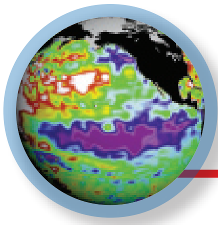
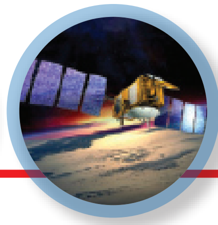
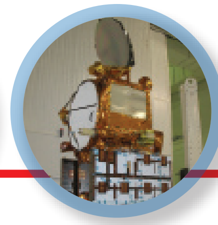
National Aeronautics and Space Administration



Ocean Surface Topography Mission/Jason-2

science writers' guide

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NASA Web sites
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http://sealevel.jpl.nasa.gov/mission/ostm.html

NOAA Web site
http://www.osd.noaa.gov/ostm/index.htm

CNES Web site
http://www.aviso.oceanobs.com/en/missions/future-missions/jason-2/index.html

EUMETSAT Web site
http://www.eumetsat.int/Home/Main/What_We_Do/Satellites/Jason/index.htm?l=en

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Cover image credit: EUMETSAT

SCIENCE OVERVIEW

The Ocean Surface Topography Mission (OSTM)/Jason-2 is an international satellite mission that will extend into the next decade the continuous climate record of sea surface height measurements begun in 1992 by the joint NASA/Centre National d'Etudes Spatiales (CNES) Topex/Poseidon mission and continued in 2001 by the NASA/CNES Jason-1 mission. This multi-decadal record has already helped scientists study global sea level rise and better understand how ocean circulation and climate change are related.

Developed and proven through the joint efforts of NASA and CNES, high-precision ocean altimetry measures the distance between a satellite and the ocean surface to within a few centimeters. Accurate observations of variations in sea surface height—also known as ocean topography—provide scientists with information about the speed and direction of ocean currents and heat stored in the ocean. This information, in turn, reveals global climate variations.

With OSTM/Jason-2, ocean altimetry has come of age. The mission will serve as a bridge to transition collection of these measurements to the world's weather and climate forecasting agencies, which will use them for short- and seasonal-to-long-range weather and climate forecasting.

Sea level rise is one of the most important consequences and indicators of global climate change. From Topex/Poseidon and Jason-1 we know mean sea level has risen by about three millimeters (0.12 inches) a year since 1993. This is about twice the estimates from tide gauges for the previous century, indicating a possible recent acceleration. OSTM/Jason-2 will further monitor this trend and allow us to better understand year-to-year variations.

The speedup of ice melting in Greenland and Antarctica is a wild card in predicting future sea level rise. Measurements from Jason-1 and OSTM/Jason-2, coupled with information from NASA's Gravity Recovery and Climate Experiment (Grace) mission, will provide crucial information on the relative contributions of glacier melting and ocean heating to sea level change.

Earth's oceans are a thermostat for our planet, keeping it from heating up quickly. More than 80 percent of the heat from global warming over the past 50 years has been absorbed by the oceans. Scientists want to know how much more heat the oceans can absorb, and how the warmer water affects Earth's atmosphere. OSTM/Jason-2 will help them better calculate the oceans' ability to store heat.

The mission will also allow us to better understand large-scale climate phenomena like El Niño and La Niña, which can have wide-reaching effects.

OSTM/Jason-2 data will be used in applications as diverse as, for example, routing ships, improving the safety and efficiency of offshore industry operations, managing fisheries, forecasting hurricanes and monitoring river and lake levels.

OSTM/Jason-2's primary payload includes five instruments similar to those aboard Jason-1, along with three experimental instruments. Its main instrument is an altimeter that precisely measures the distance from the satellite to the ocean surface. Its radiometer measures the amount of water vapor in the atmosphere, which can distort the altimeter measurements. Three location systems combine to measure the satellite's precise position in orbit. Instrument advances since Jason-1 will allow scientists to monitor the ocean in coastal regions with increased accuracy, almost 50 percent closer to coastlines that are home to nearly half of Earth's population than before. OSTM/Jason-2 is designed to last at least three years.

After its launch from California's Vandenberg Air Force Base aboard a United Launch Alliance Delta II rocket, OSTM/Jason-2 will be placed in the same orbit (1,336 kilometers) as Jason-1 at an inclination of 66 degrees to the equator. It will repeat its ground track every 10 days, covering 95 percent of the world's ice-free oceans. A tandem mission with Jason-1 will further improve tide models in coastal and shallow seas and help scientists better understand the dynamics of ocean currents and eddies.

OSTM/Jason-2 is a collaboration between NASA; the National Oceanic and Atmospheric Administration (NOAA); CNES; and the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT). CNES is providing the spacecraft, NASA and CNES are jointly providing the payload instruments and NASA's Launch Services Program at the Kennedy Space Center is responsible for Delta II launch management and countdown operations. After completing the on-orbit commissioning of the spacecraft, CNES will hand over its operation and control to NOAA. NOAA and EUMETSAT will generate the near-real-time products and distribute them to users. NASA's Jet Propulsion Laboratory, Pasadena, Calif., manages the mission for NASA's Science Mission Directorate in Washington.

INSTRUMENTS

The Ocean Surface Topography Mission/Jason-2 payload consists of five fully redundant primary science instruments and three "passenger" instruments:

PRIMARY INSTRUMENTS:

- **The Poseidon-3 radar altimeter**, provided by Centre National d'Etudes Spatiales (CNES), is the mission's main instrument. It accurately measures the distance between the satellite and the mean sea surface. Derived from the Poseidon-2 altimeter on Jason-1, it emits pulses at two frequencies (13.6 and 5.3 gigahertz) to the ocean surface and analyzes very precisely the time it takes for the signals to return.

- **The Advanced Microwave Radiometer** (**AMR**), provided by NASA, is an advanced version of the microwave radiometer that flew on Jason-1. It measures radiation from Earth's surface at three frequencies (18, 21 and 37 gigahertz) to determine the amount of water vapor present in the atmosphere. This water vapor affects the accuracy of altimeter measurements by delaying the time it takes for the altimeter's signals to make their round trip to the ocean surface and back.

- **The Doppler Orbitography and Radio-positioning Integrated by Satellite** (**DORIS**), provided by CNES, determines the satellite's precise position in orbit to within a few centimeters, information that is critical in interpreting altimetry data. It works by receiving signals in two frequencies from a ground network of 60 beacons all over the globe. The relative motion of the satellite generates a shift in signal frequency, called the Doppler shift, which is measured to determine the satellite's velocity and position.

- **The Global Positioning System Payload** (**GPSP**), provided by NASA, is a tracking system that enhances DORIS measurements by using triangulated data from the U.S. Global Positioning System constellation of navigation satellites to determine the satellite's precise position in orbit. It is nearly identical to the Turbo Rogue Space Receiver on Jason-1. Its data are used to continuously track the satellite's trajectory.

- **The Laser Retroreflector Array** (**LRA**), provided by NASA, is an array of mirrors that allow the satellite to be tracked with centimeter accuracy by 40 satellite laser ranging stations on the ground. By analyzing the round-trip time of the laser beam, the satellite's precise position in orbit can be determined. It is an exact copy of the LRA on Jason-1.

PASSENGER INSTRUMENTS:

- **The Environment Characterization and Modelisation-2** (**Carmen-2**) **instrument**, provided by CNES, will study the effects of radiation in the satellite's environment on advanced components.
- **The Time Transfer by Laser Link** (**T2L2**) **instrument**, provided by CNES, will use a laser link to compare and synchronize remote ground clocks with high accuracy.
- **The Light Particle Telescope** (**LPT**), provided by Japan, will study radiation in the satellite's environment.

In addition to their own scientific objectives, these passenger instruments are expected to improve the performance of **DORIS**.

OSTM/Jason-2 Spacecraft

FEATURE STORIES

NEW MISSION HELPS OFFSHORE INDUSTRIES DODGE SWIRLING WATERS

Hurricanes aren't the only hazards spinning up in the Gulf of Mexico—they have a liquid counterpart in the waters below called ocean eddies. Offshore industries, such as oil and gas companies, have to keep a weather eye on both. In a worst-case scenario, they could find themselves caught between the two. Satellite altimetry is helping government and industry manage those risks.

Satellite ocean observations are a standard part of marine operations around the world. Keeping track of local currents is critical for daily operations. And in the Gulf of Mexico, that means knowing the location of the Loop Current and its dangerous eddies.

Part of the Gulf Stream, the Loop Current begins as a large flow of warm water from the Caribbean. It heads up into the eastern part of the Gulf of Mexico, then turns south and finally moves out through the Straits of Florida. Deep and fast moving, the Loop Current often breaks off and forms strong, clockwise rotating eddies called anticyclones that travel westward into the Gulf. The currents along the outer edges of the Loop Current, as well as these eddies, have been clocked at speeds as high as three to four knots (three to five miles per hour), comparable to the fastest ocean currents ever observed.

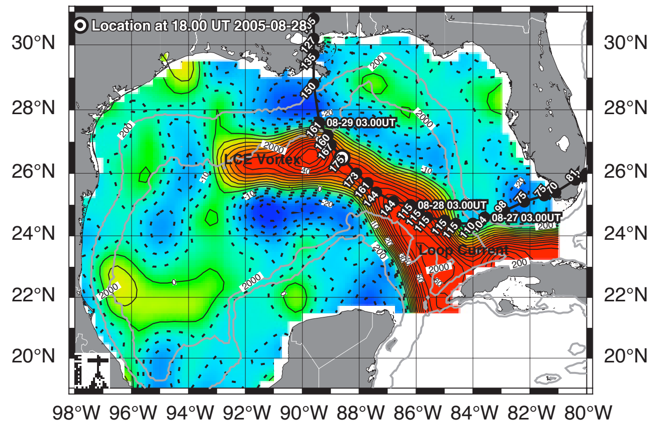
Because the Loop Current and its eddies are warmer, and thus higher in surface elevation, than the surrounding waters, they are easily spotted by satellite altimeters, such as those aboard Jason-1 and the Ocean Surface Topography Mission/Jason-2. To see what the altimeters see, many offshore operators turn to Research Professor Robert Leben and his colleagues at the University of Colorado's Center for Astrodynamics Research in Boulder. They use the latest satellite measurements of sea surface height from Jason-1 and two other satellite altimeters to create maps showing the location, direction and speed of currents in the Gulf of Mexico. Free and available on the center's Web site, these maps are used by a wide variety of people involved in marine operations, along with scientists, fishermen and sailors. As soon as measurements from the Ocean Surface Topography Mission/Jason-2 are available, they will be included in the data sets as well.

For oil companies, knowing where the Loop Current and its eddies are and are likely to go is critical. "The rate to rent a drilling rig in deep water is about $300,000 a day," said George Forristall, of Forristall Ocean Engineering, Inc., Camden, Maine. "If you've planned an operation and the

An artist depicts the OSTM/Jason-2 satellite. Credit: NASA current is too strong, you have to shut down and spend that money without accomplishing anything. Once an oil field is found and a permanent facility is built, it floats on the surface and connects to the bottom by pipes called risers. You can protect those risers by streamlining them, but that costs a lot, too. Your riser design has to be appropriate for the currents you expect at your site."

To plan and design rigs and oil platforms for the future, oil companies would like to be able to anticipate the sea conditions a particular facility may encounter in the Gulf of Mexico over its lifetime. A consortium of about 20 different companies, along with the U.S. Minerals Management Service, has asked Leben and Forristall to develop a model to help determine what the risks from strong currents may be.

"We're constructing a 1,000-year-long statistical simulation of the Loop Current and its eddies," said Leben. "While we have only 20 to 30 years of observations, using computer simulation and the right statistical methods, we can figure out how the current and eddies behave and then simulate a longer period of time."



Hurricane Katrina's maximum sustained winds increased to 150 knots (173 mph) on August 28, 2005, as it moved over and along the loop current and eddy vortex, areas of highest heat content in the Gulf of Mexico. Real-time information from satellite altimeters is used to detect the loop current and its eddies, which appear as sea surface highs greater than 15 centimeters (about 6 inches) of elevation shown by the red color in the image. Credit: NASA/JPL/University of Colorado

"It's a modeling technique called Monte Carlo simulation," he continued. "For example, even if you don't know exactly how dice work, after a number of throws, you can figure out the probabilities for certain numbers to appear."

"The idea," said Forristall, "is to map the Gulf. There are some places where there have only been a few eddies in the past. With our artificial time series, we'll be able to fill in the gaps. We'll be able to see what is the likelihood of an eddy occurring in a particular spot."

Another goal of the effort is to get a better understanding of the relationship between the Loop Current and hurricanes, which grow stronger as they pass over warm water. Leben said results of the 1,000-year Loop Current simulation will be combined with simulations of how the Loop Current's warm surface waters and eddies effect hurricane intensification. "This will give us a way to assess the likelihood of warm Loop Current events and intense hurricanes and plan for them."

"These tandem ocean/atmosphere events are rare, but they do occur," said Leben. "During Hurricane Katrina, when both strong eddy currents and a category-five hurricane hit the oil patch in the north-central Gulf of Mexico, a total of five rigs and 18 platforms were lost and many more were damaged."

Knowing more about the Loop Current and its spinning offspring will help oil companies and other offshore industries plan for the future. "Nothing designed by man will ever be perfectly safe from natural hazards," said Forristall, "but the better we understand the environment, the better we will be able to manage risk at an acceptable cost."

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Related Links:

Ocean Surface Topography from Space – The OSTM/Jason-2 Mission *http://sealevel.jpl.nasa.gov/mission/ostm.html*

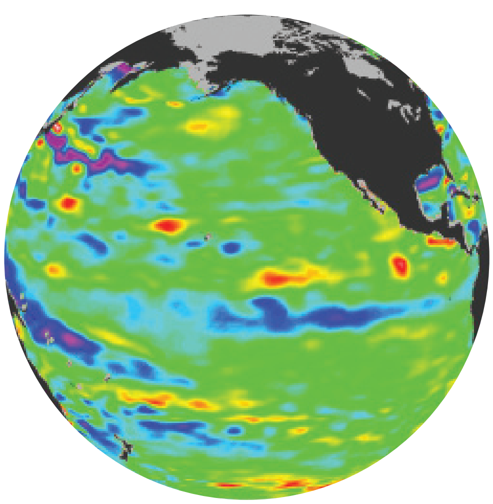
FEATURE STORIES

NASA MISSION TO BE CRYSTAL BALL INTO OCEANS' FUTURE, MIRROR TO THE PAST

Imagine the lives that could be saved from flash floods and drought, the millions of dollars in fuel costs that could be avoided for fishing vessels, and the homes that could be spared from the effects of coastline erosion if only scientists could more accurately predict the dynamics of Earth's often unpredictable oceans. Armed with increasingly more accurate forecasts, weather services in countries across the globe are improving time-sensitive warnings of cyclones, flooding and high sea winds, as well as information about when it's safe to scuba dive, sail, or fish 48 kilometers (30 miles) or more beyond coastlines.

NASA and several other international organizations have joined forces to launch into space a sort of "crystal ball" to give scientists an extended satellite data record. The data can be used to improve ocean forecasting and to test the accuracy of climate and weather models using knowledge of past ocean conditions.

The Ocean Surface Topography Mission/Jason-2 is made up of next-generation, state-of-the-art, satellite-based instruments that will provide a global view of Earth's sea surface height every 10 days. Scientists will use these data to create complex simulations of what ocean currents, tides and eddies may do. Similarly, the data will also allow scientists to "hindcast"—that is, to test how accurate the simulations of past ocean forecasts were.



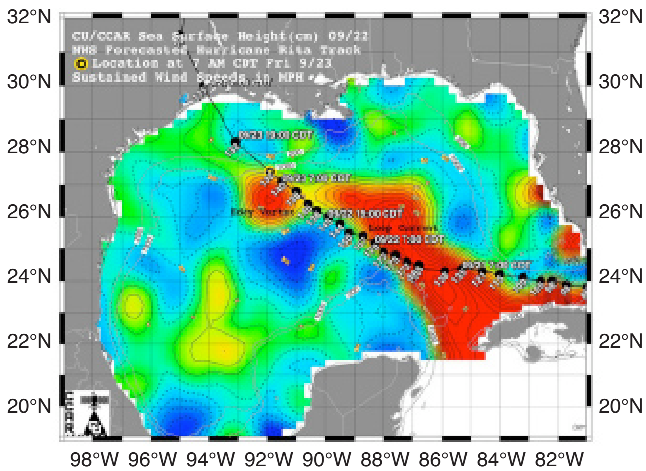
Data of sea-level heights from early February, 2007, by the Jason-1 satellite showed that the tropical Pacific Ocean had transitioned from a warm (El Niño) to a cool (La Niña) condition during the prior two months. The beginnings of a La Niña are indicated by the blue area (in the center of the image along the equator) of lower than normal sea level (cold water). Credit: NASA/JPL Ocean Surface Topography Science Team

"To borrow from an old saying, 'it's the motion of the ocean' that is of most interest to us as scientists, and our ability to forecast it and learn lessons from it," said one of the mission's science team members, Robert Leben, an associate research professor at the University of Colorado in Boulder. "The further we can look into the past with the record of ocean measurements, the better we can predict future events. That is to say, if one day we can look back at a 20- or 30-year data record, we can more accurately say what will happen in the next 10 or 15 years because we will have a data record that indicates trends or correlations that lead to specific or expected outcomes. OSTM/Jason-2 is going to add to knowledge we've gained from the Topex/Poseidon and Jason-1 missions and put us closer to this goal."

To create the simulations, also called models, that predict ocean behavior, scientists combine information about factors such as wind speed, wave height, sea level pressure, temperature and air pressure with data gathered by satellite altimeters that measure the height of the oceans' surface (more commonly known as sea level). Radar altimeters, like those on OSTM/Jason-2, measure sea level by sending a radar pulse to the sea surface and clocking the time it takes for the signal to reflect back. All these data are fed into a computer program, allowing scientists to see into the future or to gain further insight from simulations of the past when hindcasting.

OSTM/Jason-2 is slated to orbit Earth and collect this important data set for at least three to five years. It will provide scientists with significantly more data to test their models, and extend the record of information available about ocean circulation and how the ocean affects global climate. During the mission's lifetime, scientists hope to add to what they currently understand about weather phenomena like El Niño and La Niña. During an El Niño, the eastern Pacific Ocean temperatures near the equator are warmer than normal, while during La Niña the same waters are colder than normal. These fluctuations in the Pacific Ocean temperatures can wreak havoc on climate conditions around the Pacific and beyond, leading to increased rainfall or drought.

"A longer period of data from the OSTM/Jason-2 mission can tell scientists more about how El Niño and La Niña are coupled not only to seasonal or yearly changes but to decade-to-decade oscillations of the Pacific Ocean," said Leben. "Owing to data from the mission's forerunner Topex/Poseidon and Jason-1 missions, scientists have already determined that decadal fluctuations



Sea level associated with Hurricane Rita in the Gulf of Mexico during September 2005, based on altimeter data from four satellites including NASA's Topex/Poseidon and Jason-1. Red indicates a strong circulation of much warmer waters, which can feed energy to a hurricane. The red area stands 35 to 60 centimeters (about 13 to 23 inches) higher than the surrounding waters. The path of the hurricane is indicated by the black line. Credit: NASA/JPL/University of Colorado

in the Pacific enhance the frequency and intensity of shorter-term ocean events such as El Niño and La Niña. Just think of what more we'll learn as we collect future data from OSTM/Jason-2."

Knowing more about the oceans' behavior, including what El Niño and La Niña climate conditions may bring, will improve our quality of life and benefit industry. "For example, forecasts of ocean currents can predict the oceans' salt balance, which can be used to study the global water cycle," said science team member Yi Chao, a satellite oceanographer at NASA's Jet Propulsion Laboratory in Pasadena, Calif. "Water evaporates from the ocean surface, and water from rivers and land-runoff cycle back into the ocean, so more precise forecasts of these movements will boost our knowledge of and ability to manage our most precious natural resource. This mission can help us determine the role of ocean circulation in completing the global water cycle."

"On the commercial front, offshore industries such as oil and gas exploration and production require accurate information about ocean circulation to minimize the impacts from strong currents and eddies," said Leben. (see "New Mission Helps Offshore Industries Dodge Swirling Water," page 4). "Search and rescue officials, marine operators, recreational boaters, and marine animal researchers all benefit from increasingly more accessible near real-time data."

"The Topex/Poseidon and Jason-1 missions got us off to a great start," said Chao. "When the two missions operated together in tandem, they doubled the coverage area and sharpness of the resolution of the sea level data so that we could 'see' more detail. This higher resolution is critical for extending the global sea level data into coastal zones, which of course are regions of great societal importance. OSTM/Jason-2 will provide another opportunity for a tandem mission with Jason-1."

Leben pointed out that with this new mission, the focus moves from research objectives to practical ways to apply the data that benefit society in tangible and essential ways.

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Related Links:

Ocean Surface Topography from Space – El Niño and La Niña
http://sealevel.jpl.nasa.gov/science/el-nino.html

Ocean Surface Topography from Space – The OSTM-Jason-2 Mission
http://sealevel.jpl.nasa.gov/mission/ostm.html

NASA Satellites and Computer Models Contribute to Ocean Forecasting System
http://www.nasa.gov/missions/earth/oceans3d.html

FEATURE STORIES

NASA MISSION TO ANSWER LINGERING QUESTIONS FROM DEEP BLUE SEA

Ocean tides and currents across the globe still hold within their watery grasp the key to unanswered questions about our planet.

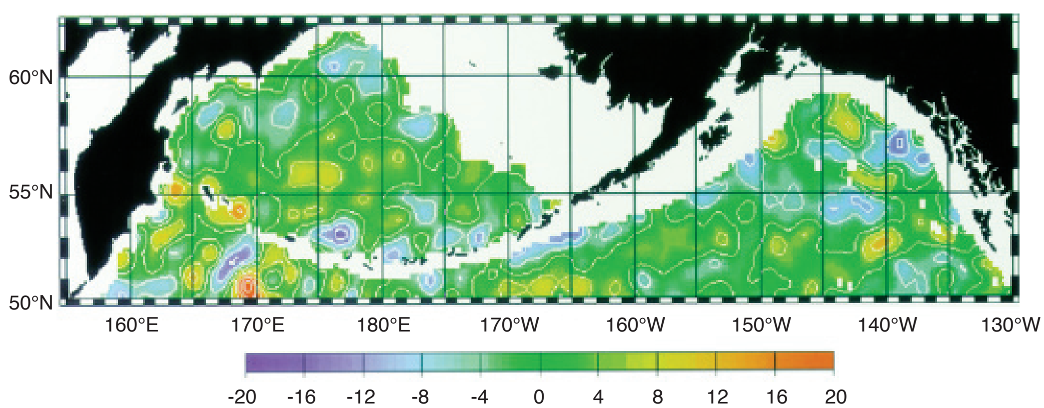
Scientists hope a new follow-on mission to the Jason-1 and Topex/Poseidon satellite missions, equipped with the latest high-tech instruments, will bring them closer to answering broad fundamental questions: How does ocean circulation vary from season to season, from year to year and from decade to decade? How much can the ocean change from natural and human-induced causes? In what ways does the ocean impact human activities?

The answers are essential when we consider that oceans cover 70 percent of Earth's surface. Their contents feed billions of humans and animals alike, support whole industries, and are the source of the rain and snow that feed the world's freshwater supply. The Ocean Surface Topography Mission/Jason-2 is poised to help scientists answer these and other critical scientific questions about ocean phenomena.

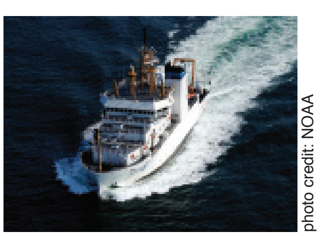
The mission, OSTM/Jason-2 for short, is set to offer a sea change in what we know about some of the prevailing weather and climate patterns driven by changes in oceanic tides and currents.

With Topex/Poseidon and Jason-1, NASA has measured the height of the ocean surface—more commonly known as sea level—with an accuracy of better than 2.5 centimeters (one inch) from an orbiting altitude of 1,336 kilometers (830 miles). This is comparable to measuring the thickness of a sheet of paper on the ground from the altitude of a commercial airliner. Sea level varies greatly over the world's oceans and is not a constant. Scientists want to learn more about how its fluctuations are related to ocean circulation, climate change, marine weather, flooding, drought, hurricane intensity and

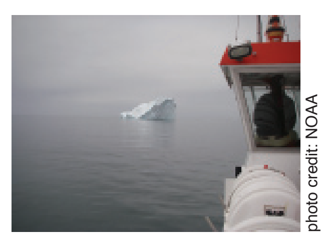
Bering Sea and Gulf of Alaska Sea-Surface Height Map of the Type Used by Marine Industry (Data obtained from the Topex/Poseidon and European Remote Sensing [ERS-2] Satellites)



Sea-Surface Height Deviations from Average (centimeters)
Data produced by Colorado Center for Astrodynamics Research



Ocean-current data help ship captains determine routes



Wave height information is essential for safe sailing in hazardous environments

Altimeter data from satellites in space are applied in practical ways to benefit society. Credit: NASA coastline erosion. The more scientists learn about ocean surface topography, as they will with OSTM/Jason-2, the better they can apply that knowledge to answer the remaining mysteries of the oceans.

Scientists know that Earth's climate system has experienced changes throughout its history. A record of ocean surface topography observations reflecting some of those changes exists for the last 15 years, thanks to Topex/Poseidon and Jason-1. However, this period accounts for relatively few moments in the planet's long history.

"The scientific community desperately needs much longer measurement records to begin to understand year-to-year and decade-to-decade changes in the ocean system," said OSTM/Jason-2 science team member Carl Wunsch, a professor at the Massachusetts Institute of Technology in Cambridge, Mass. "Of course, ultimately, our descendants will need to understand century-to-century and longer variability."

Scientists expect the mission's altimeters to offer added insight into ocean surface topography when combined with the accomplishments of the previous two missions. Mean sea level is an indicator of the amount of heat contained in a column of water from the ocean surface to the ocean floor. That heat is like the driver of a huge underwater truck that affects ocean currents as it goes. With the longer-term measurements to be captured by OSTM/Jason-2, scientists will be more in-tune with where the "driver" is going and why, how it interacts with other forces like wind and rain, and what may happen in the wake of changes in its route.

"OSTM/Jason-2 will provide a unique data history of sea level rise that will allow us to answer questions about the effects of global warming," said OSTM/Jason-2 science team member Dudley Chelton of Oregon State University in Corvalis, Ore. "This mission will also provide insight into the reason why most of the climate models underestimate the rate of sea level rise. This may be an indication that these models are underestimating other symptoms of global warming as well."

Less than four percent of ocean waters remain unaffected by humans. Through shipping, fishing, sewage and fertilizer run-off, pollution, oil spills, and auto and factory emissions, human activities are changing the chemistry of our oceans. Some of that human-induced change is combined with natural events that can also impact ocean temperatures, salinity, acidity and air pressure to influence sea surface height.

Just as humans affect oceans, oceans and related sea level likewise affect humans. Changes in sea level, like the incremental rises reported in recent years, can cause erosion of populated coastal areas, freshwater shortages, and disruption of the saltwater balance that can affect the seafood that feeds people all over the world.

With more thorough foresight into ocean circulation, specifically surface ocean currents, the fishing industry can reduce fuel costs by mapping more efficient sailing routes that consider the direction and speed of the oceans' course. Chelton believes that OSTM/Jason-2 will also lead to improved understanding of oceanic eddies and unexpected movements of jet-like ocean currents. "There is substantial evidence that these eddies play important roles in the fluctuation of the oceans' heat, momentum and various water properties," he said.

"Without this next generation of altimeters, there's almost no hope of ever understanding what is going on and what could happen," said Wunsch. "This new ocean surface topography mission is precisely what is needed as a next step in telling the oceans' story. With the technology this mission affords us and the information we can gain from it, we can take more action to enhance quality of life and protect the bodies of water that sustain us."

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Related Links:

Ocean Surface Topography from Space – The OSTM-Jason-2 Mission
http://sealevel.jpl.nasa.gov/mission/ostm.html

Ocean Surface Topography from Space – Topex/Poseidon Mission
http://sealevel.jpl.nasa.gov/mission/topex.html

Jason Monitors Increasing Ocean Levels
http://www.nasa.gov/missions/earth/jason_1.html

FEATURE STORIES

OCEAN SURFACE A BOON FOR EXTREME EVENT FORECASTS, WARNINGS

For humans in the path of destructive hurricanes and tsunamis, an accurate warning of the pending event is critical for damage control and survival. Such warnings, however, require a solid base of scientific observations, and a new satellite is ready for the job.

The Ocean Surface Topography Mission (OSTM)/Jason-2 adds to the number of eyes in the sky measuring sea surface and wave heights across Earth's oceans. The increased coverage will help researchers improve current models for practical use in predicting hurricane intensity, while providing valuable data that can be used to improve tsunami warning models.

"When it comes to predicting hurricane intensity, the curve in the last 40 years has been somewhat flat, with little advance in how to reduce error in predicted intensity," said Gustavo Goni, of the National Oceanic and Atmospheric Administration (NOAA) in Miami. Maps of sea surface height created from satellites, however, could help change the curve.

Satellites that measure sea surface height have been running operationally nonstop since November 1992. But more than one is needed to fly at the same time in order to identify all the features that could be responsible for intensification of tropical cyclones all over Earth. The OSTM/Jason-2 mission will help make the additional coverage possible.

NASA, university and NOAA investigators, including Goni, work to transform sea surface height information obtained from satellites, such as OSTM/Jason-2, into maps of ocean heat content. The maps can be used to help forecasters in their models to predict how hurricanes will strengthen.

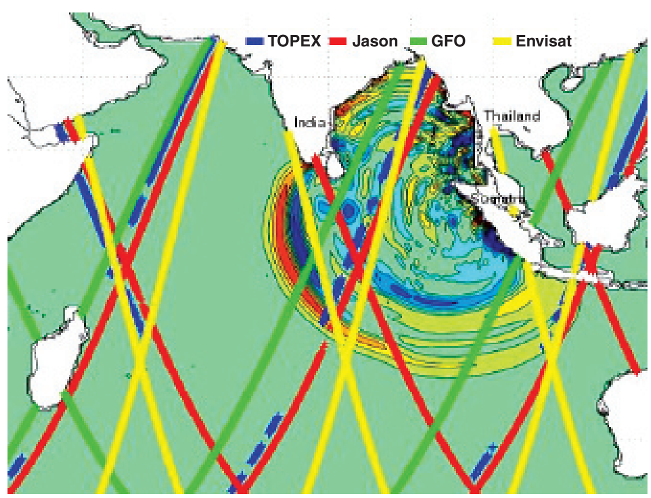
Determining heat content from sea surface height is possible because warm water is less dense and hence sits higher than cooler water. In some regions, such as inside and outside the Gulf Stream current, the temperature differences result in more than a one-meter (three-foot) difference in sea surface height. Goni and colleagues use this established concept to estimate from sea level variations how much heat is stored in the upper ocean in areas where hurricanes typically develop and intensify.

While sea surface height may not necessarily be the most significant parameter for hurricane intensity forecasts, researchers now know that if sea surface height is accounted for in current forecast models, error in forecasts for most intense storms is reduced. For weak storms, the reduction in error is not very significant. For storms in the strongest category 5 range—the heat content in the upper ocean derived from sea surface height becomes increasingly important. "This is a good thing, because these are the storms that produce the most damage," Goni said.

"OSTM/Jason-2 will help us to keep the necessary coverage that we need to identify ocean features that can be linked to tropical cyclone intensification, because with only one satellite we may miss some of them," Goni said.

Upper ocean heat content derived from sea surface height is now used in operational and experimental forecast models in all seven ocean basins where tropical cyclones exist.

In December 2004, two satellites happened to be in the right place at the right time, capturing the first space-based look at a major tsunami in the open ocean. Within two hours of a magnitude 9 earthquake in the Indian Ocean southwest of Sumatra, the Jason-1 and Topex/Poseidon satellites fortuitously passed over the path of the resulting tsunami as it traveled across the ocean. It measured the leading wave, traveling hundreds of miles per hour in the open ocean, at about 0.5 meters (1.6 feet) tall.



Satellites passed over the Indian Ocean tsunami of December 2004. Two of those satellites—Jason-1 and Topex/Poseidon—were equipped with altimeters that for the first time measured the height of a tsunami in the open ocean. Credit: NASA/JPL.

Wave height measurements like those of the Indian Ocean tsunami do not provide an early warning because the information is not relayed to ground stations in real time. That's the job of early warning systems operated by NOAA and other global organizations that currently employ a network of open-ocean buoys and coastal tide gauges. Sea surface height measurements of tsunamis can, however, help scientists test and improve ground-based models used for early warning. One such system developed at NASA's Jet Propulsion Laboratory (JPL), Pasadena, Calif., and undergoing tests at NOAA's Pacific Tsunami Warning Center, Ewa Beach, Hawaii, could become operational within about three years.

Most tsunamis are caused by undersea earthquakes. Using the JPL-developed system, when seismometers first identify and locate a large earthquake, scientists can use GPS measurements to search around the earthquake's source to see if land has shifted, potentially spurring a tsunami. Scientists can then immediately compile the earthquake's size, location, and land movement into a computer program that generates a model tsunami to determine the risk of a dangerous wave. After the wave passes, scientists can search through wave height data from satellites and verify what the model predicted.

"Satellite data play the crucial role of verifying tsunami models by testing real tsunami events," said JPL research scientist Tony Song. "If an earthquake generates a tsunami, does the satellite data match observations on the ground and model predictions?"

"One of the unique pieces of satellite observations is the large-scale perspective," said JPL research scientist Philip Callahan. Tsunamis can have waves more than 161 kilometers (100 miles) long. Such a wave would likely go unnoticed by an observer in a boat on the ocean's surface. But satellite altimeters like OSTM/Jason-2 can see this very long wave and measure its height to an accuracy of about 2.5 centimeters (one inch).

Scientists' ability to test tsunami warning models will be aided by the launch of OSTM/Jason-2. With the Topex/Poseidon mission now ended, the currently orbiting Jason-1 will soon be joined and eventually replaced by OSTM/Jason-2. This will help ensure that future tsunamis will also be observed by satellites as well as by buoys and tide gauges.

"The biggest value in satellite measurements of sea surface height is not in direct warning capability, but in improving models so when an earthquake is detected, you can make reliable predictions and reduce damage to property and people," Callahan said.

For more information on hurricane and tsunami research using satellite altimetry, contact:

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Related Links:

NASA Tsunami Research Makes Waves in Science Community
http://www.nasa.gov/topics/earth/features/tsunami-20080117.html

NASA/French Satellite Data Reveal New Details of Tsunami
http://www.nasa.gov/centers/jpl/news/jason-011105.html

Ocean Surface Topography from Space – The OSTM-Jason-2 Mission
http://sealevel.jpl.nasa.gov/mission/ostm.html

Ocean Surface Topography from Space – Topex/Poseidon Mission
http://sealevel.jpl.nasa.gov/mission/topex.html

FEATURE STORIES

NASA MISSION POISED TO HELP US GAUGE OUR RISING SEAS

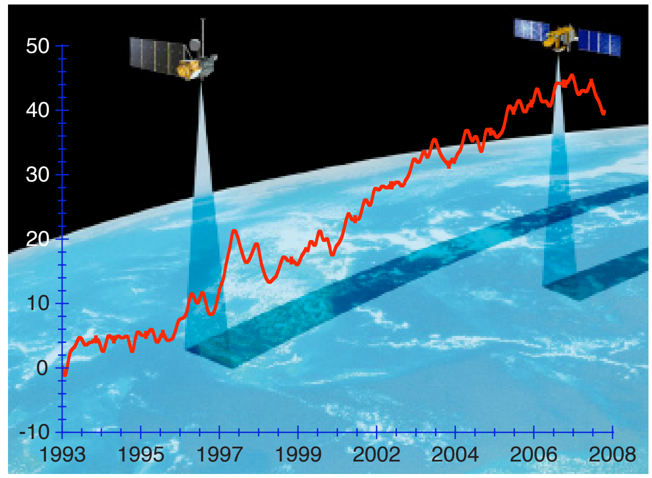
In economics, there's a metaphor that says "a rising tide lifts all boats," meaning overall improvement in the economy benefits everyone. While that's a good thing in economics, when it comes to our oceans, rising seas are a growing problem for all of us.

Global sea level has risen 20 centimeters (eight inches) in the past 100 years, and the rate of rise is predicted to accelerate as Earth warms. One obvious threat is inundation, loss of land to rising water. Melting ice from Greenland and Antarctica could raise sea level more than one meter (three feet) over the next century. Other consequences are more complex, but equally problematic—a warmer ocean can fuel more intense storms; environmental changes can adversely affect ocean life, such as coral reefs and fisheries; and alterations in ocean currents can trigger radical changes in Earth's climate.

The best hope for anticipating the future is to understand the past and present. For global sea level, the first step has been to measure it accurately, a challenge in itself. Records of global sea level in the past come from averaging tide gauge readings from many locations. But since the launch of the ocean altimeter Topex/Poseidon in 1992, followed by Jason-1 in 2001, scientists have had a precise measurement of the height of the global ocean every 10 days. Now the Ocean Surface Topography Mission/Jason-2 will continue this critical task.

"Without this data record, we would have no basis for evaluating change," said the new mission's project scientist, Lee-Lueng Fu, of NASA's Jet Propulsion Laboratory (JPL), Pasadena, Calif. He compares the global sea level record started by Topex/Poseidon to the continuous measurements of atmospheric carbon dioxide begun in the 1950s at the Mauna Loa Observatory in Hawaii. "The Mauna Loa data proved that carbon dioxide levels were indeed rising as had been predicted, and they were the basis for our understanding of the greenhouse effect," Fu said. "The height of the ocean is another fundamental measurement of our climate. The key is to have rigorous, well-calibrated data collected over a long period of time."

Satellite altimeter measurements of sea surface height do much more than document and quantify change. They're a



Global sea level has risen about 3 millimeters (0.1 inch) a year since Topex/Poseidon (on the left) began its precise measurement of sea surface height in 1993 and was followed by Jason-1 in 2001. In this graph, the vertical scale represents globally averaged sea level. Seasonal variations in sea level have been removed to show the underlying trend. Credit: University of Colorado

primary tool for understanding how the change is occurring and what the results for the planet may be.

"Sea level is showing the profound consequences of global warming," said Fu. "More than 80 percent of the heat from global warming has been absorbed by the ocean with the rest of it warming the atmosphere, land and melting ice." Warming water and melting ice are the two major factors that contribute to global sea level rise. Warm water expands and takes up more space than cold water. Melting glaciers and ice sheets add fresh water to the ocean, increasing its volume. "To predict what is going to happen in the future, you have to be able to separate the different contributors," Fu said.

Satellite altimetry is one of three key ocean-observing systems being used in combination to identify the individual sources of sea level change. The other two are the gravity-sensing twin Gravity Recovery and Climate Experiment (Grace) satellites and a global array of Argo floats operated by the National Oceanic and Atmospheric Administration, commonly known as NOAA.

"The altimeter measures the total sea level, which includes any changes due to heating or cooling, water coming in or going out, and seasonal changes," explained Don Chambers, a research scientist at the University of Texas's Center for Space Research in Austin.

"The Grace satellites sense changes in mass, the result of water added to the ocean by melting glaciers or ice sheets, precipitation and rivers, or removed through evaporation."

Subtract the change in sea level due to mass, measured by Grace, from the total sea level measured by Jason-1—and soon by OSTM/Jason-2—and the answer should reveal just how much of the change is due to heat, or thermal expansion.

For a closer look at ocean heat, scientists turn to the temperature and other measurements made by the thousands of Argo floats. "The Argo profilers give us a good representation of the upper 1,000 meters (3,281 feet) of the ocean," Chambers said. "And since altimeters and Grace measure the total ocean, using what we know about the upper ocean from Argo gives us an idea about what's going on below in the deep ocean, about which we have little data."

"We know the basics of sea level rise very well," said JPL oceanographer and climate scientist Josh Willis. But several critical elements still need to be resolved, he stressed. "Everything doesn't quite add up yet."

For example, in a recent study, Willis, Chambers and their colleague Steven Nerem of the Colorado Center for Astrodynamics Research in Boulder, compared the amount of ocean warming during 2003-2007 observed by the Argo buoys with the amount of warming calculated by combining Grace and Jason-1 altimeter data. While the two measurements closely matched with regard to seasonal ups and downs, they didn't agree at all on the total amount of warming. In fact, the Argo data showed no warming at all, while the combined Jason and Grace data did.

This is a mystery to the scientists, which they hope to resolve soon. Willis added there is no observing system yet for the deep ocean, and it could hold some real surprises.

The record of sea surface height begun by Topex/Poseidon is now 16 years old. As it grows longer with the continued health of Jason-1 and the launch of OSTM/Jason-2, some uncertainties about sea level rise are much closer to resolution.

"We are getting a better understanding of our measurement systems and just how much we can trust our numbers," said Fu. "We know that sea level is not rising everywhere at the same pace, and we are learning more every year about the natural variability in the ocean over short and long periods. We are learning more about the exchange of heat between the ocean and the atmosphere, the driving force of our climate."

So will we have disastrous sea level rise? If so, when?

We don't know yet, said Fu, but he does not rule out finding the answer.

For more information on sea level rise research, contact:

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Related Links:

Ocean Surface Topography from Space – The OSTM/Jason-2 Mission
http://sealevel.jpl.nasa.gov/mission/ostm.html

OSTM/JASON-2 SPOKESPERSONS

Charon Birkett is an associate research scientist with the Earth System Science Interdisciplinary Center at the University of Maryland College Park. Her specialty is applying satellite radar altimetry to study continental surface waters. As a principal investigator on the Ocean Surface Topography Mission/Jason-2 science team, she will use the data to improve the understanding of the hydraulics and dynamics of river basins and monitor lake and reservoir water levels around the world for use in agricultural and climate investigations. Through collaborative efforts, OSTM/Jason-2 data will also be combined with gravity data from NASA's Gravity Recovery and Climate Experiment to test the ability to predict the onset of river basin flooding.

Hans Bonekamp is an ocean mission scientist and OSTM/Jason-2 project scientist at the European Organisation for the Exploitation of Meteorological Satellites, more commonly known as EUMETSAT, in Darmstadt, Germany. His research interest is operational satellite oceanography.

Anny Cazenave is a senior scientist at the Laboratoire d'Etudes en Géophysique et Océanographie Spatiale and Centre National d'Etudes Spatiales in Toulouse, France. Her research interests are satellite geodesy and geosciences applications (gravity field, Earth rotation, precise positioning from space, temporal changes in gravity, sea level variations at regional and global scales, and land hydrology from space). She is a principal investigator for sea level change on the OSTM/Jason-2 mission. On the mission, she will explore present-day sea level variability and trends at global and regional scales, as well as natural and human-caused mechanisms that "force" climate to change.

Yi Chao is a principal scientist at NASA's Jet Propulsion Laboratory in Pasadena, Calif. Chao's research interest is physical oceanography. As part of the OSTM/Jason-2 science team, Chao will explore ocean modeling and data assimilation, and applications of satellite altimeter data in coastal oceans.

Dudley Chelton is a distinguished professor of oceanic and atmospheric sciences at Oregon State University in Corvallis, Ore. His research specialty is physical oceanography, and he is a principal investigator for the OSTM/Jason-2 mission.

John A. Church is a principal research scientist at the Centre for Australian Weather and Climate Research, a partnership between Australia's Commonwealth Scientific and Industrial Research Organisation and the Bureau of Meteorology, in Hobart, Tasmania, Australia. With a research focus on sea-level rise and climate change, Church is a co-investigator on the OSTM/Jason-2 mission. He will focus on sea-level rise.

Lee-Lueng Fu is a senior research scientist at NASA's Jet Propulsion Laboratory in Pasadena, Calif. His research interest is physical oceanography. As the NASA project scientist for OSTM/Jason-2, Fu has collaborated with the partner agencies to develop the science requirements for the mission and has participated in the selection of the principal investigators for the mission's science team. He will coordinate the calibration and validation of the mission's measurements and facilitate publication of the mission's science results in open literature. He also serves as a science spokesperson for the mission.

Gustavo Jorge Goni is an oceanographer at the National Oceanic and Atmospheric Administration's Atlantic Oceanographic and Meteorological Laboratory in Miami. His research focus is physical oceanography. Goni's OSTM/Jason-2 role will include transitioning science derived from the altimetry missions into practical, operational applications.

Gregg Jacobs is the Ocean Dynamics and Prediction Branch head at the Naval Research Laboratory at NASA's Stennis Space Center, Miss. His research interests are physical oceanography, mesoscale circulation, assimilation, and ocean environment prediction. Jacobs' science group will be working to process the OSTM/Jason-2 sea surface height observations to reduce latency to a minimum while maintaining accuracy for ocean circulation prediction. The data will be integrated into global ocean models to represent the general wide-ranging front and eddy field. Jacobs expects resulting forecast efficiency to provide benefit to commercial and research activities.

Bob Leben is a research professor at the University of Colorado's Colorado Center for Astrodynamics Research in Boulder. His research specialty is operational oceanography and outreach, with a focus on Gulf of Mexico and mesoscale oceanography. As part of the OSTM/Jason-2 science team, Leben will work on a project called Operational Ocean Circulation Monitoring for the Study of Mesoscale Dynamics.

Fabien Lefevre is a researcher at Collecte Localisation Satellites, Direction Océanographie Spatiale in Ramonville-St-Agne, France. His research focus is physical oceanography. As part of the OSTM/Jason-2 science team, Lefevre will work on the development and marketing of oceanographic applications for offshore needs, using satellite data (altimetry in particular).

Pierre Yves Le Traon is a researcher at the French Research Institute for Exploitation of the Sea in Brest, France. His research specialty is physical oceanography, satellite and in-situ observing systems, operational oceanography. His role with the OSTM/Jason-2 mission is to research mesoscale and submesoscale dynamics, joint use of OSTM/Jason-2 and Argo in-situ data in operational oceanography systems, otherwise known as ocean forecasting.

John Lillibridge is a physical oceanographer at the National Oceanic and Atmospheric Administration's Laboratory for Satellite Altimetry in Silver Spring, Md. His research interests are physical oceanography and climate change. He is the NOAA project scientist for OSTM/Jason-2.

Eric Lindstrom is program scientist for oceanography in the Science Mission Directorate at NASA Headquarters in Washington. He is a program scientist for the OSTM/Jason-2 mission.

Yves Menard is the OSTM/Jason-2 project scientist at the Centre National d'Etudes Spatiales, the French space agency, in Toulouse, France. His research interests are physical oceanography, satellite altimetry and in-situ calibration and validation of satellite observations.

Laury Miller, a physical oceanographer, is chief of the National Oceanic and Atmospheric Administration's Center for Satellite Applications and Research Lab for satellite altimetry in Silver Spring, Md. His research interests are satellite altimeter measurements to study equatorial dynamics, climate change and sea level rise. Miller is a member of the OSTM/Jason-2 science team.

Steve Nerem is a professor at the University of Colorado in Boulder. His research interests are physical oceanography, atmospheric chemistry, long-term sea level change and variations in the global water cycle. Nerem is a principal investigator on OSTM/Jason-2.

Thierry Penduff is a research scientist at the Centre National de la Recherche Scientifique in Grenoble, France. His research interest is physical oceanography.

Bob Stewart is a professor of oceanography at Texas A&M University in College Station, Texas. As part of the OSTM/Jason-2 mission, Stewart will oversee outreach and improvement of teaching oceanography at all levels.

Stan Wilson is a senior scientist at the National Oceanic and Atmospheric Administration's Satellite & Information Service in Silver Spring, Md. His research interests are physical oceanography, satellite oceanography and operational oceanography. Wilson is an advisor to NOAA on the OSTM/Jason-2 mission to help ensure that the joint NOAA/EUMETSAT Jason-3 initiative is ready for launch in late 2012, enabling a six-month overlap with OSTM/Jason-2 during the last six months of its planned five-year life.

Carl Wunsch is the Cecil and Ida Green Professor of Physical Oceanography at the Massachusetts Institute of Technology in Cambridge, Mass. His research specialties are physical oceanography, climate and paleo-climate. His role with the OSTM/Jason-2 mission is to use observations from the satellite's instruments to determine ocean circulation and its variability in combination with general circulation models.

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