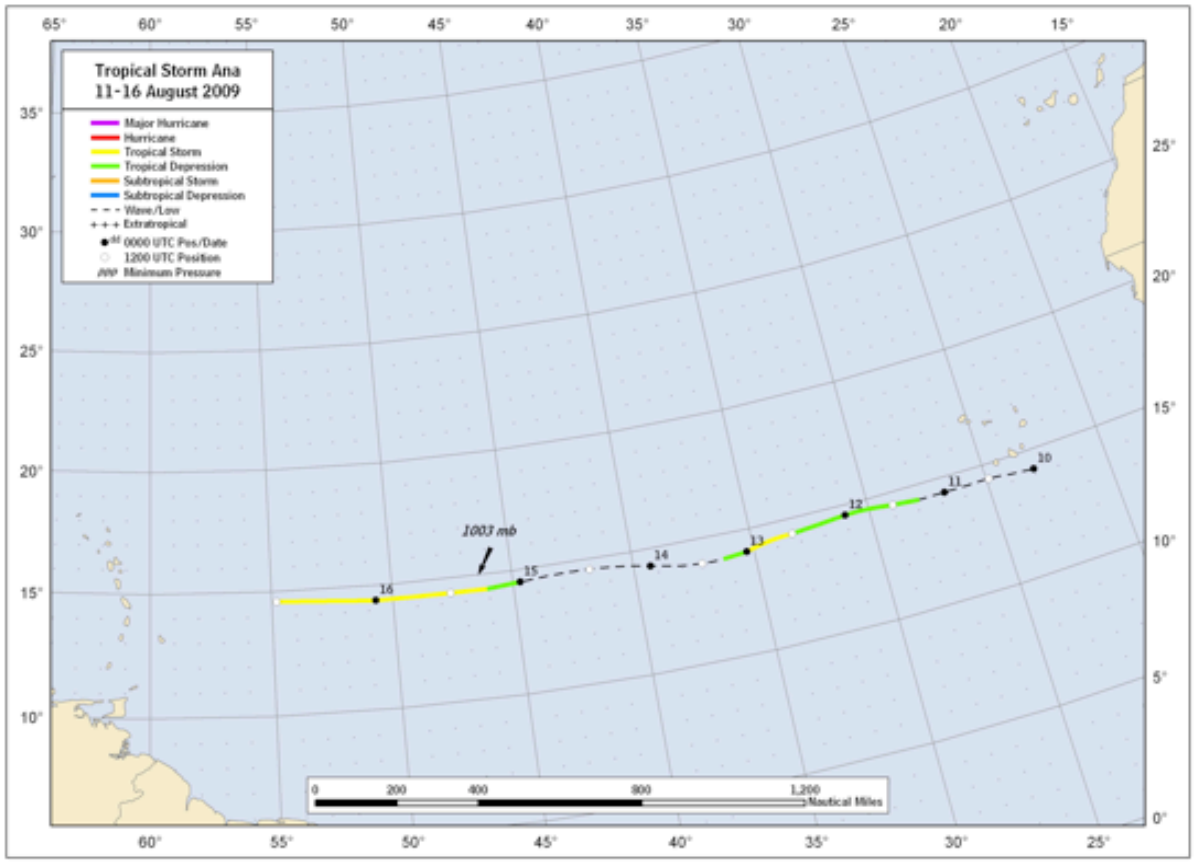


Tropospheric O_3 Longitudinal (S-N) Cross-Section

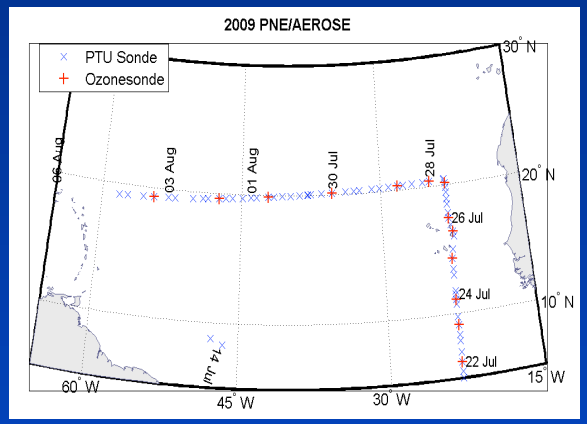
Elevated NH Trop O_3



TS ANA

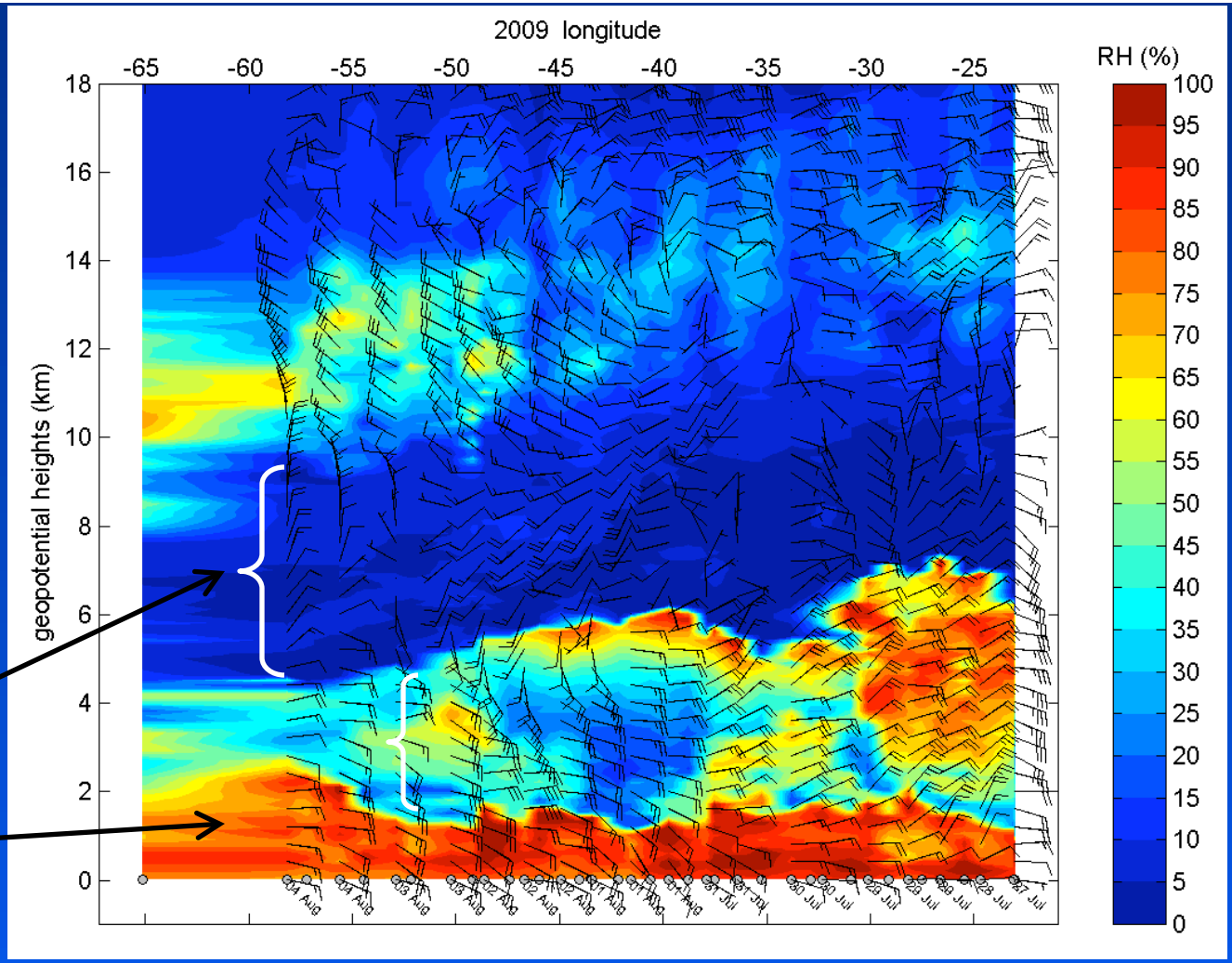


NHC summary provided courtesy of A. Reynolds (GSFC)

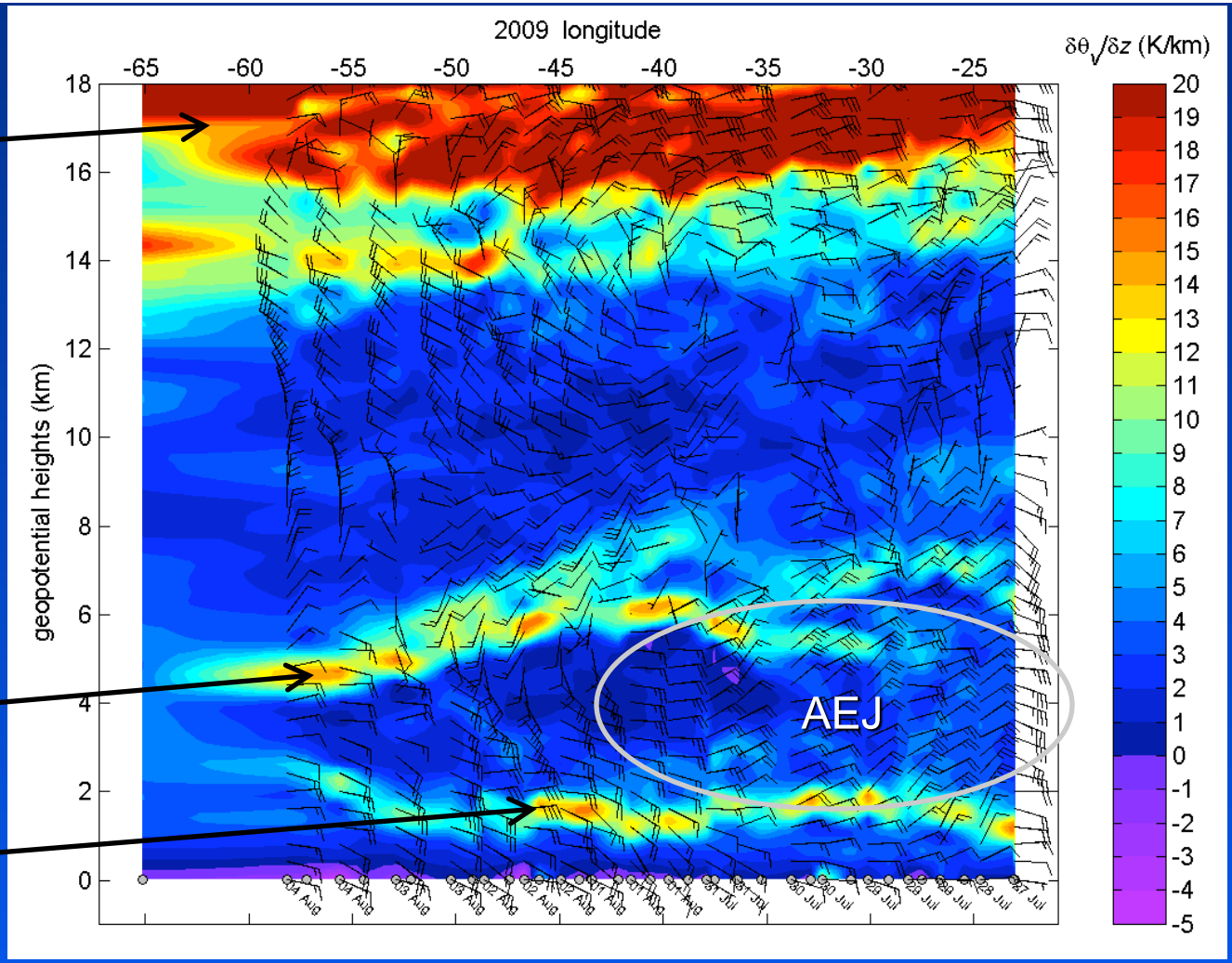


- The first half of August 2009 was quiet, with TS ANA being the first named storm.
- According to National Hurricane Center, a combination of shear, cooler SSTs, and dry air in the mid- to upper-levels appears to have caused the weakening of ANA.
- The AEROSE E-W track, about 5° to the north and just prior to TS ANA, obtained soundings that are consistent with this assessment.
- A WRF model case study is currently underway and planned to be the subject of a future paper (Joseph et al.).

Tropospheric RH Latitudinal (E-W) Cross-Section



Tropospheric VPTLR Latitudinal (E-W) Cross-Section



Tropopause

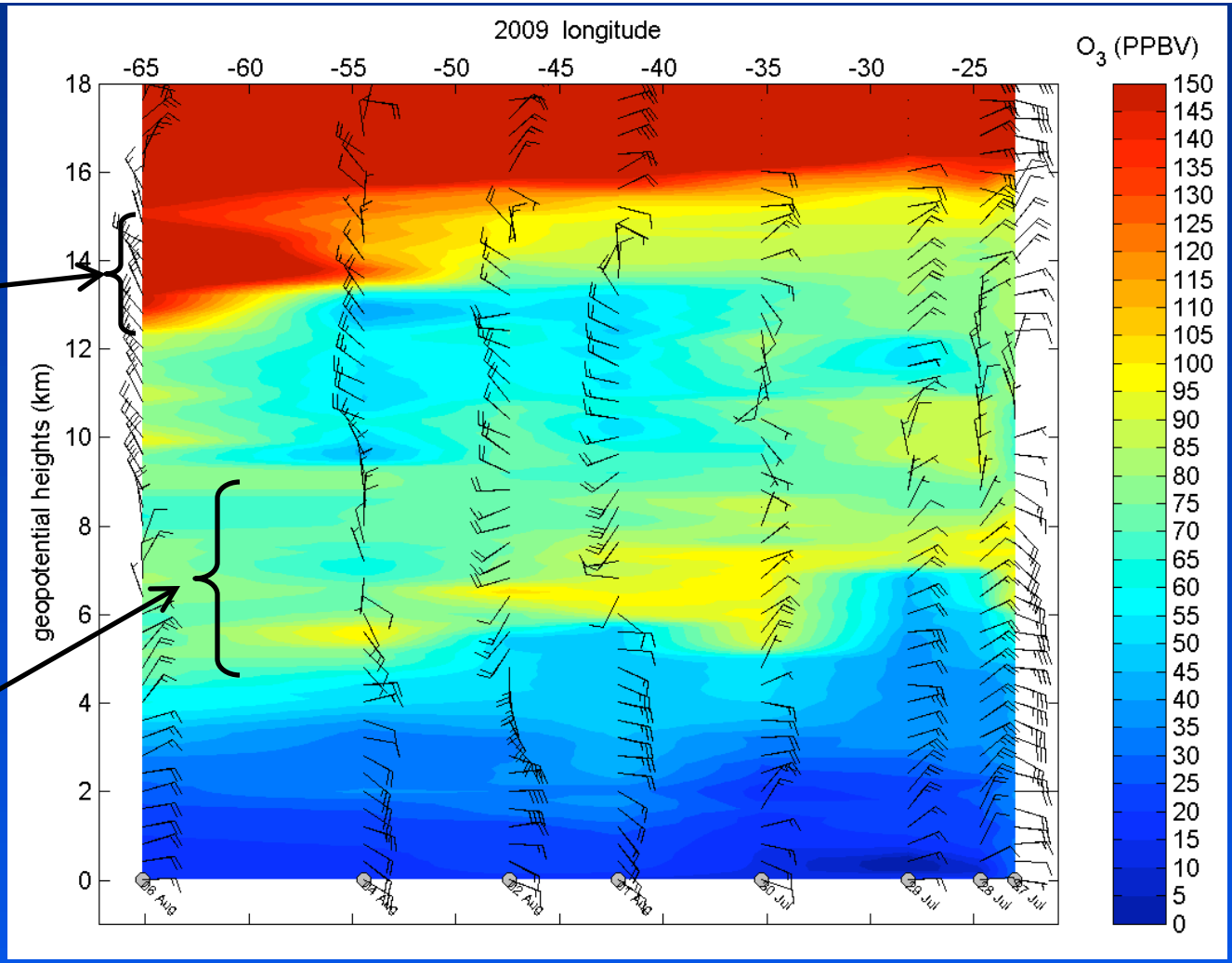
Midlevel Inversion

BL Inversion

Tropospheric O_3 Latitudinal (E-W) Cross-Section

Strat Intrusion?

Elevated NH Trop O_3 within dry layer



Summary

- The PNE/AEROSE intensive campaigns continue to compile a multiyear set of ship-based, marine *in situ* **cross-sectional correlative measurements** over the **tropical Atlantic Ocean**.
- The AEROSE cruise domains span **a region of meteorological interest** (for sounder missions) in terms of the SAL, tropical storm formation, and tropospheric ozone/carbon/aerosol chemistry and transport.
- The 2009 Campaign adds to the current data inventory from 2004, 2006–2008, including IASI and AIRS matchups.

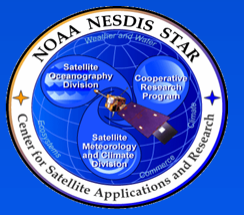
Future Work

- Manuscript on PNE/AEROSE campaigns (with emphasis on meteorological highlights and sounder cal/val) in preparation for ***BAMS***.
- Acquire IASI/AIRS matchups for latest 2009 campaign RAOBs
- Construct AEROSE CrIS/ATMS Marine Proxy Data Set (w/ G. Guo, M. Divakarla, T. King)
  - AVTP, AVMP validation over open ocean, within and without Saharan air layer, dust, smoke
  - IP validation: vertical ozone profiles, skin SSTs
- Completion of AEROSE GOES-R Proxy Data Set, including SEVIRI, AIRS/IASI granules (w/ H. Xie, T. Zhu)
  - SEVIRI/GOES-R ABI legacy profile TPW validation and demonstration; SAL detection (w/ H. Xie, J. Li)
- Acquisition of RAOB data within NPROVS (w/ T. Reale); AIRS dedicated global analysis (w/ E. Fetzer)
- Ozonesonde and surface ozone analyses; SAL and tropical cyclogenesis investigations (w/ E. Joseph, et al. HU/NCAS)
- Next PNE/AEROSE Cruises slated for early and late 2010 (w HU/NCAS, UM/RSMAS, NOAA/AOML)

Acknowledgements

- The Howard University **NOAA Center for Atmospheric Sciences (NCAS)**, supported by
  - The **NOAA Minority Serving Institutions Educational Partnership Program**
  - National Science Foundation Career Grant (ATM-9703167)
  - NASA Grant (NG-1224)
- The **Integrated Program Office**
- The **NOAA GOES-R Algorithm Working Group** Proxy Data and Soundings Application Teams
- R. Lumpkin, C. Schmid (NOAA/AOML) and the **PIRATA Northeast Extension** Project
- P. Clemente-Colón, C. Dean, T. King, Xingpin Liu (NOAA/NESDIS/STAR); T. Zhu (CSU/CIRA)
- T. Pagano, E. Fetzer (JPL), W. Feltz, R. Knuteson (UW), and the **AIRS Science Team**
- M. Szczodrak, M. Izaguirre, B. Otto, and the many students, too numerous to name here, who participated in, and contributed to, the success in the campaigns.
- The **officers and crew of the *Ronald H. Brown,*** especially J. Shannahoff (Survey Tech), for their professional support and contributions.

Extra Slides



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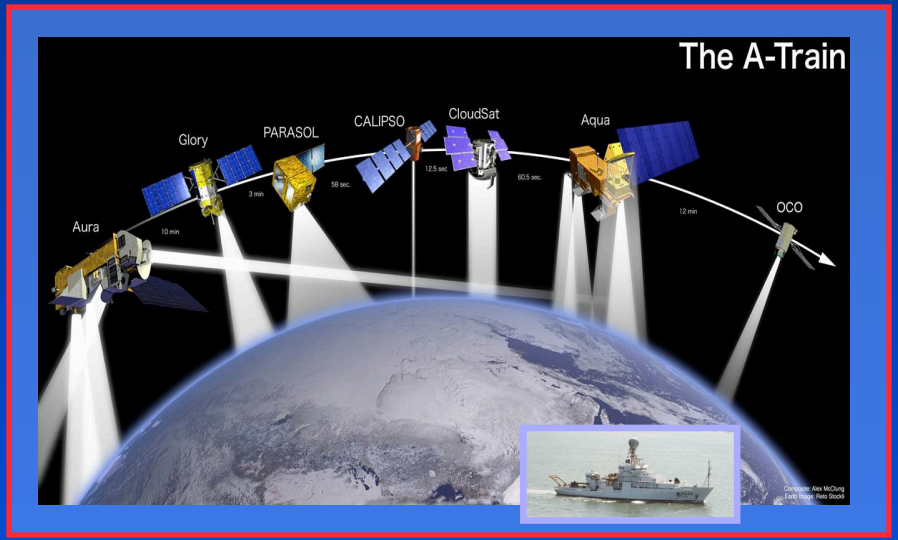
AEROSE Goals

The three central scientific questions being addressed by AEROSE are (Morris et al. 2006; Nalli et al. 2006)

1. What is the change in the mineral dust and smoke aerosol distributions as they evolve physically and chemically during trans-Atlantic transport?

2. How do Saharan and sub-Saharan outflows affect the regional atmosphere and ocean during trans-Atlantic transport?

3. What is the capability of satellite remote sensing and numerical models for resolving and studying the above processes?



PNE/AEROSE: "Synergistic Val"

- **Participating Institutions**
  - Howard University NOAA Center for Atmospheric Sciences (HU/NCAS)
  - NOAA/NESDIS/STAR; IPO
  - University of Miami/RSMAS
  - NOAA/ESRL/PSD (formerly NOAA/ETL)
  - NOAA/OAR Atlantic Oceanographic and Meteorological Laboratory (AOML)
  - NOAA Pacific Marine Environmental Laboratory (PMEL)

- **Symbiosis**
  - Engages broader science community on specific problems.
  - All parties gain access to all data. We provide satellite products, sondes and minimal manpower, and in return we get *everything*, at low-cost, low-risk.
  - AEROSE is now a key component for justifying the PNE cruises. Time onboard the *RHB* is at a premium. NOAA is thus more inclined to allocate cruises that make efficient use of resources.

"Everyone benefits."

CRUISE INSTRUCTIONS

NOAA Ship RONALD H. BROWN

14 April 2009

Cruise Number:	RB-09-04
Project:	PIRATA Northeast Extension (PNE) / AEROSE
Cruise dates:	11 July — 10 August 2009
Chief Scientist:	Rick Lumpkin, NOAA/AOML
Working Area:	Tropical Eastern Atlantic Ocean
Itinerary:	Bridgetown, Barbados to Miami, FL USA (31 days)

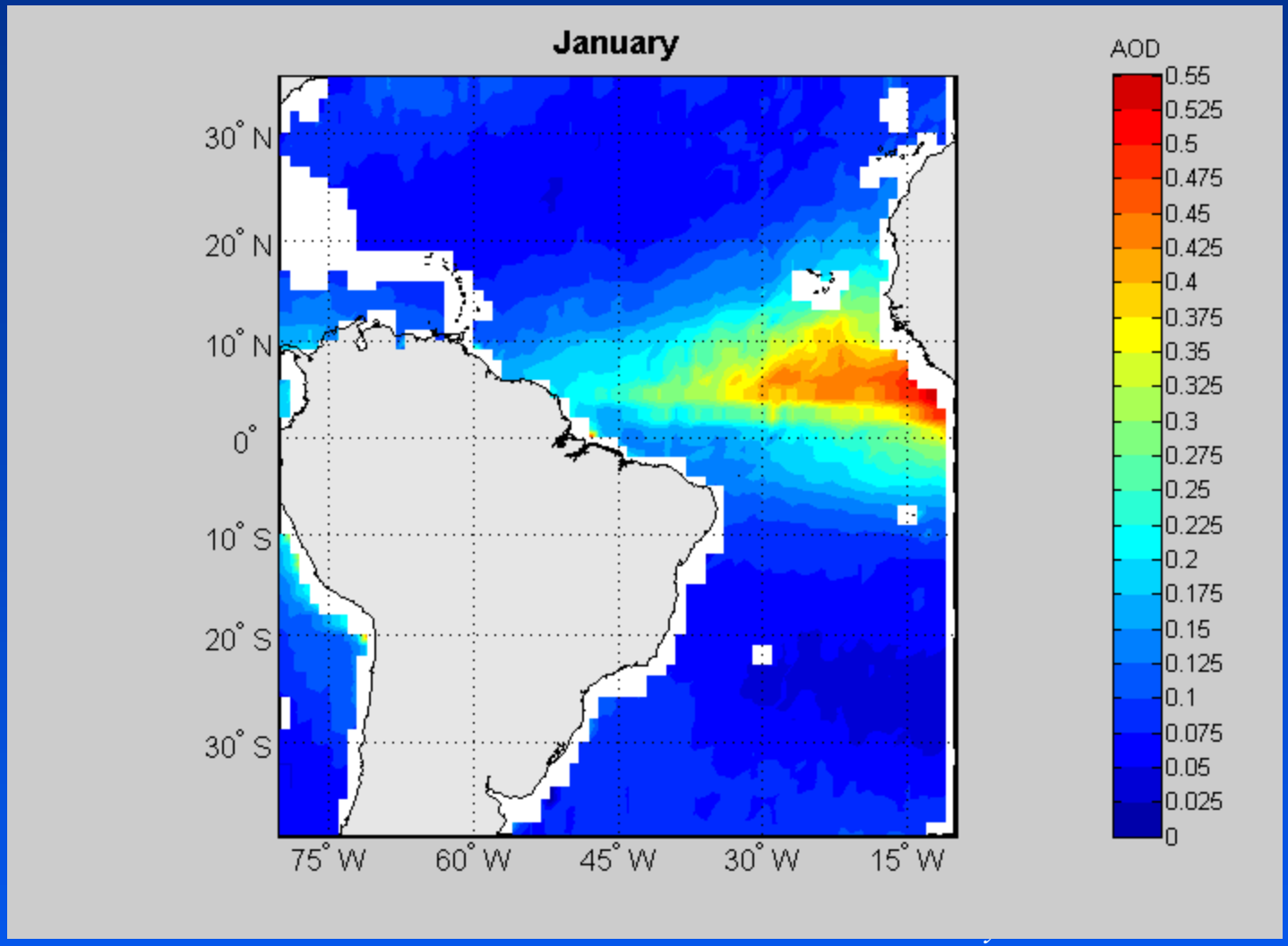
Endorsements:

Dr. Rick Lumpkin Project Lead NOAA/AOML	Dr. Robert Atlas Director, AOML Miami, FL 33149	CAPT. Emily Christman Commanding Officer, MOA Norfolk, VA 23510

Specific objectives of the *RONALD H. BROWN* cruise

The objectives of this RHB cruise address NOAA's Climate Goal and Weather and Water Goal, and are an explicit NOAA contribution to the PIRATA and AEROSE programs. Specific goals are in the areas of oceanography, marine meteorology, atmospheric chemistry and satellite validation.

Atlantic Aerosol Climatology
(AVHRR PATMOS 1985-2000)



Aerosol Impact on the Surface Energy Budget

- Direct Effect
  - Aerosols absorb in infrared (Earth emission) spectrum
    - Nevertheless, they are not “black”
  - Aerosols scatter in visible (solar emission) spectrum
    - Nevertheless, they are still semi-transmissive
  - Net impact = surface cooling
- Indirect Effect
  - Aerosols act as cloud condensation nuclei
    - Low level water clouds have high albedo (high solar reflectance) and high emissivity (high infrared absorption and reemission)
    - High level ice clouds act like aerosols, greenhouse effect