EOSDIS Update

National Aeronautics and Space Administration

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Earth Science Data and Information System (ESDIS) Project

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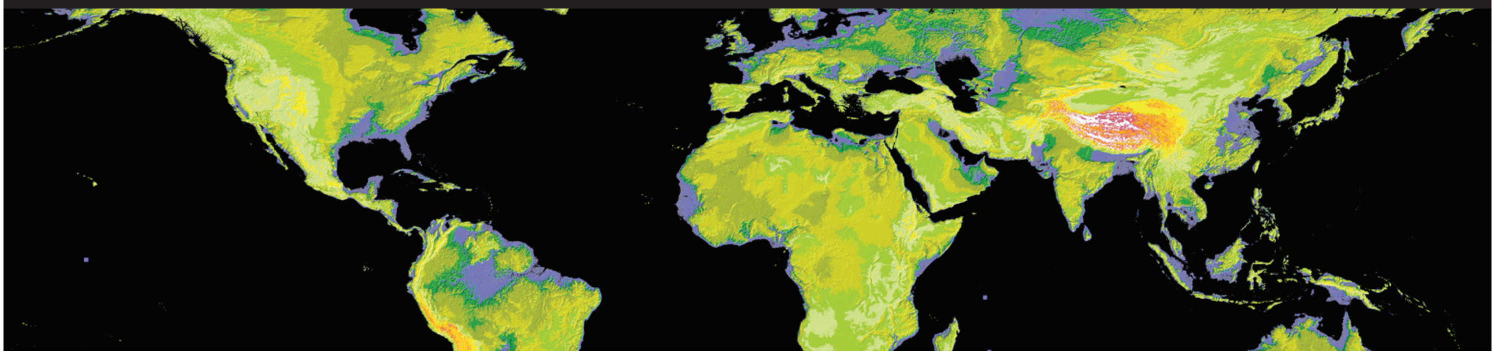

TOP STORIES

Wildfires Can’t Hide from Earth Observing Satellites

Sensors aboard Earth observing satellites and NASA’s Fire Information for Resource Management System (FIRMS) provide information about wildfires 24/7 to anyone, anywhere in the world.

Somewhere on Earth a wildfire is burning.

Wildfires are an inescapable part of living on a planet forged in fire. In the United States, an average of 69,020 wildfires (about 85% of which are human-caused, according to the National Park Service) burn an average of 6.63 million acres each year, based on data from the past 10-years compiled by the National Interagency Fire Center (NIFC). Along with the loss of life, the financial impact of these fires is immense. Insured losses from just the Mendocino Complex Fire and the Carr Fire, both of which broke out in July 2018 in California, topped $845 million, and the fires damaged or destroyed 8,900 homes, 329 businesses, and 800 private autos, commercial vehicles, and other types of property, according to figures from the Insurance Information Institute.

A global look tells a more complete picture. Between July 15 and 22, 2019, Global Forest Watch Fires, an online platform that monitors and responds to forest and land fires, sent out 782,366 worldwide Fire Alerts via email. A majority of alerts over this seven-day period were sent to subscribers in Russia (178,484), the Democratic Republic of the Congo (136,087), Angola (109,512), and Zambia (52,801).

While these fires burn, though, they can’t hide. Even in the most remote corners of the globe, their heat signatures can be detected by sensors aboard Earth observing satellites. The ability to rapidly provide information about the approximate location and movement of individual wildfires using instruments

IN THIS ISSUE:

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

aboard Earth observing satellites is a global success story that is helping save lives and property.

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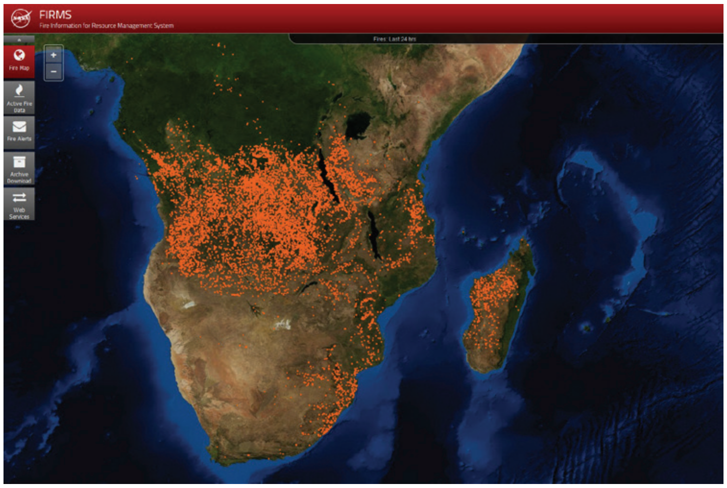

Each orange dot in this FIRMS Fire Map image of Africa and Madagascar from July 23, 2019, represents a hotspot detected over the past 24 hours by the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument aboard NASA's Terra and Aqua Earth observing satellites. Image courtesy of NASA FIRMS.

Providing information about hotspots detected by instruments aboard Earth observing satellites in near real-time is a capability that has been available for more than a decade through NASA's Fire Information for Resource Management System, or FIRMS.

FIRMS provides active fire data (including an approximate location of a detected hotspot) from NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) and Visible Infrared Imaging Radiometer Suite (VIIRS) instruments generally within three hours of a satellite overpass, with imagery available within four to five hours. Global active fire detections can be viewed interactively using the FIRMS Fire Map application, and active fire data for the last 24 hours, 48 hours, or week can be downloaded in shapefile, KML, WMS, or text file formats (data older than seven days can be obtained using the FIRMS Archive Download Tool).

FIRMS users also can sign up to receive email Fire Alerts notifying them of fires detected in specific areas of interest. Through this free service, alerts can be received in near real-time or as daily or weekly summaries. Every week approximately 250,000 FIRMS alerts (including daily alerts, Rapid Alerts, and weekly alerts) are sent to users in more than 160 countries, according to the FIRMS team.

FIRMS is part of NASA's Land, Atmosphere Near real-time Capability for EOS, or LANCE, system. LANCE provides more than 100 near real-time products from instruments aboard Earth observing satellites. LANCE, in turn, is part of NASA's Earth Observing System Data and Information System (EOSDIS), which is responsible for NASA's Earth observing data collection.

FIRMS was developed by the University of Maryland in 2007 with funds from NASA's Applied Sciences Program and the United Nations Food and Agriculture Organization (UNFAO). NASA began offering FIRMS near real-time data in 2007, and the UNFAO began offering the data in 2010 through its Global Fire Information Management System (GFIMS).

Near Real-Time vs. Standard Data

Standard data products are intended for use in scientific research and are created using the best ancillary, calibration, and ephemeris information. The extensive processing, quality assurance reviews, and validation required before standard products are made available to the public means that they are released many hours or days after they are collected.

Near real-time data, on the other hand, are not intended for use in scientific research and have far less processing. This means they can be made available rapidly to support the management of on-going events, such as tracking the spread of a wildfire or an ash plume from a volcanic eruption.

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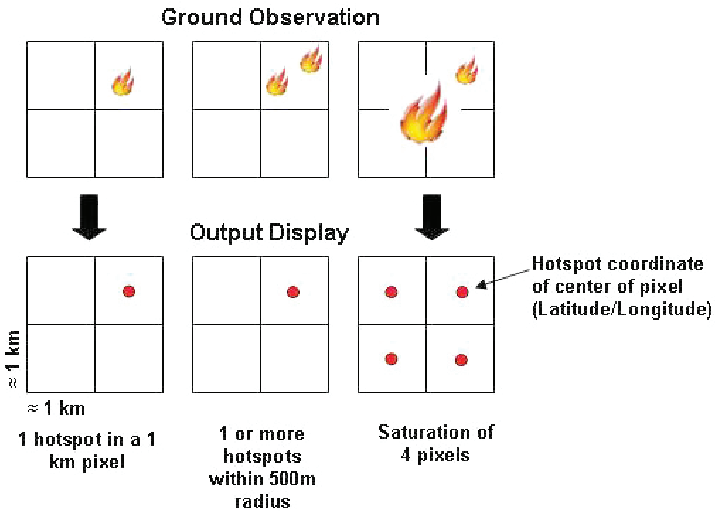
According to the U.S. Forest Service, dry woody fuels ignite when reaching a temperature of about 540°F (assuming enough oxygen is present), and an established wildfire burns at temperatures that can exceed 1,500°F. This heat is a beacon to orbiting sensors like MODIS and VIIRS, which detect radiated energy.

MODIS orbits Earth aboard NASA's Terra and Aqua satellites, while VIIRS is aboard the joint NASA/NOAA Suomi National Polar-orbiting Partnership (Suomi-NPP) satellite. If a wildfire is burning and MODIS or VIIRS orbits overhead in their normal operating mode, the fire's emitted energy generally will be detected.

The MODIS Fire and Thermal Anomalies Product (MCD14DL; doi:10.5067/FIRMS/MODIS/MCD14DL.NRT.006) is the foundation of FIRMS products. When MODIS detects a thermal anomaly, which could indicate a wildfire or any significant source of heat, a computer algorithm identifies the center of the 1-km^2 area in which the anomaly is detected. This location is plotted and available to fire crews and wildland managers (and anyone with access to the FIRMS Fire Map) within three hours of the observation and provides an approximate location of a potential wildfire or hotspot.



A hotspot plotted using the MODIS thermal anomalies algorithm represents the center of an approximately 1-km² pixel flagged as containing one or more thermal anomalies, which may indicate a fire (upper half of image). The hotspot "location" is the center point of the pixel, which is an approximation of the actual thermal anomaly (lower half of image). Illustration courtesy of NASA FIRMS.

It's important to note that the geolocation of a detected hotspot is based on predictive rather than definitive satellite orbit information (see the "Near Real-Time vs. Standard Data Products" sidebar). This means that there can be small differences—generally less than 100 meters (about 325 feet)—between an indicated hotspot and its actual location on the ground. In some instances, such as during spacecraft maneuvers or space weather events, the difference between an indicated hotspot and its actual location can increase by several kilometers.

The VIIRS I-band (375 m) Active Fire product (VNP14IMGTDL_NRT; doi:10.5067/FIRMS/VIIRS/VNP14IMGT.NRT.001) was added to the FIRMS collection in 2016 and was developed using the MODIS Fire and Thermal Anomalies product. This means that the VIIRS and MODIS fire products complement each other, and both the VIIRS 375 m product and the MODIS fire product show good agreement in hotspot detection. VIIRS, however, provides better response for smaller fires and provides improved mapping of large fire perimeters. In addition, the VIIRS 375 m product shows a better response in nighttime observations, when fire activity normally subsides. While a VIIRS 750 m active fire product also is available, FIRMS opted to distribute the 375 m product due to its increased spatial resolution and the increased number of fires detected.

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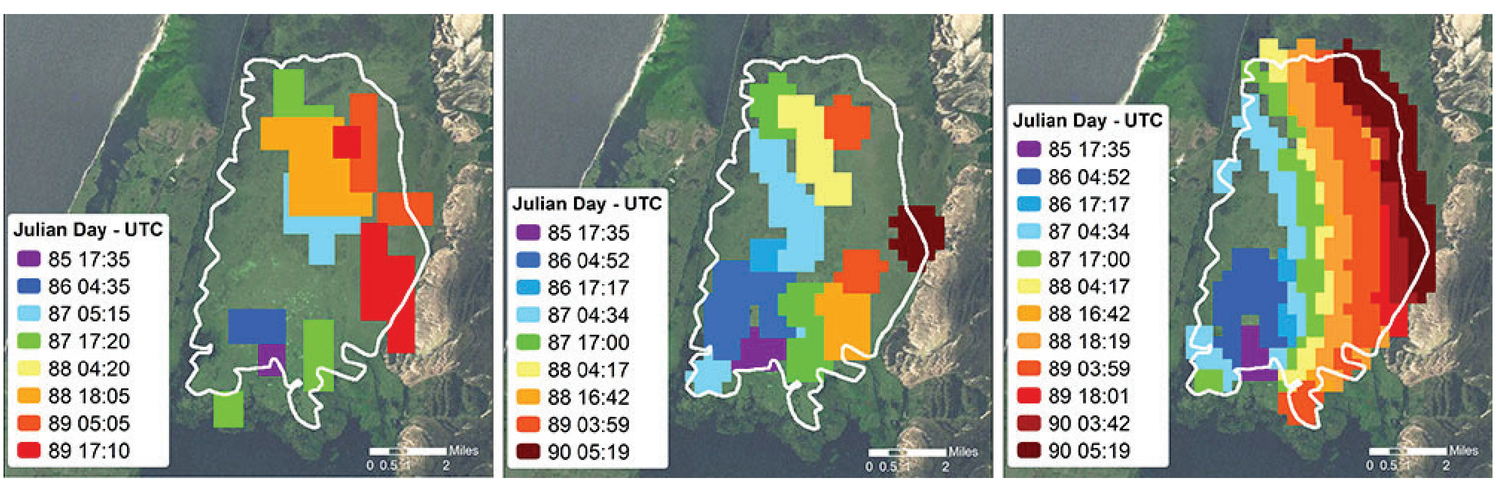
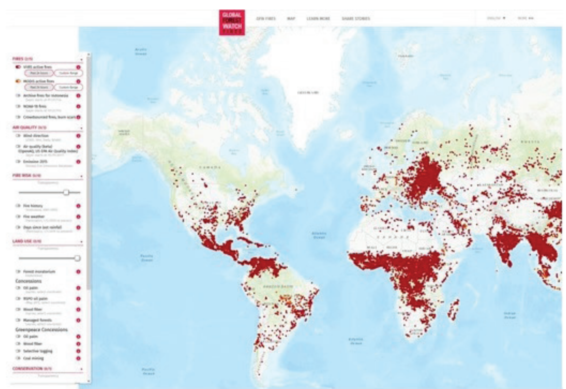
FIRMS data are an invaluable resource for managing ongoing fires and tracking their spread. As provided by NASA's open data policy, all MODIS and VIIRS data and data products are freely available. This policy also applies to the algorithms used to process the data along with the application program interfaces (APIs) that facilitate use of the data. This means that anyone, anywhere in the world who has access to a computer with an internet connection can access FIRMS data and receive emailed FIRMS Fire Alerts.

The European Forest Fire Information System (EFFIS) and the Forest Survey of India are just some of the worldwide government organizations and agencies using FIRMS, MODIS, and VIIRS fire and thermal anomaly data to



A comparison of daily fire spread mapped by 1 km Aqua/MODIS (left), 750 m VIIRS (center), and 375 m VIIRS (right) at the Taim Ecological Reserve in southern Brazil between March 26-31, 2013, which corresponds to Julian Days 85-90. The white outline represents the burned area mapped using 30 m Landsat-7 data on March 31. Note the more coherent fire spread and the excellent spatial agreement of the VIIRS 375 m data (right image). This figure is reproduced courtesy of Dr. Wilfrid Schroeder, Department of Geographical Sciences, University of Maryland.



Due to its emphasis on tropical deforestation, Conservation International's Firecast system (left image) provides FIRMS near real-time data in Bolivia, Columbia, Ecuador, Indonesia, Madagascar, Peru, and Suriname. The WRI's Global Forest Watch Fires (right image) provides FIRMS fire information worldwide. Image: CI Firecast, WRI GFW-F, NASA EOSDIS.

help safeguard lives and property. In addition, the U.S. Climate Resilience Toolkit, a federal website that serves as a clearinghouse for climate-related information from across the U.S. government, recently added FIRMS data to their Tool Webpage.

The U.S. Forest Service uses FIRMS data as an integral component of its Active Fire Mapping Program, which provides near real-time detection and characterization of wildland fire conditions in a geospatial context for the continental United States, Alaska, Hawaii, and Canada. As noted by Brad Quayle, Program Lead for the Disturbance Assessment and Services Program at the Forest Service Geospatial Technology and Applications Center, the combination of FIRMS and thermal anomaly data directly-downloaded from MODIS and VIIRS during a satellite overpass (a process called "direct readout") provides regional and national fire managers with a comprehensive view of the location, extent, and intensity of current wildfire activity throughout much of North America. In addition, the access to global active fire detection data and other relevant science products provided by FIRMS aids the Forest Service in assisting other countries with fire management and post-fire assessment mapping. "With FIRMS," observes Quayle, "we never have to worry about gaps in data availability."

Along with government agencies, numerous non-governmental organizations also have developed systems or websites that use FIRMS data. These include the Firecast system developed by Conservation International (CI) and three websites run by the World Resources Institute (WRI).

As noted by Karyn Tabor, CI's Director of Early Warning Systems, FIRMS near real-time active fire data help land managers in the tropics monitor ecosystem threats, actively manage fires, strategize patrols of protected areas, and enforce land use policies. According to Tabor, FIRMS data are critical for alerting managers to fires in areas that are impossible to patrol on foot due to terrain or size. FIRMS active fire data also are valuable for protecting restored forest areas that are vulnerable to fires. In one example, the CI Firecast active fire web map showing FIRMS data was used by the World Wildlife Fund Madagascar as part of a community outreach campaign to highlight the importance of safeguarding reforested areas in the Amoron'i Onilahy Protected Area in southwest Madagascar, which was threatened by fires originating from nearby villages.

WRI uses FIRMS data on three of its most prominent data platforms: Global Forest Watch (GFW), Global Forest Watch Fires (GFW-F), and Resource Watch. Collectively, these three tools enable users to view, analyze, download, and subscribe to active fire alerts. GFW and GFW-F also provide analyses derived from FIRMS data, which are displayed in dashboards and fire reports. Alyssa Barrett, the GFW Platform Manager, notes that most WRI fire work is tied to monitoring the intentional burning of land for agriculture. According to Barrett, FIRMS data not only provide for rapid response to detected fires, they also help identify land being burned illegally and enable those responsible for illegal burning to be held accountable.

In an example of FIRMS data in action provided by Barrett, Sudamaris Bank in Paraguay had recently started using GFW to monitor land in their investment portfolio and received a fire alert for a potential fire on a client's cattle farm. The bank notified the client, who was able to immediately begin fighting the wildfire. While the rancher lost 100 hectares of pasture, the rapid notification of the fire enabled him to save the rest of his 1,200-hectare property.

Somewhere on Earth a wildfire is burning.

Thanks to FIRMS, the world can respond. ■

Providing ACCESS to EOSDIS Data

NASA's ACCESS Program helps create and enhance technologies that make EOSDIS data more accessible for global interdisciplinary research.

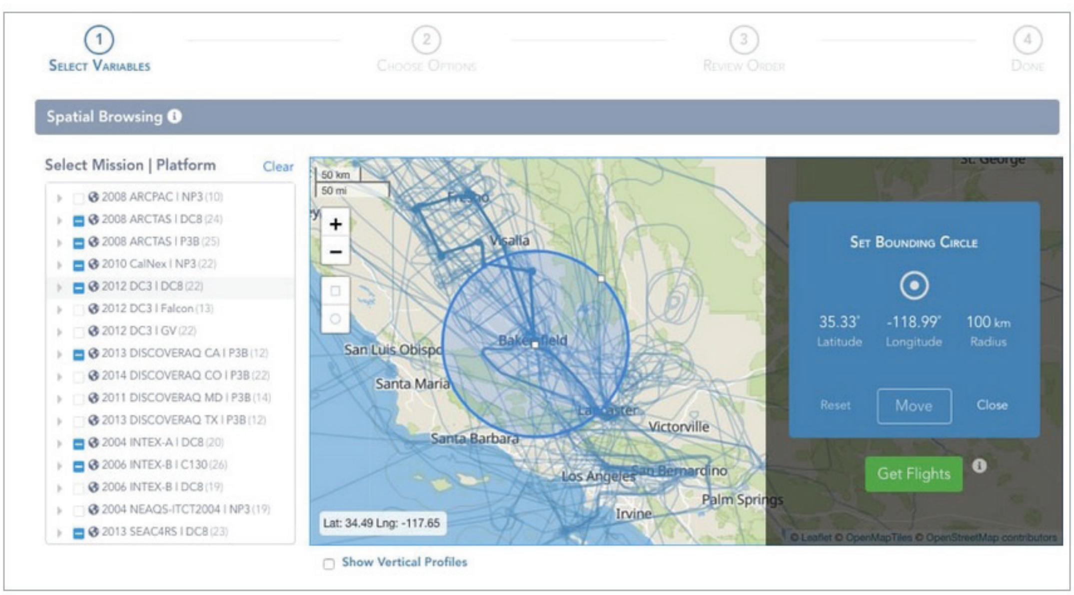
New technologies are constantly being created within the user community that can improve access to and use of the more than 27.5 petabytes (PB) of Earth observing data in NASA's Earth Observing System Data and Information System (EOSDIS) collection. Partnerships with the academic, developer, and user communities (not to mention participation in organizations such as the Committee on Earth Observation Satellites [CEOS] and the Earth Science Information Partners [ESIP] federation) enable the EOSDIS to evaluate innovative systems, applications, and programs to see how they might be applied to EOSDIS data. An important NASA initiative for facilitating these partnerships is the Advancing Collaborative Connections for Earth System Science (ACCESS) Program.

Established in 2005, ACCESS is a competitive program within NASA's Earth Science Data Systems (ESDS) Program. The ESDS Program oversees the life-cycle of NASA's Earth science data—from acquisition through processing and distribution. It accomplishes this through the EOSDIS, which provides end-to-end capabilities for managing these data.

The overall objective of ACCESS is to help develop and implement technologies for effectively managing, discovering, and utilizing NASA Earth observing data for scientific research and applications. Projects selected for ACCESS enhance NASA's data system components by enabling the rapid deployment of data system services to help bridge specific gaps within the agency's Earth science information systems. Since its inception, more than 70 projects have been part of the program; five projects are part of the current ACCESS 2017.

ACCESS Principal Investigators (PIs) work closely with NASA's Earth Science Data and Information System (ESDIS) Project to integrate their projects into the discipline-specific Distributed Active Archive Centers (DAACs) that archive and distribute EOSDIS data. For example, the ACCESS 2011 Curated Data Albums for Earth Science Case Studies project is in use at the Global Hydrology Resource Center (GHRC) DAAC and OpenAltimetry, an ACCESS 2015 project, is helping facilitate the analysis of data from NASA's ICESat and ICESat-2 missions at the National Snow and Ice Data Center (NSIDC) DAAC. In addition, the 10 ACCESS 2015 projects, which concluded in 2018 with presentations of their final work, resulted in more than 30 professional publications. Regardless of whether technology developed through an ACCESS project is integrated into the EOSDIS, these projects help NASA better understand the proposed technology solution and its utility for future consideration.

ACCESS solicitations are generally released every other year as part of NASA's Research Opportunities in Space and Earth Sciences (ROSES) research program. Each ACCESS solicitation has a specific goal or objective reflecting the needs of both NASA data systems and EOSDIS data users. For example, the goal of ACCESS 2017 was "to improve and expand the use of NASA's Earth science data by leveraging modern techniques for discovering, managing, and analyzing large and complex



Screenshot from the Subsetting Tools for Advanced Analysis of Airborne Chemistry Data (STA3CD, or "Stacked") ACCESS 2015 project. STA3CD enhances the Toolsets for Airborne Data (TAD) system developed by NASA's Atmospheric Science Data Center (ASDC) with additional geographical map capabilities to better serve the research community.

Earth science data sets," with specific focus areas in machine learning, advanced search capabilities, and cloud-optimized preprocessing and data transmission.

Out of 39 submissions, five proposals were selected for ACCESS 2017:

- Community Tools for Analysis of NASA Earth Observation System Data in the Cloud
- Data Access and the ECCO Ocean and Ice State Estimate
- Multi-Temporal Anomaly Detection for SAR Earth Observations
- STARE: SpatioTemporal Adaptive-Resolution Encoding to Unify Diverse Earth Science Data for Integrative Analysis
- Systematic Data Transformation to Enable Web Coverage Services (WCS) and ArcGIS Image Services within ESDIS Cumulus Cloud

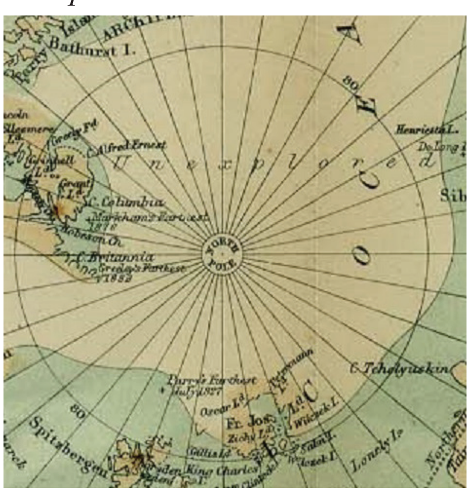
The formal ACCESS 2019 solicitation is expected to be released in November as part of NASA's ROSES-2019 omnibus solicitation (NNH19ZDA001N), and will be available through the NASA Solicitation and Proposal Integrated Review and Evaluation System (NSPIRES) website.

As noted by NASA's ESDS Program, ACCESS projects increase the interconnectedness and use of information technology software and techniques that help advance Earth science research and applications. These projects also further enhance the free and open exchange of EOSDIS data and information, which is a critical objective of NASA's Earth Science Division. Through partnerships fostered through the ACCESS Program, new and innovative technologies for accessing and using NASA Earth science data are constantly available to the millions of worldwide EOSDIS data users. ■

ICESat-2 Data Usher in a New Age of Exploration

Data from NASA's ICESat-2 mission provide incredibly accurate measurements of Earth elevation change—and much more.

Unexplored.



"North Polar Chart, showing International Polar Stations, 1882-1883," Scottish Geographical Magazine, Vol. 1, No. 12, 1885. Accessed through the NOAA Pacific Marine Environmental Laboratory, Arctic Zone, and located at the Perry-Castañeda Library Map Collection at the University of Texas at Austin.

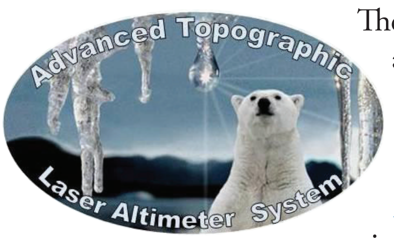
The word sits as a challenge and a tease above the notation "North Pole" on an 1885 map showing Arctic research stations. Gathering the data to measure and map the Poles was an intense undertaking, and included numerous international expeditions. The conditions were brutal and not all expedition members survived. What did survive, in many cases, were the expedition data that began to unlock the secrets of these remote regions.

Modern data and expeditions provide an ever-increasing understanding of the global implications of changes occurring in the cryosphere. The term "cryosphere" refers to Earth's frozen regions, and includes snow, river and lake ice, sea ice, glaciers, ice shelves and ice sheets, and frozen ground. Data collected by instruments aboard Earth observing satellites have ushered in a new age of cryospheric exploration and are providing measurements with a precision that could not even be imagined by late-19th century researchers.

One example is NASA's Ice, Cloud, and land Elevation Satellite-2, or ICESat-2. ICESat-2 launched on September 15, 2018, on a planned three-year mission to measure the height of a changing Earth in unprecedented detail. The initial data and data products from ICESat-2 are now publicly available through NASA's National Snow and Ice Data Center Distributed Active Archive Center (NSIDC DAAC). "The data look fantastic," says Steve Tanner, the DAAC's ICESat-2 Data Manager. "In fact, the data are coming in significantly better in a number of areas.”

This is the story of the ICESat-2 data—how these data are collected, processed, and archived, as well as how they can be accessed and used, fully and freely, by anyone anywhere in the world. These data will shed new light on an ever-changing world, all collected, in the words of the ICESat-2 team, “one laser pulse at a time, 10,000 laser pulses a second.”

ICESat-2 data and data products complement a data record that started with NASA’s original ICESat mission (operational 2003 to 2009) and continues with NASA’s ongoing Operation IceBridge airborne series of flights over the Arctic and Antarctic that started in 2009. Data from all three missions are available through the NSIDC DAAC, which is responsible for NASA data and information for snow and ice processes, particularly interactions among snow, ice, atmosphere, and ocean, in support of research related to global change detection and model validation.

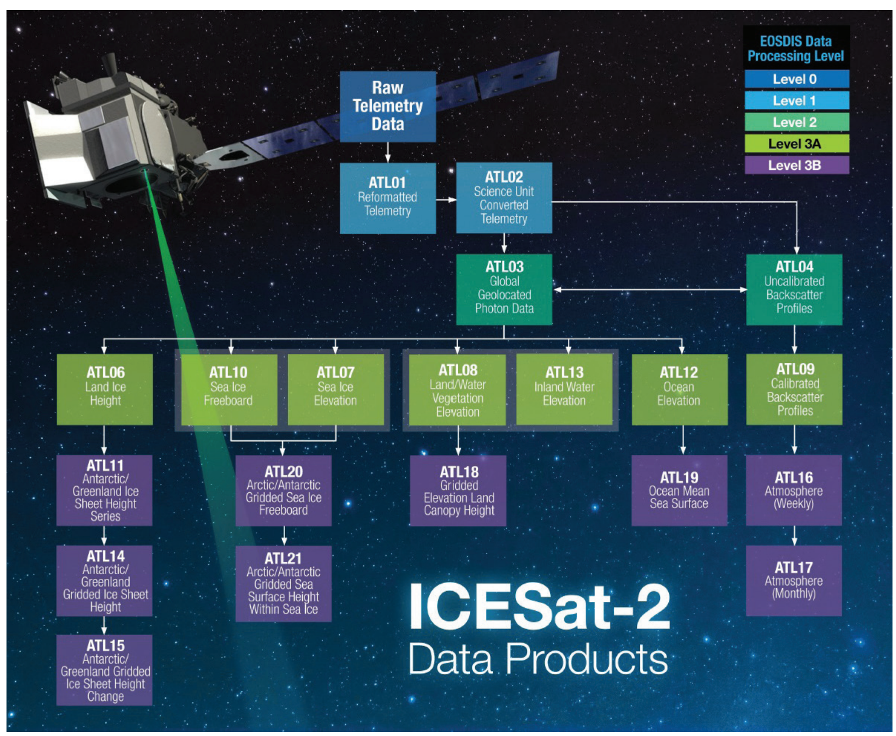


The single instrument carried aboard the ICESat-2 spacecraft is the Advanced Topographic Laser Altimeter System, or ATLAS. ATLAS has three major tasks: Send pulses of laser light to the ground, collect the returning packets of electromagnetic radiation (called *photons*), and record the photon travel time. The bright green pulses of the ATLAS laser beam leave the instrument for the ground at a rate of 10,000 pulses per second (compared with 40 pulses per second in the original ICESat laser). This high frequency enables the instrument to measure height about every 2.3 feet along the satellite’s path. As noted in the ICESat-2 mission brochure, if it flew over an American football field, the first ICESat would have taken a measurement outside each end zone; ICESat-2 takes measurements within each yard line.

About 20 trillion photons leave ATLAS with each pulse and about a dozen photons make the 3.3 millisecond return trip for detection by the satellite’s 2.6-foot diameter beryllium telescope. When this travel time is combined with the satellite’s GPS and star trackers, ICESat-2 can measure surface height to a precision of about one inch (about the length of a standard paperclip).

While the primary intent of the ATLAS instrument is to measure cryospheric elevation, the instrument is able to generate elevation data for more than just ice and frozen ground. Much more. Pre-mission experimentation by the science team found that ATLAS does a great job measuring elevation in temperate regions, including measurements of forest cover and vegetation, and is even able to detect water features (such as coral reefs and ocean waves). “These data were not the primary mission concerns, ice was primary, but it looks like these data will be significantly more useful than originally planned,” says Tanner.

Not counting raw telemetry data, 20 unique ICESat-2 data products will be produced (see illustration; note that there is no product designated “ATL05”). The mission is required to produce Level 1 through Level 3 data, based on the data processing levels of NASA’s Earth Observing System Data and Information System (EOSDIS). As Tanner notes, there almost certainly will be Level 4 derived or model data associated with the mission, especially when researchers combine ICESat-2 data with data from Operation IceBridge, the Geoscience Laser Altimetry System (GLAS) instrument aboard the original ICESat, and data from similar missions, such as the European Space Agency’s CryoSat mission.



“Freeboard” is the elevation difference between the top of the ice and the top of the ocean surface. Since roughly 1/10 of sea ice sits above the ocean surface, sea ice thickness can be estimated by measuring the freeboard. Illustration based on a table originally created by the NSIDC DAAC.

Preparing for ICESat-2 data was challenging given the large volume of data expected from the mission. While the volume of data from Operation IceBridge is about 30 terabytes (TB) per year, ICESat-2 is producing just under 1 TB of data *per day.* Also, ICESat-2 file sizes are very large. "Typically, projects try to limit file sizes to two gigabytes (GB) or less for a given file," explains Tanner. "Some of the ICESat-2 files were coming in at closer to 10 GB. We needed to make sure our computing systems were robust enough for this volume of data."

In addition, algorithms had to be developed to process ICESat-2 data. While the GLAS instrument aboard the first ICESat spacecraft looked at the intensity of a returned laser signal and detected groups of returning photons at one time, ICESat-2's ATLAS instrument detects individual photons. Along with detecting individual photons returned from a laser pulse, the instrument also senses photons from natural sunlight. Algorithms had to be developed to isolate the ATLAS photons to determine the actual elevation of Earth's surface. Developing these algorithms in advance of the ICESat-2 launch was accomplished using an airborne testbed instrument called the Multiple Altimeter Beam Experimental Lidar (MABEL).

By using MABEL early in the process, ICESat-2 subsetting, reformatting, and reprojection services could be developed at the same time—well before launch. "What this means is that as the science team is tweaking these data products to get them ready for public use, the data services are also being tweaked at the same time," says Tanner. "It's just a matter of verifying that the data services can still support the changes from the science team."

The journey of ICESat-2 data from the ATLAS instrument to the NSIDC DAAC begins as raw, unprocessed data are relayed to a NASA ground station. From there, they are sent to NASA's Earth Observing System (EOS) Data and Operations System (EDOS) located at NASA's Goddard Space Flight Center in Greenbelt, Maryland, where they are turned into Level 0 data. Level 0 data are still unprocessed, however communications artifacts, such as synchronization frames, communications headers, and duplicate data, have been removed. These Level 0 data are then sent to the NSIDC DAAC as a back-up and to the ICESat-2 Science Investigator-led Processing System (SIPS) for processing into Level 1, 2, and 3 data products. These SIPS-produced higher-level products are sent to the NSIDC DAAC for archiving and distribution. "We've been practicing with the SIPS for several years now making sure that everything is ready for the public release of these data," Tanner says.

ICESat-2 data can be accessed in several ways. The easiest is through the EOSDIS Earthdata Search application, though there are other means as well. For example, the NSIDC DAAC provides application programming interface (API) access to ICESat-2 data and services, where data users can set up programmatic access or set up a script to constantly get ICESat-2 data for a specific region. Both of these options also offer data services such as subsetting, reformatting, and reprojection, making the data easier to use and reducing the amount of network traffic generated. The ICESat-2 team has put a great deal of energy into making sure these data services meet end-user needs and that they are fully integrated into Earthdata Search and the API access.

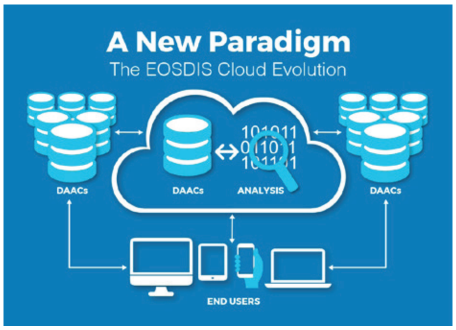
Another resource for accessing and working with ICESat-2 data is a project called OpenAltimetry. OpenAltimetry is a cyberinfrastructure platform for ICESat and ICESat-2 data discovery, access, and visualization that is funded through a grant as part of NASA's Advancing Collaborative Connections for Earth System Science (ACCESS) Program. "You can go to OpenAltimetry to quickly visualize the data to decide if these are files you want to have," explains Tanner, noting that OpenAltimetry is still in development. "It goes beyond subsetting by letting you look at the data without having to download the data. We're making OpenAltimetry available to the public to assess the value of it and to decide if we should put it into full production."

Now that ICESat-2 data are finally getting into the hands of the global user community things are about to become very interesting. As Tanner notes, the ICESat-2 science team is a small community primarily focused on the cryosphere; new applications for ATLAS data continue to be discovered far beyond the mission's primary objective. "It's turning out that ICESat-2 is truly a global satellite that can be used to study all sorts of non-cryospheric things," he observes. "We can look at rain forests, we can look at deserts, we can look at oceans. We want these data to get out there and for people to use these data in ways we haven't even imagined. To me this would be the coolest thing to come out of the mission."

Unexplored. A word that now applies to the new voyage of discovery that is being ushered in with the release of ICESat-2 data and the many ways these data will be used. ■

EOSDIS Data in the Cloud: User Requirements

Knowing how users will interact with EOSDIS data in the cloud ensures a more efficient cloud evolution and a cloud architecture that best facilitates data access and use.



NASA's Earth Science Data and Information System (ESDIS) Project and its constituent Distributed Active Archive Centers (DAACs) continue to evolve data in NASA's Earth Observing System Data and Information System (EOSDIS) collection from physical servers into the cloud. This effort is called Cumulus, and has been detailed in earlier articles in this series. The benefits of this evolution to worldwide EOSDIS data users are significant, and include the ability to work with more data more efficiently than ever before.

A key element in this process is determining user requirements to gain a better understanding of how users will interact with data in the cloud, the types of analyses they intend to conduct, and options for architecting the EOSDIS cloud environment to best facilitate data use. This is an important undertaking since the EOSDIS data collection is about to become much larger.

From its current data volume of about 27.5 petabytes (PB) at the end of the 2018 Fiscal Year, the volume is forecast to grow to as much as 250 PB by 2025. This is due to the extremely high volume of data expected from upcoming missions such as the joint NASA/French, Canadian, and United Kingdom Surface Water and Ocean Topography (SWOT) mission and the joint NASA/Indian Space Research Organisation Synthetic Aperture Radar (NISAR) mission, both of which are currently scheduled for launch in 2021. NISAR, for example, is expected to generate approximately 3 terabytes (TB) of Level 0 data each day, which is equivalent to about 3,000 gigabytes (GB) (for comparison, the five instruments aboard the Terra Earth observing satellite generate about 195 GB of Level 0 data each day, according to NASA's Earth Observing System). For most data users, the current practice of downloading data onto an individual machine for analysis simply won't work for data collections this large; collections that earn the name "Big Data."

A primary objective of hosting EOSDIS data in the cloud is to "level the playing field" so anyone can work with these Big Data collections. The ideal user experience (UX) allows data users to work next to EOSDIS data in the cloud, meaning that a user can simply point their analysis software to a data location in the cloud and begin analyzing without the need to transfer or download data. After completing their analyses, a user can view or download the results. An integral part of facilitating this is preprocessing these data into Analysis Ready Data (ARD), which enables end-users to begin working with data immediately.

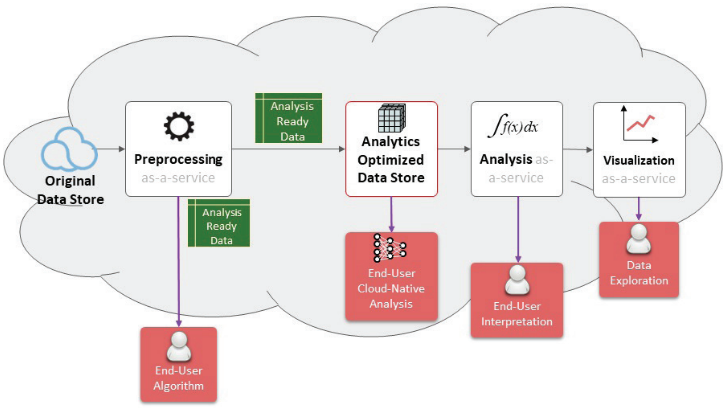
This would be a straightforward process if all EOSDIS data users interacted with data the same way. However, the millions of individual EOSDIS data users will interact with cloud-based data in different ways depending on their research and analysis requirements as well as their individual level of experience working with EOSDIS data. Some will conduct all their work inside the cloud, some will download data for analysis outside the cloud, and some will work in a hybridized fashion partially inside and outside the cloud. The ESDIS Project must be aware of these uses and have data architecture and systems ready to support these interactions.

Specifically, ESDIS and the DAACs are collecting end-user input to determine:

- What kind of analyses will be conducted?
- What do data users consider ARD and how much preprocessing can ESDIS do?
- Where will users analyze these data—in the cloud, outside of the cloud, or somewhere in-between?
- What support products (such as primers, webpages, webinars, or tutorials) will users need?

Sources for this information include the annual EOSDIS American Customer Satisfaction Index (ACSI) surveys, feedback from webinars, various early-adopter programs, interaction with data users at applications workshops and science meetings, and input from DAAC User Working Groups.

In general, four primary types of users, with distinct UX, are likely to use EOSDIS data (see illustration). Users who have their own algorithms (End-User Algorithm [left red box in illustration]) may only require data preprocessing,



Data users can work with ARD inside or outside the cloud, depending on their analysis needs, the amount of data they are using, or their experience level. ESDIS Project graphic created by Dr. Chris Lynnes, ESDIS Project System Architect.

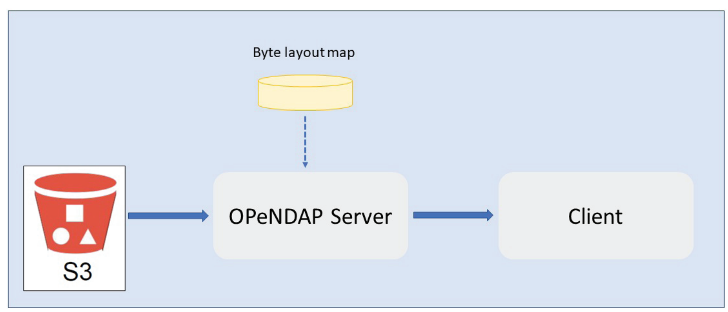
like subsetting or reformatting, then work with data inside or outside the cloud, depending on the amount of data they are using.

Users who do not have their own algorithms or who are new to EOSDIS data may just want a usable answer from a data query without having to worry about conducting their own analysis on the data. For these users, Analysis-As-A-Service and Visualization-As-A-Service can be offered, both of which will almost always result in a smaller amount of data displayed as some sort of a statistical model or as imagery (an example of Visualization-As-A-Service is the Giovanni data visualization application created by the Goddard Earth Sciences Data and Information Services Center [GES DISC], which is an EOSDIS DAAC). These users (End-User Interpretation and Data Exploration [right two red boxes in illustration]) can work with data inside or outside the cloud.

A fourth user type is more non-traditional, and will conduct their work completely inside the cloud using cloud-optimized data analysis applications (End-User Cloud-Native Analysis [red box in center of illustration]). For these users, EOSDIS would restructure ARD into a cloud-based storage form for working with cloud-native algorithms (an Analytics Optimized Data Store). These structures can include highly-scalable file systems and databases or simple data cubes. The overall objective is to re-aggregate the data to facilitate rapid data processing and analysis inside the cloud.

Knowing user requirements also helps in designing the best architecture for storing, organizing, and accessing these data, and ESDIS and the DAACs are looking at different approaches to address this. Currently, the only cloud system approved by the NASA Office of the Chief Information Officer is Amazon Web Services (AWS), and Cumulus is optimized to utilize AWS. The data storage provided by AWS is the Simple Storage Service, or S3. An S3 bucket is inexpensive and designed to store large volumes of data. The catch is that S3 is not a file system. This means that it can be difficult to get a specific segment of bytes from a file.

One solution to enable efficient in-place S3 data analysis is to use an Open-source Project for a Network Data Access Protocol, or OPeNDAP, server as an intermediary to retrieve file segments from the S3 bucket. As its name implies, OPeNDAP is an open-source protocol that provides a discipline-neutral means of requesting and providing data, and allows end-users to access the data they require using applications they possess and with which they are familiar. The OPeNDAP server stores a map ("Byte layout map" in illustration) of how the S3 bucket is organized, so it knows which bytes to retrieve from the file stored in the S3 bucket based on what the client's application is requesting.



Simple illustration showing OPeNDAP/S3 relationship. Based on an ESDIS Project graphic created by Dr. Chris Lynnes, ESDIS Project System Architect.

Another potential architecture solution being developed uses an environment called Pangeo. Pangeo is a community promoting open, reproducible, and scalable science, and the Pangeo Project serves as a coordination point between scientists, software, and computing infrastructure. The Pangeo mission is to cultivate an ecosystem in which the next generation of open-source analysis tools for Big Data geoscience datasets can be developed, distributed, and sustained. The Pangeo software ecosystem includes open-source tools such as xarray, Dask, Jupyter, and other open-source packages.

For EOSDIS cloud efforts, the Pangeo team proposes integrating open-source tools from EOSDIS DAACs and existing EOSDIS-wide data discovery applications, such as the Common Metadata Repository (CMR) and

Global Imagery Browse Services (GIBS), around a central JupyterHub (see illustration). Python-based open-source packages from the PyData ecosystem (such as Dask and xarray) will be used to facilitate scientific data analysis within the cloud, with data analysis accelerated using a Python-based Application Program Interface (API). A user can issue API commands from a laptop to trigger processing in the cloud where the data are stored. Rather than downloading data in bulk for processing on a laptop, only final results (for example figures for scientific publications or subsets of imagery) are downloaded. This, in turn, should result in a savings in data use and data egress costs for the user.

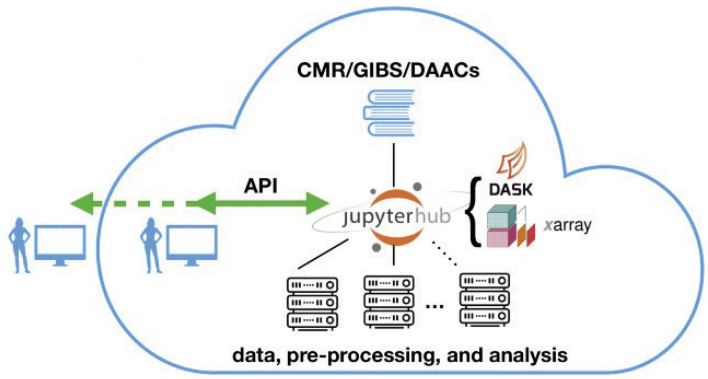


Illustration by Dr. Scott Henderson, University of Washington, and reproduced courtesy of the Pangeo Project team. More information about this project is available on the Pangeo Blog.

The Pangeo Project is part of NASA's Earth Science Data Systems' Advancing Collaborative Connections for Earth System Science (ACCESS) 2017 Program. The ACCESS Program develops and implements technologies to effectively manage, discover, and utilize NASA's archive of Earth observations for scientific research and applications, and complements work by ESDIS and the DAACs in various areas. The five projects selected for ACCESS 2017 are designed to improve and expand the overall use of NASA's Earth science data by leveraging modern techniques for discovering, managing, and analyzing large and complex Earth science datasets. Technologies developed through these projects may be incorporated into EOSDIS cloud efforts.

As the EOSDIS data collection continues to become larger and more complex, the cloud will create new avenues for research using Big Data in this collection. Having basic information ahead of time about general user requirements enables EOSDIS and the DAACs to begin putting data in the right formats and structures and to start developing the resources to help users efficiently use these data. This information also will play a critical role in developing a cloud-optimized architecture to best facilitate interdisciplinary work and research in the cloud next to EOSDIS data. Stay tuned! ■

Daymet Data in Recent Research

The Daymet dataset at NASA's Oak Ridge National Laboratory Distributed Active Archive Center (ORNL DAAC) provides nearly 40 years of environmental data about North America.

Dr. Jessica Welch, Science Communications Lead, ORNL DAAC

NASA's Oak Ridge National Laboratory Distributed Active Archive Center (ORNL DAAC) produces and archives Daymet data, which supply gridded estimates of daily weather parameters throughout North America. The Daymet Version 3 daily surface weather and climatological summaries recently have been updated to include all years 1980 through 2018 for continental North America, Puerto Rico, and Hawaii. Daymet output variables include the following parameters: minimum temperature, maximum temperature, precipitation, shortwave radiation, vapor pressure, snow water equivalent, and day length. The following recent peer-reviewed articles illustrate how researchers are using Daymet to inform a variety of applications.

Daymet used to evaluate potential effects of climate change on common milkweed

Daymet data were used to study the influence of climate change on the phenology (the timing of a plant's life cycle) of *Asclepias syriaca* (common milkweed). *A. syriaca* is a flowering plant native to much of the U.S. that relies on a variety of insects for pollination. Howard (2018) hypothesizes that the phenology of *A. syriaca* has been modified by climate change. The author retrieved daily maximum temperature and precipitation values from Daymet for the locations of individual *A. syriaca* plants recorded in the U.S. National Phenology Network database and quantified the relationship between climatic variables and the flowering dates of the plants. The results

Asclepias syriaca *(common milkweed) relies on pollinators for movement of its pollen, and evidence suggests that its populations are declining. Image courtesy of Pixabay.*

show that higher temperatures are correlated with earlier milkweed flowering dates.

Phenological studies are important because earlier flowering dates can lead to "mismatches" between the phenology of when a plant flowers and when insects are available to pollinate the plant. According to Howard (2018), "Given *A. syriaca's* potential susceptibility to the negative consequences of phenological shift, recent decline, and importance as a host plant, it is critical to this plant's future conservation that its potential response to climate change is investigated."

Publication: Howard, A.F. (2018). "*Asclepias syriaca* (Common Milkweed) flowering date shift in response to climate change." *Scientific Reports,* 8(1):17802 (doi: 10.1038/s41598-018-36152-2).

Daymet data aid research on responses of vegetation to climate variability across Yellowstone National Park

Daymet was used in combination with remotely-sensed land products to inform an analysis of changes in vegetation across Yellowstone National Park in Wyoming. To identify ecological vulnerability and guide resource management in the Western U.S., a region that experiences periodic water scarcity, Notaro, et al. (2019) retrieved temperature, precipitation, surface solar radiation, and snow-water equivalent data from Daymet. The authors identified which climate variables varied most across the study area and how those changes related to the health and seasonality of vegetation. In addition, they constructed a timeseries of monthly anomalies of both climate and vegetation variables to demonstrate how vegetation patterns varied across the park in recent decades.

Yellowstone National Park is the oldest official national park in the U.S., has a largely pristine environment, and has been the subject of intense environmental research. Through their exploration of the complex interactions between climate and vegetation, Notaro, et al. (2019) offer new insights into how climate change is manifest across a variety of topographic, climatic, and ecological gradients.

Publication: Notaro, M., Emmett, K. & O'Leary, D. (2019). "Spatio-Temporal Variability in Remotely Sensed Vegetation Greenness Across Yellowstone National Park." *Remote Sensing,* 11(7):798 (doi: 10.3390/rs11070798).

The U.S. Geological Survey (USGS) incorporates Daymet into hydrologic modeling applications

Daymet has been used in configurations of a national hydrologic model that aims to enable more effective water resources planning and management. The USGS developed the National Hydrologic Model (NHM) infrastructure "to support coordinated, comprehensive, and consistent hydrologic modeling at multiple scales for the conterminous United States." When the model is configured for use in Precipitation-Runoff Modeling (NHM-PRMS), it includes precipitation and minimum and maximum temperature derived from Daymet.

The authors, Regan, et al. (2019), note that the rationale for the NHM is to provide consistent and relevant simulations of watershed-scale hydrologic processes for effective management of water resources. Moreover, incorporating variations of local parameters into the model can contribute to studies on specific geospatial areas or conditions.

Publication: Regan, R.S., Juracek, K.E., Hay, L.E., Markstrom, S.L., Viger, R.J., Driscoll, J.M., LaFontaine, J.H. & Norton, P.A. (2019). "The U.S. Geological Survey National Hydrologic Model infrastructure: Rationale, description, and application of a watershed-scale model for the conterminous United States." *Environmental Modelling & Software,* 111:192-203 (doi: 10.1016/j.envsoft.2018.09.023).

Daymet Datasets at NASA's ORNL DAAC: Thornton, P.E., Thornton, M.M., Mayer, B.W., Wei, Y., Devarakonda, R., Vose, R.S. & Cook, R.B. (2018). "Daymet: Daily Surface Weather Data on a 1-km Grid for North America, Version 3" (doi: 10.3334/ORNLDAAC/1328).

Thornton, M.M., Thornton, P.E., Wei, Y., Mayer, B.W., Cook, R.B. & Vose, R.S. (2018). "Daymet: Annual Climate Summaries on a 1-km Grid for North America, Version 3" (doi: 10.3334/ORNLDAAC/1343).

Thornton, M.M., Thornton, P.E., Wei, Y., Mayer, B.W., Cook, R.B. & Vose, R.S. (2018). "Daymet: Monthly Climate Summaries on a 1-km Grid for North America, Version 3" (doi: 10.3334/ORNLDAAC/1345).

Thornton, M.M., Thornton, P.E., Wei, Y., Vose, R.S. & Boyer, A.G. (2018). "Daymet: Station-Level Inputs and Model Predicted Values for North America, Version 3" (doi: 10.3334/ORNLDAAC/1391).

Thornton, P.E., Thornton, M.M. & Vose, R.S. (2018). "Daymet: Annual Tile Summary Cross-Validation Statistics for North America, Version 3" (doi: 10.3334/ORNLDAAC/1348). ■

Today's Interns . . . Tomorrow's Mentors

Under the guidance of experienced mentors, summer interns are supporting tasks at the ESDIS Project Office and at EOSDIS DAACs across the country.

Mentor: 1. A wise advisor. 2. A teacher or coach. [Webster's New World Dictionary]

Justin Rice has fond memories of the two NASA mentors he worked with in 2004 and 2005 during his summer internships at NASA's Goddard Space Flight Center in Greenbelt, Maryland. "The first gentleman was very nice and encouraging; he was extremely supportive and always told the tallest of tales—he still tells them," Rice recalls. "My second mentor was just a few years older than me, but the dude was just so brilliant. He was very sharp and passionate about mentoring. In many ways, both of these gentlemen are still my mentors."

It has been more than 15 years since Justin Rice, a sophomore at Jackson State University in Jackson, MS, took his first airplane ride to Washington, D.C., to work as a NASA summer intern. Today, Dr. Justin Rice is a systems engineer with NASA's Earth Science Data and Information System (ESDIS) Project and a co-mentor to his own group of summer interns: five young men and women from across the country who were selected into the highly-competitive NASA Internship Program.

These interns—Sara Lytle, Junho Kim-Lee, Summerlyn Turner, Catherine (Kate) Hobart, and Alyssa Kaewwilai—come from different schools, different academic majors, and different backgrounds, but all are working together over an intense 10 weeks to move critical ESDIS projects forward. The end result of this crucible of accomplishment

2019 ESDIS Project Office summer interns and their mentors. Left to right: Catherine (Kate) Hobart, Junho Kim-Lee, Sara Lytle, Summerlyn Turner, mentor Chris Lynnes, Alyssa Kaewwilai, mentor Justin Rice, and mentor Valerie Dixon. Not pictured: mentor John Moses. NASA EOSDIS image.

will be better services and products for the worldwide users of NASA Earth observing data. "Our interns make a huge contribution to ESDIS Project [operations]," says Rice. "I want to be sure they know how significant their work is to the Project."

Sara Lytle, a master's degree candidate in environmental engineering at Columbia University in New York City is working with Junho Kim-Lee, a sophomore computer science major at Cornell University in Ithaca, NY, to replicate the results of a study on canopy flux using a software package called Pangeo. After they finish replicating the results, they will optimize the data to see if the data can run more effectively in the cloud. Along with Justin Rice, they also are being mentored by ESDIS Project system architect Chris Lynnes. "All of the computer science I've done in the past was with the goal of doing research for Earth science," says Sara. "This is the first time I'm working with computer science for the sake of computer science. I definitely don't do work like this in my academic environment!"

Meanwhile, Summerlyn Turner, a recent bachelor's degree graduate in geography from DePaul University in Chicago, is using a different software package to replicate the results from the same research on which Sara and Junho are working. Summerlyn's mentors include Justin Rice and ESDIS Project science processing systems manager John Moses. "I'm using a tool called PODPAC," she explains. "Right now, I'm trying to figure out PODPAC, what it is, what it can do, and how I can use it with these data. I was using ArcGIS at DePaul, so this is a little different."

Two other interns also are supporting the ESDIS Project Office under the guidance of their ESDIS Project co-mentors Valerie Dixon and Chris Lynnes. Catherine (Kate) Hobart will be starting her master's degree in geology at Baylor University in Waco, TX, this fall. She is working with Alyssa Kaewwilai, a rising senior at Gettysburg College in Gettysburg, PA, to test data in NASA's Earth Observing System Data and Information System (EOSDIS) collection with a variety of analysis tools. "We're seeing what tools work with what data," explains Kate. "We'll then do some scripting to make these tools available with the specific collection they work best with. This way, someone can easily know which tool or tools will work best with which data collection."

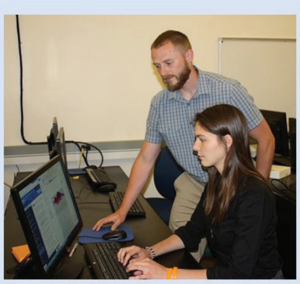
Their mentor, Valerie, oversees EOSDIS metadata and data discovery, and stresses the value of the work being done by Kate and Alyssa. "There are gobs of tools that can work with data, and we are making the assumption that not all data users know what tools are out there or what tools are the best to use for visualizing and analyzing specific data collections," she says. "Thanks greatly to the work of Alyssa and Kate, you'll be able to use Earthdata Search to look for a collection and at the same time see if there are associated tools for using or working with the data in that collection. Plus, there will be links to take you to these tools. The work that Alyssa and Kate are doing will be our poster child for showing how cool our functionality is."

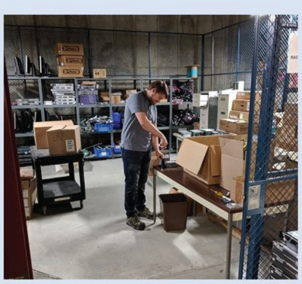
Valerie observes that this work is a true team effort. "I view my role as making sure they have the support and contacts they need to accomplish the task Chris [Lynnes] and I set out, and I make sure they have the training and the contacts they need," she says. "Alyssa and Kate are such self-starters and have great ideas and suggestions, so we're all working together to move this project forward."

NASA's Internship Program brings together talented college and graduate school students (along with recent graduates) to work on projects at NASA centers and facilities across the nation. Some NASA centers, like Goddard, also provide internship opportunities for qualified high school students. Internships are available throughout the year, with summer internships lasting a minimum of 10 weeks and fall and spring internships lasting a minimum of 16 weeks. Detailed information and an electronic application can be found on the NASA Internships and Fellowships website: https://intern.nasa.gov/.

Along with the work being done by the five ESDIS Project Office interns, another five Goddard interns are working on tasks at NASA's Goddard Earth Sciences Data and Information Services Center (GES DISC), which is the EOSDIS Distributed Active Archive Center (DAAC) responsible for NASA data related to atmospheric composition, atmospheric dynamics, global precipitation, and solar irradiance.

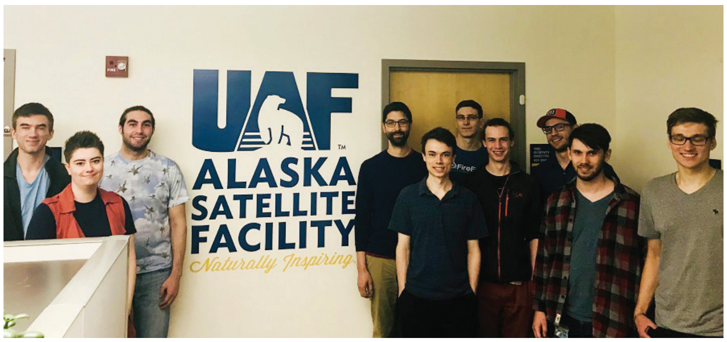
Outside of Goddard, more than 30 additional interns are supporting tasks at EOSDIS DAACs across the country this summer.





Left image: *NASA Socioeconomic Data and Applications Center (SEDAC) summer intern Dorothee Grant is working with her mentor Kytt MacManus to incorporate VIIRS nighttime lights data into SEDAC data collections. NASA SEDAC image.* ***Center image:*** *NASA Land Processes DAAC (LP DAAC) summer intern Nathan (Nate) Nelson is using his engineering skills to evaluate more than seven years' worth of hardware in the LP DAAC storage "cage." LP DAAC image.* ***Right image:*** *NASA Oak Ridge National Laboratory (ORNL) DAAC summer intern Hannah Dattilo is working with her mentor Rupesh Shrestha to develop a data platform that harmonizes ground, airborne, and satellite permafrost measurements. NASA ORNL DAAC image.*

Of course, the NASA intern experience is more than spending 40 hours a week working on assigned tasks. At Goddard, the Office of Education coordinates numerous activities to enhance the intern's summer experience. Laboratory tours, software engineering seminars, coding boot camps, a Sciences and Exploration Directorate Science Jamboree showcasing the breadth of scientific work and research conducted at Goddard, a movie festival, and a wide range of talks and forums are some of the activities that fill up a Goddard intern's day.



Summer interns supporting NASA's Alaska Satellite Facility DAAC. Left to right: Tyler Chase, Alana Kilby, George Meier, Alex Lewandowski, Jake Herrmann, Rohan Weeden, Rowan Biessel, McKade Sorensen, James Rine, Soeren Harms. Not pictured: Hal Dimarchi and Kim Fairbanks. NASA ASF DAAC image.

ESDIS staff also coordinate activities for the interns, and include interns in planning and operations meetings, lunches, and other events. "It's important for them to interact with everyone on the ESDIS team," says their mentor Justin Rice. "We bring them into meetings so they can become familiar with all of the team members, see what we do, and observe how we strategize to accomplish large tasks. We let them get a feel for who's who and who is responsible for different areas and how we interact."

For the ESDIS interns, one result of their work together has been the creation of a team of colleagues who end up mentoring each other. "I think my experience this summer in the internship is giving me great experience in working collaboratively," says Junho. "I'm working closely with Sara on this project; I mean, she's a master's student and has a lot of experience and she's been a very good mentor to me. I'm sure in my classes at Cornell I won't have the chance to have a partner with the experience as Sara."

ESDIS intern Summerlyn appreciates the benefits of being part of a diverse team. "Coming from Chicago and being in a very close-knit group at DePaul [University], it's nice to work with people with different backgrounds and skill sets," she says. "I can bounce ideas off Junho and Sara and [our mentor] Justin and everyone else here. The exposure

Summer interns supporting NASA's Physical Oceanography DAAC. Left image (left to right): Karthik Garimella, Austin Ebel, Jacqueline Kim. Right image: Andrew Joseph. NASA PO.DAAC images.

to different things has been great."

Mentor's, too, are learning from their interns. "When you have interns that have technical expertise, it brings you back to the world you aren't directly connected to anymore," says Justin. "Interns let you test the systems that you're managing. You get to see all the problems or sticking points from a technical perspective rather than hearing about these issues third-hand."

Intern mentor Valerie Dixon agrees. "We have some blind spots in our systems that we depend on our users and our interns bringing to our attention," she says. "Having Alyssa and Kate here to use our systems and directly share their experiences, good and bad, lets us know where we need to make improvements."

As the summer internships come to an end, this most recent class of ESDIS interns is preparing to take their new knowledge and experience back to their college campuses, into additional internships, or into the work world. For the interns, the experience of working at NASA has made a lasting impact, as have their mentors.

"As interns, we receive more than mentorship and guidance from our mentors—we also build lasting friendships with them," says Alyssa. "Valerie and Chris create a very positive, supportive atmosphere that makes work both enjoyable and productive, and I feel I can seek professional advice and address any concerns with them. Through critical, adaptive thinking and collaboration with my team we are always able to resolve any issues. I feel immensely grateful to have the incredible opportunity to be a NASA intern!"

"This is something I've wanted to do forever," says Alyssa's intern partner Kate. "I love working at NASA and in the NASA environment; everyone works hard and takes their job seriously. They carry on NASA's extraordinary legacy every day."

A great internship begins with having a good mentor, and a good mentor can be the start of a great career. "It takes a team, much like a village, to really ensure that the interns have the best experience possible," says Justin Rice. "These interns are much further along than I was at their age. Their respective schools do a great job of exposing them to state-of-the-art software tools and techniques, so I learn a lot from them as well. Let's face it, your workload does not decrease if you have interns and are a mentor. All of us who are mentors are more than happy to do this because this is something we believe in." ■

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 data sets in each feature. **https://earthdata.nasa.gov/user-resources/who-uses-nasa-earth-science-data-user-profiles**

Dr. Pierre Kirstetter

Who uses NASA Earth science data? Dr. Pierre Kirstetter, for improving our understanding of precipitation and flooding.

Associate Professor, the School of Meteorology and the School of Civil Engineering and Environmental Science, University of Oklahoma; Faculty Member, Advanced Radar Research Center, University of Oklahoma; Affiliate, National Severe Storms Laboratory, Norman, OK

Research interests: Radar and satellite remote sensing of precipitation, hydrometeorology, hydrology, severe weather, hydrologic hazard prediction with a focus on precipitation and related impacts, and the development of next-generation precipitation products.

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

Dr. Adam Storeygard

Who uses NASA Earth science data? Dr. Adam Storeygard, for economic studies of urbanization and development.

Photograph of Dr. Storeygard by Stephanie Alvarez Ewens for Brown University.

Associate Professor of Economics, Tufts University, Medford, MA

Research interests: Urbanization, transportation, and the economic geography of the developing world, including research to explain city growth in sub-Saharan Africa.

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

Dr. Lucy Hutyra

Who uses NASA Earth science data? Dr. Lucy Hutyra, for studying the cycling of carbon, especially in urban environments.

Photograph of Dr. Hutyra by Kalman Zabarsky for Boston University Photography.

Associate Professor of Earth and Environment, Boston University; Director, Hutyra Research Lab, Boston University, Boston, MA

Research interests: Using Earth observing data to improve our understanding of the carbon cycle, particularly how changes in vegetation and land use impact flows of carbon between the biosphere and the atmosphere.

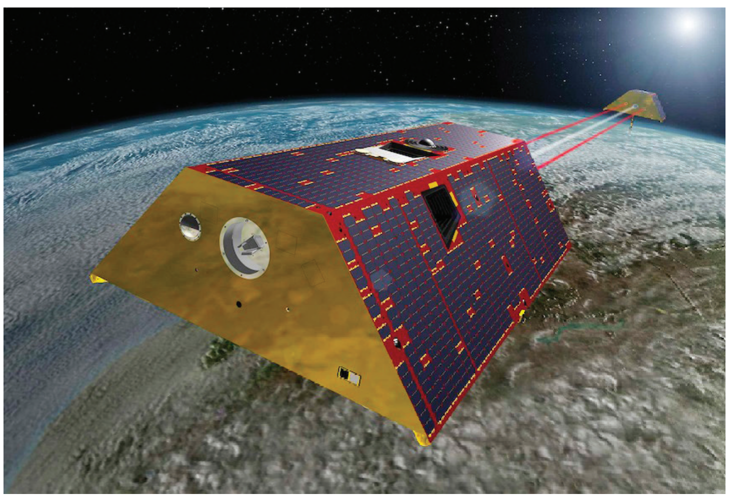
https://earthdata.nasa.gov/learn/user-resources/who-uses-nasa-earth-science-data-user-profiles/user-profile-dr-lucy-hutyra

ANNOUNCEMENTS

First GRACE-FO Data Now Available

Two datasets from the Gravity Recovery and Climate Experiment Follow-On (GRACE-FO) mission have just been released by NASA's PO.DAAC.

NASA's Physical Oceanography Distributed Active Archive Center (PO.DAAC) has released the first public data products from the Gravity Recovery and Climate Experiment Follow-On (GRACE-FO) mission. The Level 1A (doi: 10.5067/GFL1A-ASJ04) and 1B (doi: 10.5067/GFL1B-ASJ04) datasets are produced on a daily basis dating back to the launch of GRACE-FO on May 22, 2018.



Instruments aboard the twin GRACE-FO satellites precisely measure changes in the distance between them due to orbital perturbations caused by geographical and temporal variations in Earth's gravity field. NASA image.

GRACE-FO is a partnership between NASA and the German Research Centre for Geosciences, and is a successor to the Gravity Recovery and Climate Experiment (GRACE) mission (operational 2002 to 2017). Like the original GRACE mission, GRACE-FO uses twin satellites separated by roughly 220 kilometers to accurately map variations in Earth's gravity field and surface mass distribution.

GRACE-FO data expand GRACE's legacy of scientific achievements. These include tracking mass changes in Earth's polar ice sheets and mountain glaciers, which impact global sea level; estimating total water storage on land (from groundwater changes in deep aquifers to changes in soil moisture and surface water); inferring changes in deep ocean currents, which are a driving force in climate; and even measuring changes within the solid Earth itself, such as postglacial rebound and the impact of major earthquakes.

GRACE-FO mission datasets are archived and distributed by PO.DAAC. Located at NASA's Jet Propulsion Laboratory in Pasadena, California, PO.DAAC is the NASA Earth Observing System Data and Information System (EOSDIS) DAAC responsible for data and related information pertaining to the physical processes and conditions of the global oceans, including measurements of ocean winds, temperature, topography, salinity, circulation and currents, and sea ice.

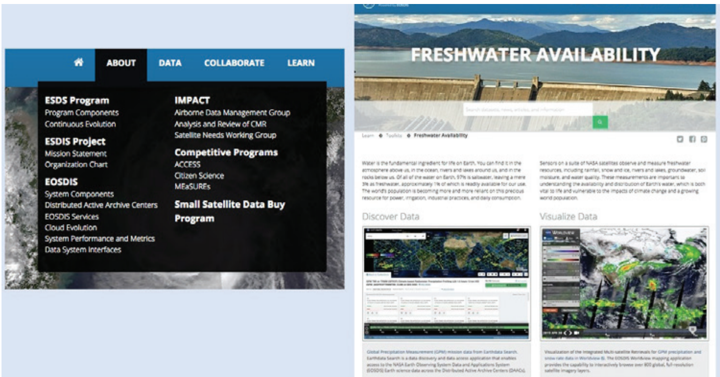
GRACE-FO datasets are described and discoverable via the PO.DAAC dataset information pages. The dataset information pages also provide access to the technical documentation, the GRACE-FO Level-1 User Handbook, and guidance on how to cite the data. ■

Improved Earthdata Navigation

A new top-level navigation for the Earthdata website and new data pages make it easier to find the information you need.

We are excited to announce the launch of a reorganized top-level navigation for the Earthdata website. These improvements highlight the breadth of resources Earthdata offers and logically regroup some menu items.

Information about NASA's Earth Science Data Systems (ESDS) Program, the Earth Science Data and Information System (ESDIS) Project, and the Earth Observing System Data and Information System (EOSDIS) is still available through the About section. This section also includes information about our newest programs and our competitive programs.



Along with navigation enhancements (left image), new theme-based data discovery pages and Pathfinder pages make it easier to discover and use EOSDIS data (right image). NASA EOSDIS image.

Information about data, tools, and services can be found in the Data section. For our newer visitors, we have created pages to help find, use, and visualize data. The new Learn section is where you will find webinars, tutorials, and Data User Profiles along with new Data Pathfinders, toolkits, and article pages to help you browse information by topic.

Finally, a new Collaborate section provides information about our standards and requirements, partnerships, and open data, services, and software.

We encourage you to explore all the new features and navigation in the updated Earthdata website. ■

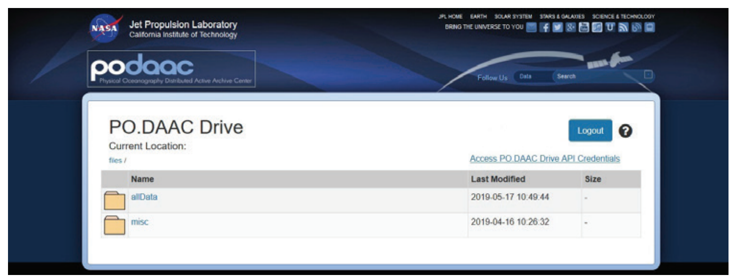
Changes to Data Download at PO.DAAC

The FTP protocol for data and information access at NASA's PO.DAAC is retired and has been replaced with PO.DAAC Drive.

File Transfer Protocol (FTP) service is no longer available at NASA's Physical Oceanography Distributed Active Archive Center (PO.DAAC). FTP has been replaced with PO.DAAC Drive, a more secure system that offers file navigation and download through an interface served directly through your browser.

PO.DAAC Drive not only offers a familiar look and feel, but also allows users to access data via a command line so that interactions can be scripted easily. Prior to downloading data using PO.DAAC Drive, users need to create a NASA Earthdata Login Profile. Instructions for doing this are available at https://urs.earthdata.nasa.gov/users/new.

PO.DAAC Drive was developed in response to two policies by NASA's Earth Science Data and Information System (ESDIS) Project, which manages NASA's Earth observing data collection: A requirement for all DAACs to transition from distributing data products using anonymous FTP to the more secure HyperText Transfer Protocol (HTTP) and a second requirement for all DAAC



PO.DAAC Drive enables users to view PO.DAAC data as if they had the entire PO.DAAC archive mounted on their own machine. For help, click on the "?" icon next to the blue Logout box in the upper right corner. Image: PO.DAAC.

and ESDIS applications to use Earthdata Login where science data products are retrieved by either humans or machines. Each DAAC was given the freedom to engineer its own solution for transitioning from FTP to HTTP data downloads and integrating Earthdata Login; the PO.DAAC solution is PO.DAAC Drive.

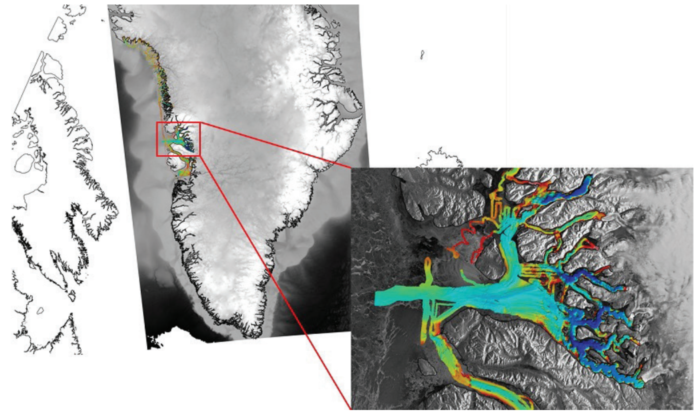
The PO.DAAC team will be happy to assist users with any technical issues or concerns to ensure that this transition is as smooth as possible. For more information, please check the following resources:

NASA Earthdata Webinar: "Goodbye FTP, New Ways to Access NASA's Physical Oceanography Data at PO.DAAC": https://youtu.be/kd8yjl6YiH8

PO.DAAC Drive Forum: https://podaac.jpl.nasa.gov/drive_forum ■

New Datasets at PO.DAAC for Investigating Global Sea Level Change

Data from the Oceans Melting Greenland (OMG) mission provide a revolutionary look at ocean/ice interactions and estimates of global sea level rise.



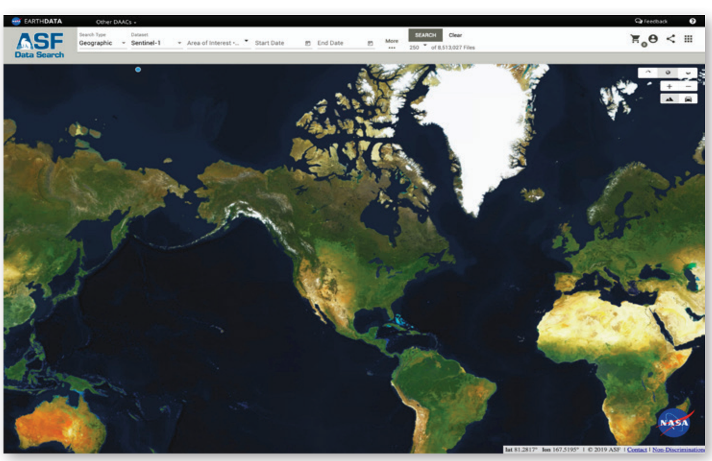
OMG image acquired Summer 2015. Colors in the inset image show ocean bathymetry, or depth, with green and blue indicating deeper water and yellow and red indicating shallower water. Image: OMG mission.

NASA's Physical Oceanography Distributed Active Archive Center (PO.DAAC) is pleased to announce the public release of the Oceans Melting Greenland (OMG) Singlebeam Echo Sounding (OMG_L2_Bathy_SBES_Gridded; doi: 10.5067/OMGEV-SBES1) and Multibeam Echo Sounding (OMG_L2_Bathy_MBES_Gridded; doi: 10.5067/OMGEV-MBES1) Bathymetry datasets. The five-year OMG mission began in 2015 and is a NASA Earth Venture Suborbital mission designed to improve estimates of sea level rise by addressing the question: To what extent are oceans melting Greenland's ice from below?

This is critical information, since Greenland's melting ice affects the whole world. In fact, Greenland's ice sheet contains enough water to raise global sea levels by 7.4 meters (25 feet), according to the OMG mission website. Using airborne, *in situ*, and ship-based observations, OMG measures changing water temperatures on the continental shelf surrounding Greenland and how marine glaciers are reacting to the presence of warm, salty Atlantic Ocean water. The complicated geometry of the sea floor around Greenland steers currents on the continental shelf and often determines whether water from the Atlantic can reach into Greenland's long, narrow fjords and interact with coastal glaciers. Knowledge of these pathways is a vital component in understanding the interaction between the oceans and ice sheet, and OMG facilitates improved measurements of the shape and depth of the sea floor in key regions.

OMG datasets are discoverable through the PO.DAAC dataset information pages, which also provide access to technical documentation and information on data citation. For more information about the OMG mission, please see PO.DAAC's OMG mission webpage. ■

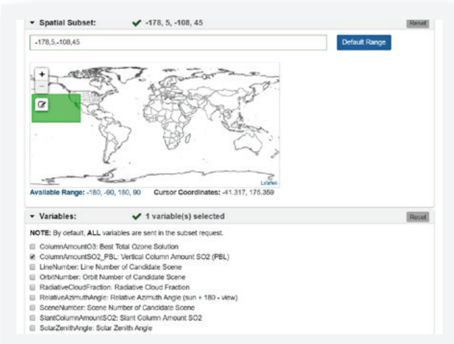
Improved SAR Data Discovery and Access at NASA's ASF DAAC



Finding synthetic aperture radar (SAR) data at NASA's Alaska Satellite Facility Distributed Active Archive Center (ASF DAAC) just got easier! The ASF DAAC's Vertex web-based data discovery and access tool has been redesigned from the ground up. Based on user input, key features of this redesign include faster search results, a cleaner search interface, and a new streamlined flow requiring fewer clicks for results. Enhanced search features such as WKT, shapefiles, enhanced map interactivity, and predictive search result counts add to the improved functionality.

Explore the new Vertex interface:
https://search.asf.alaska.edu ■

DATA Recipes



Using the NASA GES DISC Level 3/4 Regridder and Subsetter (L34S) for OMI Products

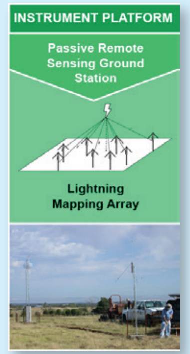
The NASA Goddard Earth Sciences Data and Information Services Center (GES DISC) has updated the Level 3/4 Regridder & Subsetter (L34RS) to include support for Ozone Measuring Instrument (OMI) Level 3 products. Currently, eight (OMI) products are supported by L34RS. OMI products are available daily from October 1, 2014 to the present at either 0.25° x 0.25° (products OMAEROe, OMDOAO3e, OMNO2d, OMSO2e, and OMTO3e) or 1° x 1° (products OMAERUVd, OMTO3d, and OMUVBd) spatial resolution.

View recipe: https://go.nasa.gov/30ojpi4

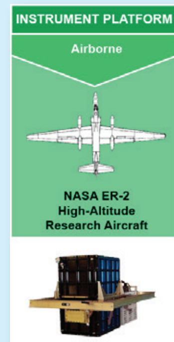
Discover other GES DISC data recipes or tutorials:
https://disc.gsfc.nasa.gov/information/howto

Featured Micro Articles

What is a micro article? Micro articles are concise, focused selections of information that allow users to quickly assess topics and locate the most useful or relevant associated data, information, and tools.



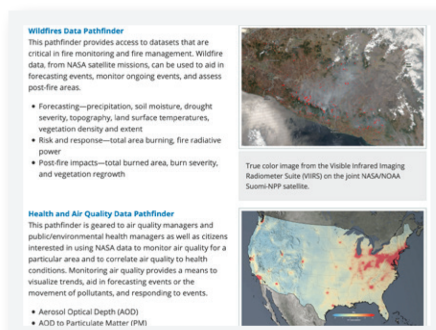
Lightning Mapping Array (LMA) Instrument micro article: **https://go.nasa.gov/2Z850Kd**



Cloud Physics LIDAR (CPL) Instrument micro article: **https://go.nasa.gov/2KXqMGM**

DATA PATHFINDERS

New to using NASA Earth science data?


Wildfires Data Pathfinder

This pathfinder provides access to datasets that are critical in fire monitoring and fire management. Wildfire data, from NASA satellite missions, can be used to aid in forecasting events, monitor ongoing events, and assess post-fire areas.

- Forecasting—precipitation, soil moisture, drought severity, topography, land surface temperatures, vegetation density and extent
- Risk and response—total area burning, fire radiative power
- Post-fire impacts—total burned area, burn severity, and vegetation regrowth

True color image from the Visible Infrared Imaging Radiometer Suite (VIIRS) on the joint NASA/NOAA Suomi-NPP satellite.

Health and Air Quality Data Pathfinder

This pathfinder is geared to air quality managers and public/environmental health managers as well as citizens interested in using NASA data to monitor air quality for a particular area and to correlate air quality to health conditions. Monitoring air quality provides a means to visualize trends, aid in forecasting events or the movement of pollutants, and responding to events.

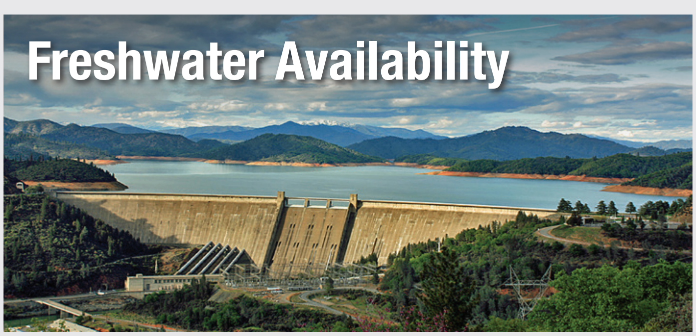
- Aerosol Optical Depth (AOD)
- AOD to Particulate Matter (PM)

Pathfinders are designed to help guide you through the process of selecting data products and to show you how to use the data.

https://earthdata.nasa.gov/learn/pathfinders

EARTHDATA TOOLKIT

Data Toolkits are designed as entry points to access NASA Earth science data resources organized by topic. They contain links to datasets, tutorials and how-tos, feature articles and Data User Profiles, as well as other useful information.



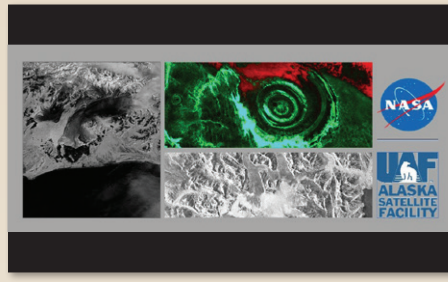
https://earthdata.nasa.gov/learn/toolkits/freshwater-availability

https://earthdata.nasa.gov/learn/toolkits/wildfires

5/8/19

Using the ISS Lightning Imaging Sensor and Release of the GOES-R Post Launch Test Observations

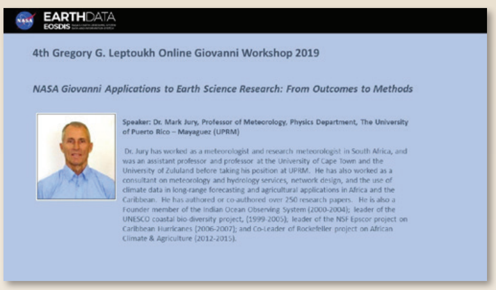
https://youtu.be/VkmkdLSPwJw



5/29/19

Easy Sentinel-1 Radiometric Terrain Corrected (RTC) Products with ASF's Beta Toolbox

https://youtu.be/aZ4xLBrxUow



6/26/19

Workshop: Examples of NASA Giovanni Applications to Earth Science Research, from Outcomes to Methods

https://youtu.be/ecvGy-9B4RU

7/10/19

Workshop: Using Giovanni for Applied Remote Sensing Training

https://youtu.be/ajVeCs_Wn-c

7/17/19

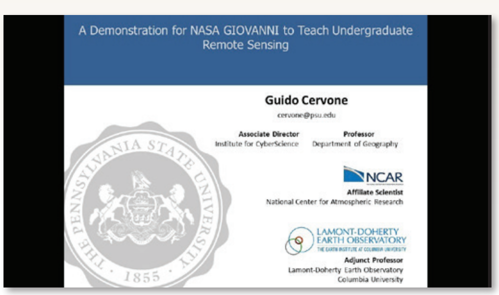
Workshop: NASA Giovanni in 2019, and the New Images Selected to the Giovanni Hall of Fame

https://youtu.be/I38MmLXG6fM

7/23/19

Explore, Access, and Customize ICESat-2 data at the NASA NSIDC DAAC

https://youtu.be/6KZOPqyp-bY

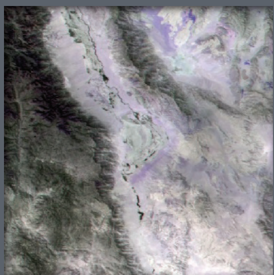


7/24/19

Workshop: Using Giovanni and R to Analyze Data in an Undergraduate Remote Sensing Class

https://youtu.be/VIRccDdmGA8

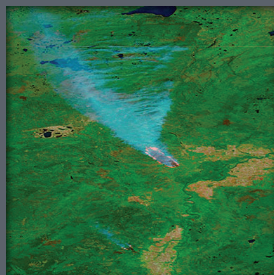
Latest NASA Earthdata Images



Sensing Plant Stress from Space

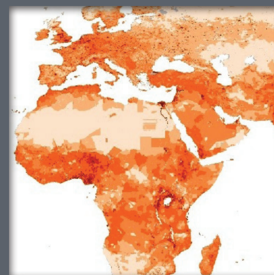
https://earthdata.nasa.gov/mastheads

(Published 5/6/19)



Wildfires in Alberta, Canada

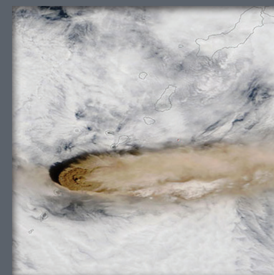
https://earthdata.nasa.gov/wildfires-in-alberta-canada



Projecting Future Population Patterns

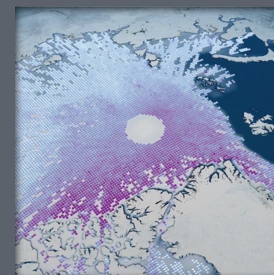
https://earthdata.nasa.gov/mastheads

(Published 5/13/19)



Eruption of Raikoke Volcano, Kuril Islands, Russia

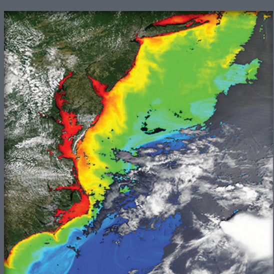
https://earthdata.nasa.gov/learn/articles/eruption-of-raikoke-volcano-kuril-islands-russia



Sensing Sea Ice from Space

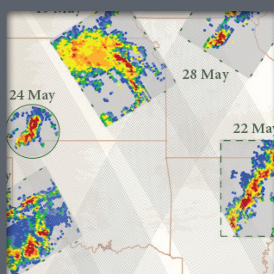
https://earthdata.nasa.gov/mastheads

(Published 6/10/19)



Chlorophyll *a* Along the Mid-Atlantic Coast, USA

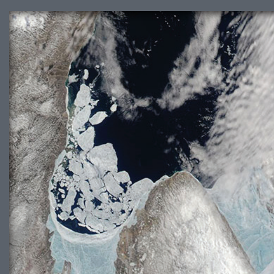
https://earthdata.nasa.gov/learn/articles/chlorophyll-a-along-the-mid-atlantic-coast-usa



Sensing Strong Storms from Space

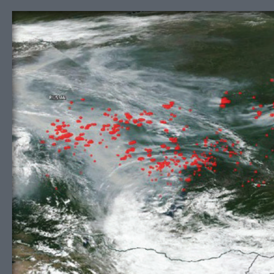
https://earthdata.nasa.gov/mastheads

(Published 6/17/19)



Ice Breakup in the Amundsen Gulf, Canada

https://earthdata.nasa.gov/ice-breakup-in-the-amundsen-gulf-canada



Sensing Fires in Russia

https://earthdata.nasa.gov/mastheads

(Published 7/29/19)

Deep Cyclone in the Bay of Biscay

https://earthdata.nasa.gov/learn/articles/deep-cyclone-in-the-bay-of-biscay

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