AOML Keynotes

NOAA'S ATLANTIC OCEANOGRAPHIC AND METEOROLOGICAL LABORATORY

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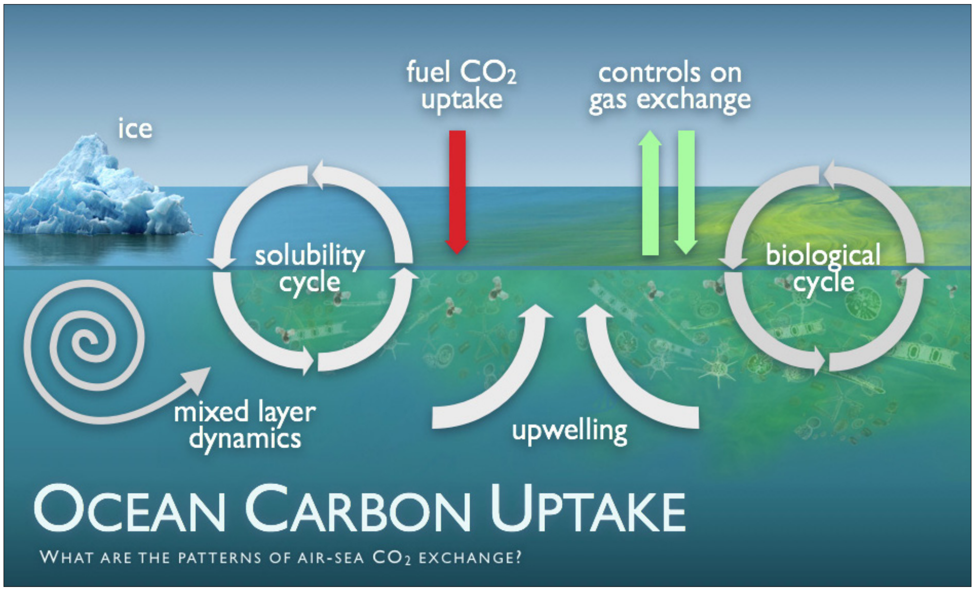
AOML is an environmental laboratory of NOAA's Office of Oceanic and Atmospheric Research located on Virginia Key in Miami, Florida

In This Issue

Global Carbon Dioxide Emissions Remained at Record High Levels in 2022



The ocean absorbs carbon dioxide from the atmosphere, forming a sink for carbon that can reduce the potential for atmospheric warming. The increased carbon in the ocean, however, has led to a more acidic ocean. Credit: NOAA-PMEL.

Global carbon dioxide emissions in 2022 remained at record high levels and natural carbon sinks were impacted by climate change, according to a recent report by the Global Carbon Project.

The report, produced by an international team of more than 100 scientists that included many experts from NOAA, projected that atmospheric carbon dioxide (CO_2) concentrations reached an average of 417.2 parts per million in 2022, more than 50 percent above pre-industrial levels. The projection of 40.6 billion tonnes of CO_2 emissions in 2022 is close to the 40.9 billion tonnes of CO_2 noted in 2019, the highest annual total ever recorded.

If the current level of emissions persists, there is a 50 percent chance that global warming of 1.5°C (2.7°F) will be exceeded in 9 years, the opposite trend needed to reverse climate change. The report also provides a detailed accounting of carbon storage in the ocean and on land.

"Looking closely at the observational data, we have learned that the ocean's capacity to be a sink is finite," says Rik Wanninkhof, PhD, an ocean carbon cycle expert at AOML and a contributor to the report. "Natural sinks are not as steady and robust as we have believed in the past. Understanding human influence on the global carbon budget is extremely important, but we also have to understand the natural world's contributions to the budget. This report provides a consensus on changes in our planet's carbon reservoirs."

The Global Carbon Budget is increasingly focused on the investigation of natural sinks, those processes on land and in the ocean that absorb and ***(cont. page 2)***

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store carbon. The ocean and land CO_2 sinks continue to increase in response to the increase in atmospheric CO_2, although climate change reduced this growth by an estimated 4 percent (ocean sink) and 17 percent (land sink) over the 2012-2021 decade.

Some of the reduction is due to climate change itself. The ocean is warming, and a warmer ocean will not take up as much.

Land-use changes, especially deforestation, are a significant source of CO_2 emissions, equivalent to about a tenth of the amount of CO_2 coming from fossil fuel emissions. Emissions from land-use change were projected to reach 3.9 billion tonnes of CO_2 in 2022.

Planting new forests counterbalances half of the deforestation emissions, and the report notes that there are opportunities to stop or slow deforestation and restore or expand existing forests to better balance the carbon budget.

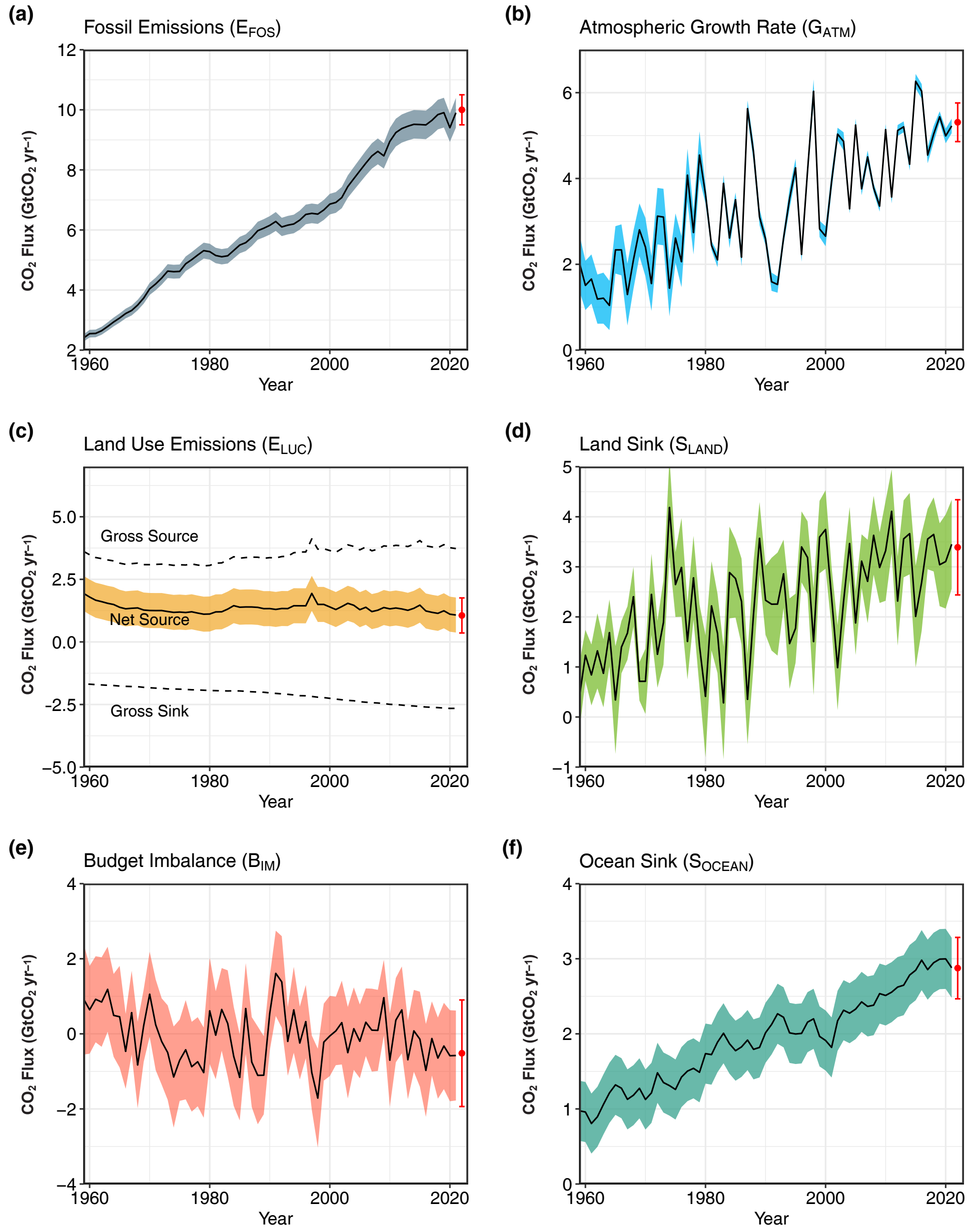
The report also accounts for emissions that add CO_2 to the atmosphere. In 2022, fossil CO_2 emissions were projected to reach 36.6 billion tonnes of CO_2, slightly above pre-COVID-19 levels.

Projected emissions from coal and oil are above their 2021 levels, with oil being the largest contributor to total emissions growth. The growth in oil-burning emissions is largely explained by the delayed rebound of international aviation following COVID-19 pandemic restrictions.

The report's authors note that it would now require a yearly decrease in fossil fuel consumption, or increasing the natural sinks by about 1.4 billion tonnes of CO_2, to reach net-zero CO_2 emissions by 2050. This decrease would be comparable to the observed drop in emissions resulting from the 2020 COVID-19 lockdowns, highlighting the scale of the action required.

The 2022 carbon budget does show that the long-term rate of fossil emission increases has slowed; however, the trend is quite small. The average rise peaked at 3 percent per year during the 2000s, while growth in the last decade has been about 0.5 percent per year.

The Global Carbon Project is an international research project within the Future



Components of the global carbon budget and their uncertainties as a function of time, presented individually for (a) fossil CO_2 and cement carbonation emissions (E_{FOS}), (b) growth rate in atmospheric CO_2 concentration (G_{ATM}), (c) emissions from land-use change (E_{LUC}), (d) the land CO_2 sink (S_{LAND}), (e) the budget imbalance that is not accounted for by the other terms, and (f) the ocean CO_2 sink (S_{OCEAN}). Positive values of S_{LAND} and S_{OCEAN} represent a flux from the atmosphere to land or the ocean. All data are in $GtCO_2\ yr^{-1}$ with the uncertainty bounds representing a ±1 standard deviation in shaded color. The red dots indicate projections for the year 2022, and the red error bars indicate the uncertainty in the projections (from Friedlingstein *et al.*, 2022).

Earth research initiative on global sustainability and is a research partner of the World Climate Research Programme. It aims to develop a complete picture of the global carbon cycle, including both its biophysical and human dimensions, together with the interactions and feedbacks between them.

NOAA contributed approximately half of all of the CO_2 ocean and atmospheric observations made in this year's report, including work from the Global Monitoring Laboratory, AOML, and Pacific Marine Environmental Laboratory, with support from NOAA's Global Ocean Monitoring and Observing program.

The 2022 global carbon budget is the 17th edition of the annual update begun in 2006, and the 11th edition made available in the journal *Earth System Science Data**.

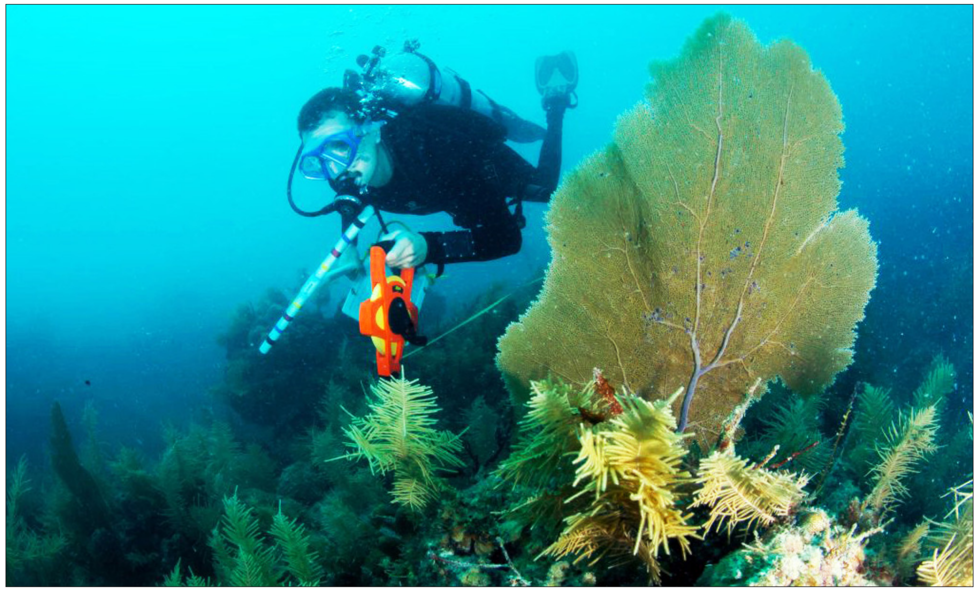
This article was originally published by NOAA Research (research.noaa.gov) on November 14, 2022.

*Friedlingstein, P., *et al.*, 2022: Global carbon budget 2022. *Earth System Science Data*, 14(11):4811-4900, https://doi.org/10.5194/essd-14-4811-2022.

Survey Finds Seventy Percent of Florida's Coral Reefs are Eroding

New research in the journal *Scientific Reports** by scientists at AOML, their NOAA partners, and the University of Miami's Cooperative Institute for Marine and Atmospheric Studies has revealed that 70 percent of Florida's coral reefs are experiencing a net loss of habitat. The study represents the largest spatial assessment of Florida's coral reefs to date and emphasizes not only the importance of restoration efforts, but also the need for enhanced management practices to preserve and prevent their further decline.

"This research helps us better understand which coral reefs along Florida's reef tract are vulnerable to habitat loss that require management and restoration efforts," said John Morris, lead author of the study. John recently received a doctoral degree in Coral Reef Ecology from the University of Miami's Rosenstiel School while working to support AOML's coral research programs. "On the contrary, we also identified reefs that may be potential holdouts to reef development and are more likely to persist in the future."



John Morris conducts a parrotfish survey to quantify parrotfish erosion rates at a reef site. Photo credit: NOAA-AOML.

The study used benthic cover and parrotfish demographic data from NOAA's National Coral Reef Monitoring Program, along with high-resolution observations from LiDAR topobathymetry, to calculate the carbonate budget of reefs across the Florida Reef Tract, the only living barrier reef system in the continental United States and the third largest coral barrier reef system worldwide. The reef tract stretches from the St. Lucie Inlet in Martin County southward to the Dry Tortugas, a distance of 350 miles.

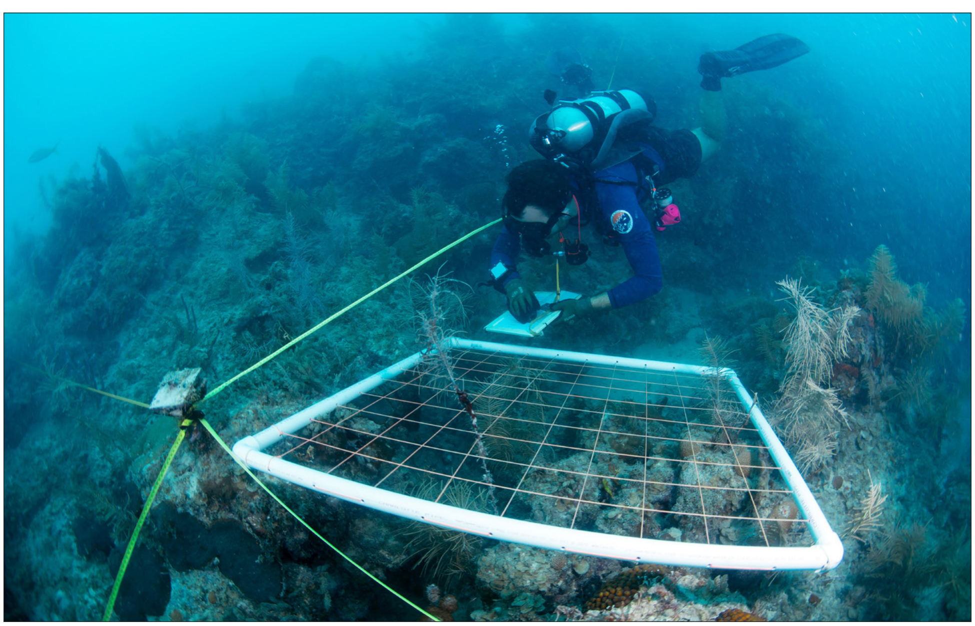
Of 723 reef sites analyzed, 506 or 70% were found to be annually losing reef habitat. This significant loss of coral cover is attributed to factors such as ocean warming, pollution, ship groundings, and diseases that include stony coral tissue loss disease, which has ravaged reefs throughout Florida and the Caribbean since 2014.

The results highlight the erosional state of the majority of the study sites, with a trend towards more vulnerable habitat in the northern Florida reef tract, especially in the southeast Florida region in close proximity to urban centers. As these reefs lose structure, the ecosystem services they provide diminish, signifying the importance of increased protections and management efforts to offset these trends.

"This study is especially informative because it takes a holistic approach, synthesizing the ecology of a biodiverse community of reef-dwellers, said Ian Enochs, PhD, study coauthor and principal investigator of AOML's Coral Program. "Unfortunately, we have found that habitat erosion is all too common in the Florida Keys, underscoring the importance of the many management and restoration efforts that NOAA, AOML, and others are involved in throughout the region."

By uncovering the state of Florida's coral reefs, scientists now have a better understanding of the reefs that require management and restoration efforts, as well as reefs more susceptible to future erosion that require preventative action.

This information will serve as a baseline to track management and restoration strategies moving forward. With improved knowledge, as well as better restoration and management practices, higher coral survival rates are possible.



Patrick Kiel performs a benthic survey to measure the percent cover of calcifying and bioeroding reef organisms. Photo credit: NOAA-AOML.

*Morris, J., I. Enochs, N. Besemer, T.S. Viehman, S.H. Groves, J. Blondeau, C. Ames, E.K. Towle, L.J.W. Grove, and D. Manzello, 2022: Low net carbonate accretion characterizes Florida's coral reef. *Scientific Reports,* 12:19582, https://doi.org/10.1038/s41598-022-23394-4.

Coral Genetic Variants and their Bacteria Linked to Elevated Nutrient and Heat Stress Resistance

***Acropora cervicornis*, or staghorn coral, is a critically endangered coral that was once one of the most prevalent coral species in the Caribbean. Its numbers have dwindled in recent decades due to numerous stressors, including disease, ocean warming, pollution, and sedimentation. Photo credit: NOAA-AOML.**

A recent study in the journal *Coral Reefs** by scientists at the University of Miami's Rosenstiel School, Cooperative Institute for Marine and Atmospheric Studies, and AOML has identified genetic variants in staghorn coral, *Acropora cervicornis*, that can tolerate elevated temperatures and nutrient pollution, two environmental stressors that put this critically endangered species at risk. The identification of stress-resistant genetic variants provides researchers with an important tool for improving coral survival rates and restoration success, as well as efforts to increase coral cover and preserve genetic diversity.

Scientists found three *A. cervicornis* variants that maintained higher survivorship and growth rates when stressed with elevated nutrients, both alone and in combination with heat. However, the combination of pre-exposure to elevated nutrient levels and heat stress had the most harmful impact on *A. cervicornis* when compared to either stressor alone.

When studying the microbial community of each *A. cervicornis* variant, a high abundance of the bacteria *Midichloriaceae* and *Spirochaetaceae* was positively correlated with higher coral survivorship. This discovery suggests that coral restoration programs could use bacteria screenings to identify other *A. cervicornis* genetic variants that may also be more tolerant to elevated nutrients and temperature.

"Scientists already use bacteria biomarkers to evaluate the health of our environment," said Stephanie Rosales, PhD, a study coauthor and University of Miami-Cooperative Institute assistant scientist at AOML. "This study suggests that we may also be able to use microbial biomarkers to evaluate the likelihood of a coral's health in certain environments." The rapid decline of *A. cervicornis* in recent decades has resulted in the overall loss of its ecological functions. For example, *A. cervicornis* "thickets," which are dense groups of corals, are now rare. This has reduced the structural complexity of reefs, as well as the habitat available for other reef organisms, including fish.

A. cervicornis is frequently used in restoration projects. To maximize the effectiveness of restoration efforts, data have shown that particular genetic makeups, or genotypes, can be selected to repopulate certain regions based on local environmental stressors. This study found that genotypes G48, G62, and G31 were the most resistant to elevated nutrients alone and when combined with heat stress, resulting in less coral mortality and smaller declines in growth rates.

Placing these more resistant genotypes in locations exposed to warmer temperatures and elevated nutrients holds the potential to increase restoration success by reducing coral mortality.

***A. cervicornis* corals exposed to elevated nitrogen levels experienced more bleaching and mortality during heat stress than corals in ambient nutrients, but some variants were less susceptible to these stressors. Photo credit: NOAA-AOML.**

*Palacio-Castro, A.M., S.M. Rosales, C.E. Dennison, and A.C. Baker, 2022: Microbiome signatures in *Acropora cervicornis* are associated with genotypic resistance to elevated nutrients and heat stress. *Coral Reefs,* 41(5):1389–1403, https://doi.org/10.1007/s00338-022-02289-w.

Hurricane Hunters Call it a Wrap for 2022 Season

Members of the NOAA P-3 science crew at the end of a mission into Fiona on September 21: Dan Wallace (Florida State University observer), Heather Holbach (AOML), Shirley Murillo (AOML), Samantha Camposano (National Hurricane Center, formerly with AOML), and Jason Sippel (AOML). Photo credit: NOAA-AOML.

The 2022 Atlantic hurricane season ended on November 30, producing 14 named storms. Throughout the season, scientists at AOML worked tirelessly to conduct research on tropical cyclones and gathered observations to help NOAA prepare communities in the path of severe weather. These observations provided vital information to forecasters at the National Hurricane Center regarding storm structure, intensity, precipitation, and the atmospheric steering currents that influence storm track and landfall location.

AOML hurricane scientists flew aboard almost all of the 68 missions conducted on NOAA's Hurricane Hunter aircraft, totaling 440 flight hours, to investigate eight tropical systems. Of these, seven developed into named storms and two—Fiona and Ian—strengthened into major hurricanes with sustained winds above 110 mph. All research missions and most operational missions were carried out in support of the Advancing the Prediction of Hurricanes Experiment, or APHEX, the main focus of NOAA's 2022 Hurricane Field Program.

Research missions were conducted in partnership with NOAA's Office of Marine and Aviation Operations, the National Aeronautics and Space Administration, and the Office of Naval Research to better understand how tropical cyclones form, rapidly intensify, and dissipate.

Operational missions were tasked by the Environmental Modeling Center and National Hurricane Center of NOAA to collect observations from the periphery and eyewall of storms for assimilation into the Hurricane Weather Research and Forecasting model for accurate, up-to-date track and intensity forecasts.

Accomplishments for the season include:

- Conducting 20 research missions over 12 consecutive days into Hurricane Earl, marking the longest series of missions ever undertaken by NOAA into a single tropical system. These missions were in support of research modules for the genesis, early, and mature stage science objectives of APHEX.
- Working with partners, including NOAA's Pacific Marine Environmental Laboratory, the Caribbean Coastal Ocean Observing System, US Navy, and others to position multiple ocean-observing instruments—saildrones, underwater gliders, surface drifting buoys, expendable bathythermographs, and Argo profiling floats—for collocated data collection with airborne instruments.
- Deploying an Altius-600 small uncrewed aircraft system into the eye of Hurricane Ian, a borderline Category-5 hurricane, to collect observations from Ian's lower altitudes, a region too dangerous for crewed aircraft due to the extreme turbulence near the ocean surface.
- Traveling thousands of miles to the Cabo Verde islands for a trailblazing mission to explore how tropical waves moving off the west African coast develop into tropical storms and hurricanes. This mission marked the farthest distance ever traveled by NOAA's Hurricane Hunters in their effort to improve track and intensity forecasts.
- Adding a "moving nest" capability to the Hurricane Analysis and Forecast System (HAFS), NOAA's next-generation hurricane model, that provides fine-scale details of environmental conditions as storms move through the Atlantic basin. HAFS is slated to become operational during the 2023 hurricane season.

An Altius-600 small uncrewed aircraft system deployed in the eye of Hurricane Ian from NOAA's P-3 Hurricane Hunter aircraft collected observations from the lower altitudes of Ian, measuring wind speeds as strong as 216 mph at 2150 feet above the ocean. Photo credit: NOAA.

Atlantic Coast Hurricanes Intensifying Faster Than Forty Years Ago

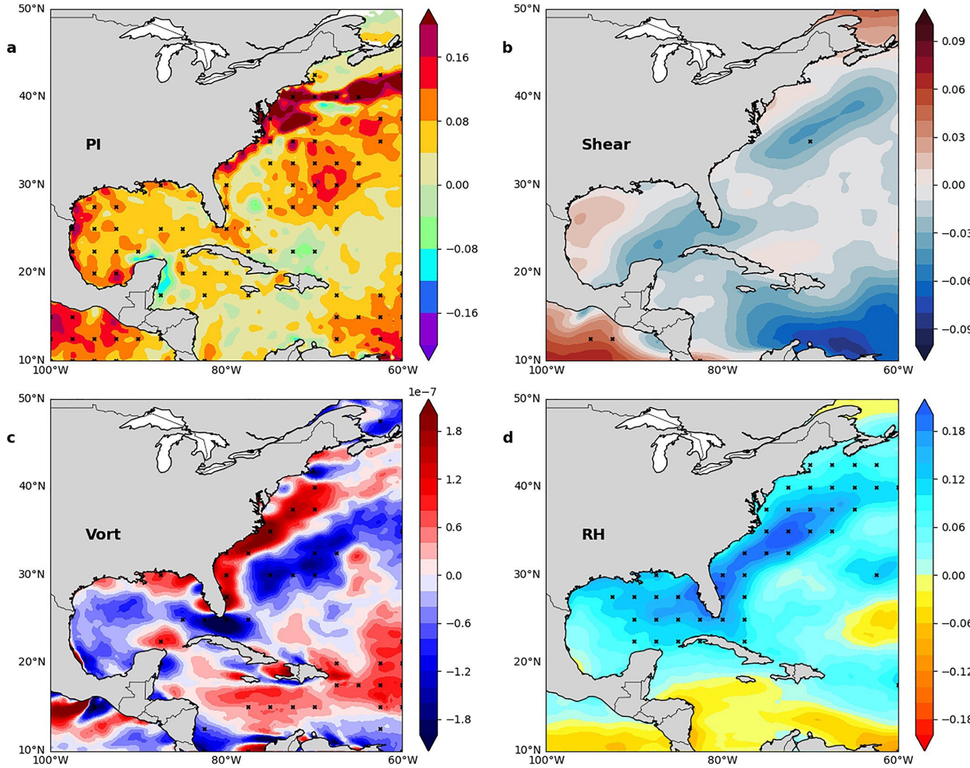
New research published in the journal *Geophysical Research Letters** finds that hurricane intensification rates near the US Atlantic coast have increased significantly over the past 40 years and will likely continue to increase in the future.

Landfalling hurricanes can cause severe damage and loss of life. When storms intensify near the coast, they pose an even greater threat and represent a bigger challenge for damage mitigation.

Using observations and climate model simulations, scientists at AOML, the Pacific Northwest National Laboratory, and University of Miami's Cooperative Institute for Marine and Atmospheric Studies analyzed hurricane intensification patterns in the 230 mile area of the shoreline using storm track data for the 40-year period from 1979–2018. They found that the average intensification rate increased by about 5.2 miles per hour near the US Atlantic coast. However, a significant increase in hurricane intensity near the Gulf of Mexico coast over the same period was not observed.

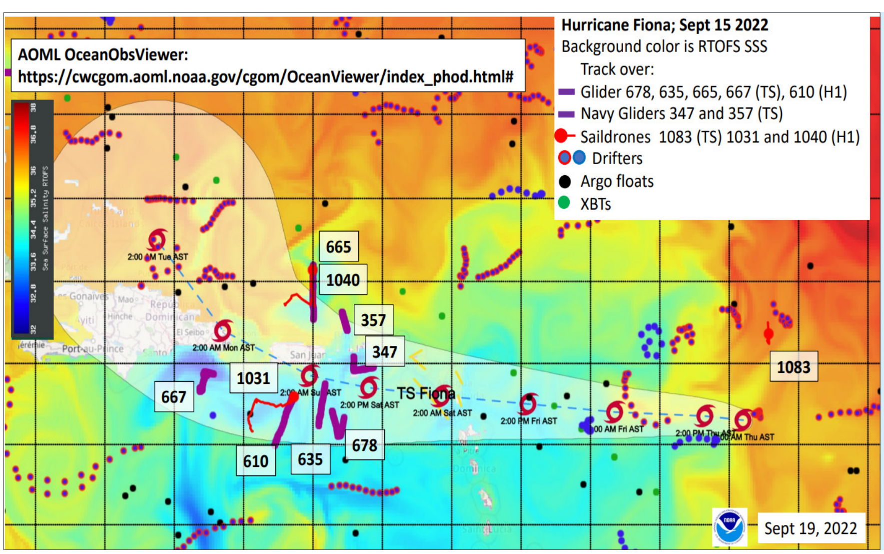
"We know that the warming of the ocean's surface can lead to more intense hurricanes," said Greg Foltz, an AOML scientist and study coauthor. "We were curious how other measures of the hurricane environment have changed. What surprised us was the consistency of these changes near the US east coast, including less wind shear, more humidity, and other factors that conspire to increase hurricane intensification."

Climate models used in the study showed that hurricanes near the US Atlantic coast enter into an increasingly favorable environment just ahead of landfall, which can cause wind speeds to quickly increase. A favorable pressure gradient across the land-sea boundary, warming ocean temperatures, and decreasing levels of vertical wind shear, i.e., the change in the wind's direction and speed with height, are all factors that help hurricanes intensify. The models project a continued enhancement of the hurricane environment near the Atlantic coast in the future, contributing to stronger, more intense hurricanes. These results are well supported by the direct simulation of hurricanes in high-resolution climate models.



Observed changes in the nearshore hurricane environment for 1979–2018. Near the US east coast the ocean's surface has warmed and the atmosphere has become less stable (a), wind shear has decreased (b), the rotation of large-scale winds has become more cyclonic, i.e., counterclockwise (c), and relative humidity has increased (d). Black crosses in various panels represent locations where the trends are statistically significant at the 95% level (from Balagaru *et al.*, 2022).

*Balaguru, K., G.R. Foltz, L.R. Leung, W. Xu, D. Kim, H. Lopez, and R. West, 2022: Increasing hurricane intensification rate near the US Atlantic coast. *Geophysical Research Letters*, 49(20):e2022GL099793, https://doi.org/10.1029/2022GL099793.

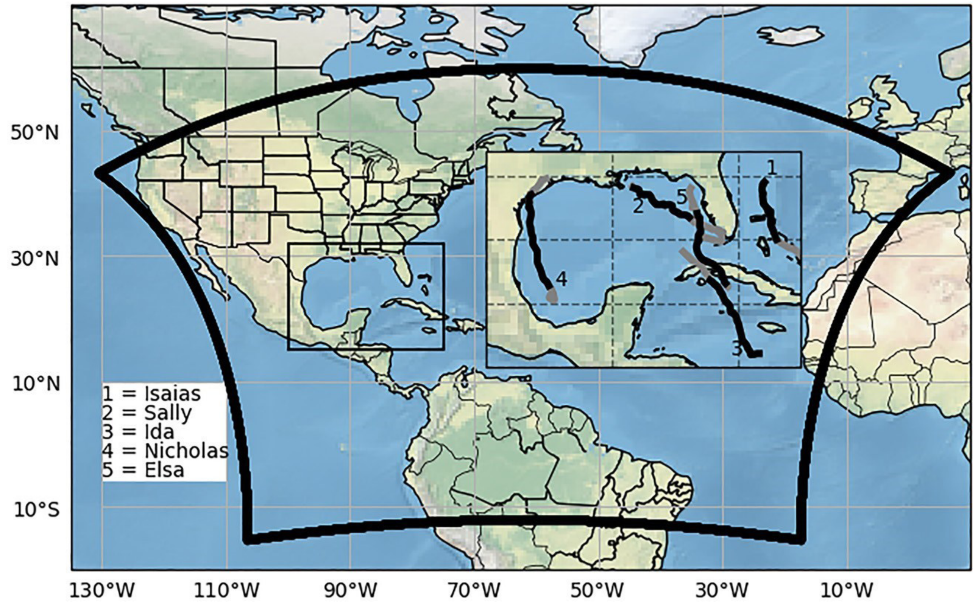


Arsenal of Instruments Monitor Marine Conditions

Ocean-observing instruments deployed throughout the summer and operated by AOML, US partners, and the international community—underwater gliders, saildrones, drifting buoys, Argo floats, expendable bathythermographs, and satellite assets—monitored ocean conditions in the Atlantic during the passage of all 2022 tropical cyclones, including Hurricane Fiona in September 2022. The instruments transmitted their data to research and operational centers, including NOAA's National Hurricane Center, for assimilation into operational and experimental forecast models that aided in assessing the ocean's role in hurricane intensity changes.

Map of the Atlantic basin showing the location of ocean-observing instruments and track of Fiona in September 2022.

Study Explores how Weak, Misaligned Tropical Cyclones Evolve Towards Alignment



Model domain outlined by a thick black line with two inset panels. The small panel shows the regions traversed by Isaias, Sally, Ida, Nicholas, and Elsa in the Gulf of Mexico, northwest Caribbean Sea, and southwest Atlantic. The large panel shows the analyzed track periods (black track lines) and unanalyzed simulation periods (gray lines) for the five tropical cyclones (from Alvey and Hazelton, 2022).

The ability to predict whether and when a tropical cyclone will become vertically aligned is critical for intensity change forecasts, as storms can quickly intensify after achieving an aligned structure. A recent study* by scientists at AOML and the University of Miami's Cooperative Institute for Marine and Atmospheric Studies shows how weak, disorganized tropical cyclones containing different center locations with height, called misalignment, can develop a vertically aligned structure.

This study seeks to improve forecasts of when vertical alignment might occur by identifying key times of the day and other tropical cyclone characteristics when alignment is more likely.

When the center of a tropical cyclone is in roughly the same location throughout the atmosphere, the system is said to be vertically aligned. This alignment allows thunderstorms to develop completely around the center, protecting the system from the surrounding environment and aiding its future intensification.

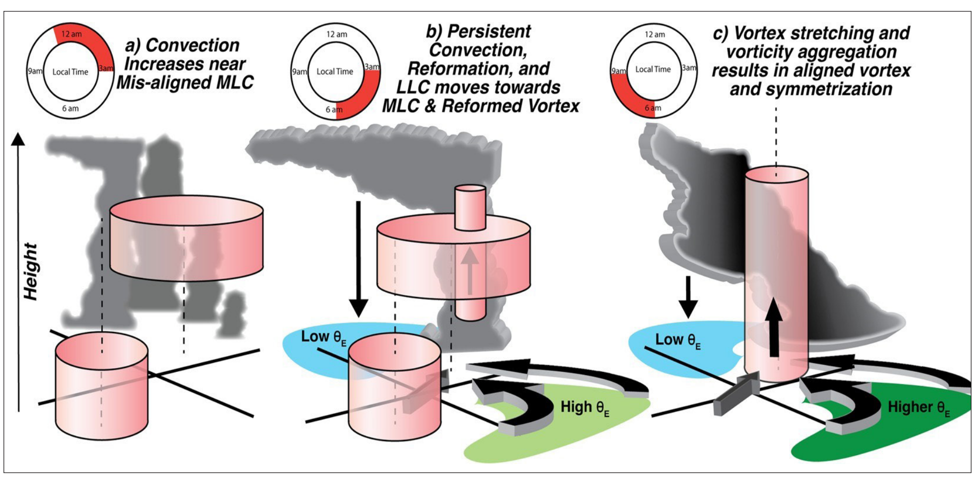
To learn how tropical cyclones become aligned, researchers used NOAA's next-generation hurricane forecast model, the Hurricane Analysis and Forecast System (HAFS), to simulate five tropical cyclones from the 2020 and 2021 Atlantic hurricane seasons: Elsa, Ida, Isaias, Nicholas, and Sally (see image, above right). These model runs were compared with radar and airborne observations to identify the model cycles that most accurately portrayed their observed pathway to alignment.

In all but one of the simulations, the tropical cyclones achieved a successful alignment of their centers, contributing to a better understanding of the processes that lead to vertical alignment and to intensification.

Thunderstorms typically develop near the mid-level center of a misaligned tropical cyclone in the early morning hours (panel A, bottom left image), which can help start an alignment of the centers.

If thunderstorms persist for a long enough period of time, the rising air is replaced by inflow, which is air flowing toward the storm center from surrounding regions of the storm that have greater heat and moisture (panel B, bottom left image). This causes instability, i.e., the ability of warm, moist air to rise and create thunderstorms, to increase.

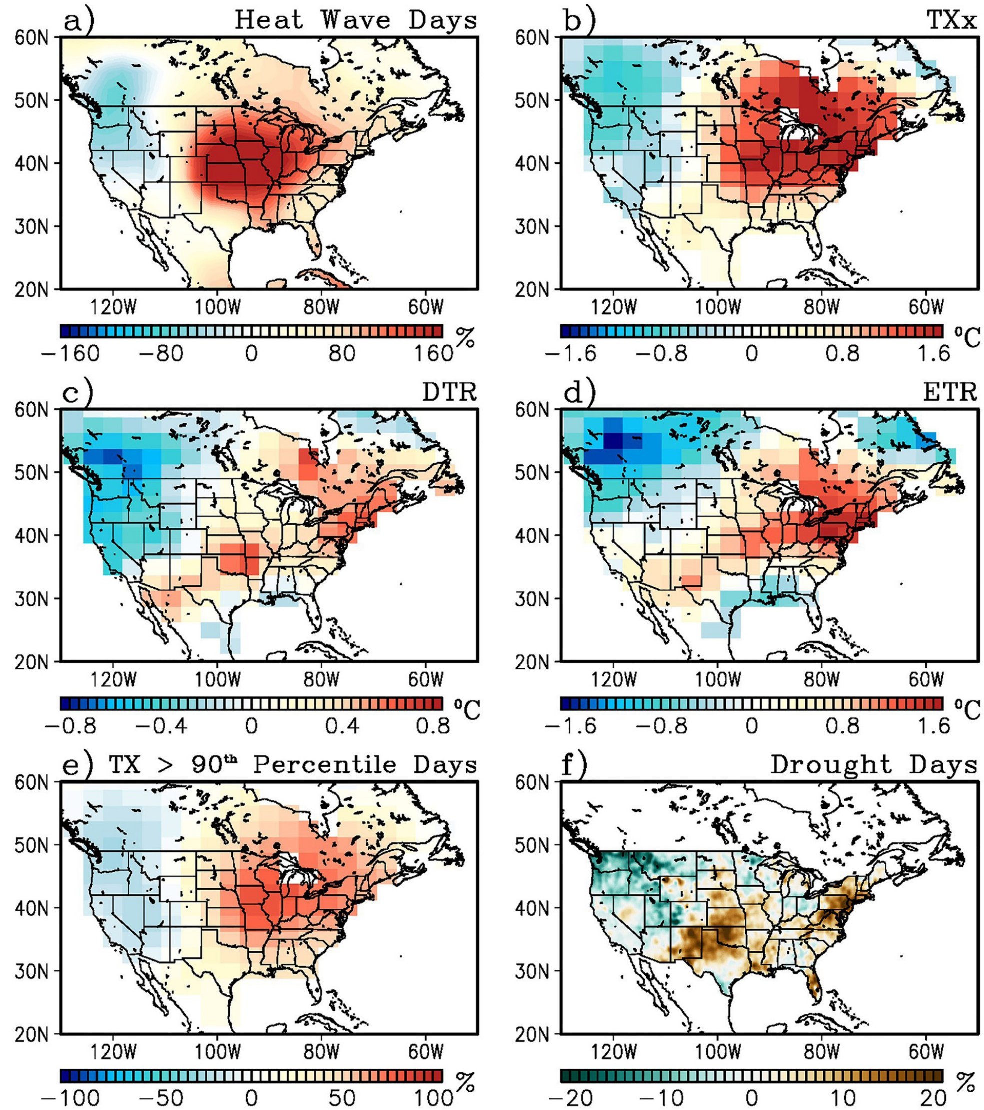
Cool air from thunderstorm downdrafts flows outward when it reaches the surface, creating boundaries with the warm, unstable air that is already there. These boundaries then push the warm, unstable air upward to initiate new thunderstorms that grow and eventually form a new tropical cyclone center. This new center develops upward with the help of thunderstorm growth that eventually pulls in the old, misaligned low-level center, which results in a vertically aligned tropical cyclone (panel C, bottom left image).



Schematic demonstrating the vortex-scale processes responsible for the rapid evolvement from misalignment to alignment. Panel (A) shows the low-level center displaced from the mid-level vortex with convection increasing near the mid-level center (indicated by clouds). The increasing convection near the mid-level center occurs during the overnight to early morning hours of 11 pm to 3 am (upper left), which also aligns with the diurnal maximum in tropical cyclone convection. From 3–6 am local time (panel B), the boundaries between lower θ_E air from downdrafts (light blue shading) and warm, unstable air (higher θ_E air, light green shading) collide and initiate more intense, persistent convection. A new, compact low-mid level vorticity core forms near the convection and induces a low-level confluent inflow that brings more warm, moist air (light green shading) toward the new center, fueling additional convection. The low-level center rapidly migrates towards the reformed core during this time period (panel c) (from Alvey and Hazelton, 2022).

*Alvey, G.R., III, and A. Hazelton, 2022: How do weak, misaligned tropical cyclones evolve toward alignment? A multi-case study using the Hurricane Analysis and Forecast System. *Journal of Geophysical Research: Atmospheres*, 127: e2022JD037268, https://doi.org/10.1029/2022JD037268.

Larger than Normal Atlantic Warm Pool Linked to an Increase in US Heat Waves



Composite difference of large minus small Atlantic warm pool years during June-July-August for: (a) the number of heat wave days, (b) highest maximum temperature, (c) diurnal temperature range, (d) extreme temperature range, (e) number of days with the maximum temperature exceeding the 90th percentile, and (f) the number of drought days. Panels (a), (e), and (f) have units of percentage as defined by the number of events during a large minus small Atlantic warm pool divided by the total events and multiplied by 100, such that a 100% increase translates into a doubling of the events (from Lopez *et al.*, 2022).

Heat waves are the number one weather-related cause of death in the United States, prompting the climate community to study the driving forces behind these extreme events to improve their prediction. A study published in the *Journal of Geophysical Research** finds that an increase in the occurrence of summertime heat waves over the US Great Plains is linked to a larger than normal tropical Atlantic warm pool.

The Atlantic warm pool is a large body of water in the low latitudes of the North Atlantic, which includes the Gulf of Mexico, Caribbean Sea, and western tropical North Atlantic. Using observational data and model simulations, this study found that the annual variability of the tropical Atlantic warm pool influences the occurrence of heat waves over the US Great Plains from June to September, the Northern Hemisphere's summer months.

The study by scientists at AOML, the University of Miami's Cooperative Institute for Marine and Atmospheric Studies, and Mississippi State University's Northern Gulf Institute found that a larger than normal Atlantic warm pool influences atmospheric circulation patterns across the Caribbean Sea and Gulf of Mexico, promoting a "heat dome" pattern over the Great Plains. This pattern reduces cloud cover, enhancing surface warming and the occurrence of heat waves.

The Great Plains is a region where soil moisture and surface air temperatures are strongly correlated. In the spring and summer, one-third of the total moisture transport into the Great Plains is caused by the Great Plains low-level jet, a fast-moving current of air that moves through the lower levels of the atmosphere. A weaker low-level jet leads to less precipitation, which increases the likelihood of extreme temperatures and heat wave days.

Additionally, the annual variability of the Great Plains low-level jet has been linked to the variability of sea surface temperatures in the tropical Atlantic. The study found that a large Atlantic warm pool weakens the Great Plains low-level jet, which causes less precipitation over the Great Plains, eventually leading to drought conditions and an increased occurrence of heat waves for most of the US east of the Rocky Mountains.

"Extreme heat events are responsible for large mortality and vast economic impact in the US. Hence, enhancing our understanding of the mechanisms causing their occurrence should lead to providing emergency managers, government officials, businesses, and the public in general with better advanced warning to minimize catastrophic loss of life and damage to critical infrastructure," said Hosmay Lopez, PhD, an AOML scientist and lead author of the study. "This effort is crucial for informing public health security and impact mitigation strategies, filling the gap and developing effective extreme heat prediction to help communities be better prepared."

Understanding the physical mechanisms that modulate the occurrence of heat waves is essential for improving the predictability and future projections of extreme heat events. While sea surface temperature anomalies in the tropical Atlantic can be skillfully forecast 3-4 months in advance, heat waves are only predicted on a 7-10 day time scale. Given the longer predictability of Atlantic sea surface temperature anomalies, understanding the connection between the two could lead to earlier predictions of US heat waves.

*Lopez, H., D. Kim, R. West, and B. Kirtman, 2022: Modulation of North American heat waves by the tropical Atlantic warm pool. *Journal of Geophysical Research–Atmospheres*, 127(21):e2022JD037705, https://doi.org/10.1029/2022JD037705.

Congratulations

AOML is pleased to recognize the outstanding achievements and vital contributions of its federal and Cooperative Institute scientists and staff, who received a record number of awards in October and November 2022.

Presidential Rank Award

John Cortinas, AOML Director, was recognized for "exceptional leadership throughout more than 15 years of federal service that has led to significant improvements in NOAA's ability to provide accurate and timely forecasts and warnings for many types of extreme weather, as well as for being an exemplary role model for NOAA's workforce and others from underrepresented communities by working tirelessly to advance diversity and inclusion across NOAA."

Department of Commerce Gold Medal

Gregory Foltz, **Gustavo Goni**, and **Francis Bringas** of AOML's Physical Oceanography Division were recognized with colleagues from NOAA's Pacific Marine Environmental Laboratory for "the successful experimental application of uncrewed surface vehicles, i.e., saildrones, to observe conditions in Atlantic tropical cyclones." AOML Cooperative Institute partners included Jun Zhang and Joaquin Trinanes.

Department of Commerce Bronze Medals

Lidia Cucurull of AOML's Hurricane Research Division was a member of a National Environmental Satellite, Data and Information Services team recognized "for ensuring that NOAA's next generation geostationary satellite system will meet the most critical observing needs of the nation and NOAA's partners."

Gregory Foltz of AOML's Physical Oceanography Division was a member of an Office of Oceanic and Atmospheric Research team recognized for "scientific achievement in the design and implementation of the complex Atlantic Tradewind Ocean-atmosphere Mesoscale Interaction campaign." AOML Cooperative Institute partners included Shaun Dolk and Denis Volkov.

Christopher Kelble of AOML's Ocean Chemistry and Ecosystems Division was a member of a National Marine Fisheries Service team recognized for "providing ready access to NOAA information and data on the status of ecosystems that support valuable US marine fisheries, species, and services."

Frank Marks, on behalf of AOML's Hurricane Research Division, was a member of an Office of Marine and Aviation Operations team recognized for "the rapid development of an application allowing aircraft acquired dropsonde data to be processed and disseminated from the ground." AOML Cooperative Institute partners included Jason Dunion, Kathryn Sellwood, and Jonathan Zawislak.

Charles Featherstone and **Emy Rodriguez** of AOML's Ocean Chemistry and Ecosystems Division were recognized for their roles in "turning the canceled GO-SHIP A13.5 cruise into a new mission that maximized autonomous instrument deployments and surface water data collection." AOML Cooperative Institute partners included Leticia Barbero (chief scientist), Leah Chomiak, Jay Hooper, Patrick Mears, and Ian Smith.

Emily Osborne and **Ian Enochs** of AOML's Ocean Chemistry and Ecosystems Division were members of an Office of Oceanic and Atmospheric Research team recognized for their "leadership in developing the "*Ocean, Coastal, and Great Lakes Acidification 2020-2029 Research Plan*" to advance NOAA's response to acidification." AOML Cooperative Institute partners included Leticia Barbero.

Paul Reasor and **John Gamache** of AOML's Hurricane Research Division were recognized for "the successful delivery of operational, near real-time Doppler radar data from NOAA's Hurricane Hunter aircraft to the National Hurricane Center."

NOAA Administrator Awards

Jasmin John of AOML's Ocean Chemistry and Ecosystems Division, in collaboration with former colleagues at NOAA's Geophysical Fluid Dynamics Laboratory, was recognized for "advancing the understanding of the Earth system by developing and applying NOAA's state-of-the-art Coupled Carbon-Chemistry-Climate model."

Claudia Schmid, **Emily Osborne**, **Molly Baringer**, and **Jay Harris** of AOML's Physical Oceanography Division were recognized for their "outstanding advances in US ocean observing and processing of biogeochemical Argo float data, leading to a new era of global oceanography." AOML Cooperative Institute partners included Jodi Brewster, Cedrick Estelhomme, Jaya Nair, Brandon Navarro, Yuan-Yuan Xu, and Bo Yang.

NOAA Silver Sherman Award

Gail Derr of AOML's Office of the Director was recognized for "exemplary service toward improving science communications at AOML through the outstanding production of AOML's quarterly *Keynotes* publication and editing services for employees at AOML."

OAR-Employee of the Year Awards

Kelly Goodwin of AOML's Ocean Chemistry and Ecosystems Division was recognized for "leading and coordinating the inception and formalization of NOAA's 'Omics Program to advance the 'omics portfolio across OAR and NOAA."

Hosmay Lopez and **Sang-Ki Lee** of AOML's Physical Oceanography Division were recognized for "groundbreaking scientific research that evaluates how El Niño-Southern Oscillation events will evolve in all seasons as a result of anthropogenic climate change, with significant implications for future Atlantic hurricane season intensities and springtime tornado outbreaks in the United States." AOML Cooperative Institute partners included Dongmin Kim.

OAR-Equal Employment Opportunity Diversity Award

Sim Aberson, **Ruth Almonte**, **Jasmin John**, **Alejandra Lorenzo**, and **Emily Osborne**, all AOML member's of the NOAA-Office of Oceanic and Atmospheric Research's Diversity and Inclusion Advisory Committee (ODIAC), were recognized for "diligent efforts to expand diversity, equity, inclusion, and accessibility activities and awareness by establishing five working groups, a "What's New" slide deck for members to share with their respective labs, programs, and staff offices, and leading the initiative to prevent sexual assault and sexual harassment during field work."

Women of Color STEM-Outstanding Achievement Award

Jean Lim of AOML's Ocean Chemistry and Ecosystems Division was recognized for "demonstrated excellence in applying machine learning, software development, and bioinformatics to improve environmental DNA (eDNA) analyses and ecosystem-based fisheries management in the Gulf of Mexico."

William Gray Award

Frank Marks of AOML's Hurricane Research Division was recognized for his "outstanding leadership and/or contributions to the field of tropical meteorology."

Welcome Aboard

Kenzie Cooke joined AOML's Ocean Chemistry and Ecosystems Division in December as a University of Miami-Cooperative Institute Undergraduate Student Assistant. Kenzie will work throughout 2023 with the Coral Group as an intern who will assist with water chemistry analyses and the design and fabrication of the Experimental Reef Laboratory's infrastructure and instrumentation. She is a Marine Biology and Ecology major at the University of Miami's Rosenstiel School of Marine, Atmospheric, and Earth Science.

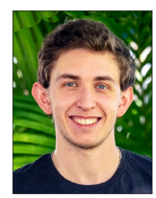
Samantha Ouertani joined AOML's Physical Oceanography Division in December as a University of Miami-Cooperative Institute Research Associate II. Samantha will work within the Global Drifter Program's Data Assembly Center, where among other tasks, she will develop a drifter ERDDAP to better serve data products and enhance user query options. She recently earned a BS degree with honors in Geophysics from Brown University. Her previous research includes investigating seismology within the Nicaraguan subduction zone under the guidance of Dr. Karen Fischer.

Omar Ramzy joined AOML's Ocean Chemistry and Ecosystems Division in September as a University of Miami-Cooperative Institute Research Associate. Omar will work with Dr. Chris Kelble and others with the South Florida Ecosystem Restoration project to run chlorophyll analyses, assist with fieldwork for the Biscayne Bay and Port Everglades projects, and help with water quality data management. He holds an MPS degree in Tropical Marine Ecosystem Management from the University of Miami's Rosenstiel School of Marine, Atmospheric, and Earth Science.

Eric Rojas joined AOML's Physical Oceanography Division in December as a University of Miami-Cooperative Institute Research Associate. Eric will work with Dr. Claudia Schmid and others in AOML's Argo Data Assembly Center to help adapt quality control software to new requirements, as well as to new float types. He holds a BS degree in Marine Science from the Kurztown University of Pennsylvania.

Dr. Katelyn Schockman joined AOML's Ocean Chemistry and Ecosystems Division in November as a University of Miami-Cooperative Institute post-doctoral scientist. Katelyn will work with the Ocean Carbon Cycle group by applying her expertise in marine physical chemistry of the inorganic carbon system in seawater to start a pilot project to produce seawater reference materials, as well as better characterize the composition of seawater to improve projections of future changes in the ocean due to ocean acidification and climate change. She earned a BS degree in Chemistry from The Ohio State University in 2015 and recently received her PhD in Chemical Oceanography from the University of South Florida's College of Marine Science.

Francis Serrano joined AOML's Ocean Chemistry and Ecosystems Division in December as a University of Miami-Cooperative Institute Research Associate. Francis will work with 'omics researchers at AOML to support the 'omics-funded projects "*Monitoring mission iconic reefs restoration using eDNA with SASe*" and "*Global eDNA partnerships supporting Atlantic and global biodiversity monitoring*." A main part of this work will involve building Subsurface Automated Sampler for eDNA (SASe) instruments for eDNA research. Francis is passionate about marine conservation and believes advancing eDNA data collection methods such as the SASe and other eDNA research are critical for conservation efforts around the world. He is an MPS graduate student at the University of Miami's Rosenstiel School of Marine, Atmospheric, and Earth Science in the Fisheries Management and Conservation track.



Zachary Zagon joined AOML's Ocean Chemistry and Ecosystems in December as a University of Miami-Cooperative Institute Graduate Student Assistant. Zach will work with the Coral Group throughout 2023 as an intern who will help with chemical analyses in the Experimental Reef Lab and an upcoming experiment as part of a Florida Department of Environmental Protection grant. He is an MPS graduate student at the University of Miami's Rosenstiel School of Marine, Atmospheric, and Earth Science in the Tropical Marine Ecosystem Management track.

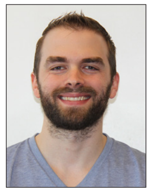
AOML Hosts Awards Ceremony and Holiday Party

Staff, friends, and family gathered in the AOML lobby on December 9 for an awards ceremony and holiday party. AOML director/deputy director John Cortinas and Molly Baringer were joined by other leaders at AOML to celebrate the outstanding work achievements of staff, as well as recognize employees for their years of dedicated federal service. A holiday party followed, complete with a delicious assortment of luncheon items and yummy desserts. Approximately 50 people attended in person, while 40 more attended remotely. Thanks to everyone who contributed to the success of these events, especially AOML's Buoys & Gulls Club, the Comms team, the Computer Network Services team, and the Facilities group.

Xuejin Zhang and Neal Dorst prepare luncheon entrees.

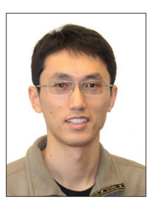
Farewell

Dr. Wilton Aguiar, a University of Miami-Cooperative Institute post-doctoral scientist with AOML's Physical Oceanography Division, resigned in December to begin a new post-doctoral position with the Australian National University in collaboration with the Australian Centre for Excellence in Antarctic Science. Wilton will work with Dr. Adele Morrison to conduct research focused on high-resolution modeling of the Southern Ocean. At AOML, he analyzed the impact of reduced anthropogenic aerosol emissions on the climate system due to the COVID-19 pandemic.



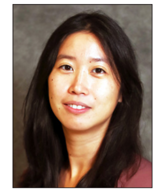
Dr. Sean Anderson, a Northern Gulf Institute researcher with AOML's Ocean Chemistry and Ecosystems Division, completed his post-doctoral appointment in September. Sean has accepted a position as a National Science Foundation-Center for Chemical Currencies of a Microbial Planet Postdoctoral Fellow at the Woods Hole Oceanographic Institution and the University of New Hampshire. During his time at AOML, Sean focused on advancing 'omics research, with an emphasis on methods development for marine environmental DNA (eDNA) extraction, sampling processing, and bioinformatics pipelines. He applied these methods to the collection of eDNA in Biscayne Bay and on research cruises in the Gulf of Mexico. Sean will continue collaborating with AOML researchers on the analysis of protist and bacteria distribution patterns in the Gulf of Mexico and their relationship to the marine carbon cycle and ocean acidification.

Samantha Camposano, a University of Miami-Cooperative Institute Research Associate III with AOML's Hurricane Research Division, resigned in October. Samantha has accepted a federal position with the Technology and Science Branch of NOAA's National Hurricane Center. During Samantha's time at AOML, she conducted an experiment to test the wind hazard recommender algorithm with Weather Forecast Office forecasters. She also worked to configure and test the Advanced Weather Interactive Processing System in the cloud for the Hurricane and Ocean Testbed.

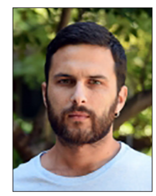


Dr. Xiaomin Chen, a Northern Gulf Institute researcher with AOML's Hurricane Research Division, resigned in December to accept an Assistant Professor position at the University of Alabama in Huntsville. Xiaomin began at AOML in 2018 as a National Research Council post-doctoral scientist and was made a research scientist with the Northern Gulf Institute in 2021. While at AOML, Xiaomin's research focused on the dynamic and thermodynamic processes related to tropical cyclone intensity and structural changes, with special attention paid to boundary-layer processes and air-sea interactions. He also used a combination of observations and numerical simulations to improve the understanding and modeling of boundary-layer processes in high-impact weather systems. Xiaomin also focused on evaluating and improving the performance of the planetary boundary layer physics packages used in the Hurricane Analysis and Forecast System (HAFS) model.

Dr. Jorge Guerra, a University Corporation for Atmospheric Research scientist with AOML's Hurricane Research Division, resigned in October to accept a position with the private sector. During Jorge's time at AOML, he supported NOAA's Quantitative Observing System and Assessment Program focused on evaluating both new and proposed observing systems by conducting experiments to determine the impact of observational data on models (existing and/or proposed). Jorge also quantified and optimized the benefits of radio occultation observations from current and proposed satellite missions.



Dr. Jean Lim, a University of Miami-Cooperative Institute post-doctoral scientist with AOML's Ocean Chemistry and Ecosystems Division, resigned in September to accept a post-doctoral position at the University of South Florida in St. Petersburg, Florida. During her time at AOML, Jean applied molecular, bioinformatics, and machine learning techniques to process environmental DNA and 'omics data on fish, microbial communities, and plankton biodiversity in marine ecosystems on high performance computing and cloud platforms. She also developed a Python-based mitochondrial reference sequence analysis tool for fish environmental DNA studies called Mitohelper.



Dr. Filippos Tagklis, a University of Miami-Cooperative Institute post-doctoral scientist with AOML's Physical Oceanography Division, resigned in December. Filippos has accepted a position with the International Monetary Fund as a Technical Assistant Advisor in the Fiscal Affairs Climate Policy Division. During his time at AOML, Filippos conducted research focused on understanding changes in ocean circulation, biogeochemistry with attention to nutrients and oxygen, and the underlying mechanisms. He also conducted research on the impact of physical oceanic processes on ocean acidification and ecosystems along the US east coast.

Dr. Jonathan Zawislak, a University of Miami-Cooperative Institute Associate Scientist with AOML's Hurricane Research Division, resigned in December to accept a federal position as a Meteorologist/Flight Director with NOAA's Aircraft Operations Center in Lakeland, Florida. Jon began at AOML through the University of Miami on a part-time basis in 2016 and transitioned to full-time employment in 2017. With his keen interest in hurricane observations and field operations, he quickly became involved with AOML's annual Hurricane Field Program, serving as its program director during the 2018 and 2019 hurricane seasons and as its deputy director for the 2020 to 2022 seasons. Jon's research involves a synthesis of long-term satellite and airborne datasets to study tropical cyclone formation and intensification, with an emphasis on the precipitation processes involved in priming these storms for intensity changes, as well as how these processes are linked to the thermodynamic and kinematic structures of storms. Jon additionally mentored numerous high school, undergraduate, and graduate students, enriching them with the same enthusiasm he has for tropical meteorology.

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Dr. Rick Lumpkin, Director
Physical Oceanography Division

4301 Rickenbacker Causeway
Miami, FL 33149
www.aoml.noaa.gov

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)*

ALVEY, G.R., and **A. HAZELTON**, 2022: How do weak, misaligned tropical cyclones evolve toward alignment? A case study using the Hurricane Analysis and Forecast System. *Journal of Geophysical Research-Atmospheres*, 127(10):e2022JD037268.

ANDERSON, S.R., and E.L. Harvey, 2022: Estuarine microbial networks and relationships vary between environmentally distinct communities. *PeerJ,* 10:e14005.

Beron-Vera, F.J., M.J. Olascoaga, N.F. Putman, **J. TRINANES**, **G.J. GONI,** and **R. LUMPKIN**, 2022: Dynamical geography and transition paths of Sargassum in the tropical Atlantic. *AIP Advances*, 12(10):105107.

CASEY, **S.P.F.**, and **L. CUCURULL**, 2022: The impact of data latency on operational global weather forecasting. *Weather and Forecasting,* 37(7):1211-1220.

CHEN, **X.**, 2022: How do planetary boundary layer schemes perform in hurricane conditions: A comparison with large-eddy simulations. *Journal of Advances in Modeling Earth Systems*, 14(10):e2022MS003088.

DEMERLIS, **A.**, A. Kirkland, M.L. Kaufman, **A.B. MAYFIELD**, **N. FORMEL**, **G. KOLODZIEJ**, D.P. Manzello, D. Lirman, N. Traylor-Knowles, and **I.C. ENOCHS**, 2022: Pre-exposure to a variable temperature treatment improves the response of *Acropora cervicornis* to acute thermal stress. *Coral Reefs*, 41(2):435-445.

Elipot, S., A. Sykulski, **R. LUMPKIN**, L. Centurioni, and **M. PAZOS**, 2022: A dataset of hourly sea surface temperature from drifting buoys. *Scientific Reports,* 9:567.

Esmaili, R., C. Barnet, **J. DUNION**, M. Folmer, and **J. ZAWISLAK**, 2022: Evaluating satellite sounders for monitoring the tropical cyclone environment in operational forecasting. *Remote Sensing,* 14(13):3189.

FISCHER, **M.S.**, **P.D. REASOR**, **R.F. ROGERS**, and **J.F. GAMACHE,** 2022: An analysis of tropical cyclone vortex and convective characteristics in relation to storm intensity using a novel airborne Doppler radar database. *Monthly Weather Review*, 150(9):2255-2278.

Freitag, A., S. Blake, P.M. Clay, A.C. Haynie, **C. KELBLE**, M. Jepson, S. Kasperski, K.M. Leong, J.H. Moss, and S.D. Regan, 2022: Scale matters: Relating wetland loss and commercial fishing activity in Louisiana across spatial scales. *Nature and Culture*, 17(2):144-169.

LOPEZ, **H.**, **S.-K. LEE**, **D. KIM**, A.T. Wittenberg, and S.-W. Yeh, 2022: Projections of faster onset and slower decay of El Niño in the 21st Century. *Nature Communications,* 13:1915.

Ming J., R. Liu, **J.A. ZHANG**, and **R.F. ROGERS**, 2022: The shear-relative variation of inflow angle and its relationship to tropical cyclone intensification. *Journal of Geophysical Research-Atmospheres*, 127(16):e2022JD037280.

OSBORNE, **E.**, X. Hu, E.R. Hall, K. Yates, J. Vreeland-Dawson, K. Shamberger, **L. BARBERO**, J.M. Hernandez-Ayon, **F.A. GOMEZ**, T. Hicks, **Y.-Y. XU**, M.R. McCutcheon, M. Acquafredda, C. Chapa-Balcorta, O. Norzagaray, **D. PIERROT**, A. Munoz-Caravaca, K.L. Dobson, N. Williams, N. Rabalais, and P. Dash, 2022: Ocean acidification in the Gulf of Mexico: Drivers, impacts, and unknowns. *Progress in Oceanography*, 102:102882.

Olivier, L., J. Boutin, G. Reverdin, N. Lefèvre, P. Landschützer, S. Speich, J. Karstensen, M. Labaste, C. Noisel, M. Ritschel, T. Steinhoff, and **R. WANNINKHOF**, 2022: Wintertime process study of the North Brazil Current rings reveals the region as a larger sink for CO_2 than expected. *Biogeosciences,* 19(12):2969-2988.

PALACIO-CASTRO, **A.M.**, **S.M. ROSALES**, C.E. Dennison, and A.C. Baker, 2022: Microbiome signatures in *Acropora cervicornis* are associated with genotypic resilience to elevated nutrients and heat stress. *Coral Reefs,* 41(5):1389-1403.

Parks, J., **F. BRINGAS**, R. Cowley, C.P. Hanstein, L. Krummel, J. Sprintall, L. Cheng, M. Cirano, S. Cruz, **M.P. GOES**, S. Kizu, and F. Reseghetti, 2022: XBT operational best practices for quality assurance. *Frontiers in Marine Science*, 9:991760.

Romdhani, O., **J.A. ZHANG**, and M. Momen, 2022: Characterizing the impact of turbulence closures on real hurricane forecasts: A comprehensive joint assessment of grid resolution, turbulence models, and horizontal mixing length. *Journal of Advances in Modeling Earth Systems*, 14(9):e2021MS002796 (2022).

TROAST, **B.V.**, L.J. Walters, and G.S. Cook, 2022: A multi-tiered assessment of fish community responses to habitat restoration in a coastal lagoon. *Marine Ecology Progress Series*, 698:1-14.

TUCHEN, **F.P.**, P. Brandt, J.F. Luebbecke, and R. Hummels, 2022: Transports and pathways of the tropical AMOC return flow from Argo data and shipboard velocity measurements. *Journal of Geophysical Research-Oceans*, 127(2): e2021JC018115.

WEST, R., H. LOPEZ, S.-K. LEE, A.E. Mercer, **D. KIM, G.R. FOLTZ,** and K. Balaguru, 2022: Seasonality of interbasin SST contributions to Atlantic tropical cyclone activity. *Geophysical Research Letters,* 49(4):e2021GL096712.