

NASA EARTH SCIENCE DATA SYSTEMS PROGRAM HIGHLIGHTS



EARTHDATA
EOSDIS NASA'S EARTH OBSERVING SYSTEM
DATA AND INFORMATION SYSTEM

National Aeronautics and
Space Administration



www.nasa.gov

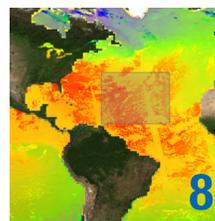
Overview

In 2018, NASA's Earth Science Data Systems (ESDS) Program continued to evolve its capabilities through improving communications with users, adopting new technologies, and supporting vibrant competitive research elements. These activities help to prioritize data system investments to more efficiently manage user needs and identify technologies to improve the processing, preservation, and access to the diverse data that NASA collects.

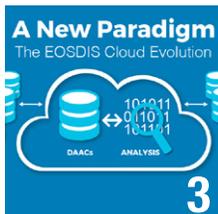
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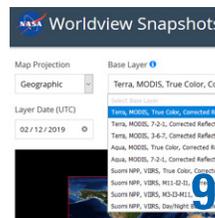
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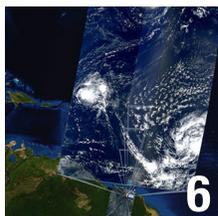
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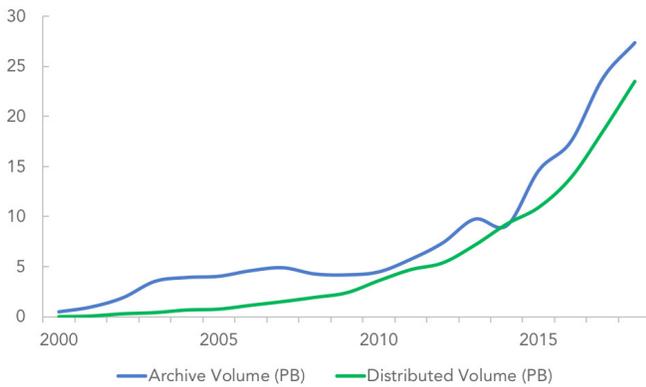
Engaging a Worldwide Community



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Earth Observing System Data and Information System (EOSDIS)

The more than 27.5 petabytes (PB) of data in NASA's Earth Observing System Data and Information System (EOSDIS) collection represent some of the most complex and diverse Earth science datasets on the planet. Data are acquired from satellites, aircraft, field measurements, and numerous other activities undertaken by NASA's Earth Science Division. During Fiscal Year (FY) 2018, NASA's Earth Science Data and Information System (ESDIS) Project continued to provide outstanding management and support for these data, distributing more than 1.61 billion data products to more than 4.4 million users globally.



In 2018, the ESDIS Project met a major milestone by completing the addition of the nearly 20-year back catalog of Moderate Resolution Imaging Spectroradiometer (MODIS) data imagery to the Global Imagery Browse Services (GIBS). These data imagery, from the MODIS instruments onboard NASA's Terra and Aqua satellites, represent the longest continuous daily global record of our planet and are now fully and openly available through the NASA Worldview data visualization application and through the GIBS APIs.

Looking forward, the ESDIS Project is preparing to collect, store, and distribute data from new and upcoming Earth science missions, such as the Ice, Cloud, and land Elevation Satellite-2 (ICESat-2), the Surface Water Ocean Topography (SWOT) mission, and the joint NASA/Indian Space Organization Synthetic Aperture Radar (NISAR) mission. The ESDIS Project is also supporting several new missions to the International Space Station (ISS), including the Total and Spectral



Tropical Cyclone Chapala in the Arabian Sea. Image captured by the MODIS instrument on board the Terra satellite on 31 October 2015.

solar Irradiance Sensor-1 (TSIS-1), the Ecosystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS), the Global Ecosystem Dynamics Investigation (GEDI), and the Orbiting Climate Observatory-3 (OCO-3).

To proactively prepare for processing and disseminating the extremely high data volume of upcoming missions like SWOT and NISAR, the ESDIS Project is continuing work on the Earthdata Cloud Project ("Cumulus"), which offers a cloud-native framework for data ingest, archive, distribution and management. Additionally, discipline-specific EOSDIS Distributed Active Archive Centers (DAACs) are developing and testing architecture and processing systems to prepare for hosting NASA Earth science data in the cloud. The Land Processes DAAC



The GEDI mission to the International Space Station.

Facility DAAC is working on the Getting Ready for NISAR (GRFN) project in preparation for the tremendous amount of data expected from the upcoming mission.

demonstrated processing for Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) instrument data and MODIS ingest/archive and the Alaska Satellite

Learn more about EOSDIS at earthdata.nasa.gov/about-eosdis

Investing in the Cloud

Building Partnerships with IMPACT



The [Interagency Implementation and Advanced Concepts Team](#) (IMPACT) was established at NASA's Marshall

Space Flight Center (MSFC) in 2018 through a charter signed by ESDS Program Executive Kevin Murphy and MSFC's Dr. Rahul Ramachandran. In response to a 2017 Satellite Needs Working Group recommendation, IMPACT was created to build partnerships with other Federal agencies, the applications community, decision makers, NGOs, and other organizations. The goal of these partnerships is to demonstrate the potential of cloud computing, especially bringing algorithms to the data to enable processing and analytics at scale and to explore approaches to artificial intelligence and machine learning techniques that improve existing data discovery and access, and address use challenges. IMPACT leverages NASA's existing data infrastructure, tools, and services in order to encourage broader use of NASA Earth observing data by a global user community, and enables technology and innovation in order to lower the barriers to using these data.

NASA hosted the "Enabling Analytics in the Cloud for Earth Science Data" workshop on February 21-23, 2018 in Annapolis, Maryland. The purpose of the workshop was to discuss the state of the art and the accompanying challenges of performing analytics on NASA's Earth observation data in the cloud. Presentations covered machine learning, analytics algorithms and tools, analytics systems and architecture, and data systems architecture. IMPACT lead Dr. Ramachandran gave the keynote talk "Making an IMPACT" at SatSummit 2018 which introduced NASA's IMPACT Program to key stakeholders in the global development community.

[Learn more about IMPACT at earthdata.nasa.gov/impact](https://earthdata.nasa.gov/impact)

Prototype portal and new toolsets

IMPACT machine learning experts developed the Deep Learning-based Hurricane Intensity Estimator portal (<http://hurricane.dsig.net/>), a prototype to objectively and accurately estimate hurricane wind speeds in real time and display the estimates in a situational awareness portal. The portal heavily utilizes Amazon Web Services (AWS) and the NASA-developed Cumulus infrastructure to automate the estimation workflow whenever a probability of tropical storm is detected. The system was highlighted by Amazon in their AWS Government, Education & Nonprofits blog (<https://aws.amazon.com/blogs/publicsector/estimating-hurricane-wind-speeds-with-machine-learning/>).

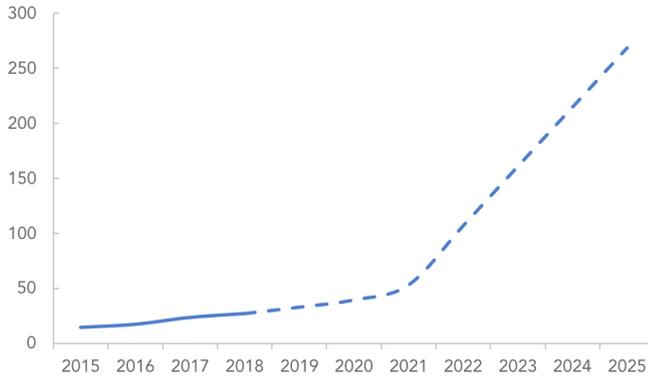
The Analysis and Review of CMR (ARC) team's metadata review tool was developed and is used by the ARC team to review EOSDIS collection- and granule-level metadata in the Common Metadata Repository (CMR) for correctness, completeness, and consistency in order to improve data discovery and accessibility. See earthdata.nasa.gov/arc for more information about ARC.

Earthdata Cloud Evolution

Over the past 24 years, EOSDIS has continuously evolved to take advantage of improved technology to meet the increasing demands of data providers and users.

By 2022, the ingest rate of data into the EOSDIS archive is projected to grow from the current 3.9 petabytes (PB) per year to as much as 47.7 PB per year. As this ingest rate increases, the total volume of data stored in the EOSDIS archive is also expected to grow to more than 37 PB by 2020; by 2025, the volume of data in the EOSDIS archive is projected to be more than 250 PB. In response to this rapid projected growth, EOSDIS completed an evaluation of the relative cost, technical performance, and security implications of utilizing the Amazon Web Services (AWS) commercial cloud environment for ingest, archive, management, and distribution of data. Based on the findings of that evaluation, the program has implemented "Cumulus," an open source, cloud-based framework.

Investing in the Cloud (CONTINUED)



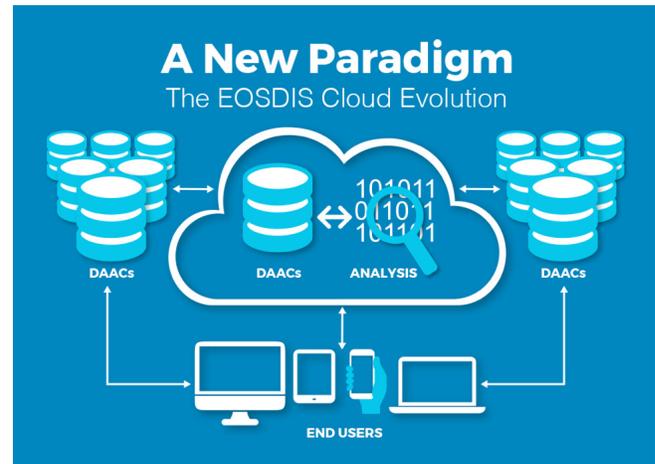
Projected growth in the volume of data in the EOSDIS archive in petabytes (PB).

The Cumulus platform is designed to support EOSDIS mission needs, including the upcoming Surface Water and Ocean Topography (SWOT) and NASA-Indian Space Research Organization (ISRO) Synthetic Aperture Radar (NISAR) missions.

It has been deployed for testing with the SWOT Science Data System and DAAC at JPL, and is integrated with the NASA Compliant General Application Platform (NGAP). NGAP provides underlying capabilities for all applications in order to meet NASA cloud security

requirements, and its initial Authorization to Operate was received in July 2018.

EOSDIS will support critical ground system tests for SWOT in late FY 2019 using the cloud-based capabilities of Cumulus.



Learn more about Cumulus at earthdata.nasa.gov/eosdis-cumulus-project

Earth Observations from Private Sector Small-Satellite Constellations

NASA is obtaining access to commercial satellite data to assess the utility of this information in achieving goals and objectives related to the NASA Earth Science Division's Research and Analysis (R&A) and Applied Sciences (AS) Programs and any associated decision-support applications. The overall objective of the pilot is to determine the viability of purchasing science data products that are directly related or lead to Essential Climate Variables (ECV) from American commercial market vendors. It is NASA's objective to determine if private sector Earth observation products derived from small-satellite constellations can provide a cost-effective means to augment and/or complement the suite of Earth observations acquired by NASA and other US government

agencies and those by International partners and agencies made available to NASA and its stakeholders. During this pilot, NASA will focus on unique imagery that might augment NASA-accessible data. NASA will also procure associated metadata (documentation, access routines, and basic characterization information) to fully assess the data's value.

On September 28, 2018 NASA awarded three vendors for the Small Constellations Satellite Data Buy Pilot: Spire Global, Inc., Planet Labs, Inc., and DigitalGlobe, Inc. There is a robust plan in place to evaluate the utility of the data with results expected in early 2020.

New Missions

NASA's Earth Observing System Data and Information System (EOSDIS) partners with data creators and providers to archive and serve their data to a global community of millions of users. EOSDIS offers this service through discipline-specific and common tools, at no cost to the data provider, with the added benefit of protecting data from disaster and technology obsolescence.

In 2018, EOSDIS updated all of the relevant processes, policies, standards, and documents that proposing data producers must complete as part of the data submission process. There are separate workflows depending upon the source of the data—orbital missions, airborne platforms, competed awards, ad hoc requests—and all of the workflows have been documented in order to make it easier for data providers to understand the process and requirements.

In 2019, new data proposers will begin using this revised collection of policies and standards to formulate their proposals and, after awards are announced, assist in the development of their documentation and data submissions. Later in the year, these processes will be augmented and clarified by the addition of new templates and procedures for creating Algorithm Theoretical Basis Documents (ATBDs).

Find policies and standards at earthdata.nasa.gov/adding-data

Support for Orbital and Airborne Missions

Two new innovative instruments aboard the International Space Station (ISS) are bringing a wealth of vital Earth observing data to the EOSDIS collection.

The ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS; ecostress.jpl.nasa.gov/), installed in July 2018, globally monitors and measures evaporation and plant transpiration, collectively known as evapotranspiration. The Global Ecosystem Dynamics Investigation (GEDI; gedi.umd.edu/), installed in December 2018, uses a light detection and ranging (lidar) laser system to create 3D images of forest and canopy structure. Finally, the Orbiting Carbon Observatory-3 (OCO-3; ocov3.jpl.nasa.gov), scheduled

for launch in April 2019, instrument will continue the global data record of atmospheric carbon dioxide (CO₂) measurements and provide a better understanding of the regional sources and sinks of CO₂.



Credit: NASA

The ECOSTRESS radiometer on International Space Station (ISS).

Work will continue in 2019 with several other flight projects, instrument teams, and science teams to prepare for upcoming missions such as Geostationary Carbon Observatory (GeoCarb), Polar Radiant Energy in the Far-InfraRed Experiment (PREFIRE), and Earth Surface Mineral Dust Source Investigation (EMIT).

The Airborne Data Management Group (ADMG, part of the IMPACT program) ensures that airborne scientific data gathered on flight missions are discoverable and usable to the airborne and other scientific communities. ADMG aims to improve communication between DAACs, airborne data producers, mission managers, and data users by serving as the point of contact and source of knowledge for all airborne data information within NASA.

ADMG began support of the Earth System Science Pathfinder (ESSP) program office's Earth Venture Suborbital-3 (EVS-3) mission (essp.nasa.gov/projects/) in 2018. In 2019, ADMG will be supporting the EVS-3 program projects by providing data managers with needed information and resources.

ADMG will also complete Phase 1 production of the Airborne Data Inventory, a campaign metadata database with a public user interface for exploring the various NASA airborne campaigns, whether historical or current.

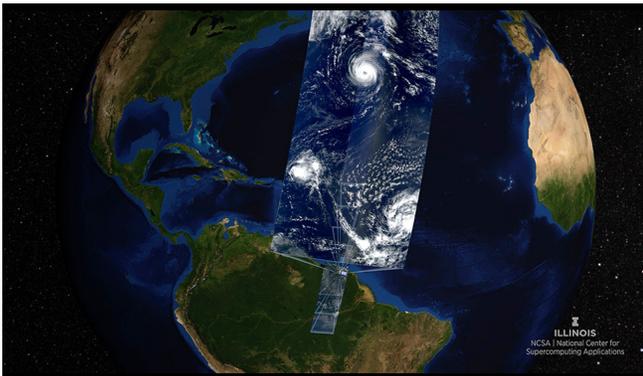
More about ADMG at earthdata.nasa.gov/admg

Competitive Programs

Advancing Collaborative Connections for Earth System Science (ACCESS)

NASA's ACCESS program develops and implements technologies to effectively manage, discover, and utilize NASA's archive of Earth observations for scientific research and applications.

The 10 projects competitively selected as part of ACCESS 2015 presented their work and submitted their final reports in August and September 2018. The goal of ACCESS 2015 was to improve data discovery, accessibility, and usability for users of NASA's Earth science data systems. In addition to the completed technologies, these projects resulted in more than 30 peer-reviewed publications, including papers in *Journal of Geophysical Research*, *Geophysical Research Letters*, *Remote Sensing*, *Geosciences*, and *Earth and Space Science*.



The Terra Data Fusion team (ACCESS 2015) developed the Climate Marble data visualization product, which will appear in the planetarium dome show "Birth of Planet Earth" and will be made available to the public in an interactive web interface in early 2019.

Five projects were selected for ACCESS 2017 awards and began work in September 2018. Project focus areas included machine learning, advanced search capabilities, and cloud-optimized preprocessing and data transmission.

Team members from "Community Tools for Analysis of NASA Earth Observation System Data in the Cloud" conducted a workshop at the 2018 AGU Fall Meeting demonstrating Pangeo, an open source community and software ecosystem for scalable geoscience based on Python. This project will include an advanced Python

API for data discovery and processing that will integrate with Pangeo to provide cutting edge scientific tools for pre-processing, regridding, machine learning, and visualization of data in the cloud.

Another project, "Systematic Data Transformation to Enable Web Coverage Services (WCS) and ArcGIS Image Services within ESDIS Cumulus Cloud," will focus on developing geospatial data transformation plugins that will transform data products as Web Coverage Services (WCS) and ESRI ArcGIS Image Services for use with popular commercial off-the-shelf and open source Geographic Information Systems (GIS) software.

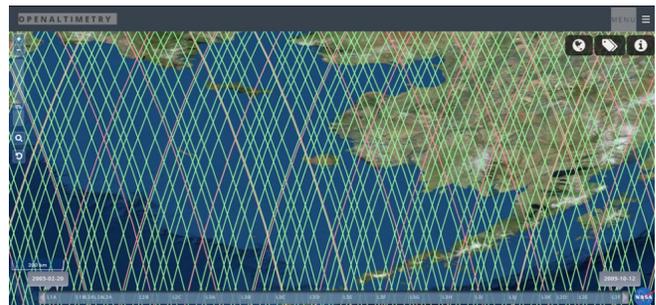
Upcoming in 2019, the OpenAltimetry project (ACCESS 2015) will be updated to include ICESat-2 data, the California Methane Data Portal (ACCESS 2015) will be made available to the public, and ACCESS 2017 projects will begin reviews with ESDIS to facilitate integration into NASA data systems.

The ACCESS 2019 call for proposals will be available in late 2019.

[Learn more about ACCESS at earthdata.nasa.gov/access](https://earthdata.nasa.gov/access)

Citizen Science for Earth Systems Program (CESP)

NASA's Citizen Science for Earth Systems Program (CESP) is focused on developing and implementing projects that harness contributions from members of the general public to advance the understanding of Earth as an integrated system. CESP awards are made in the



A web application for map-based discovery and visualization of ICESat and ICESat-2 data, OpenAltimetry provides on-demand access to underlying datasets. Photo courtesy of [OpenAltimetry](https://openaltimetry.org/).

Competitive Programs (CONTINUED)

form of cooperative agreements via two phases: Prototype Phase and Implementation Phase. Sixteen CSESP projects concluded the Prototype Phase in January 2018, with six of these projects selected to be part of the three-year Implementation Phase. These projects were chosen based on success (both scientific and citizen engagement) during the Prototype Phase, relevance to NASA's mission and objectives, and intrinsic scientific merit. Selected projects focus on air quality, snow observations, animal biodiversity, measuring aerosol optical depth, tracking water storage, and global kelp cover.



Citizen scientists, including backcountry professionals and recreationists, help gather snow observations. Image credit: Community Snow Observation

CSESP also sponsored a presentation, *Citizen Science: Engaging a Wider Community to Better Understand Our Planet* along with several poster sessions at the 2018 AGU Fall Meeting. In December 2019, CSESP will present a session at the 2019 AGU Fall Meeting.

A call for articles was issued in March 2019 for a special issue of *Earth Science Informatics*, guest-edited by ESDS program staff, that will be published March 2020. The issue focuses on the development and implementation of new technologies and modern techniques to address the challenges of managing, discovering and using Earth observations data for Earth science research and

applications. This topic will also be the focus of a session at the Pecora 21 conference in October 2019.

Learn more about CSESP at earthdata.nasa.gov/csesp

Making Earth System Data Records for Use in Research Environments (MEaSURES)

Through the MEaSURES Program, NASA is continuing its commitment to expand understanding the Earth system using consistent records. The MEaSURES projects are focused on data product generation, availability, and utility.

Highlights from 2018 include a project that produced Earth System Data Records (ESDRs) for the longest length possible (for most cases about 20 years, the length of the altimetry record) of key measures of surface water storages and fluxes. Another project, led by NASA scientists, provided precipitation products to enhance the Global Precipitation Climatology Project (GPCP) dataset, which blends outdoor rain gauges and rainfall estimates culled from satellite algorithms. The Ice Velocity Mapping of the Antarctic Ice Sheet project continued the production and distribution of ESDRs of ice velocity in Antarctica. Finally, the successful development and routine production of the ESDR of Earth's surface mass variations from GRACE and geodetic satellites became part of the standard GRACE-FO mission product suite.

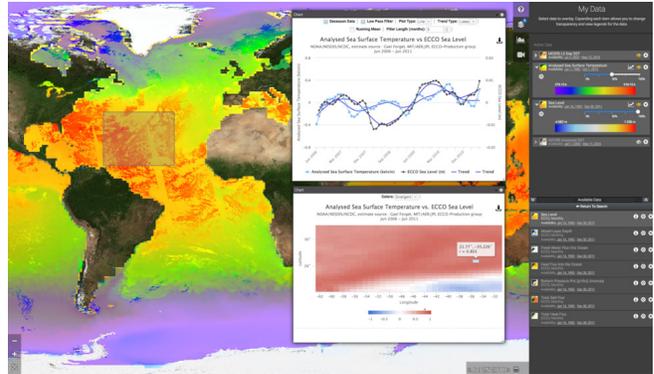
NASA selected new MEaSURES projects after the ROSES 2017 solicitation and they have entered their first year of work. A number of milestones will be reached throughout FY 2019, including establishment of the DAAC, data system user group involvement, and other project-specific tasks.

Learn more about MEaSURES at earthdata.nasa.gov/measures

Science Tools and Portals

The Sea Level Change Portal (SLCP; sealevel.nasa.gov) is NASA's primary website for sea level news and data. The portal provides a one-stop source for datasets relevant to sea level rise, and includes access to data, analysis tools, and simulations of glaciers, ice sheets, sea level, and the solid Earth.

Several new datasets were added to this portal in 2018, including support for gridded *in situ* data from the global Argo Program, which is a global array of 3,800 free-drifting profiling floats that measures the temperature and salinity of the upper 2,000 meters (about 6,562 feet) of the ocean. In addition, new features were added to the Data Analysis Tool (DAT) application, including Argo *in situ* visualization and analysis and Ice Shelf Visualization and Analysis. Finally, the SLCP engineering team constructed an animation of Vertical Ice Thickness in Postglacial Rebound Model data showing a time-series of vertical ice thickness from 122,000 years before present to the present.



The Data Analysis Tool enables regional statistical analysis, time series analysis, and comparison.

In 2019, new tools will be added to the portal, including a projection tool and coastal sea level budget tool, the Data Analysis Tool will be updated, new datasets will be integrated, and an “Annual Report” feature added.

Strategic Partnerships

Multi-Mission Algorithm and Analysis Platform (MAAP)

The joint NASA/European Space Agency (ESA) Multi-Mission Algorithm and Analysis Platform (MAAP; <https://maap.xyz/>) is a collaborative project focused on improving the understanding of global aboveground terrestrial carbon dynamics. NASA and ESA are collaborating to address issues related to increased data rates and to reinforce open data policies by jointly developing MAAP to maximize the exploitation of Earth observation (EO) data from the BIOMASS, GEDI, and NISAR missions.

The MAAP platform enables scientists to access essential NASA and ESA data and provides the tools and computing power necessary to analyze these data. The NASA/ESA team reached the first set of milestones for the development of the Pilot Phase MAAP platform

and successfully demonstrated initial interoperability touchpoints in December 2018. The team is currently working towards the second delivery in April 2019.

Google Earth Engine

NASA and the Google Earth Engine (GEE) teams are collaborating as part of the NASA Earth Science Public Private Partnerships program. The teams will help support NASA in its efforts to maintain and improve data availability and accessibility to all users in compliance with the NASA open data policy and Google's efforts to advance the utility of the Google Earth Engine platform to the scientific community.

NASA representatives and Google Earth Engine leadership met during the 2018 AGU Fall Meeting to discuss and review the scope for this activity. That plan was approved, and the two teams have continued to refine next steps, identify individuals responsible for specific

Strategic Partnerships (CONTINUED)

tasks, and have begun selecting sample NASA datasets to test the new processes.

Compiling an Essential Climate Variable (ECV) Inventory

NASA is an active participant and global leader in developing data products for long-term monitoring of the earth. NASA participates in the Joint Committee on Earth Observation Satellites/Coordination Group for Meteorological Satellite (CEOS/CGMS) Working Group on Climate (WGClimate) produce a bi-annual inventory of Essential Climate Variables. The current bi-annual ECV inventory request began in 2018.

An Essential Climate Variable (ECV) is a physical, chemical, or biological variable or a group of linked variables that critically contributes to the characterization of Earth's climate. NASA's ESDIS Project has assisted in coordinating the population of the ECV inventory with appropriate datasets produced by NASA to ensure the best data are available for researchers and operational weather forecasters.

The ECV inventory will provide the basis for a gap analysis and subsequent generation of a coordinated action plan to address any detected gaps and/or opportunities for the delivery of additional and improved Climate Data Records (CDRs). Results from this activity will be used as

the basis for a consolidated NASA response to the Global Climate Observing System (GCOS) Implementation Plan, as well as for status reporting to the United Nations Framework Convention on Climate Change Subsidiary Body for Scientific and Technological Advice (UNFCCC/SBST).



Climate Data Initiative and GeoPlatform

In 2018, a formal collaboration was established between the ESDS IMPACT team and the

Federal Geographic Data Committee (FGDC) Geospatial Platform to extend the geospatial portion of the Climate Data Initiative (CDI) collection to [GeoPlatform.gov](https://www.geoplatform.gov).

GeoPlatform offers new tools to promote the discovery and use of federal agency geospatial web services and integrates the curated collections into a new cross-domain federated catalog. Also in development is the GeoPlatform Resilience community, an interactive, topically-focused web portal to share web content, datasets, services, maps, applications, and tools relevant to environmental change and climate resilience. The GeoPlatform Resilience community will be available to the public later in 2019.

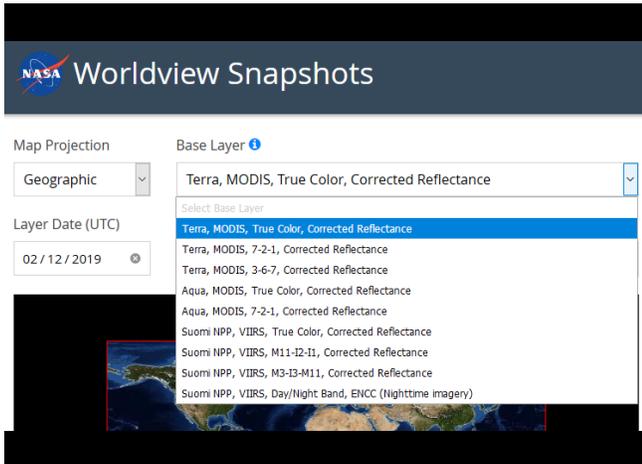
Advances in Data Visualization

The Global Image Browse Service (GIBS; earthdata.nasa.gov/gibs) and Worldview (worldview.earthdata.nasa.gov) continued to gain popularity, with over 15,000 daily users. Imagery from the Worldview platform was used in hundreds of news articles, blog posts, research articles, and other media. The Worldview application was selected as Goddard Space Flight Center's FY 2018 Software of the Year Award winner, and was featured prominently at NASA's Earth Day 2018 events. In FY 2018, the capability to directly compare imagery from different dates or across different instruments was released to the public. There are currently over 800 data imagery products available, many of which are updated daily.

In early 2019, Worldview released two new features: Snapshots and Stories. Snapshots, which replaces the Rapid Response Subsets service, is a lightweight application for quickly making satellite images from daily global MODIS and VIIRS data for any location on Earth (including the poles).

Worldview Stories offers a guided step-by-step tour through a narrative using Worldview's spatial, temporal, and data layer capabilities to explore stories such as "Earth at Night," Hurricane Maria, and the 2018 Camp Fire in California.

Advances in Data Visualization (CONTINUED)

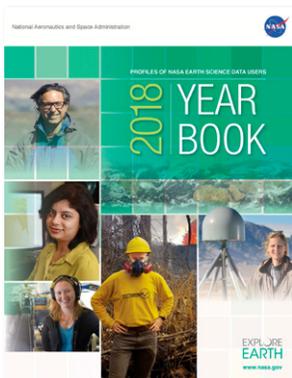


Worldview Snapshots is a lightweight tool for creating image snapshots from a selection of popular NASA satellite imagery layers.

Also coming in 2019 to Worldview is support for imagery products which have frequent temporal updates, such as the Lightning Imaging Sensor (LIS) on the International Space Station (ISS) and geostationary platforms. Worldview will also be gaining enhanced capabilities for viewing vector data sources and investigating their properties.

Engaging a Worldwide User Community

The EOSDIS Communications team collaborated across the program to generate 13 Earth science data discovery and data access webinars. Roughly 1,200 participants from over 200 countries actively participated in the live presentations and several thousand views of the recorded content were viewed on the NASA Earthdata YouTube channel (www.youtube.com/c/NASAEarthdata).



Complementing the webinars, 36 articles were published on the Earthdata website (earthdata.nasa.gov). These articles covered a wide range of topics—from short announcements about new EOSDIS and DAAC products and services to feature articles focusing on cloud computing and mission milestones, such as the

100,000th orbit of NASA's Terra satellite. The Earthdata Data User Profile series, (earthdata.nasa.gov/data-profiles)

now in its fifth year, showcases the breadth of work NASA Earth observing data enables.

NASA's Earth Science Division collaborated with the Google Earth team to produce four stories in 2018 for the Google Earth Voyager platform (earth.google.com). Three of the stories were based on imagery from the new NASA book, "Earth"—"Waterways from Space," "Ice & Snow from Space," and "Landforms." "Earth at Night," featuring NASA's "Black Marble" data and imagery, was also published in 2018 and received 1.2 million views, making it one of the top five most-viewed stories on the Voyager platform.

