THE NOAA CENTER FOR ATMOSPHERIC SCIENCES (NCAS)

Programs and Achievements

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The NOAA Center for Atmospheric Sciences (NCAS) is one of the four NOAA cooperative centers established in late 2001, under the NOAA Educational Partnership Program (http://epp.noaa.gov) with Minority Serving Institutions (MSI). NCAS is comprised of an academic and research partnership among six institutions: four minority universities [Howard University (HU) in Washington, D.C.; Jackson State University (JSU) in Mississippi; the University of Puerto Rico at Mayaguez (UPRM); and the University of Texas at El Paso (UTEP)] and two major universities [the University of Illinois at Urbana–Champaign (UIUC) and the State University of New York at Albany (SUNYA)]. Howard University is the lead institution for the NCAS partnership. Its main mission is to enhance the production of well-educated and highly qualified meteorology/atmospheric sciences graduates from traditionally underrepresented groups and to improve their representation in NOAA's workforce and that of the broader atmospheric sciences community. An equally important mission is to develop the capacity for significant scientific contributions toward the climate and weather research goals of NOAA and the nation.

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NCAS aims to advance and improve the prediction of climate, weather, and air quality through integrated measurements, models, and data analyses. Within these main themes, the center teams faculty and students from the partner institutions with NOAA scientists. NCAS will also serve as the prototype for enhancing graduate education and research programs at other minority serving institutions in the years to come.

The significant accomplishments of NCAS in graduate education and production of Ph.D. recipients from 2002 to 2006 are due to a suite of well-designed and carefully developed education and research programs. During this period, NCAS has systematically built its research capabilities in observational, theoretical, and numerical modeling studies. We hope this brief report of NCAS achievements will motivate both professionals and aspiring atmospheric scientists to seek research and educational opportunities at NCAS.

GRADUATE EDUCATION. In order to establish an effective graduate student pipeline in the atmospheric sciences, NCAS has designed a three-tier system to supplement the regular recruitment by NCAS's partner universities. This three-tier approach is motivated by the desire to significantly broaden and increase exposure of minority students to modern techniques and career opportunities. The primary mode has been hands-on training in the latest weather and climate instrumentation and models, coupled with mentorship by scientists and professionals from traditionally underrepresented groups. We believe that if the students engage with people with whom they can relate, then their perspective on career opportunities may be broadened. This addresses not only the dearth of domestic minority students pursuing atmospheric sciences or meteorology as undergraduate majors but also the declining numbers of domestic undergraduates in the physical sciences.

ECHOES

"It looks like a big monster came and took a big bite out of the road."

—Washington native SUE VIGAL, after recent record rainfall washed away a bridge and some roads near the town of Preston, about 30 miles east of Seattle. November was the wettest month in Seattle's recorded history, with a total of 15.63 inches of precipitation. A number of other towns in the state also broke records for wettest month and/or wettest November. (SOURCE: *The Seattle Post Intelligencer*)

The first component of the three-tiered system is the summer weather camp program for high school junior and senior students, which represents our efforts to encourage enrollments in undergraduate science degree programs. This program has been quite successful since its beginning in 2002. During each summer since 2002, Howard University has hosted either a two- or three-week weather camp with enrollments ranging from 12 to 15 high school students. The students learn about weather observations and forecasting. They also visit NOAA laboratories such as the National Centers for Environmental Prediction and the Air Resource Laboratory, tour local technical companies and weather TV stations, participate in teleconferences with NCAR and National Hurricane Center scientists, and perform weather forecasting experiments. Originally, the weather camp was regional, serving the District of Columbia, northern Virginia, and southern Maryland. However, in its short existence it has now also hosted students from Illinois, Pennsylvania, New York, Georgia, Tennessee, Texas, and Puerto Rico. NCAS expanded this program to JSU and UPRM in the summer of 2006.

The second component involves three summer workshops on atmospheric instrumentation and data analysis, meteorological modeling, and remote sensing and analysis for advanced undergraduates and first-year graduate students. During these summer workshops, students receive hands-on experiences with advanced atmospheric instrumentation. The students gain skills in using meteorological models and processing remote sensing data. The workshops range in length from 4 to 12 days and are distributed throughout the NCAS partner campuses. Although preference is given to students from NCAS institutions, students from non-NCAS institutions (e.g., Lehman College, City University of New York, University of Maryland at Baltimore Campus, University of Maryland at College Park, University of Virginia, Universidad Metropolitan de San Juan, and Florida A&M University) have participated in these workshops.

The third component is composed of summer internships and at-sea training programs for undergraduates in an effort to attract them to graduate programs, particularly those at NCAS partner institutions. Since 2001, NCAS partners have sponsored at-sea experiences for students, ranging from a few days to two months aboard research vessels. For example, during 2004 and 2006, NCAS faculty and students were aboard the NOAA ship Ronald H. Brown for field experiments on the Saharan air layer and its impact on regional atmosphere and ocean.

Even after only four years, NCAS is significantly increasing the total of African American and Hispanic graduate students in the atmospheric sciences. According to information presented at the Special Session for Retaining and Recruiting Minorities in Atmospheric Sciences at the 2005 AMS Annual Meeting, 17 African Americans and 30 Hispanic Americans earned Ph.D.s in atmospheric sciences between 1973 and 2002 (http://ams.confex.com/ams/Annual2005/techprogram/paper_89444.htm). Based on statistics compiled by the National Science Foundation (NSF), only 21 African Americans and 30 Hispanics graduated with Ph.D.s in atmospheric sciences from 1973 to 2004. If these numbers are further restricted to include only atmospheric and marine sciences for the decade 1994–2004, production of African-American and Hispanic Ph.D. holders was 10 and 11 respectively, as traditionally more students from these backgrounds opt to pursue degrees in geochemistry or geology than in meteorology or the atmospheric sciences. The total absence of Native Americans and Pacific Islanders in these NSF statistics is duly noted. A more recent article in the *Journal of Blacks in Higher Education* notes that no African Americans were awarded Ph.D.s in 2003 in atmospheric chemistry, atmospheric physics, or atmospheric dynamics (www.jbhe.com/news_views/46_blacks_doctoraldegrees.html).

NCAS currently supports the education of 12 Ph.D. African-American and Hispanic students in atmospheric sciences. In the summer of 2006, NCAS graduated one Hispanic and three African-American Ph.D. students. This is the largest class of minority Ph.D. recipients in this area from a single U.S. institution (Howard University) on record. The numbers

of Ph.D. recipients projected for 2007 are six African Americans and one Hispanic American, based on an estimate of enrollment, retention, and graduation rates for the Howard University Program in Atmospheric Sciences (HUPAS). Another 10 Ph.D. graduate students are being supported in other relevant areas (environmental sciences, marine sciences, physics, chemistry, and biology). As a Historically Black College and University (HBCU), Howard University has a unique advantage in educating and producing doctoral recipients from underrepresented groups. The majority of students enrolled in HUPAS are African Americans; however, the current demographics remain diverse (56% African American, 30% Hispanic, 13% international). In contrast, the near absence of diversity in most of the current domestic graduate programs in atmospheric sciences is striking.

Like most majority institutions, HU currently does not have any enrollments from Pacific Islanders or Native Americans. This is not surprising given the demographics of their pipeline and partner institutions and their surrounding communities. However, the model that NCAS has developed should be completely transferable to institutions with larger enrollments from these groups or located near larger population centers for Pacific Islanders and Native Americans. We expect NCAS to have unprecedented impact on diversifying the Ph.D. recipient pool in atmospheric sciences during the next three years. By graduating the 12 students in the current Ph.D. pipeline, NCAS will have enabled the production of a number of minority Ph.D.s representing nearly 52% of the total domestic production over the last decade.

BUILDING RESEARCH CAPACITY. The development of a lower-atmosphere measurement program at the Howard University Beltsville Campus (HUBC) is one of NCAS's most significant accomplishments. Housed on a 103-acre campus in Beltsville, Maryland, the objectives of the program are to 1) enhance NCAS's ability to conduct high-quality atmospheric observations; 2) provide hands-on student training in instrumentation and atmospheric observation; and 3) contribute to national and international climate and environmental monitoring programs. A comprehensive set of

THE RISE AND FALL OF LAKES AND PONDS

The states of Alaska and North Dakota may want to set up some sort of water exchange program, as they are having conflicting problems with bodies of water in their states. In north-central North Dakota, Devils Lake has risen approximately 26 feet since 1993. The lake has flooded about 75,000 acres of privately owned land, forced about 1,000 people to move away, and caused more than $300 million of damage. "It's like a cancer," says Joe Belford, the area's county commissioner. According to the U.S. Geological Survey, the lake's rising waters have resulted from wet weather caused by an increase in El Niño activity since the late 1970s, with particularly high precipitation rates in the area since the early 1990s. Strangely, much of the rest of the state has been experiencing severe drought conditions since 1999.

Meanwhile, recent research in Alaska found that many ponds in the state are either shrinking or have disappeared entirely. Scientists who conducted the study believe the cause is melting permafrost (caused by warmer and longer growing seasons) beneath the ponds, which is allowing the pond water to drain away. The study, which appeared in a recent issue of the *Journal of Geophysical Research,* **involved analysis of aerial photos from the past 50 years of more than 10,000 ponds. It was found that more than half of the ponds studied no longer exist, and the rest have all gotten smaller—with some losing as much as 30% of their surface area. (Source: The Associated Press)**

instruments have been deployed, including a water vapor Raman lidar, a microwave radiometer, several spectral and broadband radiometers, upper-air soundings systems, a 31-m flux and meteorological tower, gas analyzers, and particle samplers. Two of the summer instrumentation workshops for graduate and undergraduate students have been conducted at HUBC. NCAS students, scientists, and their NOAA collaborators are applying the observations at HUBC to verify and improve boundary physics in NOAA operational models, study cloud and aerosol properties and their impacts on climate, study the quality of water vapor measurements from space and balloon-borne sensors, validate and improve chemistry and physics in NOAA operational air-quality models, and much more.

NCAS has been able to extend the capabilities of the Beltsville program with several important research and education partnerships. For example, the Maryland Department of the Environment (MDE) has located one of their two research-grade air quality monitoring facilities at HUBC. This has greatly expanded the number of species monitored at the HUBC and added a 915-MHz wind profiler to the mix of meteorological sensors. As a part of the partnership, HU students have operated the only ozonesonde station in the region for MDE for the past two summers, conducting ozonesonde measurements on days of poor air-quality conditions (code-orange and -red conditions). These data are being used by MDE to understand the impact of transport on regional air quality and by NOAA to verify air quality forecasts from their operational models. Students and scientists from The Pennsylvania State University and Howard University have recently submitted to *Geophysical Research Letters* an article for publication that uses these ozonesonde observations to explain how the low-level jet, which is frequently present during the summer, affects transport and the mixing of ozone under nocturnal boundary-layer conditions. Additional partnerships include a three-year project with NASA; University of Maryland, Baltimore County; and University of Maryland, College Park, on NASA/AURA validation, and deployment of a C-band Doppler radar at the site for broadcast, research, and training applications with the local Fox television affiliate. During the summer of 2006, HUBC was the site chosen for the Water Vapor Validation Experiment—Satellite/Sondes (WAVES) program, where scientists from NASA, NOAA, and several universities participated in conducting various observation and comparison experiments.

NCAS field programs also include observation facilities at the other partner institutions. Jackson State University leads NCAS participation in the development of a Mississippi Mesonet, a state-of-the-art mesoscale observing network in Mississippi that provides an important collaborative opportunity for JSU and other NCAS partners to develop high-quality ground-truth data for model validation, case studies, and service to the NWS and local communities. Examples of the Mesonet data can be found on the Web at http://weather.jsums.edu/~white/mesonet.htm. The University of Puerto Rico at Mayaguez hosts atmospheric and marine observation facilities that include marine vessels for oceanographic surveys,

air–sea interaction studies, and atmospheric observations. Students are routinely offered short at-sea educational trips aboard vessels from the UPRM or other collaborating oceanographic facilities. The Isla Magueyes Field Station routinely collects meteorological, radiation, and aerosol observations, and a Coral Reef Early Warning System (CREWS) station in southwestern Puerto Rico monitors coral bleach monitoring and observations. Details of the CREWS network can be found on the Web at www.coral.noaa.gov/crews. A field site for aerosol and surface radiation measurements is currently being established at University of Texas at El Paso. Though these facilities are not as comprehensive as the Howard Beltsville site, they offer both students and faculty significant opportunities. In all these cases, the NCAS facilities are unique additions to the research and educational offerings at the respective host institutions.

NCAS led a 27-day Trans-Atlantic Saharan Dust Aerosols and Oceanographic Science Expedition (AEROSE) from 29 February through 26 March 2004 aboard the NOAA ship *Ronald H. Brown*; more details can be found at the project Web site (http://orbitnet.nesdis.noaa.gov/orad/sar/oceansar/AEROS2004). This international mission science team was comprised of faculty and graduate students from HU and UPRM and civil servants from NOAA's NWS and National Environmental Satellite, Data, and Information Service. Other primary participants included the University of Miami, Rosenstiel School of Marine Sciences, the University of Wisconsin, the University of Washington Applied Physics Laboratory, the Laboratory for Atmospheres at NASA's Goddard Space Flight Center, the University of Dakar, the Instituto Canario de Ciencias Marinas, and the Spanish Institute of Oceanography.

The program Web site featured a portal to the scientists during the cruise that was monitored by several elementary schools in Puerto Rico and Washington, D.C. Students and the public were encouraged to view the scientists' log and ask them questions during the mission. Researchers on board responded to the inquiries in near-real time. Some of the preliminary results of AEROSE have been presented at recent American Geophysical Union and AMS meetings and published in *Geophysical Research Letters.* AEROSE was the first of three planned cruises; follow-on experiments focused on trans-Atlantic Saharan dust transport and the Sarahan air layer have been proposed through 2010, with cruises in summer 2006 and another scheduled for March 2007.

The main accomplishment in theoretical and modeling research has been focused on the NCAR version of the Weather Research Forecast (WRF) model. Some of the results have been published in scientific journals and presented at conferences. Among these research results are the developments of comprehensive surface boundary conditions specific to mesoscale regional climate model applications, an improved treatment of topography for regional model downscaling, a new parameterization for subgrid cloud overlap and inhomogeneity effect, numerical investigations of dry-line dynamics, and numerical studies of hurricane landfall, just to mention a few. Currently, NCAS is expanding into the testing of the NCEP Non-hydrostatic Mesoscale Model (NMM) version of WRF model for air-quality, weather, and climate research applications.

During the last few years, NCAS has made significant accomplishments in both graduate student education and atmospheric sciences research. The nine African Americans now pursuing degrees in atmospheric sciences already represent 43% of the total number of African-American Ph.D. degree holders who graduated from 1973 to 2004. Furthermore, by developing facilities, NCAS clearly has increased the research and educational capacities of partner universities. We hope this brief report of NCAS achievements will motivate both professionals and aspiring atmospheric scientists to seek research and educational opportunities at NCAS.

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CONFERENCE NOTEBOOK

What Causes Mammatus?

Mammatus clouds are an intriguing enigma of atmospheric fluid dynamics and cloud physics. Most commonly observed on the underside of cumulonimbus anvils, mammatus also occur on the underside of cirrus, cirrocumulus, altocumulus, altostratus, and stratocumulus, as well as in contrails from jet aircraft and pyrocumulus ash clouds from volcanic eruptions. Despite their aesthetic appearance, mammatus have been the subject of few quantitative research studies. Observations of mammatus have been obtained largely through serendipitous opportunities with a single observing system (e.g., aircraft penetrations, visual observations, lidar, radar) or tangential observations from field programs with other objectives. In a paper in the October 2006 *Journal of the Atmospheric Sciences*, we evaluated the existing literature to determine the likely mechanisms responsible for mammatus. Surprisingly, about 10 different theories had been offered in the literature, but none had been rigorously tested. Such theories remain untested as adequate measurements for validation do not exist because of the small distance scales and short time scales of mammatus. In the past, numerical modeling studies of mammatus were virtually nonexistent. As a result, relatively little is known about the environment, formation mechanisms, properties, microphysics, and dynamics of mammatus.

Fig. 1. Mammatus over Norman, OK, looking to the west, on 13 June 2005 at 8:55 p.m. local time. (Schultz et al.; Photo: K. Kanak, CIMMS/ University of Oklahoma)

To address some of the most likely formation mechanisms, we conducted high-resolution, idealized numerical modeling experiments of portions of cumulonimbus anvils initialized with soundings taken in the vicinity of observed mammatus. These simulations are believed to be the first to model mammatus-like clouds explicitly. The simulations were sensitive to the subcloud moisture, indicating that subcloud sublimation of ice crystals and snow aggregates that fall out of the