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)

Vernon Morris and Lizette Roldan*
Atmospheric Sciences, Howard University

Roy Armstrong and Yasmin Detrés
Department of Marine Sciences, University of Puerto Rico Mayagüez

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 Propulsion 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.

*Corresponding author address: Lizette Roldán, Howard University, 525 College St. NW, Washington, DC
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.
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 μm. 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 8. We did not include the data for March 9 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.

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

The authors would like to express thanks to the following elements of NOAA for sponsorship and support of the AEROSE mission: OMAO, the NWS, EPP/MSI, and NESDIS ORAD. We also acknowledge the AEROSE science team members, the outstanding crew of the Ronald H. Brown during RHB-04-01, and the MODIS, GLAS, and SeaWiFS support from NASA.