Technological Innovation and Scientific Advances that Improve Our Lives

NOAA Research Matters

O A R

National Oceanic and Atmospheric Administration
Office of Oceanic and Atmospheric Research

VISION

A society that uses the results of our research as the scientific basis for more productive and harmonious relationships between humans and the environment.

MISSION

To conduct environmental research, provide scientific information and research leadership, and transfer research into products and services to help NOAA meet the evolving economic, social, and environmental needs of the Nation.

NOAA Research Matters

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Image, this page: A diver coaxes a transparent organism into a collection jar during a 2007 exploratory mission. Opposite page: OAR scientist, Jeremy Potter, on a 2005 NOAA Arctic mission.

The Challenges of a Changing Planet

A Letter from the Assistant Administrator

Richard W. Spinrad, Ph.D., CMarSci
Assistant Administrator for
Oceanic and Atmospheric Research

"The research impacts in this document tell the story of some of the preeminent contributions OAR scientists and our partners have made to build the knowledge base, tools, products, and services through which we can better understand and address the dynamics of our changing planet."

Dear Reader:

In the decades and century to come, we will experience extraordinary changes in our world's oceans and atmosphere, with consequences that may dramatically change the way we live our lives. Reducing uncertainty, whether in predicting future climate, severe weather, or changes in our ecosystems, requires a solid understanding of the Earth as an interdependent system of ocean, air, and land.

Through the preeminent research conducted and sponsored by NOAA's Office of Oceanic and Atmospheric Research, or OAR, we render knowledge and technology that drive products and services that reduce those risks. Ultimately, these products and services prevent loss of human life, improve management of natural resources, build understanding of the Earth-system, and strengthen the economy. This document represents OAR leadership in understanding how the ocean, atmosphere, and climate change that impact our health, our economy, and our future.

As we look to the future, OAR will tackle a number of large societal challenges. Perhaps the greatest is climate change. Defining the nature of climate change, and its potential impacts, is foremost in our research agenda. Our scientists will build on the CM2.1 climate model, which has become known as one of the best climate models in the world, to help anticipate more accurately future societal needs.

"...OAR will tackle a number of large societal challenges. Perhaps the greatest is climate change."

Americans rely on weather forecasts and warnings that save lives, and protect property. Technologies transitioned from NOAA research labs and programs into weather forecast offices across the Nation are the backbone of today's weather services.

Though our weather forecasting capabilities have improved dramatically over the past two decades, the public expects even more accurate forecasts and earlier warnings. Working with the National Weather Service, as part of the proposed 10-year Hurricane Forecast Improvement Project (HFIP), OAR researchers will apply expert science to support better predictions of hurricane intensity. Over the next few years, the NEXRAD Doppler radar system will upgrade to a dual-polarized radar system to detect different types of precipitation better. In a decade, we anticipate an even more sensitive technology, Multi-function Phased Array Radar (MPAR), an innovative application of proven Navy technology, will provide longer lead times for warning on forecasts of hazardous weather.

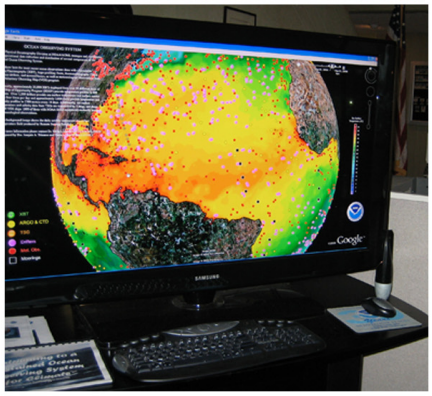
Recognizing that air safety relies on accurate and timely weather predictions, OAR is engaged in developing a single national NextGen Network Enabled Weather system (NNEW) for the Federal Aviation Administration (FAA). NNEW will be a conduit to tens of thousands of weather observations and forecasts updated in real-time explicitly for the FAA to reduce delays and accidents in commercial aviation.

Drought and flooding likely will intensify as a result of global warming. This impacts our ability to produce food and manage water resources. The NOAA-led National Integrated Drought Information System (NIDIS), a collaboration between numerous federal agencies and state governments, promises to provide vital information for community planners and decision makers.

Marine life, from microscopic life forms at the bottom of the food web to larger species such as coral, shellfish, and commercial fisheries, will be affected by "ocean acidification." Commercial fisheries, already failing, may suffer further economic loss. OAR researchers are at the forefront of studying and monitoring this marker of climate change. Currently, a lone buoy equipped with sensors measures the extent of acidification in the Gulf of Alaska. We will need more and better sensors, technologies for studying impacts on physiology and ecosystems, and modeling efforts to provide ecological models, predictions, and forecasts.

All OAR research is grounded in observation data. Unmanned Aircraft Systems (UAS) will revolutionize NOAA's ability to monitor the global environment, improve predictive services, and enhance homeland security. UAS will fill critical observation gaps and benefit climate change research, weather and water resources forecasting, ecosystem monitoring and management, and coastal mapping.

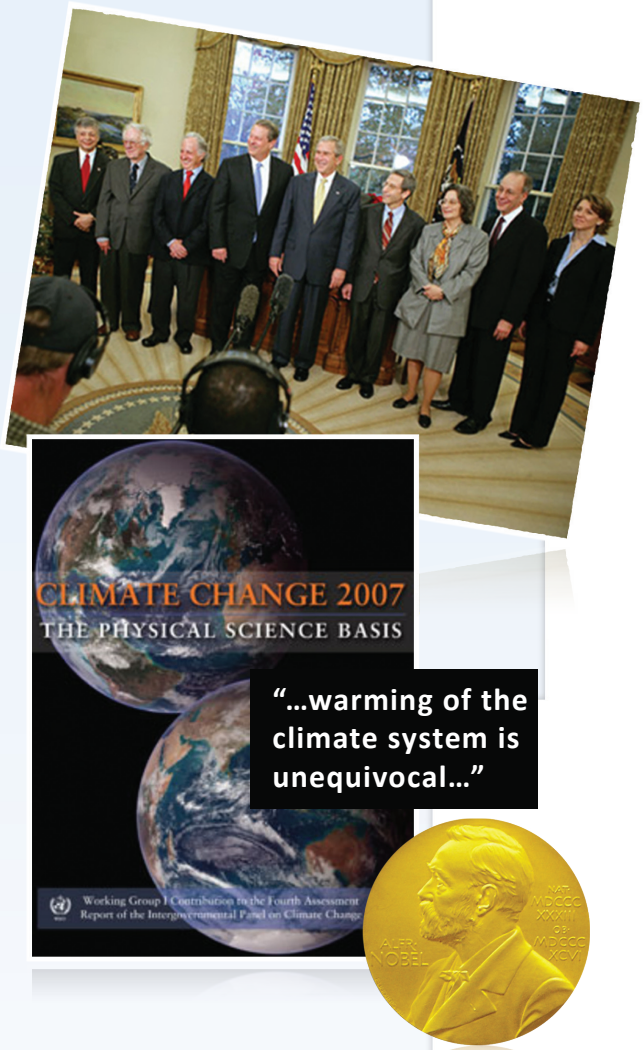
The research impacts in this document tell the story of some of the preeminent contributions OAR scientists and our partners have made to build the knowledge base, tools, products, and services through which better understand and address the dynamics of our changing planet. OAR will remain a world leader in understanding our oceans, atmosphere, and climate – and how they impact our health, our economy, and our future.



Images, top to bottom: A Remotely-Operated Vehicle is deployed during the Arctic 2005 Exploration; A Google Earth display of Global Ocean Observing System data; an Aerosonde® Unmanned Aircraft System is launched in Nov. 2007 from a moving platform to rendezvous with Hurricane Noel.

Richard W. Spinrad, Ph.D., CMarSci
Assistant Administrator for Oceanic and Atmospheric Research

OAR Scientists Bring Home Nobel Prize for Climate Change Leadership



Recognized "for their efforts to build up and disseminate greater knowledge about man-made climate change, and to lay the foundations for the measures that are needed to counteract such change," more than 120 NOAA scientists contributed to the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report which shared the 2007 Nobel Peace Prize.

Impact

Scientific consensus about climate change and its causes

Of the NOAA Nobel group, just under half were OAR researchers. OAR contributions for this international effort, included leadership, model simulations, analysis, authorship and editoral review, all highlighting the preeminent science conducted by our researchers. Dr. Susan Solomon, a senior scientist of OAR's Earth System Research Laboratory (ESRL), co-chaired Working Group 1, the Physical Science Basis. OAR scientists from OAR laboratories, programs, and joint and cooperative institutes served as contributors and government reviewers of the final report -- based upon published peer-reviewed literature. For this report, more than 5,000 scientific publications were referenced.

The 2007 IPCC Fourth Assessment Report was more insistent than earlier reports that there has been "dangerous anthropogenic [man-made] interference with the climate system."

In 1988, the United Nations established the IPCC "to provide the decision-makers and others interested in climate change with an objective source of information about climate change." The IPCC Assessments, internationally recognized as the premier source about climate change, are used by scientists and policy makers worldwide to describe the science behind climate change and to anticipate future trends. The IPCC relies on world-class scientists from 113 governments to scour and evaluate the body of scientific literature on climate science. The latest assessment received over 30,000 comments by 650 scientists, each painstakingly taken into account in the final synthesis.

The names of all NOAA Nobel recipients were recorded in the 2008 Congressional Record at the request of Senator Olympia Snow (R-Maine).

"A unanimous, definitive world statement"

House Science and Technology Committee Chairman Bart Gordon (D-Tenn), Washington Post, *February 3, 2007*

Learn More:
www.ipcc.ch/ipccreports/assessments-reports.htm

Images, top to bottom: President George W. Bush meets in the Oval Office with the 2007 Nobel Peace Prize recipients including Dr. Susan Solomon, OAR; IPCC Fourth Assessment Report; Nobel Medal.

Predicting Our Future: Climate Models Recognized Around the World

Impact

World-class climate modeling set a new benchmark for long-term prediction

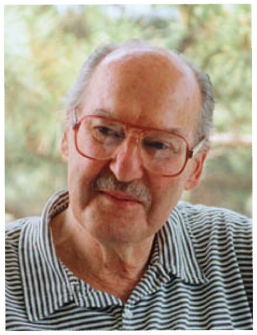
One of the most highly-regarded climate models in the world, deve-loped by OAR's Geophysical Fluid Dynamics Laboratory (GFDL), had a prominent role in the Fourth Assess-ment of the Inter-governmental Panel on Climate Change (IPCC). The GFDL CM2.1 global coupled climate model provides increased cred-ibility for understanding the observed past climate changes and for making future climate change projections.

Climate models are computer-based simulations that use mathematical formulas to re-create the chemical and physical processes that drive Earth's climate. GFDL has produced groundbreaking work in climate modeling since the late 1960s when it released the first-of-its-kind general circulation climate model that combined oceanic and atmospheric processes.

Recently, GFDL scientists have used a "descendant" from the very first climate model to understand the factors driving 20th century climate change, and to simulate the projections of climate changes over the 21st century and beyond that may be induced by increasing atmospheric levels of carbon dioxide.

Looking to future climate modeling needs, the model incor-porates the next generation in modeling infrastructure, the Flexible Modeling System. The system provides a common platform for diverse research activities, from weather to seasonal prediction to anthropogenic (man-made) climate change.

Research is now underway to improve reso-lution of the model, to increase the realism of the climate processes represented in the model, and to reduce the key uncertainties. Future models enabled by necessary advances in computing will enhance NOAA's ability to simulate regional climate change, as well as abrupt shifts and extremes in climate.



OAR's Joseph Smagorinsky, GFDL Founding Director (1924 – 2005): visionary in numerical weather prediction and climate modeling

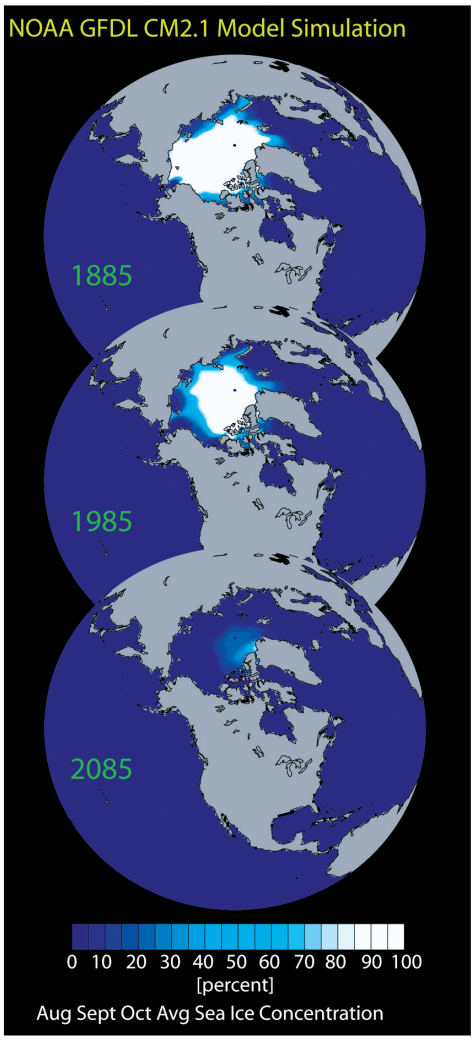


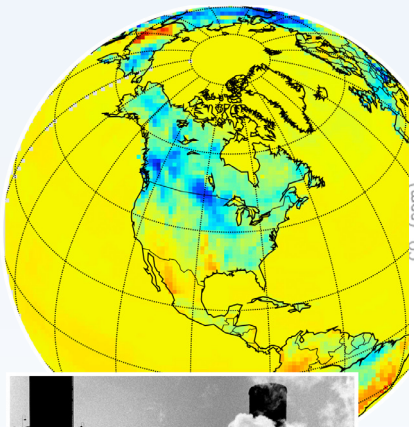
Image: Geophysical Fluid Dynamics Laboratory CM2.1 Model depicts Arctic sea ice changes.

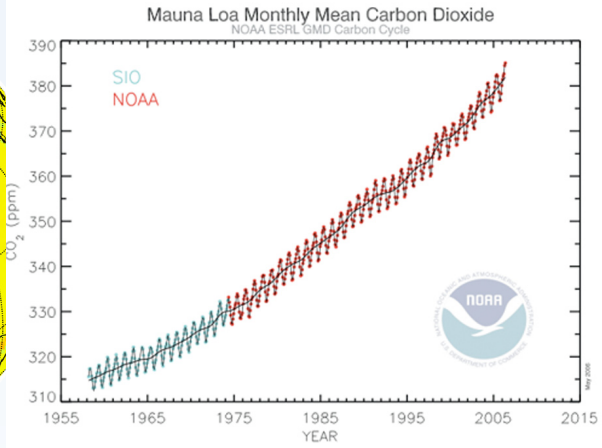
OAR's GFDL scientists created simulations for more than 5,000 years of past, future and idealized climate standards, setting the bar for climate modeling.

Learn More: gfdl.noaa.gov

Tracking CO_2: A Global Climate Record

CarbonTracker, a newly-released tool visualizing global CO_2 measurements, is a valued resource for corporate and government sectors in evaluating the effectiveness of their carbon emission reduction efforts.





The "Keeling Curve," an iconic example of climate change

Impact

Historic global carbon measurements inform society of a changing planet

The striking profile of the last half century's rising carbon dioxide levels, known among scientists as "the Keeling Curve," has become an icon of climate change science. This longest-continuous record of atmospheric carbon dioxide (CO_2) concentration in the world, found its roots first at the South Pole and shortly thereafter at NOAA's Mauna Loa Observatory in Hawaii. At the time this work began, very little was known about CO_2 levels in the environment.

Just over 50 years ago, Charles Keeling plotted the first data points on his graph from data collected at both locations. Keeling, an atmospheric scientist at Scripps Institute of Oceanography, along with colleague Roger Revelle and others, were in pursuit of a theoretical model speculating that accelerated burning of fossil fuels could potentially alter the Earth's climate dramatically by increasing atmospheric CO_2. A feat of historic proportions, Keeling's legacy lives on as OAR's Earth System Research Laboratory (ESRL) researchers continue to collect data at the Mauna Loa Observatory daily. The U.S. Department of Energy's Carbon Dioxide Information Analysis Center (CDIAC), one of many portals for these data, has logged over 10,000 requests for the Mauna Loa CO_2 records since 1984, when Keeling first made the dataset available to CDIAC.

Keeling's work stimulated formation of an international global climate observations network, which provides valuable input into assessments of global climate change, most notably, the Intergovernmental Panel on Climate Change (IPCC) Assessments.

Expanding on the Mauna Loa record, ESRL researchers developed a new tool, CarbonTracker, which visualizes global CO_2 measurements. Released in 2007, CarbonTracker is of interest to corporate and government sectors that seek to evaluate the effectiveness of efforts to reduce or store carbon emissions. CarbonTracker is a NOAA contribution to the North American Carbon Program.

Images, top to bottom: CarbonTracker graphic; carbon dioxide emissions.

Learn More:

www.mlo.noaa.gov

www.co2conference.org

www.esrl.noaa.gov/gmd/ccgg/carbontracker

Extreme Weather Impacts: Predicting El Niño and La Niña

Impact

Seasonal and inter-annual predictions yield billions of dollars in benefits

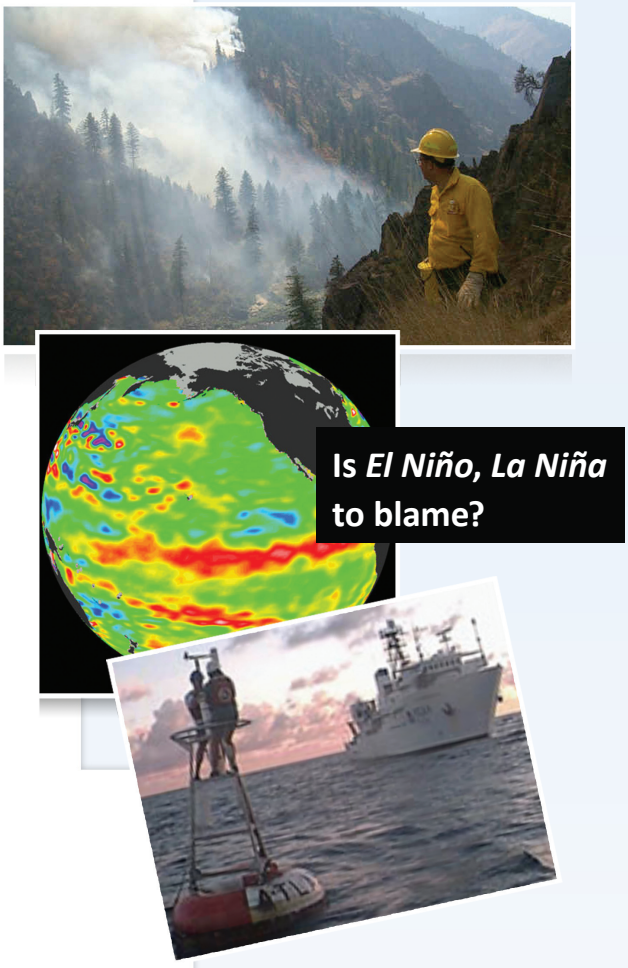
Called a "crowning achievement" by the American Geophysical Union, the Tropical Atmosphere Ocean (TAO)/ TRITON array has vastly improved observational capabilities over large areas of the Pacific Ocean. Developed by OAR's Pacific Marine Environmental Laboratory (PMEL) with funding from a forerunner of the OAR Climate Program Office, the array is a major component of the El Niño/Southern Oscillation (ENSO) Observing System, the Global Climate Observing System (GCOS) and the Global Ocean Observing System (GOOS).

Development of the array was a monumental technological achievement. Previoiusly, the capability for deep ocean moored data buoys did not exist. Today, the low-cost, deep ocean moorings measure surface meteorological and subsurface oceanic parameters, and transmit all data to shore in real-time via satellite relay.

Once in place, the TAO data in concert with modeling efforts led the National Weather Service to antcipate the arrival of the 1997-1998 El Niño and forecasted expected impacts. Armed with a six-month advance warning of the 1997-98 El Niño, California alone estimated saving $1 billion as a result of preparedness measures taken by individuals, businesses, and government officials. Total U.S. economic impacts of the 1997-1998 El Niño were estimated to be on the order of $25 billion.

The TAO array transitioned to the National Weather Service in 2005. Today, PMEL will lead research and development for tropical moored buoy technology, continuing its strong tradition of science innovation for marine sensing.

When La Niña arrives, drought appears likely for some parts ot the U.S. Through the support and urging of the Western Governors' Association, NOAA established NIDIS, the National Integrated Drought Information System, in 2006 to provide an integrated, interagency drought monitoring and forecasting system for the Nation. NIDIS is another OAR Climate Program Office-led effort.



"Scientists generally agree that ocean observatories' shining accomplishment has been the prediction of *El Niños*...[enabled by] the network of buoys known as the Tropical Atmosphere Ocean array..."
Science News, 2002

Images, top to bottom: Drought can lead to higher forest fire risk; OAR tracks El Niño Southern Oscillation; TAO buoy moored in the Pacific Ocean.

Learn More:
www.pmel.noaa.gov/tao/
www.drought.gov

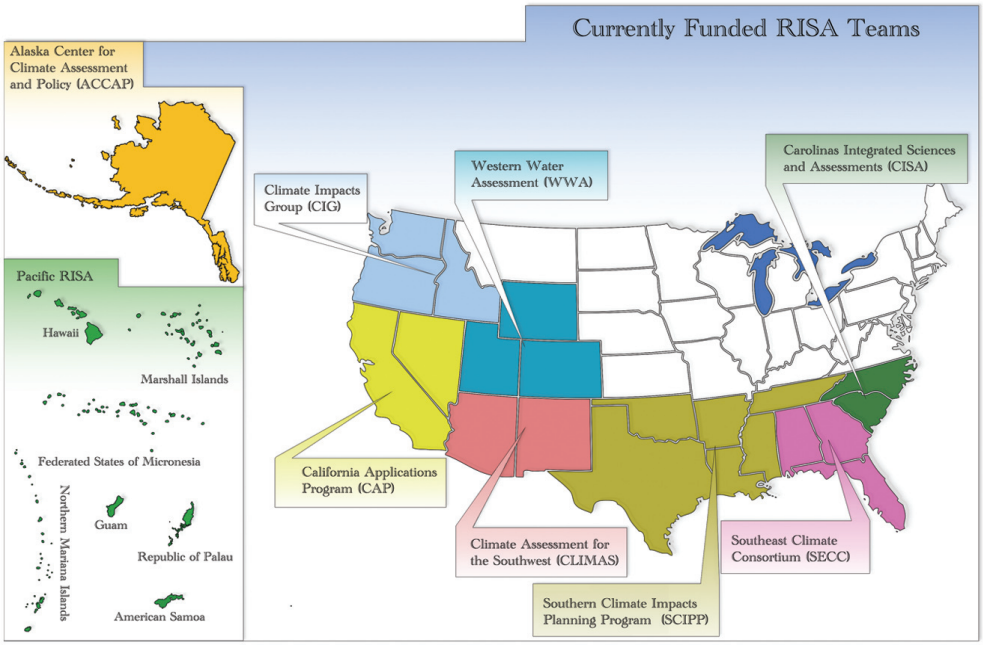
RISA was one of four federal programs praised for generating "original data on potential impacts and governance responses" to climate change, according to the National Research Council 2007 preliminary evaluation of the U.S. Climate Change Science Program.

Partnerships for Bridging Climate Science and Society

Impact

A more climate-literate public that prepares and adapts to change

With each passing year, communities deal with growing impacts of climate variability and change on water availability, wildfires, public health, agriculture, and energy issues. At the same time, climate research produces knowledge that could aid decision makers dealing with these issues. How can OAR make climate research useful and usable for the public?



Since the 1990s, OAR has worked to solve this conundrum through an innovative research and outreach program called the Regional Integrated Sciences and Assessments Program (RISA). Supported through OAR's Climate Program Office, today nine RISAs work to make science useful and usable on local and regional scales.

The knowledge RISA partners produce helps communities think broadly about ways to use climate science to mitigate risks. Each RISA project pairs scientists with regional and/or local stakeholders to address needs in their area. For example, RISAs provide the climate information that farmers use to plan seasons in advance to increase profitability and decrease risks. RISA scientists studying snow hydrology are developing cutting-edge hydrological models to aid water resource planning as well as anticipate, track, assess, and respond to drought. In addition, RISAs work with extension agents to address coastal impacts such as erosion and sea-level rise, help community planners meet growing energy needs, and help fishery operations and salmon recovery efforts.

Most RISA projects conduct workshops and training sessions in their regions, publish periodic seasonal outlooks and climate summaries, and develop tools that enable stakeholders to consider climate impacts information in their decisions. The result is shifting the paradigm of how decision makers at all levels use climate information to improve health, safety and quality of life.

RISAs help farmers, ranchers, and resource managers use climate information to produce the Nation's foods and fibers, and Pacific Islanders figure out how to weave climate information into their quest for sustainability.

Learn More:
www.climate.noaa.gov/cpo_pa/risa/

Pinpointing Shifts in America's Changing Climate

Impact

The newly-completed Climate Reference Network improves our ability to understand and predict trends and variation in climate

If several people tested the old adage "It's so hot you could fry an egg on the sidewalk!," they would find that city and rural conditions vary because of factors including the "urban effect" where heat is trapped and emitted by buildings, streets, and even the sidewalk itself. NOAA researchers considered this urban effect when choosing locations for the 114 atmospheric observation stations that comprise the newly-completed U.S. Climate Reference Network (CRN).

Funded through OAR's Climate Program Office, and installed by the Air Resources Laboratory, the CRN tracks and collects national average changes in temperature and precipitation trends with exceptional precision and accuracy. The CRN pinpoints shifts in America's changing, often unpredictable, climate. The placement of each CRN station is crucial to obtain accurate information on current and likely future climatic conditions. All stations are constructed in rural environments, away from urban areas that could confound the interpretation of any precipitation and/or temperature trends observed.

Each CRN station logs real-time measurements of surface temperature, precipitation, wind speed and solar radiation. NOAA's geostationary satellites relay the data from these ground-based stations to NOAA's National Climatic Data Center, in Asheville, NC, which posts the observations online. NOAA climate forecasters use CRN data to develop the U.S. Drought Monitor, which assesses the status of drought nationwide. National Weather Service forecasters use CRN data to verify forecasts and monitor meteorological conditions.

As a result of installing the additional stations, NOAA has improved its ability to understand and predict trends and variation in climate. This data network will be instrumental in collecting climate observations with precision for the next 50-100 years.

"We're entering a new age of understanding climate change, by adding more sound, reliable data about what's really happening in the atmosphere and on the ground."

Dr. Tom Karl, Director of NOAA's National Climatic Data Center.

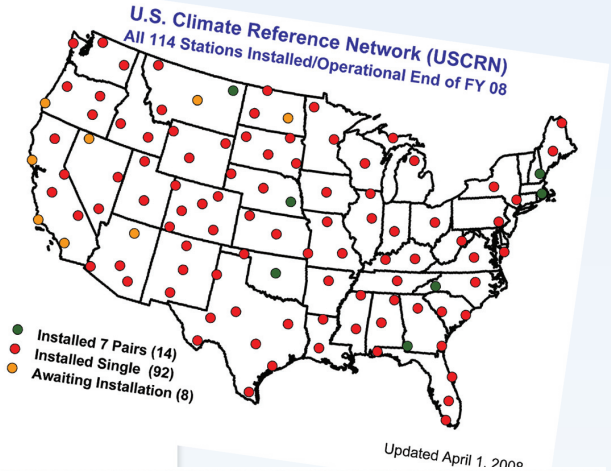
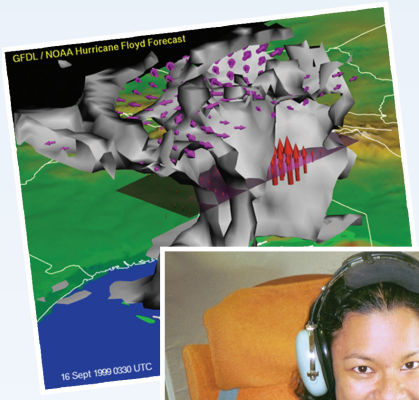


Image : A CRN station in Baker, NV.

Learn More:
www.arl.noaa.gov/CRN.php

Hurricanes: Improved Track and Intensity Predictions

Track forecast improvements up to 20 percent are possible using dropsonde data. A 20 percent reduction in track errors should reduce the average warning area by at least 10 percent (34 miles), saving the public more than $45 million over 5 years.



The 10-year Hurricane Forecasting Improvement Project (HFIP) recently proposed to Congress will address "rapid intensification" as the number one problem of hurricane forecasting.

Learn More:

www.aoml.noaa.gov/themes/Hurricanes/hurricanes.html

uas.noaa.gov

Where a hurricane tracks, if it will intensify, and ultimately how hard it will hit are main concerns of NOAA hurricane forecasters and researchers. OAR models, data collection, and analyses contribute to the National Weather Service's improved average hurricane track forecasts. In fact, today's average 5-day track forecast is as good as the 3-day track forecast was ten years ago.

Impact

More timely and reliable forecasts for improved community outcomes

NOAA's hurricane forecast accuracy is tied to improvements in computer-based numerical weather prediction models. The National Hurricane Center uses many models, including those developed by OAR's Geophysical Fluid Dynamics Laboratory (GFDL) and the Atlantic Oceanographic and Meteorological Laboratory (AOML).

AOML researchers on NOAA "Hurricane Hunter" aircraft fly into the eye of these dangerous storms to collect and analyze data. Global Positioning System (GPS) dropsondes, an innovative technology developed by AOML, provide key data in real time to the National Hurricane Center and are crucial for studying the wind structure in the eyewall region of hurricanes.

During the 2007 Hurricane Season, AOML and NASA successfully flew an Aerosonde® Unmanned Aircraft System (UAS) through hurricane-force winds and at record low altitudes into Tropical Cyclone Noel. Using UAS to monitor tropical storms and hurricanes is important because UAS thermodynamic and wind observations can be obtained at altitudes unsafe for manned aircraft. In NOAA, the UAS program is managed by OAR's Earth System Research Laboratory (ESRL).

In spite of this progress, rapid intensification remains the number one challenge of hurricane forecasting. The 10-year Hurricane Forecast Improvement Project (HFIP), managed by OAR and the National Weather Service, will improve hurricane forecasts so emergency management officials can make informed decisions in advance of storms with more confidence. HFIP planning began after the 2005 hurricane season – the most active on record – which produced several monster storms, including Hurricane Katrina. OAR research efforts in the next decade will target HFIP objectives to reduce track and intensity errors by 50 percent, and improve prediction of rapid intensification events.

Images, top to bottom: Three-dimensional depiction of GFDL Hurricane model; OAR hurricane research scientist Shirley Murillo; National Hurricane Center's 3-day forecast for Hurricane Katrina, Aug. 26, 2005.

Tornadoes: Heroic Technology Advances Weather Forecasting

Impact

Four-fold increase in tornado warning lead times saves lives

When killer tornadoes tore through Oklahoma and Kansas in May 1999, NOAA's Norman, OK, Weather Forecast Office issued warnings up to one hour in advance of some of the twisters. The office credited the NEXRAD (NEXt generation weather RADar) system and the Advanced Weather Interactive Processing System (AWIPS) for helping the team quickly and accurately assess the weather conditions and get out life-saving warnings. In fact, after this event, national media deemed NEXRAD a "hero." Together, with emergency managers and the media who helped disseminate NOAA warnings, an estimated 600 lives and countless dollars were saved. Both NEXRAD and AWIPS were developed by OAR researchers.

"Technology has bought a precious 15-20 minutes in life-saving and property-saving time. The hero: a lowly radar called the 88-D …. mark[s] an unambiguous case indeed of government improving lives – by saving them."

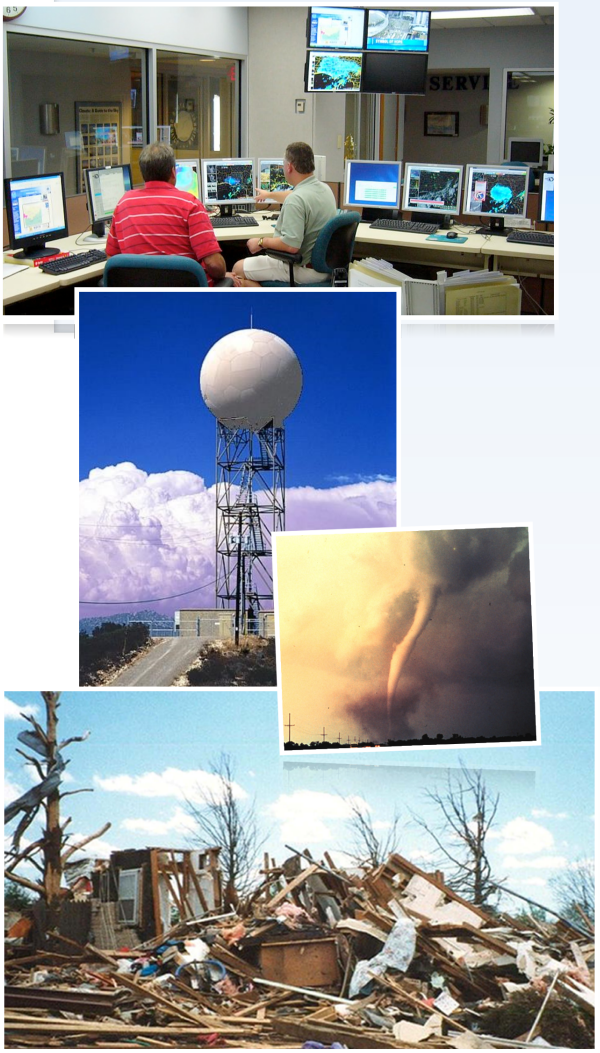
USA Today, May 6, 1999

Three decades ago, successful tests of Doppler radar led by OAR's National Severe Storms Laboratory (NSSL), the National Weather Service, the Federal Aviation Administration, and the Air Force's Air Weather Service led to NEXRAD in the 1990s, a national network of 158 Doppler radars.

The AWIPS workstation, developed by a predecessor of OAR's Earth System Research Laboratory (ESRL) with the NWS and contractor PRC, fundamentally changed how NWS forecasters access radar, satellite, model outputs and other weather data streams. Without AWIPS, forecasters accessed radar via one computer, satellite imagery on another, and had no capability to overlay different streams of data on a single visual. With continuous improvements in AWIPS, forecasters have tremendous flexibility to manipulate information, develop a forecast and use automated tools to rapidly communicate warnings to tailored geographic areas.

Looking to improve warning times even further, NSSL and its partners are investigating how the U.S. Navy's AEGIS phased array radar system may be applied to tornado detection, forecasts, and warnings in a multi-use environment. Multi-function Phased Array Radar (MPAR) could extend average warning lead times significantly. A single network of MPAR units could theoretically replace seven single-function conventional radar networks that currently serve aviation, defense, homeland security, and weather forecasting needs.

A 2005 external evaluation calculated storm-related injuries were down by 40 percent and fatalities by 45 percent after NOAA implemented NEXRAD.



Today, tornado warning times average 15 minutes. Only a three-minute warning was possible 20 years ago.

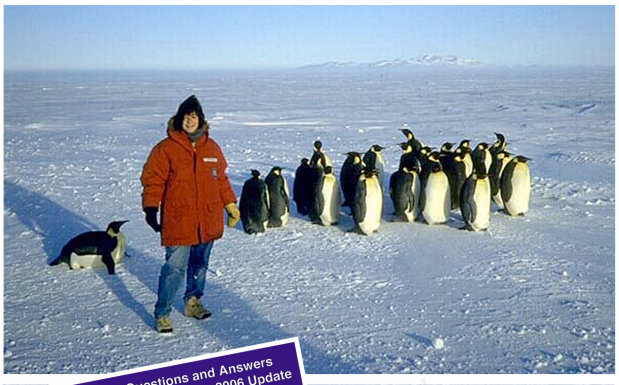
Images, top to bottom: Advanced Weather Interactive Processing System; NEXRAD Doppler radar; tornado and tornado damage.

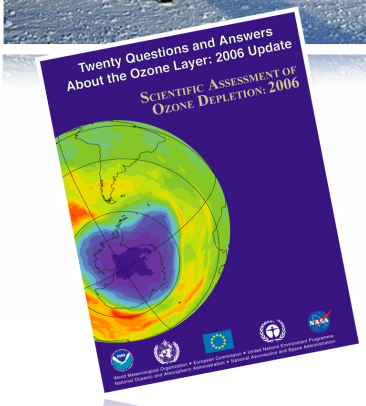
Learn More: www.nssl.noaa.gov

Ozone: Changing Environmental Outcomes Through Discovery and Mitigation

In 1999, Dr. Susan Solomon earned the U.S. National Medal of Science for "key insights in explaining the cause of the Antarctic ozone hole."

As a result of this research, the Montreal Protocol put policies in place to reduce production and consumption of the man-made compounds that were depleting atmospheric ozone. Ratified by 180 nations, it is considered by many to be the most successful multilateral environmental agreement to date.





Most of us know the phrase "ozone hole," but what exactly is it? And how does it affect our lives? Dr. Susan Solomon is the OAR scientist qualified to provide you with answers.

Impact

Mandated cutbacks of chlorofluorocarbons (CFCs) that result in millions of U.S. lives saved

Solomon's story began in the 1980s, when the scientific community first discovered that chlorofluorocarbons (CFCs) were becoming more prevalent in the atmosphere at the same time that ozone was lessening. This was distressing because the ozone layer protects the Earth from the Sun's damaging ultraviolet-B (UVB) radiation. Too much UVB radiation can result in cancer. In 1986, Solomon and colleagues offered a theory for diminished ozone: Human-produced chlorine compounds interacting with stratospheric ice clouds. In the unique meteorological setting of the Earth's polar regions, this interaction could produce extreme ozone losses. It was a remarkable insight and scientific breakthrough.

The U.S. Environmental Protection Agency estimates that actions to protect and restore the ozone layer will save 6.3 million U.S. lives that would have been lost to skin cancer.

Solomon and her colleagues were right. Together with colleagues from the international scientific community, NOAA scientists embarked on the National Ozone Expeditions of 1986 and 1987 to Antarctica. The data they collected confirmed their theory as the only explanation that fit the observations.

Recognizing the implications of the data, governments around the world agreed to the Montreal Protocol on Substances that Deplete the Ozone Layer on September 16, 1987. The Montreal Protocol put policies in place to reduce production and consumption of man-made compounds that deplete atmospheric ozone.

In late 2008, a NOAA-led assessment of the global ozone layer found the United States has reduced by 97-98 percent the production of ozone damaging substances since the late 1980s.

Images, top to bottom: Dr. Susan Solomon and some new friends on Antarctic ozone expedition in 1987 near McMurdo Station; Twenty Questions and Answers About the Ozone Layer: 2006 Update*, a joint publication of NOAA, NASA, the U.N. Environmental Program, and the World Meteorological Organization.*

Learn More: www.esrl.noaa.gov/gmd

Air Quality: Nailing Down the Source of Ozone Pollution

Impact

Curbing ozone emissions by petrochemical facilities to reduce respiratory illness

High concentrations of ground level ozone can cause shortness of breath, wheezing, coughing, headaches, and nausea. These effects are worse for children and those who already suffer from lung diseases.

When the state of Texas planned in the late 1990s to solve their ozone pollution problems, they targeted cars as the number one concern. Officials were surprised when OAR researchers said that the real culprits were hydrocarbon emissions leaking from petrochemical facilities heavily concentrated on the Texas Gulf Coast. What was even more astounding was that emission reductions recommended by OAR researchers could save Texas $9 billion and 64,000 jobs over 10 years compared to alternative options. The economic study was conducted by The University of Chicago and The University of Houston.

OAR's Earth System Research Laboratory (ESRL) led the Texas Air Quality studies in 2000 as part of a State Improvement Plan aimed to bring the region into compliance with the Clean Air Act. Prior to the study, Texas had taken a traditional approach to reducing nitrogen-containing pollutants, focusing on reducing automobile emissions. When ESRL researchers released their findings, they changed the course of the state's plans, and -- doing what OAR does best – provided needed expertise and data to devise practical environmental action, which will save taxpayers and industry money.

Asked to assess the effectiveness of targeted reductions, OAR researchers along with multiple federal, state, and local governmental agencies and academics followed up with a 2006 study. The new information shed light on complex air quality problems elsewhere in the Nation and assisted efforts to meet Environmental Protection Agency standards for ozone, airborne particles or aerosols, and regional haze. NOAA's primary planning and funding partners in the 2006 study were the Texas Com-mission on Environmental Quality and the Texas Environ-mental Research Consortium.

Image: Houston skyline.

The Texas Gulf Coast is home to two-thirds of the Nation's petrochemical production. It suffers from the highest ozone pollution levels in the country, exceeding Federal standards an average of 32 days each year (1999-2002).

Emission reductions by petrochemical facilities were estimated to save the state of Texas $9 billion and 64,000 jobs over 10 years.

Learn More:

www.etl.noaa.gov/programs/2006/texaqs

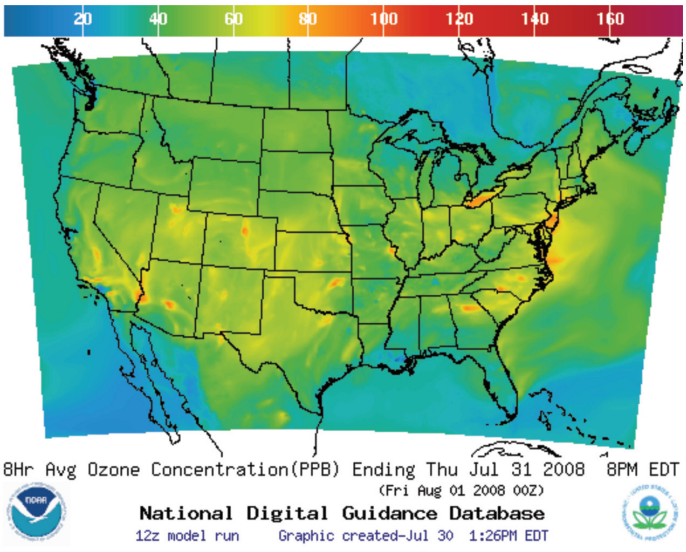
Air Aware

NOAA works with the Environmental Protection Agency (EPA) and state, local, and tribal governments to provide the public with accurate warnings about unhealthful levels of air pollution.

A Breath of Fresh Air: Improving Air Quality Predictions for the Nation

Whether it's ground-level ozone, fine particulate matter, or other airborne substances, all three may be carried through the air into our lungs. OAR's Air Resources Laboratory (ARL) has developed models that predict where airborne substances will go so at-risk people can be warned.

Impact
Air quality forecasts and warnings for health and safety



High ozone levels near the ground cause thousands of premature deaths annually in the U.S. The familiar "code red" ozone alerts issued by state governments warn the public when pollution levels are expected to be high. These alerts also allow people to voluntarily reduce air pollution by driving less and mowing their lawn when conditions improve. OAR's ARL developed the ozone modeling system that forecasters use to determine when alerts should be issued.

The accidental or intentional release of chemical, biological or nuclear agents can have a significant health, safety, national security, economic, and ecological implications. The Hybrid, Single Particle Lagrangian Integrated Trajectory or HySPLIT Model developed by ARL can be used to predict the path of multiple types of airborne hazards. For example, air quality forecasters rely on HySPLIT predictions to determine when their communities will be affected by forest fire smoke. Airlines rely on HySPLIT to steer aircraft around volcanic ash plumes, which can ruin plane engines. The World Meteorological Organization and the International Atomic Energy Agency rely on HySPLIT to predict and track radiation from large nuclear incidents. And local emergency managers also depend on HySPLIT to map the path of chemical plumes, so that first responders and the public can move out of harm's way.

HySPLIT predicts smoke plume locations from forest fires, and allows aircraft to avoid dangerous ash from volcanic eruptions. Understanding sources of hazardous air pollutants allows air quality managers to mitigate critical air quality problems.

Images, top to bottom: NOAA prediction of ground-level ozone; ash from volcanic eruptions is a serious aviation hazard; forest fires can significantly degrade air quality.

Learn More: www.arl.noaa.gov

Argo's "Robotic Oceanographers" Take the Ocean's Vital Signs

Impacts

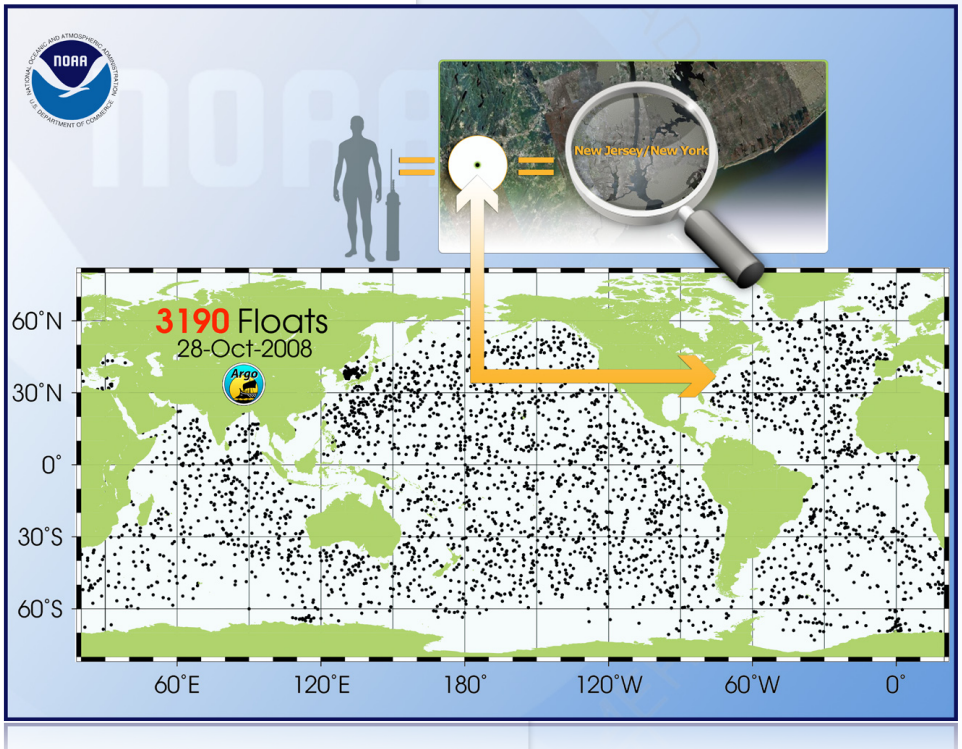
A worldwide picture of ocean characteristics for industry use and climate forecasting

Ocean observations are critical for coastal management, shipping, offshore industry and climate forecasting. NOAA researchers lead ocean observations through an innovative use of "robotic oceanographers" that measure ocean temperature, salinity, and currents. Called the Argo array, NOAA initiated its contribution to this international effort in 2000 by pledging to participate in the deployment of 3,000 free-drifting floats around the globe.

Scientists agree that sea levels are rising as a result of global climate change. Knowing how quickly and how high sea level will rise will help policy makers better protect coastal communities from the threat of inundation. Argo floats are collecting data that may help answer these questions.

Unlike satellites which cannot "see" below the ocean surface, Argo floats spend most of their life collecting data from the surface to a depth beneath the surface of up to 2,000 meters.

Accurate climate forecasts depend on improving ocean observations within the upper layers of the ocean. Satellites relay Argo data to land-based receiving stations. From there, the data are made available within 24 hours for operational forecast centers -- and with more rigorous quality control within five months for scientists.

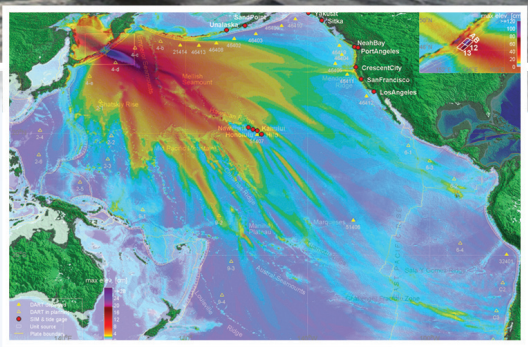


The array, which is sponsored by OAR's Climate Program Office, is a major component of the Global Ocean Observing System (GOOS). OAR's Atlantic Oceanographic and Meteorological La-boratory (AOML) is a U.S. Argo data center. AOML also has been active in Argo capacity building efforts for Atlantic nations, including 12 West African countries, as well as Korea and China. OAR's Pacific Marine Environmental Laboratory in Seattle calibrates Argo floats before deployment and monitors quality control.

Image: Map of Argo float locations. NOAA has contributed nearly half of the Argo floats to a growing worldwide network.

Learn More:
www.aoml.noaa.gov/phod/goos.php

NOAA's DART® patent is licensed to a private company. Chile and Australia have purchased DART® systems.



For his groundbreaking work on tsunami warning, Dr. Eddie Bernard, Director of OAR's Pacific Marine Environmental Laboratory (PMEL), earned the 2008 Service to America Homeland Security Medal from the Partnership for Public Service.

Tsunamis: Getting Beyond "If the ground shakes, if the water recedes, or if you hear a loud roar"

Impacts

Tsunami detection and warnings save lives and property, while decreasing unnecessary false alarms

"How could we detect a tsunami, tell you how big it's going to be in advance, and tell you what to expect when it arrives?" These were the questions Dr. Eddie Bernard, Director of OAR's Pacific Marine Environmental Laboratory (PMEL), and his team had been asking for 25-plus years. They had to build an instrument that could detect a tsunami in the open ocean, get the data fed into a numerical model which would generate the prediction, and find a way to relay the data back to a warning center within minutes. In 1995, their research gave birth to DART®, the Deep-Ocean Assessment and Reporting of Tsunami system, the first operational tsunami detection system in the world.

Tsunamis are caused by earthquakes or land slides on the ocean floor. Seismic alerts are broadcast, but are no guarantee of a tsunami. What had frustrated people like Bernard for years was the 75 percent false alarm rate caused by a system built on tide gauges and seismometers. Waves with tsunami potential are sneaky. They can be subtle and incredibly difficult to detect. This is what makes DART® such an ingenious invention. Its exceptionally sensitive pressure recorder anchored miles below the surface on the ocean floor is capable of detecting a half-inch wave. Data are transmitted to a surface buoy then relayed to PMEL and the NOAA Tsunami Warning Centers in Alaska and Hawaii via satellite.

In 1986, Hawaii spent $40 million on a needless evacuation due to a false alarm. In 2003, a false alarm was cancelled saving an estimated $68 million.

The Indian Ocean tsunami disaster in December 2004 brought a real urgency to implementing DART® throughout waters surrounding the United States and in other places around the globe. Thirty-nine second-generation DART® systems with two-way communication for remote maintenance are now at work in the Pacific, Indian, and Atlantic Oceans, the Caribbean Sea, and Gulf of Mexico.

Bernard has been as passionate about public education as developing this life-saving system. He saw the public's heightened awareness of the 2004 tragedy as an opportunity for enhanced tsunami preparedness education. "It didn't take much because the visuals that were coming in from Thailand, and India. All you had to do was just remind people that this can happen to them when they are on the beach."

Images, top to bottom: NOAA DART® II buoy; NOAA animation of the December 2004 Indian Ocean tsunami; Dr. Eddie Bernard, DART® creator.

Learn More: nctr.pmel.noaa.gov

Ocean Acidification: Climate Change Impacts on the Marine Environment

Impact

Understanding of climate change impacts on the ocean may lead to policies that better protect marine life

Anyone who has had fish as pets knows that changes in pH levels can destroy life in an aquarium. The same is true in the ocean. About one-third of carbon emissions generated by human activities has been absorbed by the world's oceans. And at a current uptake rate of 22 million tons a day, ocean absorption of carbon dioxide is lowering the pH, causing what is known as "ocean acidification." Scientists at OAR's Pacific Marine Environmental Laboratory (PMEL) are at work understanding this phenomenon. In field studies along the west coast of North America between Canada and Mexico, the PMEL team along with a large number of international collaborators found, for the first time, corrosive water caused by the ocean's absorption of carbon dioxide (CO_2) now exists on the continental shelf of western North America.

Ocean acidification has serious implications for marine life. By the end of this century, many of the ocean's creatures dependent on calcium to form their protective "shells" could be seriously impacted. Among them are marine algae and free-swimming zooplankton that serve as food for larger species. Fish larvae survival is also reduced, likely affecting commercial fisheries for years to come. Researchers at OAR's Atlantic Oceanographic and Meteorological Laboratory have recently shown that coral reefs in the naturally acidic eastern tropical Pacific are becoming "unglued" as a result of the lack of cements that bind individual coral skeleton and larger reef structures. This makes reefs in high CO_2 waters more susceptible to erosion.

NOAA deployed the first buoy dedicated to monitoring ocean acidification in 2006

In their quest to continuously monitor and assess the impact of rising CO_2 on the world's oceans, PMEL and partners have launched the first system specifically designed to monitor ocean acidification in the Gulf of Alaska. The buoy is part of a National Science Foundation project awarded to oceanographers at PMEL and the University of Washington in Seattle, in collaboration with Fisheries and Oceans Canada and the Institute of Ocean Sciences in Sidney, British Columbia.

"It's just been an absolute time bomb that's gone off both in the scientific community and, ultimately, in our public policymaking."

Rep. Jay Inslee (D-Wash.) talking about ocean acidification in The Washington Post in 2006

International scientists found "acidified" water on the continental shelf from Canada to Mexico.

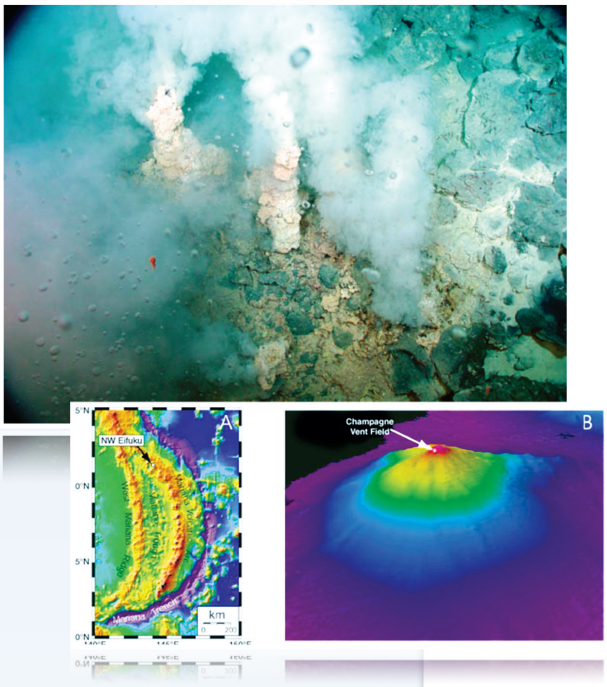
Images, top to bottom: Part of the largest coral reef in the continental United States along Florida's coast; a free-swimming pteropod with a calcium carbonate shell; OAR scientist Christopher Sabine on a field study in the Southern Ocean aboard the NOAA Ship Ronald H. Brown.

Learn More:

www.pmel/noaa.gov/co2/

www.aoml.noaa.gov/ocd/gcc/co2research

The Ocean as Laboratory: Undersea Vents as Models for Ocean Acidification, Carbon Capture, and the Unknown



"We were just going from one incredible event to the next, seeing things we had never witnessed before."
Bill Chadwick, volcanologist, OAR's Cooperative Institute for Marine Resources Studies at Oregon State University.

Impact

Tapping the potential of previously unknown ocean resources

Like champagne bubbles rising from the sea floor, liquid carbon dioxide (CO_2) was identified by OAR scientists and colleagues during a 2004 voyage to the Submarine Ring of Fire – volcanoes lying along the Marianas Arc in the western Pacific. Located approximately one mile below the surface, the pressure of the water column is so great that the gas forms a liquid. Researchers with OAR's Pacific Marine Environmental Laboratory (PMEL) and Office of Ocean Exploration and Research (OER) had found a natural laboratory where the effects of carbon dioxide on marine organisms could be studied.

The significance of this liquid CO_2 discovery relates to changes in ocean chemistry resulting from climate change. About one-third of the world's carbon dioxide is absorbed by the ocean, which has led to ocean acidification. PMEL researchers and colleagues asked how their underwater liquid CO_2 discovery could help them understand and possibly predict the effects of ocean acidification.

Using special technology deployed from a robotic submersible, the scientists collected samples. The Champagne Vent field, where the liquid CO_2 was found, also spews out hot gas-rich fluid. Back in the lab, the scientists found that the vent was a high carbon flux system, rich in CO_2. Not only is this finding important for studying ocean acidification in a natural state and the ocean's role in carbon cycling, but it also may be an important model for studying carbon sequestration, a method for taking excess carbon from the air and storing it in the ocean's depths.

Ocean exploration is discovering the unknown. The ocean is a vast resource full of unidentified organisms, which might produce a cure for cancer or a biotechnology that can be harnessed for alternative fuel production.

The expedition has been called "path finding" by many in the ocean community, and underscores the fact that there is so much to learn about one of the Earth's most important features – the ocean.

Images, top to bottom: A champagne vent, where bubbles of liquid CO_2 escape from the white chimneys and surrounding seafloor; bathymetry of Eifuku in the Marianas Arc where liquid CO_2 vents were found.

Learn More:
http://oceanexplorer.noaa.gov/explorations/04fire/welcome.html

"America's Ship for Ocean Exploration": New Technologies Bring the Excitement of Real-time Discovery Ashore

Impacts

Sharing the excitement of real-time discovery with scientists and the public

Stay dry, and explore the ocean from the comfort of your living room! Through technologies aboard the NOAA Ship *Okeanos Explorer* – the only vessel in the world dedicated to ocean exploration – OAR's Office of Ocean Exploration and Research has launched a new paradigm for exploration, giving shore-based explorers of all ages access to the excitement of real-time discovery.

Commissioned in August 2008, the *Okeanos Explorer* is outfitted with a deep-water mapping system, remotely-operated vehicles (ROVs), and unique "telepresence" technology. This newest member of the NOAA fleet will explore our largely unknown ocean for the purpose of discovery and advancing knowledge.

The deep-diving ROV system – capable of operating at depths of 6,000 meters – consists of a maneuverable vehicle fully equipped to collect high-definition video and take samples of its surroundings and a non-maneuverable "camera sled," positioned to film as it investigates interesting features and habitats.

Telepresence, is the key technology that promises to change ocean exploration fundamentally. Traditionally, scientists explore the ocean from the ship. In contrast, telepresence uses real-time broadband satellite communications and high-speed Internet to bring the ship and its discoveries to scientists. When situated at any of five Command Centers, scientists also can interact directly with the *Okeanos Explorer* and remotely participate remotely in each mission.

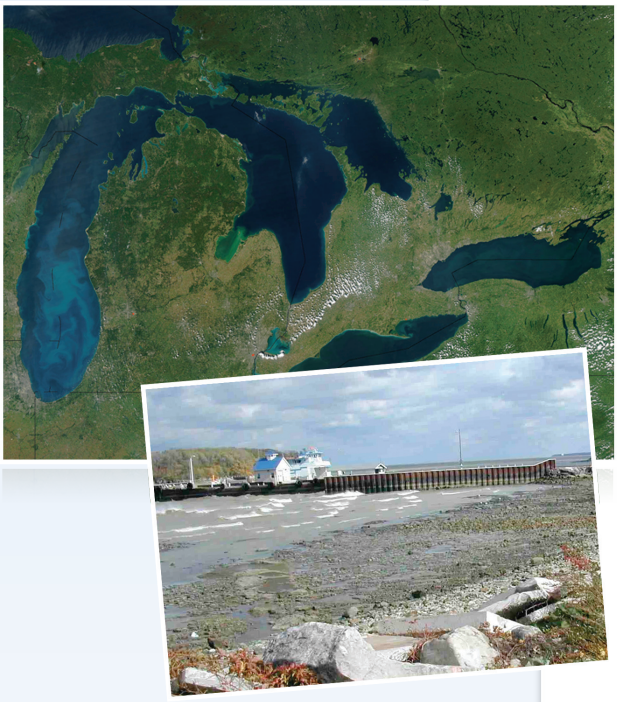
Also, anyone with a computer and web access can watch and listen in on operations aboard ship, bringing real-time exploration into living rooms, offices, schools, and businesses around the globe. Our goals are to advance knowledge and, at the same time, excite and engage people so they are able to make informed decisions about environmental issues that relate to the ocean, climate, and life on our planet. We also hope to inspire a new generation of oceanographers, scientists, and engineers.

The ocean covers more than 70 percent of the Earth's surface, driving weather, regulating temperature, and supporting life on this planet. The ocean remains 95 percent unexplored, unknown, and unseen by human eyes.

Through telepresence, NOAA Ship *Okeanos Explorer* brings live broadcasts of exploratory missions directly into the classroom.

Images, top to bottom: NOAA Ship Okeanos Explorer*; NOAA research diver; high school students investigating water quality as part of the NOAA Emerging Scientist Program.*

Learn More: oceanexplorer.noaa.gov



Safe and Prosperous Transport: Water Level Prediction in the Great Lakes

When low water levels prevail in the Great Lakes, commercial navigation, recreational boating, marinas, beaches, fishing, homeowners, and the aquatic ecosystem are adversely affected. In 2000, during a low level period, lake carriers transporting iron ore, coal, grain, and other commodities were forced to "light load," carrying 5-8 percent fewer goods. Also, marinas spent millions to dredge boat slips, channels, and harbors.

Impacts

Enhancing economic value and keeping ships and cargo moving through safe port-to-port transport

Addressing a need for Great Lakes' water level prediction, OAR's Great Lakes Environmental Research Laboratory (GLERL) developed the Great Lakes Operational Forecast System. Deemed operational in 2005, the system provides lake carriers, mariners, port managers, emergency response teams and recreational boaters with present and future conditions of water levels, currents and water temperatures.

The Great Lakes Operational Forecasting System combines two NOAA products: "nowcasts" for present conditions and "forecast" guidance for future conditions. Both use information generated by a three-dimensional hydrodynamic model that uses real-time data for winds and other meteorological parameters to predict water levels, currents and temperatures at thousands of locations throughout the five lakes. Key products include data plots and animated map plots of water levels, currents, and temperatures. "Nowcast" conditions are updated hourly, while 30-hour forecasts are produced four times daily.

The transition of the Great Lakes prediction system to operations at NOAA's National Ocean Service was a joint effort between OAR's GLERL, National Ocean Service, private industry (Aqualinks.com), and academia (Ohio State University).

Changes in water level have an impact on the shipping industry. For every inch that the water level drops, 270 tons less in cargo can be shipped for a 1,000-foot-long ship. The port authority also loses revenue as a result.

Images, top to bottom: The Great Lakes; low water levels on the Great Lakes can significantly impact shipping and commerce.

Learn More: www.glerl.noaa.gov

Alternative Energy: Harvesting the Ocean's Potential

Impacts

Exploring the ocean for alternative energy to strengthen U.S. energy security

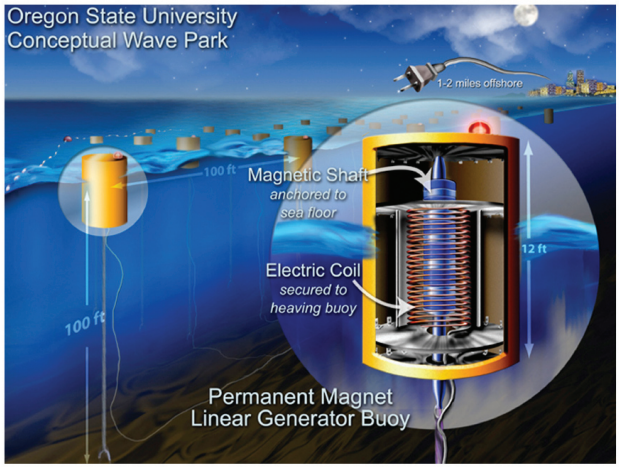
One way to reduce carbon emissions is to replace carbon-based fuels with an alternative energy source. OAR's Sea Grant Program is putting a menu of possibilities on the table.

At Oregon State University, Sea Grant engineering researchers have been developing wave energy extraction devices for the past two years with funding from NOAA and the National Science Foundation (NSF). They have created prototypes for three types of buoys for generating electricity from wave energy and have scoped out a site for a pilot wave power plant.

Researchers also are exploring use of a wave energy device currently used off the coast of Scotland. Deployed off Oregon's coast, researchers predict that 200 buoys could potentially power something comparable to the demands of Portland's business district. Oregon State Sea Grant researchers are not alone in considering energy harvested from the ocean. Other coastal states, including Washington, Hawaii, California, Massachusetts, Rhode Island, and Maine, also are exploring ocean energy technologies.

In the mid-Atlantic, Delaware Sea Grant completed a survey looking at Delaware residents' opinions on offshore wind power. Ninety percent of the 949 residents surveyed favor placing wind turbines as high as 40 stories off the Delaware coast, even if their electric bills increased up to $30 per month. The survey reflects OAR's support for social science research to improve our understanding of the true impact of NOAA research on human lives.

One only needs to watch the rhythmic rolling of ocean waves to see their potential as an energy source. The density of ocean water—about 1,000 times that of wind—also is significant to its potential for generating electricity.



About Sea Grant…

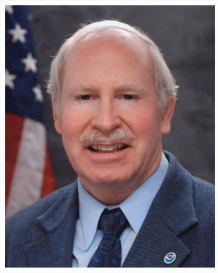
OAR administers the National Sea Grant College Program, a nationwide network of 32 university-based programs that conduct scientific research, education, training, and extension projects designed to foster science-based decisions about the use and conservation of our aquatic resources.

Image: Oregon Sea Grant supports new wave energy research at Oregon State University.

Learn More: seagrant.noaa.gov

Science on a Sphere®: Seeing the Dynamics of a Changing Earth

Science on a Sphere® provides an exciting means for engaging students in science – an important step toward interesting young people in pursuing careers in science, vital to our Nation's future as a leader in scientific achievement.



Dr. Alexander E. "Sandy" MacDonald, inventor of Science on a Sphere® has excelled as few others in both conducting and communicating science to a wide variety of audiences.

Impacts

A creative, compelling method for bridging the gap between scientific knowledge and citizen understanding

Until recently, scientific data were presented in two dimensions. That changed in 2002, when an OAR scientist and visionary unveiled a way to present complex Earth data the way that nature presents it – on a sphere. Scribbles on napkins and a beach ball were the humble beginnings of an exciting scientific advancement that gives an estimated 11.3 million people annually a view of our fragile planet unlike any they have ever seen before.

Called "Science on a Sphere®" (SOS), this wrap-around cinema system – invented by Dr. Alexander E. "Sandy" MacDonald, Director of OAR's Earth System Research Laboratory and Deputy Assistant Administrator for Laboratories and Cooperative Institutes, uses four computer-driven video projectors to display images on a smooth, white fiberglass sphere. A fifth computer is used to control the operation of the display computers. The computers communicate with each other through a network. Each computer is a relatively powerful PC, with dual processors and high-end graphics cards.

Some of the first images displayed on SOS were the Earth's topography and bathymetry, lights of the Earth at night, infrared satellite imagery showing clouds in motion, and X-ray images of the Sun with solar storms raging across the face of the sphere. Today, the SOS team has worked with science centers and museums to place SOS displays at more than two dozen locations internationally, including the Smithsonian's new Sant Ocean Hall. One of the highlights of the U.S. visit by Great Britain's Queen Elizabeth and Prince Philip in 2007 was a royal showing of Science on a Sphere®, displaying a Hurricane Katrina sequence, climate change models such as Sea Ice Change, Nighttime Lights of the Earth, and images of deep space and the planets.

Image: Britian's Queen Elizabeth and Prince Phillip view Science on a Sphere®.

Learn More: sos.noaa.gov

Joining the "YouTube Generation": Ocean Explorer Website

Impacts

Inspires ocean stewardship, a new generation of ocean explorers, and encourages scientific discovery

Does the thought of browsing a government website make you yawn? *Scientific American* thinks OAR's *Ocean Explorer* website will change your mind. "Poseidon beware! NOAA is determined to penetrate every minnow hideout and barnacle cluster of your realm, and with technology this advanced, there's no stopping this league of swashbuckling scientists. *Ocean Explorer* is full of buried treasure," wrote the prestigious science magazine's editors in honoring *Ocean Explorer* with their Sci/Tech Web Award.

Ocean Explorer is a public portal to an ocean of sensory delights. Joining the YouTube generation, the *Ocean Explorer*'s Ocean Channel explores underwater volcanoes, coral reefs, and historic shipwrecks to name a few. Newsworthy events and mission stories are told in video and audio podcasts. Each mission has its own section on the website, and is accompanied by a log that records the experiences of the mission's various team members while out at sea.

For anyone interested in a career in ocean exploration and research, the OceanAGE section provides profiles of over 20 people involved in ocean exploration. Along with scientists from multiple disciplines there are some unusual options, such as submersible pilot, NOAA Corps officer, marine archaeologist, research coordinator, and administrator. Resources for teachers, including modules to accompany missions, lesson plans, a glossary, and other activities, are also available. The *Ocean Explorer* website is used by teachers around the world.

Since its inception in April 2001, NOAA *Ocean Explorer* has been featured on hundreds of web sites and print media sources, and received many awards and special recognitions.

Scientific American is not alone in recognizing the site. *Ocean Explorer* has been featured in *Discover* magazine, on the *Animal Planet* TV channel, and is a CNN science link. It has also been a site of the week on *Voice of America*. And, by the way, many of the videos at *Ocean Explorer* also appear on *YouTube.*

"This site…dares to go where no site has gone before. With a wealth of online goodies that will amaze even grizzled mariners of the Web, it tracks, records, photographs, and thrills to a fleet of deep sea expeditions. There's so much to talk about that it's almost painful to narrow it down…"

Yahoo! Picks, May 2006

Image: Screen capture of award-winning Ocean Explorer website.

Learn More: oceanexplorer.noaa.gov

For more information contact us:

OAR Headquarters
1315 East-West Highway
Silver Spring, MD 20910
301-713-2458
www.oar.noaa.gov

Images, top to bottom: NOAA Smart Balloon being launched by (left to right) John Porter and Jonathan Tytell of the University of Hawaii, and Randy Johnson of the NOAA Air Resources Laboratory Field Research Division; Students at the Urban Collaborative Accelerated Program (UCAP) school in Providence, RI talk by satellite phone with NOAA scientist and former UCAP employee Catalina Martinez, who is in a submersible more than 8,000 ft deep in the Gulf of Alaska.; NOAA diver Barbara Moore tests chemical instrumentation outside the Hydrolab Habitat off Freeport, Grand Bahama Island.

OAR Laboratories and Programs

NOAA's Office of Oceanic and Atmospheric Research (OAR) conducts research at our seven laboratories around the country, and with our partners at Cooperative and Joint Institutes and through sponsored research funded by the Climate Program Office, National Sea Grant College Program, and the Office of Ocean Exploration and Research.

Air Resources Laboratory (ARL)
(301) 713-0295
www.arl.noaa.gov
ARL, with offices in Silver Spring, MD; Oak Ridge, TN; Las Vegas, NV; and Idaho Falls, ID, develops, evaluates, and applies air quality models; provides policy-relevant and scientific information about the exchange of air pollutants with the land surface; improves prediction of atmospheric dispersion of hazardous materials; develops climate observing systems; and provides new insights into climate variability and trends.

Atlantic Oceanographic and Meteorological Laboratory (AOML)
(305) 361-4450
www.aoml.noaa.gov
AOML in Miami, FL, conducts research in oceanography, meteorology, atmospheric and oceanic chemistry, and acoustics through its Divisions of Hurricane Research, Ocean Chemistry, and Physical Oceanography. AOML seeks to understand the physical characteristics and processes of the ocean and the atmosphere, both separately and as a coupled system.

Climate Program Office (CPO)
(301) 734-1200
www.climate.noaa.gov
CPO in Silver Spring, MD, manages the competitive programs by which NOAA funds sustained global climate observing systems and high-priority climate research to advance understanding of how atmospheric and oceanic processes affect climate. CPO also provides strategic guidance and oversight for the agency's climate science and services programs that build knowledge of climate variability and change, and how they affect our health, our economy, and our future.

Earth System Research Laboratory (ESRL)
(303) 497-6643
www.esrl.noaa.gov
ESRL in Boulder, CO, conducts research to observe and understand the Earth system and to develop products to advance NOAA's environmental information and service on global-to-local scales.

Geophysical Fluid Dynamics Laboratory (GFDL)
(609) 452-6503
www.gfdl.noaa.gov
GFDL in Princeton, NJ, conducts leading-edge research to expand the scientific understanding of the physical processes that govern the behavior of the atmosphere and the oceans, to understand and predict the Earth's climate and weather, including climate modeling to better understand the impact of human activities.

Great Lakes Environmental Research Laboratory (GLERL)
(734) 741-2393
www.glerl.noaa.gov
GLERL in Ann Arbor, MI, conducts interdisciplinary environmental research in support of resource management and environmental services in coastal and estuarine waters, with a special emphasis on the Great Lakes. GLERL improves understanding and prediction of coastal and estuarine processes, and interdependencies with the atmosphere, and sediments.

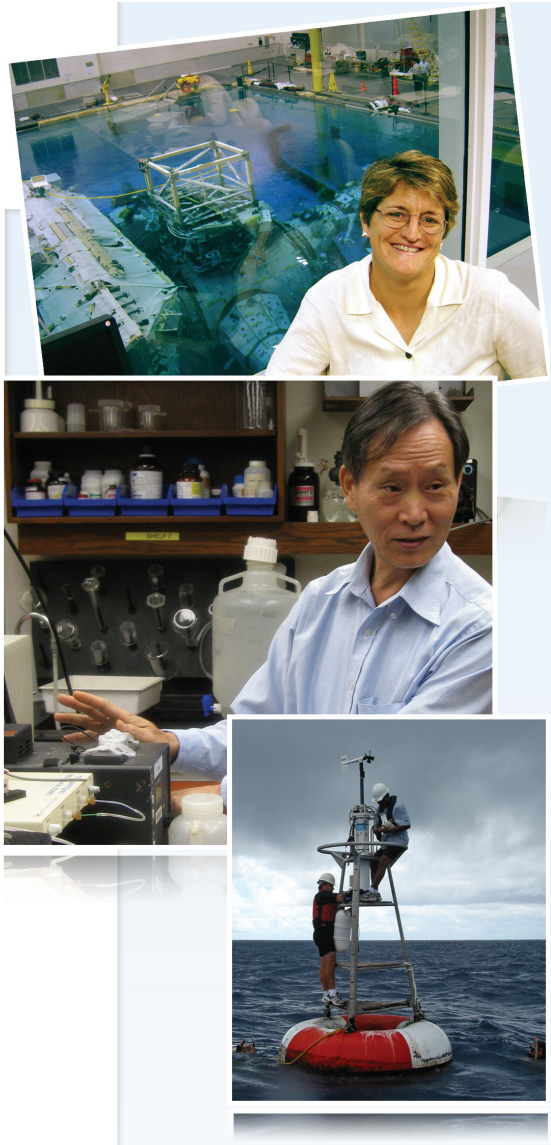
National Sea Grant Office
(301) 734-1066
www.seagrant.noaa.gov
The National Sea Grant Office in Silver Spring, MD, administers the National Sea Grant College Program, a nationwide network, of 30 university-based programs that work with coastal communities. Sea Grant conducts scientific research, education, training, and extension projects to foster science-based decisions about the use and conservation of our aquatic resources.

National Severe Storms Laboratory (NSSL)
(405) 325-6907
www.nssl.noaa.gov
NSSL in Norman, OK, improves severe weather warnings and forecasts to save lives and reduce property damage. NSSL's basic and applied research focuses on understanding severe weather processes, developing weather observation technology, and improving forecast tools, with emphasis on weather radar, hydrometeorology, and forecast and warning improvements.

Office of Ocean Exploration and Research (OER)
(301) 734-1010
www.oceanexplorer.noaa.gov
OER in Silver Spring, MD, discovers and investigates new ocean areas and phenomena, conducts the basic research required to capitalize on discoveries and seamlessly disseminates data and information-rich products to a multitude of users. OER also develops technological solutions to critical problems in undersea exploration.

Pacific Marine Environmental Laboratory (PMEL)
(206) 526-6239
www.pmel.noaa.gov
PMEL in Seattle, WA, conducts research to improve our understanding of the world's oceans, defines the processes driving the global climate system, and improves environmental forecasting capabilities, including tsunami detection and warnings, for public safety, marine commerce, and fisheries.

Cooperative Research Institutes
(301) 734-1090
www.nrc.noaa.gov/ci
NOAA's 21 Cooperative Research Institutes in 17 states bring together the resources of a research-oriented university or institution to develop and maintain a center of excellence in research relevant to understanding the Earth's oceans, the Great Lakes, inland waters, Arctic regions, solar terrestrial environment, intermountain west and the atmosphere.



Images, top to bottom: Karen Kohanowich, deputy director of the NOAA OER Program, at the Neutral Buoyancy Lab at the Johnson Space Center in Houston, Texas; Dr. Jia-Zhong Zhang, AOML, conducts nutrient analysis research; NOAA buoy technician Dane Jaynes (left) and scientific observer Alex Ysam (right) repair a TAO mooring while Ka'imimoana Commanding Officer (CO) Commander (CDR) Mark Pickett (left) and CO CDR Chris Beaverson (right) dive to repair subsurface instrumentation on the mooring.

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