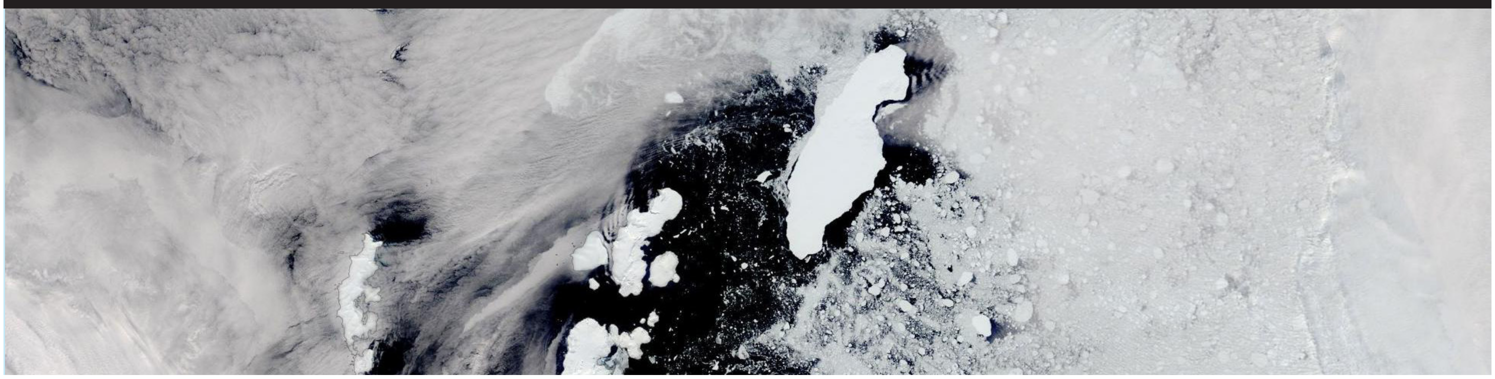
EOSDIS Update

National Aeronautics and Space Administration

WINTER 2019-2020

Earth Science Data and Information System (ESDIS) Project

A PUBLICATION OF NASA's EARTH OBSERVING SYSTEM DATA AND INFORMATION SYSTEM (EOSDIS), CODE 423



TOP STORIES

Terra: Five Instruments—One Monumental Data Record

After more than 20 years in space, the five instruments aboard NASA's Terra satellite continue their singular achievement of compiling a climate data record of Earth.

E pluribus unum (Latin; "Out of many, one")

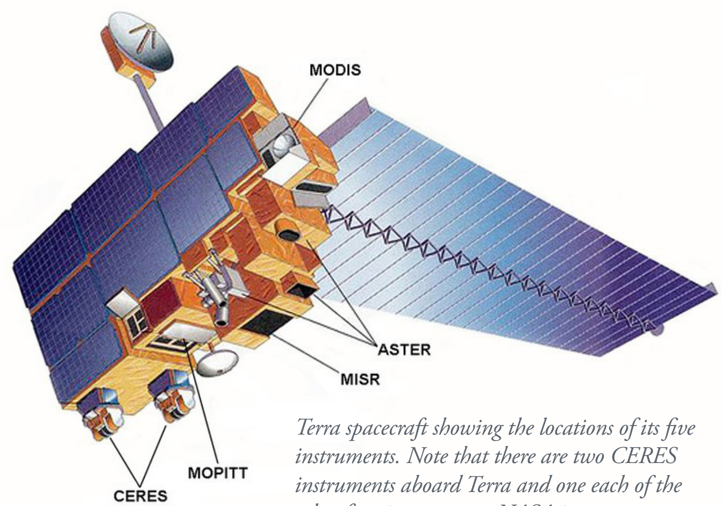
A satellite is a vessel, a container for one or more instruments. With the launch of NASA's Terra satellite on December 18, 1999, five instruments began a historic journey, a journey that has now extended more than 20 years—far beyond Terra's six-year expected design life.

While the five individual instruments aboard Terra measure and collect data about specific properties of Earth and its interrelated systems, their combined data record represents a singular achievement in observations of our planet.

But an instrument is more than just an assemblage of sensors, mirrors, and electronics. An instrument—and the data derived from the instrument—is also an assemblage of people. While it is impossible to talk with the thousands of individuals who have been, and are, responsible for Terra's five instruments and for ensuring the quality and validity of instrument data, conversations with Terra instrument Principal Investigators (PIs) and Science Team Leaders provide a glimpse into the significance of these instruments and the data they collect, along with how these instruments work together compiling an invaluable data record of Earth. From five instruments, one 20-year climate data record; out of many, one.

IN THIS ISSUE:

Unless otherwise noted, all articles written by Josh Blumenfeld, EOSDIS Science Writer.



Terra spacecraft showing the locations of its five instruments. Note that there are two CERES instruments aboard Terra and one each of the other four instruments. NASA image.

Terra

Terra is the flagship mission in NASA's Earth Observing System (EOS). The EOS was established to acquire a long-term record of Earth observations to provide a better understanding of the total Earth system and the effects of natural and human-induced changes on the environment. Conceived in the 1980s and implemented in the 1990s, NASA's EOS comprises an integrated constellation of satellites, a science component, and a data system. EOS data are the responsibility of NASA's Earth Observing System Data and Information System (EOSDIS) and are managed by NASA's Earth Science Data and Information System (ESDIS) Project, both of which are part of NASA's Earth Science Data Systems (ESDS) Program.

Terra's mission is to explore the connections between Earth's atmosphere, land, snow and ice, ocean, and energy balance to derive a better understanding of the planet's climate and climate change, along with the impact of human actions on these processes. Once established in its Sun-synchronous polar orbit approximately 705 kilometers above Earth's surface, Terra began collecting data in early 2000. Five instruments provided by NASA and international partners are aboard the spacecraft:

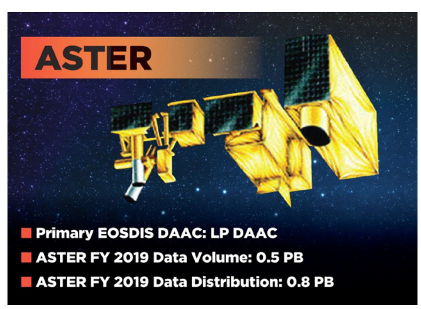
- Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER)
- Clouds and the Earth's Radiant Energy System (CERES)
- Multi-angle Imaging SpectroRadiometer (MISR)
- Moderate Resolution Imaging Spectroradiometer (MODIS)
- Measurement of Pollution in the Troposphere (MOPITT)

All instruments continue to provide data that are processed into a wide range of standard data products for use in scientific research as well as near real-time (NRT) data for use in monitoring and managing on-going events such as storms, wildfires, and volcanic eruptions (a detailed description of Terra's data processing system and strategy is available in the Earthdata article *Terra: The Hardest Working Satellite in Earth Orbit*).

According to figures from the ESDIS Metrics System (EMS), approximately 6.2 petabytes (PB) of Terra data were in the EOSDIS collection at the end of 2019, making up roughly 18.2 percent of the approximately 34 PB EOSDIS data collection. During the 2019 Fiscal Year (FY), which runs from October 1, 2018, to September 30, 2019, 12.65 PB of Terra data were distributed. Since 2000, the year the first Terra data were publicly available, approximately 50 PB of Terra data have been distributed to global data users. Distribution of data from Terra's MODIS instrument remains the highest of any instrument data in the EOSDIS collection, and 10 PB of MODIS data were distributed during FY 2019. Terra instrument data are available through several discipline-specific EOSDIS Distributed Active Archive Centers (DAACs).

These numbers, however, represent only part of the Terra story. The data record compiled by Terra's individual instruments, and how these instruments are used together, provides a better picture of the true monumental accomplishments of this mission over two decades orbiting our planet.

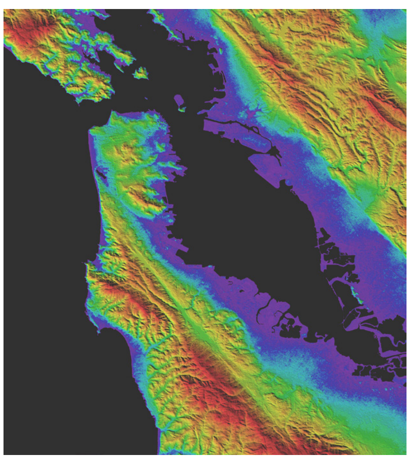
ASTER: Terra's high-resolution imager



ASTER is a partnership between NASA and Japan's Ministry of Economy, Trade and Industry (METI), and, notes ASTER U.S. Science Team Leader Michael Abrams, represents one of the longest-running—if not the longest-running—partnerships between NASA and another country's space agency.

ASTER is the "zoom lens" of Terra, and has the highest spatial resolution of the five instruments. It also is pointable, which means it can view targets outside of its imaging swath and can be tasked to capture images of specific areas and events as well as produce global land maps. As Abrams notes, it often is used in conjunction with other instruments. "In MODIS data, you might have a pixel showing a vacant field with a little bit of vegetation; you don't know what is causing the MODIS signal," he says. "You go to a high-resolution instrument like ASTER to more closely examine the MODIS pixel to determine, say, that 80 percent of the area shown is fallow field or 10 percent is remnant forest and the other 10 percent might have some winter crop. ASTER gives you more information."

ASTER comprises three infrared-sensing telescopes: a visible near infrared (VNIR), a shortwave infrared (SWIR), and a thermal infrared (TIR), all three of which are pointable. One component of Terra's SWIR telescope failed after nine years in operation. While the overall SWIR system is still recording data and sending signals back, the data are not usable; the Japanese manufacturer wants to keep the system running to do lifetime tests on the components.



ASTER GDEM Version 3 shaded relief topography of San Francisco, California, USA. Image: NASA/METI/AIST/Japan Space Systems, and U.S./Japan ASTER Science Team.

An additional feature of ASTER's VNIR telescope is a backward-looking telescope to complement the downward looking (nadir) telescope. Combining the high-resolution data from the two VNIR telescopes allows the ASTER team to produce stereoscopic images and detailed terrain height models. These data were used to produce one of the most significant ASTER accomplishments: the ASTER Global Digital Elevation Model, or GDEM. "We have a stereo camera, so you can calculate vertical relief," Abrams says. "In 2009 we decided we had enough scenes in our archive to cover just about all of Earth's surface and produced a global digital topography map with 30-meter spatial resolution covering all the land surface of Earth divided into one-degree-by-one-degree tiles."

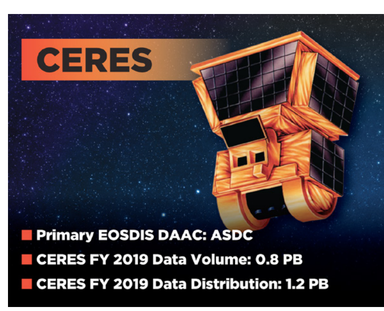
The third version of the ASTER GDEM was released in 2019. "There are about 22,000 tiles that cover the entire Earth, and Japan distributes the same product," says Abrams. "Between LP DAAC and Japan, we've distributed around 83 million tiles."

The ASTER GDEM, along with Level 1 and Level 2 ASTER data products, are available through NASA's Land Processes DAAC (LP DAAC). If ASTER data are not available for an area of interest, users can submit a Data Acquisition Request (DAR) to the ASTER team using the ASTER DAR Tool.

Along with the ASTER GDEM, Abrams notes that ASTER data are components of several other projects. These include the Global Land Ice Monitoring from Space (GLIMS) project run by the National Snow and Ice Data Center (NSIDC) that uses ASTER DEMs to examine changes in glacier thickness and volume; the ASTER Volcano Archive, which covers about 1,500 active volcanoes and includes every ASTER scene showing these volcanoes; and the Global Emissivity Database (GED) that was created by a team at NASA's Jet Propulsion Laboratory (JPL) from ASTER thermal observations.

As Abrams observes, the 30-year ASTER collaboration between NASA and Japan continues to work well, and a new seven-year extension of the agreement was signed in October 2019. "This has been one of the most interesting parts of my involvement with this whole mission—getting to work with people from another culture for a common goal and learning together how we can approach problems through our two cultures," he says. "So far, we've been able to solve all our problems, so we must be doing something right."

CERES: Observing Earth's radiation budget



CERES measures reflected solar and emitted thermal infrared radiation from Earth. These data provide a better understanding of what drives Earth's climate system and how it is changing. "The energy exchange between Earth and space is fundamental to climate," explains Dr. Norman Loeb, the CERES PI. "It's a record you need to have for a long, long time."

The two CERES instruments aboard Terra continue a data record that began in 1997 with the launch of the first CERES instrument aboard the joint NASA/Japan Aerospace Exploration Agency Tropical Rainfall Measuring Mission (TRMM; operational 1997 to 2015). Six CERES instruments are currently in space. Along with the two CERES aboard Terra, two CERES instruments are aboard NASA's Aqua satellite (operational 2002 to present) and a single CERES instrument is aboard the joint NASA/NOAA Suomi National Polar-orbiting Partnership (Suomi NPP; operational 2011 to present) and NOAA-20 (operational 2017 to present) satellites.

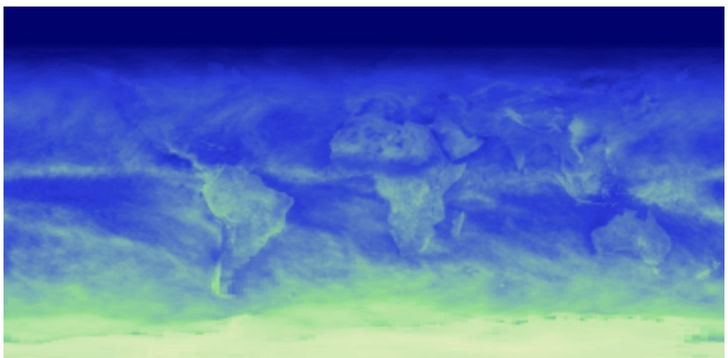


Image created from Terra and Aqua CERES instrument data showing shortwave energy (in Watts per square meter) reflected by Earth for November 2019. Brighter, whiter regions show where more sunlight is reflected; green regions show intermediate values; blue regions are lower values. Image by Jesse Allen, NASA Earth Observatory, based on FLASHFlux data provided by the FLASHFlux team, NASA Langley Research Center.

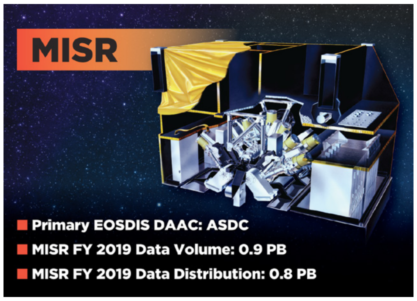
CERES data are available through NASA's Atmospheric Science Data Center (ASDC), which archives and distributes EOSDIS data related to Earth's radiation budget, clouds, aerosols, and tropospheric composition. Algorithm work is done by the CERES science team, which delivers approved algorithms to ASDC for data product generation. CERES data can be subset, visualized, and ordered using the CERES Browse and Subset ordering tool, which was co-developed by the CERES science team and ASDC.

Dr. Loeb notes that the two Terra instruments with the most synergy with CERES are MISR and MODIS. MODIS and MISR retrievals of cloud, aerosol, and surface properties provide climate researchers with unique data to probe what drives variations in Earth's radiation budget observed by CERES over a range of time and space scales. The CERES team uses the multi-angle capability of MISR to verify some of the algorithms they developed, and MODIS data are used to infer atmospheric and surface properties. "Within a CERES footprint, the higher spatial resolution of MODIS gives context to the CERES measurement," says Dr. Loeb. "The MODIS data are also used as input to a radiative transfer model that calculates radiative fluxes at the surface and within the atmosphere."

The strength of the CERES data record is clearly seen when CERES data are fused with data from other instruments aboard both polar-orbiting and geostationary satellites. The CERES team used these data to create a fully-resolved global diurnal cycle of Earth's radiation budget at the surface, multiple levels in the atmosphere, and at the top-of-atmosphere. "Doing this data fusion at the level at which we're able to do it, fusing data from instruments aboard so many different satellites to produce a seamless climate data record, is one of the major accomplishments of the CERES team and ASDC," Dr. Loeb says. "If you bring multiple instruments with complementary capabilities together in a self-consistent manner, you end up with a far more complete picture of Earth's radiation budget than what is achievable with just a single instrument."

Dr. Loeb observes that with CERES flying aboard so many Earth observing satellites with long data records like Terra (20+ years), Aqua (17+ years), and Suomi NPP (8+ years), systematic trends in the data are beginning to appear. "When you show people an intriguing yet subtle change in Earth's radiation budget from the Terra [CERES] data, and then show that Aqua, Suomi NPP, and NOAA-20 are all seeing the same thing, it makes a very compelling case that the observed change is real and the CERES instruments on these different platforms are performing exceptionally well," he says. "This lends a lot more confidence going forward when we won't have the luxury of so many CERES instruments operating simultaneously. Having all of these measurements, having them all together, and having these beautiful long records has been really, really useful for science."

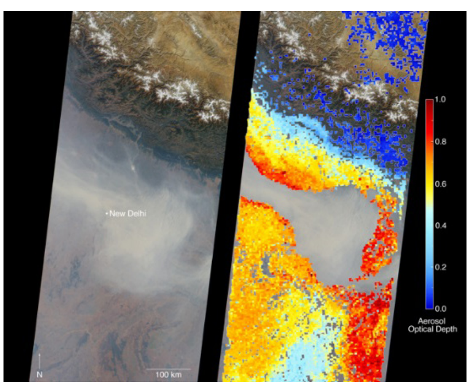
MISR: Multi-angle studies of Earth's atmosphere and surface



"There had never been an instrument like MISR flown before Terra," says MISR PI Dr. David J. Diner. "Even now, there are no other instruments similar to MISR in orbit."

MISR uses nine cameras to capture multi-angular images of reflected sunlight scattered by Earth's surface, clouds, and suspended airborne particles, called *aerosols*. MISR provides sensitivity to aerosol abundance and type, which is important for climate studies because the particles come in different sizes, shapes, and compositions, and, depending on their properties, can counteract or enhance warming due to greenhouse gases.

When the MISR proposal was submitted to NASA's EOS in 1988, a main objective was to use this multi-angular dimension primarily for acquiring data about the effect of aerosols and clouds on the solar radiation budget and to study the angular reflection of light from vegetation to provide information about how plants interact with their environment.



MISR acquired these views of an episode of extreme air pollution over New Delhi, India, on November 5, 2016. Left image is from MISR's nadir (vertical viewing) camera. Right image is an overlay of aerosol optical depth, which is a measure of the abundance of airborne particles (aerosols). Red/yellow colors indicate higher concentrations of aerosols. Image courtesy of NASA/GSFC/LaRC/JPL-Caltech, MISR Team.

Dr. Diner notes that looking at the atmosphere from oblique angles accentuates the reflection of sunlight from aerosols relative to the surface. It also enhances the information content of these measurements. "At the start of the EOS era, we knew pretty well how to retrieve aerosol amounts over deep ocean because the surface is very dark and most of the scattered light is from the atmosphere," he explains. "This is not the case over land. You have aerosols over deserts and urban areas that are bright. The challenge is how to separate out how much of the light is coming from the atmosphere. This has been a main thrust of research by the MISR science team and other EOS instrument investigators over the last two decades. It's now routine to use satellites for retrieving aerosol concentrations over land."

While Dr. Diner estimates that about two-thirds of published peer-reviewed papers using MISR data relate to atmospheric aerosols, he notes that in recent years there has been roughly a 50-50 split between using MISR aerosol data for climate and air pollution studies. In fact, linking near-surface particulate matter to air quality and human health is now one of the principal applications of MISR data.

Since launch, the science team has shown that MISR data are useful for many other applications than were anticipated in the original proposal. Besides sensitivity of MISR's multi-angular observations to vegetation canopy structure, the data also are able to characterize ice sheet and sea ice surface roughness, which is an indicator of seasonal ice conditions. Furthermore, as the MISR instrument passes over an area, its cameras continuously collect images from nine different angles over a period of seven minutes. The result is imagery depicting clouds or aerosol plumes from different times as well as at different angles.

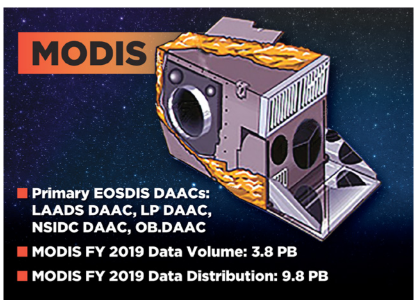
These temporal and stereoscopic elements provide the ability to use imagery from multiple cameras to depict the heights of aerosol plumes and cloud tops, along with their speed and direction of motion. This information is valuable for studying climate and environmental impacts. MISR-observed winds have also proven useful for improving the accuracy of weather forecasts. "What MISR has shown us is the tremendous power of multi-angle imagery," Dr. Diner observes.

MISR is also used together with the other Terra instruments. The fusion of MISR and MODIS aerosol products with an atmospheric model has led to the generation of maps of near-surface particulate matter concentrations that have been used in numerous health studies such as the Global Burden of Disease, which estimates that more than four million premature deaths occur each year due to exposure to airborne particles.

While CERES also has a multi-angular capability, its spatial resolution is much coarser than MISR's. This enables cross-comparison and validation of MISR and CERES data on the solar radiation budget. MISR and MOPITT have been used together to help map pollution from aerosols and carbon monoxide to track sources of air pollution. Finally, higher-resolution ASTER data have been used to improve MISR estimates of cloud fraction and to validate MISR stereoscopic results.

"The fact that we have a 20-year record only enhances the uniqueness of Terra data because now we can look at how things are changing over the long term," says Dr. Diner. "There are a host of applications of MISR data. They may only be limited by our imaginations."

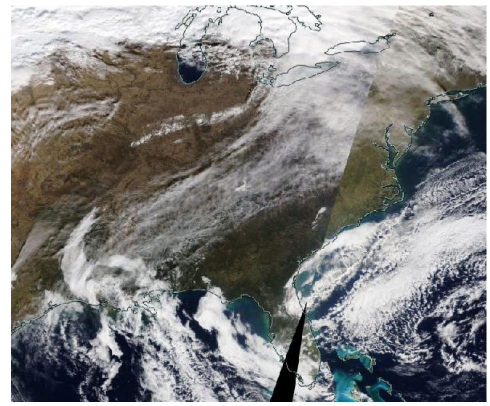
MODIS: Creating multi-disciplinary, broad-scale images of Earth



When you open the NASA Worldview data visualization application, the default base map you see is the current daily true-color image of Earth acquired by MODIS. By its sheer breadth of applications along with its ability to image almost every place on Earth every day, MODIS is the most heavily-used sensor aboard Terra based on the volume of data distributed, and continually collects data in 36 spectral channels in 2,330 km by 10 km swaths.

As noted by Dr. Michael King, the MODIS Science Team Leader, MODIS data are being used in studies across numerous disciplines. "It's used to look at vegetative health, changes in land cover and land use, oceans and ocean biology, sea surface temperature, and cloud studies," he says. "It provides information about cloud properties that no previous instrument has been able to do. It also is used extensively for monitoring fires and natural hazards along with oil spills and all kinds of things."

As a result of its multi-disciplinary use, MODIS data are archived at and distributed through multiple discipline-specific EOSDIS DAACs. After being downloaded, raw MODIS data are sent to NASA's Goddard Space Flight Center in Greenbelt, Maryland, for processing by Science Investigator-led Processing Systems (SIPS). Processed MODIS land products are sent to the USGS Center for Earth Resources Observation and Science (EROS) in Sioux Falls, SD. NASA's Land Processes DAAC (LP DAAC) is co-located at EROS and archives and distributes MODIS land products. MODIS atmosphere products are processed and analyzed at Goddard, stored on NASA's MODIS Adaptive Processing System (MODAPS), and distributed through NASA's Level-1 and Atmosphere Archive and Distribution System (LAADS DAAC).



Terra MODIS Corrected Reflectance (True Color) NASA Worldview base map image of the Eastern U.S. from December 25, 2019. More than 20 years of Terra MODIS global base map images can be interactively explored using NASA Worldview. NASA Worldview image.

MODIS ocean biology and ocean color data are processed at Goddard by the Ocean Color Processing Group and archived at and distributed through NASA's Ocean Biology DAAC (OB.DAAC). Finally, MODIS snow and ice data products are sent to NASA's National Snow and Ice Data Center (NSIDC) DAAC. "The data and data processing have evolved greatly over 20 years," Dr. King says. "Today, it's a very automated and efficient process."

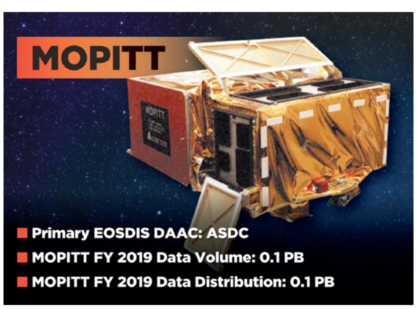
Like his colleagues, Dr. King notes how MODIS data and capabilities complement those of other Terra instruments. "The MODIS cloud mask and clear sky data are used regularly in combination with MOPITT data for carbon monoxide monitoring and for knowing if MOPITT data are being collected through clouds or clear sky," he says. "CERES data are used with MODIS data all the time. They use the aerosol optical product from MODIS and they use a lot of the MODIS spectral bands to identify the scene and determine cloud coverage or if the scene includes water clouds or ice clouds."

MISR has similar capabilities as MODIS, and the two instruments are well-suited for use in aerosol monitoring as well as in studies of Polar winds. While ASTER imagery is acquired at a higher resolution than MODIS imagery, the ASTER instrument does not continually collect data like MODIS. This means that MODIS can be used to find targets for ASTER. This is especially useful when using MODIS thermal anomaly data to pinpoint the location of heat sources that could be wildfires or volcanic eruptions. ASTER can then be targeted to capture higher-resolution imagery of the MODIS-detected heat source.

Another important use of MODIS data is their adaptation into low-latency, real-time and near real-time data. "There's direct broadcast, with stations around the world that can download raw MODIS data in very much real-time directly from the satellite," says Dr. King. "Separate from this is NASA's Land, Atmosphere Near Real-time Capability for EOS, or LANCE, which is able to provide several MODIS products generally within three hours of observation." While these products do not have the extensive processing required for use in scientific research, their rapid availability make them valuable tools for monitoring on-going events like wildfires, volcanic eruptions, ice concentrations, and air quality.

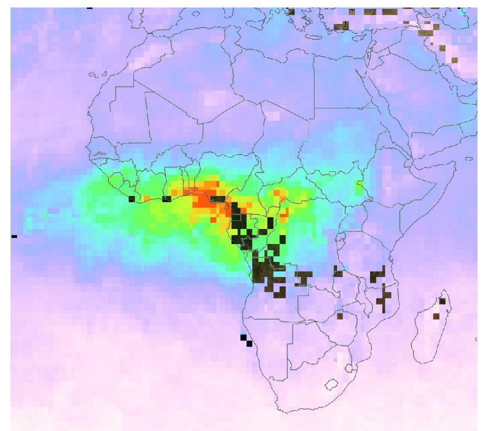
For Dr. King, the significance of the MODIS data record is quite clear. "Because we have 20 years of MODIS data, you can see the evolution of change over a long time," he observes. "It's quite powerful to see these data over 20 years."

MOPITT: Measuring carbon monoxide in lower levels of the atmosphere



It's not enough to know that microscopic suspended particles in the atmosphere are present, you also need to know the source of these particles. For example, if you know aerosols are coming from biomass burning, you can expect them to be in the form of organic carbon and black carbon. Powerplants, on the other hand, emit a lot of sulfur dioxide, but not much carbon monoxide. Terra's MOPITT instrument helps determine the sources of aerosols, along with other information about atmospheric composition.

MOPITT is a joint venture of NASA and the Canadian Space Agency. As noted by Dr. Helen Worden, the MOPITT U.S. PI, MOPITT is the only Terra instrument focused on trace gas pollution, specifically carbon monoxide. Comparing MOPITT data with data from MODIS and MISR, both of which measure aerosol optical depth, provides more information on the sources of atmospheric aerosols. "We were the first continuous global observations of carbon monoxide," says Dr. Worden. "This showed how pollution from large urban and biomass burning sources, like fires in the Amazon, is transported globally. People take this for granted now, but this wasn't the case until you had the satellite view of carbon monoxide transport."



Terra MOPITT image from February 1, 2019, showing monthly total column carbon monoxide concentrations in the lower atmosphere over Africa measured in mole per square centimeter. Red/yellow indicates higher concentrations of carbon monoxide. NASA Worldview image.

Carbon monoxide in the atmosphere is unique in that it's much shorter-lived in the atmosphere than gasses like methane and carbon dioxide. As Dr. Worden notes, carbon monoxide plumes can travel around the world and still be easily tracked since it is possible to detect the enhancements caused by large sources. "With methane it's harder to see this because it stays in the atmosphere around 11 years and the background levels are higher from all the methane that's accumulated," Dr. Worden explains. "And carbon dioxide stays in the atmosphere even longer, so satellite instruments need higher precision to see an enhancement [of carbon dioxide] against the background in the atmosphere."

The MOPITT instrument was constructed by a consortium of Canadian companies and funded by the Space Science Division of the Canadian Space Agency. MOPITT instrument operations and data processing are divided between U.S. and Canadian teams. "The Canadian MOPITT team does all the instrument commanding and engineering," says Dr. Worden. "The U.S. team works with NASA's ASDC to do all the data processing, with algorithm updates and data validation done at the National Center for Atmospheric Research (NCAR) in Boulder, Colorado."

In a practical use of MOPITT data, Dr. Worden describes a study on which she worked looking at changes in carbon monoxide during the 2008 Summer Olympics in Beijing, China. The Chinese government significantly limited traffic during the Olympics. The result was a dramatic reduction in carbon monoxide emissions from automobiles and trucks. "You can see the effects of pollution reduction from space using MOPITT and use these data to make projections about the transportation sector and impacts on both carbon monoxide and carbon dioxide emissions," she says.

MOPITT is currently the longest running record of carbon monoxide concentrations collected from space. "This is a great success story," says Dr. Worden. "In addition to understanding decadal scale trends in carbon monoxide, when a new satellite instrument measuring carbon monoxide goes up, they have a reliable record against which they can compare to verify that their instrument is performing properly and collecting reasonable data."

Five instruments; one data record

When Terra was launched more than 20 years ago it was expected to be the first of three satellites designed to compile a 15-year record of Earth processes. The single Terra data record now stretches beyond 20 years. All five instruments have performed far beyond their design expectations, and continue, with few minor issues, to provide a steady stream of data that form the foundation of a monumental climate data record.

The value of these data is evident in the amount of peer-reviewed research conducted using Terra data, such as the 15,185 unique peer-reviewed publications based on MODIS data (with 1,867 articles published in 2019, according to MODIS science team metrics); the 479 peer-reviewed publications based on MOPITT data as of January 22, 2020; or the more than 1,820 peer-reviewed CERES-based publications. As Terra data continue to be added to NASA's EOSDIS collection, so does the research conducted using these data—research that furthers our understanding of Earth's vast array of interconnected processes.

From five instruments, one data record. From the many, one. *E pluribus, unum.*

E pluribus … Terra. ■

Read more about 20 years of Terra
Twenty Years of Terra in our Lives

Earth in the Third Dimension: First GEDI Data Available

Data from NASA's Global Ecosystem Dynamics Investigation (GEDI) mission are adding to our understanding of carbon cycling and the structure and development of global biomes.

From red angelim trees in the Amazon towering hundreds of feet above the ground to clusters of shrubs hugging the surface, terrestrial biomes develop in height and density as well as in length and width. Data depicting this three-dimensional structure, however, are limited. This gap is being filled with several recently-launched Earth observing missions. The first data from one of these missions—NASA's Global Ecosystem Dynamics Investigation (GEDI)—are now publicly available through NASA's Land Processes Distributed Active Archive Center (LP DAAC).

Launched on December 5, 2018, and installed on the International Space Station's Japanese Experiment Module-Exposed Facility (JEM-EF), GEDI is led by a science team at the University of Maryland in collaboration with NASA's Goddard Space Flight Center in Greenbelt, Maryland. As noted on the GEDI mission website, data are initially transferred to the GEDI Mission Operations Center (MOC) and then processed through the Science Operations Center (SOC), both of which are located at Goddard. Its primary two-year mission is to produce high-resolution laser ranging observations of Earth in order to characterize the effects of climate change and land use on ecosystem structure and dynamics.

GEDI DATA PRODUCTS	Data Level Product	Description	DAAC Location
Level 1: Waveforms/Geolocated Waveforms Raw GEDI waveforms collected by the GEDI system and waveforms geolocated by the GEDI science team. **Format: HDF5**	Level 1B	Geolocated waveforms	LP DAAC
Level 2: Footprint level canopy height and profile metrics The waveforms are processed to provide canopy height and profile metrics, which provide easy-to-use and interpret information about the vertical distribution of the canopy material. **Format: HDF5**	Level 2A	Ground elevation, canopy top height, and Relative Height (RH) metrics	LP DAAC
	Level 2B	Canopy Cover Fraction (CCF), CCF profile, Leaf Area Index (LAI), and LAI profile	LP DAAC
Level 3: Gridded canopy height metrics and variability Gridded by spatially interpolating Level 2 footprint estimates of canopy cover, canopy height, LAI, vertical foliage profile and their uncertainties. **Format: GeoTIFF**	Level 3	Gridded canopy cover, canopy height, LAI, and uncertainty	ORNL DAAC
Level 4: Footprint and Gridded Above Ground Carbon Estimates Level 4 data are model output. Footprint metrics derived from Level 2 data products are converted to footprint estimates of aboveground biomass density using calibration equations. These footprints are used to produce mean biomass and its uncertainty in cells of 1 km using statistical theory. **Format: GeoTIFF**	Level 4A	Footprint level aboveground biomass	ORNL DAAC
	Level 4B	Gridded aboveground biomass density [AGBD]	ORNL DAAC

Image by Felix Mittermeier from Pixabay

Table of publicly-available GEDI data products, their NASA EOSDIS DAAC location, and format. Along with Level 1B and Level 2 data products, NASA's LP DAAC also will archive GEDI Level 0 and Level 1A products. These raw data products will be available upon request to LP DAAC. Graphic based on a table created by the GEDI science team.

GEDI data will be archived and distributed through two discipline-specific NASA Earth Observing System Data and Information System (EOSDIS) Distributed Active Archive Centers (DAACs). Lower-level data (Level 1 and Level 2) are currently available through NASA's LP DAAC. LP DAAC is a partnership between NASA and the USGS, and provides tools and services for discovering and analyzing EOSDIS data related to land cover and land use.

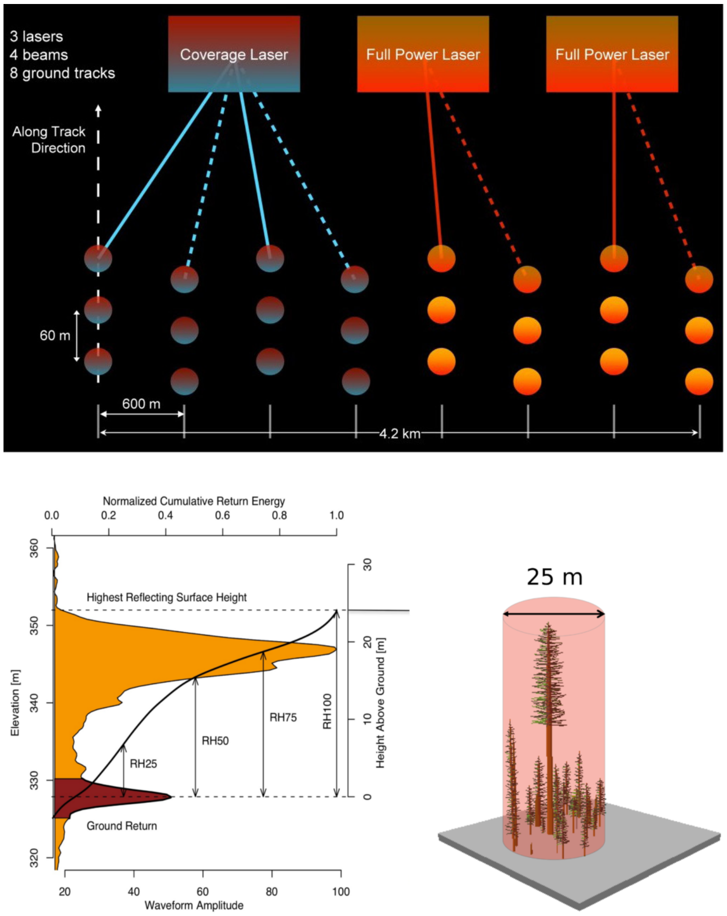
Higher-level data (Level 3 and Level 4) will be archived and distributed by NASA's Oak Ridge National Laboratory DAAC (ORNL DAAC). ORNL DAAC is a partnership between NASA and the U.S. Department of Energy, and is responsible for EOSDIS data related to biogeochemical dynamics, ecological data, and environmental processes. Level 3 data are expected to be available in mid-2020, with Level 4 data available in early-2021.

Having lower-level GEDI data at LP DAAC and higher-level GEDI data at ORNL DAAC supports the data needs of different user communities. Researchers interested in land surface and vegetation studies who traditionally acquire data through the LP DAAC will have access to similar GEDI data products along with the tools to subset, reprocess, and reformat these data. Likewise, researchers involved in ecosystem and carbon cycle studies will be able to acquire these focused GEDI products at the ORNL DAAC and have access to specialized tools to use these data.

GEDI data can be searched for and discovered using the EOSDIS Earthdata Search application. In addition, both the LP DAAC and the ORNL DAAC have developed GEDI landing pages on their websites. Lower-level GEDI data also can be discovered using the LP DAAC Data Pool, which provides a direct way to access LP DAAC data product files that can be bulk downloaded using secure HTTPS. The ORNL DAAC will provide direct HTTPS download and will also use their Spatial Data Access Tool (SDAT) to provide subsetting, reformatting, and re-projecting of GEDI higher-level gridded data.

GEDI data are acquired using a light detection and ranging (lidar) laser system. Lidar is a remote sensing technique that uses laser beam pulses to measure the distance of objects from the laser. When paired with a global positioning system (GPS) receiver, lidar can be used to create extremely accurate 3D measurements of Earth. "GEDI's lidar is particularly useful for measuring things like canopy height, ground elevation, and canopy profiles," says Tom Maiersperger, the LP DAAC Project Scientist. "GEDI will be the king of vegetation lidar."

The three lasers comprising the GEDI lidar system produce eight parallel observation tracks. Each laser fires 242 times each second and illuminates a 25-meter spot



GEDI has the highest resolution and densest sampling of any lidar ever put in orbit. GEDI's 25-meter footprint is large enough to measure whole trees while being small enough to accurately detect ground on steep terrain. ***Top image*** *shows how GEDI's three lasers are divided into eight parallel observation tracks to collect data.* ***Bottom image*** *illustrates how the resulting waveforms from returned laser pulses are used to determine relative height (RH). GEDI science team images.*

on the surface over which the surface's 3D structure is measured. Each 25-meter spot is separated by 60 meters along track, with about 600 meters between each of the eight tracks. Approximately 10 billion observations will be produced over the two-year mission.

The sole GEDI observable is the waveform of the returned laser pulse, and all data products are derived from this measurement. Lidar waveforms quantify the vertical distribution of vegetation by recording the amount of laser energy reflected by plant material (stems, branches, and leaves) at different heights above the ground. Signal processing is used to identify the ground within the waveform, and the distribution of laser energy above the ground can be used to determine the height and density of objects within the 25-meter GEDI footprint. Four types of structure information can be extracted from GEDI waveforms: surface topography, canopy height metrics, canopy cover metrics, and vertical structure metrics.

GEDI data will contribute significantly to research studying the development of terrestrial biomes, and will help further refine our understanding of the carbon cycle and atmospheric concentrations of carbon dioxide (CO_2). Along with helping provide answers to how deforestation has contributed to atmospheric CO_2 concentrations, how much carbon forests will absorb in the future, and how habitat degradation will affect global biodiversity, GEDI data also will help identify and provide a better understanding of how physical disturbances affect ecosystems and carbon storage.

GEDI's location on the space station means that the instrument does not collect data in a standard data pattern, such as polar-orbiting satellites like NASA's Terra or Aqua that cross the same point on Earth at the same time every day. "Being on the space station, GEDI has a rather strange, precessing orbit that is not Sun-synchronous, covers about 53 degrees north and south latitude, and is angled across the equator," explains Maiersperger. "This means it can't cover the entire Earth and it completes about 12 to 16 orbits per day. If you flatten this orbit out, you end up with these four-kilometer-wide swaths that the GEDI lasers are firing across in these spaghetti-looking patterns."

The GEDI instrument also can be pointed, which provides further coverage for the GEDI lidar. The ability to rotate the instrument up to six degrees allows the lasers to be pointed as much as 40 km on either side of the space station's ground track. This feature enables GEDI to sample Earth's surface as completely as possible given the space station's orbital track.

Once the GEDI data product generation cadence is set, LP DAAC expects to provide approximately 16 terabytes (TB) of GEDI data per month. "From a data volume standpoint, GEDI is not a big deal for us," says Cody Hendrix, a systems engineer on the LP DAAC GEDI data team. "Probably the bigger challenge is we'll have 10 billion individual laser shots [over the two-year mission] that we'll have to keep track of and try to distribute to users in a cogent way. Because of the space station's acquisition and orbital characteristics, there's a lot more education I think we're going to have to do with the end users to help them understand the very non-standard orbit [of the space station]."

Now that the first GEDI data are available through NASA's LP DAAC (and soon will be available through NASA's ORNL DAAC), the global research community is about to embark on an exciting new era of ecosystem studies. "There are a lot of people in a wide range of fields who are just out of their minds excited about getting their hands on GEDI data and using these data," says Maiersperger. "It will be a very rich dataset." ■

Learn more about GEDI and GEDI data

GEDI mission website: https://gedi.umd.edu/

LP DAAC GEDI Landing Pages:

- Level 1B: https://lpdaac.usgs.gov/products/gedi01_bv001/
- Level 2A: https://lpdaac.usgs.gov/products/gedi02_av001/
- Level 2B: https://lpdaac.usgs.gov/products/gedi02_bv001/

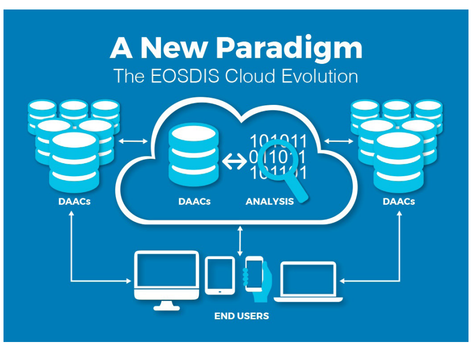
ORNL DAAC GEDI Landing Page (Level 3 data expected in mid-2020; Level 4 data expected in early-2021): https://daac.ornl.gov/gedi

2019 Cumulus Highlights

Work to host NASA EOSDIS data in the commercial cloud, an effort called Cumulus, made significant strides in 2019.

Katie Baynes, NASA EOSDIS System Architect

Josh Blumenfeld, NASA EOSDIS Science Writer



Between the end of September 2018 and November 2019 the volume of data in NASA's Earth Observing System Data and Information System (EOSDIS) collection grew from 27.4 petabytes (PB) to more than 33 PB. This significant growth is expected to not only continue, but increase at an even more rapid rate with several upcoming Earth observing missions that will add a tremendous amount of new data to the EOSDIS collection over the next five years.

With NASA's charge to provide these data freely to global data users, NASA's Earth Science Data and Information System (ESDIS) Project launched Cumulus—a multi-year effort to develop a cloud-based framework for data ingest, archive, distribution, and management. For more information about Cumulus and overall efforts to host EOSDIS data in the commercial cloud, please see the Earthdata Cloud Evolution page on the Earthdata website.

Cumulus is an open source workflow system specific to the Earth science archive domain. The system is intended to be used by ESDIS Distributed Active Archive Centers (DAACs) as they are migrating their archived data to the Amazon Web Services (AWS) commercial cloud, which has been approved for use by NASA's Office of the Chief Information Officer. The core team for Cumulus comprises several contributing members, including developers from the Land Processes DAAC (LP DAAC) and the National Snow and Ice Data Center (NSIDC) DAAC. The diverse composition of the core team not only provides different perspectives, but also brings to bear decades of archival experience to tackle the challenges related to this cloud migration effort.

Significant accomplishments by the ESDIS Cumulus Core team and ESDIS DAACs in 2019 furthered this effort toward fruition. These included the addition of new features and capabilities along with enhancements to make Cumulus more robust and secure.

Throughout 2019, the Cumulus Core team focused on meeting the needs of two specific user communities: integrators and operators.

Integrators are traditionally software developers beginning to deploy and use the system for developing product workflows, and are driving the technical capabilities of the system by focusing on system scalability, robustness, and security. These highly technical users are dependent on well-documented, well-tested, and easily-extended interfaces and Application Program Interfaces (APIs). The Cumulus Core team continues to refine the system based on the experience and feedback received from integrators.

Operators, on the other hand, are the day-to-day users working with the Cumulus ingest, archive, and distribution system to ensure that NASA's EOSDIS data are processed properly into the system as they arrive and are archived and maintained via vigilant data stewardship. Operators require streamlined and intuitive tools that provide dashboards, metrics, and alerts that are relevant and actionable. Throughout 2019, the Cumulus Core team worked to develop new systems and enhance existing systems to provide these necessary tools and metrics.

Along with supporting integrators and operators, the Cumulus Core team continued preparations for upcoming data-intensive missions. One of these is the Surface Water and Ocean Topography (SWOT) mission, scheduled for launch in 2021. The mission will make the first global survey of Earth's surface water, observe the fine details of ocean surface topography, and measure how water bodies change over time.

Over its three-year planned mission, SWOT is expected to generate as much as 23 PB of data. These data will be archived at and distributed by NASA's Physical Oceanography DAAC (PO.DAAC). During 2019, PO.DAAC, as the SWOT Systems Integrator, completed all SWOT technical qualification requirements for hosting and distributing this high volume of data in the commercial cloud.

Existing mission data also continued their evolution to the cloud in 2019. NASA's Global Hydrology Resource Center DAAC (GHRC DAAC) and Alaska Satellite Facility DAAC (ASF DAAC) supported operational transition of beta data products from the Spaceborne Imaging Radar C (SIR-C, operational April to October 1994) project to the commercial cloud. SIR-C was part of the joint U.S./German/Italian SIR-C/X-Band Synthetic Aperture Radar (SIR-C/X-SAR) project that used a highly sophisticated imaging radar carried aboard the Space Shuttle Endeavor to capture images of Earth.

The ASF DAAC efforts are paving the way for another large mission on the horizon: the joint NASA/Indian Space Research Organization (ISRO) Synthetic Aperture Radar (NISAR) mission. NISAR will use a dual-frequency Synthetic Aperture Radar (SAR) to study natural hazards and environmental change. Over its planned three-year mission, NISAR is expected to produce an unprecedented volume of data—more than 128 PB, or almost four times the current size of the entire EOSDIS data collection.

Along with these high-level achievements, numerous new features and capabilities were added to Cumulus in 2019 that will facilitate a better user experience (UX) and metrics collection. These include:

- Enhanced Cumulus dashboard capabilities based on feedback from operational users and UX designers
- Implementation of auto-scaling functionality to support large ingest loads
- The development of support for bulk re-ingest and ingest prioritization
- Integration of automated Disaster Recovery backup and recovery procedures into system workflows and the Cumulus dashboard
- Implementation of a cloud-based metrics system

In addition, enhanced security measures designed to comply with NASA's General Application Platform (NGAP), which provides a cloud-based Platform-as-a-Service (PaaS) and Infrastructure-as-a-Service (IaaS) for ESDIS applications, were implemented. This was complemented with an integration of the Cumulus dashboard and APIs with NASA Access Launchpad authentication. Access Launchpad, or Launchpad, is an internal NASA system that enables secure access to NASA applications.

Of course, a complex undertaking like Cumulus also requires training. New training materials were developed during 2019 to support the on-boarding of new developers and integrators into the Cumulus ecosystem and sessions during the annual ESDIS Systems Engineering Technical Interchange Meeting (SE-TIM) were devoted to introducing DAAC staff to Cumulus. Finally, the Cumulus Core team continued to engage integrators and operators through working groups designed to solicit feedback and smooth the transition from on-premise systems into the Cumulus cloud-based system. Feel free to see our work in progress by looking at the documentation and source code.

The work and accomplishments of the Cumulus Core team and EOSDIS DAACs during 2019 laid a firm foundation to move Cumulus forward in 2020. Feedback and input from integrators and operators will continue to play a large role in work by the Cumulus Core team to further refine requirements, systems, and tools for hosting EOSDIS data in the commercial cloud and efficiently providing these data to worldwide data users. ■

USER **PROFILES:**

NASA Earth Science Data User Profiles highlight our diverse end-user community worldwide and show you not only how these data are being used for research and applications, but also where these data are being used – from the plains of West Texas to the Sea of Oman and everywhere in between. You'll also learn where you can download the datasets in each feature. **https://earthdata.nasa.gov/learn/user-resources/who-uses-nasa-earth-science-data-user-profiles**

Dr. Priscila Kienteca Lange

Life on Earth would not be possible without the help of phytoplankton. Dr. Priscila Kienteca Lange uses NASA ocean biology data to study the biomass and distribution of these microscopic organisms.

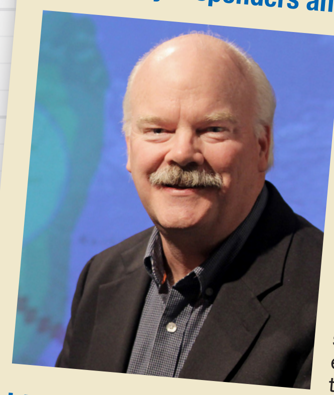
NASA Post-Doctoral Fellow and Scientist (Universities Space Research Association), Ocean Ecology Laboratory, NASA's Goddard Space Flight Center, Greenbelt, MD

Research interests: Using satellite ocean color data to study how different types of phytoplankton influence marine life and biogeochemical cycles, and how they respond to physical and chemical processes.

https://earthdata.nasa.gov/learn/user-resources/who-uses-nasa-earth-science-data-user-profiles/user-profile-dr-priscila-kienteca-lange

Dave Jones

NASA near real-time Earth observing data are vital to emergency response. Dave Jones enables these data to be used collaboratively in real time across platforms by emergency responders and managers.



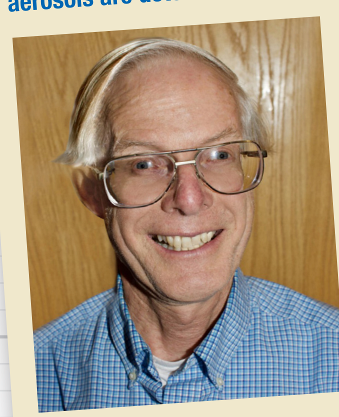
Founder, President, and CEO, StormCenter Communications, Inc., Halethorpe, MD

Research interests: Developing systems and applications to collaboratively share Earth observing and infrastructure data from multiple sources to improve situational awareness and decision-making between subject matter experts, emergency managers, and the public.

https://earthdata.nasa.gov/learn/user-resources/who-uses-nasa-earth-science-data-user-profiles/user-profile-dave-jones

Dr. Steven Massie

Aerosols have a huge impact on climate and human health. Dr. Steven Massie uses remotely-sensed data to better understand these impacts and improve how aerosols are detected by Earth observing satellites.

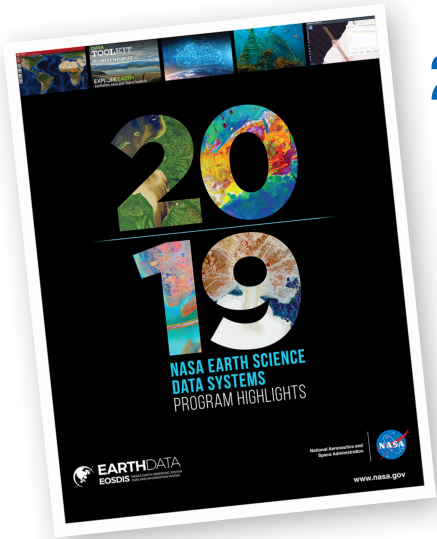


Research Associate, Laboratory for Atmospheric and Space Physics (LASP) at the University of Colorado, Boulder, CO

Research interests: Effects of aerosols and clouds on the interpretation of NASA satellite data and the physical effects of aerosols on the troposphere.

https://earthdata.nasa.gov/learn/user-resources/who-uses-nasa-earth-science-data-user-profiles/user-profile-dr-steven-massie

ANNOUNCEMENTS



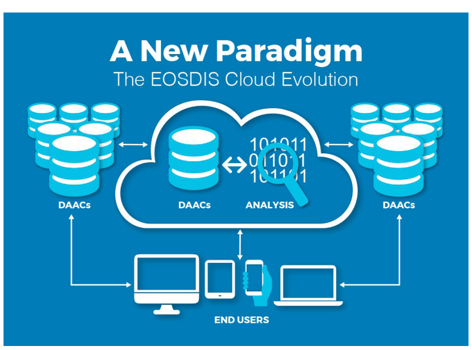
2019 NASA Earth Science Data Systems Program Highlights

Initiatives and projects by NASA's Earth Science Data Systems (ESDS) Program are enabling science, exploring commercial and international partnerships, encouraging the development of new applications, and advancing research.

Learn more about 2019 Program highlights: https://earthdata.nasa.gov/esds/nasa-earth-science-data-systems-program-highlights-2019 ■

Recent Articles Highlight Earthdata Cloud Evolution

Efforts to migrate NASA Earth observing data and services to the commercial cloud made significant advances in 2019.



Between October 1, 2018, and September 30, 2019, the volume of data in NASA's Earth Observing System Data and Information System (EOSDIS) collection grew from approximately 27 petabytes (PB) to almost 34 PB. Over the next five years, this volume is expected to grow to more than 245 PB, according to estimates by NASA's Earth Science Data Systems (ESDS) Program. In order to provide these data efficiently to global data users and facilitate scientific research using these data, NASA's Earth Science Data and Information System (ESDIS) Project is undertaking a monumental effort to migrate NASA Earth observing data and data services into the commercial cloud.

Three recent Earthdata articles provide more information about the current state of this work. These articles describe the overall cloud evolution effort (called *Cumulus*), specific 2019 Cumulus accomplishments and highlights, and work by NASA's Global Hydrology Resource Center Distributed Active Archive Center (GHRC DAAC) to become the first EOSDIS DAAC to migrate their data collection into the commercial cloud.

All three articles, along with numerous supplemental articles about migrating EOSDIS data and data services into the commercial cloud, are available on the Earthdata Cloud Evolution page of NASA's Earthdata website. ■

Read More

Earthdata Cloud Evolution

2019 Cumulus Highlights

GHRC DAAC Moves to the Earthdata Cloud

NASA, Partners Name Satellite for Noted Earth Scientist Dr. Michael Freilich

NASA and several partners are renaming a key ocean observation satellite in honor of Dr. Michael Freilich, former head of NASA's Earth Science Division.

NASA—along with the European Space Agency (ESA), the European Commission (EC), the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), and NOAA—announced January 28 that they have renamed the Sentinel-6A ocean observing satellite in honor of Earth scientist Dr. Michael Freilich. Dr. Freilich retired in 2019 as head of NASA's Earth Science Division, a position he held since 2006. The satellite, which is scheduled for launch this fall, will now be known as "Sentinel-6 Michael Freilich."

Dr. Freilich during remarks at NASA Headquarters during the NASA ceremony announcing the renaming of the Sentinel-6A satellite in his honor. An image of the satellite is projected behind Dr. Freilich. NASA image.

"This honor demonstrates the global reach of Mike's legacy," said NASA Administrator Jim Bridenstine. "We are grateful for ESA and the European partners' generosity in recognizing Mike's lifelong dedication to understanding our planet and improving life for everyone on it. Mike's contributions to NASA—and to Earth science worldwide—have been invaluable, and we are thrilled that this satellite bearing his name will uncover new knowledge about the oceans for which he has such an abiding passion." ■

Learn more:

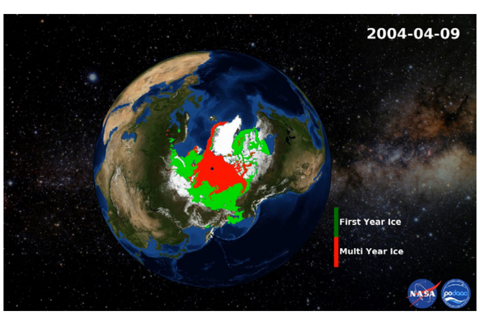
NASA press release: https://go.nasa.gov/37AC91p

NASA Science YouTube video: https://youtu.be/oGiASYMBk58

New PO.DAAC Arctic Sea Ice Data Animation

A new animation created from SeaWinds scatterometer data shows changes in Arctic sea ice age between 2002 and 2009.

A new animation showing Arctic sea ice age derived from daily data collected by the SeaWinds scatterometer aboard the QuikSCAT satellite is available at NASA's Physical Oceanography Distributed Active Archive Center (PO.DAAC). The data used in the animation were collected from June 20, 2002, through November 23, 2009, and colors in the animation indicate Arctic sea ice age: red indicates older ice and green indicates first-year ice. First-Year sea ice is defined as ice that forms only during that specific year; older, multi-year sea ice is defined as winter-time ice that survives the summer melt season and persists into the next season.



The data used in the animation are part of the SeaWinds on QuikSCAT scatterometer-derived Arctic sea ice classification dataset, which was created by researchers at Brigham Young University and is available through NASA's PO.DAAC. QuikSCAT was launched on June 19, 1999, and was operational from 1999 through 2009. ■

View the animation: https://youtu.be/6jo8p9xK06c (Note that there is no sound with the animation.)

Explore the data at NASA's PO.DAAC: SeaWinds on QuikSCAT Arctic Sea Ice Age Classification (DOI: 10.5067/QSSIA-BYU01)

STORY MAPS

Arctic Wildfires

Wildfires in the Arctic often burn far away from populated areas, but their impacts are felt around the globe. From field and laboratory work to airborne campaigns and satellites, NASA is studying why boreal forests and tundra fires have become more frequent and powerful and what this means for climate forecasting, ecosystems, and human health. In this Story Map created by NASA's Atmospheric Science Data Center (ASDC), read how a variety of different Earth observing datasets are being used to study wildfires.

Image Credit: NASA/Peter Griffith

Read Story Map: http://bit.ly/2SVZ7uU

Mapping Deforestation

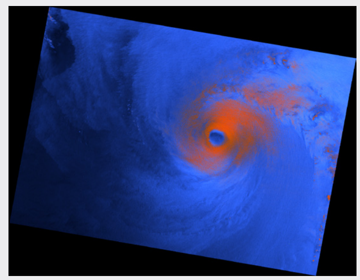
The southeastern Asian country of Cambodia continues to struggle with extensive loss of its forests. In 2013, Dr. Matthew Hansen and colleagues found that Cambodia lost nearly 12,600 square kilometers of forest from 2000 to 2012. Since 2012, Cambodia has continued to experience forest loss at alarming rates, loss that has extended even into the country's national parks and protected areas.

In this Story Map, created by NASA's Land Processes DAAC, read how NASA Moderate Resolution Imaging Spectroradiometer (MODIS) Land Cover and Vegetation Continuous Fields datasets can be used to highlight land cover changes.

Image Credit: Flickr/Vladimir Mokry

Read Story Map: http://bit.ly/371nufC

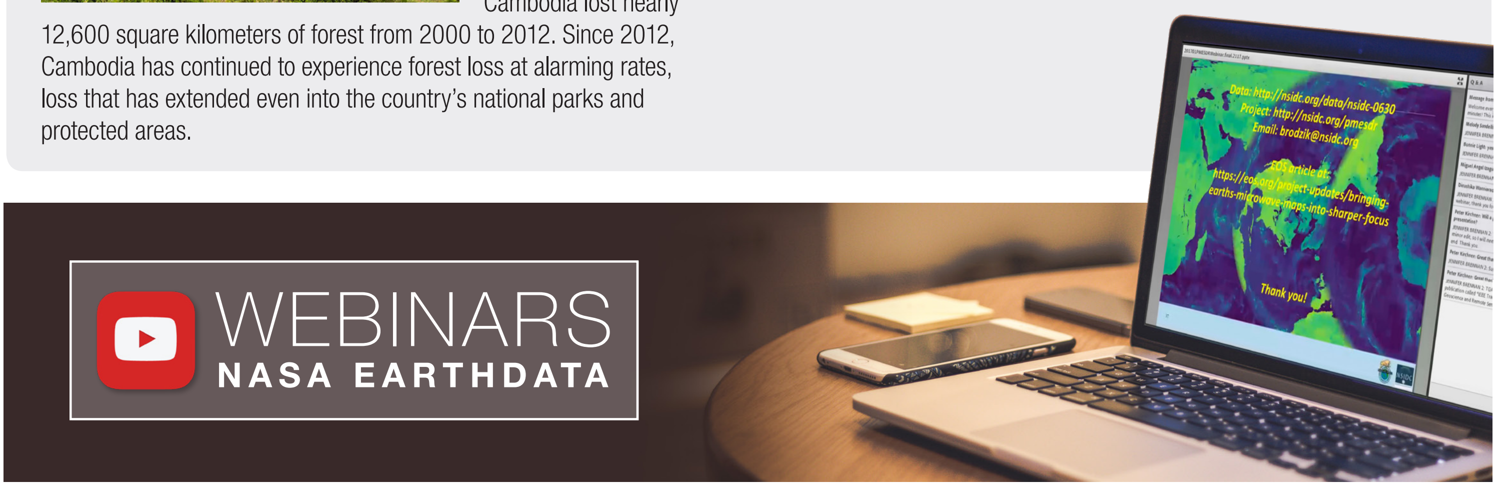
Hurricane Dorian

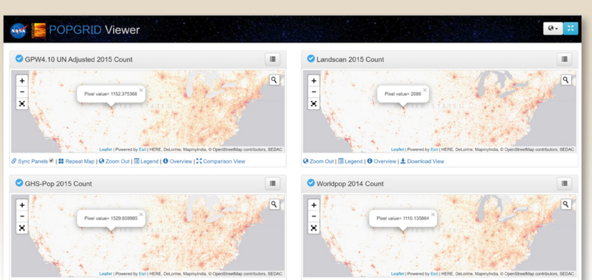


The European Space Agency's (ESA's) Copernicus Sentinel-1 Synthetic Aperture Radar (SAR) mission captured imagery of Hurricane Dorian in late August and early September 2019. NASA's Alaska Satellite Facility DAAC (ASF DAAC) processed the source Ground Range Detected SAR granules from ESA to display geocoded color decomposition images from the co-polarization (VV) and cross-polarization (VH) amplitude values. The images were not terrain-corrected.

Image Credit: ASF DAAC 2019 using GAMMA software. Contains modified Copernicus Sentinel data 2019, processed by ESA.

View SAR images of Hurricane Dorian in this Story Map: http://bit.ly/37W6yH8





12/3/19

Gridded Population and Settlement Data—An Introduction to the POPGRID Data Collaborative

https://www.youtube.com/watch?v=AsE_qXfRDF0&feature=youtu.be

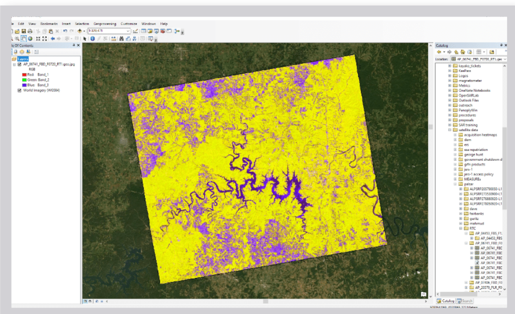
DATA Recipes & Tutorials

Jupyter Notebook Availability with GES DISC Recipes

Several NASA Goddard Earth Sciences Data and Information Services Center (GES DISC) data recipes or tutorials have been updated to include Jupyter Notebook code and instructions.

Visit https://disc.gsfc.nasa.gov/information/howto and type "Jupyter" into the search bar, or look for this icon to identify the updated recipes:

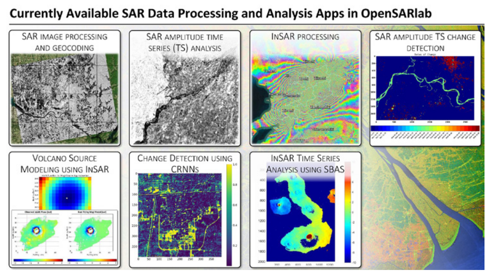
GIS Tools - ASF ArcGIS Desktop SAR Toolbox



NASA's Alaska Satellite Facility Distributed Active Archive Center (ASF DAAC) has developed a Toolbox for use with either ArcGIS Desktop or ArcGIS Pro, containing tools that perform geoprocessing tasks useful for working with Synthetic Aperture Radar (SAR) data. The tools were designed to be used with Radiometric Terrain Corrected (RTC) SAR datasets, but several of the tools have the potential to be used with a variety of rasters, including non-SAR datasets.

Download recipe: https://asf.alaska.edu/how-to/data-tools/gis-tools/

Introduction to Alaska Satellite Facility's OpenSARlab: A Cloud Based Service for SAR Analysis



This tutorial provides an introduction to NASA's ASF DAAC OpenSARlab, a cloud-hosted service providing a playground for learning, developing, and employing Synthetic Aperture Radar (SAR) analysis techniques. In this video, a brief introduction to SAR and a tutorial using Jupyter Notebook for performing amplitude time series and change detection analyses on data downloaded from ASF Hyp3 is provided. *Note: OpenSARlab is not open to the general public at this time. The Alaska Satellite Facility, which is the home of NASA's ASF DAAC, developed OpenSARlab to support algorithm development for the upcoming NASA/Indian Space Research Organization SAR (NISAR) mission and ASF's educational and outreach activities.

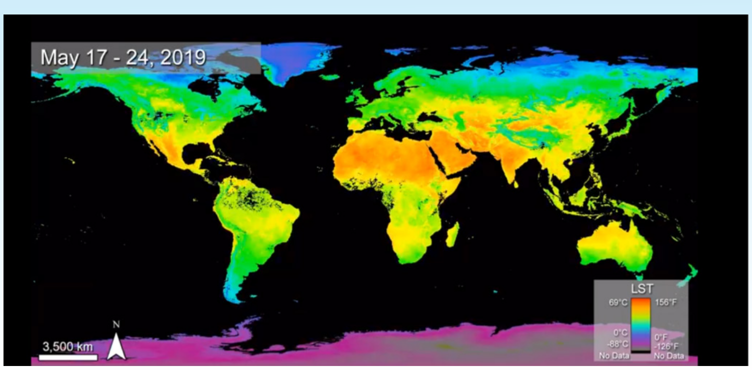
View tutorial: https://www.youtube.com/watch?v=MsRpBA1Fp-o

Artificial Intelligence (AI) Generated Water Masks

AI Water is a machine learning program currently in development by student interns George Meier, McKade Sorensen, and Rohan Weeden at NASA's ASF DAAC. This video tutorial explains how machine learning is used to automatically generate water masks using dual-band (VH+VV) Synthetic Aperture Radar (SAR) images, gives a demonstration of how the training data are generated, and shows our preliminary results.

View tutorial: https://www.youtube.com/watch?v=zalhHwu6Rpc

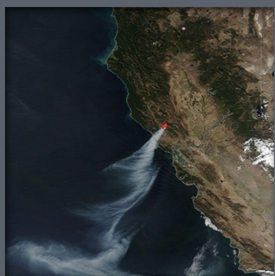
SPECIAL FEATURE VIDEO



Global Land Surface Temperature from 2019 as observed by Terra MODIS

The surface temperature of the land changes rapidly across the world throughout the course of one year. This video shows the changing temperatures throughout 2019 using 8-day land surface temperature (LST) data from the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument aboard NASA's Terra satellite. Terra MODIS recorded the highest LST value from 2019 as 68.99°C (156.18°F) and the coldest LST value as -87.75°C (-125.95°F). https://youtu.be/hw9_LshWMZc

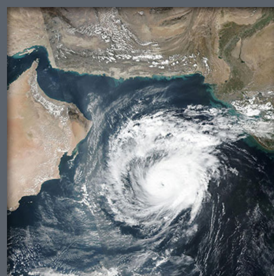
Latest NASA Earthdata Images



VIIRS Views the Kincade Fire

https://earthdata.nasa.gov/mastheads

(Published 11/4/19)



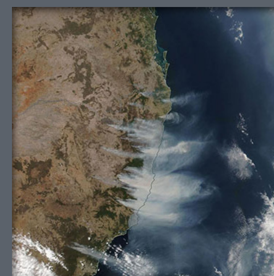
Tropical Cyclone Maha in the Arabian Sea

https://earthdata.nasa.gov/worldview/worldview-image-archive/tropical-cyclone-maha-in-the-arabian-sea

Phytoplankton in the Gulf of California

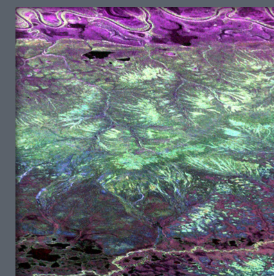
https://earthdata.nasa.gov/mastheads

(Published 12/2/19)



Smoke from Fires in New South Wales, Australia

https://earthdata.nasa.gov/worldview/worldview-image-archive/smoke-from-fires-in-new-south-wales-australia-12-nov-2019



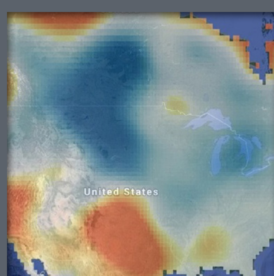
Sensing Alaskan Permafrost

https://earthdata.nasa.gov/mastheads

(Published 12/23/19)

Iceberg A68A moving away from the Antarctic Peninsula

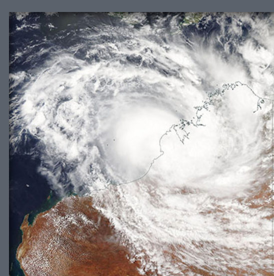
https://earthdata.nasa.gov/worldview/worldview-image-archive/iceberg-a68a-moving-away-from-the-antarctic-peninsula



Trends in Global Freshwater Availability

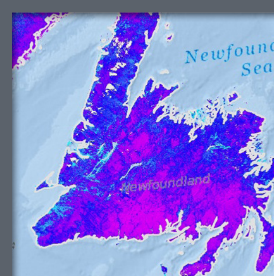
https://earthdata.nasa.gov/mastheads

(Published 1/13/20)



Tropical Cyclone Blake Approaching Western Australia

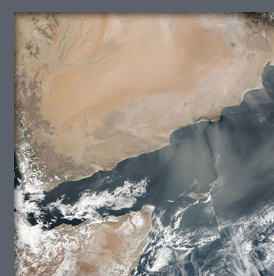
https://earthdata.nasa.gov/worldview/worldview-image-archive/tropical-cyclone-blake-approaching-western-australia



Estimating Snow Cover Using VIIRS

https://earthdata.nasa.gov/mastheads

(Published 1/27/20)



Dust off the coast of Oman and Yemen

https://earthdata.nasa.gov/worldview/worldview-image-archive/dust-off-the-coast-of-oman-and-yemen

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