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# AOML Keynotes

ATLANTIC OCEANOGRAPHIC AND METEOROLOGICAL LABORATORY

*AOML is an environmental laboratory of NOAA's Office of Oceanic and Atmospheric Research on Virginia Key in Miami, Florida*

## Worldwide Coral Bleaching Could Become the Norm by 2056

The coral bleaching phenomenon, often associated with prolonged periods of elevated water temperatures at reef sites, poses a serious threat globally to coral communities. In a world predicted to experience increasingly warmer air and water temperatures due to climate change, scientists are concerned for the well being of reefs and want to learn if coral bleaching will become more frequent and widespread over the course of the next century.

A recent study published in *Nature Climate Change** examines how warming ocean temperatures might impact coral reefs. AOML coral researcher Ruben van Hooidonk, along with colleagues Jeffrey Maynard and Serge Planes from the Centre de Recherches Insulaires et Observatoire de l'Environnement located in French Polynesia, used the latest climate models to show how varying carbon emission scenarios are likely to cause more frequent and severe coral bleaching events, and where and when these events are likely to occur.

In the analysis, which assumes carbon emissions remain on their current path, most of the world's coral reefs (74%) are projected to experience coral bleaching conditions annually by 2045. However, the rate at which coral reefs begin experiencing annual bleaching varies over a period of years, with some reefs starting as early as the 2030s and others holding off until the 2050s. Nevertheless, by 2056 coral reefs globally are all projected to experience annual coral bleaching.

The regions that are more susceptible, with a quarter of these reefs experiencing annual bleaching events five or more years earlier than average, lie in northwestern Australia, Papua New Guinea, and some equatorial Pacific islands.

**A healthy Polynesian coral reef (Photo credit: Thomas Vignaud).**

Coral reefs in parts of the western Indian Ocean, French Polynesia, and the southern Great Barrier Reef seem to fare better and have been identified as temporary refugia from rising sea surface temperatures. These locations are not projected to experience bleaching events annually until five or more years later than the median year of 2040, with one reef location in the Austral Islands of French Polynesia protected from the onset of annual coral bleaching conditions until 2056.

The study also considered reduced carbon emission scenarios, which delayed annual bleaching by more than two decades in nearly a quarter of the world's reef locations. To some degree, reduced emission scenarios also delayed the onset of annual bleaching for nearly all coral reef locations. However, scientists are uncertain if these additional 20 years will provide enough time for reefs to improve their capacity to adapt to the projected temperature changes.

Some corals have been known to change the type of zooxanthellae they house after a bleaching event, abandoning a more temperature-sensitive algae for a more resilient type. Studies have also shown that some corals that are exposed to more variability can become more tolerant of heat stress. Yet, these possible adaptations will not likely be a response or natural solution to coral reefs globally by 2056.

The researchers involved in the study all concur that projections that combine the threats posed to reefs by increases in sea temperature and ocean acidification will further resolve which coral reef locations will fare better or worse in a world of climate change.

*van Hooidonk, R., J.A. Maynard, and S. Planes, 2013: Temporary refugia for coral reefs in a warming world. *Nature Climate Change*, 3(5):508-511 (doi:10.1038/nclimate1829).

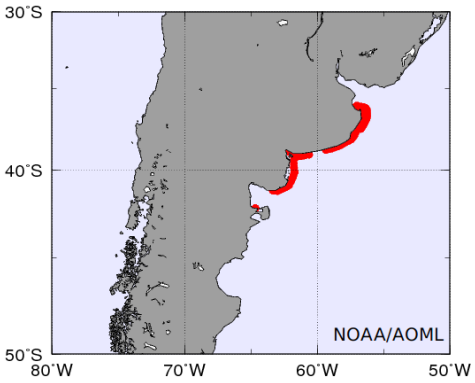
### What Causes Coral Bleaching?

*Coral bleaching occurs when zooxanthellae, the colorful algae that live in coral limestone, are ejected from the coral due to stress factors such as warm water temperatures. With the algae expelled, corals appear colorless or "bleached."*

# Thermosalinograph Data from the RV *Dr. Bernardo Houssay* Augment Ocean Observing Efforts in the South Atlantic Ocean

With the start of thermosalinograph (TSG) operations aboard the Argentine research vessel *Dr. Bernardo Houssay* in March, the TSG network led by scientists at AOML received an important stimulus in its effort to increase the amount of oceanographic data collected globally.

Currently commissioned as an oceanographic research vessel by the Argentine Coast Guard, the RV *Dr. Bernardo Houssay* is considered the oldest serving oceanographic research vessel in the world. The sailboat was previously known as the RV *Atlantis* and used by the Woods Hole Oceanographic Institution as its main platform for oceanographic research from 1931 to 1964.




**Map of the coastal Argentine regions (in red) where the first TSG data transmissions from the RV *Dr. Bernardo Houssay* were received at AOML.**

The TSG operations recently begun on the ship represent a collaborative effort between AOML and the Argentine Coast Guard, with AOML providing the needed equipment for real-time data collection and transmission, as well as data management and distribution services.

Thermosalinographs are installed on research and commercial vessels to continuously measure sea surface salinity and sea surface temperature along a ship's track. TSG observations provide critical information to determine frontal regions and mixed layer depths.

The data received from the RV *Dr. Bernardo Houssay* will augment the number of observations in the South Atlantic Ocean, a severely undersampled region. Although the first data transmitted from the ship were from coastal areas offshore from Argentina (see map at left), the vessel is expected to gather observations in open ocean waters. TSG data from the RV *Dr. Bernardo Houssay* will also be crucial for the calibration of the NASA Aquarius satellite mission.

**The RV *Dr. Bernardo Houssay* has served as an oceanographic research vessel for more than 80 years.**

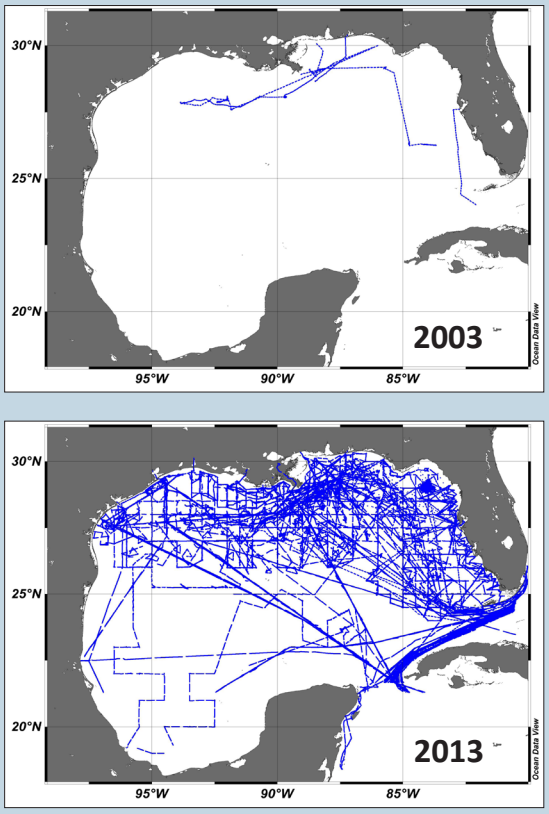
AOML currently supports a TSG network comprised of seven commercial vessels and 10 ships in the NOAA fleet. All of the TSG data received at AOML from the network are quality controlled by real-time control tests and then distributed through NOAA's National Oceanographic Data Center (NODC) and Coriolis, the French project for in situ operational oceanography.

In March, Rik Wanninkhof and Leticia Barbero of AOML's Ocean Carbon Program attended a Gulf of Mexico Coastal Synthesis Workshop in St. Petersburg, Florida, convened in support of the multi-agency North American Carbon Program that aims to inventory the stocks and flows of carbon in the United States and surrounding oceans. The two researchers are leading an effort with academic partners at Texas A&M University, the University of South Florida, and the University of Delaware to produce the first monthly air-sea carbon dioxide ($CO_2$) flux and ocean acidification climatology for the Gulf of Mexico.

The endeavor relies heavily upon data obtained by ships of opportunity through NOAA's Climate Observations and Ocean Acidification programs. In the past ten years, NOAA's ship-of-opportunity efforts to monitor the upper ocean have increased data by ten-fold to 350,000 partial pressure of $CO_2$, or $pCO_2$ data points, making the production of the climatology possible (see figures at right).

For synthesis purposes, the Gulf of Mexico is divided into distinct biogeochemical regions. The northern province is strongly influenced by the outflow of the Mississippi and Atchafalaya rivers that drain most of the central and eastern U.S. and is thus a direct link for carbon stocks between the land and the ocean.

The West Florida Shelf region is unique because of copious groundwater input and phosphate supply that stimulates biological productivity. While the amount of data for the region located off the Yucatan Peninsula is very limited, outreach activities have been initiated with Mexican colleagues to improve data availability.




**Carbon data have increased ten-fold in the Gulf of Mexico over the past decade, making it possible to produce a monthly air-sea $CO_2$ flux/ocean acidification climatology for the region.**

# Coral Researchers Refurbish Saipan CREWS Station, Conducts Site Surveys

Coral researchers at AOML traveled to Saipan in April to refurbish the Coral Reef Early Warning System (CREWS) station in Lao Lao Bay and conduct site surveys for the potential location of a moored autonomous $pCO_2$ ($MApCO_2$) buoy. Staff from the Pacific Islands Ocean Observing System (PacIOOS) program in Honolulu joined them during the site visit hosted by the Division of Environmental Quality (DEQ) of the Commonwealth of the Northern Mariana Islands (CNMI).

Since its establishment in August 2011, the CREWS station in Lao Lao Bay has experienced intermittent communication outages and power failures. In September 2012, its equipment was removed for inspection, diagnosis, and repair. A failed plug for one of the underwater instruments was identified as the cause of the power failures, and plans were made to restore the station with entirely new equipment.

On the $MApCO_2$ buoy side, NOAA is currently implementing its National Coral Reef Monitoring Plan, which calls for sustained monitoring of climate, biological, and socio-economic metrics at all U.S. coral reefs. As part of the plan, three sentinel sites in the Atlantic and Pacific basins are to be established for high-resolution monitoring of climate change variables such as temperature and carbon dioxide. Saipan was identified as a potential candidate for one of the Pacific sentinel sites based on the successful installation of the CREWS pylon in 2011 and the ongoing relationship between DEQ, AOML, and other groups.

**A thriving, colorful reef at Obyan Beach, one of the sites visited in Saipan for the possible location of a $MApCO_2$ buoy to monitor ocean temperatures and carbon dioxide levels.**

Over a two-week period, work on the two projects proceeded in tandem. CNMI personnel performed all of the refurbishment efforts on the upper portion of the CREWS station with guidance, as needed, from the AOML team, while AOML and PacIOOS divers deployed the underwater sensors and secured their cables.

CREWS stations gather data in near real-time to assess the health of coral reefs and are a key component of NOAA's Integrated Coral Observing Network managed by researchers with AOML's Coral Health and Monitoring Program. $MApCO_2$ buoys gather data to measure carbon fluxes and ocean acidity. These measurements are critical to understanding the impacts of increased carbon dioxide on the global ocean ecosystem.

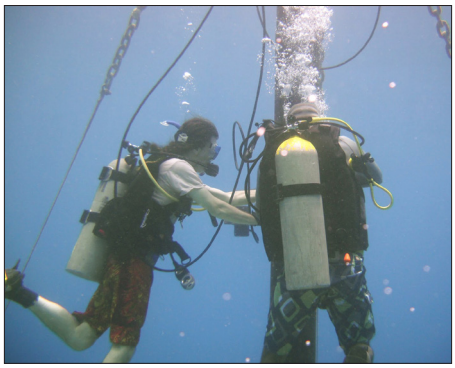
Results from the CREWS reinstallation have been mostly favorable. All instruments are now connected and working normally for the first time since October 2011, but there remains some concern over the status of the station's rechargeable batteries, which were drained by a short-circuit and left uncharged on site for seven months. While not optimal, however, battery levels have kept the station running non-stop since its redeployment. A separate concern remains about the quality of cellular service at the site and the need for frequent intervention by the service provider to resolve communication outages. These outages are being addressed by the PacIOOS team.

While the CREWS team worked to reconfigure the station, the first of several $MApCO_2$ site surveys took place in Lao Lao Bay, followed by surveys conducted in Boy Scout Reef, Managaha Bay, and Sugar Dock.

The $MApCO_2$ team arrived in Saipan with the hope of finding the optimal buoy site close to the CREWS station in Lao Lao Bay. Somewhat to their surprise, however, Sugar Dock emerged as the most favorable buoy deployment site due to its almost year-round accessibility and freedom from issues that might interfere with ocean acidification monitoring such as groundwater, runoff, and sedimentation.

While no final decisions have yet been made about the $MApCO_2$ buoy placement, the team departed Saipan having met with many of the key people in CNMI and having learned a great deal about the ongoing data collection efforts at these sites for the past many years.

The AOML team, consisting of Derek Manzello, Ian Enochs, and Mike Jankulak, thanks all of their collaborators in these two projects, including Fran Castro, Steven Johnson, Ryan Okano, John Iguel, and David Benavente (who made a special trip from Guam), as well as PacIOOS' Gordon Walker and Joe Gilmore, who traveled to Saipan from Honolulu, Hawaii.



**AOML's Mike Jankulak and Gordon Walker from PacIOOS install a CTD (conductivity-temperature-depth) sensor along the CREWS pylon.**

**AOML's Ian Enochs surveys Lao Lao Bay.**

The Gulf of Mexico Alliance (GOMA) has posted a new Molecular Marker Registry on its website that contains a repository of information on molecular source tracking assays for microbes, including bacteria, viruses, fungi, protozoa, and other pathogens, that can potentially contaminate Gulf of Mexico waters. The registry enables scientists and environmental managers to more quickly identify pathogens, their source and potential impacts, based upon genetic markers, helping to ensure beaches and wetland habitats remain healthy and seafood from Gulf coastal regions is safe for public consumption.

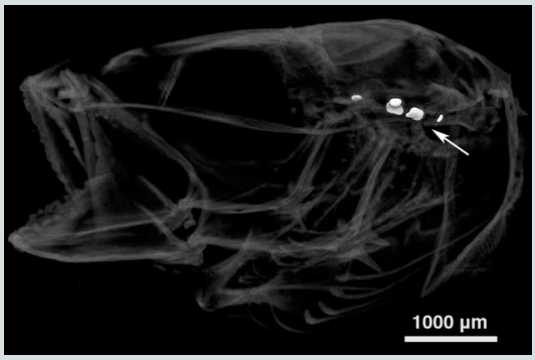
**A qPCR (quantitative real-time polymerase chain reaction) instrument at AOML is used to amplify and detect targeted DNA molecules.**

Chris Sinigalliano of AOML's Environmental Microbiology Program is the co-facilitator of the GOMA Water Quality Team that put together the Molecular Marker Registry and archive. Chris was closely involved in the development of the registry and continues to aid its ongoing expansion and optimization as a living digital resource for the microbial water quality community. Two of the assays featured in the registry (for dog and gull/seabird fecal source tracking) were developed at AOML and validated through multi-laboratory testing.

The Molecular Marker Registry can be accessed from the GOMA website at http://www.gulfofmexicoalliance.org/issues/water_quality.php.

**High school student intern Aditya Shetty loads samples into a real-time qPCR instrument to test for a human fecal genetic marker.**

Researchers with AOML's Ocean Chemistry Division and the University of Miami (UM) collaborated on the use of an innovative three-dimensional technology to determine how changing ocean chemistry might impact cobia, an economically important, pan-tropical fish species. This represents the first time this type of technology has been applied to fish species, and the protocols developed enable similar studies on almost any other juvenile fish species.




**Three-dimensional micro-computed tomography image that shows the otoloith stones of a juvenile cobia.**

AOML's new three-dimensional micro-computed tomography technology allowed researchers to peer inside the skeletons of juvenile fish to measure minute changes in their growth and structure. This allowed UM researchers to document changes in the size and density of small ear stones called otoliths, structures that have traditionally needed to be physically removed to be examined.

To conduct the experiment, AOML and UM scientists adapted protocols typically used to study changes in coral specimens. Thousands of x-ray images were digitally reconstructed into a three-dimensional image stack and then manipulated to view a cobia specimen from any angle and even zoom in on a particular structure. This allowed researchers to collect very detailed measurements that documented how a cobia specimen was affected by certain environmental changes.

The study considered the impact of ocean acidification on cobia, which shares many life history traits with a diversity of high-value tropical open ocean fishes. Ocean acidification increased the size, density, and mass of otoliths, which could lead to a 50% increase in hearing range. This may improve detection of some sounds, but could also lead to increased sensitivity to disruptive background noises.

The study, published in the *Proceedings of the National Academy of Sciences,** was led by Sean Bignami, Su Sponaugle, and Robert Cowen of UM's Rosenstiel School of Marine and Atmospheric Science and Ian Enochs and Derek Manzello with UM's Cooperative Institute for Marine and Atmospheric Studies at AOML. The researchers concluded that altered hearing may have an impact on larval navigation, dispersal, and population distribution, depending on the species.

*Bignami, S., I.C. Enochs, D.P. Manzello, S. Sponaugle, and R.K. Cowen, 2013: Ocean acidification alters the otoliths of a pan-tropical fish species with implications for sensory function. *Proceedings of the National Academy of Sciences USA*, 110(18):7366-7370.


Stan Goldenberg, a research meteorologist with AOML's Hurricane Research Division, helped out with the NOAA booth during the 2013 Miami-Dade County Fair and Exposition. Thousands of people, both young and old, visited the NOAA booth during the course of the three-week event in March, and Stan was able to speak with some of them during the hours he was there.

Meeting six-year old Priscilla was one of the highlights for Stan this year since he had already met her and her Mother last year at a Hurricane Andrew Day event hosted at the Miami Science Museum. Priscilla is an very inquisitive young girl who wants to become a meteorologist when she grows up!

**Stan Goldenberg helps six-year old Priscilla "touch" a tornado in the Tornado Simulator.**

## Farewell

NOAA Corps officer LTJG Marina Kosenko departed AOML in April after resigning from the NOAA Corps. During her time at AOML, Marina provided support for the Ocean Chemistry Division's coastal ecosystems and environmental research programs. She served as both a driver and crew member on the small boats RV *Hildebrand* and RV *Cable* and was also a capable team member for the Florida Area Coastal Environment (FACE) program.

Dr. Verena Hormann departed AOML's Physical Oceanography Division after completing her two-year position with the University of Miami's Cooperative Institute for Marine and Atmospheric Studies as a post-doctoral associate. While at AOML, Verena participated in a PIRATA Northeast Extension cruise and wrote two research articles about the tropical Atlantic using PIRATA data. The first (Hormann *et al.,* 2012, *J. Geophys. Res.,* 117:C04035) examined interannual variations in the North Equatorial Countercurrent using several different data sources. The second (Hormann *et al.,* 2013, *J. Atmos. Oceanic Tech.,* in press) described a generalized method to determine the location of the Atlantic equatorial cold front and applied the methodology to derive mean drifter currents in a frontal coordinate system. Verena is now at the Scripps Institution of Oceanography in La Jolla, California, working with Dr. Luca Centurioni to study the motion of the satellite-tracked drifters of NOAA's Global Drifter Program.

## Welcome Aboard

NOAA Corps Officer ENS Michael Doig joined the staff of AOML in March. While stationed at AOML, Michael will provide small boat, diving, and logistical support for the Ocean Chemistry Division's coastal ecosystem and environmental research programs. He will also support the Office of the Director's communications and outreach activities.

ENS Doig recently completed his first sea assignment aboard the NOAA Ship *Pisces*, where he held the Navigation and Operations Officer positions. Prior to joining the NOAA Corps, Michael was as a New York City Teaching Fellow where he taught earth and marine science at an alternative high school in Brooklyn, New York.

Michael holds a M.S.T. degree in science education from Pace University in New York City and a B.S. degree in zoology from the University of Hawaii at Manoa. While living in Hawaii, Michael worked for the Waikiki Aquarium, Hanauma Bay Education Center, and the Hawaii Institute of Marine Biology where he caught and tagged juvenile hammerhead sharks.


On March 3rd, AOML oceanographer Evan Forde volunteered his time and services to work as the official photographer at the South Florida Special Olympics athletic competition for the 11th consecutive year. This year's track and field event, held at Traz Powell Stadium on the north campus of Miami-Dade College, hosted more than 500 athletes, some as young as 8 years of age. The family event also featured an Olympic Village with music, entertainment, activities, and food. The Special Olympics program provides a wide variety of sports training and competition opportunities for athletes with intellectual and developmental disabilities. "For this one day each athlete is a star, and working to see their eyes light up with joy quickly becomes a labor of love" said Forde.


**Evan Forde of AOML (lower right corner) photographs a high flying Special Olympian during his high jump attempt.**

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# Recent Publications *(AOML authors are denoted by bolded capital letters)*

Bell, M.M., **M.T. MONTGOMERY,** and W.-C. Lee, 2012: An axisymmetric view of concentric eyewall evolution in Hurricane Rita (2005). *Journal of the Atmospheric Sciences,* 69(8): 2414-2432.

**ENOCHS, I.C.,** and **D.P. MANZELLO,** 2012: Species richness of motile cryptofauna across a gradient of reef framework erosion. *Coral Reefs,* 31(3):653-661.

Holthuijsen, L.H., **M.D. POWELL,** and J.D. Pietrzak, 2012: Wind and waves in extreme hurricanes. *Journal of Geophysical Research,* 117:C09003 (doi:10.1029/2012JC007983), 15 pp.

Larsen, S., **S.-K. LEE, C. WANG,** E.-S. Chung, and **D. ENFIELD,** 2012: Impacts of non-canonical El Niño patterns on Atlantic hurricane activity. *Geophysical Research Letters,* 39:L14706 (doi:10.1029/ 2012GL052595), 6 pp.

Laureano-Bozeman, M., D. Niyogi, **S. GOPALAKRISHNAN, F.D. MARKS, X. ZHANG,** and V. Tallapragada, 2012: An HWRF-based ensemble assessment of the land surface feedback on the post-landfall intensification of Tropical Storm Fay (2008). *Natural Hazards,* 63(3): 1543-1571.

**LINDO-ATICHATI, D., G.J. GONI, F. BRINGAS,** B. Muhling, F.E. Muller-Karger, and S. Habtes, 2012: Varying mesoscale structures influence larval fish distribution in the northern Gulf of Mexico. *Marine Ecology Progress Series,* 463: 245-257.

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**MANZELLO, D.P., I.C. ENOCHS, N. MELO, D.K. GLEDHILL,** and **E.M. JOHNS,** 2012: Ocean acidification refugia of the Florida Reef track. *PLoS ONE,* 7(7):e41715 (doi:10.1371/journal.pone.0041715), 10 pp.

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Pattanayak, S., U.C. Mohanty, and **S.G. GOPALAKRISHNAN,** 2012: Simulation of very severe cyclone Mala over Bay of Bengal with HWRF modeling system. *Natural Hazards,* 63(3):1413-1437.

**POWELL, M.D.,** and S. Cocke, 2012: Hurricane wind fields needed to assess risk to offshore wind farms. Comment on "Quantifying the hurricane risk to offshore wind turbines." *Proceedings of the National Academy of Sciences USA,* 109(33):E2192.

Toth, L.T., R.B. Aronson, S.V. Vollmer, J.W. Hobbs, D.H. Urrego, H. Cheng, **I.C. ENOCHS,** D.J. Combosch, R. van Woesik, and I.G. Macintyre, 2012: ENSO drove 2500-year collapse of eastern Pacific coral reefs. *Science,* 337(6090):81-84.

Wainer, I., **M. GOES,** L.N. Murphy, and E. Brady, 2012: Changes in the water mass formation rates in the global ocean for the last glacial maximum, mid-Holocene, and pre-industrial climates. *Paleoceanography,* 27:PA3101, 11 pp.

**WANG, C., S. DONG,** A.T. Evan, **G.R. FOLTZ,** and **S.-K. LEE,** 2012: Multidecadal co-variability of North Atlantic sea surface temperature, African dust, Sahel rainfall, and Atlantic hurricanes. *Journal of Climate,* 25(15): 5404-5415.

Wang, G., J. Li, **C. WANG,** and Y. Yan, 2012: Interactions among the winter monsoon, ocean eddy, and ocean thermal front in the South China Sea. *Journal of Geophysical Research,* 117:C08002 (doi:10.1029/2012JC008007), 10 pp.

Wu, C.-C., S.-G. Chen, C.-C. Yang, P.-H. Lin, and **S.D. ABERSON,** 2012: Potential vorticity diagnosis of the factors affecting the track of Typhoon Sinlaku (2008) and the impact from dropwindsonde data during T-PaRC. *Monthly Weather Review,* 140(8):2670-2688.

**YEH, K.-S., X. ZHANG, S.G. GOPALAKRISHNAN, S. ABERSON, R. ROGERS, F.D. MARKS,** and **R. ATLAS,** 2012: Performance of the experimental HWRF in the 2008 hurricane season. *Natural Hazards,* 63(3):1439-1449.

***AOML conducts research to understand the physical, chemical, and biological characteristics and processes of the ocean and the atmosphere, both separately and as a coupled system. The principal focus of these investigations is to provide knowledge that leads to more accurate forecasting of severe storms, better utilization and management of marine resources, better understanding of the factors affecting both climate and environmental quality, and improved ocean and weather services for the nation.***