Recent Advances in NOAA Altimetry Outreach & Education

Laury Miller[1], John Lillibridge[1], Eric Leuliette[1], Walter Smith[1], Karen Marks[1], & Lori Brown[2]

1. NOAA Laboratory for Satellite Altimetry
2. StormCenter Communications, Inc.

Talk Outline

- New Satellite Altimetry Web Pages (Jason Program, Sea Ice, Bathymetry, Sea Level Rise)
- NOAA View
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- Twitter
- NOAA Science on a Sphere
- Bottom Topography From Altimetry in MH370 Search Area

Jason Program Web Pages

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Laboratory for Satellite Altimetry (LSA)

The LSA specializes in the application of satellite altimetry to a broad array of climate and weather related issues, including global and regional sea level rise, coastal and open-ocean circulation, weather prediction — from hurricane intensity forecasting to El Niño and La Niña events -- and monitoring the changing state of the Arctic Ocean. The following are some primary areas of focus:

Jason Altimeter Program

- With the planned launch of Jason-3 in 2015, NOAA and its operational European partner, EUMETSAT, will assume primary responsibility for maintaining the more than 22-year TOPEX/Jason series of high accuracy, global sea level observations used to monitor ocean circulation and sea level rise. The LSA is the science focal point for the Jason Program within NOAA. Read more

Jason Users

Jason Ocean Altimetry: Benefits to the Nation

The Earth's oceans and atmosphere are inextricably linked. Only from space can we observe the vast oceans on a global scale and monitor critical changes in ocean currents, sea surface height, and heat storage. Since 1992, U.S. and European partners have jointly developed and operated the series of ocean altimetry satellites to provide precise, continuous global measurements: Jason-2 is the satellite currently on orbit; Jason-3 is scheduled for launch in March 2015 to provide uninterrupted data continuity. These data, in conjunction with data from current and next-generation geostationary and polar-orbiting satellites, are used operationally by government agencies and the private sector, to make more accurate weather predictions over land and ocean, from hurricane intensity forecasting to inter-annual events such as El Niño and La Niña. The bottom line? Ocean weather models in some cases will be substantially degraded and in others – such as those used in search & rescue and oil spill response - cease functioning if altimetry observations are not available, putting lives and property at risk. The following are some of the applications and end users that depend on the ocean weather models that data from Jason makes possible:

Weather – Ready Nation:

Hurricane Forecasting

The National Hurricane Center uses Jason data to derive ocean heat content to improve hurricane intensity forecasting as much as 3 days in advance. This improved information aids in planning evacuations, thus saving lives and property. (Image: ocean heat content map based on Jason data shows Katrina intensifying to Category 5 hurricane when passing over Loop Current).
End Users – National Weather Service (NWS), Federal Emergency Management Agency (FEMA), Department of Homeland Security (DHS), U.S. Navy, news organizations, state and local disaster managers.

High Wave Warnings

The NWS provides operational high wave warnings in the open ocean based in part on Jason observations that save lives and property.
End Users – USCG, U.S. Navy, NWS, commercial ship operators, cruise ship operators, commercial fisherman, offshore oil platform operators, Federal and State coastal managers.

El Niño/La Niña Seasonal Forecasting

The NWS uses Jason observations to initialize seasonal El Niño/La Niña forecasts which provide early warnings of droughts in some regions and excessive precipitation elsewhere. Persistent El Niño conditions can cause weaker than normal upwelling and lower biological production. These conditions can affect Pacific Ocean ecosystems and valuable West Coast fisheries.
End Users – NWS, DHS, U.S. Navy, Department of the Interior, news organizations, State and local disaster managers, agriculture sector, Federal and State wildfire fighting agencies.

Healthy Oceans:

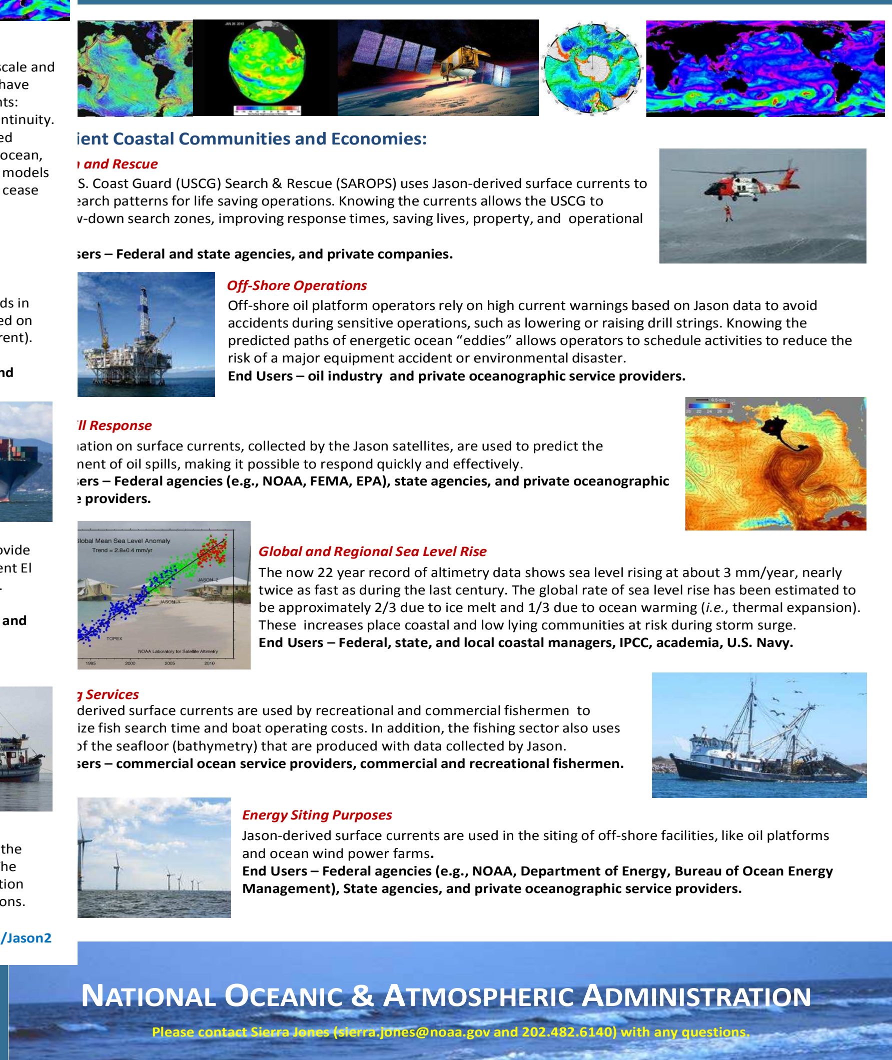
Fisheries and Trust Species Management

Jason data used to map surface currents are also used in ecosystem models to help scientists and policy makers understand how changes in the environment affect fish stocks. NOAA's National Marine Fisheries Service (NMFS) uses sea surface height to provide essential data on ocean fronts and eddies to identify and forecast habitat to help understand and protect species of interest like the northern fur seal, Loggerhead turtles, and Pacific albacore tuna.
End Users – NMFS, State agencies, Sea Grant Institutions, management councils.

Ocean Hypoxia Dead Zones

Multi-decade declines in oxygen (hypoxia) have been observed in the coastal waters off the West Coast and Gulf of Mexico, causing serious disruption to the marine environment. The phenomena are influenced by air and water-borne pollution and changing ocean circulation patterns monitored and investigated with ocean models initialized with Jason observations.
End Users – Federal and State coastal managers, academia, Sea Grant Institutions.

For more information, please visit: http://www.ospo.noaa.gov/Operations/Jason2



ient Coastal Communities and Economies:

and Rescue

S. Coast Guard (USCG) Search & Rescue (SAROPS) uses Jason-derived surface currents to earch patterns for life saving operations. Knowing the currents allows the USCG to v-down search zones, improving response times, saving lives, property, and operational

sers – Federal and state agencies, and private companies.

Off-Shore Operations

Off-shore oil platform operators rely on high current warnings based on Jason data to avoid accidents during sensitive operations, such as lowering or raising drill strings. Knowing the predicted paths of energetic ocean "eddies" allows operators to schedule activities to reduce the risk of a major equipment accident or environmental disaster.
End Users – oil industry and private oceanographic service providers.

ll Response

ation on surface currents, collected by the Jason satellites, are used to predict the nent of oil spills, making it possible to respond quickly and effectively.
ers – Federal agencies (e.g., NOAA, FEMA, EPA), state agencies, and private oceanographic providers.

Global and Regional Sea Level Rise

The now 22 year record of altimetry data shows sea level rising at about 3 mm/year, nearly twice as fast as during the last century. The global rate of sea level rise has been estimated to be approximately 2/3 due to ice melt and 1/3 due to ocean warming (*i.e.*, thermal expansion). These increases place coastal and low lying communities at risk during storm surge.
End Users – Federal, state, and local coastal managers, IPCC, academia, U.S. Navy.

g Services

derived surface currents are used by recreational and commercial fishermen to ize fish search time and boat operating costs. In addition, the fishing sector also uses of the seafloor (bathymetry) that are produced with data collected by Jason.
sers – commercial ocean service providers, commercial and recreational fishermen.

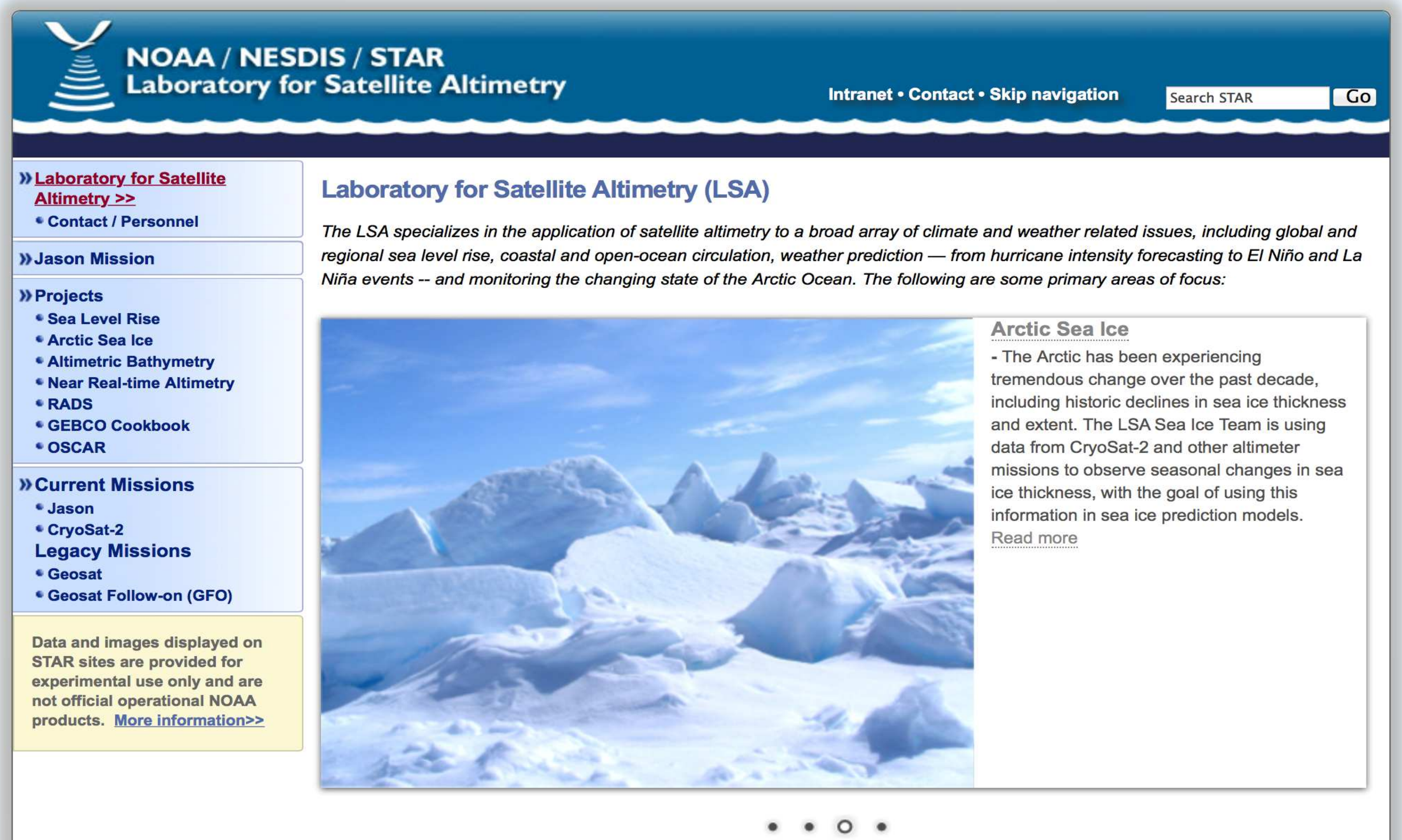
Energy Siting Purposes

Jason-derived surface currents are used in the siting of off-shore facilities, like oil platforms and ocean wind power farms.
End Users – Federal agencies (e.g., NOAA, Department of Energy, Bureau of Ocean Energy Management), State agencies, and private oceanographic service providers.

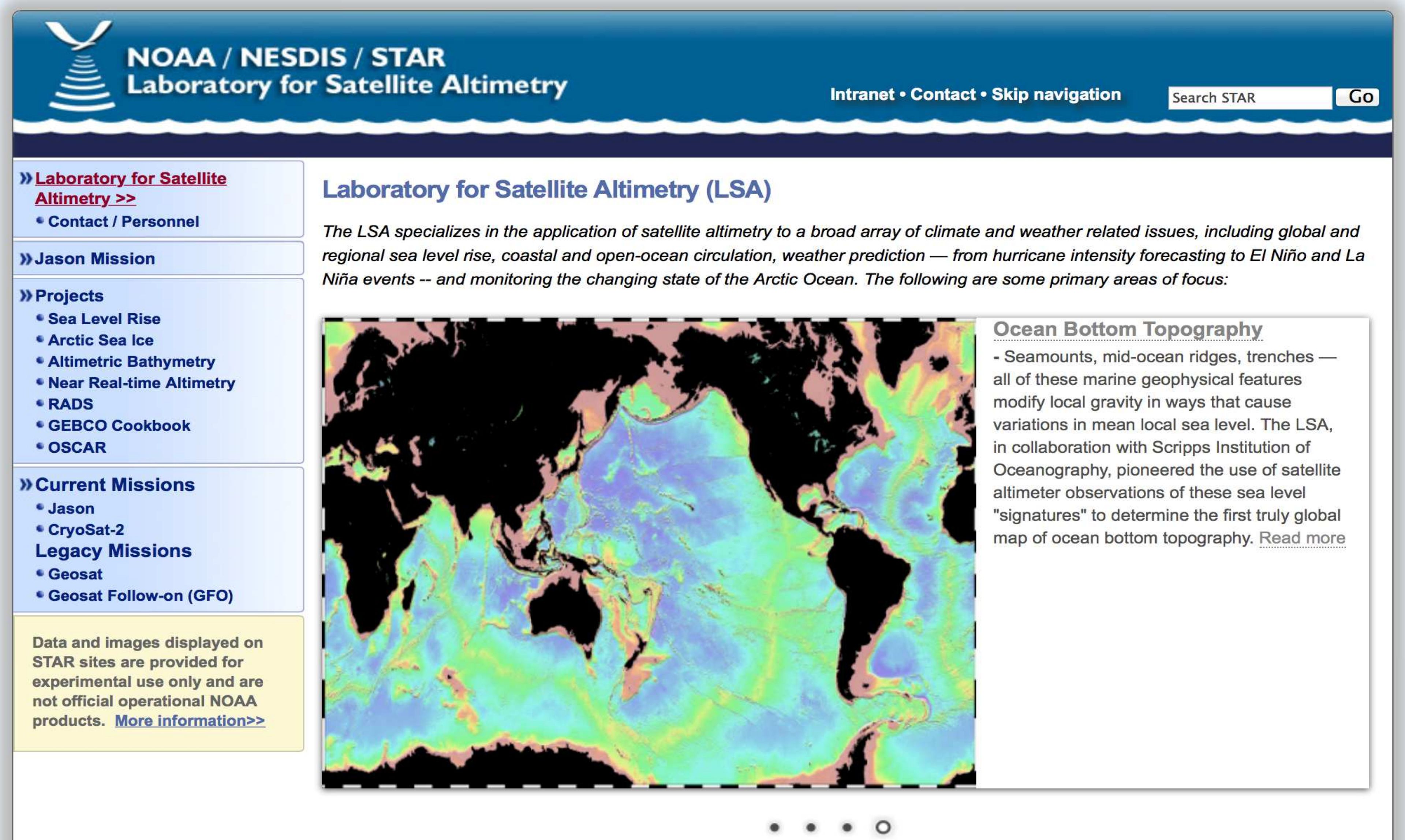
NATIONAL OCEANIC & ATMOSPHERIC ADMINISTRATION

Please contact Sierra Jones (sierra.jones@noaa.gov and 202.482.6140) with any questions.

Sea Ice Program Web Pages



Bathymetry Program Web Pages



Sea Level Rise Web Pages

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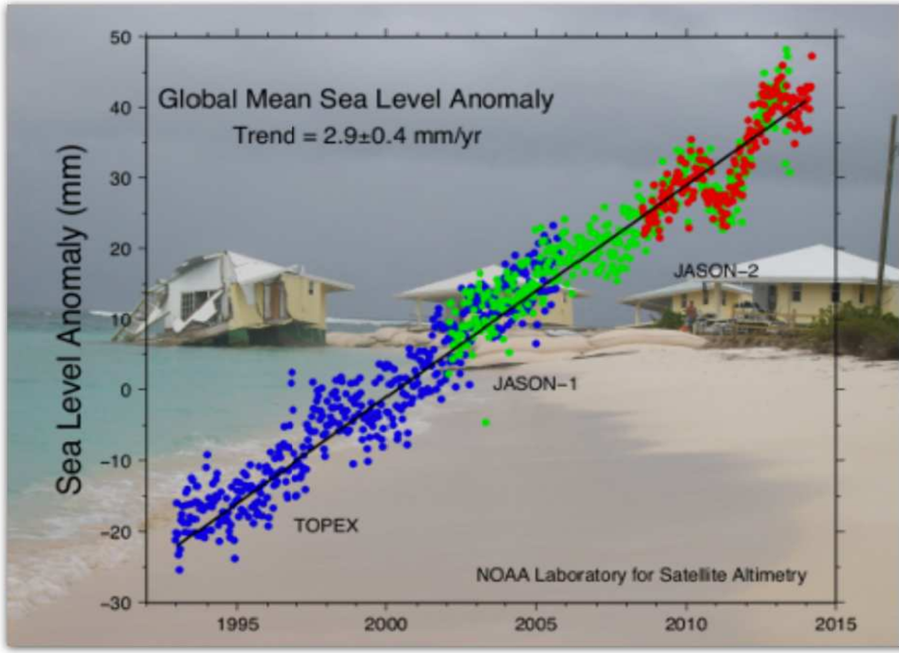

Sea Level Rise

- The Jason global mean record shows sea level rising at about 3 mm/year, nearly twice as fast as during the last century. Research into the causes of sea level rise, through the addition of ice melt water, ocean warming (thermal expansion), and changes in ocean circulation is a major Lab activity. Read more

Global Sea Level Rise Data

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Laboratory for Satellite Altimetry / Sea Level Rise

Sea level rise

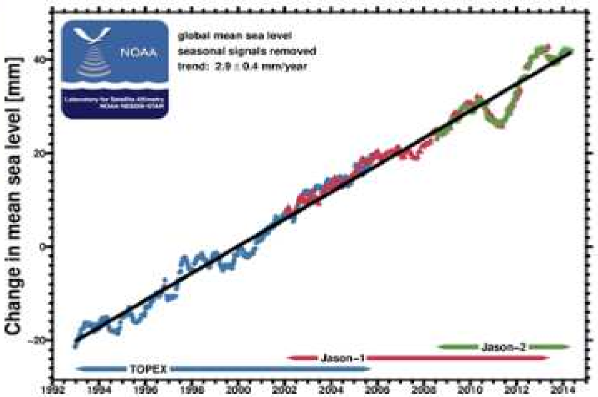
One of the most significant potential impacts of climate change is sea level rise that may cause inundation of coastal areas and islands, shoreline erosion, and destruction of important ecosystems such as wetlands and mangroves. As global temperatures increase, sea level rises due to a thermal expansion of upper layers of the ocean and melting of glaciers and ice sheets.

The measurement of long-term changes in global mean sea level can provide an important corroboration of predictions by climate models of global warming. Satellite altimeter radar measurements can be combined with precisely known spacecraft orbits to measure sea level on a global basis with unprecedented accuracy. A series of satellite missions that started with TOPEX/Poseidon (T/P) in 1992 and continued with Jason-1 (2001–2013) and Jason-2 (2008–present) estimate global mean sea level every 10 days with an uncertainty of 3–4 mm.

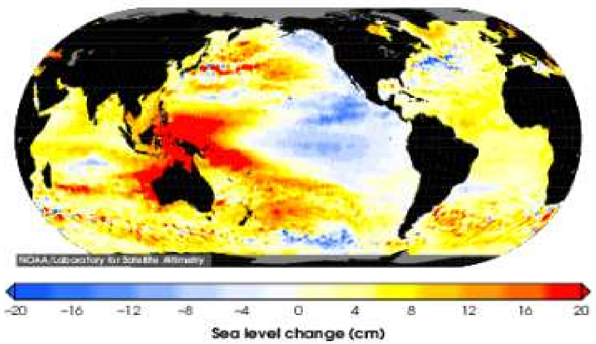
Jason-2, launched 20 June 2008, is a joint effort between NOAA, the National Aeronautics and Space Administration, France's Centre National d'Etudes Spatiales (CNES) and the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT).

The latest mean sea level time series and maps of regional sea level change can be found on this site.

Global mean sea level from TOPEX/Poseidon, Jason-1, and Jason-2



Total sea level change since 1993



Global Mean Sea Level Series

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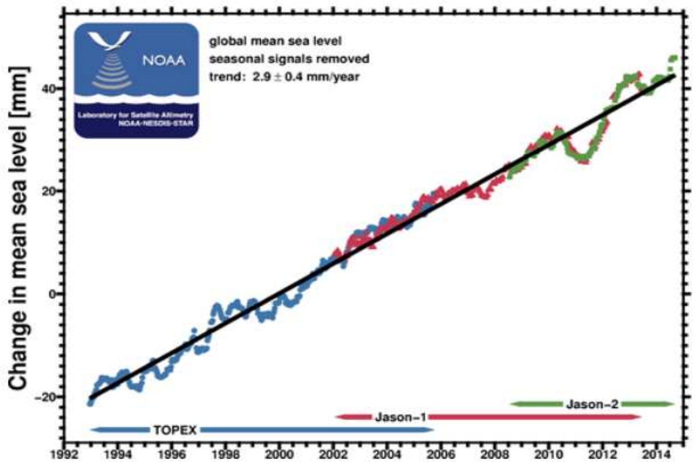
Laboratory for Satellite Altimetry / Sea Level Rise

The following tables provide estimates of sea level rise based on measurements from satellite radar altimeters. Plots and time series are available for TOPEX/Poseidon (T/P), Jason-1, and Jason-2, which have monitored the same ground track since 1992, and for most of the altimeters that have operated since 1991, including T/P, Jason-1, Jason-2, ERS-2, GFO, and Envisat.

Only altimetry measurements between 66°S and 66°N have been processed. An inverted barometer has been applied to the time series. The estimates of sea level rise do not include glacial isostatic adjustment effects on the geoid, which are modeled to be +0.2 to +0.5 mm/year when globally averaged.

Global sea level time series

Global mean sea level from TOPEX/Poseidon, Jason-1, and Jason-2



Regional sea level time series data and plots

Region	TOPEX, Jason-1, and Jason-2		Multiple altimeters	
	Seasonal signals retained	Seasonal signals removed	Seasonal signals retained	Seasonal signals removed
global mean sea level	Text (CSV) (22 kB) NetCDF (19 kB) pdf (93 kB) png (95 kB)	Text (CSV) (22 kB) NetCDF (19 kB) pdf (93 kB) png (84 kB)	Text (CSV) (47 kB) NetCDF (35 kB) pdf (116 kB) png (119 kB)	Text (CSV) (47 kB) NetCDF (35 kB) pdf (116 kB) png (97 kB)

Global Sea Level Rise Maps

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Laboratory for Satellite Altimetry / Sea Level Rise

Products / Sea level rise maps

The following maps provide estimates of sea level rise based on measurements from satellite radar altimeters. The local trends were estiamted using data from TOPEX/Poseidon (T/P), Jason-1, and Jason-2, which have monitored the same ground track since 1992.

An inverted barometer has been applied. The estimates of sea level rise do not include glacial isostatic adjustment effects on the geoid, which are modeled to be +0.2 to +0.5 mm/year when globally averaged.

Map of sea level rise from TOPEX, Jason-1, and Jason-2

Download local sea level trends as a COADS-compliant NetCDF file (465 kB).
Download local sea level trends as an ASCII file (6 mB).
Download local sea level trends as a Google Earth kml file (2 kB).

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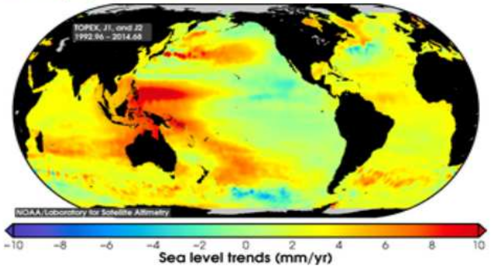

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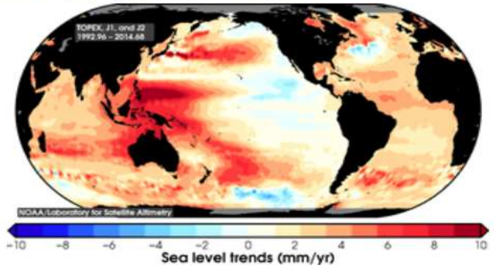

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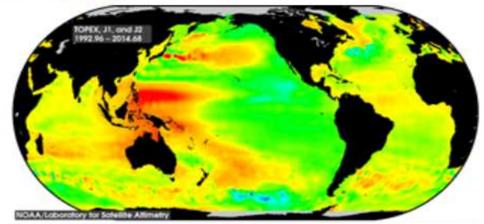
A 251 kB png opens in a new window.



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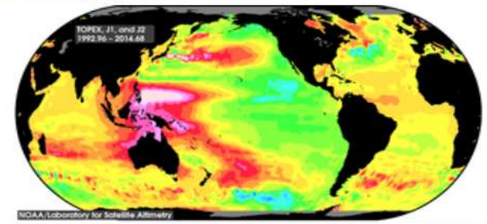
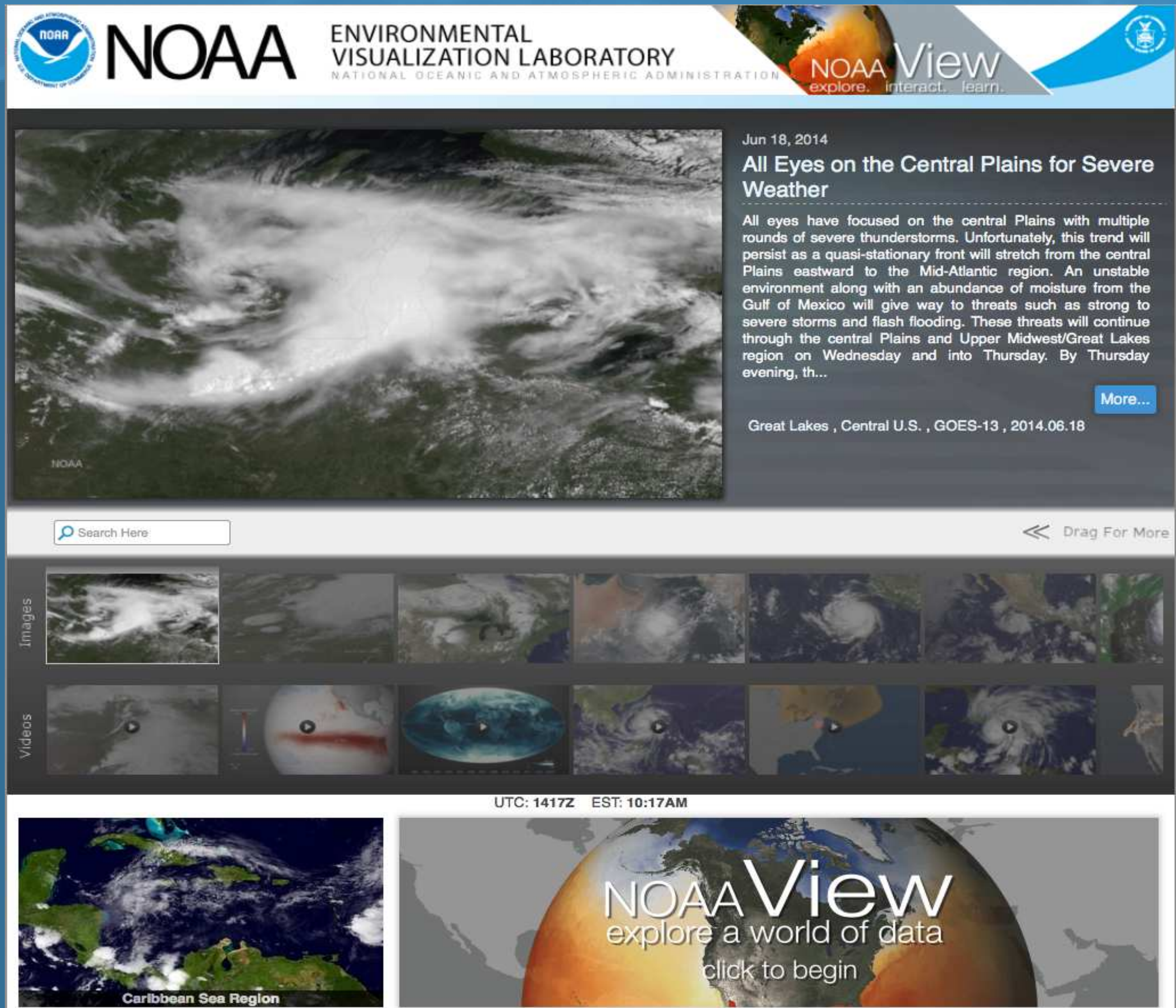
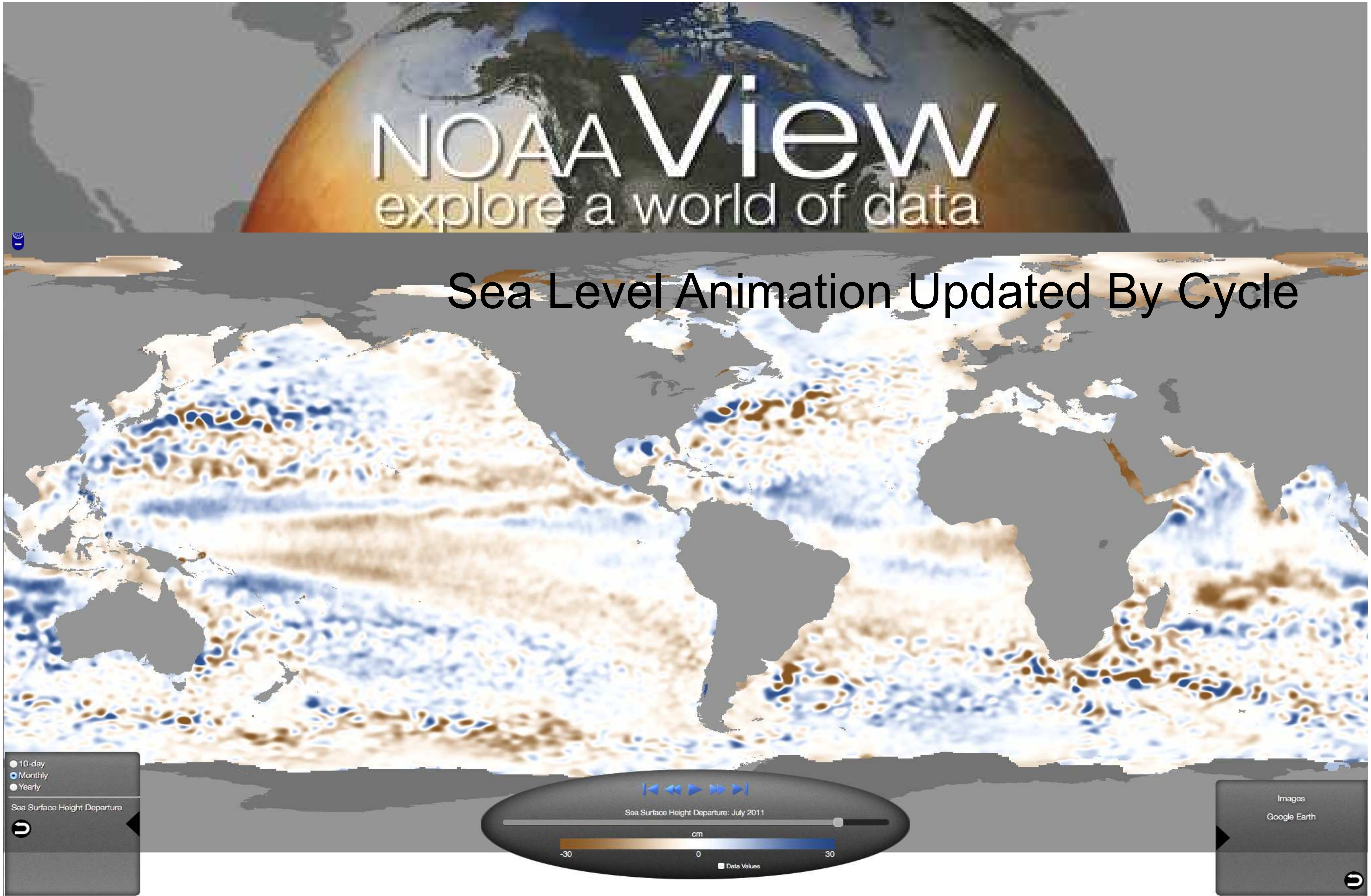


Jason on *NOAAView*



Sea Level Animation Updated By Cycle



SCIENCE: New CryoSat & Jason-1 Gravity Map Reveals Buried Structure

INSIGHTS | *PERSPECTIVES*

GEOPHYSICS

Seafloor secrets revealed

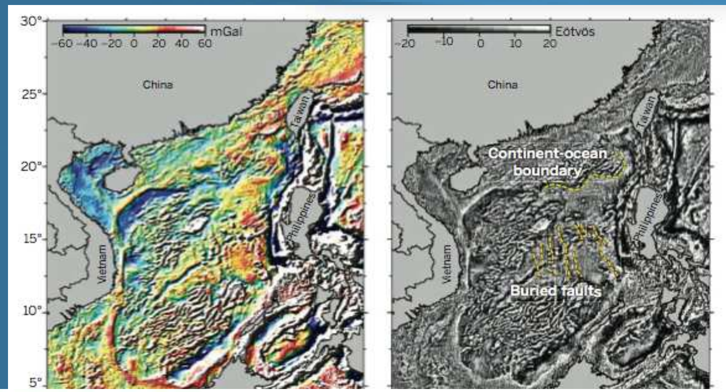
Satellite data reveal formerly unknown tectonic structures

By **Cheinway Hwang**[1] *and* **Emmy T. Y. Chang**[2]

The trenches and ridges on Earth's seafloor are shaped by tectonic processes such as seafloor spreading and plate subduction. Detailed knowledge of seafloor tectonics is lacking in many

center in the South China Sea, can be seen in Sandwell *et al.*'s data (see the figure).

A method called waveform retracking is used to refine the radar return time and thereby improve altimeter ranging accuracy. The retracking techniques used by Sandwell *et al.* are designed to improve the accuracy of sea surface slopes determined from altim-

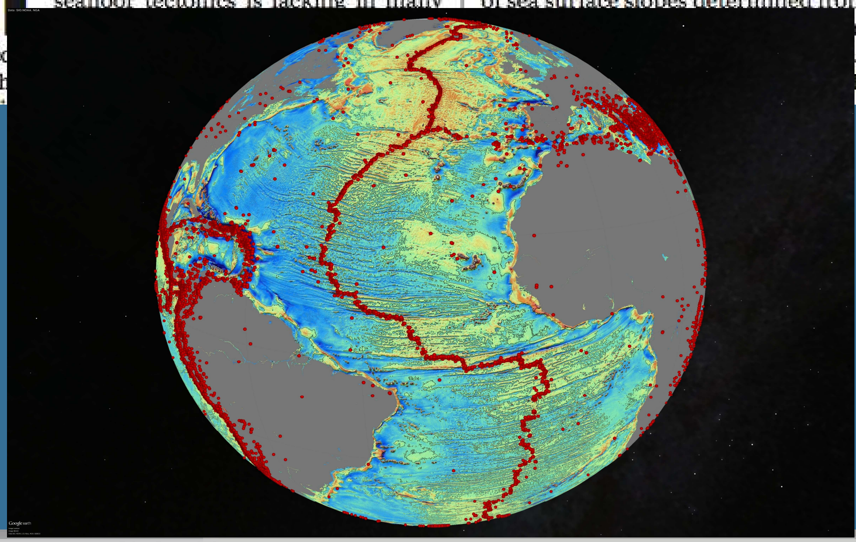


MARINE GEOPHYSICS

New global marine gravity model from CryoSat-2 and Jason-1 reveals buried tectonic structure

David T. Sandwell,[1*] R. Dietmar Müller,[2] Walter H. F. Smith,[3] Emmanuel Garcia,[1] Richard Francis[4]

Gravity models are powerful tools for mapping tectonic structures, especially in the deep ocean basins where the topography remains unmapped by ships or is buried by thick sediment. We combined new radar altimeter measurements from satellites CryoSat-2 and Jason-1 with existing data to construct a global marine gravity model that is two times more accurate than previous models. We found an extinct spreading ridge in the Gulf of Mexico, a major propagating rift in the South Atlantic Ocean, abyssal hill fabric on slow-spreading ridges, and thousands of previously uncharted seamounts. These discoveries allow us to understand regional tectonic processes and highlight the importance of satellite-derived gravity models as one of the primary tools for the investigation of remote ocean basins.



Sandwell, et al. Report Accompanied by Perspective

SCIENCE Gravity Article on FACEBOOK

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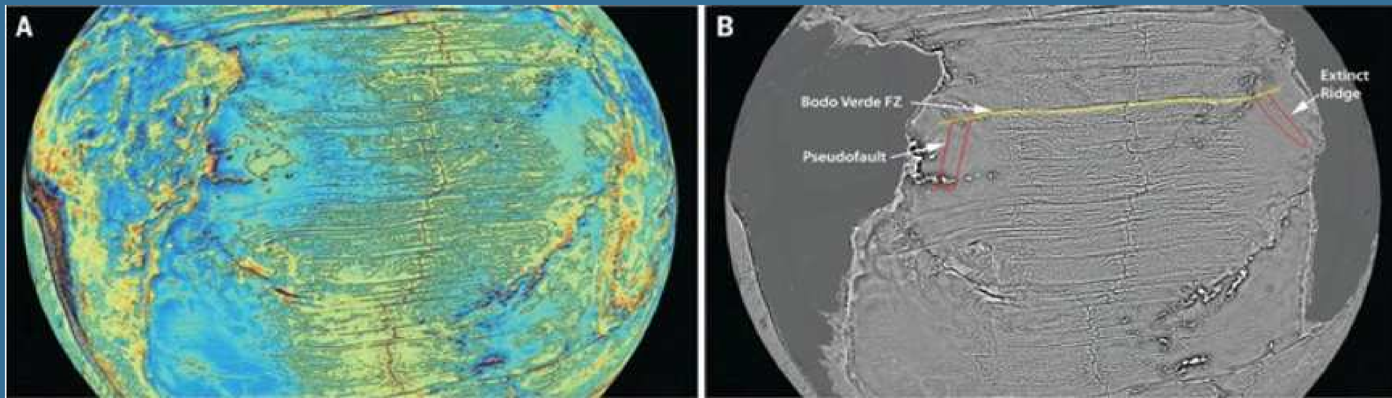

NOAA Satellite and Information Service
Improved Gravity Map Reveals New Mountains Under the Sea:

An international team of scientists including W. H. F. Smith of NOAA's STAR Laboratory for Satellite Altimetry developed a new global marine gravity map that is twice as accurate as previous models. The new map derived from satellite altimetry data (from the Jason-1 satellite and European Space Agency's CryoSat) reveals significant new se... See More

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NOAA/NWS Jason-2 Wave Warnings on *TWITTER*

NWS OPC
@NWSOPC

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#Altimeter pass in the E #Atlantic at 0514 UTC detected phenomenal wave heights near 63 ft just west of Ireland!
pic.twitter.com/5UMNfoLpFv

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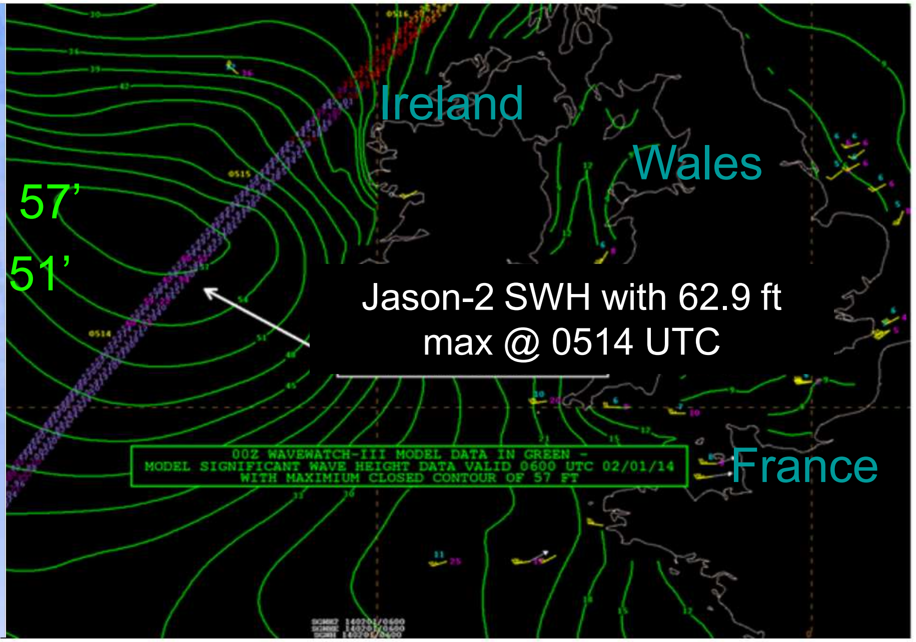
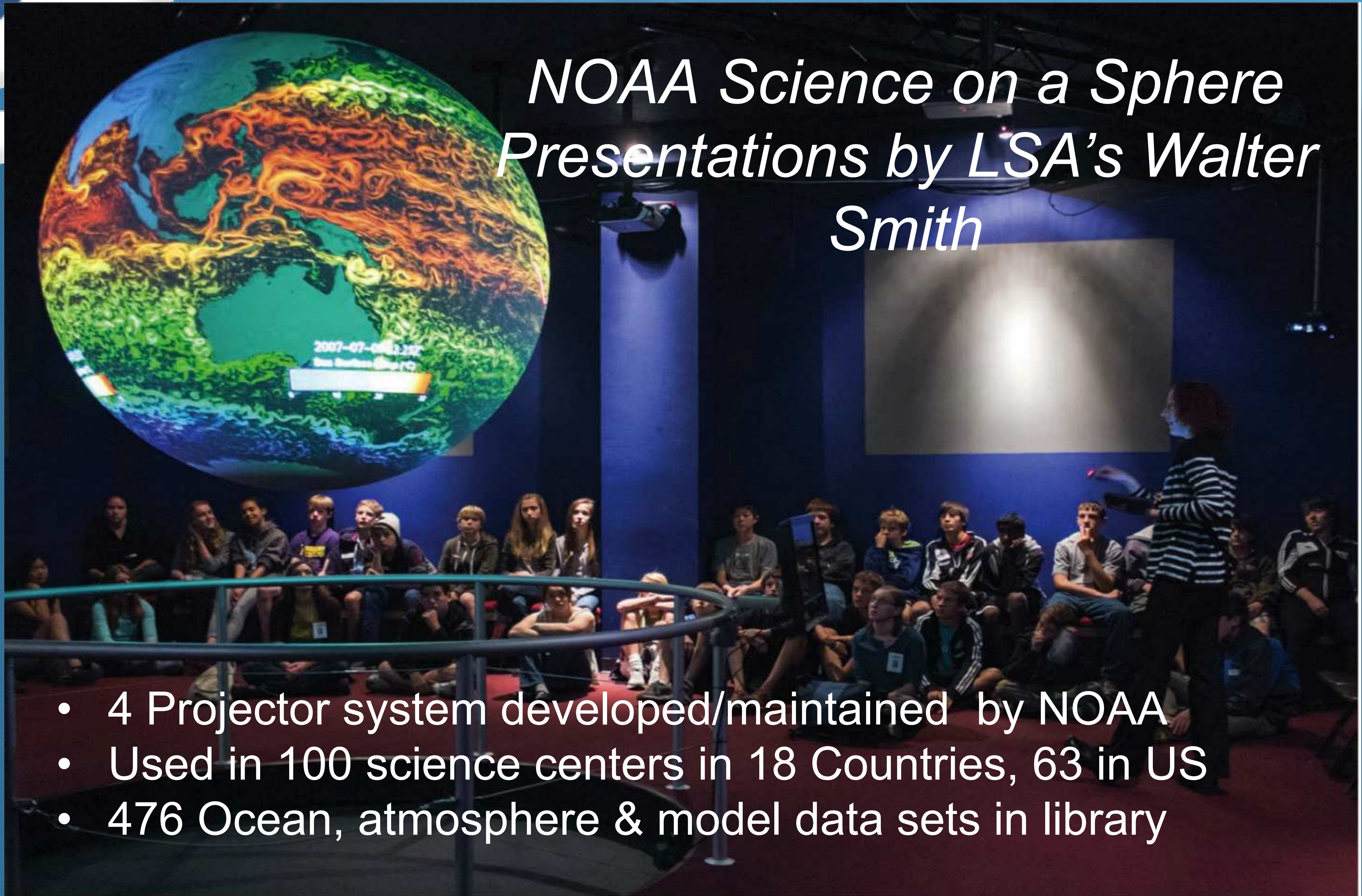


Near real-time comparison with WAVEWATCH III model (green contours) shows excellent agreement.

End Users: USCG, U.S. Navy, commercial ship operators, recreational boaters, fishermen, offshore rig operators, Federal & State managers.

WWW.TWITTER.COM/NWSOPC

NOAA Science on a Sphere Presentations by LSA's Walter Smith



- 4 Projector system developed/maintained by NOAA
- Used in 100 science centers in 18 Countries, 63 in US
- 476 Ocean, atmosphere & model data sets in library

Bottom Topography in Malaysia Airlines MH370 Search Area From Satellite Altimetry

EOS

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Seafloor in the Malaysia Airlines Flight MH370 Search Area

On the morning of 8 March 2014, Malaysia Airlines flight MH370, from Kuala Lumpur to Beijing, lost contact with air traffic control shortly after takeoff and vanished. While the world waited for any sign of the missing aircraft and the 239 people on board, authorities and scientists began to investigate what little information was known about the plane's actual movements.

As days and weeks passed, the search began to focus on the Indian Ocean to the west of Australia—far from the flight's intended path. Clues to how the plane got so far off course may be in the plane's "black boxes"—its flight data and cockpit voice recorders. Finding the recorders is therefore a top priority.

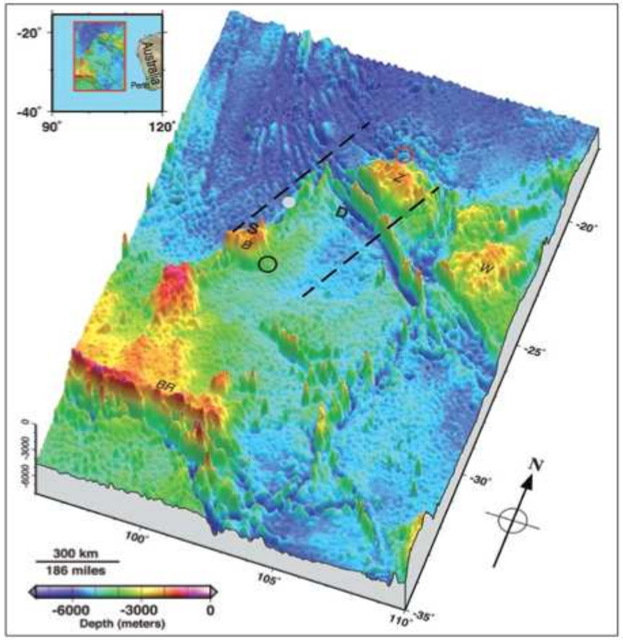
Little is known about the seafloor from ship-borne echo sounder measurements in the region where flight MH370 is believed to have crashed. Available depth measurements cover only 5% of the 2000 by 1400 kilometer area in Figure 1 (a high-resolution copy of this figure may be found in the additional supporting information in the online version of this article), and only a very few of them were acquired with modern acoustic and navigational systems. This lack of data makes the search for MH370 all the more difficult. It also highlights how most seafloor features are very poorly resolved. However, satellite altimeter measurements provide global bathymetry estimates at a

aircraft and the satellite while Doppler shifts in the handshake allowed a rough estimate of the aircraft's velocity away from the satellite.

This analysis, completed about 10 days after the disappearance, was combined with estimates of when the plane might have run out of fuel. Together they suggested that the aircraft might be anywhere in a large area of the Indian Ocean west of Australia.

MH370's black boxes were equipped with "pingers" programmed to emit acoustic signals if the boxes fell into the sea. The expected battery life of these pingers was approximately 1 month, so there were only a few days of expected pings left when it was reported that the Chinese vessel *Haixun 01* had detected pings on 4 and 5 April in the water above the east flank of the Batavia Plateau (see black circle in Figure 1). Over the next 3 days the Australian vessel *Ocean Shield* reported three other contacts, one contact apparently hearing pings emitted by two distinct devices, in an area above the north flank of the Zenith Plateau (see red circle in Figure 1).

The Batavia and Zenith contact locations are approximately 600 kilometers apart, and it seems unlikely that pingers at the end of their battery life could be heard over such distances, yet sound propagation in the ocean is quite complex. Nonetheless, Chinese and Australian authorities seemed confident that the carrier frequency, duration,



- Smith and Marks, Eos Trans AGU, 27 May 2014
- Satellite altimeter data provides broad area coverage.
- Only 5% area surveyed by ships
- Article reported in Science & Nature Geoscience & many news outlets

EOS MH370 Featured in *SCIENCE Magazine* & *Nature Geoscience* Editorials

Science $10 30 MAY 2014 AAAS

EDITORIAL

The hunt for MH370

In a world that is increasingly connected, that grows smaller every day, and where so many human actions are exposed to prying eyes, it seems almost incomprehensible that the world's largest twinjet aircraft, with 239 passengers and crew, could vanish for more than 2 months. Determining the crash site of Malaysia Airlines Flight 370 (MH370) has become a scientific detective story, emerging through a combination of scientific technologies used to address problems for which they were never designed. The search for MH370 illustrates a humanitarian dividend from past investments in science as searchers attempt to bring closure to the families and friends of the victims of the tragedy.

MH370 went incommunicado on 8 March 2014. A single Inmarsat satellite exchanged six brief messages with the MH370 Aircraft Communications Addressing and Reporting System. Oceanographers and other mariners have relied on Inmarsat's system of geostationary telecommunications satellites in remote parts of the world's oceans for data and voice communication. Significantly, it is not a navigation system. From the Doppler effect, engineers calculated the plane's velocity relative to the satellite at each time interval, and the delay in the return signal gave them the distance of the aircraft from the satellite. The Doppler was key in choosing the southern over the northern route. Using additional information on the plane's range, they then triangulated to estimate the likely crash site to within 160 km (100 miles). This was the first-ever use of Inmarsat in this mode.

The search area is a remote part of the Indian Ocean. Planes searched for wreckage with no success; ships listened for pings as time ran out on the 30-day batteries sustaining the black boxes. Some promising signals were detected, but the area still to be searched is largely unexplored. The survey tool of choice was a Bluefin-21 autonomous underwater vehicle (AUV). Bluefin Robotics was spun out of the Massachusetts Institute of Technology's Sea Grant Lab. The Bluefin-21 vehicle inherited its distinct construction, gimbal-ducted propeller, mission-control software, and side-scan sonar payload from roots in academic research. Its deep-sea rating that enabled the MH370 response was initially driven by academic applications. The best available bathymetry to help the AUV avoid crashing into rough terrain as it scanned for the debris field of MH370 was assembled from a combination of very sparse ship sonar and satellite altimetry. Satellite altimeters, first launched nearly 40 years earlier to map the ocean surface, produced better maps of the seafloor than were available from shipboard echo-soundings alone, by using small-scale features in the marine geoid to estimate the shape of the seafloor. Scientists had been using these maps to better understand Earth beneath the ocean; now the map would help guide the AUV in a search area still needle-in-a-haystack large and more than 4000 m deep.


A New Zealand military plane searches for debris.

"We should use better technology to track what is too valuable to lose."

As of this writing, the search continues. In April 2011, a team from the Woods Hole Oceanographic Institution found the debris field from Air France Flight 447, which had crashed into the Atlantic Ocean 2 years before, after a week of searching with similar AUV technology,* bringing resolution to the families of the victims. Finding the black boxes is vital to avoiding similar incidents happening again. We hope for the same outcome for the MH370 search. But it took 2 years to narrow the search to the right part of the Atlantic. In both cases, the response could have been improved by filling known gaps in scientific understanding (see the News story on p. 963). For example, the resolution of the satellite-derived map guiding the Bluefin-21 is ±250 m vertical and 15 km horizontal. Relative to the plane's dimensions, the unknowns are serious. For comparison, the resolution of features on Mars is ±1 m vertical and 1 km horizontal. And knowing where to look saves precious time, whether one seeks a plane full of passengers or a truck full of Nigerian schoolgirls. We should use better technology to track what is too valuable to lose.

– **Marcia McNutt**

10.1126/science.1255963


Marcia McNutt is Editor-in-Chief of Science.

*www.whoi.edu/page.do?pid=96017&tid=3622&cid=96189&c=2.

PHOTO: STACEY PENTLAND PHOTOGRAPHY; (INSET) AFP/GETTY IMAGES

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editorial

Recovery and discovery

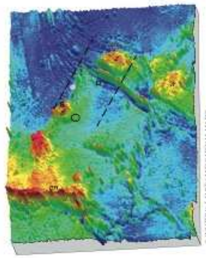
The recent disappearance of a commercial airliner has highlighted our poor knowledge of the ocean floor. Through the years, human tragedies have helped inspire deep sea research, but it is time to explore more systematically.

On 8 March 2014, a commercial airliner carrying 239 people disappeared almost without a trace. The path of flight MH370, which fell off military radar a few hours after take-off, was painstakingly reconstructed from a few bits of data gleaned from a telecommunications satellite. The analysis suggested the plane made an abrupt turn away from its original destination of Beijing, instead heading south over the Indian Ocean. Guided by the satellite data and sightings of possible airplane debris, search teams narrowed in on an area of the Indian Ocean west of the Australian coast. But as the teams began their — ultimately fruitless — search of this patch of the ocean floor, they hit a snag: the topography of the sea floor in this region was virtually unknown. This piece of uncharted territory is not exceptional: broad swathes of the ocean floor are yet to be fully explored.

Mapping of the sea floor is not just an exercise in disaster recovery. Much of the ocean's internal mixing is attributed to rough topography at the sea floor; this sort of mixing is a key way in which wind and tidal energy is dissipated throughout the ocean (Nikurashin, M., Vallis, G. K. & Adcroft, A. *Nature Geosci.* **6**, 48–51; 2013). Poor knowledge of how energy is transformed in the world's oceans hinders forecasts of everything from the path of tsunamis to the ocean's uptake of heat and carbon dioxide (Smith, W. H. F. & Marks, K. M. *Eos* **95**, 173–174; 2014).

For the Indian Ocean floor off the coast of western Australia, progress is being made. In late May, a map using satellite data to fill in the blanks between the sparse bathymetric surveys of this region was released (Smith, W. H. F. & Marks, K. M. *Eos* **95**, 173–174; 2014). And as the search area expanded to a zone of around 60,000 km², the Australian government initiated an exercise to map the sea floor at a far higher resolution than can be obtained from satellites.

The Australian government has indicated the data will be made publicly available to aid future scientific studies. Yet, even the relatively coarse satellite seafloor map released in May shows dramatic relief. The peaks and plateaux charted in the map hint at pieces of continental crust left behind by the break-up of Australia and the Indian subcontinent. With a high-resolution map to come, we will undoubtedly learn more about the evolution of the Indian Ocean floor, and its impacts on ocean processes and climate.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The flight recorders of MH370 are not the only hidden remains of human tragedy spurring exploration of the sea floor. Lying at a depth of 3,800 m beneath the Atlantic Ocean, the wreck of the RMS *Titanic* has captivated the imagination of generations of budding oceanographers. Exploration of the wreckage by remotely controlled vehicles and the DSV *Alvin* submersible vehicle led to the identification of a novel bacterium (*Int. J. Syst. Evol. Microbiol.* **60**, 2768–2774; 2010) as well as a thriving ecosystem built on the ship's remains. In preparation for the making of his popular movie *Titanic* in 1997, the director James Cameron took part in dives to the wreckage. His growing fascination with the mysteries of the sea floor inspired his involvement with the building of the Deepsea Challenger (http://deepseachallenge.com/). He eventually piloted the submersible to the deepest known point on Earth. During test dives to over 8,000 m in the New Britain trench, Cameron encountered the deepest pillow lavas found to date; these features formed as lava was extruded under the high pressures of the ocean. In the Sirena Deep, he and expedition scientists found microbial mats growing around an area thought to host serpentinization. Analyses of these mats could provide insights into both the chemical processing and the life that evolved to take advantage of it. The Deepsea Challenger was later donated to the Woods Hole Oceanographic Institution.

In the western Pacific, the rugged terrain of Nikumaroro Atoll may hide the remains of Amelia Earhart's Electra 10E aircraft, suggests the International Group for Historical Aircraft Recovery (www.tighar.org). Earhart and her navigator disappeared along with their plane in 1937, while trying to land on Howland Island. They were nearly three-quarters of the way into an attempt to fly around the world. The atoll is considered one of the most pristine coral reefs in existence, based on SCUBA surveys. Seafloor mapping of the western edge of the atoll by TIGHAR shows the steep, rugged topography of the deeper coral reef.

A funding appeal for an undersea search of the atoll's western flank, scheduled to take place in the autumn of 2014, is currently underway (http://go.nature.com/nZJ8am), with a plan for two submersibles to search for evidence of wreckage and to carry out a survey of the deep reef. It is hoped that the assessment will provide a baseline for reef diversity and health.

Just as rewards such as mineral deposits and hotspots of biodiversity lurk beneath the ocean's surface, so do hazards. Yet the ocean's floor is less well-charted than the surface of Mars or the Moon. Clearly, a blanket of a few thousand metres of sea water is a serious obstacle to exploration. But if we can reach these depths when disaster strikes, technology is clearly not the barrier to mapping the ocean floor. We just need to set our minds (and funds) to the task. ❐

EOS MH370 Article Media Attention

Thank You!

Regional Mean Sea Level Series

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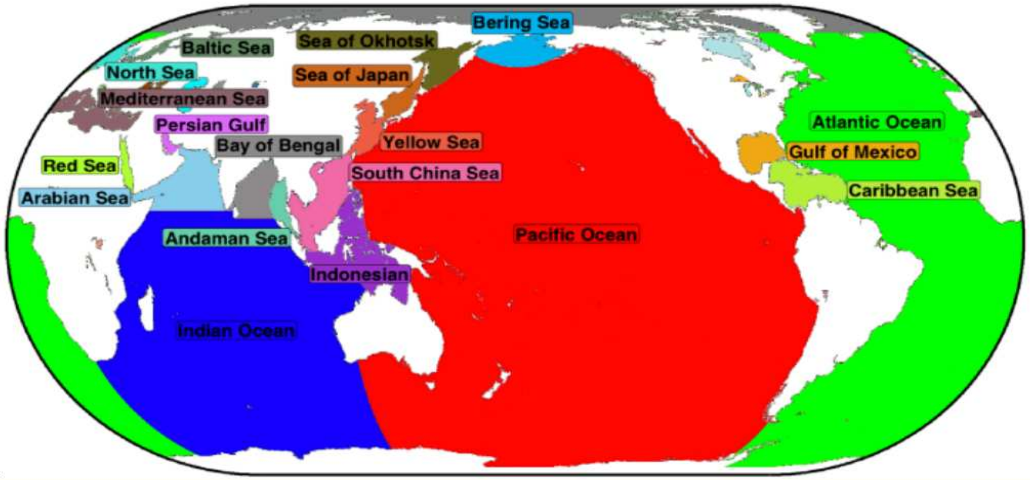
Laboratory for Satellite Altimetry / Sea Level Rise

Regional sea level time series

The following tables provide estimates of sea level rise based on measurements from satellite radar altimeters. Plots and time series are available for TOPEX/Poseidon (T/P), Jason-1, and Jason-2, which have monitored the same ground track since 1992, and for most of the altimeters that have operated since 1991, including T/P, Jason-1, Jason-2, ERS-2, GFO, and Envisat.

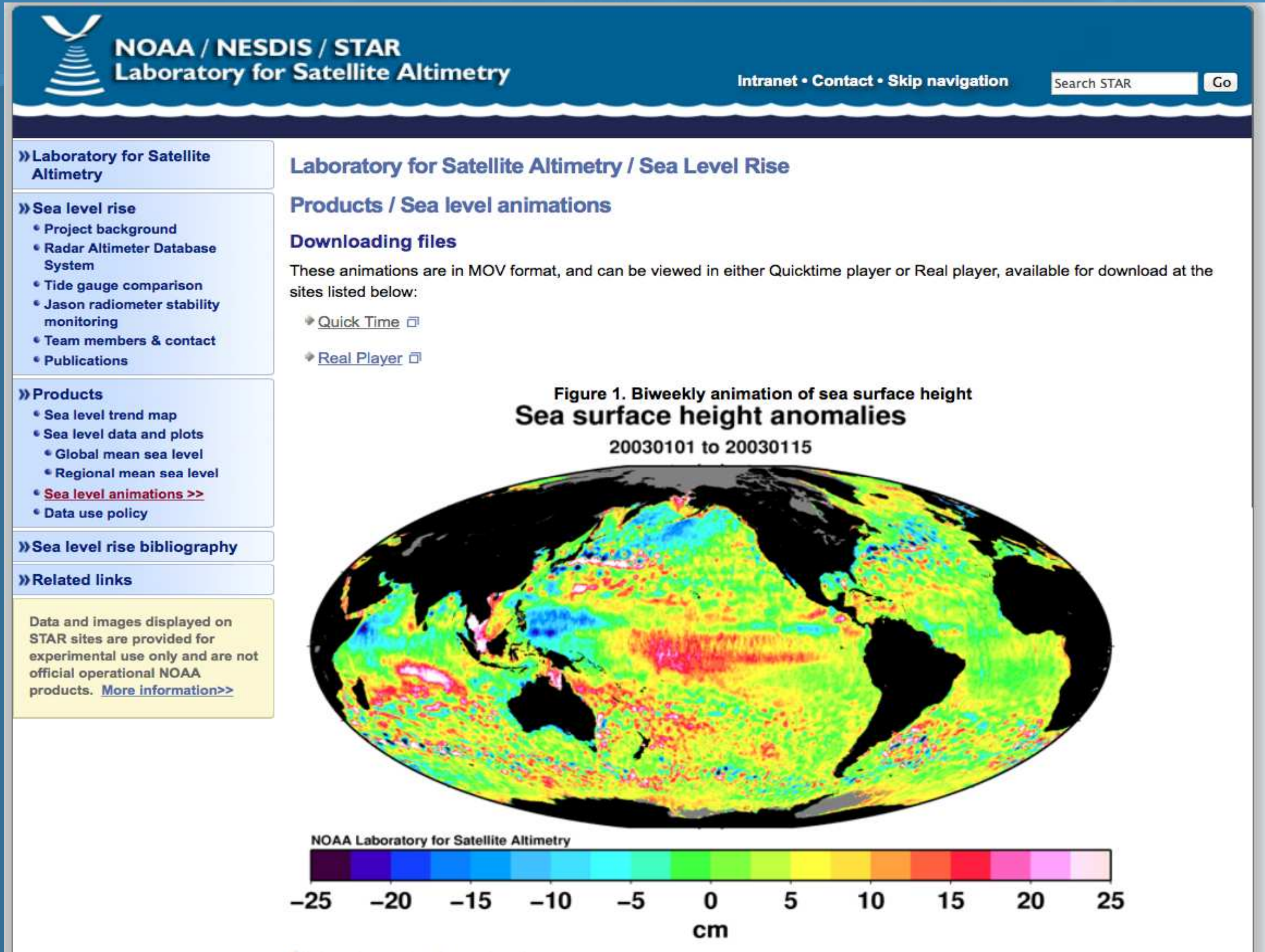
Only altimetry measurements between 66°S and 66°N have been processed. An inverted barometer has been applied to the time series. The estimates of sea level rise do not include glacial isostatic adjustment effects on the geoid, which are modeled to be +0.2 to +0.5 mm/year when globally averaged.



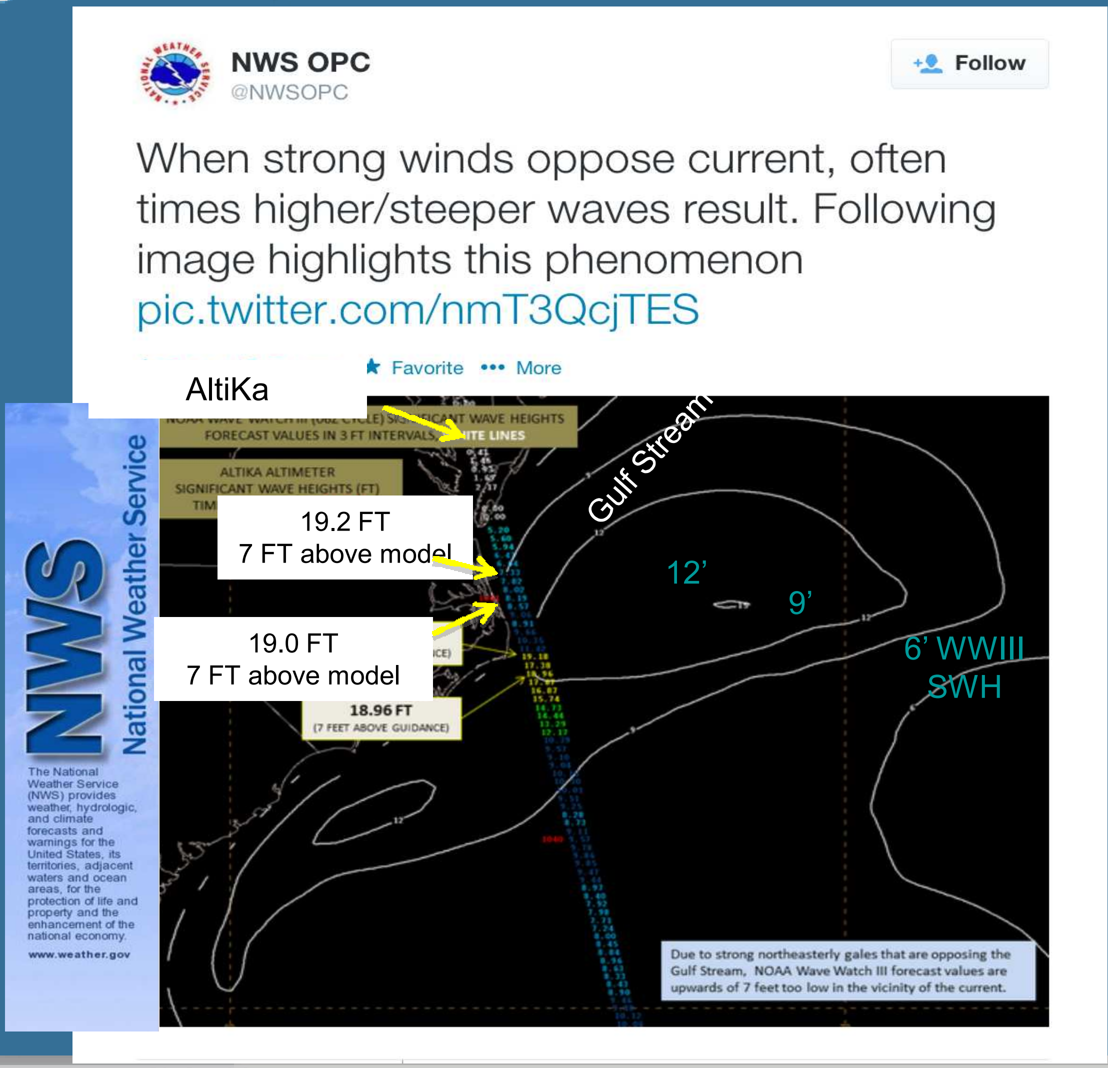
Regional sea level time series data and plots

Region	TOPEX, Jason-1, and Jason-2		Multiple altimeters	
	Seasonal signals retained	Seasonal signals removed	Seasonal signals retained	Seasonal signals removed
Pacific Ocean	Text (CSV) (22 kB) NetCDF (19 kB) pdf (93 kB) png (95 kB)	Text (CSV) (22 kB) NetCDF (19 kB) pdf (93 kB) png (91 kB)	Text (CSV) (47 kB) NetCDF (35 kB) pdf (116 kB) png (117 kB)	Text (CSV) (47 kB) NetCDF (35 kB) pdf (116 kB) png (110 kB)

Global Sea Level Animations



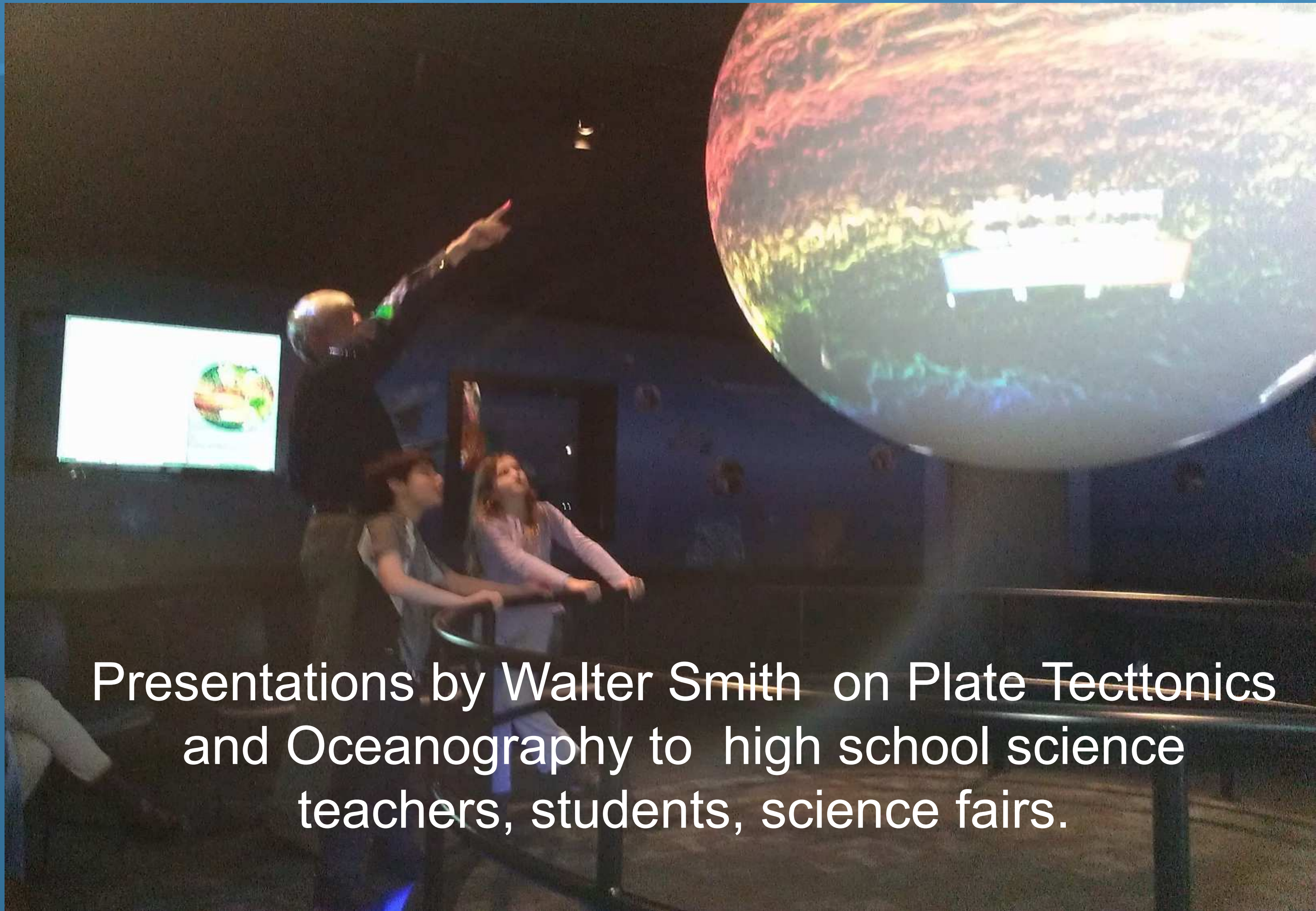
NOAA/NWS AltiKa Wave Warnings on *TWITTER*



- AltiKa SWH shows 7' error in WAVEWATCH III model SWH in Gulf Stream.
- Error caused by model not correctly accounting for opposing strong winds and surface currents

WWW.TWITTER.COM/NWSOPC

NOAA LSA Science on a Sphere



Presentations by Walter Smith on Plate Tecttonics and Oceanography to high school science teachers, students, science fairs.