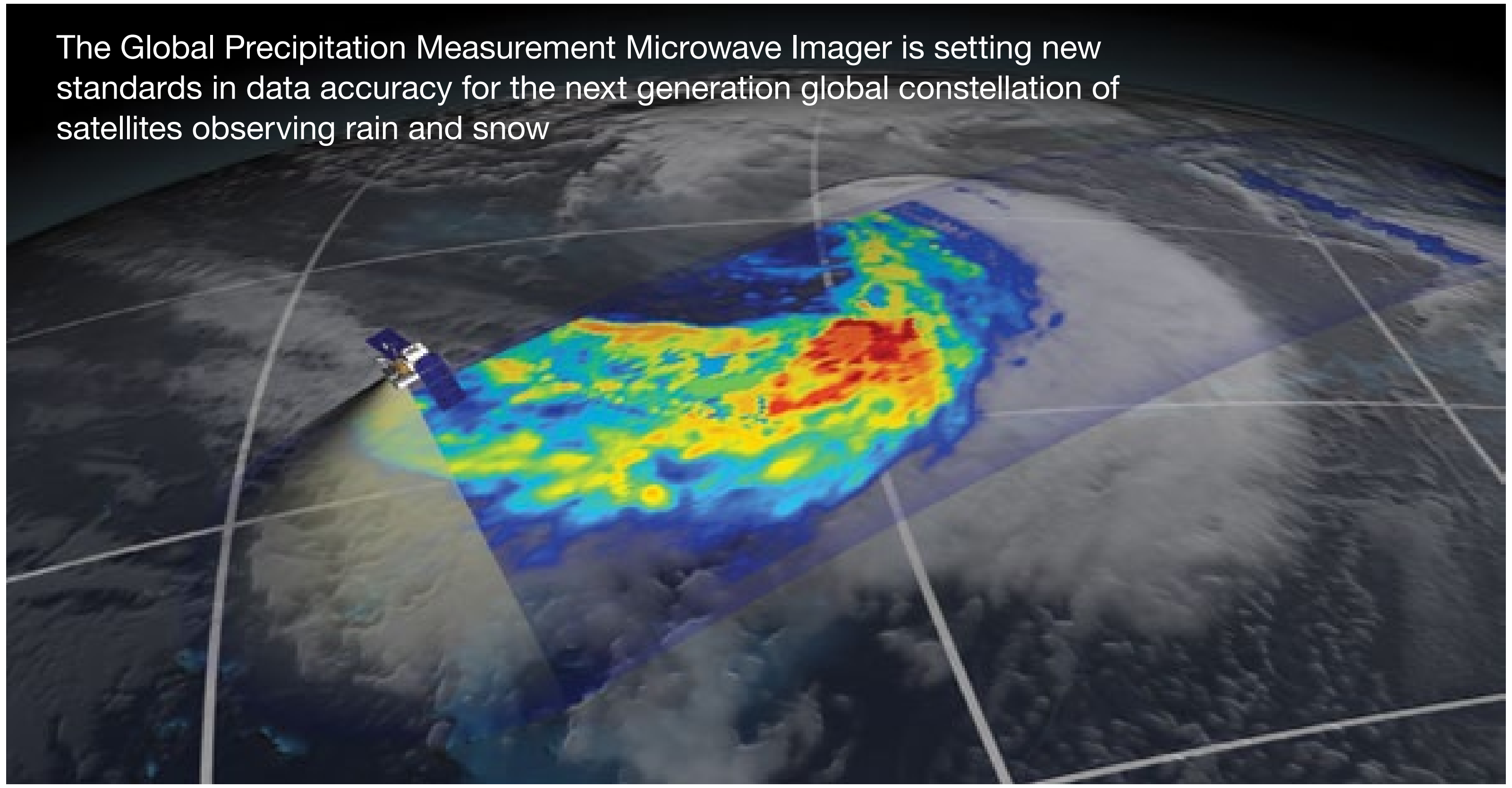
by Don Figgins

REIGN CHECK

Imagers on NASA's GPM will give global coverage over a wide range of precipitation types

The Global Precipitation Measurement Microwave Imager is setting new standards in data accuracy for the next generation global constellation of satellites observing rain and snow



GMI/NASA image showing rain rates across a 550-mile (885km) wide swath of an extra-tropical cyclone observed off the coast of Japan on March 10, 2014. Red areas indicate heavy rainfall, while yellow and blue indicate less intense rainfall. The upper right blue areas indicate falling snow

Two new instruments aboard NASA's Global Precipitation Mission (GPM) Core Observatory launched on February 27, 2014, are giving forecasters the timely, detailed data they need to improve tracking of extreme weather events and climate change patterns.

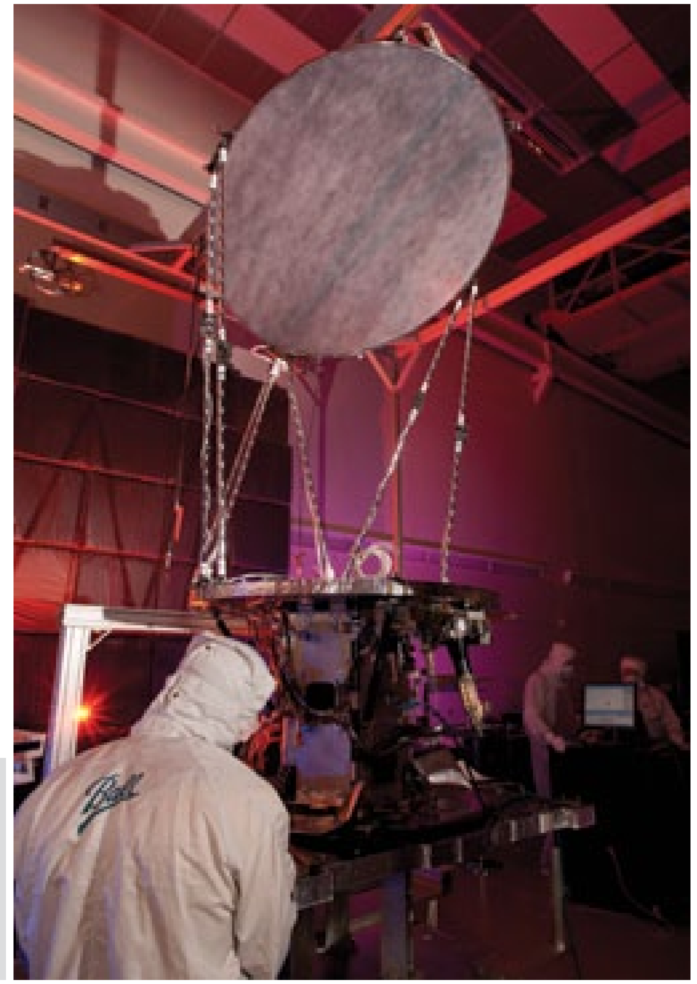
GPM is a joint effort of NASA and the Japan Aerospace Exploration Agency (JAXA) and represents a major advancement the work pioneered by the NASA/JAXA Tropical Rainfall Measuring Mission (TRMM), launched in 1997. TRMM primarily measures tropical and subtropical rainfall and was the only current satellite that carried weather radar prior to the launch of the GPM Core Observatory. Three of TRMM's five instruments were the first to provide 3D maps of storm structures. GPM provides advanced measurements, including coverage over medium to high latitudes, improved estimates of light rain and snowfall, advanced estimates over land and ocean, and coordination of radar and microwave observations to unify and refine precipitation estimates from a constellation of research and operational satellites.

Global coverage

GPM's instruments are advancing technology in several areas. The GPM Microwave Imager (GMI) is able to provide more accurate data due to its ability to measure smaller size rain droplets and light snow. These precipitation events are often underestimated in terms of the amount of water actually produced. GMI has specific channels that will detect frozen particles in general and hail in particular. This will provide crucial information about storm severity because hail is an indicator of severe storms.

The other prime instrument on the core observatory is the Dual-frequency Precipitation Radar (DPR) developed by JAXA and the National Institute of Information and Communications Technology (NICT). The DPR is a space-borne precipitation radar capable of making accurate rainfall measurements by examining the 3D structure of storms.

GPM Constellation graphic: Image: NASA



The GPM Microwave Imager in a test clean room at Ball Aerospace. Image: Ball Aerospace

In addition, GPM will provide global coverage and a three-hour data refresh cycle. TRMM flew only within 35° on either side of the equator, but GPM's 65° low Earth orbit takes it from Canada's far north to the tip of South America.

The high-frequency channels on GMI, coupled with the increased sensitivity of the DPR, will enable GPM to improve forecasting by estimating light rain and snow falling over land outside the tropics, even in the winter seasons, which current satellites are unable to measure. These advanced measurements will extend current capabilities in monitoring and predicting hurricanes and other extreme weather events, as well as improved forecasting for floods, landslides and droughts.

Water power

Flooding is the number one weather-related killer in the USA and one of the world's most costly disasters, both in terms of lives lost and property destroyed. Flash flooding around the world kills or displaces thousands, so forecasters need to have accurate, timely data that can serve as an early warning system.

Flash floods are defined as usually arriving within a six-hour window after a major storm or weather event. GMI, with a three-hour data refresh, can feed Numerical Weather Prediction (NWP) models timely data, enabling forecasters to issue earlier and more accurate flash flood warnings. GMI, especially at mid-latitudes, extends forecasters' abilities to detect and measure light rain and small snow particles so that NWP models can generate earlier warnings.

If GMI had been operating at the time Hurricane Katrina struck the US Gulf Coast in 2005, forecasters might have been able to detect how much rain was coming across the Gulf of Mexico during the storm's trek and take precautions far in advance, evacuating those closest to the levees at risk. GMI will also help detect storm surges and enable forecasters to better predict how far above sea level water will rise.

Global precipitation measurement

Advanced technology

GMI is a conical scan microwave radiometer with 13 channels operating from 10.65GHz to 183.3GHz. With its 1.2m (3.9ft) aperture, the GMI can provide 4.4km (2.7 miles) to 32km (19.8 miles) resolution at an altitude of 407km (253 miles). Ball Aerospace & Technologies Corp. in Boulder, Colorado designed, built and tested GMI, in addition to providing pre- and post-launch support for the instrument.

Precipitation emits radio waves that indicate different sizes and types of precipitation. The 10ft tall GMI picks up radio wave emissions in a wide range of microwave frequencies. The four high-frequency millimeter wave channels on GMI are tuned to measure small particles of ice, snow and rain droplets. GMI's refined algorithms measure data at various frequencies that provide different types of data.

The GMI scanner spins every two seconds, and on each rotation four calibration points ensure a high degree of data accuracy. Electronic filters remove noise picked up by the sensitive microwave channels and turn the data into digital downloads for the NASA Operations Center at Goddard Space Flight Center in Greenbelt, Maryland.

The GPM Core Observatory has an unusual orientation to the sun, so GMI was designed to minimize solar intrusion, which creates errors in data. GMI was also engineered using composite structures instead of aluminum, which reduced mass and weight by a third. Using an advanced circuit design with solid-state electronics, including miniature microwave integrated circuit technology, reduced power consumption by 20% compared with previous radiometers. Efficiencies built into the instrument leave more resources available for the mission's science objectives.

GMI also takes Earth brightness temperature samples from various locations on the globe. Brightness temperature measures microwave radiation that travels up from the top of Earth's atmosphere. Microwave radiometer brightness temperatures are considered a fundamental climate data record. They are used to formulate ocean measurements of wind speed, water vapor, cloud liquid water, rain rate and sea surface temperature. The DPR is expected to be more sensitive than its TRMM predecessor, especially in the measurement of light rainfall and snowfall in high latitudes. The DPR consists of a Ku-band precipitation radar (KuPR) and also a Ka-band precipitation radar (KaPR).

Ball-built Global Precipitation Measurement (GPM) Microwave Imager (GMI) in a Ball Aerospace clean room prior to shipment to Goddard Space Flight Center for integration with the spacecraft. Image: Ball Aerospace

While the GMI captures precipitation intensities and horizontal patterns, the DPR provides insights into the 3D structure of rain, snow and other precipitation particles, and an accurate estimate of rainfall rate. Together, these two instruments will provide a database of measurements that will be used with observations of other partner satellites to upgrade the quality of all collected data and to provide uniform precipitation estimates everywhere in the world, refreshed every three hours.

The high accuracy provided by GMI is being used as a 'gold standard' to calibrate the other radiometers in the GPM eight-satellite constellation. The constellation includes the Ball-built Suomi National Polar-orbiting Partnership (Suomi NPP) satellite launched in 2011 and the first Joint Polar Satellite System satellite (JPSS-1), currently in development at Ball and scheduled for an early 2017 launch. GMI will enable correlation between GMI products, Suomi NPP model data and actuals.

GPM Constellation Partners include the GPM Core Observatory, NOAA-18 & -19, GCOM-W1, DMSP F17-20, TRMM, MetOp B/C, Suomi NPP and JPSS-1.

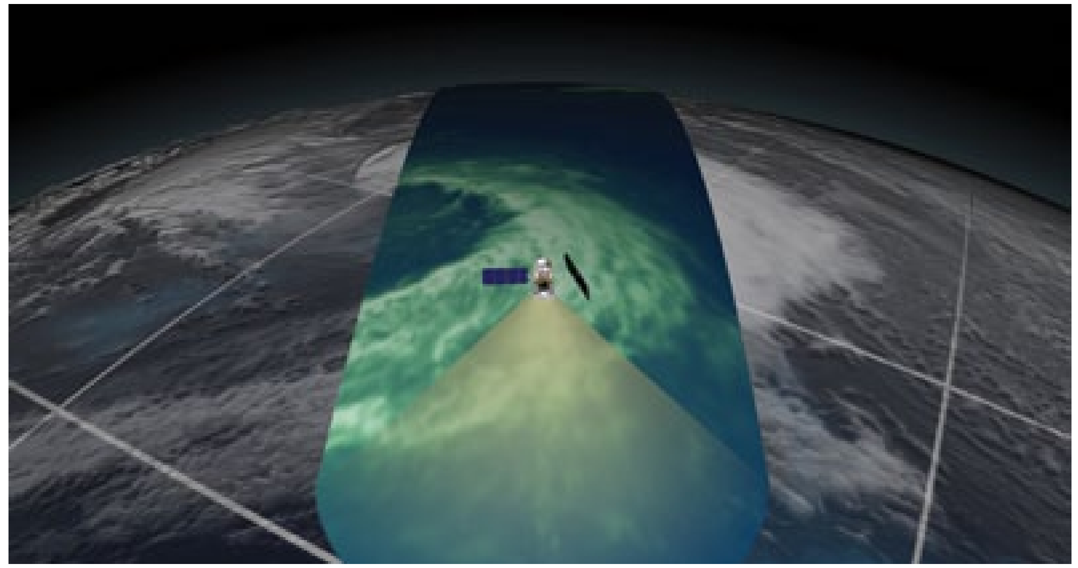
Space measurement

The scientific impetus behind obtaining extremely accurate precipitation measurements is twofold: the rarity of freshwater on Earth, and early warning for severe weather events. Even though two-thirds of the planet is covered by water, just 2% of that is life-sustaining freshwater. With changing climate patterns and a growing population, understanding the water cycle will help prepare for drought, and advance knowledge of storms will enable communities to prepare for severe weather events like floods and landslides. Scientists need a better understanding of the water cycle to know how much rain falls over the ocean and how rain patterns move from one location to another.

Measuring precipitation from space is necessary because reliable ground-based precipitation measurements are difficult to obtain. Most of the world is covered by water and many countries don't have precise rain measuring equipment. Also, the type of information available from space-based sensors is not available from ground-based measuring systems. Precipitation is difficult to measure because precipitation systems can be random and evolve very rapidly. During a storm, precipitation amounts can vary greatly over a very small area and over a short time.

Space-based sensors provide data derived from cloud-top radiation, and microwave radiometers provide direct precipitation measurement based on radio waves emitted from precipitation particles. In addition, GPM is advancing space-based measurement even farther by combining active and passive sensing capabilities – GMI being passive and DPR active.

GPM can improve climate prediction through better understanding of surface fluxes, soil moisture storage, cloud/precipitation microphysics, and latent heat release in Earth's atmosphere. By providing 4D measurements of global precipitation that varies over time and space, GPM will deliver better understanding of precipitation systems, water cycle variability and freshwater availability.



NASA image of GPM/GMI collecting 37GHz horizontally polarized brightness temperature data (colored in shades of aquamarine) on March 10 over a Pacific storm east of Japan

Sensor synergy

Suomi NPP's five instruments, which measure a variety of weather and climate phenomena, and GMI's prediction measurements on precipitation dovetail to enhance predictive and actual precipitation amounts. GMI will confirm what Suomi NPP finds. For example, if 1.5 inches of rain are predicted by the data Suomi NPP's instruments are feeding into NWP models, GMI's data will give forecasters an accurate reading of the quantity of rain that actually falls.

On May 1, NOAA's Satellite and Information Service named Suomi NPP as its primary operational polar-orbiting satellite system for NOAA's day-to-day operations. The US National Weather Service uses Suomi NPP global measurements in its Numerical Weather Prediction models, and its advanced imagery of clouds, ocean surface, land features and other physical parameters is used by civilian and US Department of Defense forecasters with environmental prediction responsibilities from the tropics to the poles. Suomi NPP's precise observations of the physical environment are improving the accuracy and extending the range of global forecasts three to seven days in advance of significant weather events, including hurricanes and winter storms.

Suomi NPP was launched from Vandenberg Air Force Base on October 28, 2011 and has since logged more than 12,000 orbits. Its sensors have surpassed expectations for low noise and accuracy, and have provided useful data to forecasters beginning well before it gained operational status. Suomi NPP data, in conjunction with other polar weather satellite data, was essential to predicting the path of 2012's Hurricane Sandy more than four days in advance. The instruments on board the satellite are: Advanced Technology Microwave Sounder (ATMS), Cross-track Infrared Sounder (CrIS), the Visible Infrared Imaging Radiometer Suite (VIIRS), Ozone Mapping and Profiler Suite (OMPS) and Clouds and the Earth's Radiant Energy System (CERES). ∎

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NEXT GENERATION

Suomi NPP is part of NOAA's next generation Joint Polar Satellite System (JPSS) constellation of polar-orbiting environmental satellites. It provides continuity for NASA's Earth Observing System (EOS) and is a bridge between NOAA's legacy Polar Orbiting Environmental Satellites (POES) and the JPSS-1 satellite, which is being built and integrated at Ball's spacecraft manufacturing facility in Boulder, Colorado.

On schedule for a 2017 launch, the JPSS-1 spacecraft began undergoing nine months of integration and testing of satellite components and subsystems in March 2014 and will be ready for instrument integration at the satellite level beginning in November 2014. NOAA recently announced that all five instruments that will fly on the JPSS-1 satellite are now in the environmental testing phase, including the Ozone Mapping and Profiler Suite being built by Ball.

The advanced precipitation measurement capabilities of GPM, with its GMI and DPR instruments, is making a major contribution to the accuracy and timeliness of the critical weather data fed in into numerical weather prediction models. Combined with Suomi NPP, the data from other satellites in the GPM constellation and the most advanced satellite weather technology built into JPSS-1, forecasters, scientists and disaster response planners will have even more timely access to life-saving information. More detailed knowledge of climate change will enable us to better manage the heightened level of extreme weather events occurring around the globe and help us be better prepared for the effects of Earth's changing climate patterns.