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RESEARCH & DEVELOPMENT

Ocean explorers on NOAA Ship *Okeanos Explorer* observed two species of marine life scientists believe have never before been seen together at a hydrothermal vent — chemosynthetic shrimp and tubeworms. They also observed the first known live tubeworms ever seen at a hydrothermal vent in Atlantic waters during an expedition to the Mid-Cayman Rise south of Grand Cayman Island in the Caribbean. Most other life on Earth is photosynthetic — relying on energy from the sun. These new hydrothermal vent animals, by contrast, exist on the deep and dark ocean floor where no sunlight penetrates. Instead, they derive energy from chemicals that rise in the hot water of hydrothermal vents making them chemosynthetic.

This photo captures the first live tubeworm seen at a hydrothermal vent site in Atlantic waters.



NOAA RESEARCH & DEVELOPMENT



From the control room on NOAA Ship Okeanos Explorer, technicians send data, including high-definition video from the seafloor to scientists ashore, live via satellite and Internet telepresence pathways. NOAA's Office of Ocean Exploration and Research develops and applies telepresence and other technologies to explore, with the idea that discovery leads to research which in turn leads to products and processes benefiting NOAA and the nation. Image credit: Carl Verplanck/NOAA.

NOAA is the single federal agency with operational responsibility to protect and conserve ocean, coastal, and Great Lakes resources and to provide critical and accurate weather, climate, and ecosystem forecasts that support national safety and commerce. The foundation and forward planning for this mission of science, service, and stewardship is supported by NOAA research and development. NOAA provides research-to-application capabilities that can recognize and apply significant new understanding to questions, develop research products and methods, and apply emerging science and technology to the needs of constituents such as local governments, businesses, and the general public. The agency also has made a firm commitment to protect scientific findings from being suppressed, distorted or altered, to strengthen science, and to encourage a culture of transparency through the recent release of the Scientific Integrity Policy. This policy firmly supports scientists and their scientific activities, as well as instills further public trust in NOAA science.

The NOAA Research Council, an internal body composed of senior scientific personnel from every Line Office in the agency, provides corporate oversight to ensure that NOAA's research activities are of the highest quality, meet long-range societal needs, take advantage of emerging scientific and technological opportunities, and shapes a forward-looking research agenda. The research and development portfolio underlies and supports NOAA's Next Generation Strategic Plan's four long-term goals that are central determinants of resilient ecosystems, communities, and economies. The goals are: **1) Climate Adaptation and Mitigation, 2) Weather-Ready Nation, 3) Healthy Oceans, and 4) Resilient Coastal Communities and Economies.**

Highlighted in this chapter are NOAA's selected research and development accomplishments for FY 2011.

PRIVATE SECTOR TEAMS WITH NOAA ON HAIL AND SEVERE STORMS RISK MANAGEMENT INITIATIVE

The NOAA National Severe Storms Laboratory (NSSL) formed a research collaboration with Atmospheric and Environmental Research (AER). AER is a private company that provides weather risk management solutions for many insurance companies and other industries affected by severe storms, helping the insurance industry anticipate and react to storm damage, saving time and money. The alliance combines NSSL's years of research and development in weather radar technology with AER's expertise in providing data-driven solutions that improve industry practices. Partnerships to share weather information can lead to more productive and efficient industries in those sectors. **(Goal: Weather-Ready Nation)**



THREAT TO COMMON GULF OF MEXICO FISH STIR FEARS OF A DOMINO EFFECT

Atlantic croaker, one of the most abundant fish in the Gulf of Mexico, are starting to exhibit changes that appear to be related to the massive summer “dead zone”, a hypoxic or low-oxygen area. A National Centers for Coastal Ocean Science sponsored study found croakers exposed to low oxygen for as few as 10 weeks underwent hormonal alterations that transformed some of their female reproductive tissue into male tissue. Compounding this bad news, the male tissue was incapable of fertilizing eggs, and hatching rates were a tenth of normal. All of these factors are quite capable of causing a population crash in one of the Gulf’s top 10 recreational fisheries. Because croaker are closely related to several species of fish in the Gulf, this study indicates there are many fish susceptible to crashing if hypoxic conditions persist.¹ Research results such as these can provide an understanding of the effects of the dead zone on fish populations and recreational fisheries. **(Goal: Resilient Coastal Communities and Economies)**



Atlantic croaker (Micropogonias undulatus) is a coastal marine fish inhabiting the east coast of the United States with an \$8 million annual commercial fishery.

CHANGES IN WINTER CLIMATE WILL RESULT IN DRIER SOUTHWESTERN UNITED STATES

Scientists with NOAA’s Geophysical Fluid Dynamics Laboratory coauthored a paper² theorizing that the projected drying of southwestern North America is driven by a reduction of the winter precipitation, a decline in mountain snow mass due to warming, and an earlier spring snow melt that disrupts natural water storage systems. These results offer improved scientific understanding of the linkages between changing climate systems and the impacts on water, a valuable natural resource. **(Goal: Climate Adaptation and Mitigation)**

ADVANCEMENT IN SENSOR TECHNOLOGY FOR REGIONS WITH EXTREME ARCTIC ENVIRONMENTS

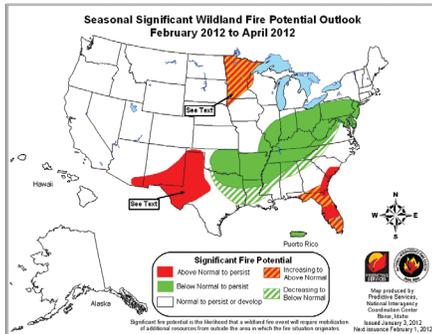
The NOAA National Ocean Service’s Center for Operational Oceanographic Products and Services (CO-OPS) has developed an innovative system design to collect water level data in remote, cold climate regions where winter sea ice precludes traditional tide station installations. The systems are equipped with a high-stability pressure sensor, conductivity sensor, an acoustic modem, disposable ballast, and a pop-up buoy for recovery. The data obtained represent one of the most unique and valuable data sets collected by NOAA on the North Slope. The results have already contributed to improved elevation measurements, known as a vertical reference system, for the region that will contribute to future shoreline and bathymetric surveys necessary for

¹ P. Thomas, M. S. Rahman. *Extensive reproductive disruption, ovarian masculinization and aromatase suppression in Atlantic croaker in the northern Gulf of Mexico hypoxic zone.* Proc. R. Soc. B, 279, 28-38 (January 7, 2012).
² R. Seager, G. A. Vecchi, *Greenhouse warming and the 21st century hydroclimate of southwestern N. America,* Proceedings of the National Academy of Sciences, 107(50), 21277-21282 (December 14, 2010).



informing Arctic communities and economies of changing conditions. **(Goal: Resilient Coastal Communities and Economies)**

NATIONAL SEASONAL FIRE OUTLOOKS ALLOW ADVANCED PLANNING



A National Seasonal Fire Outlook map for January-March 2012..

The National Seasonal Assessment Workshops (NSAW) produced annual pre-season fire potential outlooks for the United States. In February 2011, the seasonal fire outlook provided advanced warning of crippling wildfires in Texas. Using the outlook, the National Interagency Fire Center was able to make an informed decision to send interagency assistance to Texas, dispatching firefighters, support staffers, fire engines, dozers, helicopters, fixed wing aircraft and air tankers in order to mitigate the threat of the fires. The NSAW are developed by a partnership among the NOAA Climate Program Office, the NOAA-supported Climate Assessment for the Southwest program, the National Interagency Coordination Center's Predictive Services, and the Program for Climate, Ecosystem and Fire Applications at the Desert Research Institute. **(Goal: Climate Adaptation and Mitigation)**

SIDE SCAN SONAR AUTONOMOUS UNDERWATER VEHICLES (AUVS) RESPOND TO EMERGENCIES

After 3 years of testing, evaluation, and determination of standard operating procedures, AUVs equipped with side scan sonars have been accepted as an operational tool for responding to emergency situations. This highly portable survey system provides autonomous side scan sonar capability to commercial port areas within the United States. The system "sweeps" an area for new obstructions potentially posing hazards to commercial surface navigation. During the evaluation period, the AUV was successfully deployed to gather data to clear ship channels for traffic after tropical storm and hurricane strikes at east coast and Gulf of Mexico ports. **(Goal: Resilient Coastal Communities and Economies)**

CATCH-SHARE STUDIES SHOW GROUND FISH VESSELS EARN MORE, LAND LESS IN 2010

The Northeast Fisheries Science Center's (NEFSC) Social Sciences Branch examined the social and economic performance of the groundfish fishery in 2010. This is the first year the fishery was managed under a catch-share system—one in which fishermen either joined with others to form a group called a "sector" and fished an allotted share of the total allowed catch, or fished individually with a limit on the number of days spent fishing. Most vessels with a substantial history of landing groundfish fished under the sector option. The studies showed that despite lower catch limits required to end overfishing and rebuild stocks, the groundfish industry obtained higher prices for fish and earned more value from fewer fish landed and less fishing effort expended. These are the first reports generated by the NEFSC, with extensive consultation from stakeholders in the region. Findings were presented to industry and the New England Fishery Management Council and are



being used to formulate actions to help fishermen and fishing communities operate successfully under catch quotas in an effort to end overfishing and rebuild stocks. Results indicated that the fishery's overall economic health improved and suggested that new management processes are beginning to work towards building and sustaining economically robust coastal communities. **(Goal: Healthy Oceans)**

REAL-TIME FLOOD IMAGERY FOR MAJOR DISASTERS

NESDIS provided real-time flood maps to support emergency response to the March 2011 tsunami in Japan and the May 2011 flooding in the U.S. Midwest. The Geostationary Operational Environmental Satellite R Series (GOES-R) land application team used satellite images to create a product to detect flooding and standing water. The imagery was used to rapidly communicate information to decision makers and the public permitting more informed disaster response. **(Goal: Weather-Ready Nation)**

UPGRADE OF NOAA'S CLIMATE FORECAST SYSTEM ENHANCES DECISION MAKING TOOLS

The National Weather Service's National Centers for Environmental Prediction implemented a new operational version of the Climate Forecast System (CFSv2) that combines predictions of atmosphere, ocean, sea ice, and land. The CFSv2 took seven years of development by a team of NOAA scientists and has resulted in improved operational forecasts for sub-seasonal and seasonal timescales. For example, forecasts of heavy rainfall over the U.S. west coast, cold air outbreaks over the eastern United States, and tropical cyclone activity have increased from 6 to 17 days out. The CFSv2 also has improved the skill of other seasonal forecasts. These forecasts can be used by a wide community of users in their decision making processes for areas such as water management for rivers and agriculture, transportation, energy use by utilities, wind and other sustainable energy, and seasonal prediction of the hurricane season. **(Goal: Climate Adaptation and Mitigation)**

NEW DETECTION METHOD FOR VIRULENT-TYPE *VIBRIO VULNIFICUS* MAY LEAD TO SAFER OYSTERS

A Louisiana Sea Grant-sponsored project developed an improved rapid and reliable method to detect virulent-type *Vibrio* pathogen in oysters. Results of the study have been accepted for publication.³ *Vibrio vulnificus* is a rare but severe cause of oyster-related illnesses in humans, which could be fatal for certain at-risk consumers. Rapid, accurate, and reliable testing methods that can detect *V. vulnificus* strains with potential to cause human illnesses are currently not available. This improved toxin monitoring will be of great value to regulatory agencies to increase resource managers' knowledge of ecological stressors and to inform management decisions. **(Goal: Resilient Coastal Communities and Economies)**

³ F. Han, F. Wang, B. Ge, *Detecting virulent-type Vibrio vulnificus strains in raw oysters by quantitative loop-mediated isothermal amplification*. Applied Environmental Microbiology. (2011).

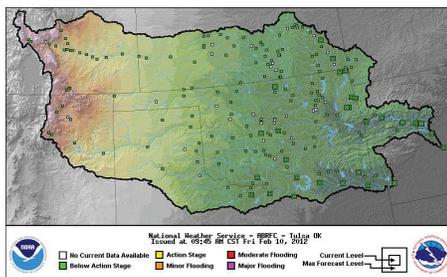


A 27-YEAR DATA RECORD OF STRATOSPHERIC TEMPERATURE CHANGE

Using observations from seven NOAA satellites, the National Environmental Satellite, Data, and Information Service (NESDIS) Center for Satellite Applications and Research (STAR) developed a 27-year data record of climate change in the stratosphere (the second major layer of Earth's atmosphere). It is the first well-documented data record available to the public that is capable of determining accurate trends of stratospheric temperature change both regionally and globally. Research on decadal timescales is needed to understand feedback between atmospheric temperatures and the rate of global-to-regional climate impacts. **(Goal: Climate Adaptation and Mitigation)**

RELIABLE RIVER FORECASTING FROM HOURS TO SEASONS

NOAA has developed a reliable method to combine data about precipitation (i.e. rain) and temperature over different time scales ranging from hours to seasons. These groupings or ensembles will drive NWS hydrologic (river) forecast models to produce forecasts, which could predict water levels or flooding conditions. The first user of the upgraded forecast system is the city of New York, which manages a complex system of reservoirs for its water supply. The system in the future will be made available to all River Forecast Centers to serve water resource and environmental managers, city planners, the general public, and private-sector value-added firms. **(Goal: Weather-Ready Nation)**



Interactive map of up-to-the minute observed/forecast river conditions for the Arkansas-Red Basin River Forecast Center, one of 13 River Forecast Centers in the National Weather Service.

RESEARCHERS DETERMINE EFFECT OF DEEPWATER HORIZON CONTROLLED BURNS ON AIR QUALITY

During the 2010 Deepwater Horizon oil spill, an estimated one of every 20 barrels of spilled oil was deliberately burned off to reduce the size of surface oil slicks and minimize impacts of oil on sensitive shoreline ecosystems and marine life. Scientists from NOAA's Earth System Research Laboratory (ESRL) and the Cooperative Institute for Research in Environmental Sciences (CIRES) found the black smoke that rose from the water's surface during the controlled burns pumped more than 1 million pounds of black carbon (soot) pollution into the atmosphere. This is an amount roughly equal to the total black carbon emissions normally released by all ships that travel the Gulf of Mexico during a nine-week period. Publications⁴ from these findings will help improve information on the connection between human activities and air quality and the impacts to the Gulf region from this spill. These research activities support the NOAA service of providing forecast guidance for air quality that is based on weather prediction models. **(Goal: Weather-Ready Nation)**



Black smoke billows from a controlled burn of surface oil during the 2010 Deepwater Horizon oil spill. A new study by NOAA and the Cooperative Institute for Research in Environmental Sciences (CIRES) investigated the effects of the burn on air quality. Photo Credit: U.S. Coast Guard.

⁴ A. E. Perring, J. P. Schwarz, J. R. Spackman, R. Bahreini, J. A. de Gouw, R. S. Gao, J. S. Holloway, D. A. Lack, J. M. Langridge, J. Peischi, A. M. Middlebrook, T. B. Ryerson, C. Wameke, L. A. Watts, D. W. Fahey, Characteristics of black carbon aerosol from a surface oil burn during the Deepwater Horizon oil spill. *Geophysical Research Letters*, 38, L17809 (2011; <http://www.agu.org/pubs/crossref/2011/2011GL048356.shtml>).



BLUEFIN TUNA WEAK HOOK RESEARCH LESSENS BYCATCH MORTALITY

An 82 percent decline in the adult population of Atlantic bluefin tuna (*Thunnus thynnus*) resulted in a prohibition on directed commercial fishing of this species in the Gulf of Mexico (GOM). Concern continues though because of the high levels of spawning bluefin tuna bycatch and mortality by the GOM pelagic longline fleet when pursuing more profitable yellowfin tuna (*Thunnus albacores*). From 2008 to 2011, gear researchers with the Southeast Fisheries Science Center collaborated with industry leaders in the GOM to test the effectiveness of a new “weak hook” designed to reduce bluefin tuna bycatch. Relying upon the difference in overall size, weight and pulling strength between commercially caught bluefin and yellowfin tuna, the weak hook is designed to straighten and safely release a captured adult bluefin tuna. Direct catch comparisons were made between standard hooks and the new weak hooks over three fishing seasons and the results of the research showed that the weak hooks were capable of reducing bluefin tuna bycatch by 56.6 percent, with little difference in the catch of yellowfin tuna. This research demonstrates that progress toward sustainable fishing and recovery of a depleted species can be achieved through sound science and industry partnership. **(Goal: Healthy Oceans)**



An example of the weak hook designed to reduce bluefin tuna bycatch.

MORTALITY STUDIES PREDICT FUTURE THREATS TO COHO SALMON IN URBANIZING WATERSHEDS

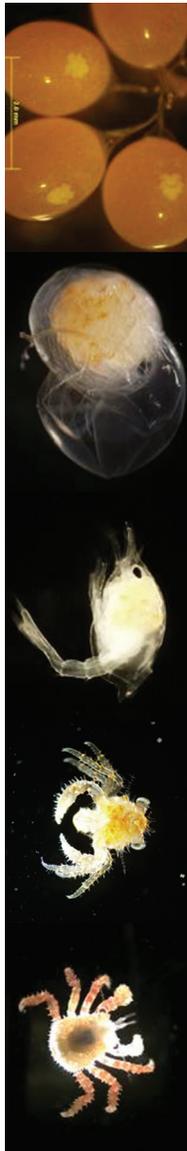
Urban waterways in coastal areas provide spawning habitats for important migratory marine species such as salmon. For over a decade, scientists in the Pacific Northwest have worked to solve the mystery of why adult Coho salmon are dying prematurely in urbanized watersheds when they return from the ocean to spawn. Researchers at the North West Fisheries Science Center and other federal, state, and tribal partners found that the seasonal Coho mortality is linked to toxic urban stormwater runoff. These results indicate a potential for steep salmon declines in response to future changes in land cover. As an important sentinel for ecological resiliency, salmon health and survival can be used to monitor the effectiveness of current land-use strategies, and in turn inform sound coastal planning to ensure healthy habitats for an economically valuable species. **(Goal: Healthy Oceans)**



A typical example of pre-spawn mortality. This female Coho salmon was found dead and unspawned in Longfellow Creek, West Seattle. Photo credit: Northwest Fisheries Science Center.

OCEAN ACIDIFICATION REDUCES SURVIVAL AND GROWTH IN EARLY LIFE HISTORY STAGES OF COMMERCIAL CRAB SPECIES

Crustacean (crab and shrimp) fisheries account for approximately \$1.2 billion in domestic U.S. landings, with king crab and Tanner crab accounting for approximately \$86 million and \$85 million respectively. Recent research conducted at the National Marine Fisheries Service, Alaska Fisheries Science Center, Kodiak Laboratory suggests that predicted increases in oceanic CO₂ levels over the next century may negatively affect the early life history stages of crustaceans. More acidic seawater reduces the availability of calcium based minerals which are used by marine organisms to build shells. The



Red king crab (*Paralithodes camtschaticus*) early life history stages (top to bottom): embryo, hatching, larvae, glaucothoe, and juvenile. Photo credit: Kodiak Laboratory (Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA).

results of this laboratory research may have important implications for future fisheries and the coastal economies that depend on this source of income. **(Goal: Healthy Oceans)**

SCIENCE TO SUPPORT DAM REMOVAL DECISION IN THE WEST

In March 2012, the Secretary of the Interior, in consultation with the Secretary of Commerce, will decide whether to remove four dams on the Klamath River in the western United States based on two criteria: whether dam removal will advance restoration of salmonid fisheries and whether it is in the public interest. The Southwest Fisheries Science Center (SWFSC) has been heavily involved for almost three years in a major interagency effort to produce research to inform the decision. Based on results of a model developed by the SWFSC⁵, dam removal is projected to increase average annual salmon harvest during 2012-2061 by 43 percent for the ocean commercial and recreational fisheries, 8 percent for the in-river recreational fishery, and 50 percent for the tribal fishery. Based on economic models developed by the SWFSC, these harvest increases are expected to yield increases in jobs, labor income, and net economic value to all fisheries. Dam removal would also yield important social and cultural as well as economic benefits to Klamath Basin tribes associated with enhanced subsistence, ceremonial, and commercial use of fish. Measuring the social and economic impacts of habitat restoration efforts will provide policy makers with key information to develop effective management plans. **(Goal: Healthy Oceans)**

DECLINE IN GREAT LAKES PHYTOPLANKTON LINKED TO INVASIVE SPECIES

The unanticipated expansion of invasive zebra and quagga mussels has resulted in an unplanned decrease in phytoplankton, with implications for Great Lakes fisheries. Phytoplankton serves as the base of the food chain in the lakes, which supports a substantial fishery. This study suggests that it may be time to re-examine traditional lake-wide nutrient strategies to recognize the changed nature of habitats and ecological processes in the Great Lakes.⁶ NOAA's Great Lakes Environmental Research Laboratory teamed with the University of Michigan to show that from the 1980s-2000s, nutrient management strategies were successful in reducing excessive phytoplankton blooms in Lakes Huron and Michigan. **(Goal: Resilient Coastal Communities and Economies)**

NEW SPACE WEATHER PREDICTION MODEL IMPROVES NOAA'S FORECAST SKILL

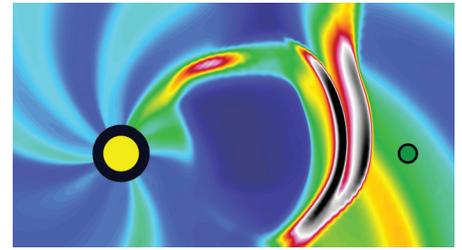
NOAA's Space Weather Prediction Center is now using a sophisticated forecast model, WSA-Enlil, which substantially improves predictions of the impacts on Earth from space weather - measurements of the state of the Sun used to forecast changes in the environment between the Sun and

⁵ L. Thorsteinson, S. VanderKooi, W. Duffy, Eds., *Proceedings of the Klamath Basin Science Conference, Medford, Oregon, February 1-5, 2010* (U.S. Geological Survey Open-File Report 2011).

⁶ M. A. Evans, G. Fahnenstiel, D. Scavia, *Incidental oligotrophication of North American Great Lakes*. *Environ. Sci. Technol.*, 45(8), 3297-3303 (2012).



the Earth (e.g., sunspots, solar flares).⁷ Variations in space weather have the potential to disrupt virtually every major public infrastructure system, including transportation systems, power grids, telecommunications, and global positioning systems. Before this model was available, forecasters could predict timing of space weather impacts within a 30-hour window, on average. The new model allows forecasters to narrow that window to 12 hours, so that electric power grid and satellite operators and airlines can take better protective measures to limit outages and long-lasting damage. Better space weather forecasts offer additional protection for people and the technology-based infrastructure we use daily in our economy. **(Goal: Weather-Ready Nation)**



A space weather forecast model, which forecast the arrival of three successive coronal mass ejections - big blasts of plasma from the Sun - in early August, 2011.

SEA GRANT INTEGRAL TO DEVELOPMENT OF FIRST FEDERALLY-APPROVED OCEAN SAMP

Rhode Island Sea Grant has worked with the state’s Coastal Resources Management Council to develop and implement a coastal and marine spatial planning tool known as Special Area Management Plans (SAMPs). SAMPs are scientific ecosystem-based management plans that comprehensively review ecosystems, regulatory environments and social structures, then propose guidance on regulations to be adopted by the state. Such guidance is closely tailored to the unique ecological and social conditions of each place. The Ocean SAMP also focuses on the state’s interest in developing renewable offshore energy from wind. **(Goal: Resilient Coastal Communities and Economies)**

VARIATIONS IN CLIMATE LEAD TO PRECIPITATION EXTREMES OVER THE SOUTHEAST UNITED STATES

Since the early 1980s, an area of high pressure over the North Atlantic has increasingly influenced rainfall patterns over the southeastern United States. The position of this subtropical high plays an important role in whether the southeast receives a drought or deluge. The region experiences more rainfall when the subtropical high dips to the southeast and less precipitation when the high moves to the northwest. Research supported by the NOAA Climate Program Office discovered that the variance of weather extremes has been enhanced in recent decades by a persistent intensification of the high, along with a westward march of its western edge. An understanding of the current state of climate as well as the likely impacts of that climate is important for regional stakeholders in the southeast. **(Goal: Climate Adaptation and Mitigation)**

⁷ V. Pizzo, G. Millward, A. Parsons, D. Biesecker, S. Hill, D. Odstrcil, Wang-Sheeley-Arge–Enlil cone model transitions to operations, *AGU Space Weather*, 9, S03004 (2011).



MULTI-USE OF AIRBORNE LIDAR DATA FOR SAFE NAVIGATION AND COASTAL SCIENCE

NOAA has recently implemented new production procedures for using light detection and ranging (lidar) data to map the National Shoreline depicted on the Nation's nautical charts. Lidar systems use pulsed lasers in aircraft to measure ranges to the surface below. The range measurements are combined with position and orientation data to obtain accurate, 3D spatial coordinates (e.g., latitudes, longitudes, and heights) of points on the Earth's surface, including below the water surface in the case of bathymetric lidar. The National Shoreline mapped using these procedures supports safe marine navigation, as well as legal boundary determination. Application of lidar data is also useful to ongoing research in a wide range of coastal science and management applications through NOAA's Integrated Ocean and Coastal Mapping (IOCM) initiative – for example, mapping and monitoring of coral reefs, and analyzing shoreline erosion rates and other related effects of climate change. **(Goal: Resilient Coastal Communities and Economies)**



RESEARCH & DEVELOPMENT STATS

The Office of Management and Budget (OMB) defines the conduct of Research and Development (R&D) as "...creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications." NOAA tracks the conduct of R&D as well as assets which support R&D, including equipment and facilities. Those assets include vessels that support research missions and high performance computing infrastructure.

The following charts display the scope and nature of R&D at NOAA:

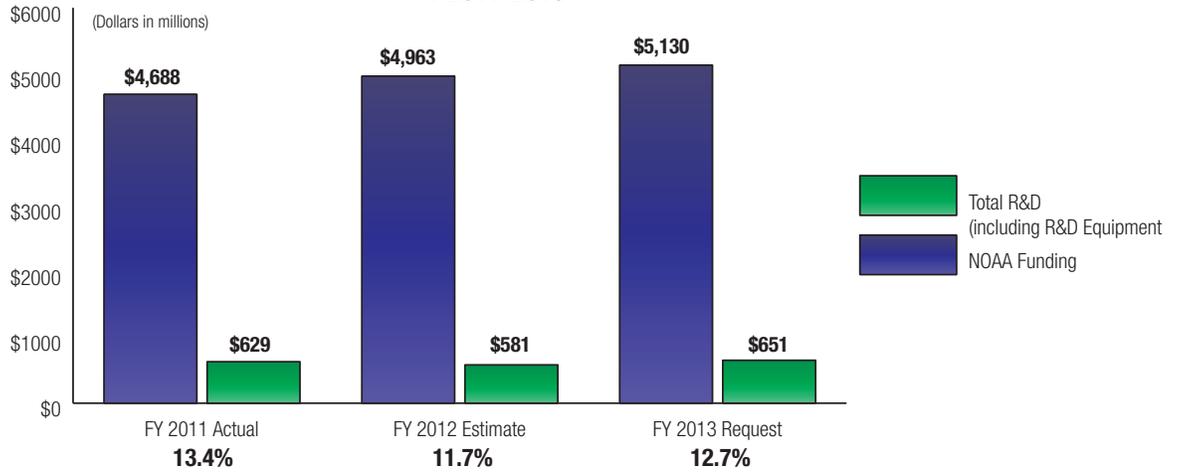
- NOAA requests a total of \$651 million for R&D funding (including R&D Equipment) in FY 2013.
- R&D funding (including R&D Equipment) represents 12.7 percent of total NOAA funding for FY 2013.
- NOAA's R&D budget is comprised of 8.6 percent Development, 69.4 percent Research, and 22.0 percent Equipment.
- 73.0 percent of NOAA's R&D funding, excluding equipment, is intramural and 27.0 percent is extramural.
- NOAA's Office of Oceanic & Atmospheric Research (OAR) manages 62 percent of NOAA's R&D funding, excluding equipment. The remainder of R&D is distributed among the operational Line Offices.

Definitions

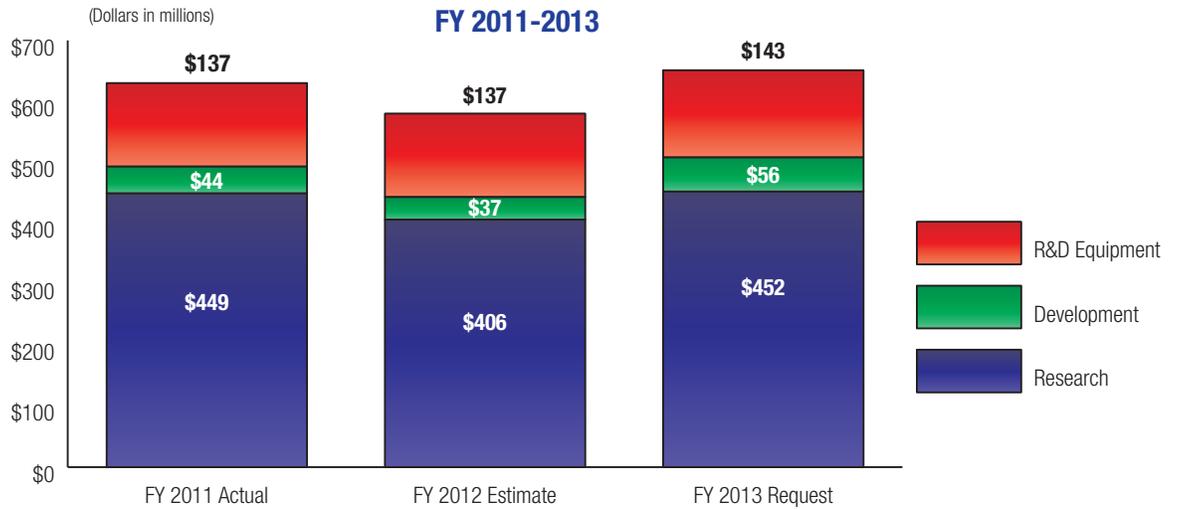
- Research and Development includes those activities aimed at broadening general knowledge about scientific topics, applied investigations on specific topics, and development of new technologies.
- Research is defined as systematic study to gain knowledge or understanding about a topic.
- Development is defined as systematic application of knowledge or understanding, directed toward the production of useful materials, devices, and systems or methods, including design, development, and improvement of prototypes and new processes to meet specific requirements.
- Equipment includes infrastructure to support Research & Development such as the Office of Marine and Aviation Operations (OMAO) research vessels, High Performance Computers, and laboratory equipment.
- Extramural research is that which is ultimately performed by non-Federal entities and may include private companies, academia, non-profits, state and local governments, etc.
- Intramural research is that which is performed by Federal Agencies.



NOAA R&D COMPARED TO TOTAL FUNDING FY 2011-2013



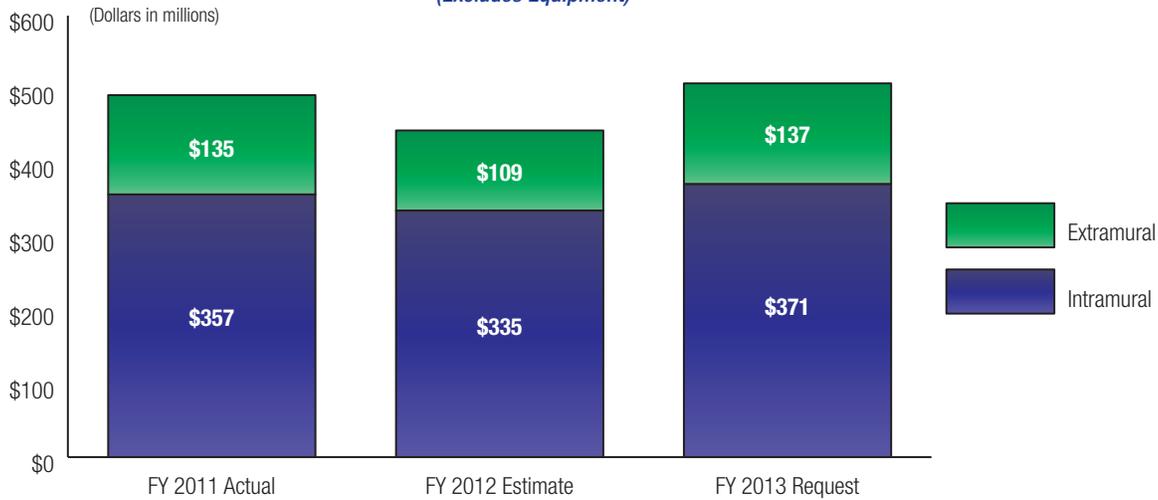
NOAA R & D FUNDING BY TYPE FY 2011-2013





R&D FUNDING BY EXTRAMURAL & INTRAMURAL, FY 2011-2013

(Excludes Equipment)



FY 2013 R&D FUNDING BY LINE OFFICE

