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the earth observer

Editor's Corner

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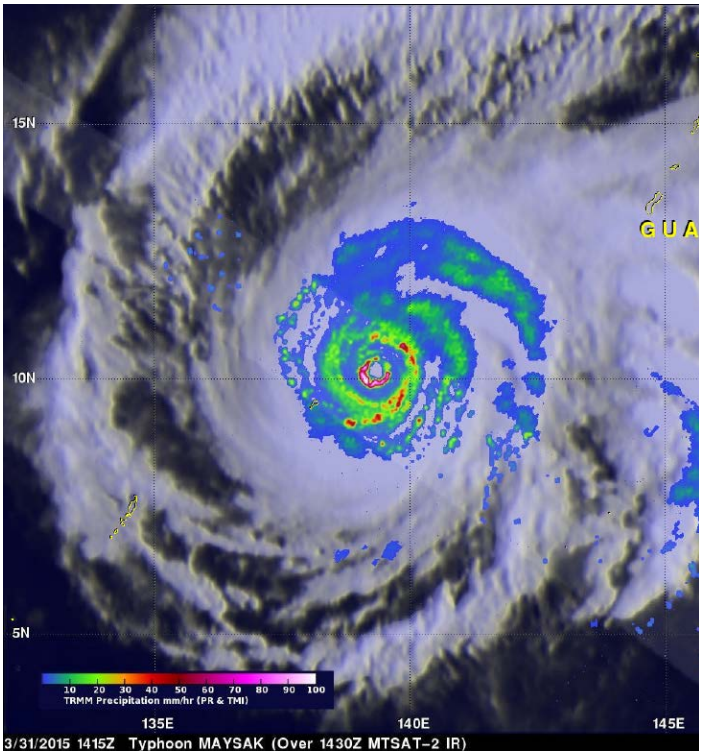
The Tropical Rainfall Measuring Mission (TRMM), a joint mission between NASA and JAXA to study rainfall for weather and climate research, was launched in November 1997, with a design lifetime of three years. TRMM officially came to an end on April 8, 2015 (see *pmm.nasa.gov/trmm/mission-end*); the spacecraft is expected to reenter the Earth's atmosphere in mid-June. TRMM became a fixture over the global tropics, producing over 17 years of valuable scientific data. TRMM carried five instruments: a three-sensor rainfall suite consisting of the Precipitation Radar (PR), TRMM Microwave Imager (TMI), and Visible and Infrared Scanner (VIRS); and two related instruments, the Lightning Imaging Sensor (LIS) and Clouds and Earth's Radiant Energy System (CERES). Its unique 17-year dataset of global tropical rainfall and lightning became the space-based standard for measuring precipitation, and led to research that improved our understanding of tropical cyclone structure and evolution, convective system properties, lightning-storm relationships, climate and weather modeling, and human impacts on rainfall. The data also supported operational applications such as flood and drought monitoring and weather forecasting.

Prior to its being shut down on April 1 for the upcoming end-of-mission processes, TRMM's PR captured an image of Super Typhoon Maysak as it roared through the warm waters of the West Pacific, south of Guam on March 31, 2015 (see below). It shows the rain intensities within the very heart of the typhoon as it undergoes an eye wall replacement cycle, and is emblematic of the nature and quality of data that TRMM has provided for so many years. Congratulations and kudos to the many TRMM teams that made the mission such a success—from initial mission concept through design, implementation, and operations.



Meanwhile, TRMM's successor, the Global Precipitation Measurement (GPM) Core Observatory, is one year into its three-year prime mission (May 2014-May 2017). With a little more than

continued on page 2

As its final image acquisition, the Precipitation Radar on TRMM captured a textbook example of an eye wall replacement cycle in a tropical cyclone in progress on March 31, 2015. The eye of Super Typhoon Maysak, [*center*] is characterized by descending air and calm conditions. Immediately surrounding the eye is the original inner eye wall (reds and purple) where air is rising in convective updrafts and releasing heat through condensation. Continuing further out from the eye, an outer eye wall is forming (green) that will eventually replace the inner eye wall.

Image credit: Image produced by **Hal Pierce** [NASA's Goddard Space Flight Center (GSFC)/Science Systems and Applications, Inc. (SSAI)] and shortened caption by **Stephen Lang** [GSFC/SSAI]. The full caption with descriptive details can be viewed at *pmm.nasa.gov/mission-updates/trmm-news/trmm-satellite-makes-direct-pass-over-super-typhoon-maysak.*

editor's corner

In This Issue

Reminder: To view newsletter images in color, visit *eospso.nasa.gov/earth-observer-archive.*

a year of overlap between TRMM and GPM, there were multiple cyclones, typhoons, and hurricanes, and just about every type of weather event observed (nearly) simultaneously by both missions. This joint dataset has proved valuable in that the GPM team has shown that the GPM Microwave Imager (GMI) is one of the better calibrated precipitation radiometers currently operating in space. All of the GPM products have been released, including the powerful Integrated Multi-satellite Retrievals for GPM (IMERG) dataset at a 30-minute interval and a 0.1 x 0.1° grid. IMERG is produced in near-real-time (4-6 hrs) for applications, and with a 3-month latency for research studies. In September 2015 the revised GPM products will be released with new algorithm versions.

In other mission-related news, although ISS-RapidScat has been deployed on the space station for only seven months (deployed September 23, 2014), forecasters are already finding this new eye-in-the-sky helpful as they keep watch on major storms around the globe. ISS-RapidScat measures Earth's ocean surface wind speed and direction over open waters. The instrument's data on ocean winds provide essential measurements for researchers and scientists to use in weather predictions—including hurricane monitoring. ISS-RapidScat has observed the already active 2015 Southern Hemisphere hurricane season as well as the Northern Hemisphere's winter storm season. Please turn to the news story on page 32 of this issue to see several examples of the data being returned from ISS-RapidScat.

Previously, we reported that the antenna on Soil Moisture Active Passive (SMAP)—launched January 31, 2015—was successfully "spun up" to nearly 14.6 RPM in a two-stage process in late March[1]. With its spin-up activities complete, the observatory's radar and radiometer instruments were powered on from March 31 to April 3 in a test designed to verify the pointing accuracy of the antenna and the overall performance of the radar and radiometer instruments. The radar data acquired from the test have been processed to generate data products with a spatial resolution of about 30 km. The radiometer data from the instrument test have also been processed to map microwave emissions from Earth's surface, expressed as brightness temperatures, at a spatial resolution of about 40 km. These images appear as Figure 1 and 2, respectively, in the news article on page 30 of this issue, where you can learn more about what these images reveal.

Looking toward the future, Jason-3 is currently scheduled for launch on July 22 from Vandenberg Air Force Base in California onboard a SpaceX Falcon 9 launch vehicle. Jason-3 is the latest in a series of U.S.-European satellite missions that have been measuring the height of the ocean surface for 23 years. The mission's predecessors were TOPEX/Poseidon (launched in 1992), Jason-1 (2001), and the Ocean Surface Topography Mision (OSTM)/Jason-2 (2008, *still active*). Sea level height is a critical piece of information about Earth's natural cycles and how humans are affecting our planet. The Jason satellites have provided the most accurate measurements of global sea level rise to date. Knowing sea level height also improves hurricane forecasts, global

[1] See the Editorial of the March–April 2015 issue of *The Earth Observer* [**Volume 27**, **Issue 2**, p. 2].

positioning and navigation, and the efficiency of fisheries, and other offshore industries.

Jason-3 is an international partnership led by NOAA with participation from NASA, CNES, and EUMETSAT. As they did for the previous missions in the series, JPL built Jason-3's radiometer, GPS, and laser reflector, is procuring the launch, and will help oversee the science team that is responsible for ensuring the quality of the data. The primary science instrument in all these satellites is a radar altimeter, which transmits a microwave pulse to the ocean's surface and determines the signal's return time. When combined with information on the precise location of the spacecraft, the returned radar signals give a record of sea-surface height. Having consistently out-performed their required accuracy, the altimeter has not required a major redesign since Jason-1[2].

In addition, NASA and the USGS will continue their long-standing partnership as they work to develop the Landsat 9 mission. The President's fiscal year 2016 budget request calls for initiation of work on a Landsat 9 spacecraft as an upgraded rebuild of Landsat 8. The budget also calls for the exploration of technologies and systems innovations to provide more cost effective and advanced capabilities in future land-imaging missions beyond Landsat 9, e.g., finding ways to miniaturize instruments to be launched on smaller, less-expensive satellites.

"Moving out on Landsat 9 is a high priority for NASA and USGS as part of a sustainable land imaging program that will serve the nation into the future as the current Landsat program has done for decades," said **John Grunsfeld** [NASA Headquarters—*Associate Administrator for Science*]. "Continuing the critical observations made by the Landsat satellites is important now and their value will only grow in the future, given the long term environmental changes we are seeing on planet Earth."

As they have done with all previous Landsat missions, NASA will build, launch, and perform the initial checkout and commissioning of Landsat 9; USGS will operate the satellite, and process, archive, and freely distribute mission data. GSFC will lead development of the Landsat 9 flight segment and build the Thermal Infrared Sensor (TIRS). With launch planned for 2023, Landsat 9 will propel the Landsat program past 50 years of continuous observations of Earth's changing land surface. Please turn to the news story on page 34 of this issue to learn more about the plans for Landsat 9.

Finally, in this issue we report on the Gregory G. Leptoukh Online Giovanni Workshop, which took place on November 10, 12-14, 2014. Named in honor of one of the founders of the Giovanni online visualization and analysis environment (*disc.sci.gsfc.nasa.gov/giovanni*), the workshop took place in the Earth Science Data and Information System (ESDIS) Adobe Connect Webinar environment. This workshop also featured an interactive global poster session, during which the authors of online posters accepted and responded to questions sent by email on the day designated for the session. Please turn to page 14 to learn more about the latest research results obtained using Giovanni.

On a related note, the Goddard Earth Sciences Data and Information Services Center (GES DISC) recently added 49 data variables to Giovanni-4 (the latest version of Giovanni, which is described in the article referenced above) including: AIRS Carbon Dioxide, NASA Ocean Biogeochemical Model (NOBM), SeaWiFS Deep Blue Aerosol Climatology, TOMS Aerosol and Ozone, TRMM *Version 7*, and TRMM Real-Time Daily. ■

Acronyms used in the Editorial and Article Titles

AIRS	Atmospheric Infrared Sounder
CNES	Centre National d'Études Spatiales [French Space Agency]
ECOSTRESS	ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station
EOSDIS	Earth Observing System Data and Information System
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
Giovanni	Geospatial Interactive Online Visualization ANd aNalysis Infrastructure
GPS	Global Positioning System
GRACE	Gravity Recovery and Climate Experiment
GSFC	NASA's Goddard Space Flight Center
ISS-RapidScat	International Space Station Rapid Scatterometer
JAXA	Japan Aerospace Exploration Agency
JPL	NASA/Jet Propulsion Laboratory
NOAA	National Oceanic and Atmospheric Administration
SeaWiFS	Sea-viewing Wide Field-of-view Sensor
RPM	Revolutions Per Minute

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[2] To learn more about Jason-3, please visit *www.nasa.gov/jpl/jason-3-will-add-to-record-of-the-seas-rise-and-fall*.

feature articles

Seeing is Believing: EOSDIS Worldview Helps Lower Barriers for NASA Earth-Observing Data Discovery and Analysis

Josh Blumenfeld, NASA's Goddard Space Flight Center/ADNET Systems, Inc., joshua.c.blumenfeld@nasa.gov

The EOSDIS is responsible for managing, processing, archiving, and distributing NASA's Earth-observing data, and currently manages the more than nine petabytes of data collected by NASA's satellite, airborne, and field missions.

Introduction

When a sensor aboard one of NASA's Earth-observing satellites sends its raw data back to Earth, the data are in the form of numbers—often a lot of numbers. If you have the right background and training (not to mention time), it is possible to sift through the lines of numbers to discern what the data may indicate. On the other hand, an image created from the same data allows you to rapidly and efficiently begin to make inferences about the data's spatial and temporal significance, and discover patterns that later can be studied and verified through analysis of the numbers behind the image.

Developing and providing efficient and innovative ways for scientists, researchers, students, and others to interact with NASA's tremendous amount of Earth Observing System (EOS) data is an important objective of NASA's Earth Observing System Data and Information System (EOSDIS[1]). The EOSDIS is responsible for managing, processing, archiving, and distributing NASA's Earth-observing data, and currently manages the more than nine petabytes (PB) of data collected by NASA's satellite, airborne, and field missions. To put this amount of data into perspective, one PB is roughly equivalent to 20-million four-drawer filing cabinets filled with text.

Providing Rapid Access to Visualizations of NASA's EOS Data

Once EOS data are collected, they are sent to one of the EOSDIS's 12 discipline-specific Distributed Active Archive Centers (DAACs) for processing, archiving, and distribution. Additional data products are produced by several Science Investigator-led Processing Systems (SIPS) and sent to the appropriate DAAC or DAACs for storage and distribution.

The EOSDIS Worldview data-browsing interface[2] allows users around the world to interactively view images created from EOS data. Worldview is enabled by the EOSDIS's Global Imagery Browse Services (GIBS[3]) products—see **Figure 1**. The goal

[1] The evolution of EOSDIS has been detailed previously in "The Earth Observing System Data and Information System: Where We Were and Where We Are, Parts I and II" in the July-August [**Volume 21**, **Issue 4**, pp. 4-11] and September-October 2009 [**Volume 21**, **Issue 5**, pp. 8-14] issues of *The Earth Observer*. For more information, visit *earthdata.nasa.gov*.
[2] Worldview is accessible at *worldview.earthdata.nasa.gov*
[3] GIBS is accessible at *earthdata.nasa.gov/gibs*

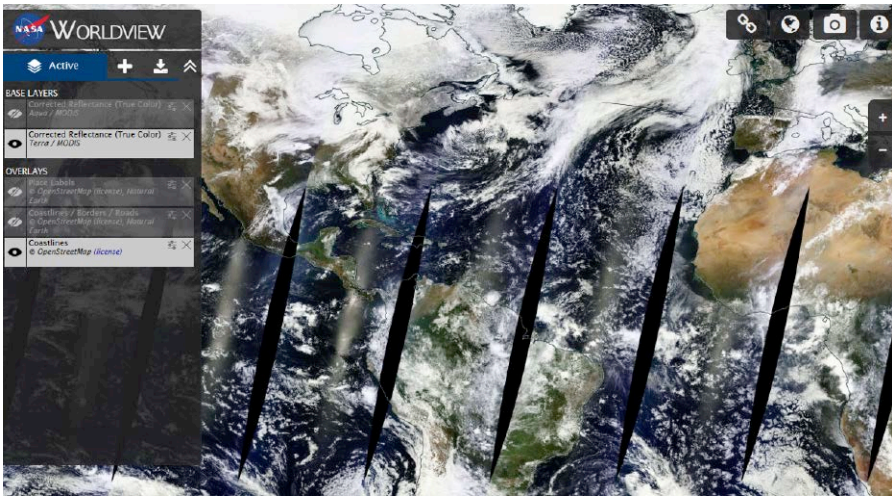


Figure 1: The default base layer on the Worldview home page shows the Earth as it looked within a few hours of a satellite overflight, including clouds, snow cover, storms, and vegetation. The black gaps in this image are areas not covered by the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument aboard the Terra satellite overpass on March 25, 2015. GIBS imagery can be selected using the Add Layers button (the "+" symbol under the word "Worldview" in the upper left menu). The Download Data button is under the end "w" in "Worldview." **Image credit:** NASA Worldview

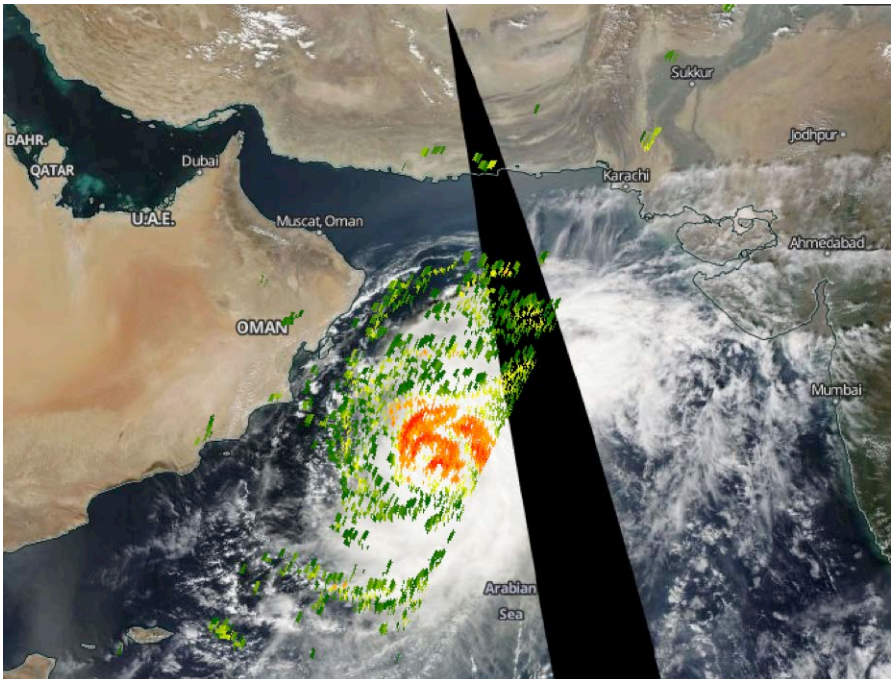


Figure 2: Worldview image of Cyclone Nilofar obtained on October 28, 2014, showing Rain Rate data from the Global Precipitation Measurement (GPM) satellite overlaid on Moderate Resolution Imaging Spectroradiometer (MODIS) Corrected Reflectance data from the Aqua satellite. **Image credit:** NASA Worldview

of the Worldview and GIBS development teams is to transform the way users discover and use EOSDIS data. "I think Worldview and GIBS improve the approachability of the data," says **Ryan Boller** [NASA's Goddard Space Flight Center (GSFC)—*Worldview* and *GIBS Project Manager*]. "For new users, it's an attempt to reduce the barriers to using what we have."

The *standard data products* (that is, data products created using the best available ancillary, calibration, and ephemeris information) that are produced, archived, and distributed by the DAACs are designed for scientific research and other applications that require the most accurate data possible. The trade-off with turning raw data into research-quality data is that those data often are not available until days or even weeks after they are collected.

This time lag, or latency, makes it difficult, if not impossible, to use standard data products to analyze and manage ongoing natural events such as wildland fires or storms. For these applications, data visualizations that are produced as rapidly as possible after a sensor collects the data provide the information necessary to make immediate management decisions. "The applications community, especially the wildland fire community, was really interested in being able to see the imagery rapidly," says Boller. "They didn't need to get to the underlying data; they just needed to determine if there was a fire or not."

*"I think Worldview and GIBS improve the approachability of the data. For new users, it's an attempt to reduce the barriers to using what we have."—**Ryan Boller** [GSFC]*

The EOSDIS solution for enabling rapid access to EOS data is the Land, Atmosphere Near real-time Capability for EOS (LANCE)[4]. LANCE provides more than 100 *near real-time* (NRT) products that are served as imagery through GIBS and can be viewed using Worldview and other client systems, usually within four hours after a sensor collects the data. If desired, users can easily download the data used to create the image—see **Figure 2**.

A Closer Look at Worldview

The EOSDIS development team released Worldview in 2011; it facilitates the interactive browsing of images retrieved from GIBS and enables users to:

- visually analyze data and quickly discern patterns in the data;

[4] LANCE is accessible at *earthdata.nasa.gov/data/near-real-time-data*. It has been discussed in previous articles, the most recent being "NASA FIRMS Helps Fight Wildland Fires in Near Real-Time" in the March–April issue of *The Earth Observer* [**Volume 27**, **Issue 2**, pp. 14-17].

- manage ongoing, time-critical natural events such as wildland fires, dust storms, and floods through the use of NRT data; and
- acquire the data underlying the imagery, which can be retrieved using the Download Data button on the Worldview menu.

The default Worldview base layer is a true-color image of Earth from the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument on NASA's Terra and Aqua Earth-observing satellites that shows the Earth as it looked within the past few hours. Overlays, including national borders, coastlines, and place names, can be added to the base map with a single click. Users have the option of several additional base layers, including Corrected Reflectance in several MODIS bands, NASA's *Blue Marble*[5] image of Earth, and *Earth at Night*—last two base layers are shown in **Figure 3**.

Figure 3: Worldview features more than a dozen static and dynamic base layer options. Shown here are the *Blue Marble* (August 2004, shaded relief and bathymetry), from MODIS [*left*], and *Earth at Night* 2012, from Suomi National Polar-orbiting Partnership (NPP)/Visible Infrared Imager Radiometer Suite (VIIRS) [*right*]. Both images are available via NASA's Earth Observatory website (*earthobservatory.nasa.gov*). **Image credit:** NASA Worldview

Once a base layer is selected, users can overlay more than 120 data visualizations by simply selecting a check box. These visualizations include data from instruments on the Terra, Aqua, Aura, and Global Precipitation Measurement (GPM) missions, as well as socioeconomic data products from NASA's Socioeconomic Data and Applications Center (SEDAC). Over the next year, data from the Advanced Microwave Scanning Radiometer 2 (AMSR2) on the Global Change Observation Mission-Water 1 (GCOM-W1), Sea Ice Concentration data from the Scanning Multichannel Microwave Radiometer (SMMR) on Nimbus-7[6], and data from the Soil Moisture Active Passive (SMAP) mission will be added. Users have great flexibility to add multiple layers to analyze a wide range of environmental criteria to create the visualization needed—see **Figure 4**.

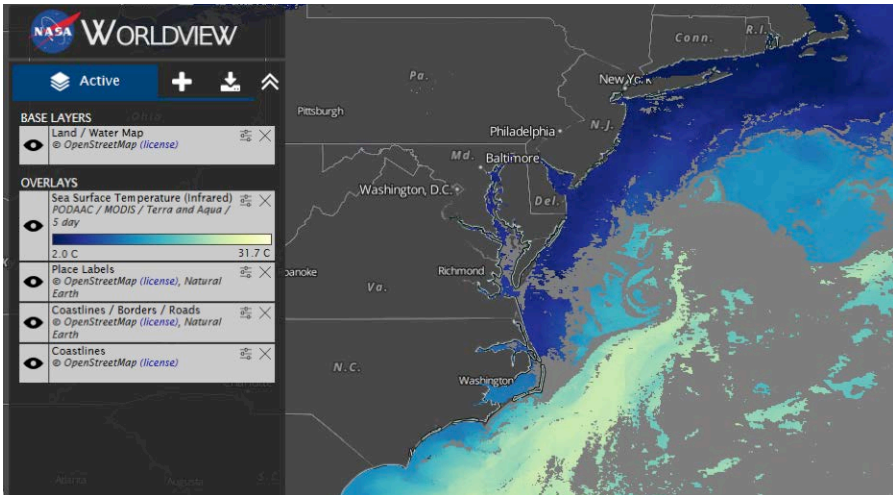


Figure 4: Worldview image from April 1, 2015, using the Land/Water Map base layer with an overlay of sea surface temperature (infrared). The "Blue 9" color palette is selected for the key. **Image credit:** NASA Worldview

[5] The Blue Marble: Next Generation is a series of color images of Earth for each month of 2004 with a resolution of 500 m (1640 ft) per pixel at a global scale. To learn more please visit *earthobservatory.nasa.gov/Features/BlueMarble*.

[6] To learn more about history of, accomplishments of, and measurements from the Nimbus series of satellites, see "Nimbus Celebrates Fifty Years" in the March–April 2015 issue of *The Earth Observer* [**Volume 27**, **Issue 2**, pp. 18-31].

Current data products can be compared with data from earlier days, months, and years by using the slider along the bottom of the Worldview home page. Data dating back to May 2012 currently are available, although data dating back to the start of the Terra and Aqua missions will be available in several stages throughout 2015 and 2016 (see *Future Plans,* below).

A Closer Look at GIBS

GIBS, which also was released in 2011, is a set of Web services that provide access to NASA's Earth-observing imagery and serve visualized data products to Internet-enabled clients, such as Worldview. It is important to note that Worldview is not part of GIBS, rather Worldview displays GIBS data. This allows anyone to use the GIBS open services to build their own client or to retrieve imagery available through GIBS for use in other venues, such as educational websites—see *Worldview is One of Many GIBS Clients* below.

GIBS servers ingest imagery created by EOSDIS DAACs, SIPS, LANCE, and other data providers and save these images as full-resolution, mosaicked layers. These layers are then divided into preconfigured tiles that are stored at predefined zoom levels and can be delivered rapidly to client systems like Worldview. "Once the imagery is in GIBS, loading it into Worldview [or other GIBS clients] is very fast since everything is defined at this point," says Boller.

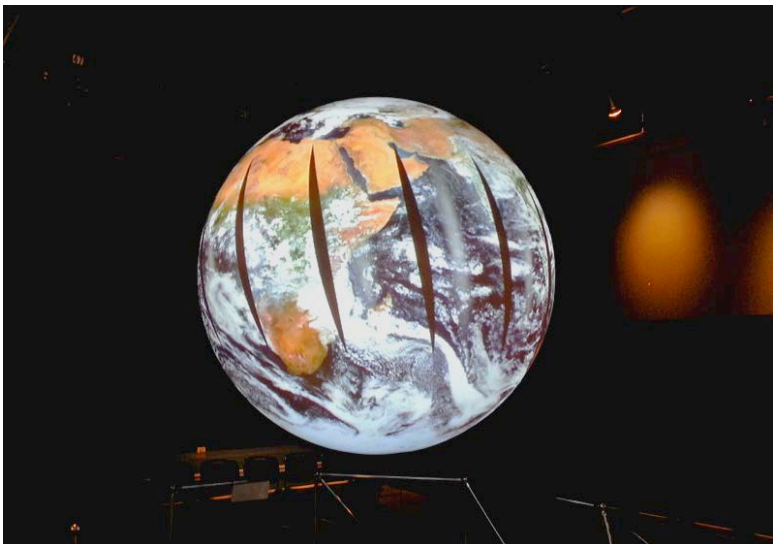
Future Plans

The Worldview and GIBS development teams are working on several enhancements that will further improve the usefulness of these systems for users of NASA Earth-observing data.

One of the most eagerly anticipated developments is the addition of the entire MODIS data record into GIBS. While MODIS data date back to 1999 (the launch of NASA's EOS Terra satellite) and 2002 (the launch of the EOS Aqua satellite), MODIS data in GIBS go back only to 2012. "Right now, we have imagery starting in May of 2012 and it runs through a few hours ago," Boller says. "Having the entire MODIS archive within GIBS is a major goal of ours."

Worldview is One of Many GIBS Clients

Along with *Worldview*, other GIBS clients include the Public Broadcasting Service, which uses GIBS imagery on its *Cloud Lab* website (*www.pbs.org/wgbh/nova/labs/lab/cloud*), and the National Oceanic and Atmospheric Administration's *Science on a Sphere*® presentations. The National Weather Service uses images provided by GIBS to help pinpoint ice accumulations for shipping, and the Environmental Protection Agency combines data from ground stations measuring air quality with satellite imagery from GIBS to provide better context for air-quality data. The Hayden Planetarium at the Rose Center for Earth and Space at the American Museum of Natural History in New York City even uses GIBS imagery in some of its planetarium shows.



Science on a Sphere® uses computers and video projectors to display GIBS data on a 1.8-m (6-ft)-diameter sphere at GSFC's Visitor Center. **Image credit:** Ryan Boller

The open services that GIBS provides can be found at *wiki.earthdata.nasa.gov/display/GIBS*, and sample Web clients can be found at *github.com/nasa-gibs/gibs-web-examples*. This access allows users to build their own clients to access and use GIBS products. "We want to separate GIBS and Worldview because we want people to use GIBS if they want to build their own clients," Boller says. "If you don't have your own client, then you can still look at the imagery and download the data using Worldview."

Since its introduction in 2011, Worldview has become an integral component in initial analysis and discovery of NASA's Earth science data. In addition, its ability to provide access to visualizations of data within four hours of when the data were collected makes Worldview an invaluable tool for land managers, forecasters, or anyone needing NRT data to manage ongoing natural events.

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In Worldview, a new Events Feed will enable users to select specific events, such as a hurricane or a dust storm, and immediately jump to visualizations of these events. This feature may help Worldview users discover other datasets that can assist in their research—not just to show that an event is happening, but that there are many datasets available that may be useful for gaining a deeper understanding of that event.

Of course, as Earth-observing missions are developed and launched, new data will be added to the DAACs and subsequently find their way to GIBS as new image products. For example, the launch of the SMAP mission this past January will lead to a host of new products relating to global soil moisture, crop health, and drought.

Finally, EOSDIS development teams are making improvements to GIBS that will enable it to handle thousands of data products and serve client systems more rapidly. As a result, Worldview users and other GIBS clients should expect a dramatic increase in the number of GIBS products over the next year or two.

Summary

Since its introduction in 2011, Worldview has become an integral component in initial analysis and discovery of NASA's Earth science data. In addition, its ability to provide access to visualizations of data within four hours of when the data were collected makes Worldview an invaluable tool for land managers, forecasters, or anyone needing NRT data to manage ongoing natural events.

While Boller is the first to admit that Worldview is still a system under development, he also is clear that it is achieving its intended purpose.

"Worldview and GIBS help to lower the barriers involved with using [NASA's] data," he says. "I think they enable not just easier use, but also new discoveries to be made and new applications to be developed." ■

kudos

Kudos

Claire Parkinson [NASA's Goddard Space Flight Center (GSFC)—*Climate Change Senior Scientist and Project Scientist for Aqua*] has been named this year's recipient of the William Nordberg Memorial Award for Earth Science. This high-achievement award recognizes a GSFC scientist who exhibits qualities of broad scientific perspective, enthusiastic programmatic and technical leadership on the national and international levels, wide recognition by peers, and substantial research accomplishments in understanding Earth system processes.

Parkinson has been awarded this prestigious honor for her work enabling a deeper understanding of the role of sea ice in the climate system, for outstanding leadership of Earth Observing System (EOS)/Aqua science, and for impressive educational outreach accomplishments.

Parkinson has been a climatologist at GSFC since July 1978 and a Senior Fellow at GSFC since 2005. Her research emphasis has been on polar sea ice and its connections to the rest of the climate system and to climate change, with a particular emphasis on satellite remote sensing. Since May 1993, Claire has additionally been the Project Scientist for the Aqua satellite mission, which launched in May 2002 and is transmitting data on many atmospheric, ocean, land, and ice variables. She has also written several books and is now Chair of the GSFC Senior Fellows.

Please join us in congratulating Parkinson on this award.