AOML Keynotes

NOAA'S ATLANTIC OCEANOGRAPHIC AND METEOROLOGICAL LABORATORY

July-September 2021

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

Ocean Drone Sails into Category-4 Hurricane Sam

"Using data collected by saildrones, we expect to improve forecast models that predict the rapid intensification of hurricanes. New data from saildrones and other uncrewed systems that NOAA is using will help us better predict the forces that drive hurricanes and provide earlier warnings for coastal communities."

Greg Foltz, AOML oceanographer

Saildrone 1045 made history in September when it became the first uncrewed surface vehicle to collect observations from inside the eye of a hurricane. A specially-designed hurricane wing enabled the 23-foot drone to withstand the extreme winds and chaotic sea state encountered in Hurricane Sam. Video footage from an onboard camera can be viewed at https://www.noaa.gov/news-release/world-first-ocean-drone-captures-video-from-inside-hurricane.

Saildrone 1045 (SD 1045) became the first uncrewed surface vehicle to successfully collect observations from inside an Atlantic hurricane when it was remotely steered into the eyewall of Category-4 Hurricane Sam by AOML oceanographer Greg Foltz on September 29.

This accomplishment, the result of a partnership between Saildrone Inc. and NOAA, is expected to provide new insights into how heat, moisture, and momentum move between the ocean and atmosphere, a key process that affects the energy available for storms to develop and intensify.

Improving the value of NOAA's track and intensity forecasts is dependent upon accurate real-time knowledge of atmospheric and oceanic conditions, including their realistic representation in hurricane forecast models. But, observations from near the ocean's surface have been difficult to obtain due to the treacherous conditions found in this turbulent region of the hurricane environment.

To meet this challenge, Saildrone Inc. created a specially-engineered hurricane wing to improve the stability and mettle of its saildrones to withstand the punishing conditions in tropical cyclones. Scientists with NOAA's Pacific Marine Environmental Laboratory and AOML deployed five of these new extreme weather saildrones in the Atlantic during the 2021 hurricane season in areas where tropical cyclones typically travel.

Powered by wind and solar energy and remotely piloted, the drones have gathered round-the-clock observations of humidity, solar irradiance, winds, waves, barometric pressure, air and water temperatures, salinity, and other parameters since their deployment, some within the vicinity of tropical storms Fred, Grace, Henri, and Peter.

SD 1045 survived towering 50-foot waves and winds topping 120 mph during its encounter with Hurricane Sam. The data collected from this rarely observed region where the ocean and atmosphere intersect were transmitted in real-time to the World Meteorological Organization's Global Telecommunication System and distributed to major forecast centers worldwide. Additionally, an onboard camera captured the first video footage ever recorded by an uncrewed vehicle of the tumultuous surface conditions inside a hurricane (see caption above for a link to access the video footage).

"The biggest gap in our understanding of hurricanes are the processes by which they intensify so quickly, as well as the ability to accurately predict how strong they will become," said Jun Zhang, a Cooperative Institute hurricane scientist at AOML. "To improve our understanding, we need in-situ observations collected during a storm."

The data gathered by SD 1045 will help researchers better understand the physical processes that fuel the development and intensification of tropical cyclones, paving the way for better forecasts that protect life and property.

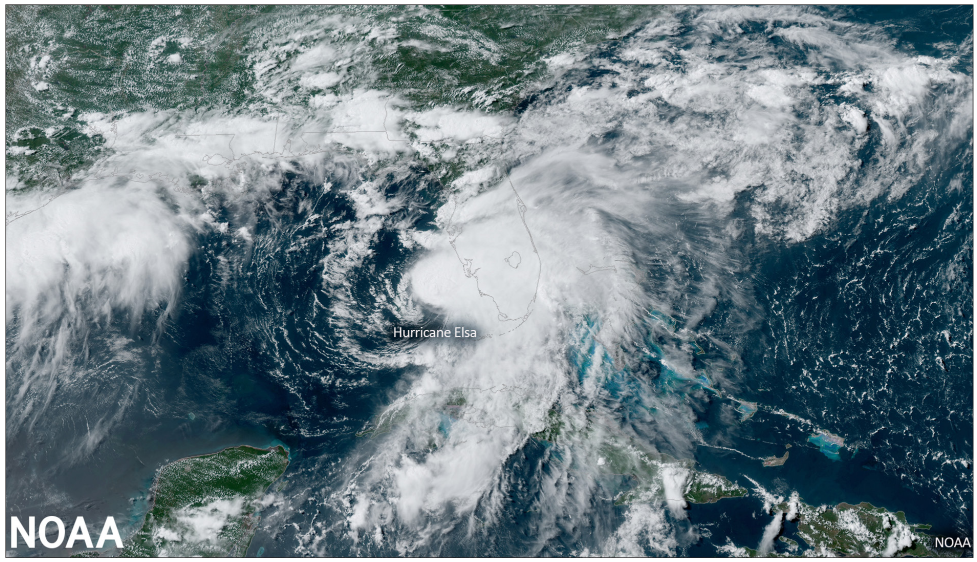
Scientists Sample Multiple Storms as Tropics Enter Peak for Hurricane Formation

Hurricane scientists at AOML sampled multiple storms this summer as the Atlantic entered its peak period for hurricane formation. From Elsa to Sam, the observations they gathered supported NOAA's mission of preparing the public for severe weather by providing critical data for accurate, up-to-date forecasts.

Missions aboard NOAA's P-3 and G-IV Hurricane Hunter aircraft began in early July as Elsa, the first hurricane of the 2021 season, approached the northwest Caribbean islands. They ended in late September as Hurricane Sam, the last and most powerful hurricane of 2021, plowed through the central Atlantic.

Observations collected in Elsa and subsequent storms enabled specialists at NOAA's National Hurricane Center to keep abreast of the changing temperature, moisture, and wind structure of each storm, providing invaluable information on the strength and direction of the wind, the regions of heaviest rainfall, and the atmospheric steering currents influencing their path and landfall location. They will also stimulate future studies to better understand how and why tropical cyclones form, intensify, and dissipate.

P-3 missions focused on gathering measurements from the dense bands of thunderstorms that circle the eye, while missions aboard the G-IV high-altitude jet collected measurements from the surrounding atmosphere. AOML ground crews provided additional situational awareness, quality controlled data obtained from dropsondes, tail Doppler radar, and other instruments, and ensured the data were transmitted in real-time to NOAA's Hurricane Weather Research and Forecasting computer model to improve track and intensity forecasts.



Airborne missions in support of NOAA's Hurricane Field Program began with Hurricane Elsa, which formed in the eastern Atlantic on July 1. Elsa made landfall along the Florida Panhandle on July 7 as a robust tropical storm with sustained winds of 65 mph.

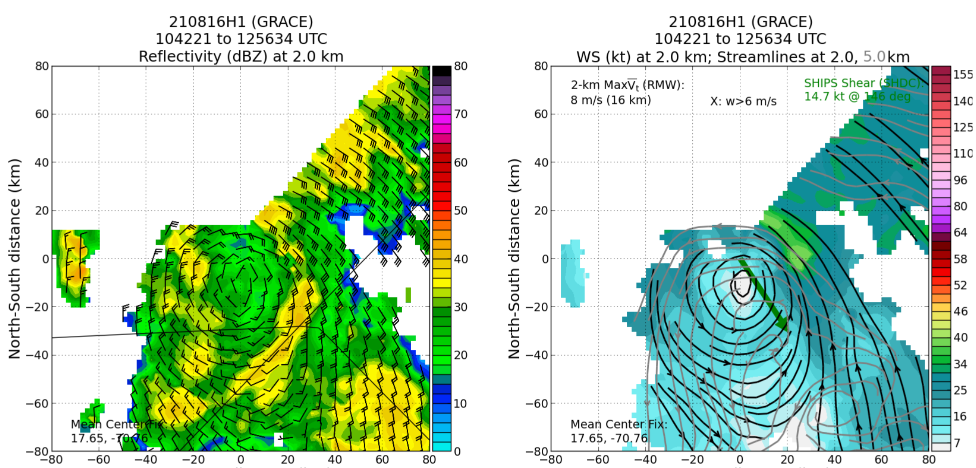
Following Elsa, Fred, Grace, Henri, and Ida formed in quick succession, with Fred forming roughly a week after NOAA issued its updated seasonal outlook on August 4, reiterating that atmospheric and oceanic conditions would remain conducive for above-average hurricane activity for the duration of the 2021 season.

The first mission into Tropical Storm Fred occurred before the system had a well-defined center. Subsequent missions sampled the dry air and wind shear around Fred that inhibited its development, while tail Doppler radar data provided three-dimensional depictions of the complicated structure of Fred's core.

Hurricane Grace developed in the north central Caribbean but moved westward into the Gulf of Mexico. The first P-3 mission began as Grace was becoming a tropical depression, with subsequent missions showing Grace's core becoming better organized into a single, coherent vortex.

A highlight of these flights was the first-ever deployment of Air-Launched Autonomous Micro Observer (ALAMO) floats from the P-3. The release of two Navy ALAMO floats ahead of Grace allowed for observations of how much energy was in the warm surface water and water below to fuel Grace's intensification. One final P-3 (***continued on page 3***)

AOML hurricane researchers Joshua Wadler and Frank Marks aboard the NOAA P-3 on August 10 during a mission into Tropical Storm Fred.



Tail Doppler radar analysis composite of data collected during the morning P-3 flight into then Tropical Storm Grace on August 16, 2021. The left-side image shows where the strongest thunderstorms (yellow) were located surrounding Grace's center. The right-side image shows that the center of Grace 2 km above the surface (black lines) and 5 km above the surface (gray lines) were not in the same locations, suggesting that Grace was still disorganized and unable to rapidly intensify.

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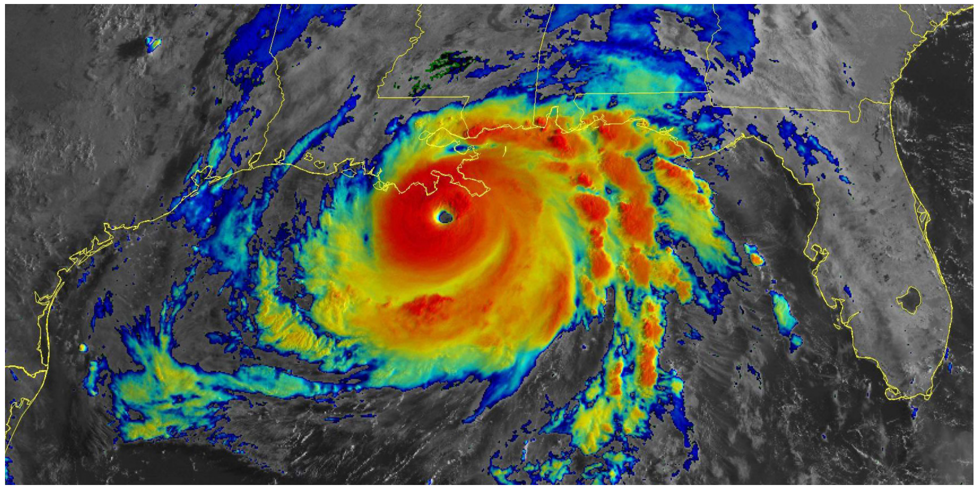


NOAA GOES East satellite image of Hurricane Ida on August 29, 2021 as a destructive Category-4 hurricane. The P-3 mission flown near the time of Ida's landfall was coordinated with land-based research teams from the University of Florida, University of Oklahoma, and Texas Tech University. These teams deployed ground-based radars and instrumented towers to obtain measurements in support of the Coastal Act as Ida swept ashore.

flight was conducted in the Bay of Campeche as Grace emerged from the Yucatan coast and began its rapid intensification before final landfall near Veracruz, Mexico.

While the P-3s were still observing Grace, attention quickly turned to Hurricane Henri as it threatened the New England coast. The G-IV conducted three missions above and around the periphery of Henri to obtain information on the steering flow around the system that would determine Henri's track and landfall location.

A highlight of the Henri missions was flying over a saildrone uncrewed surface vehicle that samples both the ocean and the atmosphere. At its closest approach, the P-3 launched a dropwindsonde and an airborne expendable bathythermograph to validate the atmospheric and oceanic surface measurements being collected by this new instrument.

Hurricane Hunter missions resumed a few days after missions into Henri ended, as Hurricane Ida crossed over the Cayman Islands and western Cuba. Missions aboard the P-3 observed Ida during a critical time when the storm was reorganizing and developing an eye. Subsequent P-3 missions observed Ida's rapid intensification into a major hurricane and ended with the storm's devastating landfall near Port Fourchon, Louisiana with sustained winds of 150 mph.

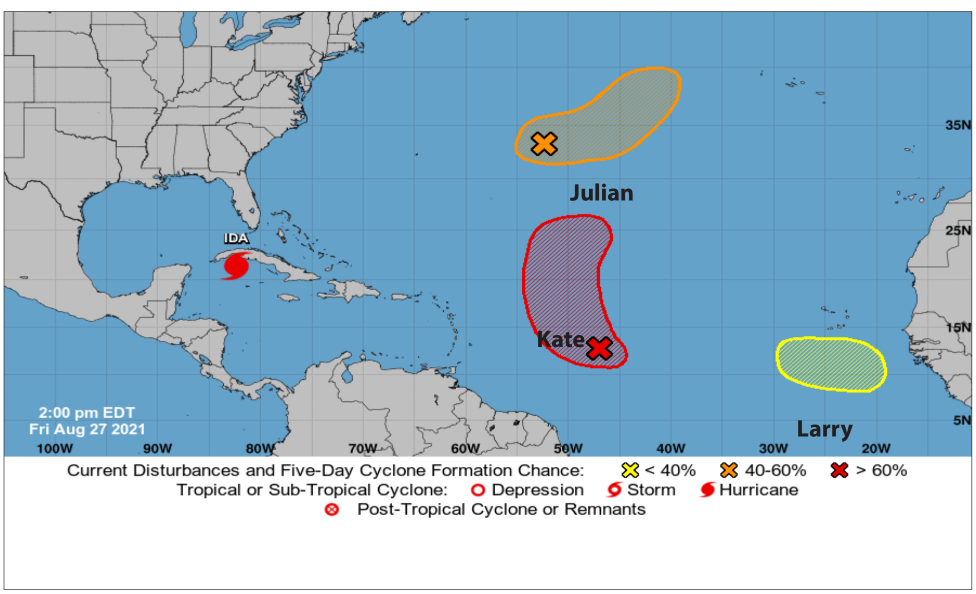
Missions into Hurricane Larry enabled researchers to examine how day-night fluctuations in radiation affect the intensity and structure of hurricanes. One component of these oscillations is a phenomenon called the tropical cyclone diurnal cycle where the cloud fields of storms are seen to expand and contract each day.

Hurricane Hunter flight crews and aircraft deployed to St. Croix in late September to observe Hurricane Sam. Sam strengthened into a deadly Category-4 hurricane with top winds of 155 mph while moving through the central Atlantic, becoming the season's strongest storm. Although Sam remained at sea for the duration of its life cycle, the storm provided an excellent opportunity to collaborate with Office of Naval Research partners to study the process of rapid intensification.

A highlight of the missions was Sam's passage over a saildrone uncrewed surface vehicle, which captured the first data ever obtained from the surface of a hurricane. These data will help shed light on the ocean's role in hurricane intensification.

From Elsa to Sam, all missions were conducted in support of NOAA's annual Hurricane Field Program and its Advancing the Prediction of Hurricanes Experiment (APHEX). APHEX was developed in concert with numerous partners—NOAA's Environmental Modeling Center, National Hurricane Center, Aircraft Operations Center, and the Office of Naval Research—to improve the understanding and prediction of hurricane track, intensity, and structure, as well as associated hazards.

In total, hurricane scientists at AOML participated in 53 missions aboard Hurricane Hunter aircraft, racking up 400 flight hours. The observations they collected in seven tropical cyclones supported NOAA's mission of building a more weather-ready nation, helping vulnerable communities better prepare for severe weather during a busy hurricane season.



National Weather Service map showing active and potential storms in the Atlantic on August 27: Hurricane Ida about to cross over western Cuba; two areas of concern in the central Atlantic—an orange x that would become Tropical Storm Julian and a red x that would become Tropical Storm Kate; plus a yellow area of low pressure off the west coast of Africa that would become Hurricane Larry.

AOML hurricane scientists Lisa Bucci (left foreground) and Jun Zhang (middle background) take a selfie with Nikki Hathaway and Ashley Lundry, both flight directors with NOAA's Aircraft Operations Center, after a mission into Hurricane Sam aboard the P-3 on September 29.

Characterizing Coral Resilience in the Anthropocene: A Reef in the "New Normal"

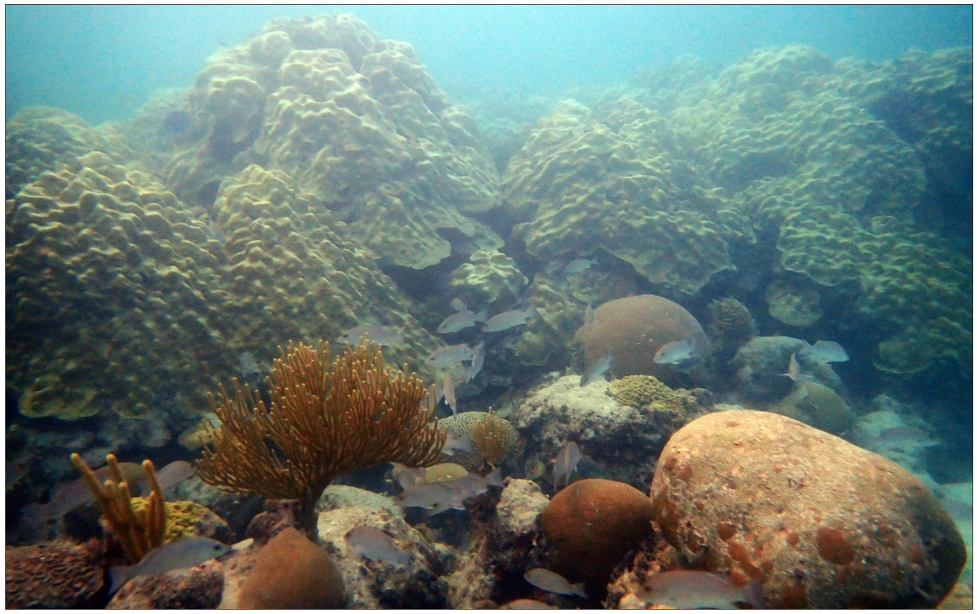
This article is derived from an AOML website post by Dr. Anderson Mayfield

It can be hard to stay upbeat as a marine biologist, especially with the onslaught of existential threats like climate change facing the planet. Coral reefs are arguably the ecosystem that stands to lose the most with respect to climate change, namely because the resident organisms are highly sensitive to elevated temperatures. Furthermore, the limestone-based reef framework itself is diminishing before our very eyes due to the concomitant rise in carbon dioxide levels, which decrease oceanic pH and lead to ocean acidification.

That being said, there are corals out there that display resilience, continuing to thrive in habitats that would appear decidedly marginalized to even the untrained eye. Turbid, low-visibility, warm (up to 93°F), and, at times, high-light reefs of the Upper Florida Keys inshore reef tract (see image in upper right) are among those reefs that are faring better than one might expect.

However, the now-prevalent stony coral tissue loss disease is rapidly chipping away at many of the corals that had previously adapted or acclimatized to nearly annual marine heatwaves, events that had already killed off many of these corals' offshore brethren.

To better understand the mechanisms of resilience to high temperatures displayed by these corals, we took small cores from colonies of the massive star coral *Orbicella faveolata* (see image at bottom) from both inshore and offshore reefs, with the latter being markedly less tolerant of rising seawater temperatures, and exposed them to dramatically elevated temperatures in the Experimental Reef Laboratory developed by AOML research ecologist Ian Enochs to undertake just these types of studies.*



A structurally complex, resilient coral reef in the murky waters of the Upper Florida Keys known as "Cheeca Rocks."

Upon sampling corals of diverse genotypes exposed to controlled and elevated temperatures at both short- (5 days) and longer-term (one month) timescales, we extracted the proteins from the coral hosts, as well as those of the dinoflagellates that reside within their cells (and are, as it happens, responsible for the formation of all of Earth's coral reefs). Then, we separated the proteins via liquid chromatography and sequenced the "proteomes" with a mass spectrometer.

After many months of developing novel analytical methods to characterize these complex "meta-proteomes" (i.e., the protein profiles of multiple organisms analyzed in tandem), we found that even control corals from these reefs of the Upper Florida Keys essentially use their cellular stress responses at all times.

On the one hand this trend, which we have documented in other coral species of the Indo-Pacific, could be seen as a desirable trait; perhaps these seemingly robust corals are just always "on," ready to fight future environmental change at a moment's notice. However, this is not a common strategy for any life form, from simple microbes to complex multi-cellular organisms. Most of us know all too well that staying perpetually stressed is unsustainable and can lead to a dramatic decline in health.

Like us, then, these corals are clearly living in a "new normal" with respect to the highly compromised state of their external milieu, hence the dubbing of this epoch by scientists as the "Anthropocene." Only time will tell if a constantly stressed phenotype is a viable means of persistence for these Caribbean reef builders, as well as other coral species across the globe.

Pale colonies of the mountainous star coral *(Orbicella faveolata)* at Cheeca Rocks reef. These colonies ultimately recovered after partially bleaching due to high temperatures in the summer of 2019.

*Mayfield A.B., C. Aguilar, I.C. Enochs, G. Kolodziej, and D.P. Manzello, 2021: Shotgun proteomics of thermally challenged Caribbean reef corals. *Frontiers in Marine Science* 8:660153, https://doi.org/10.3389/fmars.2021.660153.

Does the Risk of *Vibrio* Infection Increase with a Warming Planet?

Vibrio infections have increased globally over the past few decades. A new study combines climate modeling forecasts with population and socioeconomic projections to provide more accurate estimates of future Vibrio illness on a global scale.

In a recent study published in *Lancet Planetary Health*,* a new generation of climate, population, and socioeconomic projections were used to map future scenarios for the distribution and seasonal suitability of *Vibrio,* a pathogenic bacteria. In so doing, global estimates for the populations at risk of developing vibriosis for different time periods are provided for the first time.

Vibrio is a genus of bacteria with a strong affinity for freshwater and marine environments. These bacteria cause food-borne illnesses through the consumption of undercooked seafood, as well as infections to wounds from exposure to contaminated water.

Infections caused by *Vibrio* species have undergone a non-uniform global expansion over the past few decades, reaching new areas of the world where environmental conditions were previously considered unfavorable for these organisms. In fact, some areas have shown a rapid increase in infections (see image, top right).

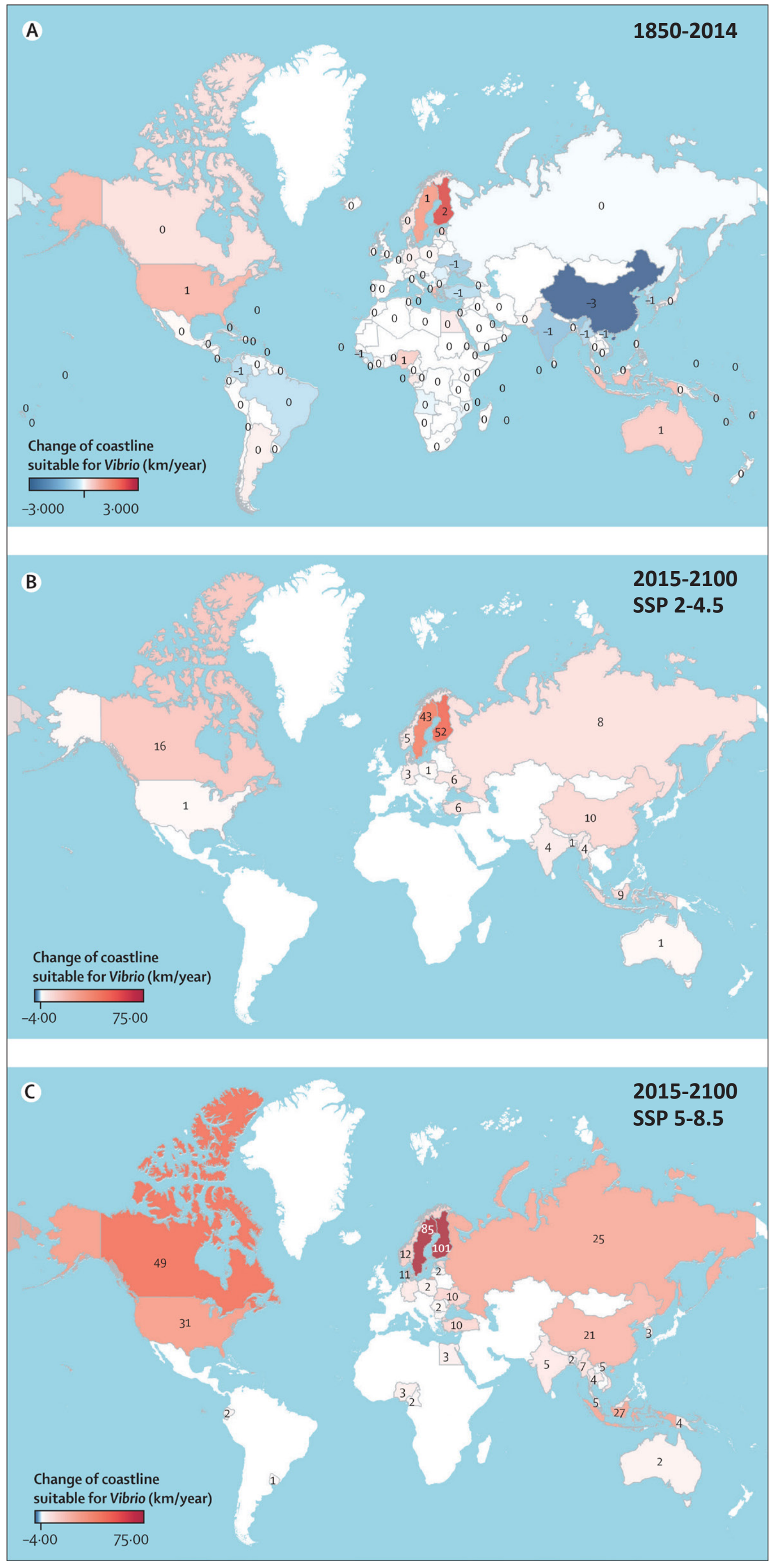
According to Joaquin Trinanes, a scientist at AOML and lead author of the study, "we combined new climate modeling forecasts with demographic and socioeconomic projections to improve our knowledge of future *Vibrio* illness on a global scale. Future work will take into account additional factors such as sea level change and exposure to improve the results."

The abundance of *Vibrio* in the water is controlled by temperature and salinity, with warmer waters allowing more bacteria to grow and lower salinity levels expanding the area where *Vibrio* can thrive. Impacts from climate change, such as increases in sea surface temperatures, are altering infection patterns for some diseases that are particularly sensitive to ecological changes. The expansion of *Vibrio* matches what has been observed with similar diseases caused by bacteria in the water.

The human population at risk of *Vibrio* illness almost doubled from 1980 to 2020 (from 610 million to 1100 million). But, according to these projections, the growth trend will subside in upcoming decades and should stabilize at around 1300 million after 2050. This is due to a projected stabilization of the world population in regions with *Vibrio* risk.

Under the most unfavorable future scenario (see image, bottom right), the study shows that regions suitable for *Vibrio* could expand to cover more than 38,000 kilometers of new coastal area by 2100. The length of the season is also expected to expand, such that disease conditions will be favorable in more places for longer periods of time, with an expansion rate of around 1 month every 30 years.

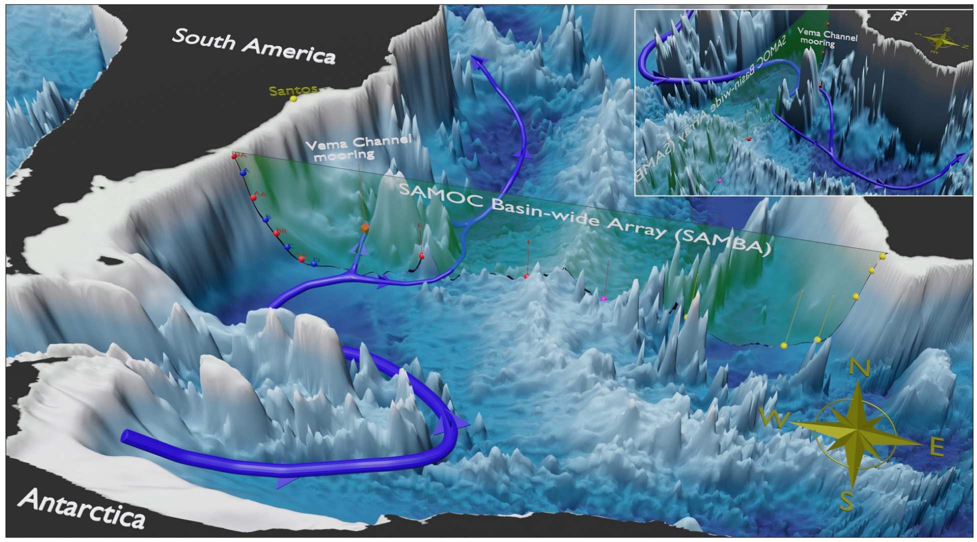
The results of this modeling study can be used to develop a new generation of early warning systems to identify and forecast coastal areas and periods at risk for *Vibrio* illness, helping public health officials create more robust intervention plans that anticipate future scenarios of *Vibrio* risk.



Global maps that show how coastal regions of various countries have been and could be impacted by the development of suitable environmental conditions for pathogenic *Vibrio*: (A) the historical period of 1850-2014; (B) the shared socioeconomic pathway (SSP) scenario 2-4.5 for 2015-2100; and (C) the SSP 5-8.5 scenario for 2015-2100. Projections under the SSP 2-4.5 scenario indicate a total of 15,555 km of new coastline will have become favorable for *Vibrio* by 2100, while a total of 38,165 km of new coastline under the SSP 5-8.5 scenario could become favorable for *Vibrio* by 2100.

*Trinanes, J., and J. Martinez-Urtaza, 2021: Future scenarios of risk of *Vibrio* infections in a warming planet: A global mapping study. *The Lancet Planetary Health*, 5(7):E426-E435, https://doi.org/10.1016/S2542-5196(21)00169-8.

Deep Ocean Warming Continues in the Vema Channel



Schematic of Antarctic Bottom Water entering the South Atlantic and flowing through the Vema Channel. Moorings from the international South Atlantic MOC Basin-wide Array (SAMBA) are shown by red and yellow circles, while NOAA's southwest Atlantic MOC (SAM) moorings are shown by blue circles. The inset shows a closeup version of the flow from a different orientation. Figure generated by Betrand Dano, UM/CIMAS.

In a recent study published in the journal *Geophysical Research Letters**, AOML scientists Shenfu Dong and Renellys Perez contributed to an international study that confirmed a warming trend and the possibility of increased rates of warming in one of the deepest channels of the southwest Atlantic Ocean, the Vema Channel.

The Vema Channel is a deep narrow passage in the South Atlantic Ocean and a key area for study because of the cold water that flows through it. A large portion of Antarctic Bottom Water, the Southern Ocean's coldest, densest water, flows northward through the channel and contributes to the deep/abyssal cell of the Meridional Overturning Circulation (MOC).

The MOC is a component of the global ocean circulation, consisting of an upper layer of warmer, lighter water flowing northward and North Atlantic Deep Water flowing southward underneath. This upper cell sits atop a cell of colder, denser water, i.e., the abyssal cell.

These water masses travel throughout the global ocean, exchanging temperature, salinity, carbon, and nutrients along the way. Increased rates of ocean warming could change the strength of the MOC's circulation, affecting weather and climate, and nutrient delivery, with impacts to coastal regions and offshore fisheries.

Other studies based on observations have confirmed the warming of ocean waters since the last decades of the 20th Century, but those studies were focused on the upper 2,000 m of the ocean. More recently, scientists have investigated warming in the deep ocean below 2,000 m using new and existing instrumentation to determine the impact of global warming on the overall ocean system.

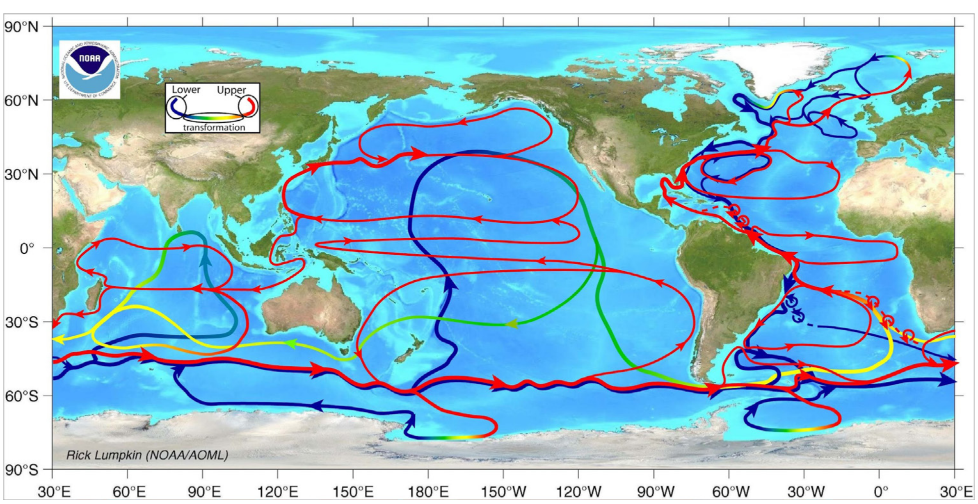
This study presents a newly observed temperature time series from a mooring near the bottom of the Vema Channel, collected from February 2019 to August 2020. This time series of the Vema Channel, in combination with historical mooring and hydrographic data, confirms a persistent warming trend of Antarctic Bottom Water flowing through the Vema Channel.

The data suggest the abyssal waters in the Vema Channel have warmed by about 0.06 degrees Celsius (°C) from January 1991 to August 2020. They further suggest the possibility of an accelerated warming from 0.0016°C per year, between the early 1990s and 2005, to 0.0026°C per year since 2005.

"This study shows the importance of curating and preserving historical datasets, so that new datasets can be compared against these benchmark observations, to understand and quantify longer-term changes," said AOML oceanographer Renellys Perez. "It also highlights the importance of collaborations between an international team of scientists, which allows us to collectively construct long-term records."

The ocean has absorbed the majority of excess heat injected into the atmosphere over the past century. As a result, the global ocean has warmed significantly at all depths. However, this warming may not have reached all parts of the deep ocean, so it is important to compare different locations to fully understand the ocean circulation processes taking place.

The Vema Channel is one of the only channels deep enough for Antarctic Bottom Water to flow through, making it a critical component of the MOC's abyssal cell and an important location to study. Variations occurring in Antarctic Bottom Water serve as indicators of the effects of climate change on the deeper ocean.



The Meridional Overturning Circulation is one of the main mechanisms the ocean uses to move heat, salt, carbon, and nutrients throughout the global ocean. Figure generated by Rick Lumpkin, NOAA-AOML.

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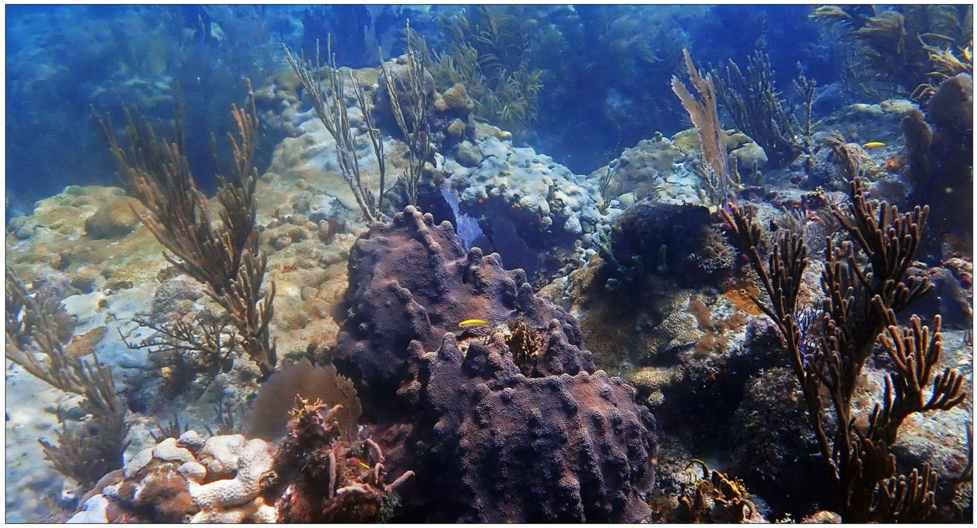
*Campos, E.J.D., M.C. van Caspel, W. Zenk, E.G. Morozov, D.I. Frey, A.R. Piola, C.S. Meinen, O.T. Sato, R.C. Perez, and S. Dong, 2021: Warming trend in the abyssal flow through the Vema Channel in the South Atlantic. *Geophysical Research Letters*, 48(19):e2021GL094709, https://doi.org/10.1029/2021GL094709.

Urban Corals Persist in Unlikely Places



A reefscape at Emerald Reef, one of the offshore sites used to compare coral health with the inshore urban corals at the Port of Miami sites.

When we look at the state of corals globally it can be difficult to see a silver lining, but a recent paper published in *Frontiers in Marine Science** shows hope for corals in unlikely places. In the study, scientists at AOML and the Cooperative Institute for Marine and Atmospheric Studies at the University of Miami compared the molecular processes of brain corals (*Pseudodiploria strigosa*) living in urban waters at the Port of Miami with offshore corals at Emerald Reef.

They found the urban corals had adapted to challenging conditions that helped them differentiate and consume healthy food particles over diseased organisms. Specialized proteins were also activated in the Port of Miami corals that defended them against toxic substances and water pollutants. They even hosted symbionts, tiny algae that help corals survive, that were better adapted to live in shallow, turbid, high-nutrient waters.

Anthropogenic or man-made stressors have contributed to coral mortality worldwide. This is especially noticeable along the Florida reef tract, which has suffered from bleaching events and the spread of disease. The Port of Miami, with its dense boat traffic, river-stormwater runoff, eutrophication, and dredging activities, presents an "anthropogenic obstacle course" of environmental stressors for marine life. Surprisingly, researchers found a high abundance of healthy brain corals at the port compared to their Florida reef tract counterparts.

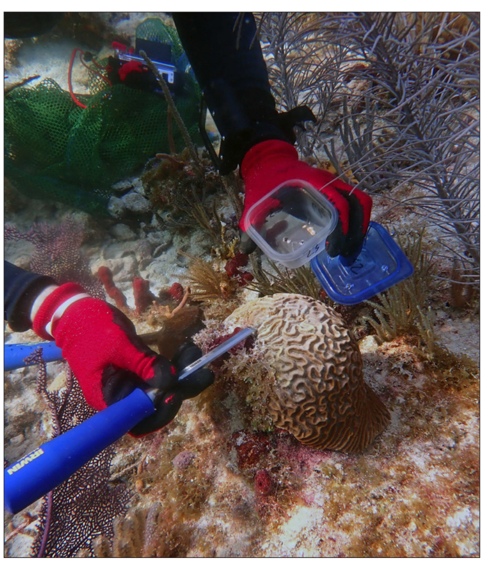
"For me, the strange irony is that I spent years surveying some of the most remote, aesthetically pleasing, and perceivably most pristine reefs on the planet, only to find that those corals, which had never before encountered significant environmental perturbation, are now more prone to climate change stressors. In the Port of Miami, we have the opposite scenario: corals flourishing in an environment that, at first glance, would not appear to be amenable to coral survival," said Anderson Mayfield, a Cooperative Institute coral scientist at AOML.

Contrary to surrounding areas, brain corals in the Port of Miami basin have made use of urban conditions, growing on man-made structures such as concrete walls and artificial boulders known as riprap. These corals appear to be healthy, with no signs of disease or bleaching since 2017. So what is it about these corals that have allowed them to persist in the harsh conditions found in urban waters?

The comparison study showed that genetic receptors, digestive enzymes, and defensive immunity proteins protected them against disease and enabled brain corals to select healthy food particles. In short, the "molecular mechanisms" in urban brain corals have been the key to their survival and persistence in stressful conditions at the Port of Miami.

These findings are important for establishing an understanding of the molecular markers of coral resilience and how corals acclimate to less-than-ideal conditions. With upgrades to existing infrastructure and new coastal development, Port of Miami corals may need to be moved and better decisions made about the type of suitable habitat for their relocation.

Beyond urban waters, this research enhances coral monitoring, conservation, and restoration activities by providing hope for coral survival and ecosystem resilience in the face of climate change and other environmental challenges.

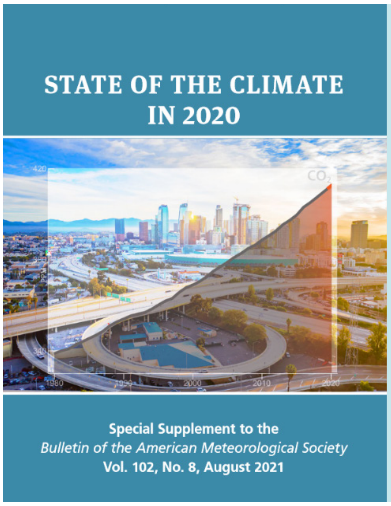


Left: **Coral scientist Graham Kolodziej collects small samples of brain coral (*P. strigosa*) from the offshore control site at Emerald Reef to compare its physiology to its more resilient counterparts at the Port of Miami's urban coral sites. *Right:* A metallic tag is held next to an urban brain coral in the murky waters of the Port of Miami that will later be used to match the photograph with the small biopsies collected with hammer and chisel.**

*Rubin, E.T., I.C. Enochs, C. Foord, A.B. Mayfield, G. Kolodziej, I. Basden, and D.P. Manzello, 2021: Molecular mechanisms of coral persistence within highly urbanized locations in the Port of Miami, Florida. *Frontiers in Marine Science*, 8:695236, https://doi.org/10.3389/fmars.2021.695236.

International Science Community Meets to Discuss Challenges, Future Outlook of Coral Reefs

Coral scientists at AOML virtually attended and presented their research at the 14th International Coral Reef Symposium in July. The quadrennial event brought together more than 2,500 coral reef experts, early career researchers, policy makers, environmental managers, and other stakeholders. This diverse group met to share information and research findings focused on the current and future outlook of coral reefs, which globally face a multitude of threats. Presentations by AOML's coral scientists highlighted research on reef communities impacted by eutrophication, pollution, ocean warming, and ocean acidification, but also brought to light new research on the resilience of coral reefs persisting in urbanized regions under less-than-ideal conditions.



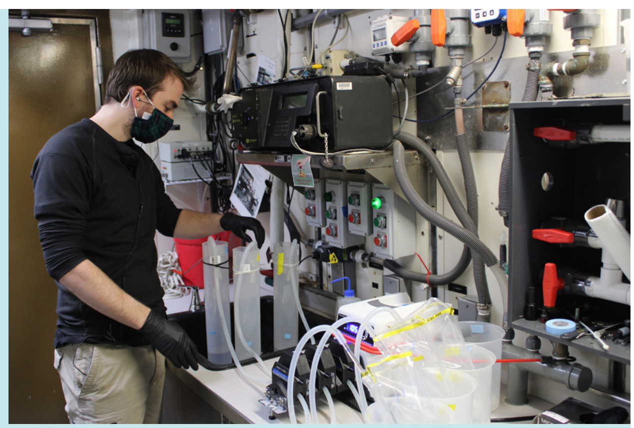
Latest State of the Climate Report Shows Global Ocean Processes are Shifting

The *2020 State of the Climate* report was released in August by the American Meteorological Society, with 2020 being denoted as one of the hottest years on record since the start of the Industrial Revolution. Even with environmental cooling factors, such as the transition from the El Niño of 2018-2019 to the La Niña of late 2020, global trends still indicate the Earth is warming and sea levels are rising. The report, the 31st in an annual series, describes and analyzes the weather and climatic events that shaped 2020 based on the contributions of more than 400 scientists from around the globe. A number of scientists at AOML contributed this international effort, serving as coauthors for sections of the report dedicated to the ocean's uptake of carbon dioxide, ocean precipitation and salinity patterns, surface and thermohaline circulation changes, thermal expansion at the ocean surface and in the deep sea, the 2020 Atlantic hurricane season, and other topics. The report documents planet Earth's changing climate and will be used to inform research, policy decisions, and management actions.

UN Ocean Decade Endorses AOML Collaborative Initiatives

Several collaborative initiatives featuring research by scientists at AOML were recently endorsed in the first Ocean Decade Actions announcement made by the United Nations Intergovernmental Oceanographic Commission (IOC). The United Nations General Assembly proclaimed 2021-2030 as the UN Decade of Ocean Science for Sustainable Development, also known as the "Ocean Decade," in 2017 to address the degradation of the ocean and encourage innovative science initiatives to better understand and ultimately reverse its declining health.

Scientists at AOML collaborate with national and international partners and stakeholders to conduct research that supports the vision of the UN Ocean Decade through initiatives that include the Observing Air-Sea Interactions Strategy (OASIS), Ocean Biomolecular Observing Network (OBON), Global Ocean Biogeochemistry Array (GO-BGC), and Ocean Acidification Research for Sustainability (OARS).



AOML-Northern Gulf Institute postdoctoral scientist Sean Anderson filters seawater for environmental DNA (eDNA) during a recent reef fish survey in the Gulf of Mexico that will provide the OBON initiative with valuable data.

AOML contributes to OASIS through the Surface Ocean CO_2 Reference Observing Network. AOML also provides OASIS with hourly observations of mixed layer currents, near-surface temperatures, and barometric pressure changes from a variety of observing platforms.

OBON will develop a global biomolecular observing system to better understand marine ecosystems and use this knowledge to manage and protect them. AOML supports the development of this next-generation observing system by working with partners to help communities detect biological hazards such as harmful algal blooms and other pathogens.

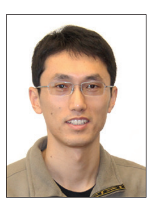
The GO-BGC project will revolutionize the understanding of ocean biogeochemical cycles through the development of a global network of biogeochemical Argo (BGC Argo) floats. AOML supports this initiative by hosting the US Argo Data Acquisition Center. Scientists at AOML will process and quality control all BGC-Argo chemical and biological sensor data collected by US entities.

AOML contributes to the OARS initiative by participating in several international research programs that track carbon changes in the ocean, e.g., GO-SHIP (the Global Ocean Ship-based Hydrographic Investigations Program), CLIVAR (Climate and Ocean Variability, Predictability, and Change), and SOOP (Ship of Opportunity Program). These programs enable researchers to better understand the dynamics, interaction, and predictability of the climate system, as well as the impacts of increasing carbon dioxide levels on marine ecosystems.

Congratulations

Sim Aberson, a meteorologist with AOML's Hurricane Research Division, is a member of NOAA's Diversity Professional Advancement Working Group (DPAWG) that was recognized in September by the Global Employee Resource Group Network. The DPAWG is a grassroots group whose goal is to improve the recruitment, retention, and advancement of a diverse workforce within NOAA. It received a 2021 Diversity Impact Award as the fifth best employee resource group in the nation. Two other NOAA employee resource groups—Generations with Genius (dedicated to creating an atmosphere where all of NOAA's diverse generations exercise their talents to their fullest potential, fourth) and the Accommodating Differently Abled People Team (ADAPT, 21st)—were also recognized. The awards were presented on September 17 during the 2021 ERG & Council Conference.

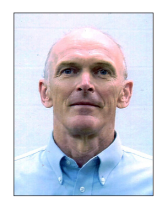
Francis Bringas, Gustavo Goni, and Ulises Rivero, all with AOML's Physical Oceanography Division, along with LCDR Benjamin LaCour of NOAA's Office of Marine and Aviation Operations, received a 2021 Department of Commerce Bronze Medal in September for successfully coordinating and operating a "picket fence" of underwater gliders during the 2019 Atlantic hurricane season for improved forecasts. Gliders are autonomous platforms that profile the temperature and salinity of the water column to depths of half a mile below the ocean's surface. The data they gather improve how the ocean is represented in operational forecast models. The hurricane glider picket fence is a NOAA across-Line Office, multi-institutional, interdisciplinary, international project geared toward obtaining ocean temperature and salinity profiles to better understand air-sea interactions that occur during tropical cyclone events. Since 2014, AOML and its partners have deployed gliders in regions of the Caribbean Sea, Atlantic Ocean, and Gulf of Mexico where tropical cyclones often travel and intensify. The Bronze Medal, the highest honor award granted by the Under Secretary of Commerce for Oceans and Atmosphere, recognizes federal employees for their scientific and engineering accomplishments. The project is also supported by numerous AOML-University of Miami/Cooperative Institute and contractor staff, including Zachary Barton, Caridad Ibis Gonzalez, George Halliwell, Matthieu Le Hénaff, Grant Rawson, Christian Saiz, Joaquin Trinanes, and Diego Ugaz.



Xiaomin Chen, a Northern Gulf Institute research scientist with AOML's Hurricane Research Division, has accepted an invitation from the American Meteorological Society to become an Associate Editor for the *Journal of the Atmospheric Sciences*. Xiaomin's editorial term with the journal began on September 1. For the next 3 years, Xiaomin will review and assess research articles submitted to the journal with a focus on tropical cyclones and boundary layer processes. The journal publishes basic research related to the physics, dynamics, and chemistry of the atmosphere of Earth and other planets.

Derek Manzello, a former oceanographer with AOML's Ocean Chemistry and Ecosystems Division, received a 2021 Department of Commerce Bronze Medal in September. Derek led a NOAA team that was recognized for deploying the first Moored Autonomous Partial Pressure of Carbon Dioxide (MAP-CO_2) buoy in a US Southern Hemisphere coral reef (Fagatele Bay, American Samoa) to monitor ocean acidification. The buoy, deployed in 2019, complements a national array of MAP-CO_2 buoys deployed by NOAA across the Pacific, Atlantic, and Caribbean regions to document the evolving state of ocean carbon chemistry and its impact on tropical coral reef ecosystems. The Bronze Medal is awarded to federal employees for their scientific and engineering accomplishments. AOML-University of Miami/Cooperative Institute staff, including Michael Jankulak and Graham Kolodziej, also supported this effort. Derek is currently the Coral Reef Watch Coordinator with NOAA's Center for Satellite Applications and Research.

Frank Marks, the director of AOML's Hurricane Research Division, received the Joanne Simpson Tropical Meteorology Research Award from the American Meteorological Society in July. Frank was recognized for his outstanding contributions to the understanding and prediction of tropical cyclones through scholarship, field contributions, and community leadership. Over the years Frank has worked tirelessly to advance the state of tropical cyclone knowledge, spearheading improvements that have led to advancements in ground-based, airborne, and spaceborne radar technology, data analysis, and numerical modeling. These advances have facilitated a greater understanding of the processes that fuel storm development and intensification, as well as provided more skilled forecast guidance to the National Hurricane Center. Frank is also an accomplished speaker, adept at communicating NOAA-related science and research to non-scientific audiences of all ages. He will receive the award in January 2022 at the American Meteorological Society's 102nd Annual Meeting in Houston, Texas.

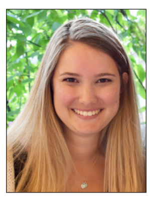


Rik Wanninkhof, AOML's senior scientist and a long-term oceanographer with AOML's Ocean Chemistry and Ecosystems Division, received a 2021 Department of Commerce Distinguished Career Award in September. Rik has been an inspirational leader of ocean carbon research at NOAA for the past three decades with a focus on the transfer of carbon dioxide across the air-sea interface. His career is distinguished by outstanding scholarly effort (296 publications with 31,395 citations) and as a visionary who has led NOAA Research on evolving issues from exploratory research to sustained observational efforts and the socio-economic aspects of increased ocean carbon content as it pertains to ocean health and the blue economy. He has done so as a leader, mentor (more than 30 students and post-doctoral fellows), and collaborator. Rik was recognized for his "outstanding scientific leadership of ocean carbon cycle research in support of NOAA's mission to understand a changing climate and support ocean health." The Distinguished Career Award honors significant accomplishments across all NOAA program areas and functions that have resulted in long-term benefits to the bureau's mission and strategic goals.

Welcome Aboard

Dr. Wilton Aguiar joined AOML's Physical Oceanography Division in August as a University of Miami-Cooperative Institute post-doctoral scientist. Wilton will work with Drs. Hosmay Lopez, Shenfu Dong, and Sang-Ki Lee on research to analyze the impact of reduced anthropogenic aerosol emissions on the climate system due to the COVID-19 pandemic. He recently earned a PhD in Oceanography from the Federal University of Rio Grande in Brazil.

Dr. Ricardo Campos joined AOML's Physical Oceanography Division in July as a University of Miami-Cooperative Institute assistant scientist. Ricardo will work with researchers at AOML, along with colleagues at NOAA's Environmental Modeling Center, Ocean Prediction Center, and the National Centers for Environmental Prediction to produce wave forecasts. The goal of this research is to generate a wave reforecast using the Global Ensemble Forecast System, a weather model, and then use the results to develop probabilistic tools and machine learning post-processing models. Ricardo holds a PhD in Naval Architecture and Ocean Engineering from the University of Lisbon.



Samantha Camposano joined AOML's Hurricane Research Division in July as a University of Miami-Cooperative Institute Senior Research Associate III. Samantha will work to support research to operations, splitting her time between AOML and the National Hurricane Center. She will be involved with the Joint Hurricane Testbed expansion, also know as the Tropical Marine Testbed, as research projects transition into National Weather Service operations, including working with the Advanced Weather Interactive Processing System. Samantha will also help test new products, technology, and techniques from researchers to operational forecasters and beyond. No stranger to AOML, Samantha interned with the Hurricane Research Division in 2018 while attending the University of Miami's Rosenstiel School to earn an MPS degree in Atmospheric Science.

Jordan Logarbo joined AOML's Ocean Chemistry and Ecosystems Division in September as a 2021 Science Policy Fellow with the National Academies of Science Gulf Research Fellowship Program. Jordan will work for the next year to better integrate the policy process with science programs at AOML. She will initially focus on collaborations with commercial fishermen to better understand red tide, hypoxia, and estuarine impacts, including ocean acidification on fisheries, and how this information feeds into the management process. Jordan recently graduated with a MS degree from the School of Renewable Natural Resources at Louisiana State University.

Dr. Aurpita Saha joined AOML's Physical Oceanography Division in August as a University of Miami-Cooperative Institute post-doctoral scientist. Aurpita will work with Dr. Greg Foltz on the analysis of ocean observations and model output in the tropics in support of the Argo program. She recently earned a PhD in Earth System Sciences–Oceanography from the University of Hamburg.

Farewell

Dr. Karina Apodaca, a University of Miami-Cooperative Institute Associate Scientist with AOML's Hurricane Research Division, resigned in September to accept a position with Spire Global, Inc. Karina began at AOML in 2018 as a Cooperative Institute employee with Colorado State University to work with NOAA's Qualitative Observing System Assessment Program led by Dr. Lidia Cucurull. She primarily led NOAA-proposed research on the implementation of observation operators for the GOES/Geostationary Lightning Mapper lightning flash rate and non-Gaussian data assimilation for NOAA's Gridpoint Statistical Interpolation system. Karina later became a University of Miami-Cooperative Institute employee to work on adapting a variational quality control technique for improved use of Aeolus satellite wind observations for NOAA's FV3 Global Forecasting System. At Spire Global, Inc., Karina will propose and implement innovative approaches to data assimilation, data processing, and quality control.

Charita Atluri, a University of Miami-Cooperative Institute Senior Research Associate II with AOML's Physical Oceanography Division, resigned in July to pursue other career opportunities. During Charita's 9 years at AOML, she was a valued member of the Argo team. Among her many accomplishments, Charita designed and developed new code, served as a mentor for new team members, and aided the team's transition from the Unix to Linux operating systems by converting and migrating legacy software, data, and profile details to the newer platform.

Manuel Fraga, a Facility Management Specialist with AOML's Office of the Director, retired in September after 19 years of federal service. Manny was a mainstay at AOML, tirelessly working to maintain the aging AOML facility, a job that kept him perpetually busy. Be it renovating offices, upgrading old flooring and lighting, coping with cranky electric generators, repairing leaky faucets and windows, and an endless list of other items, Manny always got the job done. Because of his long-term efforts, the AOML facility provides all employees with a safer, more energy efficient, and contemporary working environment.

Dr. Marion Kersalé, a University of Miami-Cooperative Institute post-doctoral researcher with AOML's Physical Oceanography Division, resigned in August. Marion has accepted a permanent engineering position with the Ministry of Defense in Paris, France. During her 5 years at AOML, Marion studied the connections between the shallow and deep limbs of the Atlantic Meridional Overturning Circulation (MOC) at both 34.5°S and 26.5°N. She was the lead author of four peer-reviewed papers, the first two of which examined the variability of eastern boundary currents in the South Atlantic, resolving for the first time the daily evolution of a deep eastern boundary current. Marion's third and fourth papers focused on estimating the daily variability of the volume and heat transports in the South Atlantic MOC using a basin-wide array of moored oceanographic sensors along 34.5°S.

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Keynotes is published quarterly to highlight AOML's recent research activities and staff accomplishments.

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

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