2008 RB-08-03 Interhemispheric Transit Cruise Summary

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Atmospheric Sounding Team Meeting
Beltsville, MD
15 October 2008

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)
  - AMMA*/AEROSE-II piggyback (June-July 2006)
    - Leg 1 (4 weeks)
    - Leg 2 (4 weeks)
  - PNE*/AEROSE-III piggyback (May 2007; 4 weeks)
  - **RB-08-03 Interhemispheric Transit** piggyback (Apr-May 2008; 3 weeks)

- The AEROSE campaigns include one of the most comprehensive 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

AEROSE Goals

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

1. What is the extent of 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?

Participating Institutions

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

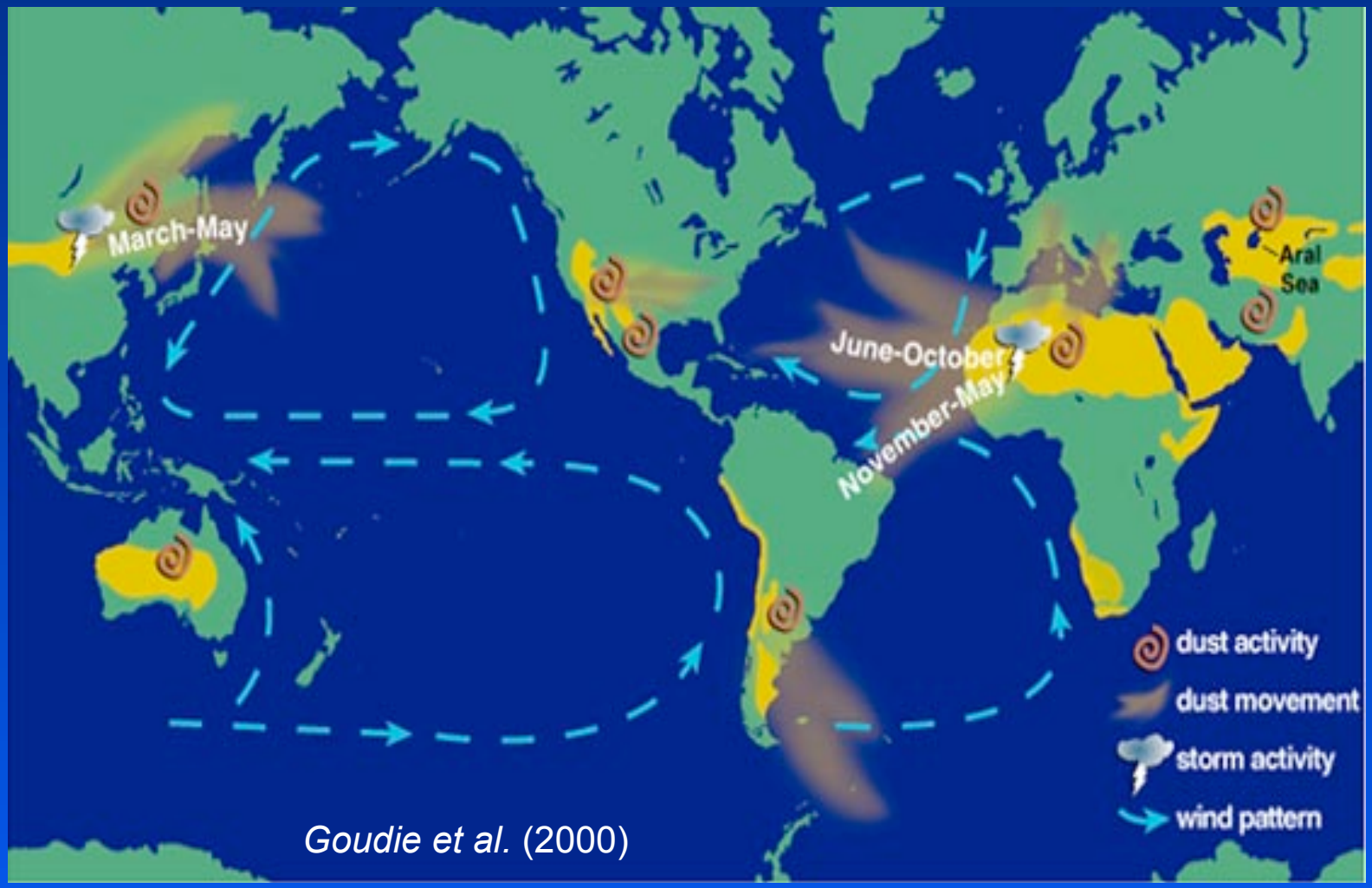
Key Onboard Collaborators

NAME	INSTITUTION	RESPONSIBILITY
C. Schmid R. Lumpkin	NOAA/AOML	PNE Chief Scientists; TAO Moorings; CTD, XBTs (PNE MISSION CANCELED)
B. Otto	NOAA/ESRL/PSD (formerly NOAA/ETL)	Chief Scientist, RB-08-03 Descoped Mission
V. Morris E. Joseph Grad Students	HU/NCAS	Aerosols; Chemistry; Radiation Budget; Ozonesondes
N. Nalli	NOAA/NESDIS/STAR (PSGS, Inc.)	Dedicated RS92 Rawinsondes and AIRS/IASI/GOES-R Validation
M. Szczodrak	UM/RSMAS	M-AERI Measurements; MW Radiometer; All-sky camera

Key Shoreside Collaborators

NAME	INSTITUTION	COLLABORATION
C. Barnet, W. Wolf M. Goldberg Hua Xie, J. Wei	NOAA/NESDIS/STAR IMSG, PSGS	AIRS, IASI, SEVIRI Data and Retrievals
D. Wolfe	NOAA/OAR/ESRL/PSD (formerly NOAA/ETL)	Vaisala sounding system; Surface Flux Measurements; C-Band Radar; Wind Profiler; Sea Space Satellite Uplink
P. Minnett M. Izaguirre	UM/RSMAS	M-AERI Data; All-sky camera
S. DeSouza-Machado L. Strow	UMBC	AIRS/IASI/M-AERI Radiative Transfer Modeling
T. Pagano	JPL	RS92 validation rawinsondes

Global Circuit of Mineral Dust Sources

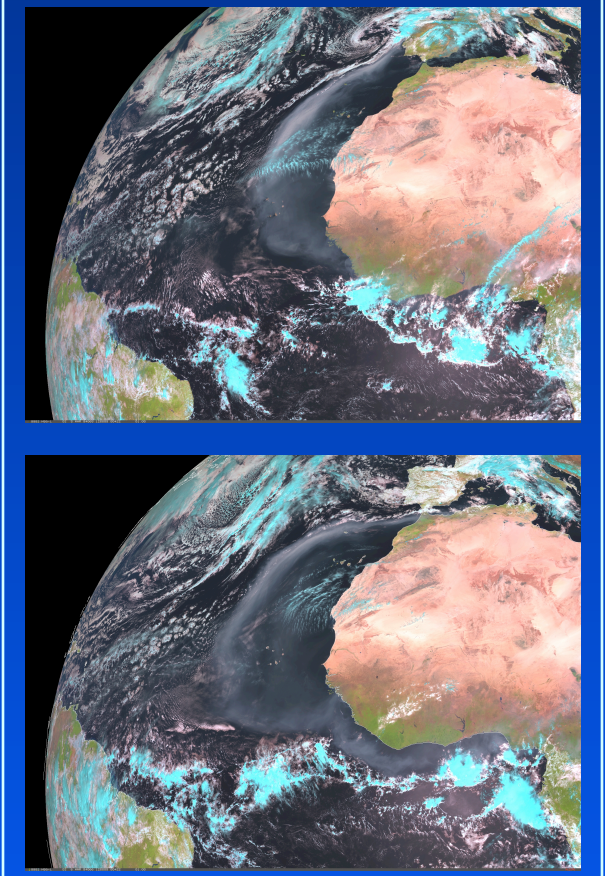


Goudie et al. (2000)

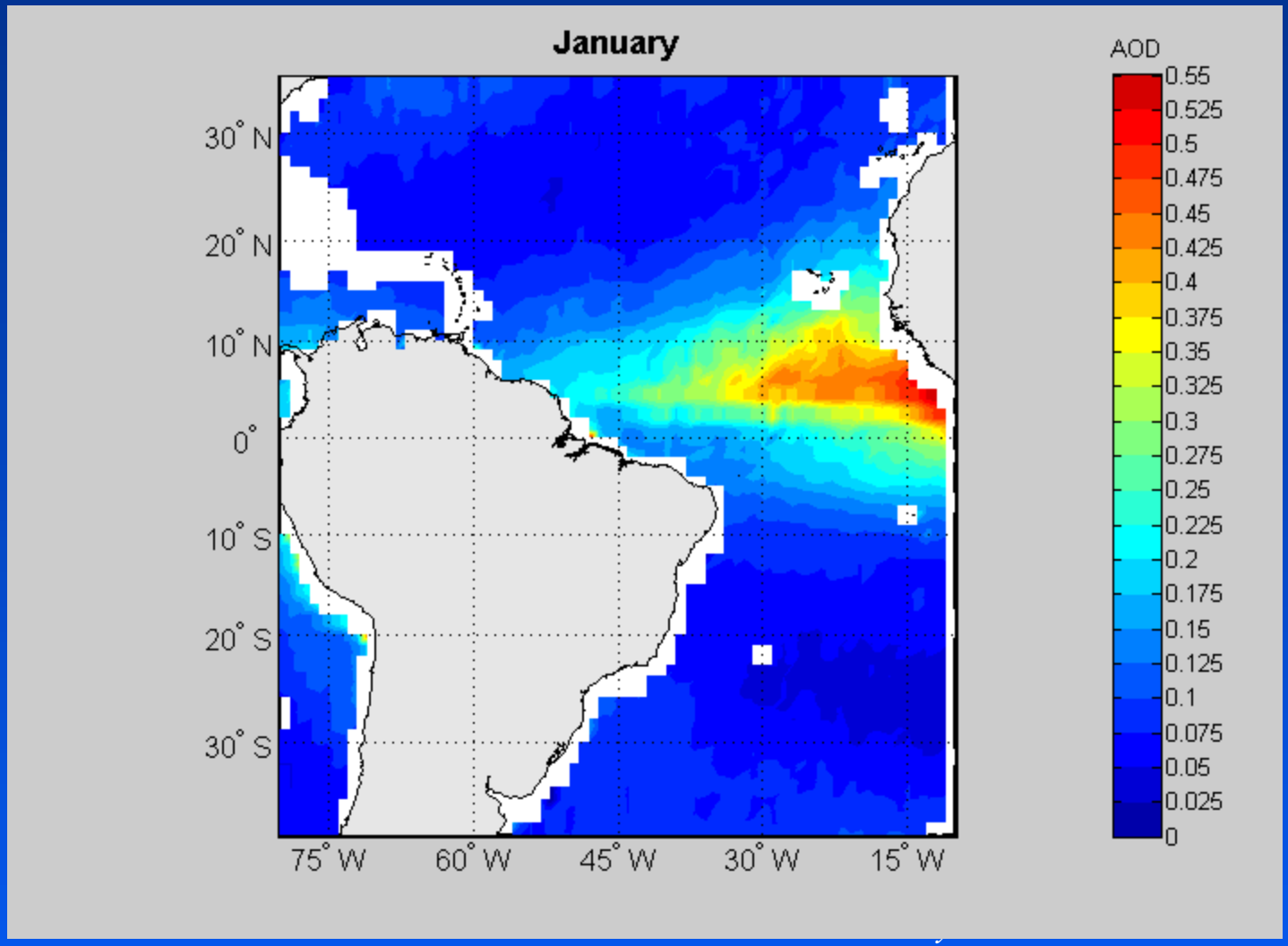
Saharan Dust Aerosols

- 2 billion metric tons of mineral dust are injected into the atmosphere from the Sahara annually
- Saharan dust is often transported well across the Atlantic
- Westward flow accounts for the 30–50% of the dust output, peaking during NH summer and springtime

Dust outflow event, 6-7 Mar 04, observed by Meteosat SEVIRI



Atlantic Aerosol Climatology
(AVHRR PATMOS 1985-2000)



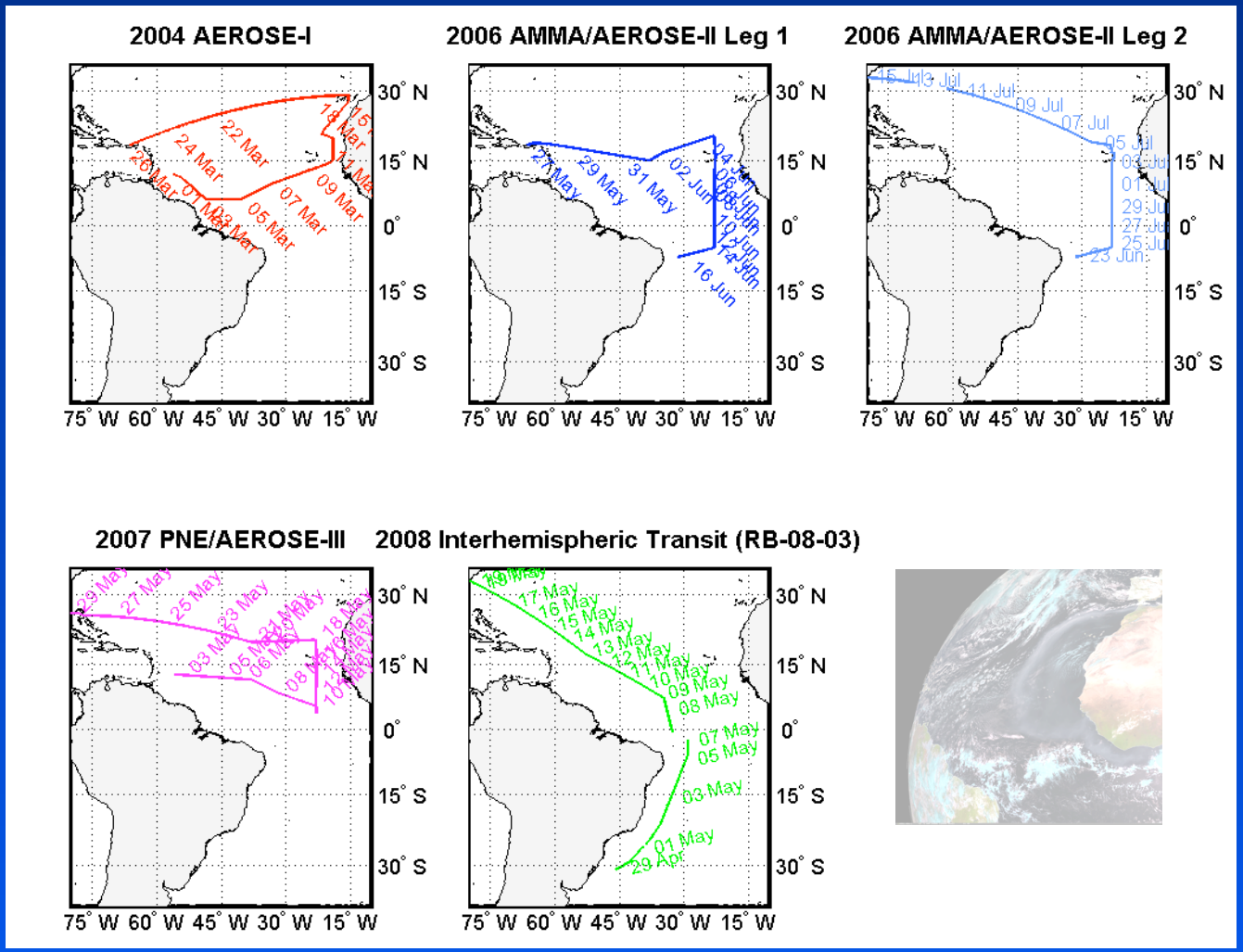
Saharan Air Layer

- 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
  - Directly observed during AEROSE 2004 (Nalli et al. 2005), and PNE/AEROSE 2006 and 2007
- These conditions hypothetically act to suppress hurricane formation over the Atlantic (e.g., Dunion and Velden, 2004; Evan et al. 2006)
- Hyperspectral IR sounders (AIRS, IASI and NPP/CrIS) are tools whereby the SAL can be observed synoptically; therefore, **validation in this region is all the more important**

AEROSE Cruises to Date
Combined Marine-SAL Validation Data

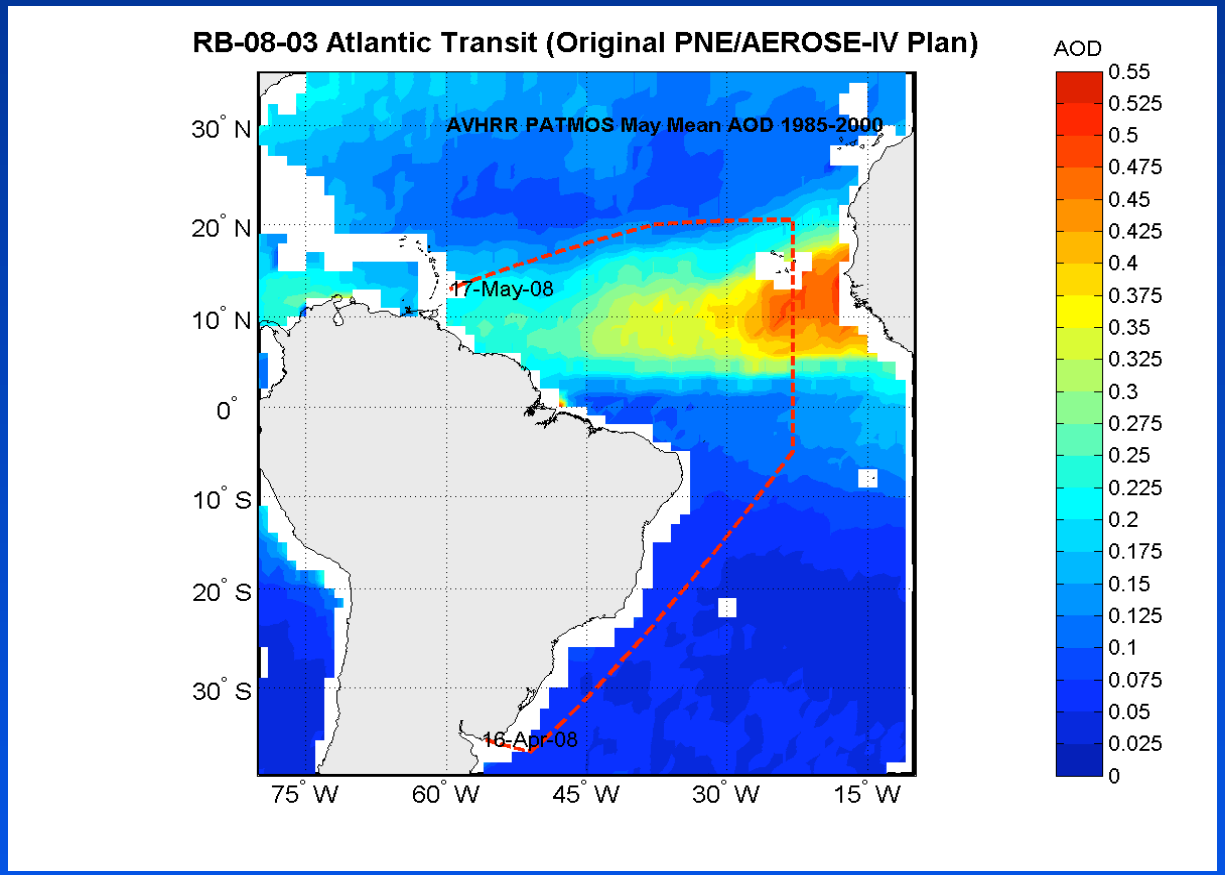
- **March 2004: AEROSE-I**
  - Primary mission onboard *Ronald H. Brown*
  - 3-hourly RAOBs (RS80/90), including EOS-Aqua AIRS overpasses (156 total)
  - Marine Atmospheric Emitted Radiance Interferometer (M-AERI)
    - Up and downwelling IR spectra
    - Sea surface skin temperature
  - Microtops sun photometer
  - CIRIMS (skin SST)
  - Broad band SW and LW fluxes
- **Jun-Jul 2006: Piggyback mission (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
  - SW/LW fluxes
- **May 2007: Piggyback mission (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, SW/LW fluxes
- **Apr-May 2008: Piggyback mission (RB-08-03 Interhemispheric Transit)**
  - Cruise radically descoped due to severe 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, SW/LW fluxes
- *2009 PNE/AMMA and beyond?*

Cruise Tracks 2004-2008

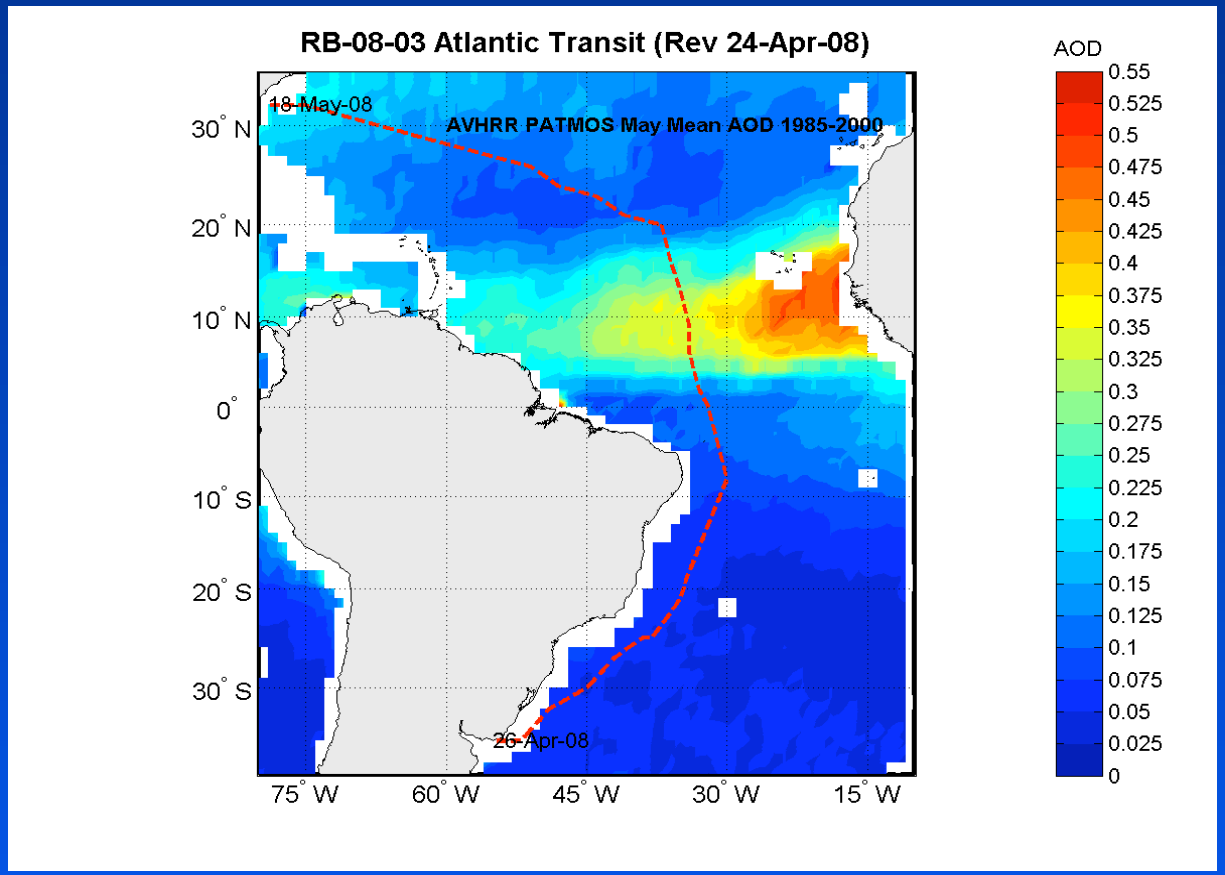


The Devolution of the URCHIN*

** Uruguay to Charlestown Inter-hemispheric transit*



The Devolution of the URCHIN



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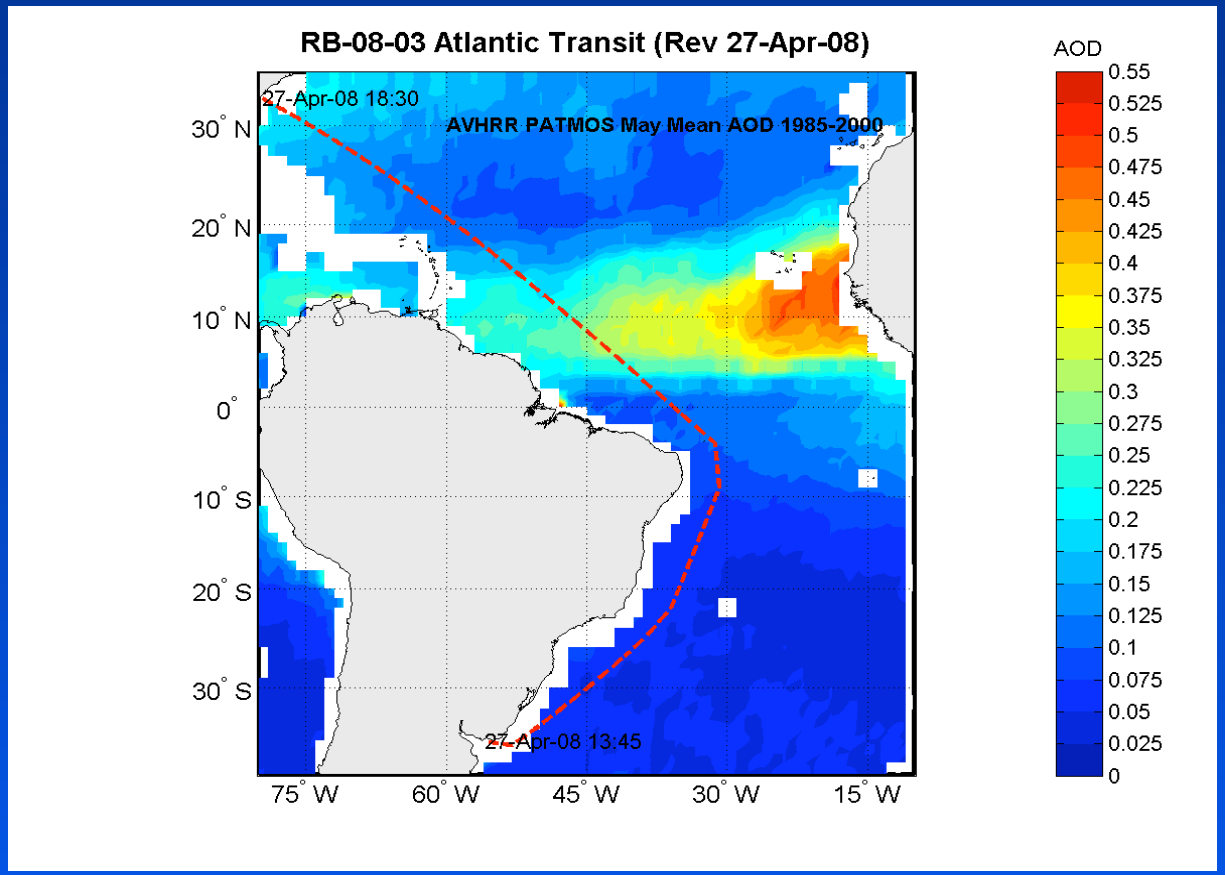

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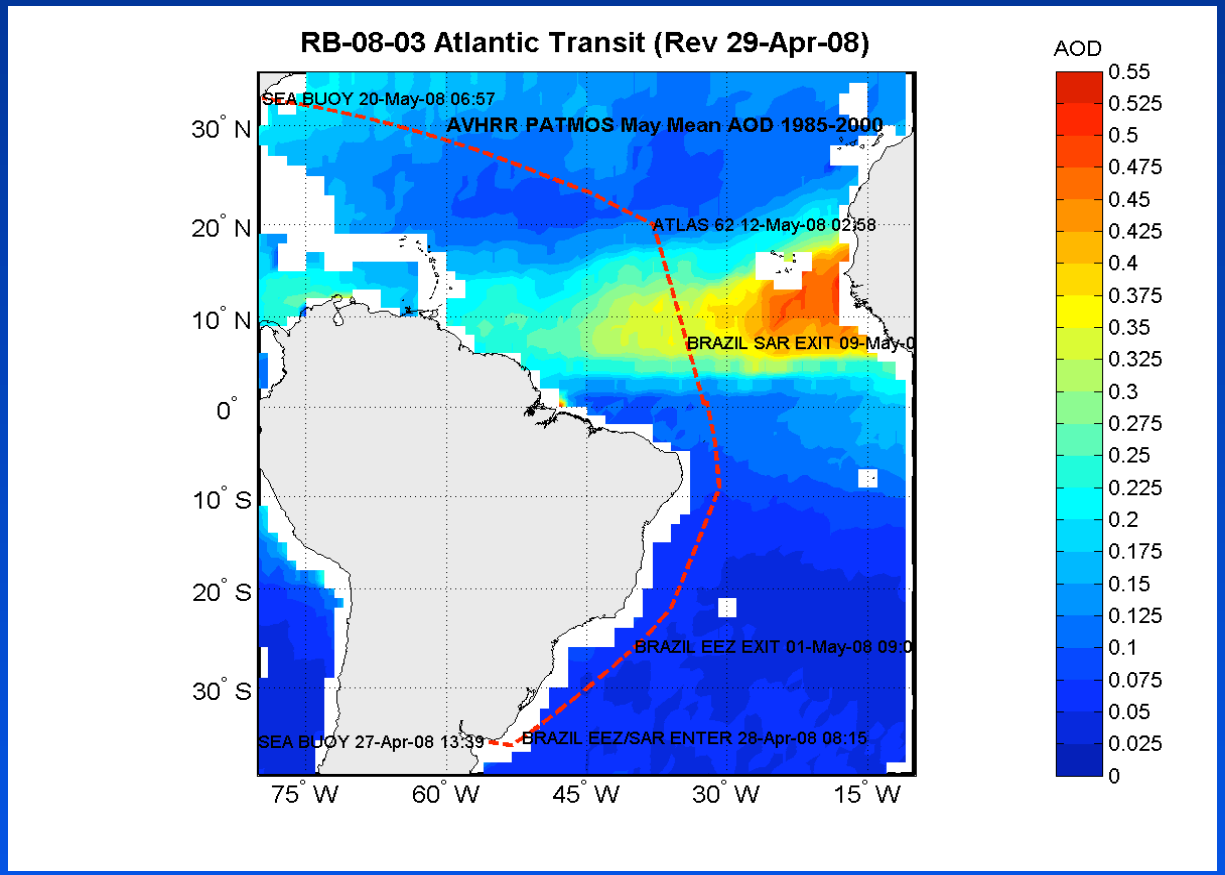

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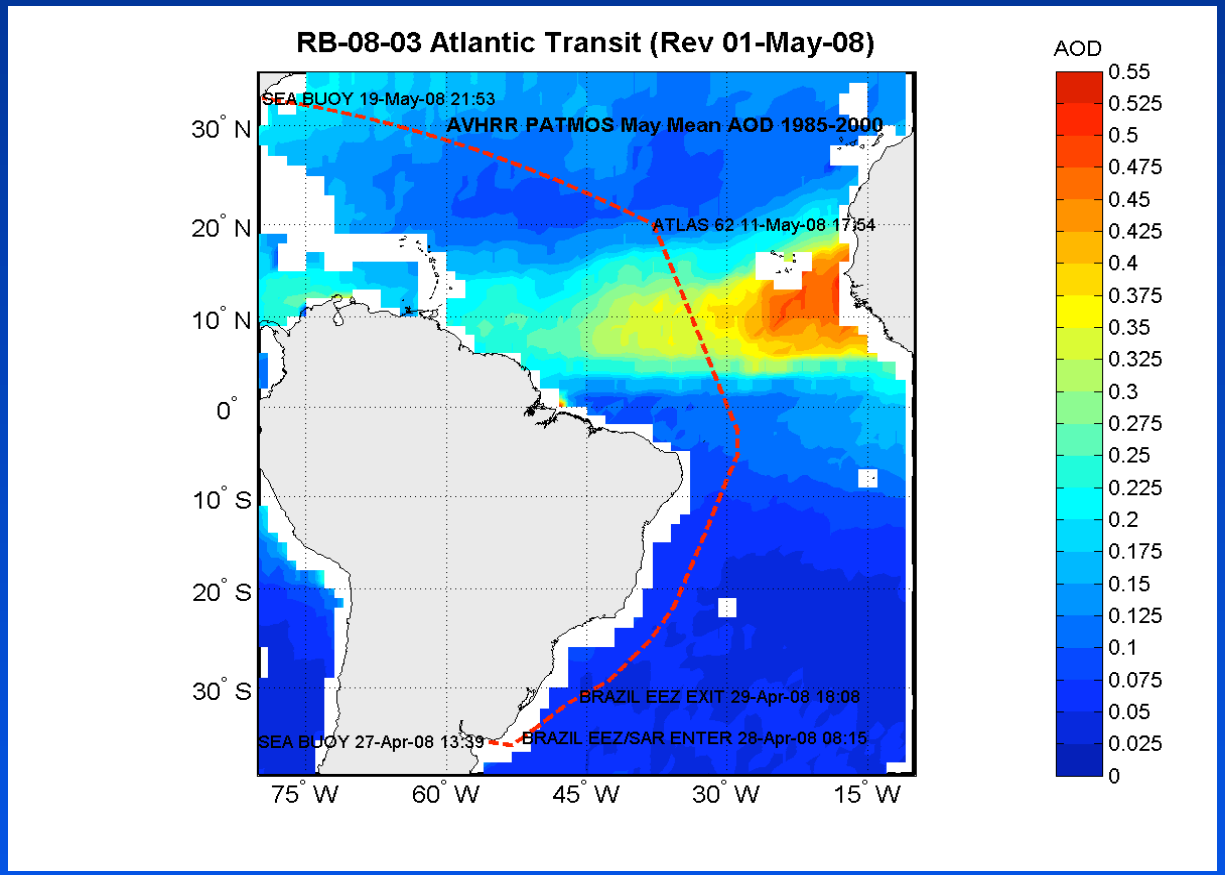

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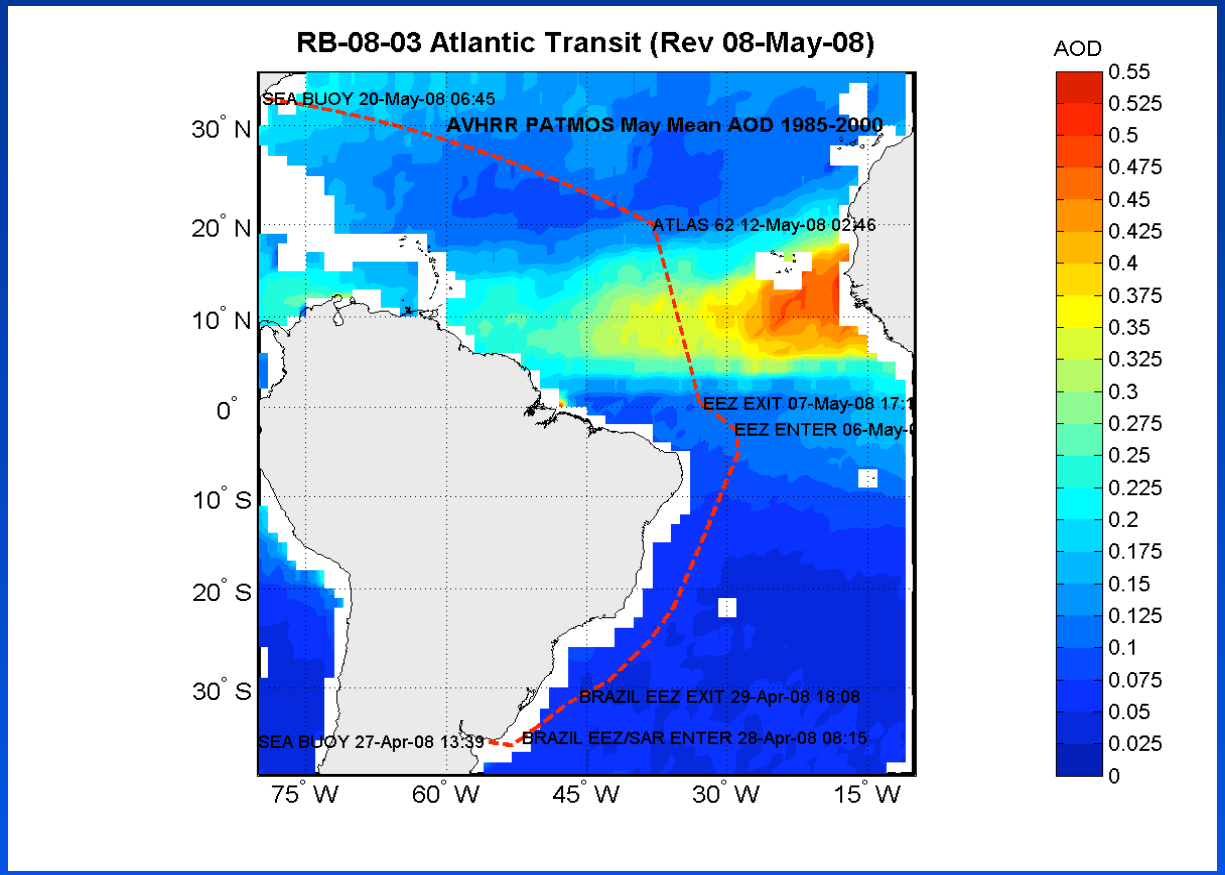

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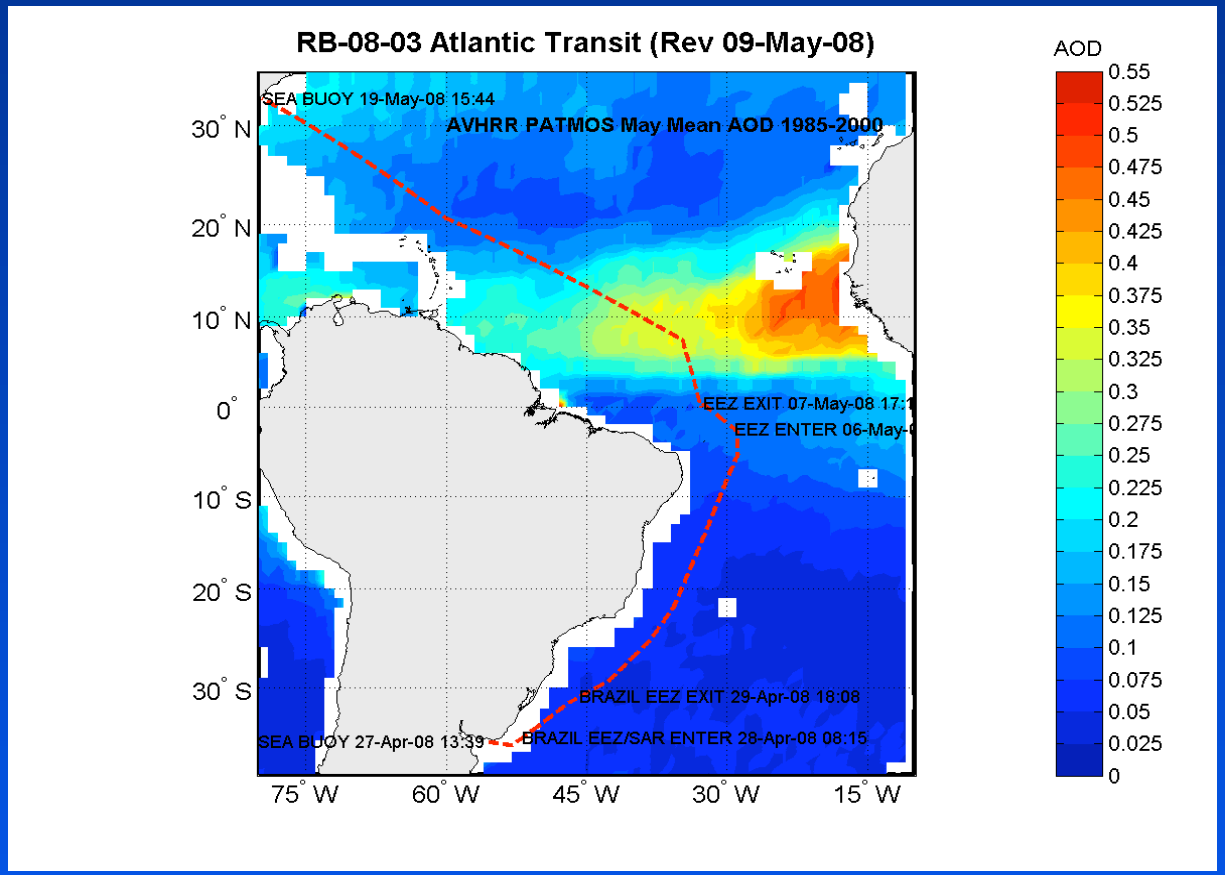
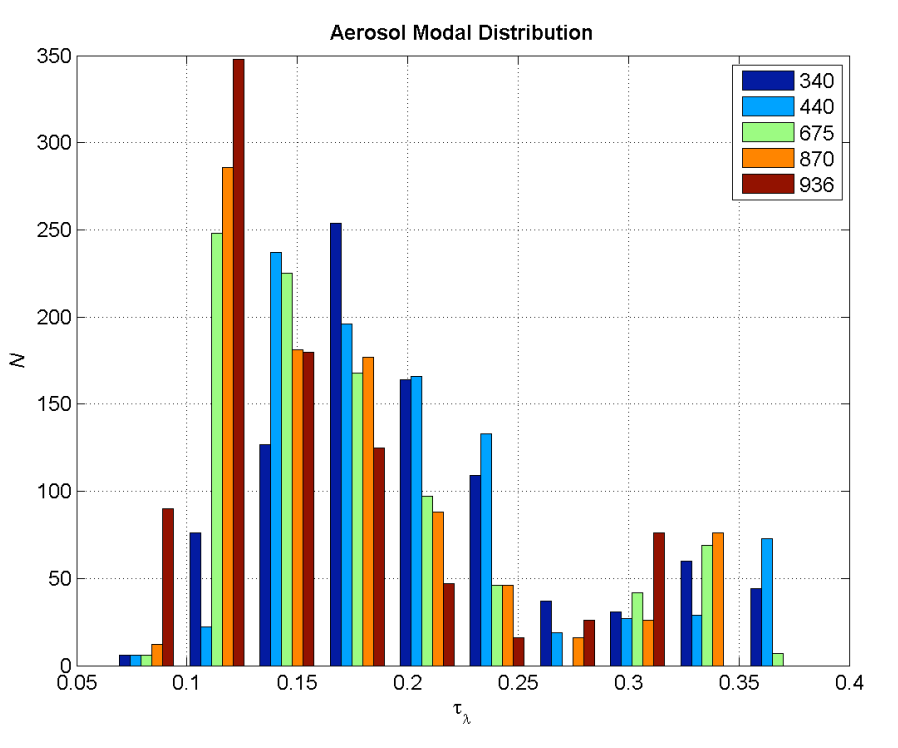
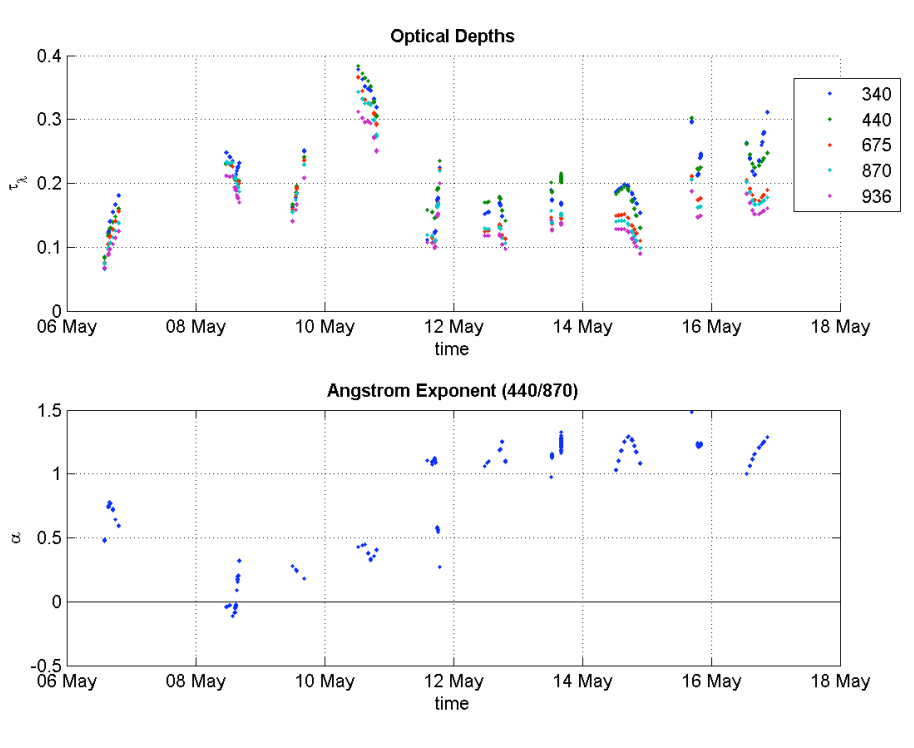


Microtops Aerosols

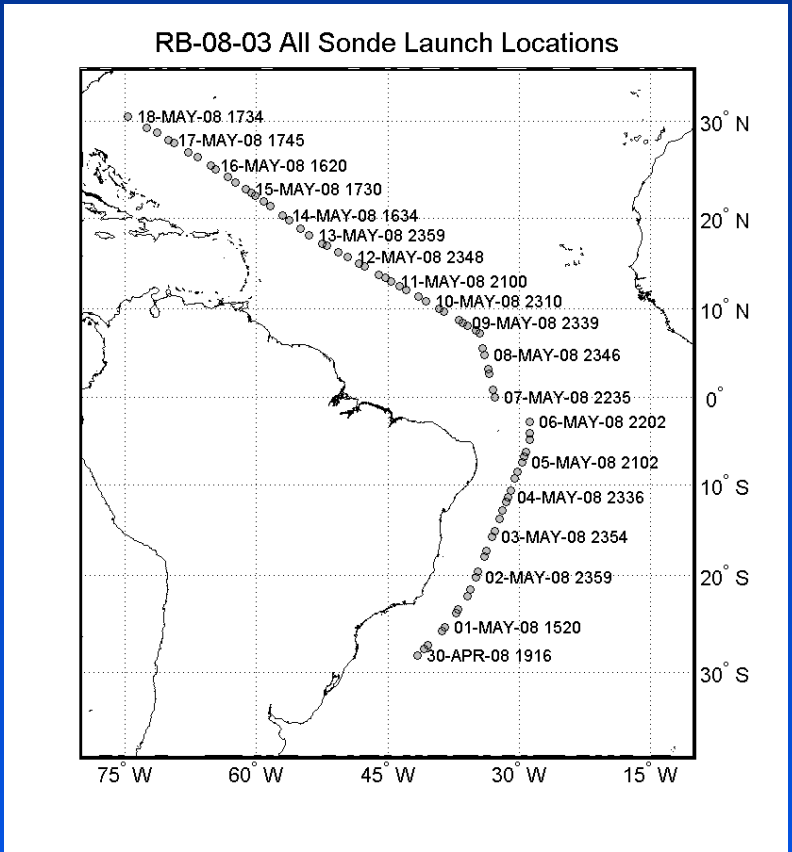


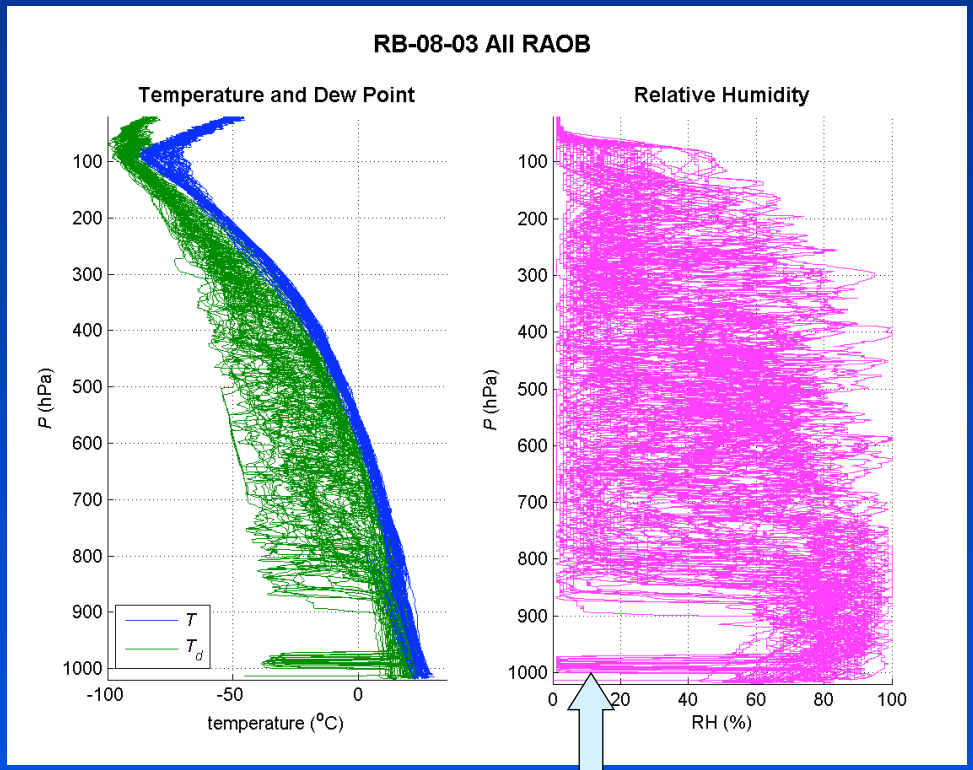


Radiosonde Observations (RAOBs)

- **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
  - **75** successful '08 launches
  - **423 soundings** to date
- **Ozonesondes** ~1/day during AIRS/IASI overpasses
  - **16** successful '08 launches
  - **53 O_3 soundings** to date

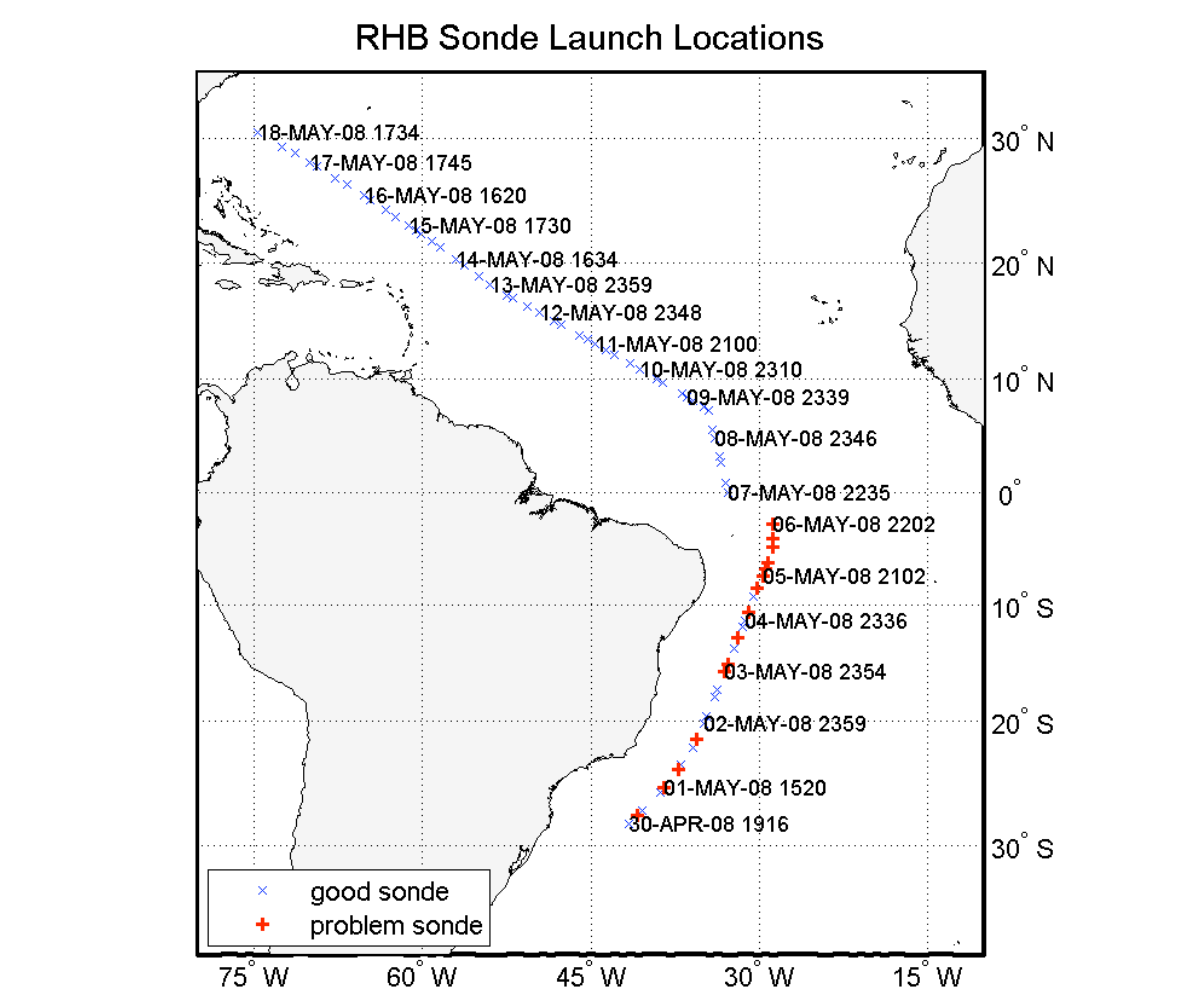
RS92 RAOBs



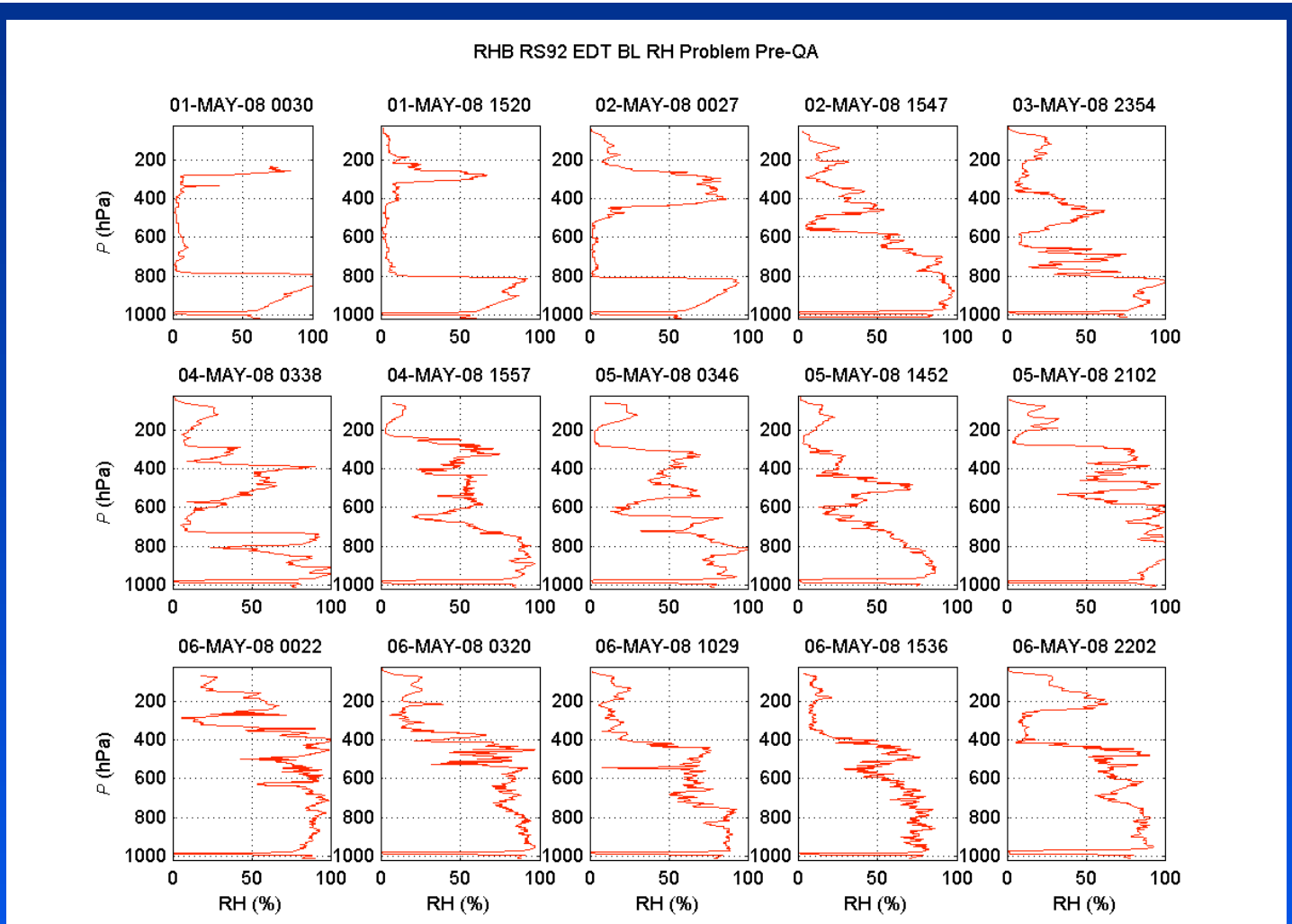


RH problem in Vaisala processing

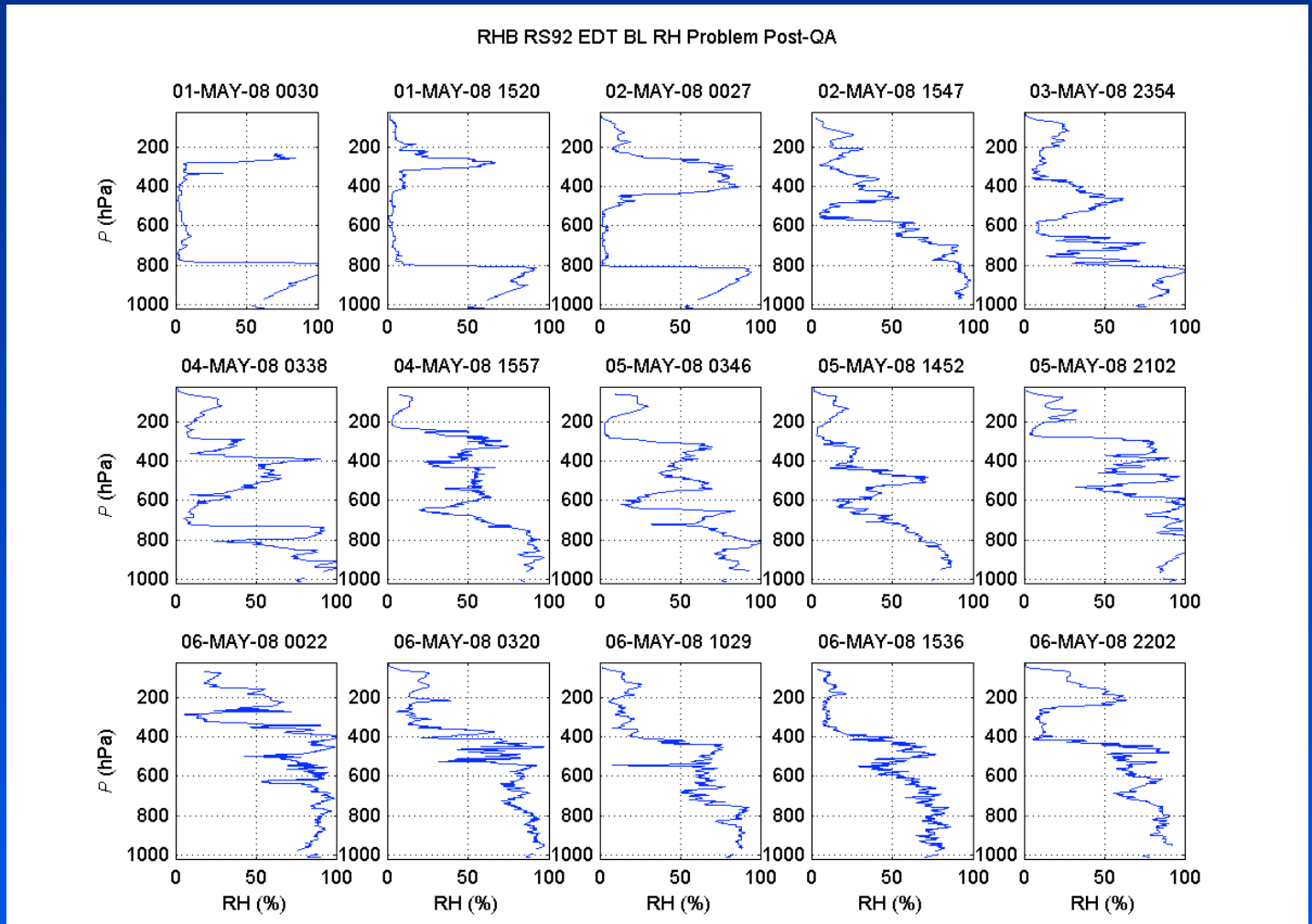
Vaisala RH Processing Problem



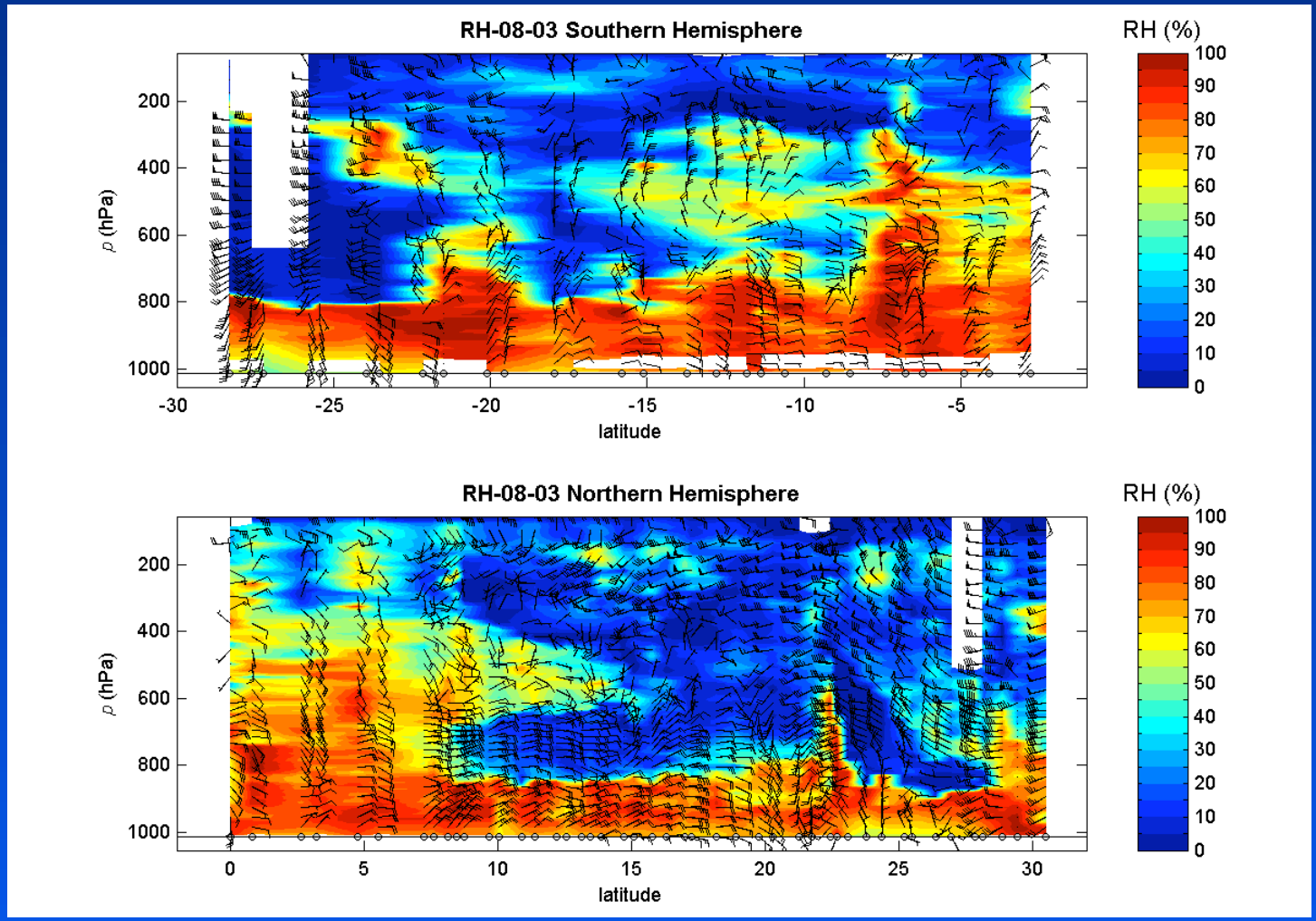
Problem Sondes



Problem Sondes After QA

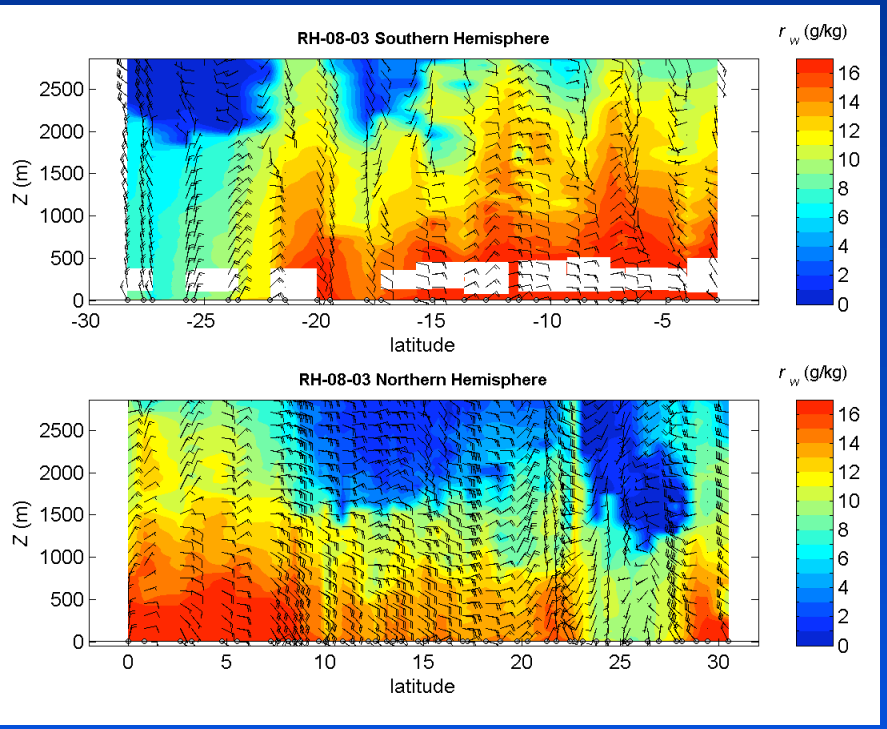


Interhemispheric Tropospheric RH X-Sections

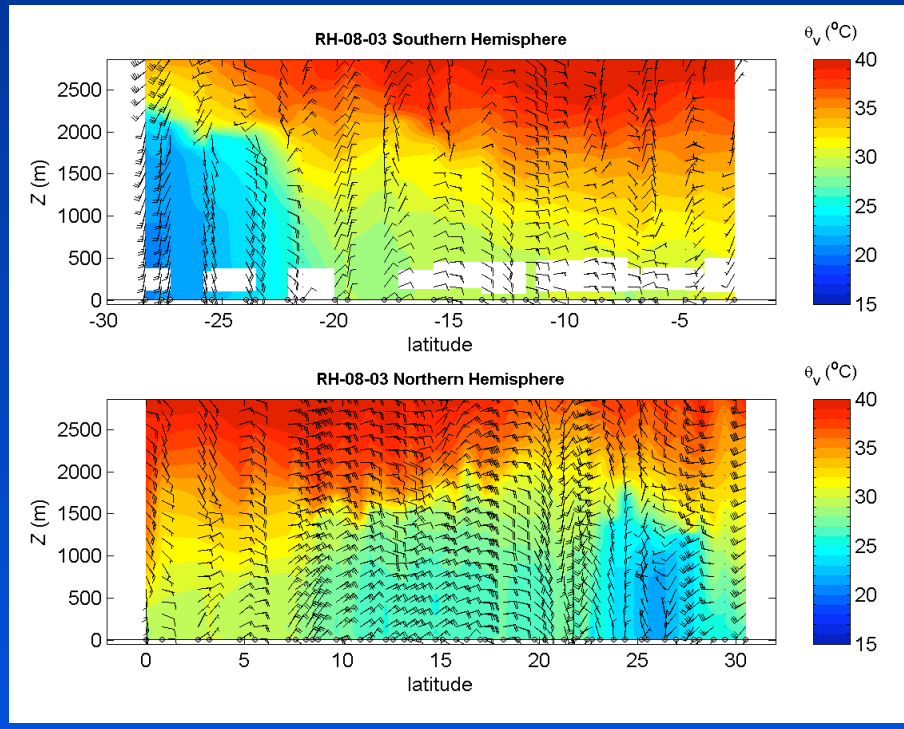


Interhemispheric BL X-Sections

Mixing Ratio

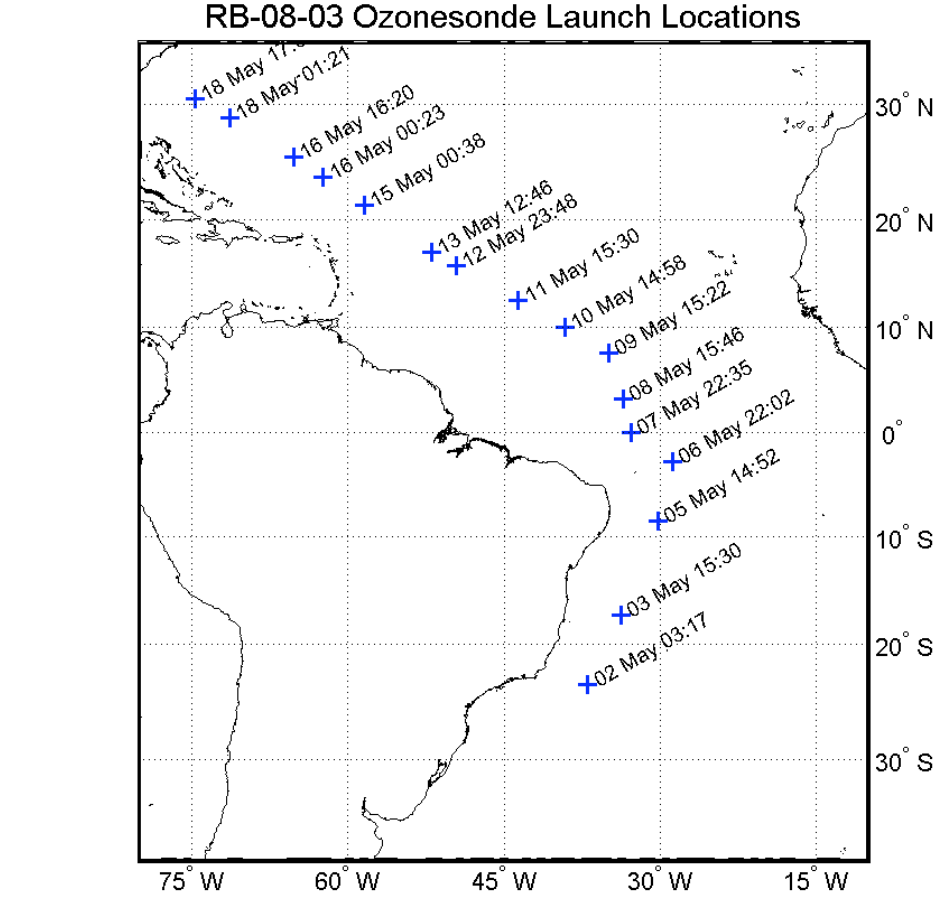


Virtual Potential Temperature

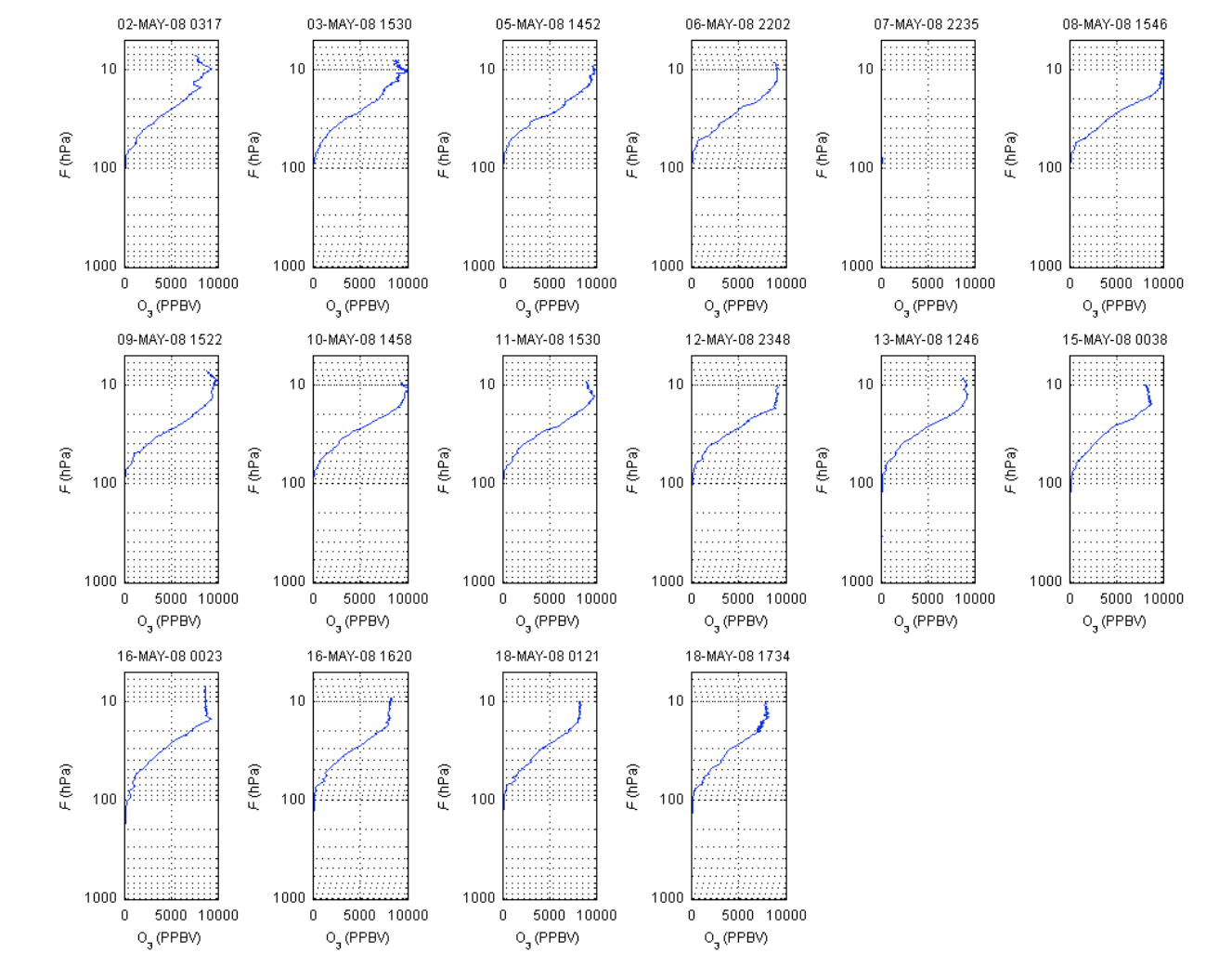


Ozonesondes

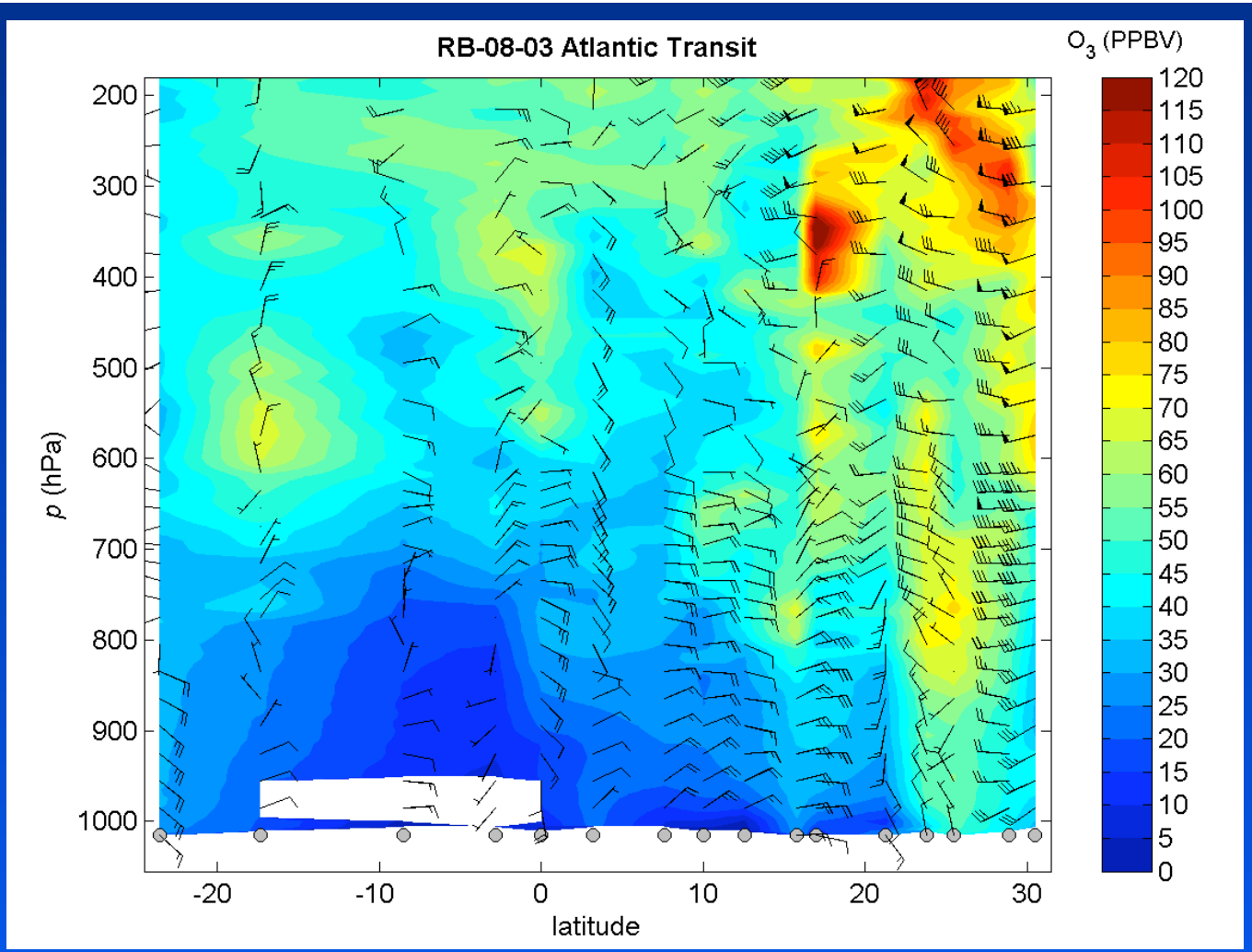
Ozonesonde Locations



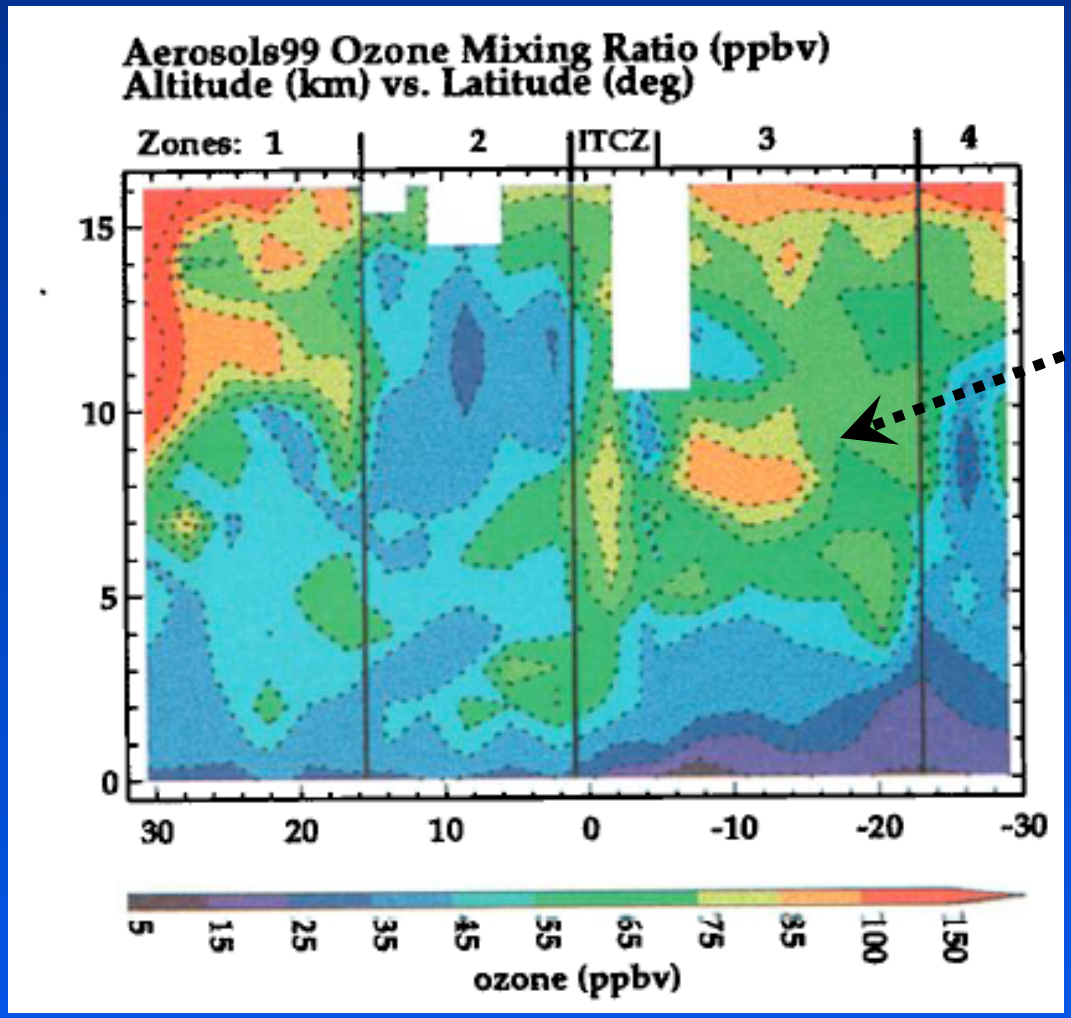
Ozonesonde Profiles



Interhemispheric Tropospheric Ozone

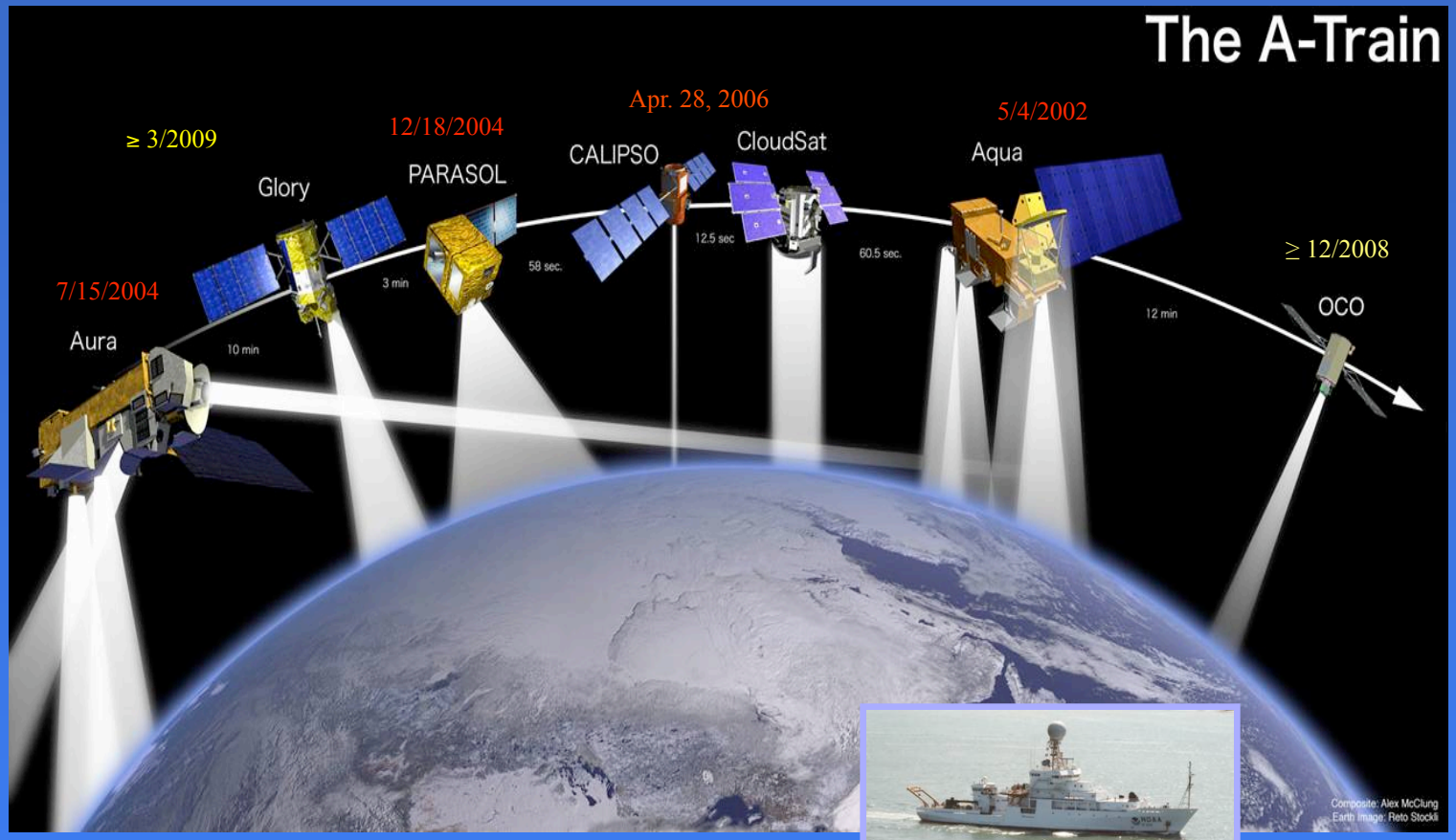


Cf. Aerosols99 Interhemispheric Tropospheric Ozone (Thompson et al. 1999)



The **"Tropical Atlantic Paradox"**

Satellite Cal/Val



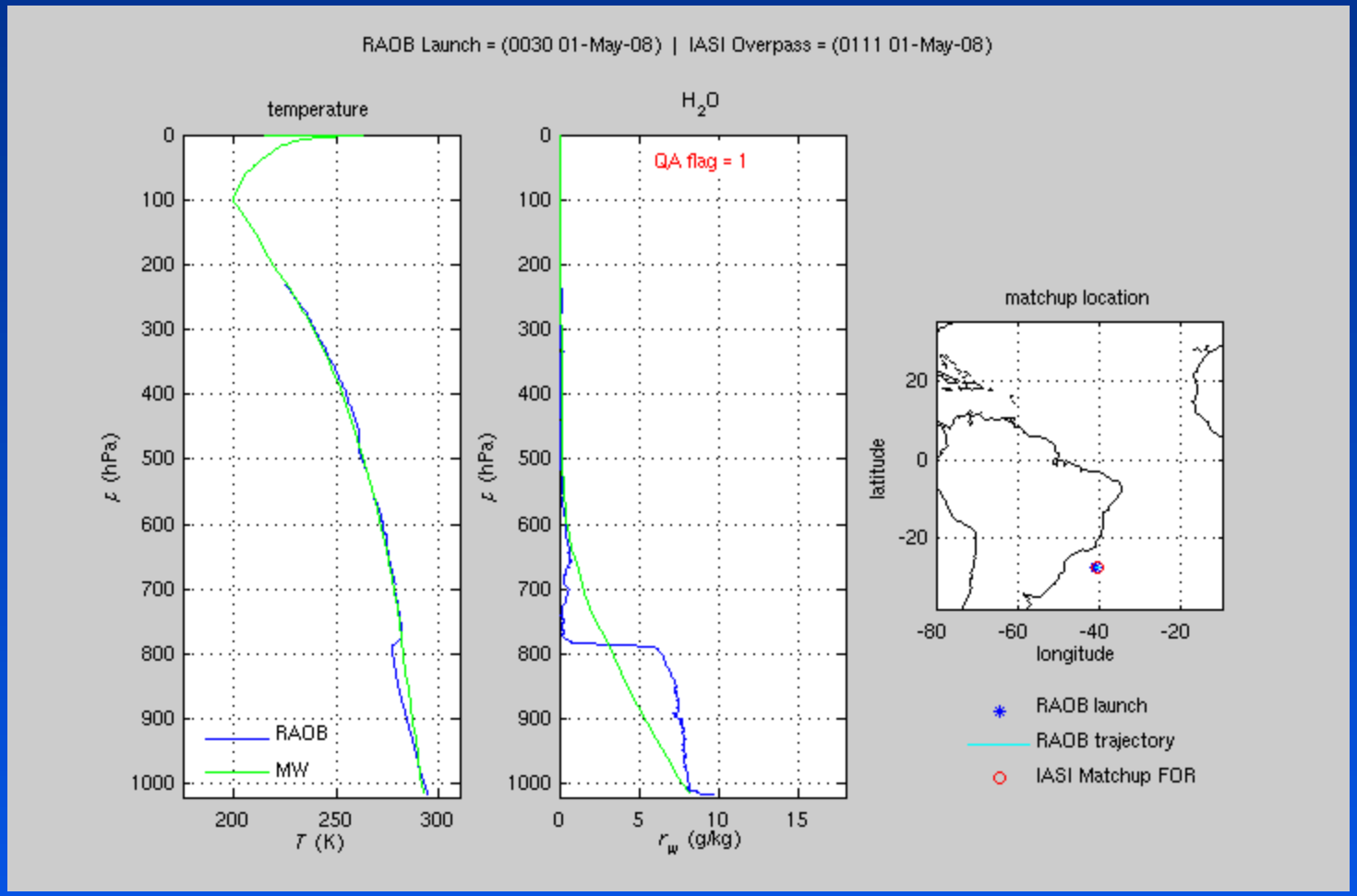
Validation Schemes

- **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 way to sample over open ocean
  - **Dedicated sites (e.g., GRUAN, ARM)**
    - Research-quality data acquired during overpass times
- **Measurements over the ocean** are valuable for validation
  - Surface is far simpler to specify and better characterized
  - Oceans are where satellite remote sensing stands to make its biggest impact (where there is no *in situ* data)

Potential Satellite Validation

- **IASI** and **AIRS** (humidity, ozone, temperature soundings; skin SST)
- **GOES-R ABI** Legacy Sounding Products via Meteosat-9 Spinning Enhanced Visible and Infrared Imager (SEVIRI) empirical proxy dataset
- RTM w/scattering (e.g., aerosols)
- AURA/OMI (ozone profiles)
- AVHRR (SST, clouds, AOD)
- MODIS (aerosol, clouds, Chl-a, SST)
- SAR (winds, ocean features)
- TRMM (vertical precipitation profiles)

IASI-RAOB Matchups



End Matter

Summary

- The PNE/AEROSE intensive campaigns continue to compile a multiyear set of ship-based, marine *in situ* validation "ground-truth" measurements over the open ocean.
  - The 2008 RB-08-03 Interhemispheric Transit adds to the current data inventory from 2004, 2006 and 2007, and includes IASI and AIRS matchups.
  - While the descoped cruise track did not enable extensive sampling of the SAL and dust, it did provide a **interhemispheric latitudinal cross section of the mid-Atlantic Ocean**.
- The AEROSE cruise domains have all spanned tropical Atlantic Ocean, **a region of great interest** in terms of the SAL, tropical storm formation, and tropospheric ozone/carbon/aerosol chemistry and transport.

Future Work

- IASI/AIRS/M-AERI marine temperature/H_2O profile *statistical* validation (using averaging kernels) over *open ocean* and *within Saharan air layer;* RS92 sonde RH bias corrections; skin SSTs
- Ozonesonde and surface ozone analyses; Saharan air layer investigations using IASI/AIRS (w/ E. Joseph, HU/NCAS)
- IASI/AIRS O_3 retrieval marine validation downwind of Saharan dust and biomass burning
- 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)
- Aerosol retrievals/modeling (w/ S. DeSouza-Machado and L. Strow)
- Continue exploiting PNE Cruise piggyback opportunities in 2009 (and beyond?) (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 **NOAA GOES-R Algorithm Working Group** Proxy Data and Soundings Application Teams
- R. Lumpkin, C. Schmid (NOAA/AOML) and the **PIRATA Northeast Extension** Project
- The NASA **AIRS Science Team**
- Tom King, Charlie Dean, Lihang Zhou, Xingping Liu (PSGS, Inc.); T. Zhu (CSU/CIRA); Walter Wolf, P. Clemente-Colón (NOAA/NESDIS/STAR)
- The **AEROSE Science Team** members and the many students who participated in, and contributed to, the success in the cruises.
- The **officers and crew of the *Ronald H. Brown*** for their professional support and contributions.