3.4

SIZE-RESOLVED AEROSOL MASS AND AEROSOL NUMBER DISTRIBUTIONS DURING THE NOAA CENTER FOR ATMOSPHERIC SCIENCES (NCAS) TRANS-ATLANTIC SAHARAN DUST AEROSOL AND OCEANOGRAPHIC SCIENCE EXPEDITION (AEROSE)

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INTRODUCTION

The NOAA Center for Atmospheric Sciences (NCAS) at Howard University successfully led a 27-day Trans-Atlantic Saharan Dust AERosols and Oceanographic Science Expedition (AEROSE) in 2004, designated as RB-04-02. The mission began on February 29, 2004 in Bridgetown, Barbados and ended in San Juan, PR on March 26 with a stopover at Las Palmas, Gran Canaria. The Chief Scientist of the mission was Dr. Pablo Clemente-Colón of NOAA National Environmental Satellite Data and Information Service (NESDIS). The Principal Investigator and co-Chief Scientist was Howard University Associate Professor, Dr. Vernon R. Morris. NESDIS scientists and graduate students from Howard University and Senagal provided shore-side support for AEROSE through meteorological forecasting and satellite data analysis. The AEROSE ship tracks are shown in Figure 1.

In addition to HU, AEROSE included the participation of the University of Puerto Rico at Mayagüez (UPRM), the Canary Institute of Marine Sciences (ICCM), the Spanish Institute of Oceanography (IEO), the Laboratory of Atmospheric Physics Siméon Fongang (LPASF) in Dakar, Senegal, the University of Miami Rosenstiel School of Marine and Atmospheric Science (RSMAS), the University of Washington Applied Physics Laboratory (UW/APL), the City University of New York (CUNY) and the NOAA CREST center at CUNY, the NASA Goddard Space Flight Center (GSFC), NASA Jet Propoulsion Laboratory (JPL) and NOAA/NESDIS/ORA.

In addition to the first-rate science, this mission was also distinguished by being the first to be led by an HBCU, the first to be led by an African-American, and the first to have a majority of scientists from underrepresented backgrounds in the sciences (African-American, Puerto Rican, and female). The cruise was be followed by middle school students at St. Thomas More in Washington, DC and an elementary school in Mayagüez, Puerto Rico.

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Figure 1. Planned ship tracks for AEROSE

An interactive website maintained at NESDIS featured a daily log from the ship, location-tracking, satellite imagery, question-and-answer communications between scientists and students, and photos of the research activities. AEROSE scientists fielded questions from the schoolchildren as well as from the general public throughout the cruise. The web address is: http://orbit-net.nesdis.noaa.gov/orad/sar/oceansar/AEROSE2004/.

AEROSE received an overwhelming amount of national and international press coverage. Press conferences were held in both Las Palmas, Gran Canaria and in San Juan Puerto Rico. AEROSE scientists were interviewed for both newspaper articles and TV news broadcasts in both cities. Samples of the news item listing of AEROSE from a recent web search are provided in Appendix 2. Other news articles from Gran Canaria and Puerto Rico will be placed on the AEROSE website.

AEROSE04 is the first of three planned cruises. The follow-on experiments have been proposed for summer and winter 2006 (in collaboration with Chile and Spain). Howard University is planning to lead the atmospheric sciences components of each of these missions.

AEROSE Science

The primary mission of the AEROSE 2004 cruise was to provide a set of critical measurements to characterize the impacts and microphysical evolution of Saharan dust aerosol transport across the Atlantic Ocean. The cruise supported a full complement of atmospheric and aerosol measurements, bio-optics and oceanographic observations including water sampling, spectroradiometry, and in-water optical measurements. These observations are being used to study the effect of the dust on the marine boundary layer, to characterize water masses along the cruise path, and to investigate upwelling conditions off the Northwest coast of Africa.

The key areas of focus during AEROSE were climate impacts of aerosols, heterogeneous chemistry, aerosol microphysics, atmospheric deposition and impact. The three central questions guiding the science in AEROSE were: (1) How does Saharan dust affect atmospheric and oceanographic properties during trans-Atlantic transport? (2) How do the Saharan dust aerosol distributions evolve physically and chemically during transport? and (3) How well are the above processes resolved from satellite measurements? A brief summary of the scientific results follows.

The AEROSE mission obtained high-resolution sounding measurements of both the atmosphere (through the entire troposphere – upwards of 25,000 ft) and ocean (down to 2000 ft below the surface) along the cruise track from Barbados to the Canary Islands and back to Puerto Rico.

A sample of the radiosonde data obtained during the cruise is shown below. This figure depicts the boundary-layer evolution during March 3- 9, 2004. The intrusion and affects of the continental air mass on the marine boundary-layer virtual potential temperature and water vapor mixing ratio are quite marked. The drying corresponds well to other physical observations during the dust storm.

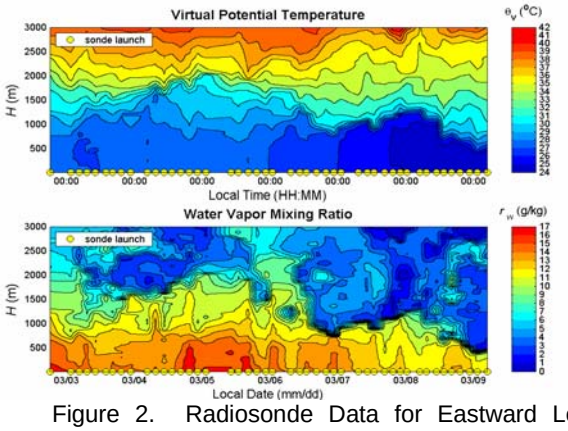


Figure 2. Radiosonde Data for Eastward Leg of AEROSE

This paper provides a brief overview of the extensive suite of aerosol measurements and size-segregated sampling performed to characterize aerosol mass distributions, number densities, black carbon content, $PM_{2.5}$, aerodynamic size, and chemical composition throughout the cruise.

Ambient samples were collected using $PM_{2.5}$ and PM_{10} RAAS high-volume air samplers and a quartz crystal microbalance (QCM) cascade impactor. Figure 3 illustrates the mass density as perceived by the $PM_{2.5}$ high-volume samplers.

Aerosol samples were obtained at 48-hr intervals in various portions of the plume to characterize the chemical aging of the dust as it crossed the Atlantic Ocean. Chemical and microbiological analysis will be performed on these samples.

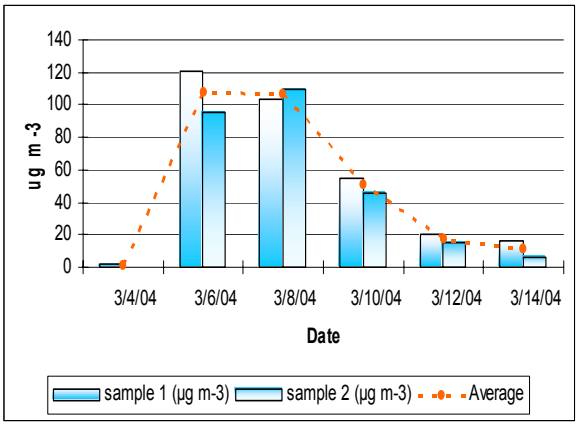
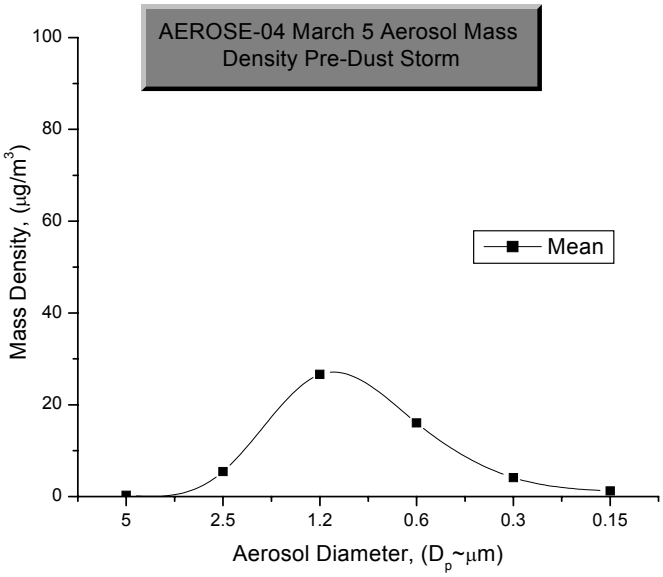


Figure 3. Daily averaged $PM_{2.5}$ during the eastward leg of AEROSE



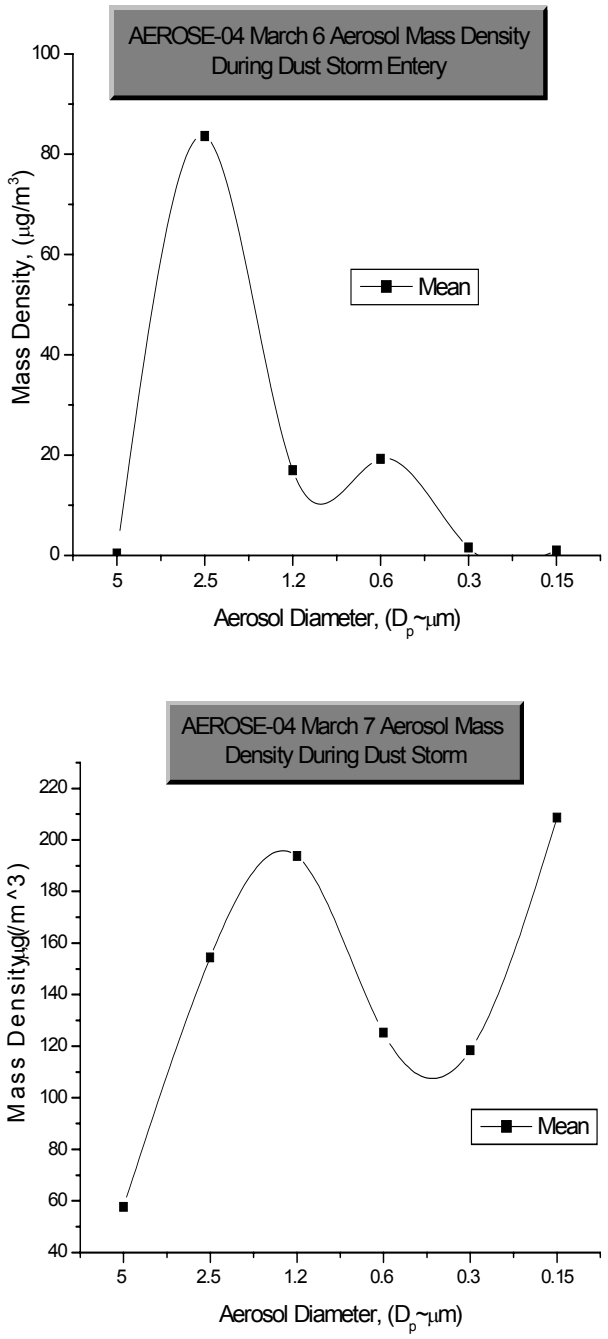


Figure 4. Evolution of the QCM Daily Averaged Mass Distributions for March 5-7, 2004.

The QCM instrument obtains much smaller samples (a few nanograms maximum) but allows for high temporal resolution in its measurements. Two QCMs were deployed during AEROSE. The size fractions were 0.15, 0.3, 0.6, 1.2 and 5.0 m. Figure 4 shows the evolution of the mass distribution as determined by the six-stage QCM during March 5-7, 2004. We performed statistical analysis and plotted the mean.

The aerosol mass density prior to the dust storm (March 5th) had a peak in the 1.2 micron size range, as the dust was entering (March 6th) a bi-modal distribution was observed in the 2.5 and 0.6 micron size range. A bimodal distribution was observed during the dust storm (March 7th) in the 1.2 micron and 0.15 micron.

The bar chart shown in figure 5 illustrates the daily averaged PM_{10} and $PM_{2.5}$ values as determined by the HU QCM during the forward leg of AEROSE. There is a clear indication of a dust intrusion on March 6 that extended through March 8th. We did not include the data for March 9th because it needs further analysis. The March 10 – 11 corresponds to increased levels of dust loading nearer to the source region as well as differing amounts of smoke from the biomass fires in West Africa.

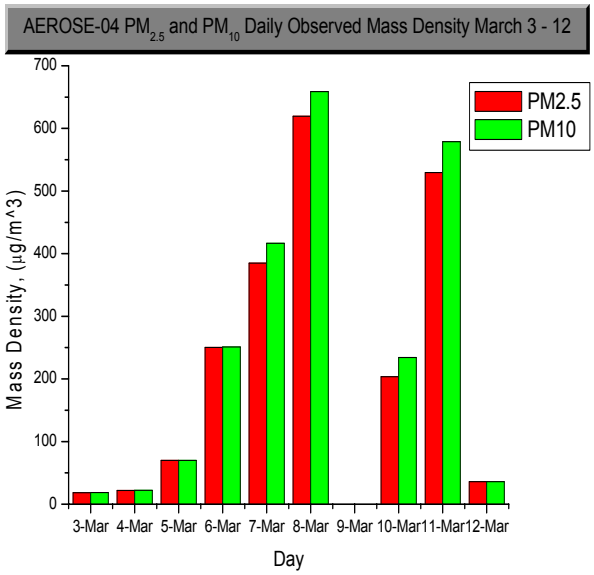


Figure 5. Daily averaged $PM_{2.5}$ and PM_{10} for eastward leg of AEROSE

One of the interesting "experiments of opportunity" was the observation of smoke-influenced dust storms. The figure below shows data from the HU Multi-Angle Aerosol Photometer (MAAP) which measures black carbon aerosol.

Figure 6 shows the profile of black carbon during the large dust storm encounter during March 8-11. The black carbon content of the plume rose steadily during March 8 to a sharp peak value on March 9, and decreased throughout the remainder of the time in the storm.

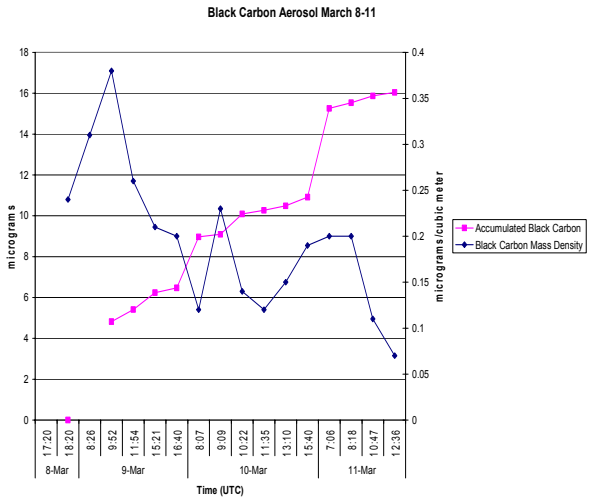


Figure 6. Black carbon measurements during AEROSE.

Outcomes and Outlooks

By using a combination of satellite observations and meteorological forecasts, NCAS was able to steer the vessel directly into one of the largest (with respect to spatial extent) dust storms observed during March ever recorded. The AEROSE team encountered several separable dust events, completed the intensive column measurements to secure a unique and valuable open ocean data set, successfully obtained the validation data for three US satellite instruments, and obtained a rich data set of aerosol properties before, during, and after a major dust event.

Finally, AEROSE provided satellite validation experiments for three satellite instruments: NOAA's advanced very high resolution radiometer (AVHRR) (measuring sea-surface temperature, skin temperature, and column water), NASA's Moderate Resolution Imaging Spectrometer (MODIS) (measuring column water, temperature profile, and aerosol optical thickness) aboard the AQUA and TERRA satellites, and the Atmospheric Infrared Sounder (AIRS) (measuring air temperature, surface temperature, and column water) also aboard the AQUA satellite. Plans to provide validation for a fourth satellite instrument, the NASA Geoscience Laser Altimeter System (GLAS), aboard the ICESat satellite were cancelled due to instrument problems aboard this platform. NCAS scientists continue to collaborate with GLAS scientists to analyze data obtained during AEROSE. Another NASA collaboration within AEROSE was an agreement with the international space station (ISS) team to take photos of events along the AEROSE cruise tracks.

The validation experiments consisted of hourly sun photometer measurements, 3-hourly radiosonde launches, and sea-surface temperature (SST), skin temperature, and surface temperature measurements taken every minute throughout the cruise. This work was performed in collaboration with the University of Wisconsin, the University of Miami (RSMS), between Howard University, and NESDIS.

Figure 7. Space station photo on March 8, 2004 encountered by AEROSE during March 8-11, 2004

Acknowledgements

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