Overview of the Aerosol and Ocean Science Expedition (AEROSE): Analysis Of Dust Optical Properties And Their Impact On The Thermodynamics of The Saharan Air Layer

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AEROSE Overview

• Aerosol and Ocean Science Expeditions – series of trans-Atlantic intensive observation campaigns

General Science Questions

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

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

• What is the capability of satellite remote sensing and numerical models for resolving and studying the above processes?
PIRATA Northeast Extension (PNE)/AEROSE

(BOURLÈS et al 2008 – BAMS)
Attributes and Impacts of Saharan Air Layer

- Negative impact on EWs and TCs – Dunion and Velden 2004
- Suppress deep convection; e.g., Wong and Dessler, 2005; Nalli et al., 2005
- Alter radiation balance of the atmosphere (e.g., Slingo et al., 2006)
- Self-sustaining due to dust heating (Wong et al., 2009)
AEROSE Satellite Cal/Val

- AEROSE Rawninsondes and Ozonesondes provide independent correlative data for pre-launch phase validation of environmental data records (EDRs) from
  - NOAA Joint Polar Satellite System (JPSS) and Preparatory Project (NPP);
  - Crosstrack Infrared Microwave Sounding Suite (CrIMSS)
  - NOAA Geostationary Operational Environmental Satellite R series (GOES-R) Advanced Baseline Imager (ABI).

- Through the development of “proxy datasets” (i.e., sensor data approximated from existing satellite systems with similar specifications).
  - CrIMSS sounding system will be designed to operate like IASI
  - GOES-R ABI like SEVIRI onboard Meteosat

- Measurements over ocean advantageous for cal/val (e.g., Hagan and Minnett 2003)
  - Sea surface radiative properties (i.e., emission skin temperature and spectral emissivity/reflectivity) well characterized and uniform (e.g., Smith et al. 1996; Nalli et al. 2006, 2008a), allowing these state parameters to be specified accurately.
  - Over oceans (70% of Earth’s surface area), where satellite data are known to make their biggest impact on NWP, but where observation are limited for cal/val
Selected AEROSE Measurements

- Sun Photometer AOD
- Bulk Samplers PM2.5 and 10
- Size Densities (0.3 – 25 mum)
- Mass Densities and Composition (0.15 – 5 mum)
Radiosonde and O3 Sonde Observations

- **Vaisala RS92 GPS rawinsondes** (RS80/90 in 2004) launched coinciding with Aqua-AIRS/AMSU and MetOp-IASI/AMSU-A overpasses
  - Sondes typically 4/day at ~01:30, 09:30, 13:30, 21:30
  - ~578 (253, 148) soundings as of 2010

- **Ozonesondes** (En-Sci ECC) ~1/day during AIRS/IASI overpasses
  - 89(51,36) O₃ soundings as of 2010
Radiosonde and O3 Sonde Observations

Locations/dates of rawinsondes (blue ×)/ozonesondes (red +) during AEROSE 2004 and 2006–10 campaigns. Locations of PTU/O3 launches from the Aerosols99 cruise are also. (Nalli et al. 2011)
Additional Measurements

Unenhanced digital color photograph of the forward 02 level of the *Ronald H. Brown* during the major Saharan dustoutflow 13 May 2007 (Nalli et al. 2011)
Result Highlights
Sounding Cross Sections

- ITCZ – deep column moist air from the surface to upper troposphere; moisture divergence northward and southward
- Beneath moisture plumes deep layers of very dry air in mid to upper Troposphere with inversions present at their bases
- SAL apparent – dry varying depth but horizontally extensive, easterly winds at low levels

Cross-sectional of radiosonde RH measurements (%) latitude and geopotential heights (km); horizontal-component wind vector – speeds half, full, and pennant feathers for increments of 2.5, 5.0, and 25 m s⁻¹ (Nalli et al. 2011)
NOAA IASI retrieved cross sections:

- Capture large-scale phenomena: ITCZ and moisture plume advection aloft, deep layers of subsidence drying, and the MBL height.
- Can resolve relatively deep SAL (May 2007), but misses shallow SAL (2010; expected)
- Tend to have higher relative humidity in the upper troposphere (Nalli et al. 2011)
Dust and Smoke Properties
Aerosol Classification from AEROSE

2006-2010 AOD (440nm) vs Angstrom Exponent from AEROSE cruises

April – May 2010 Pollution Outflow WA and east coast US

Jun Jul 2006 Moderate Biomass Burning Event

Jul Aug 2009 Extreme Biomass Burning Event

Jun Jul 2006 and 2009 Moderate Dust Events

May 2007 Extreme Dust Event

\[ \alpha = -\frac{\ln[\tau_a(\lambda_1)/\tau_a(\lambda_2)]}{\ln(\lambda_1/\lambda_2)} \]

- Range of moderate and extreme aerosol events
- Classifying dust, smoke, urban pollution

May 2007 Extreme Dust Event
Major Dust Outflow Event 12-15
May 07

(Nalli 09)

AVHRR PATMOS May Mean AOD 1985-2000

NOAA-17 AVHRR VIS 12-MAY-07 1336 UTC

NOAA Ship Ronald H. Brown
Major Dust Outflow Event 12-15 May 07

ITCZ

Saharan Air Layer

Highest AODs

PNE/AEROSE-III S-N

RH (%)

PNE/AEROSE-III All Sonde Launch Locations
• Vertical distribution of aerosols
• ITCZ and well defined dust front
• Filaments aloft
• Structure from wakes and eddies
• Also thermodynamic/microphysical on clouds apparent

May 11-18, 2007, AEROSE-III South-North Leg Aerosol Optical Depth

• Dual channel column integrated aerosols
• High AODs coincident with filaments aloft
05/11/07 - 05/18/07 Backscattering Averaged

May 11-18, 2007, AEROSE-III South-North Leg
An increase in the concentrations of CO and black carbon occurred after peak of event, suggesting the presence of air masses containing biomass burning aerosols.

BC only 1% total aerosol mass

Fires burning in western Africa in Guinea, Sierra Leone, and Liberia
• Evolution of Aerosol Surface Elemental Composition
  - Variation as a function of size frac., composition, time
  - Constant Carbon as result of biomass products
• Shortwave forcing at the surface due to the dust aerosols (1.4 to 1.8 OD) was estimated to be as high as 200 W/m².
• Using GERB preliminary atmospheric absorption ~ 25 W/m²
• How much of this significant extinction of SW by the aerosols is contributing to warming at base of SAL – and stability of the SAL?
• Dunion and Velden (2004) suggests that the temperature inversion helps to keep the SAL (stable/dry) intact well across the Atlantic Ocean, and maintains trade wind inversion
Summary

• The AEROSE campaigns have in conjunction with PNE acquired one of the most comprehensive ship-based *in situ* and remotely sensed data sets across the tropical Atlantic.

• The 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.

• These data are being used for process studies and model and satellite validation.
Students are Key to Our Success!
Thank You
<table>
<thead>
<tr>
<th>Dates</th>
<th>Vaisala radiosondes</th>
<th>EN-SCI ECC ozonesondes</th>
<th>M- AERI</th>
<th>Microtops</th>
<th>Ceilometer</th>
<th>LW/SW fluxes</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004 Mar</td>
<td>156 (42,0)</td>
<td>0 (0,0)</td>
<td>24</td>
<td>21</td>
<td>0</td>
<td>25</td>
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<tr>
<td>2006 Jun–Jul</td>
<td>96 (69, 0)</td>
<td>20 (18, 0)</td>
<td>37</td>
<td>28</td>
<td>51</td>
<td>45</td>
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<tr>
<td>2007 May</td>
<td>96 (40, 43)</td>
<td>17 (7, 10)</td>
<td>24</td>
<td>18</td>
<td>30</td>
<td>27</td>
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<tr>
<td>2008 Apr–May</td>
<td>74 (33, 34)</td>
<td>16 (8, 8)</td>
<td>23</td>
<td>10</td>
<td>21</td>
<td>22</td>
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<tr>
<td>2009 Jul–Aug</td>
<td>81 (32, 33)</td>
<td>17 (8, 9)</td>
<td>0</td>
<td>17</td>
<td>25</td>
<td>26</td>
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<tr>
<td>2010 Apr–May</td>
<td>75 (36, 38)</td>
<td>19 (10, 9)</td>
<td>24</td>
<td>19</td>
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<tr>
<td>Totals</td>
<td>578 (252, 148)</td>
<td>89 (51, 36)</td>
<td>132</td>
<td>113</td>
<td>149</td>
<td>169</td>
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Microtops Sun Photometer 440nm AOD for AEROSE II, III, IV & V

Highest AOD and low AC associated with significant smoke outflow. Corresponding AOD’s also high.

55N + 20N eastern North Atl

Latitude

Microtops Sun Photometer 440nm/870nm AC for AEROSE II, III, IV & V

BM 0.88
Dust 0.36 Voss et al 2001

Angstrom Coefficient

Lowest AOD and high AC. associate with clean marine air and urban outflow.

AEROSE Cruises 2004-2008

North Atl

Latitude
Cross-sectional of VPTLR, $\delta \theta / \delta z$ in latitude and geopotential heights (km); Horizontal-component wind vector – speeds half, full, and pennant feathers for increments of 2.5, 5.0, and 25 m s$^{-1}$ (Nalli et al. 2011)
Sounding Cross Sections

- SALs were present, to varying degrees and extents, in all the transects, some extending as far as 40°W

- In 2009 and 2006 presence of relatively high RH

- 2007 very dry

Cross-sectional of VPTLR, $\delta \theta / \delta z$ in longitude and geopotential heights (km); Horizontal-component wind vector – speeds half, full, and pennant feathers for increments of 2.5, 5.0, and 25 m s$^{-1}$ (Nalli et al. 2011)
SEASONAL CYCLE

- Dust persistent in NA atmos
- Northward translation of plume axis boreal summer; spring/summer most intense and westward outflows
- Peak dust flow in Gulf of Guinea Dec-Mar
- Smoke (biomass burning): south ITCZ (May-Sept); north ITCZ winter; Yucatan (April-May)

AVHRR Pathfinder Atmospheres Extended (PATMOS-x) monthly climatological mean tropospheric AOD for a 1981–2008 (Nalli et al. 2011)