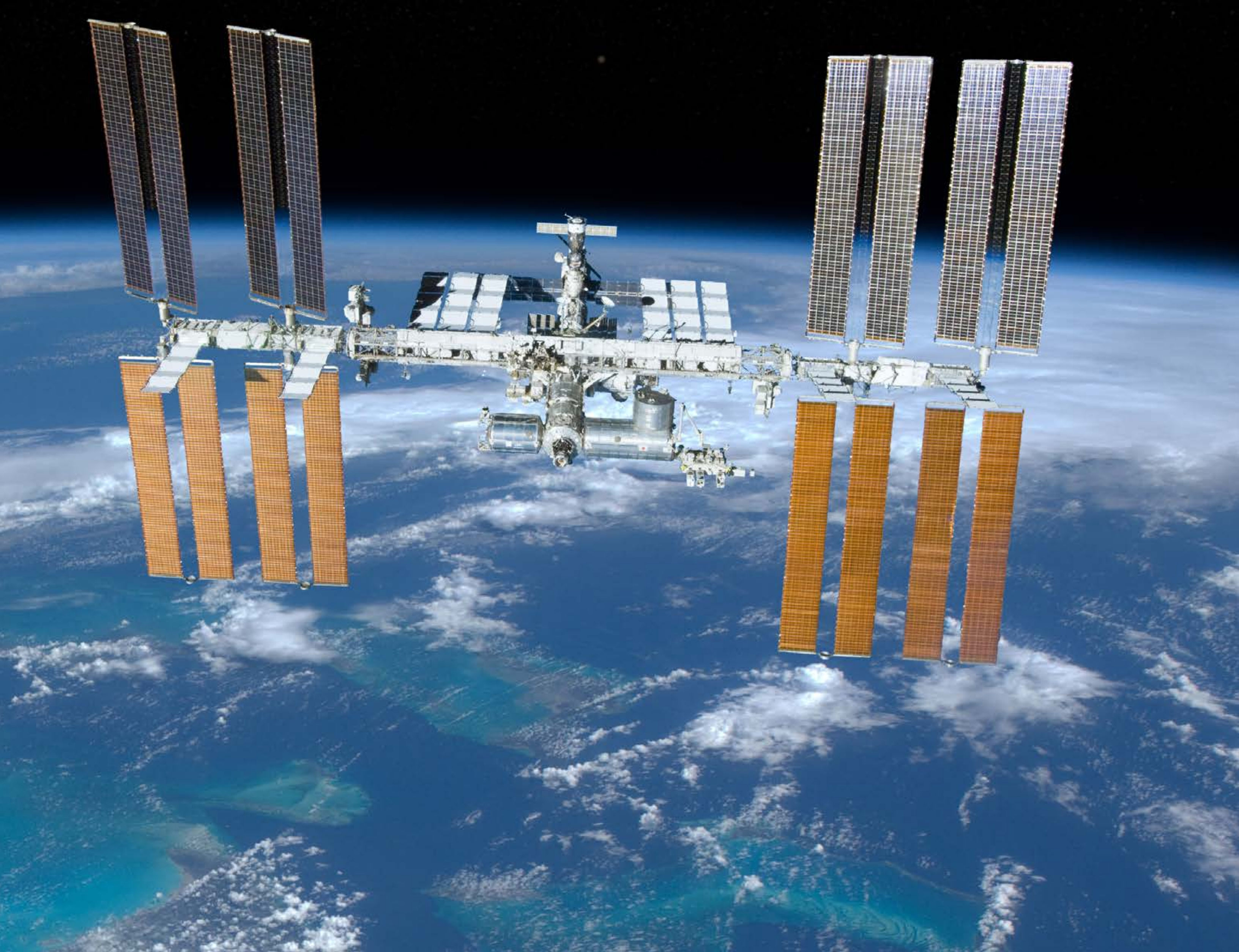
National Aeronautics and Space Administration

ISS - RapidScat

A New Measure of Ocean Winds from the International Space Station



NASA's International Space Station Rapid Scatterometer, or ISS-RapidScat, is the first scientific instrument specifically created to observe Earth winds from the space station. Scheduled for launch in late 2014, the experimental mission will measure ocean surface wind speeds and directions, providing data that are needed to support weather and marine forecasting—including tracking storms and hurricanes—and climate research. The space station's unique orbit will allow ISS-RapidScat to make the first direct observations of how ocean winds vary over the course of the day.

Acknowledgments

ISS-RapidScat
winds.jpl.nasa.gov/missions/RapidScat

Special thanks to the ISS-RapidScat science team for making this publication possible.

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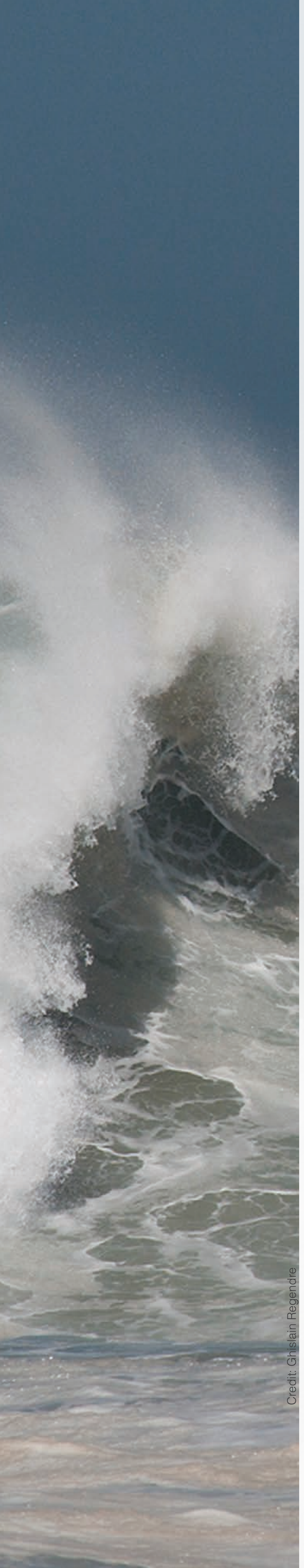

Credit: Ghislain Regendre

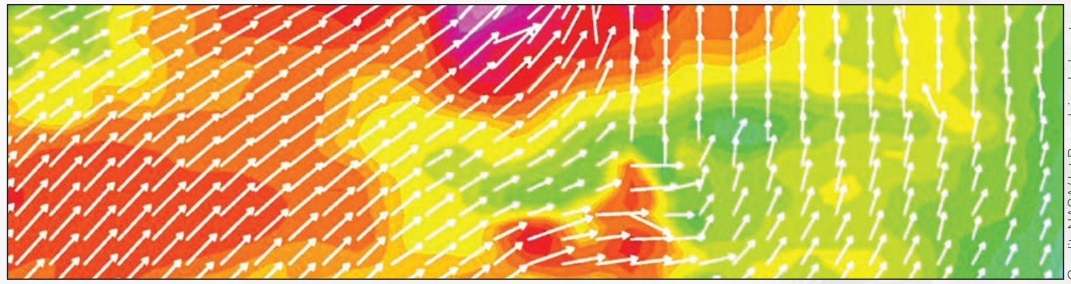
Measuring Ocean Winds from Space


Credit: NASA

[*Above*] Shown here is an overhead view of the Skylab space station cluster in Earth orbit as photographed from the Skylab-4 Command and Service Modules during its final fly-around before returning home. The space station is contrasted against a cloud-covered Earth.

The ocean covers about 70% of Earth's surface. Winds over the ocean are a critical factor in determining regional weather and climate patterns. In severe storms such as hurricanes, ocean winds can inflict major damage to shore populations. Ocean winds also impact productivity by blowing warm surface waters away from shorelines, allowing cool nutrient-rich water to well up from the ocean depths, nourishing marine life and benefiting coastal fisheries and the economy. Studying changes in ocean winds helps scientists better predict small-scale weather phenomena as well as large-scale patterns connected with Earth's climate, such as El Niño and La Niña.

Radar scatterometers are the only remote-sensing instruments that can provide accurate, frequent, high-resolution measurements of ocean-surface wind speed and direction in most weather and cloud conditions. From the beginning, these instruments have played an important role in oceanographic, meteorological, and climate studies.

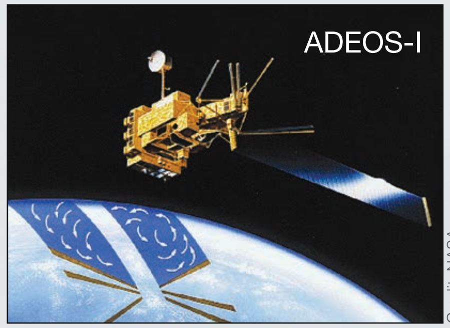

Credit: NASA/Jet Propulsion Laboratory

History of Scatterometry

The first scatterometer that NASA built was a "technology demonstration" instrument built by NASA's Langley Research Center that flew onboard NASA's Skylab—the United States' first space station—from 1973 to 1979. There were three manned missions to Skylab, each carrying a three-astronaut crew. All three crews operated the scatterometer. The data returned proved that ocean-surface winds could be accurately measured from orbit.

NASA's Langley Research Center also built the second scatterometer, named the Seasat-A Scatterometry System, which flew onboard NASA's Seasat-A mission, launched in June 1978. Seasat-A's power system failed after only three months in orbit and it would be 18 years before NASA flew another scatterometer in space. In the meantime, the European Space Agency flew scatterometers onboard its European Remote Sensing (ERS)-1 and ERS-2 satellites, which launched in 1991 and 1995. The next NASA instrument was called the NASA Scatterometer, or NSCAT. Designed and built at NASA's Jet Propulsion Laboratory (JPL), NSCAT launched in August 1996 on Japan's first Advanced Earth Observing Satellite, or ADEOS-I. Unfortunately, it suffered a power system failure and was lost less than a year after launch, in July 1997.

Credit: NASA



Credit: NASA

When ADEOS-I failed and NSCAT was lost earlier than anticipated, NASA needed a replacement to continue ocean wind measurements. JPL quickly built two identical new instruments called SeaWinds. The first launched in 1999 on the Quick Scatterometer, or QuikSCAT, satellite, and the second launched near the anticipated end of the first instrument's lifetime in 2002 on Japan's ADEOS-II satellite. Scientists wanted the two to overlap to enable intercomparison and they assumed SeaWinds on ADEOS-II would replace SeaWinds on QuikSCAT. However, ADEOS-II suffered an eerily similar fate to its predecessor; the spacecraft failed less than a year after launch in October 2003.

Credit: NASA

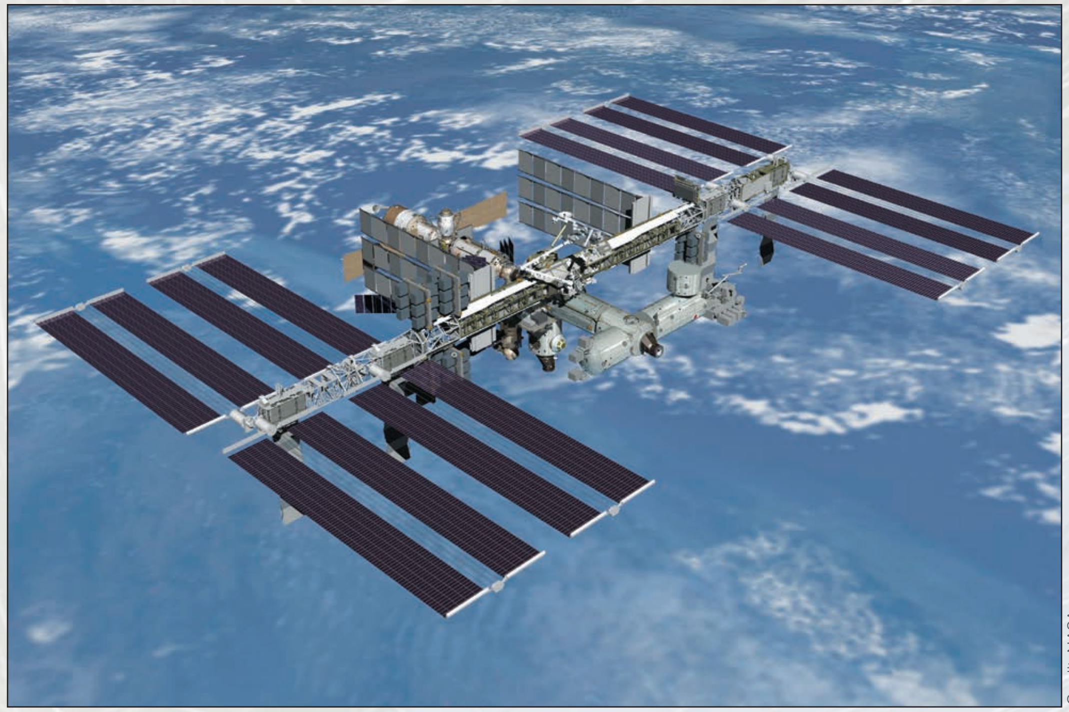
This left NASA in the precarious place of having only one operational scatterometer. The good news is that SeaWinds on QuikSCAT well exceeded its expected lifetime, and remained fully operational until 2009, when a bearing in the radar antenna's spin mechanism failed. While the instrument performance was not affected by the spin mechanism failure, the scatterometer's coverage area was and remains significantly reduced. Data from SeaWinds, however, remain important for calibrating other scatterometers currently in orbit.

The loss of SeaWinds' full capacity, coupled with the recent demise of an Indian scatterometer, has significantly reduced the observational capabilities of the international scatterometer constellation. To mitigate this loss and improve our understanding of Earth's weather and climate, NASA has, in a sense, gone back to the beginning—back to a space station. It has developed a new ocean scatterometry mission called the International Space Station Rapid Scatterometer, or ISS-RapidScat, to measure ocean-surface wind speed and direction. ISS-RapidScat will be the sixth NASA scatterometer instrument since the 1970s.

Mission Overview

Key Science Objectives

- ISS-RapidScat will provide ocean vector wind data to scientists and weather forecasters to mitigate the loss of SeaWinds data (from QuikSCAT).
- Data from ISS-RapidScat will serve as a calibration standard to the international scatterometer constellation, enabling the continuation of the SeaWinds data record, and enabling monitoring of climate variability and change over multiple decades.
- ISS-RapidScat will allow scientists to fully sample the diurnal and semi-diurnal wind cycles (between 51.6 degrees north and south latitude) from space at least once every two months.



Credit: NASA

[*Above*] ISS-RapidScat is the first Earth-observing science instrument to measure winds from the space station.

In the summer of 2012, NASA's International Space Station (ISS) program manager offered scientists at NASA's Jet Propulsion Laboratory (JPL) a mounting location for a new scatterometer to mitigate the loss of coverage from SeaWinds on QuikSCAT, as well as a "free ride" into space on a resupply mission in 2014. The mission has been built in the two years since then—an extraordinarily short timeline compared to most spaceborne missions, which spend many years or even decades in preparation—hence the name ISS-RapidScat.

The two-year design time meant that engineers at JPL could not start from scratch and design an entirely new instrument. Instead, ISS-RapidScat engineers adapted hardware that had originally been built for a QuikSCAT "engineering model"—a copy of the instrument built specifically for testing—and added a new, smaller reflector antenna. Although some of the QuikSCAT components have been warehoused since the 1990s, they have proven capable of meeting the ISS-RapidScat mission needs. In addition to keeping the mission on schedule, the choice to reuse heritage (existing) parts has significantly reduced the overall cost of the mission. This unique development approach leverages space station capabilities, inherited hardware, and the NASA commercial cargo strategy.

ISS-RapidScat will provide cross-calibration of the international constellation of ocean wind satellites, extending the continuity and usefulness of the scatterometer data record. This capacity will allow scientists to extend the ten-year record from the SeaWinds instrument (onboard QuikSCAT) with measurements from ISS-RapidScat, creating a continuous and accurate data record for years to come—see *Calibration and Continuity* below.

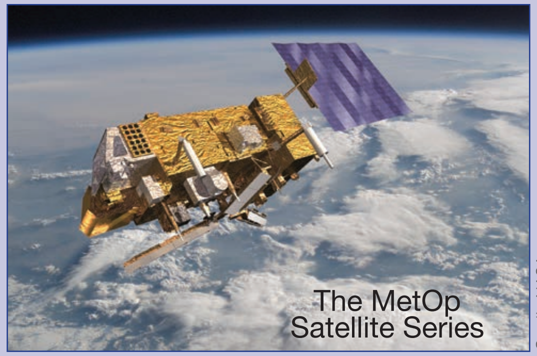
Calibration and Continuity

For satellite observations to have research value, they must not be affected by changes in the spacecraft environment such as fluctuations in electrical power and temperature, and they must remain stable during the instrument's lifetime. Calibration is the process of ensuring that the data are, and continue to be, accurate and consistent. Instruments that collect the same kind of data, such as spaceborne scatterometers, also need to be cross-calibrated with each other so that researchers can combine different datasets seamlessly.

Credit: NASA/Ball Aerospace

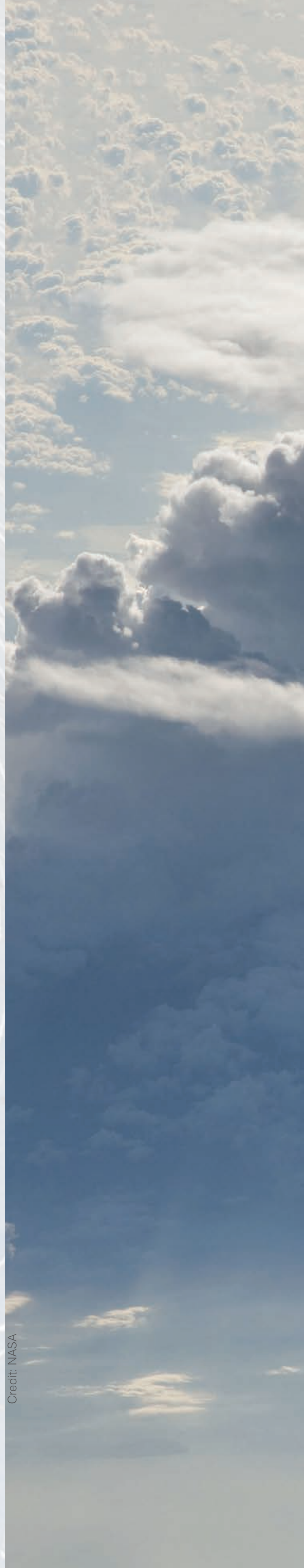
There are currently three scatterometers operating in orbit: SeaWinds onboard QuikSCAT and two Advanced Scatterometer (ASCAT) instruments on the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) MetOp-A and MetOp-B satellites. SeaWinds takes measurements at different wavelengths than the ASCAT instruments and does not pass over the same Earth regions at the same time of day. This means there are limited opportunities to cross-calibrate data from SeaWinds (onboard QuikSCAT) with data from the ASCAT instruments.

ISS-RapidScat, however, will intersect the orbits of both ASCAT instruments and SeaWinds, as well as the planned orbit of ScatSat, a scatterometer that the Indian Space Research Organization (ISRO) [India's space agency] expects to launch in 2015 to replace the lost OSCAT scatterometer. Therefore data from ISS-RapidScat can be used to cross-calibrate all other scatterometer instruments. As the space station's orbit shifts during the year, RapidScat will intersect with the other instruments over different locations on Earth's surface. Over time this will allow any biases connected with wind speed or underlying geography to be revealed.



Credit: NASA

NASA plans to regularly cross-calibrate data from ISS-RapidScat and SeaWinds on QuikSCAT when the two instruments make overlapping measurements of the same Earth scene. This ongoing calibration effort will alleviate any issues that might arise with ISS-RapidScat due to its unique environment on the space station. The calibrated ISS-RapidScat will then be used as the gold standard to identify and correct biases in the instruments, so that all spaceborne scatterometers, current and planned, will have a common reference frame and will produce a consistent dataset.



Credit: NASA

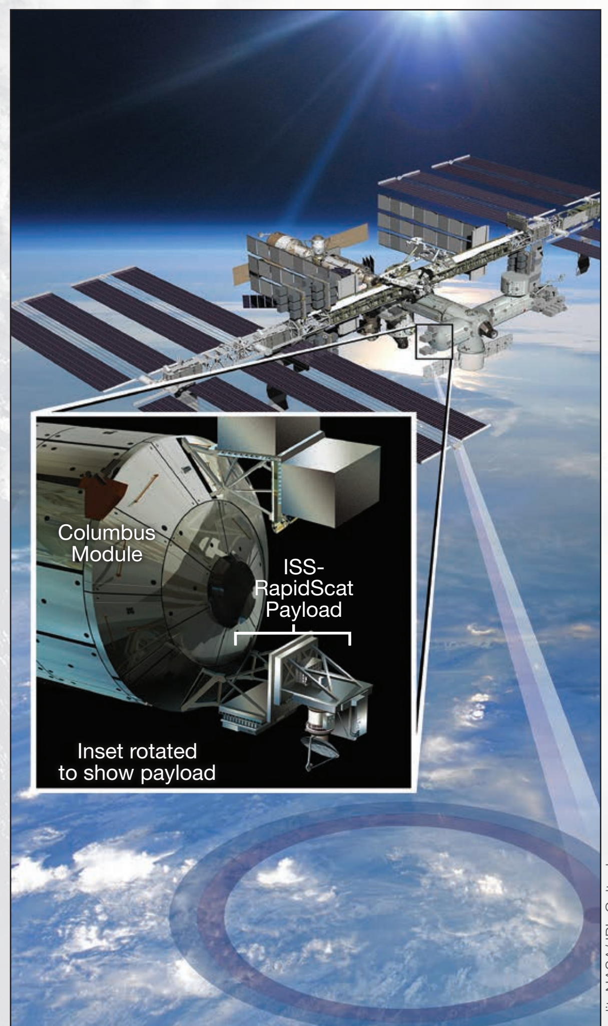
Instrument Overview

[*Above*] Technicians at JPL attach the ISS-RapidScat Instrument to the Nadir Adapter as part of a fit check between the two payload elements.

Credit: NASA/JPL-Caltech

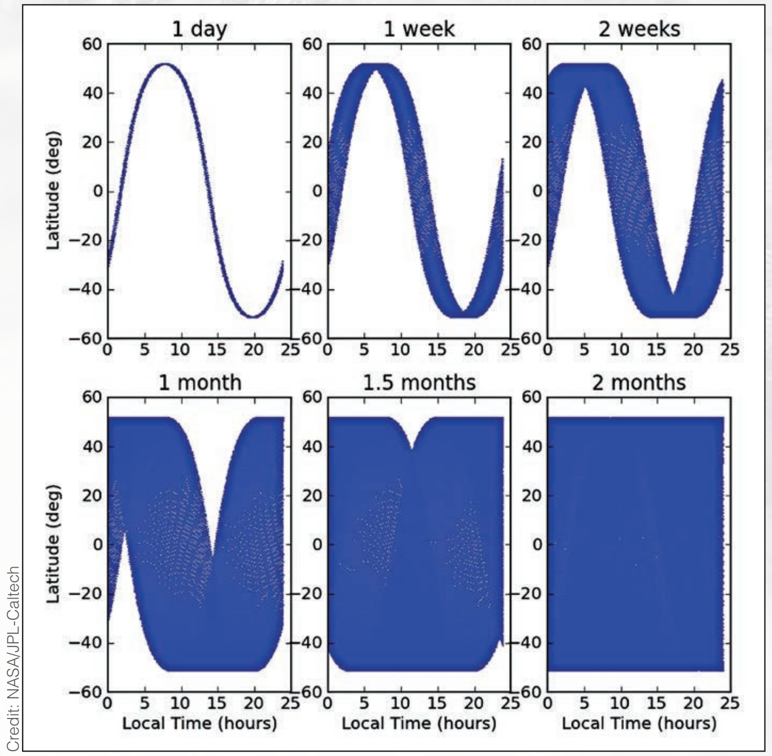
ISS-RapidScat is a radar scatterometer designed to sense near-surface winds over the ocean. The instrument sends a pulse of microwaves towards the Earth's surface and measures the intensity of the return pulse that reflects back from the surface. In general, strong radar return signals represent rough surfaces, while weak radar return signals represent smooth surfaces. Over the ocean, stronger winds produce larger waves and therefore stronger radar return signals. The return signal also tells scientists the direction of the wind, since waves line up in the same direction the wind is blowing.

Operating at the microwave frequency of 13.4 gigahertz, ISS-RapidScat will measure the strength and direction of the reflected signal with a precision comparable to that of the SeaWinds instrument. Onboard the station, ISS-RapidScat will orbit between 375 kilometers (~230 miles) and 435 kilometers (~270 miles) above the Earth's surface. The conically scanning instrument design will observe a data swath approximately 900 kilometers (560 miles) wide, covering the majority of Earth's ocean between 51.6 degrees north and south latitude within 48 hours. Due to the unique orbit path of the ISS, RapidScat will observe the same spot on Earth at different times each day. This will enable RapidScat to observe all points on Earth's surface between its northern and southern limits at all times of day in roughly two months. While polar-orbiting scatterometers cover a wider latitude range, ISS-RapidScat will offer a significant improvement over the observing capabilities of current scatterometers over the tropics and mid-latitudes.



[*Right*] This artist's rendering of NASA's ISS-RapidScat Instrument (inset) shows where the payload will be located onboard the International Space Station. It will be installed on the end of the station's Columbus module and the conically scanning instrument design will allow data collection across a 900 kilometer-wide swath.

Credit: NASA/JPL-Caltech

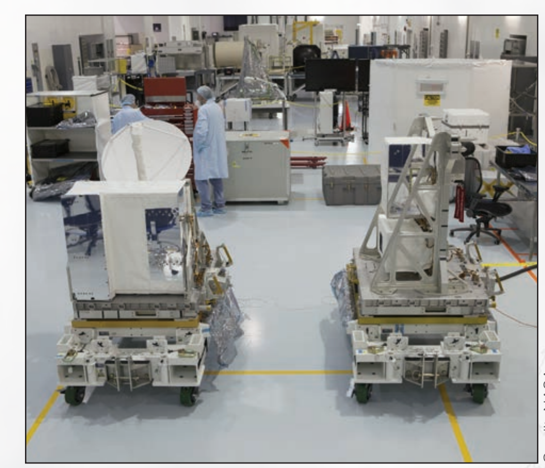


Credit: NASA/JPL-Caltech

[*Left*] The space station revisits the same latitude at slightly different local times on each orbit. This means it covers all points on Earth's surface between 51.6 degrees north and south latitude at all times of day in roughly two months.

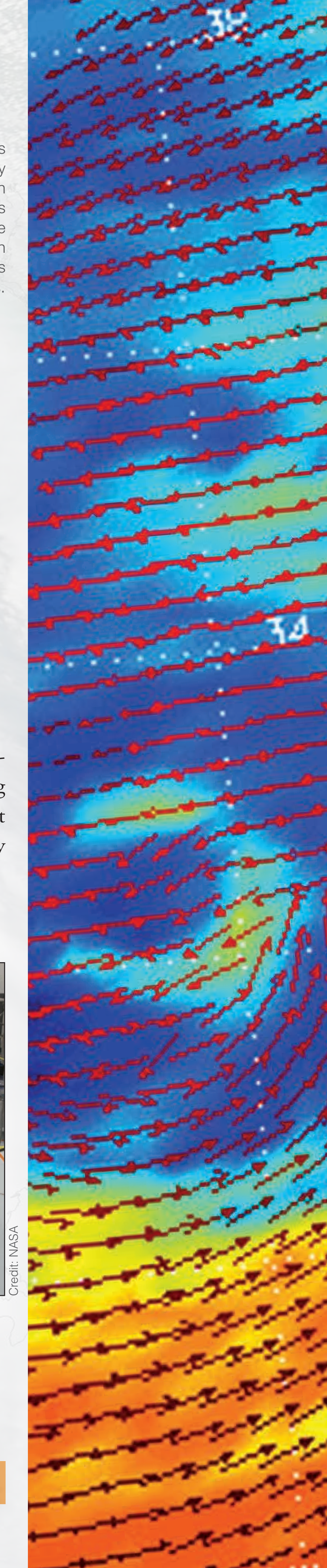
As the first wind-observation instrument to be mounted on the space station, ISS-RapidScat presented some unique challenges to its engineering team. For starters, the docking point (where the instrument will be mounted) faces outward toward space, not toward Earth. In addition, the space station's flying angle changes as new instruments and other parts are mounted, and that affects the station's atmospheric drag. To overcome these challenges, NASA engineers designed a new downward-pointing mounting device called a Nadir Adapter, which allows downward viewing of Earth and houses new power and digital interface electronics.

Another concern was that one of the space station's docking ports is within the scatterometer's field of view. To avoid having to turn off the instrument when the docking port is in use, the engineers devised a unique scanning pattern that avoids the port while still scanning across the vast majority of the instrument's viewing range. These engineering challenges notwithstanding, ISS-RapidScat will gain the unique opportunities offered by the space station orbit.



Credit: NASA

[*Above*] The components of NASA's ISS-RapidScat payload (i.e., the Instrument and Nadir Adapter) rest side-by-side after removal of their shipping cover inside Kennedy Space Center's Space Station Processing Facility.



Getting to the Space Station

Launch Vehicle and Installation

Credit: SpaceX

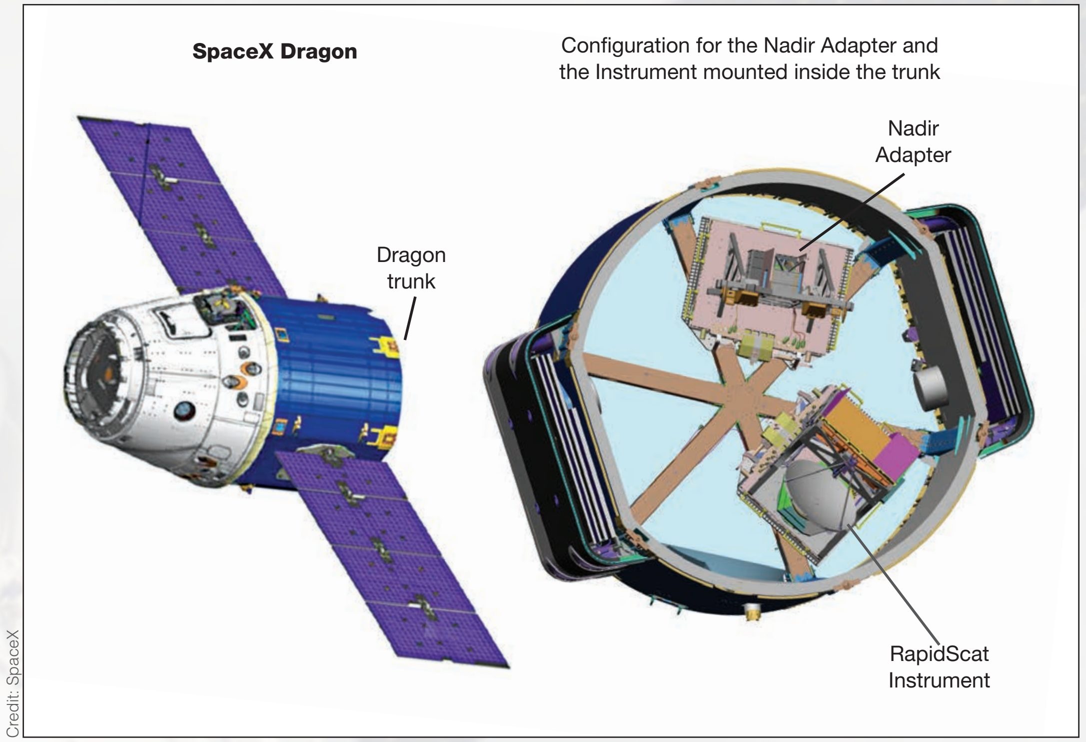
[Above] A Falcon 9 launch vehicle (pictured here) will send SpaceX-4's Dragon spacecraft to the space station.

Credit: NASA/JPL-Caltech

[Above] This photograph shows the SpaceX Dragon cargo spacecraft being berthed to the space station. The SpaceX-4 mission will carry ISS-RapidScat to the station in late 2014.

The ISS-RapidScat payload will launch as two separate parts—the Instrument and the Nadir Adapter—onboard the SpaceX Cargo Resupply-4, or SpaceX-4, mission to the ISS. SpaceX-4 consists of a Dragon cargo spacecraft mounted atop a Falcon-9 launch vehicle. The RapidScat Instrument and Nadir Adapter are mounted inside the Dragon's unpressurized trunk, which provides power to the payloads' survival heaters from launch until they are removed for installation.

When it reaches the space station, the Dragon spacecraft will be robotically berthed. A robotic arm on the space station, controlled by ground controllers at NASA's Johnson Space Center, will then extract the Nadir Adapter from the Dragon trunk and install it onto the Columbus module, or laboratory. During the transfer, the Instrument and Nadir Adapter will be unpowered, and they must be installed within a specific time frame to ensure that they do not get too cold. Once the Nadir Adapter has been installed, ground



Credit: SpaceX

[Above] Prior to launch, the RapidScat Instrument and Nadir Adapter will be strategically mounted inside the Dragon trunk on SpaceX.

commands will be issued to restore power to its survival heaters. While that is taking place, the RapidScat Instrument will be heated in the Dragon trunk for at least 20 hours until it is warm enough to survive its unpowered transit and installation. The robotic arm will then extract the Instrument from the Dragon trunk and attach it to the Nadir Adapter, completing installation on the Columbus.

Credit: NASA

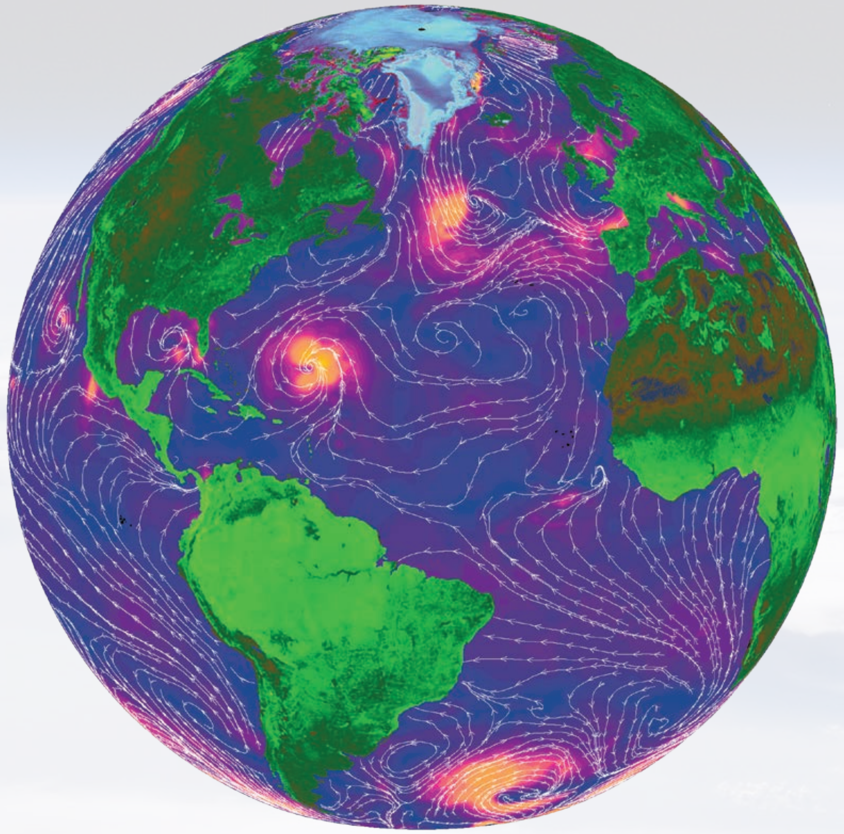
[Above] The ISS-RapidScat payload will be berthed to the Columbus module onboard the station—a seven-meter-long research laboratory installed in February 2008.

Credit: SpaceX

[Above] When the SpaceX-4 Dragon reaches the Columbus module, the Canadarm2 robotic arm will attach the spacecraft to the station before the installation process begins.

Credit: NASA

Expected Science Outcomes

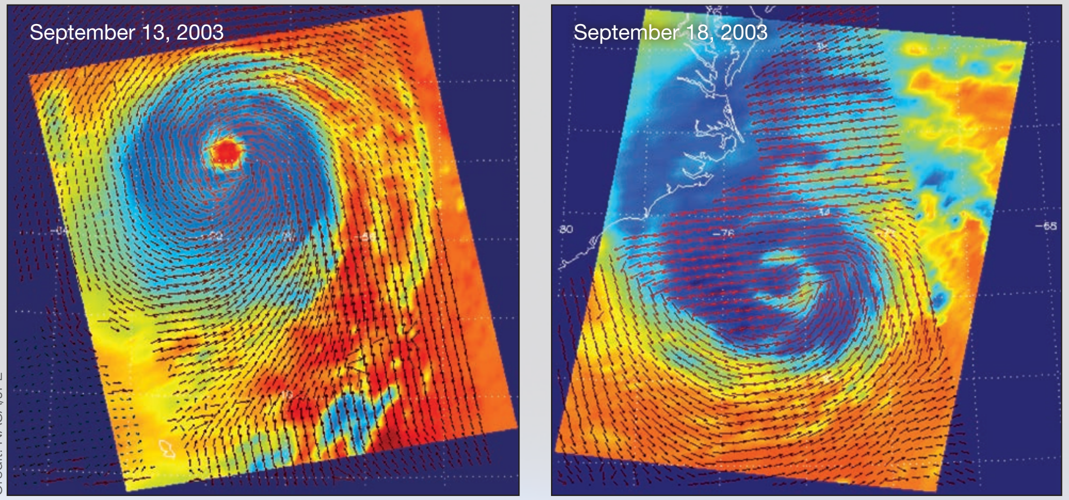


Credit: NASA/JPL-Caltech

[*Above*] This false-color image from September 20, 1999, was created with data from SeaWinds onboard NASA's QuikSCAT satellite. Over the ocean, colors indicate wind speed with orange as the fastest wind speeds and blue as the slowest. White streamlines indicate the wind direction. The large storm in the Atlantic off the coast of Florida is Hurricane Gert. Tropical Storm Harvey is evident as a high wind region in the Gulf of Mexico, while farther west in the Pacific is tropical storm Hilary. An extensive storm is also present in the South Atlantic Ocean near Antarctica.

In the tropics, sunlight creates daily and more frequent cycles in the rise and fall of winds. In the tropical Pacific, for example, scientists have found that variations in solar energy account for considerably more than half of the daily variation in wind speed. These wind cycles in turn strongly influence the formation of tropical clouds and rain, important components of Earth's water and energy cycles.

To date, all satellite scatterometers have flown in sun-synchronous orbits, which means that they observe the same Earth scene at the same local time each day. All of these scatterometers combined have not collected enough observations at enough different times of day for scientists to understand daily and semi-daily wind cycles.



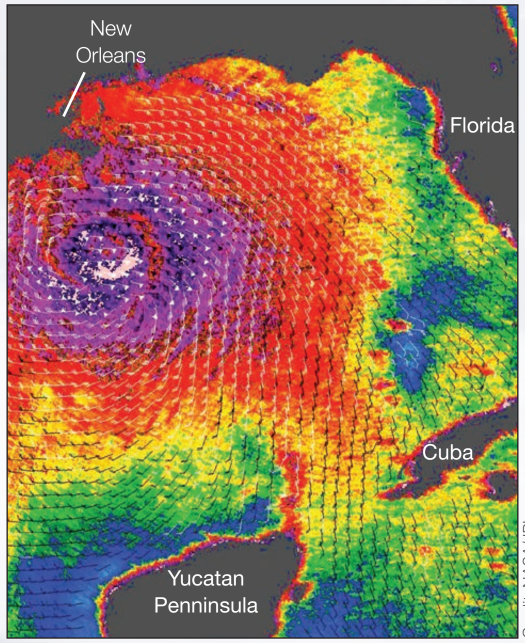
Credit: NASA/JPL

[*Left*] These two images show ocean-surface wind speed and direction [*arrows*] associated with Hurricane Isabel as viewed by each of the two SeaWinds scatterometers onboard ADEOS-II [*left*] and QuikSCAT [*right*]. The wind data from both SeaWinds instruments is overlaid on data that shows the temperatures of clouds and the surface, as viewed by the Atmospheric Infrared Sounder (AIRS) onboard NASA's Aqua satellite. The image on the left was taken on September 13, 2003, when Isabel was a Category 5 storm. The image on the right shows Isabel near North Carolina on September 18. Blue shades represent cold cloud tops, while orange and red shades represent warm ocean-surface temperatures.

For one six-month period, oceanographers received data from two scatterometers of the same kind: SeaWinds on QuikSCAT and another SeaWinds instrument on the ADEOS-II spacecraft. Data from these two instruments allowed scientists to make initial estimates of daily wind cycles in some parts of the ocean. During this brief period, however, they also discovered the difficulties in cross-calibrating two such similar instruments and recognized what an advantage it would be to have a single instrument in a non-sun-synchronous orbit. They now have that opportunity with ISS-RapidScat.

For the first time ever, ISS-RapidScat will allow scientists to fully sample the diurnal and semi-diurnal wind cycles (between 51.6 degrees north and south latitude) from space at least once every two months. Within the planned two-year life of the mission, scientists expect to be able to accurately estimate diurnal and semi-diurnal wind cycles—more accurately than if they were relying on data from multiple instruments.

Although the mission is primarily meant to observe the ocean, data from ISS-RapidScat are also expected to improve calibration and cross-calibration functions for scatterometers over land. For example, scientists can calibrate a scatterometer by pointing it at a large, homogeneous landmass, like the Amazon rain forest, and watching for inconsistencies in the resulting data. Photosynthesis and evaporation, however, change the amount of water within plants over the course of the day, which leads to variation in the radar backscatter and subsequent uncertainty in the calibration process. Since ISS-RapidScat will pass over the same spot on Earth's surface at different times of day, the data can be used to create a profile of that variability throughout the day, which can assist with the calibration of all spaceborne scatterometers.



Credit: NASA/JPL

[*Left*] Nearly the entire Gulf of Mexico was churning with the powerful winds and rains of Hurricane Katrina on August 28, 2005, when NASA's QuikSCAT satellite captured this image. The image depicts relative wind speeds swirling around the calm center of the storm as observed by the SeaWinds instrument onboard. The highest wind speeds, shown in shades of purple, circle a well-defined eye, with gradually weakening winds radiating outward. The barbs reveal wind direction, and the white barbs indicate heavy rainfall. At the time this image was taken, the National Hurricane Center reported that Katrina had winds of 257 kilometers per hour (160 miles per hour).


Credit: Penywise/morguefile.com

Benefits to Science and Society


Credit: NASA

[*Above*] Data from ISS-RapidScat, combined with data from other sources, will be used to support weather and marine forecasting, including tracking storms and hurricanes, as well as climate studies.

With the recent demise of an Indian scatterometer (in 2014) and limited data coming from SeaWinds on QuikSCAT, a significant gap has opened in the international scatterometer constellation's ability to monitor hazardous weather events like hurricanes, typhoons, and other storms at sea. Timely monitoring of these hazards improves weather forecasting and helps civil agencies plan their response to threatening storms. National Oceanic and Atmospheric Administration (NOAA)-sponsored studies have shown that timely forecasts also help ships reroute their course around severe storms, thus saving millions of dollars—and protecting human life. NOAA's National Hurricane Center has endorsed ISS-RapidScat as beneficial to accomplishing its mission, and forecasters at both NOAA and European forecasting centers plan to use data from ISS-RapidScat.

To give some specific examples, during the time SeaWinds on QuikSCAT was fully functional, its data were used to improve wind atlases, which sailors depend on to plan their routes over the high seas. Closer to shore, extreme surfers used the data to track swell-producing storms in their quest for the "perfect wave." Since ISS-RapidScat is expected to have similar performance to the earlier instrument—but


Credit: © 2009 David Young

with increased coverage of the tropics—sailors and surfers alike will benefit from the new data.

More significantly, ISS-RapidScat will also assist in global climate studies. As has been described above, the cross-calibrated scatterometer data can be used to correct both past and future observations from scatterometers, creating a consistent, long-term ocean wind dataset. The record will reveal trends in atmospheric circulation that may have societal impacts, such as whether the winds that drive ocean upwelling at the coasts are changing as climate changes—which is very relevant to the long-term health of fisheries. Another question that such long-term ocean wind datasets are expected to help answer is whether the extent of the tropical and subtropical circulation is changing and how changes might affect rainfall patterns over the continents. Data from ISS-RapidScat are expected to provide new perspectives of ocean winds that will help answer these and other questions and benefit societal needs for years to come.

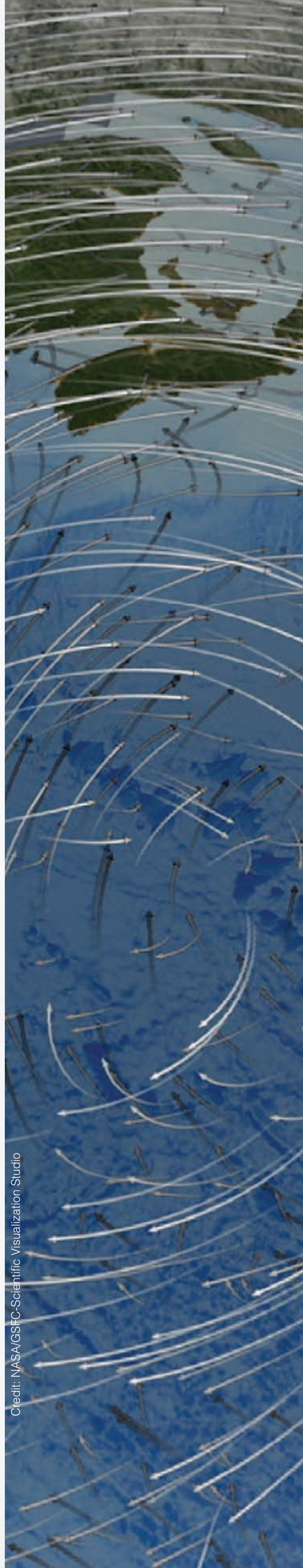
Partners

ISS-RapidScat is a partnership between:

- NASA's Jet Propulsion Laboratory,
- the International Space Station Program,
- NASA's Science Mission Directorate,
- NASA's Johnson Space Center,
- NASA's Kennedy Space Center,
- NASA's Marshall Space Flight Center, and
- the European Space Agency.

Science Data Distribution

Data from ISS-RapidScat will be freely available for download via:
podaac.jpl.nasa.gov


Credit: NASA/GSFC-Scientific Visualization Studio

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