National Aeronautics
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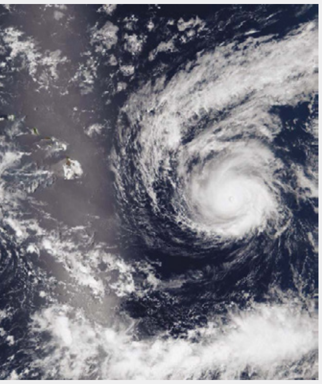


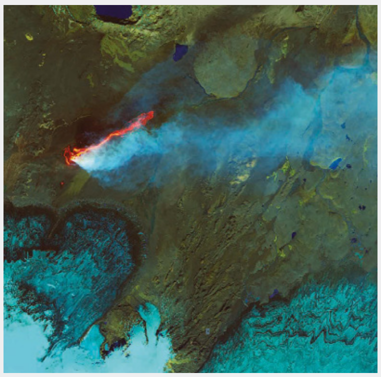


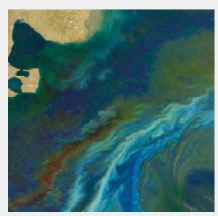


2018
Annual Summary

NASA Earth Science
Applied Sciences Program

Disasters

NASA Disasters Program 2018 Annual Summary

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Disasters Program Websites:
http://appliedsciences.nasa.gov/programs/disasters-program
https://disasters.nasa.gov/
https://maps.disasters.nasa.gov

I. Overview

a. Introduction

The NASA Disasters program promotes the use of Earth observations to improve the prediction of, preparation for, response to, and recovery from natural and technological disasters by addressing the research, response, and resiliency aspects of disasters. By sponsoring application science, the program advances the readiness of results to enable disaster management practices, advance damage reduction, and build resilience. We target a broad spectrum of natural and man-made disasters including, but not limited to floods, earthquakes, volcanoes, and landslides, as well as combined hazards and cascading impacts. When disasters occur, our researchers also become providers and distributors of images, data, and damage assessments. The Disasters Team and its network of partners and volunteers assist with hazard assessment, evaluation of severity, and identification of impacts near vulnerable infrastructure, crops, and lifelines, especially in remote areas where observations are sparse, to provide guidance for action.

b. Disaster Research for 2018

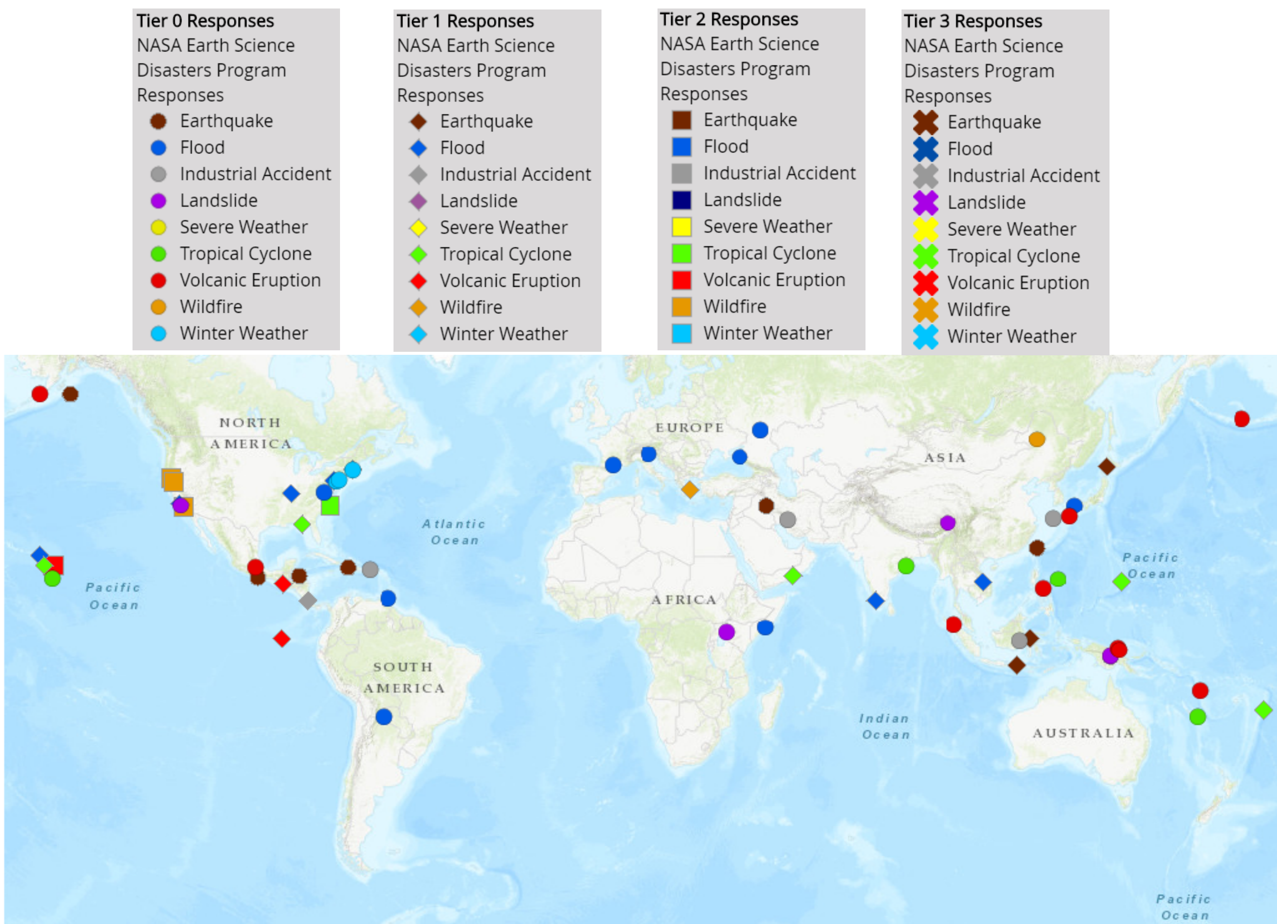
A portfolio of diverse disaster research projects are at the program's core. These projects stem from three primary vehicles, which include responses to NASA Research Opportunities in Space and Earth Science (ROSES) 2011 A.33 Disasters solicitations, ROSES 2017 A.50 Group on Earth Observation (GEO) Work Programme Projects, ROSES Rapid Response and Novel Research in Earth Science (RRNES) solicitations, Topical Workshops Symposia and Conference (TWSC) solicitations, and NASA Earth and Space Science Fellowship projects. The majority of NASA ROSES 2011 A.33 Projects were completed at the end of 2017; however, several were extended at no-cost in order to reach their goal Applications Readiness Level (ARL). A 2018 TWSC award supported an applications workshop for the Flood Risk Workshop in Boulder, Colo., during the first week of October.

In 2018, we released and collected proposals for the NASA ROSES Earth Science Applications: Disaster Risk Reduction and Response Solicitation NNH18ZDA001N-DISASTERS, which will support new disaster research. Details concerning the call for proposals may be found at:
https://nspires.nasaprs.com/external/solicitations/summary!init.do?solId={9CEF8BAC-CBF7-809C-51BD-8334579799C8}&path=open. A selection panel was convened in October and award notifications for 10 new research grants are scheduled to go out in early 2019.

c. Disaster Response for 2018

The response support area of the Disasters program functions in a unique way within the Applied Sciences Program, as well as the greater NASA community. The response team comprises a Headquarters-based team of program management and support, emergency managers, and GIS specialists, as well as disaster coordinators located at six NASA Centers across the United States. Each Center has one or more assigned coordinators who work across the agency as a single group during disaster-response situations. The role of each coordinator includes relevant engagement with any person or group at each Center who may be in a position to contribute relevant information or data in a disaster response situation. Fostering widespread relationships within individual NASA Centers and in relevant fields is critical. Bringing these relationships and bodies of knowledge together across Centers promotes and strengthens the program's effectiveness and reach. Such knowledge is critical to the program's success because coordinators must be aware of all available avenues of collecting data in a short timespan following any particular disaster situation on a global scale. The Disasters program responded to 76 events in CY2018. These are detailed in Section II.

NASA Applied Sciences Disasters Program Responses



Hazards that activated the Disasters program in 2018.

d. Disaster Risk Reduction and Resilience

In 2017, the NASA Disasters program began a new area of activities related to disaster risk reduction and resilience, which seeks to expand the application of Earth-observation systems to elements across the disaster cycle—including prevention and preparedness, and reconstruction and recovery. This focus has led to the ongoing development of partnerships and projects with organizations such as the Red Cross Red Crescent Climate Centre, the Global Facility for Disaster Reduction and Recovery of the World Bank, Mercy Corps, and a number of insurance and re-insurance companies including MiCRO, Willis Towers Watson, and SwissRe. Each of these partnerships reflects social, environmental, and economic elements necessary for understanding systemic risk and building resilient systems. Internally, this program area serves as a test bed for the possible integration of response efforts (e.g., response-related data products) into other elements of the disaster cycle. The Disaster Response Playbooks reflect this activity, which allows for the designing of research and application projects based on the identified needs of the users in the After Action Reports. The purpose of all risk reduction and resilience-focused activities is to co-develop products directly with the user/partner, and ensure transition of data knowledge for sustained application. The associated projects of this area are detailed in Section III.

e. Disaster Mission Applications

Until a new mission applications paradigm was promulgated, Applied Sciences Program area managers were assigned as Program Applications (PA) leads with applications development readiness responsibilities for upcoming NASA Earth Science satellite missions. Four NASA missions have been assigned to the Disasters program to date. These are listed below along with the Principle Investigator (PI) and the Deputy Program Applications (DPA) Lead, and detailed in Section VI.

- *Cyclone Global Navigation Satellite System* (*CYGNSS*) Mission Science Team formally ended its Mission Operations role on December 31, 2018.

- *NASA ISRO Synthetic Aperture Radar* (*NISAR*). The *NISAR* mission is scheduled for launch in 2021. PI Paul Rosen, JPL. DPA's Sue Owen and Natasha Stavros, JPL.

- *Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats* (*TROPICS*). The *TROPICS* mission, originally scheduled for launch in 2022, has been put on hold indefinitely; however, the Applications Team is still conducting quarterly telecons. PI Bill Blankenship, MIT Lincoln Laboratory. DPA Emily Berndt, NASA MSFC.

- *Lidar Surface Topography* (*LIST*). The *LIST* Tier 3 Decadal Survey mission remains in concept design phase. DPA David Harding, NASA GSFC.

II. 2018 Disaster Response

The Disasters program, within Applied Sciences, supports NASA Earth Science within the Science Mission Directorate (SMD). The program's focus is to apply the appropriate methods of scientific research to natural and/or human caused disasters in efficient and effective support of operational response agencies, as well as all other identified end user entities on a global scale. In this capacity, the Disasters program acts as a force multiplier, leveraging existing science missions and expertise to add value to disaster response end users.

The program's activation criteria ensure that response efforts have maximum impact, considering the number of disasters that occur consistently on a global level and the limitations of current Disasters staff. A four-tiered response framework has evolved as the program has consistently reviewed prior responses and derived lessons learned and best practices. This framework is used to identify whether NASA can or should respond to or support an event, as well as what level of support is warranted. For 2018, the same tier structure was used as in 2017 (described below). A re-evaluation of the tier structure began in 2018 and continues into 2019.

NASA Disasters Program Activation Tier Structure

Tier 0: Evaluation tier in which the Disasters program coordinates internally and/or conducts a rapid assessment to determine whether support is needed and can be provided. In some instances, an event will be evaluated but an activation will not transpire. This may happen if no end user for the products has been identified or if NASA support is not needed.

Tier 1: A Tier 1 activation occurs when there is an identified end user, and useful products are developed. This requires an event to be set up in the ESRI Portal. Support is provided to the disaster response and recovery by developing products that are ad-hoc, or specific to the event on an "as available" basis. This is in addition to data collection and distribution systems already in place.

Tier 2: Under this activation tier, NASA's potential contributions are considerable given the extent of the disaster, and are worth some impact to the ongoing activities of NASA's Centers and programs. Products developed will have a clear technical relevance for identified end users, meaning that the product will help answer a question or solve a problem for the end user that they were not able to address with other data sources.

Tier 3: A Tier 3 activation occurs when there is an event of such magnitude that it directly affects national safety, security, or interests. All relevant personnel would be expected to review their activities for possible support to the disaster and/or be on call to be tasked based on needs identified by clearly defined end users. Space and airborne assets from current, existing, and/or scientific campaigns will be redeployed to support the response as directed by the relevant NASA Associate Administrators.

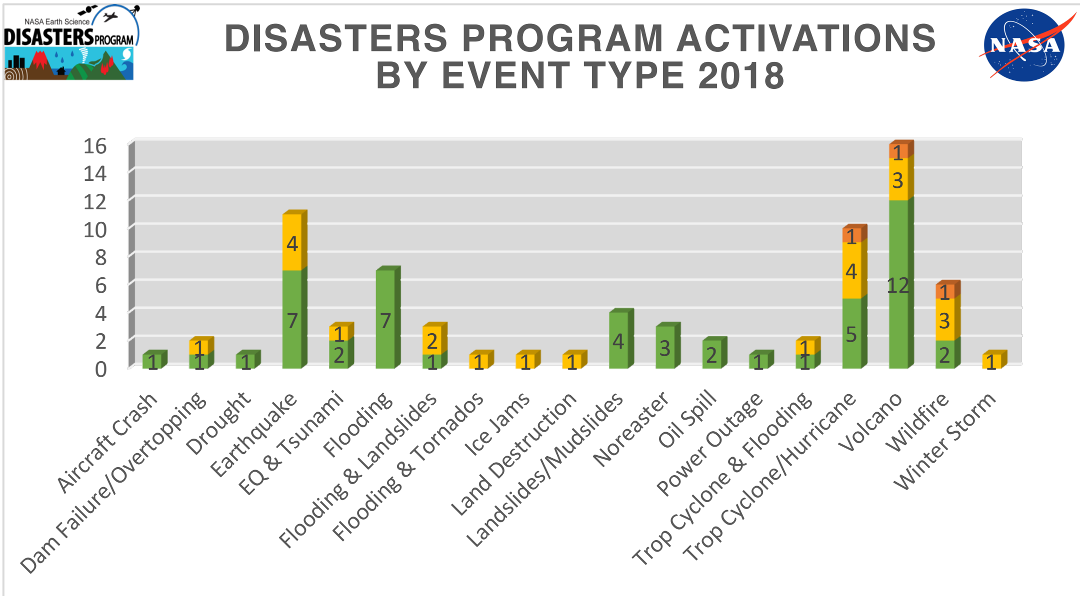


Figure 1: Flood, tropical cyclone, volcano, wildfire, and earthquake constitute the most frequent programhazard responses.

The Disasters program responded to 76 events in CY2018, as outlined in Figure 1 above. These responses included 19 unique hazard categories which developed into disasters based on their impacts to human life and infrastructure. Volcano events were the most common hazard, accounting for 16 of the 76 program responses. Earthquake-related responses occurred 14 times, while there were 12 tropical cyclone responses, 11 flooding-related responses, and six separate wildfire responses. Additional information regarding specific event responses conducted in CY18, including examples of data provided to end users, can be found on the Disasters program website.

Highlights of the 2018 responses are below:

a. California Wildfires

In 2018, the Disasters program activated to provide support for the Mendocino, Carr, Camp, Hill, and Woolsey fires. Satellite and airborne imagery, imagery-based products, and NASA decision-support products were provided in support of federal and state agencies responding to the fires. Agencies supported included the National Forest Service, FEMA, CAL FIRE, California Office of Emergency Services, California National Guard, and the California Environmental Protection Agency, among others. Products included damage assessment maps derived from synthetic aperture radar (SAR) imagery, false color RGB imagery of fire extent from the MASTER airborne instrument, high-resolution imagery from the International Space Station (ISS), and airborne SAR imagery of the affected areas.

In 2018, some of the wildfire project teams also assisted and supported in fire suppression and post-fire recovery activities on the California wildfires mentioned above. Keith Weber (Idaho State University—RECOVER project) and Mary Ellen Miller (Michigan Tech Research Institute—NASA Burned Area Emergency Response (BAER) project) supported the incident teams and BAER teams on wildfire events in California, including the Northern California Mendocino Complex (RECOVER use), the Carr Fire (working with the National Park Service on RECOVER products), and the Woolsey Fire (Southern California employing RECOVER). For the Woolsey Fire support, RECOVER effort produced a fire-affected vegetation layer. Their support helped to effect post-fire rehabilitation strategies on the fire, particularly during mop-up operations and in post-fire precipitation events, which caused severe mudslides in regions burned by the fire, affecting infrastructure and homes in their path.

Both teams' investigators supported other fires throughout the United States, and other investigators supported fire management activities with Earth-observing data and access, and provided expert knowledge on a number of additional events.

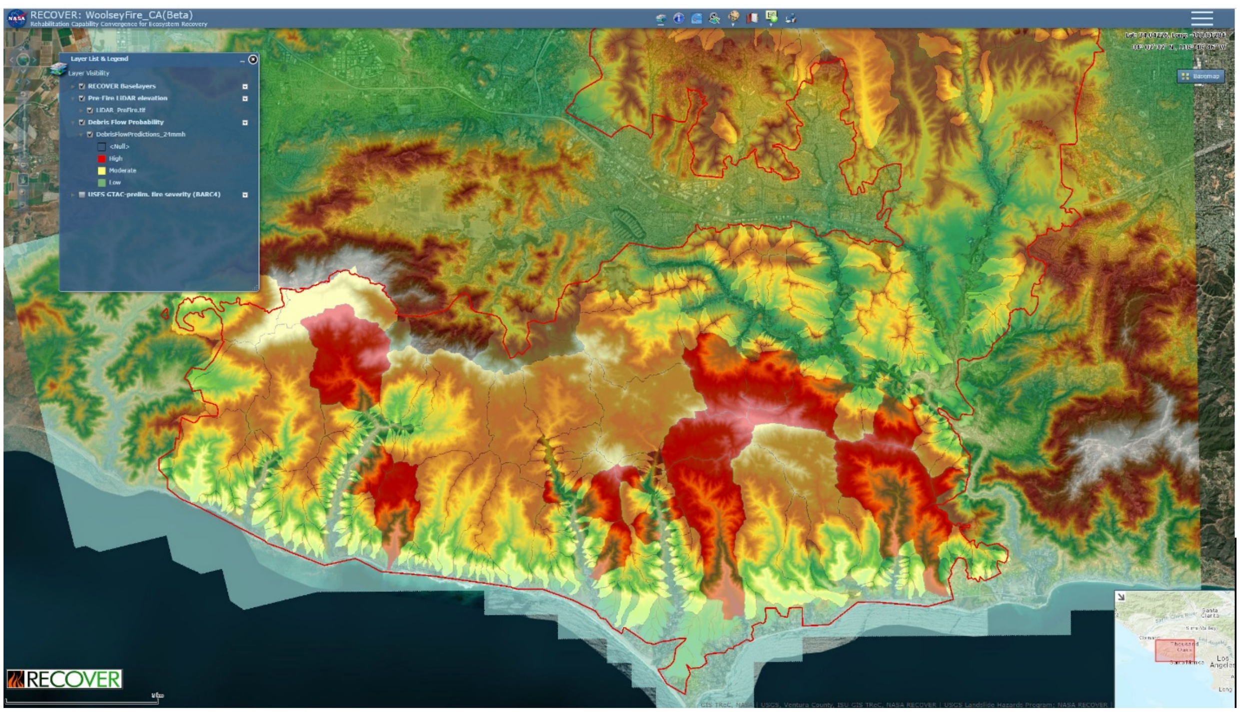


Figure 2: The Woolsey Fire was a destructive wildfire that burned in Los Angeles and Ventura counties, California, in November 2018. The fire consumed 96,949 acres of land, destroyed 1,643 structures, killed three people, and prompted the evacuation of more than 295,000 people. This graphic of the RECOVER DSS shows the pre-fire Lidar elevation database information, with the USFS Geospatial Technology Applications Center preliminary burn-severity index, derived from EO data (Landsat), and the Debris Flow Probability (High (R), Moderate (Y), Low (G)) based on the modeling of those combined data sets for the region within / surrounding the fire area. The RECOVER DSS results were generated for the incident team and post-fire BAER teams, with support from the RECOVER DSS-developing institute (Idaho State University GIS Lab; K. Weber).

b. Hurricane Florence

In September, the NASA Disasters program supported FEMA's response to Hurricane Florence, with Marshall Space Flight Center serving as the event lead. During the event, routine observations of Florence were made from the *GPM* satellite and broader constellation of microwave imagers to capture the internal structure of the storm and related precipitation accumulations. Florence imagery and products, complemented by dramatic astronaut photography acquired from the ISS, were provided routinely to the operational weather forecasting community. These images and other products were posted on the NASA Disasters Mapping Portal.

Routine conference calls within the Disasters program took place to facilitate the sharing of event information and status of products generated. Team members from multiple NASA Centers, including Headquarters, Marshall, Goddard, Langley, Ames, Johnson, and the Jet Propulsion Laboratory, coordinated on the call. As the predicted impacts of Florence began to take form and included record-setting rainfall and flooding throughout the Carolinas, NASA/JPL UAVSAR was mission assigned by FEMA coordinators and the research aircraft team deployed from Armstrong Flight Research Center. To support engagement between FEMA partners, UAVSAR, and other aspects of the Disasters program, Dr. Andrew Molthan of Marshall deployed to FEMA Headquarters to serve as the NASA liaison during FEMA's response, supporting the efforts through remote sensing guidance, advice to FEMA, and help to the UAVSAR team in coordinating collections throughout the week.

Daily coordination calls between the NASA Disasters team, UAVSAR team, and representatives from FEMA, NOAA National Water Center, U.S. Geological Survey, U.S. Army Corps of Engineers, and U.S. Forest Service were held. Disasters and UAVSAR teams made daily decisions about which rivers, flood basins, and populated areas to collect SAR data. Team members collaborated with FEMA to exploit the use of low-latency products from UAVSAR to facilitate the extraction of water/flood information and complement other satellite imagers that otherwise did not fully map water underneath dense vegetation canopies. High-resolution UAVSAR output products on flood extent were then used by FEMA to aid in their situational awareness and response.

Additionally, NASA optical and European Space Agency SAR satellite data were processed by JPL's Advanced Rapid Imaging and Analysis (ARIA) team to produce damage proxy and flood proxy maps. GSFC produced estimations of flood inundation, other SAR products, and Black Marble nighttime power outage images. MSFC produced Landsat and Sentinel-1 products in collaboration with the Alaska Satellite Facility and other NASA Disasters Team partners. Combined, these products were provided to FEMA, collaborative partners, and the NASA Disasters Mapping Portal to support response and after-action efforts. Post-event, the team participated with FEMA in an after-action review to identify areas for future improvement. Data sets collected by UAVSAR continue to be used in post-event assessment of streamflow and inundation simulations made by Pacific Northwest National Labs and other partners. The rich data sets collected by UAVSAR, along with ground observations of high-water marks and other data sources, will benefit community preparations toward applications from *NISAR*.

c. Kilauea Volcano Eruption

On May 3, the Kilauea volcano on Hawaii's Big Island erupted from new fissures and sent lava flowing over streets and neighborhoods. Wiping out 700 homes and moving more than 2,000 people, no U.S. eruption has been as disruptive since Mount St. Helens blew ash up to the stratosphere in 1980. As the disaster response on the ground led by the U.S. Geological Survey (USGS) kicked into gear, managers from NASA's Earth Science Disasters program sent out a call to NASA's own researchers, data managers, and satellite teams: What can we do to help?

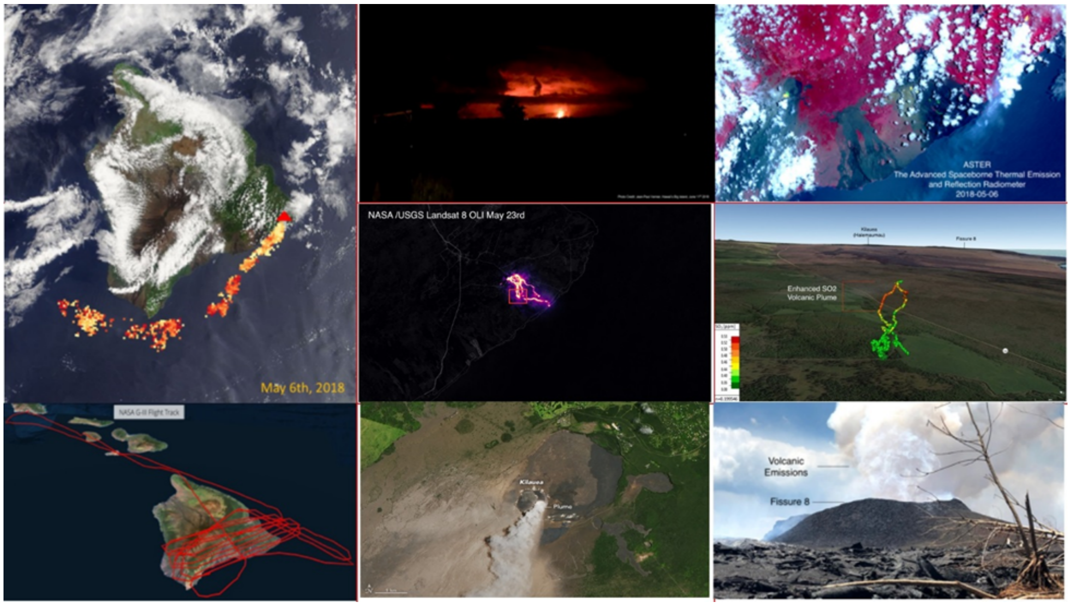
With an array of sophisticated Earth-observing sensors in orbit, and partnerships with space agencies around the globe, NASA had many assets to offer. The Kilauea eruption raised the NASA Disaster's Program activation to Tier 2, a level triggering a coordinated response of NASA scientists among all of the 10 NASA Centers with phone calls three-to-four times a week during the epicenter of the crisis.

The Disaster team coordinated the analysis and use of near-real-time satellite observations from visible, infrared, and synthetic-aperture radar sensors to monitor ground deformation, new volcanic fissures, and lava fields on the Big Island of Hawaii. This information was made available on the NASA Disasters Mapping Portal to help their USGS colleagues in their decision-making processes.

But more information was needed to determine when the eruption would stop. A team of JSC/JPL scientists studying glacier evolution in Greenland turned the Glacier and Ice Surface Topography Interferometer (GLISTIN) into an instrument to map out the lava fields and produce data for models to estimate the expected duration of the eruption, based on the size of the magmatic chamber and volume of lava spilled out. As the new fissures continued to erupt, the main crater of the volcano, Halemaumau, was called for a major awakening with ash that could spew up into commercial aviation routes.

NASA's Disasters scientists had their satellite pointing to the volcano to follow what would happen next. Through observations of multiple spectral bands through sensors on different platforms—OMPS and VIIRS on *Suomi-NPP*, OMI on *Aura*, MISR, ASTER and MODIS on *Terra*, MODIS on *Aqua*, and CALIOP on *CALIPSO*—scientists mapped out the horizontal and vertical extension of the volcanic cloud. The aviation threat remained a threat, but the Kilauea eruption turned into a nightmare for air quality on the ground.

The volcanic fog, also known as vog, blanketed the Big Island of Hawaii with a thick, greyish cloud seen by NASA's satellites. The NASA Disaster team gathered its data to support air quality folks and warn people on the ground about where and when it was too dangerous to go outside. But scientists had to get closer to the volcanic sources to help predict the impacts of the eruption.

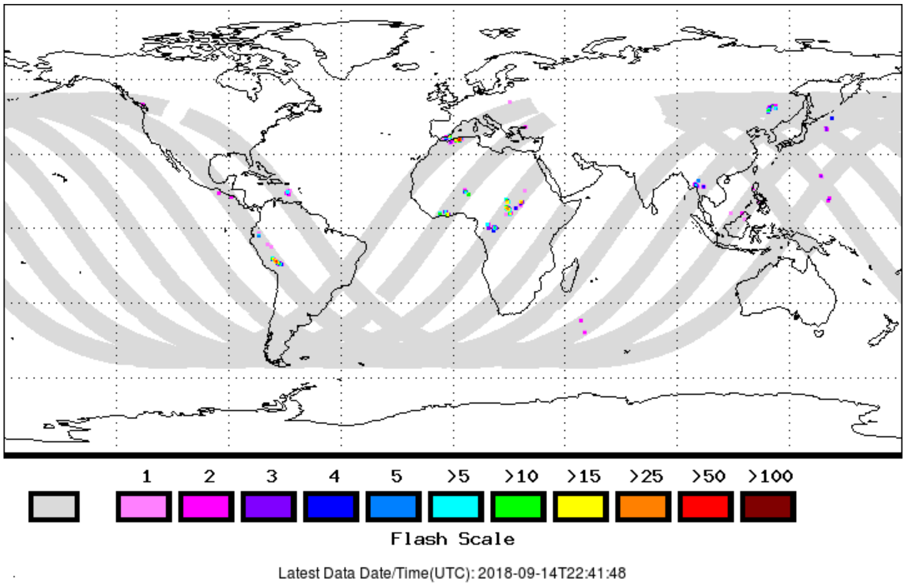


(1). Kilauea aerosol plume dispersion observed on 6 May 2018 by the Multi-angle Imaging Spectro-Radiometer (MISR). (2) Night-time photo of Fissure 8 from J.-P. Vernier. (3) Thermal Imagery from the Advanced Spaceborne Thermal Emission and reflection Radiometer (ASTER) on 6 May 2018. (4) Thermal imagery of the Lava fields from Landsat 8 on 23 May 2018. (5) Balloon-borne sulfur dioxide profile from the minigas instrument obtained during the VolKilau campaign on 15 June 2018. (6) NASA G-III Flight tracks with the GLacier and Ice Surface Topography Interferometer (7) Photography of the Kilauea main crater (Halemaumau) and emitted plume taken by astronaut from the International Space Station. (8) Picture of volcanic fissure 8 taken by J-P. Vernier on 18 June 2018.

Within 15 days, the Volcano Rapid Response Campaign (VolKilau) was on the ground of on the Big Island of Hawaii, immediately downwind from fissures and the Halemaumua crater to study sulfur dioxide and aerosol emissions from the Kilauea eruption. The NASA Langley-led team deployed a variety of balloon measurement payloads downwind from the eruptive vents to assess the impact of the eruption on air quality, improve model simulations, and validate satellite observations of sulfur dioxide and aerosols. With satellite observations from space and measurements on the ground near the fissures, NASA's Disasters team had its eyes on Kilauea to support the people of Hawaii.

d. International Space Station Role in Disaster Response

The International Space Station (ISS) participated in ESD's disaster response efforts during 2018 by collecting digital handheld, visible wavelength camera images acquired by astronauts for the Kilauea eruption that began in May, as well as for Hurricane Florence, which impacted the eastern U.S. coastline in September. The ISS Lightning Imaging Sensor acquired information on lightning frequency related to Hurricane Florence.



The Lightning Imaging Sensor (LIS) on International Space Station (ISS) acquired this near real-time lightning flash data on September 14, 2018 several hours after Hurricane Florence made landfall, and indicates elevated lightning activity along the North Carolina coastline. The ISS-LIS contains a staring imager which is optimized to locate and detect lightning with a storm-scale resolution of 4 km at nadir (directly below the instrument) increasing to 8 km at limb (at edge of measurement region), over a large region of about 550 km of the Earth's surface. The Field-of-View (FOV) is sufficient to observe a point on the Earth or a cloud for about 90 seconds with a 2 millisecond sampling frequency, which is adequate timing to estimate the lightning flash rate of many storms.

Target requests for both events were developed for the ISS crew by the JSC Earth Science and Remote Sensing (ESRS) Unit, which assessed opportunities for imagery throughout the duration of each event. Following collection and downlink of data, the ESRS team then fully georeferenced the handheld imagery for delivery to the USGS Hazards Data Distribution System and NASA Earth Science's Disasters program for access by end users.

This handheld, visible wavelength (red-green-blue) digital camera image of a steam and ash plume rising from Hale Ma'uma'u Crater on Kilauea Volcano, Hawai'i was taken by a crew member on the International Space Station (ISS) on May 13, 2018 using a Nikon D5 camera and an 1600 mm lens. The image was taken during the 2018 Kilauea Volcano Lower East Rift Zone eruptive activity. Crew members on the ISS were requested to take images throughout the eruption by the JSC Earth Sciences and Remote Sensing (ESRS) Unit. Imagery collected by handheld cameras was then georeferenced by the ESRS for delivery to end users (the United States Geological Survey and NASA Earth Sciences Disasters Program).

For Hurricane Florence, the ISS crew was also directed to obtain oblique imagery of the storm system prior to landfall in order to assist with visualization and storm development analysis activities.

This panoramic handheld, visible wavelength (red-green-blue) digital camera image of Hurricane Florence was taken by a crew member on the International Space Station (ISS) on the morning of September 12, 2018 using a Nikon D5 camera and a 50 mm lens. At the time the image was taken, the storm eye was approximately 966 kilometers (~ 600 miles) from the southeastern US coastline. Crew members on the ISS were requested to take images of the storm and effected regions both pre- and post-landfall by the JSC Earth Sciences and Remote Sensing (ESRS) Unit in support of disaster response activities.

e. Airborne Response

Several missions flown during 2018 can be considered disaster response missions of opportunity. These missions were useful for providing post-event data:

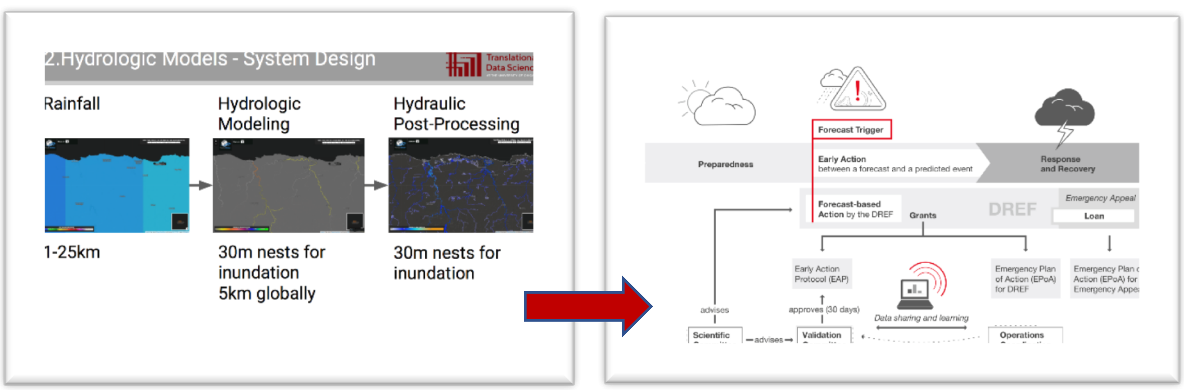
- The G-LiHT mission returned to South Florida and Puerto Rico to survey post-hurricane recovery from hurricanes Irma and Maria.
- The C-20A mission carrying UAVSAR (L-band) obtained SAR imagery of flooding and damage following the deluge produced by Hurricane Florence in North Carolina.
- The G-III mission carrying GLISTIN-A flew multiple flight lines over the Kilauea volcano in Hawaii to map the evolving topography caused by lava flows and crater collapse.
- The ER-2 mission flew MASTER over the fire scar caused by the massive Thomas fire in Southern California.

The JSC G-III supported eight flights in Hawaii to produce high-resolution topographic maps with the UAVSAR Ka-band instrument. The team imaged the Kilauea volcano during its eruption to generate lava volume estimates, as lava flowed from the caldera toward farms and residential areas. JPL and USGS scientists are developing new approaches to measure lava flows with remote sensing, with the goal of improving volcanic models. Flights were conducted in May, June, and September, at the tail end of the eruption.

In September 2018, the Air Force Reserve Command C-20A conducted six flights to image areas impacted by Hurricane Florence with the L-band instrument. The objective of the experiment was to observe the flood water cresting and receding over floodplain sites identified by stakeholders from FEMA. False color polarimetric quick-look images were delivered post-flight and posted at the NASA Disasters data portal. UAVSAR images filled gaps between radar satellite coverage overpasses so flood responders could determine and predict where neighborhoods and key facilities were impacted by flood waves.

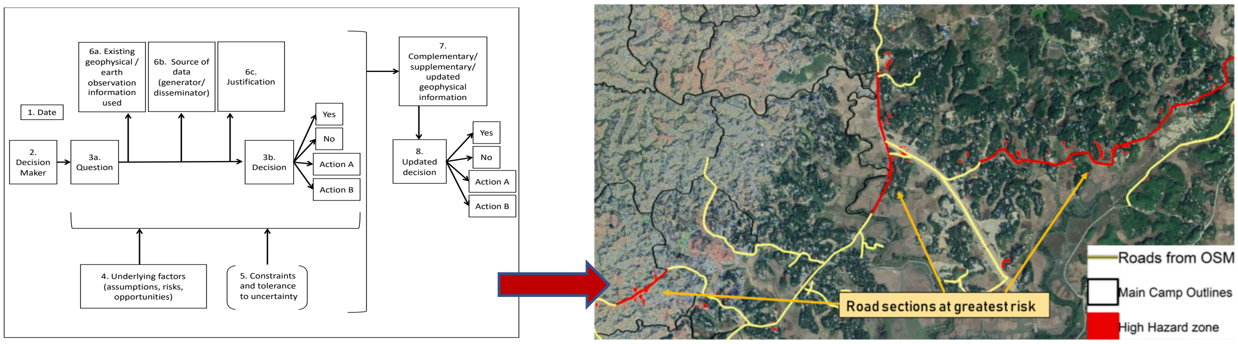
III. Disaster Risk Reduction and Resilience

The Disasters program directly supports the GEO Global Flood Risk Monitoring (GFRM) Community Activity, which responds to the need for credible data and derived products that assess flood-related disaster risks, and the ability to make risk-informed decisions. In 2018, the GEO Flash Flood effort under the GFRM, for example, is actively engaged with local hydromet services located within Peru, Ecuador, and Bangladesh and working with Red Cross Red Crescent Climate Centres in these regions to directly integrate the data into their Forecast-based Financing mechanisms globally.



The calibrated flash flood models from the NASA EF5 (left) are developed in alignment with the Standard Operating Procedures of the Red Cross's Forecast-Based Financing program (right), and tailored to specific needs for early action in country.

The 2018 RRNES activity on Connecting Earth Observations to Decision Makers for Preparedness Actions works to integrate a social-science led approach to understanding the process of humanitarian decision makers, in order to 1) identify information necessary for co-development of data products, and 2) for determining entry points for EO data into humanitarian preparedness actions. The NASA data developed in this project includes landslide susceptibility/risk and flash flood risk, additional data was provided by UN agencies and integrated into the models, and the application of this data directly serves the humanitarian preparedness activities of the UN agencies working on the Rohingya crisis in Bangladesh.



UNDP Programme Officers in Cox's Bazaar, Bangladesh completed the COMPAS Decision-Making Flowcharts (left) which strengthened the development of landslide susceptibility maps (right) to meet UNDP emergency warning needs.

Finally, the ESD-level partnership activity between NASA and Mercy Corps, led by the Disasters program, seeks to leverage the knowledge of fragile and crisis-affected areas where Mercy Corps works and integrate this knowledge into the use of Earth-observation systems in order to build a better understanding and ability to visualize resilience in a humanitarian context. In 2018, this partnership activity developed a joint Scope of Partnership and Learning agenda plan, which identified the major gaps in information reported by Mercy Corps technical support units working in country. Next steps of this activity include mapping EO data to bridge these gaps and identify opportunities to pilot this pairing of information.

Additional areas for exploration include activities relating to building risk-informed cities and urban areas. In 2018, the Disasters program provided a Scoping Document to the Applied Sciences Program and USGEO for consideration of possible areas of integration of EO data in this context. Future activities under this area remain under discussion.

IV. NASA Disasters Mapping Portal

The beta version of the Disasters Mapping Portal was launched in January 2018 and moved out of the beta stage in the summer. The Portal hosted products for 25 different disaster responses. The largest response was Hurricane Florence containing 68 different products. The Kilauea volcanic eruption story map had more than 12,000 views and the California Fall Wildfires story map had more than 4,300 views. Multiple Portal improvements included story maps embedded in the home page, as well as an improved user interface and more organized layout of disaster response products using product galleries. Disaster-specific story maps evolved beyond displaying each product and started to pull in additional data to tell a more complete story and explain the disaster's impact. Near real-time products were added including a landslide nowcast, relative soil moisture, MODIS flood products, NASA's Fire Information for Resource Management System's active fires, and *GPM* accumulation products.

V. Meetings and Collaboration

a. Understanding Risk Forum

Kristin Lambert, Mercy Corps' Agricultural Expert presents on NASA's Hyperwall at the Understanding Risk Forum in Mexico City, Mexico on the application of EO data for managing Mongolian dzud events.

In May 2018, the NASA Disasters program participated in the World Bank's GFDRR Understanding Risk (UR) Forum in Mexico City, Mexico. In addition to leading and participating in 8 side events and sessions, the Disasters program supported the facilitation of the Water Youth Networks' "Pressure Cooker" event, which engaged 35 young professionals from 13 countries to address risk communication challenges and produce interdisciplinary solutions through collaboration. The NASA Hyperwall was a highlight of the UR Forum, and—for the first time—engaged NASA and non-NASA partners in presenting their work on disaster risk reduction. This event has led to ongoing partnership activities with GFDRR/World Bank, including the publication of an article in the UR Proceedings, a Risk Communication Workshop at AGU 2018, and an upcoming workshop on integrating NASA data into the recovery/reconstruction activities of the Disaster Risk Management team.

b. Cities on Volcanoes 10

From September 2–7, 2018, the NASA Disasters program participated in the 10th Cities and Volcanoes Commission's conference in Naples, Italy. In addition to presenting a paper on "NASA Disasters Program's Response to the 2018 Kilauea Eruptions", the program also centrally hosted an Augmented Reality (AR) art installation to provide a user-friendly interface for understanding volcano-induced surface deformation as seen with the use of Interferometric Synthetic Aperture Radar. The use of AR in this manner provided a 3-D visual understanding of volcanic risk and the associated impacts on the topography and people. The installation was well received by scientists, policy makers, children and families.

Participants at the Cities on Volcanoes conference (left) gain a better understanding of INSAR data and surface deformation following the Kilauea eruption through the use of augmented reality. Associate Program Manager John Murray presents on NASA's role in supporting the Kilauea response activities (right).

c. Colorado Flood Meeting

People in academia, industry, insurance, and government agencies are estimating flood hazards, identifying areas at current risk, and predicting how risk and vulnerability will change across a range of spatial and temporal scales. There is a recognized need to identify flood risk and exposure at global scales—with both higher resolution and greater precision. Existing research either leverages satellite data to map hazard and exposure to flooding at large spatial scales, or uses models to make flood predictions for various flow return periods, but with high uncertainty for extreme events at the tail end of historical data distribution. Extant exposure and derived vulnerability data are often licensed or of restricted access, providing challenges in widespread use. New technologies (e.g. micro- and nano-satellites, drones), advances in artificial intelligence (AI), improved use of crowd-sourced and social-media data, as well as interoperability standards, promise significant and potentially game changing progress in this field for the coming years.

Group photo of the NASA-supported Flood Risk Workshop, CSDMS, 1-3 October 2018, Boulder, CO.

The NASA Disasters program sponsored a three-day international Flood Risk Workshop (FRW) at the University of Colorado-Boulder, October 1–3, 2018, which brought together ~80 people from many different sectors and organizations, including state and national agencies, humanitarian and aid-development agencies, NGOs, private companies active in flood risk or space, academia, and (re-)insurance businesses. The aim was to reach a consensus of priority actions as a new Flood Risk Community of Practice to solve the main challenges in flood risk estimation at global scales, and aligning those actions with the goals of GEO Global Flood Risk Monitoring (GEO 2017-2019 Work Programme) and of the Sendai Framework for Disaster Risk Reduction.

The workshop identified technical aspects that will help everyone better understand and access tools to mitigate flood risk and take action. Long-term objective: develop, test and apply methods to utilize satellite remote sensing and other Earth observations with models and maps to estimate location, intensity and duration of floods globally in real-time and a durable monitoring system of flood risk with climate change.

d. Group on Earth Observations (GEO) Portfolio Activities

Global Flood Risk Monitoring (GFRM) Community Activity

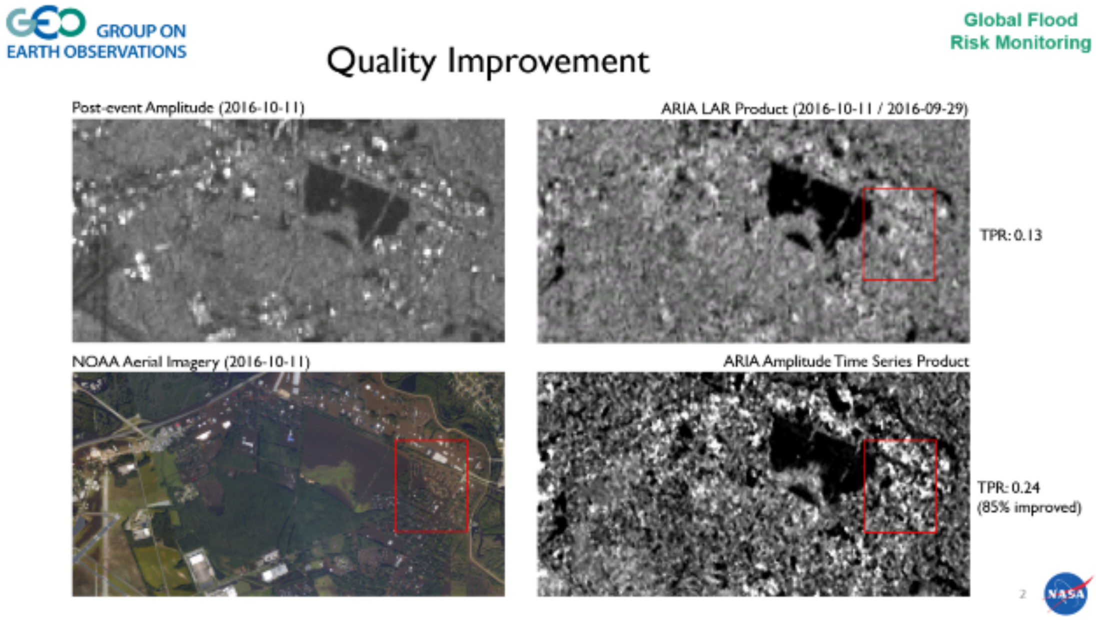
The Group on Earth Observations (GEO) Global Flood Risk Monitoring (GFRM) Community Activity supports and integrates efforts that leverage Earth observations to improve the ability to assess flood risk on a global scale and translate risk information to impacts at the community, national and regional level by supporting risk-informed decision making. Understanding and reducing flood risk is a complex task that can benefit from the unique perspectives offered by Earth observations that shed light on not only individual global processes that contribute to flood risk, but their interactions. Action informed by Earth observations to reduce flood risk can only be taken if credible data can be provided to decision makers, allowing them to correctly assess relevant risk and make subsequently informed decisions. These data must be easily available, understandable and most importantly free.

To realize these goals, the GFRM Community Activity reorganized throughout 2018 and positioned itself to create a formalized Community of Practice, creating a space where new and existing data/product providers and consumers can come together. This Community of Practice, led by three NASA Applied Sciences-funded GEO ROSES projects, will demonstrate the viability of flood risk monitoring on a global level informed by Earth observations, therefore creating these new connections and increasing the use of flood-risk Earth-observation information in decision-making situations.

- Global Rapid Flood Mapping System with Space borne Synthetic Aperture Radar (SAR) Data

Led by Sang-Ho Yun (NASA JPL), this project is streamlining an end-to-end automated flood response process and demonstrating through responses to extreme flood events in several targeted GEO member countries, through partnerships with relevant agencies, international GEO member organizations and USGEO member agencies. Project goals and implementation details were designed strictly based on lessons learned from historical flood response efforts in coordination with the Federal Emergency Management Agency (FEMA), U.S. Geological Survey (USGS) and the National Oceanic and Atmospheric Administration (NOAA).

Several primary accomplishments in 2018 include the formation of a collaborative relationship with the Earth Observatory of Singapore (EOS) where a clone of the JPL Advanced Rapid Imaging and Analysis (ARIA) system was creating for testing and updating, and multiple flood response efforts were jointly undertaken. In addition, multiple new scripts were developed allowing download of new data sources such as *GPM*, local weather station records and *SMAP* data.



Quality improvement examples of ARIA flood products, towards the development of a robust end-to-end automatic system to rapidly generate and deliver flood extent maps to GEO partners.

- <u>Towards A Global Flood and Flash Flood Early Warning Early Action System Driven by NASA Earth Observations and Hydrologic Models</u>

Led by Andrew Kruczkiewicz (Columbia University), this project is working to enhance analyst and decision maker capacity to better prepare, response and recover from floods. To achieve this, a global dataset on historical flash floods will be created. The need for a technical working group for identification of actions to potentially decrease risk of flash flood disasters will be examined, and intercomparison of forecasts for flash flood risk with be conducted. Finally, the development of a Flash Flood Early Warning Framework is underway.

Andrew Kruczkiewicz co-presenting with Ahmadul Hassan at the Asia-Pacific Forecast-based Financing (FbF) Regional Dialogue Platform.

Several primary 2018 results and accomplishments include the further scoping of inclusion of flash flood datasets and formatting for development of a global database and the identification of operational systems, such as the one hosted by ETH (Swiss Federal Institute of Technology in Zurich) for the Swiss government. A draft publication on the complexities of decision making in situations of risk for multiple flood types has been completed. Two events in Kuala Lumpur, Malaysia, and Arequipa, Peru, have been facilitated, providing a lens to focus on flash floods.

- Integrating Global Remote Sensing and Modeling Systems for Local Flood Prediction and Impact Assessment

Led by Robert Brakenridge (Dartmouth Flood Observatory (DFO)), this project leads an effort to produce state-of-the-art, globally scoped, flood prediction, monitoring capabilities and risk evaluations, continuing to automate wherever possible relevant systems and directly address needed connections to multiple end users in order to provide useful flood data and information. The project focus is on integrating aspects of NASA-based global flood systems, including DFO River Watch, University of Maryland Global Flood Monitoring System, the NASA Goddard automated MODIS flood product, and SAR-based flood mapping. These data are actively being produced and distributed for a variety of flood events, as both static data products and as dynamic map services.

Recent technical tasks completed include the installation of River Watch system on the DFO Web Map Server, responses to multiple flood events which tested new capabilities (Bangladesh Refugee Camps, Laos, Hawaii and the central United States). The Land Atmosphere Near-real-time Capabilities for EOS (LANCE) implementation of the NRT Flood System, continued development of automated SAR processing supported by ESA have also been completed.

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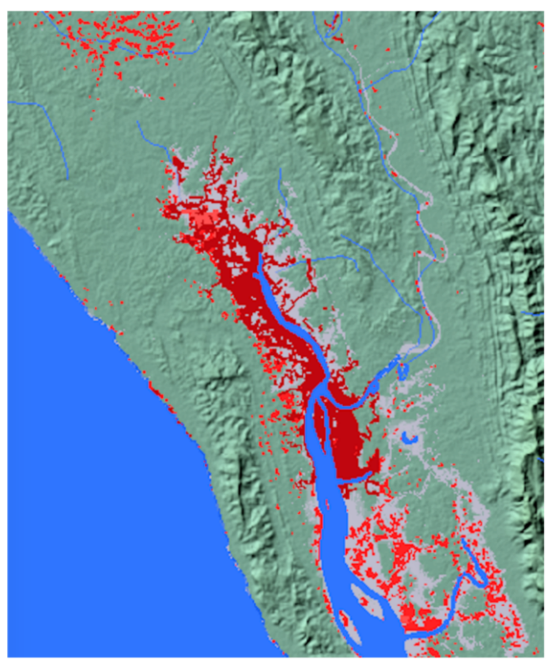
~ 1 million refugees from Myanmar are being temporarily housed in refugee camps set up in Bangladesh: at locations subject to landslide and flood risk during the monsoon and tropical storm season. NASA GEO project team members are providing imaging and surface water maps on a monitoring basis and in preparation for any large events. DFO is using Sentinel SAR and its own mapping algorithm: light red. Also, though a university agreement with Digital Globe, it is obtaining very high spatial resolution images for water mapping (when cloud cover permits). This is shown in the map as dark red (map does not show detail available). Previous floods have been mapped in this area and are shown in light gray. A better "normal water mask" (blue) is needed to mask the river also showing in gray.

P. Matgen at LIST in Luxembourg, a GEO project collaborator, will also provide results of the automated SAR processor there.



Global Wildfire Information System (GWIS) Initiative

GWIS aims to provide a continuous and smooth platform of harmonized information on wildfires that could be used at different scales, from national to global. At the global level, where information on wildfires is scattered and not harmonized, GWIS will be a unique source of information for global initiatives and policies, while supporting the analysis of wildfire regimes at this scale. The calibration of the system and the validation of the different modules will require the close collaboration with regional and national partners. In countries that currently do not have a wildfire information system, GWIS will fill this gap and help countries engage in international collaboration. For countries and regions where wildfire information systems exist, GWIS will provide a complementary and independent source of harmonized information adding to the national/regional information sources.

NASA Disasters continued to contribute to the global GWIS effort throughout 2018, promoting the awareness and integration of three Applied Sciences funded GEO ROSES projects that helped GWIS towards its goal of transforming scientific results into value added operations.

GWIS is a web map service that focuses on providing a continuous and smooth web map service and data platform of harmonized wildfire information that can be used at different scales, from national to global. The GWIS was matured from the European Forest Fire Information System (EFFIS) in the late 1990s, and expanded into the GWIS system by a consortium of contributing international wildfire remote sensing community members. GWIS is housed, maintained and served by the European Commission (EC) Joint Research Council (JRC) in Ispra, Italy. NASA EO data (primarily MODIS) has been the foundational sensor data for supporting the GWIS. NASA serves on the GWIS Coordination Board, providing guidance on the GWIS developments. The GWIS – GEO Global Initiative submitted in early 2019 to the GEO Work Program 2020-2022, builds on the work already performed in GEO GI-09, in the WP 2016, and the GWIS Initiative in the GEO WP 2017–19. In 2017, NASA solicited proposals to support enhancements to GWIS to enable operational deployment globally. Three proposals were selected for support, and their first year activities (2018) are described here:

- <u>Using the NASA Polar Orbiting Fire Product Record to Enhance and Expand the Global Wildfire Information System (GWIS)</u>

Led by Luigi Boschetti (Idaho State University) and David Roy (University of Michigan), this effort provides GWIS enhancements for improved on-demand statistics, tabular information, and graphical information at state, regional, national, sub-continental, continental, and global scales, at monthly, seasonal and annual time periods, based on 15-years of MODIS Collection 6 fire products. As a result, GWIS will become the only portal that provides global to sub-national summary, science-quality information on fire seasonality, fire size, and annual rankings of fire activity, in easily accessible formats for national policy makers and natural resource managers.

Accomplishments in 2018 included downloading, collating, and preprocessing of the 2000–2018 MODIS MCD64 fire record, and ancillary land cover and country boundary datasets; the prototyping of the code to generate monthly MCD64 composites for visualization in GWIS, and delivery of a 1-year test datasets to the European Commission's Joint Research Centre GWIS team. Additionally, Boschetti and Roy consulted and involved stakeholders and potential users of the proposed fire metrics though the GOFC-GOLD Fire IT and regional network meetings, and established collaboration with the UN Food and Agriculture Organization (FAO) for data access to enhance their database developments in GWIS. They also prototyped the code to generate country-level fire metrics and appropriate plots and charts, a key enhancement to the visualization capabilities of GWIS's Web Map Service.

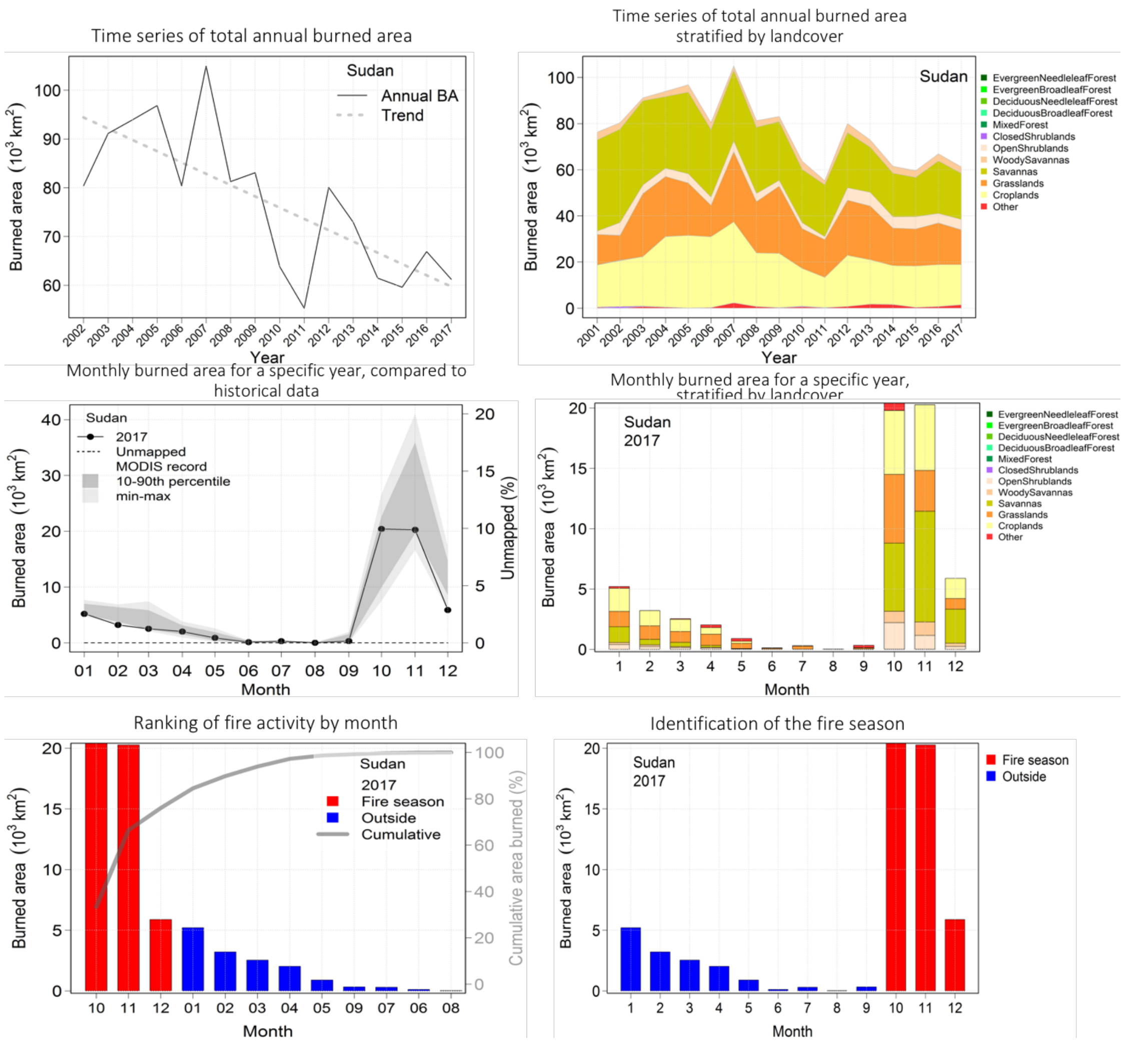


Figure 3: Country-level charts of fire activity for Sudan, based on the 2002–2018 MODIS MCD64 Burned Area Record now included as additional graphical/tabular information in the GWIS beta version.

- <u>Development of a Harmonized Multi-Sensor Global Active Fire Data Set</u>

Led by Louis Giglio (University of Maryland) and Wilfrid Schroeder (NOAA), this project effort will include the integration of new generation geostationary satellite sensors offering greatly improved capabilities for routine fire detection and characterization. Building on these new capabilities, they propose to develop a global geostationary “network of fire products” to complement existing polar orbiting satellite fire monitoring products, such as those collected by Landsat 8, Sentinel-2A/B, and VIIRS to enhance the GWIS-provided fire information. Outreach and training activities in coordination with regional fire networks are being developed to provide original material to educate fire data users and practitioners on those new capabilities.

Accomplishments in 2018 included an initial validation of the *GOES*-16 Advanced Baseline Imager (ABI) and MSG SEVIRI (Meteosat Second Generation Spinning Enhanced Visible and Infrared Imager) active fire products. The team also began working with the JRC GWIS team to coordinate the format of, and time frame for deliveries of data to GWIS, as well as several potential users of the harmonized fire data. The team also obtained the remaining geostationary active fire data sets for the initial study period (November 2017–February 2018 & July 2018–September 2018), and completed initial validation of *GOES*-16 ABI and MSG SEVIRI fire products. Giglio also presented the project initial results at the 2018 Fall AGU meeting in Washington D.C.

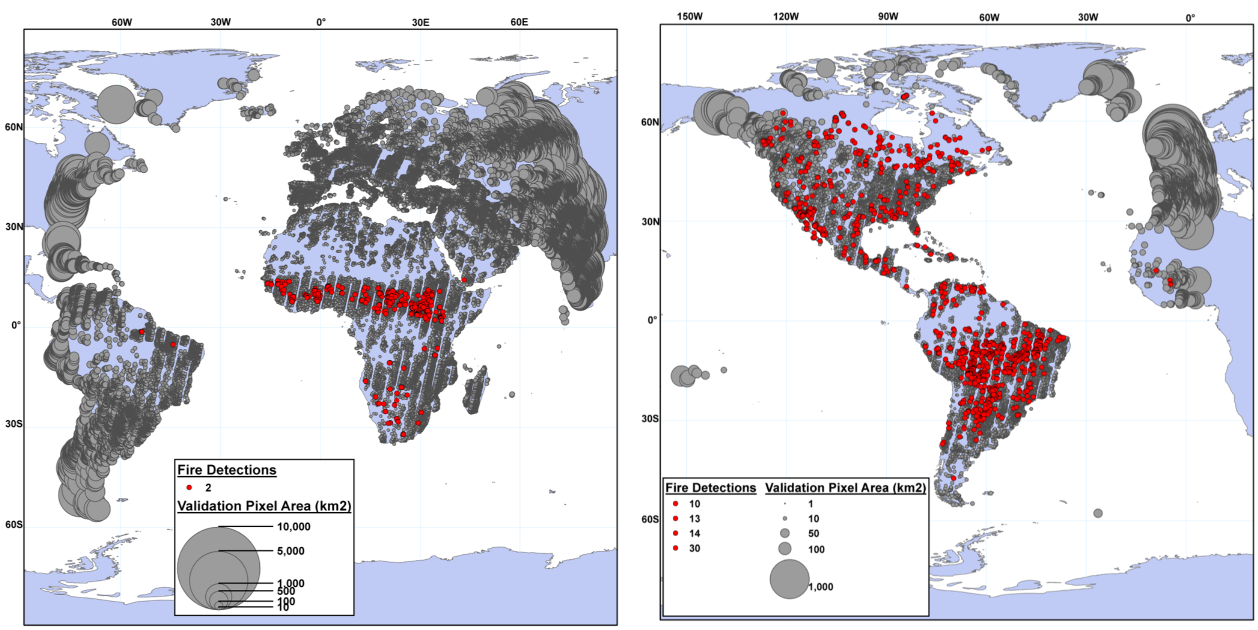


Figure 4: GOES-16/ABI (left panel) and MSG/SEVIRI (right panel) validation points; gray circles represent pixel area in km². Fire pixels from ABI and SEVIRI sensors are superimposed in red.

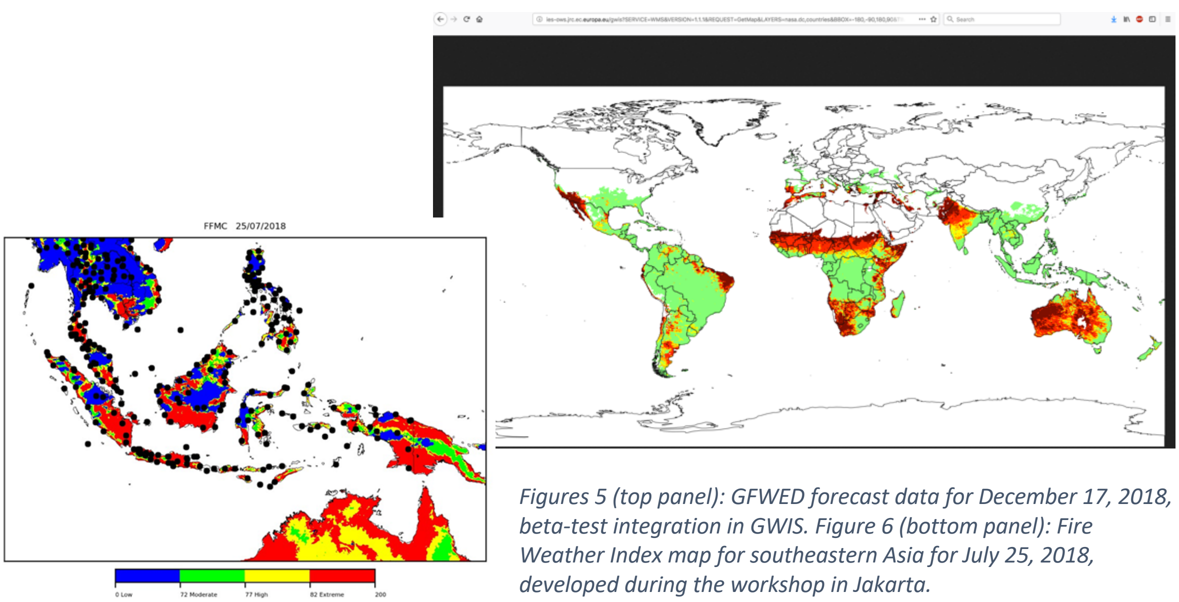
- <u>Enhancements to the Global Wildfire Fire Information System: Fire Danger Rating and Applications in Indonesia</u>

Robert Field (Columbia University), leads an effort to develop a 10-day global Fire Weather Index (FWI) forecasts by integrating the Global Fire Weather Database (GFWED) data into GWIS, which will increase the real-time FWI data sets in use there from one to four, increase historical FWI data from one to eight, and add an additional 10-day FWI forecast to GWIS. Because of the close collaboration with Indonesia, Field and team will regionalize their focus in this high fire-prone section of the globe to advance the current Fire Danger Rating System there, and train personnel in the use of the enhanced GWIS fire management products developed in their efforts and other investigators.

With the developments in 2018, Field and team helped integrate the new Global Wildfire Weather Database (GFWED) forecast data in near-real-time into the GWIS, and have developed a prototype rendering system, shown below for the17 December 2018 Fire Weather Index. The next step (in 2019) is to distribute the data alongside complementary European Centre for Medium-Range Weather Forecasts (ECMWF) products through the public GWIS portal (http://gwis.jrc.ec.europa.eu/). Field also led a Fire Danger Rating Workshop in Jakarta, Indonesia, in July 2019, to train on the use of *GPM*-based precipitation estimates to strengthen fire danger rating systems there.

e. Committee on Earth Observation Satellites (CEOS) Activities

<u>Working Group on Disasters (WGDisasters)</u>



Figures 5 (top panel): GFWED forecast data for December 17, 2018, beta-test integration in GWIS. Figure 6 (bottom panel): Fire Weather Index map for southeastern Asia for July 25, 2018, developed during the workshop in Jakarta.

CEOS is committed to supporting disaster risk management in the context of the *2030 Agenda for Sustainable Development* and the *Sendai Framework for Disaster Risk Reduction 2015-2030*, and enhancing the contribution of space-based Earth observations in support of disaster risk reduction. CEOS Agencies work closely with key stakeholders (e.g.

GEO, UN agencies, donor institutions like the Asian Development Bank, World Bank/Global Fund for Disaster Risk Reduction, scientific communities, national resource management agencies, civil protection agencies, local decision makers and others) to foster the use of satellite EO data. The overarching goal of the WGDisasters is to increase and strengthen the contributions of satellite EO to the various Disaster Risk Management (DRM) phases, and to inform politicians, decision-makers, and major stakeholders of the benefits of using satellite EO in each of those phases. The WGDisasters in 2018, with the support of the NASA Disasters program, kicked off a review activity, which will begin in earnest at its 11th meeting in Athens, Greece, in March 2019, with a view to taking stock of what has been achieved in the recent pilots and demonstrators and reviewing the long-term strategy of the Working Group toward achieving the goal described above

Disasters program contributions to WGDisasters in 2018 included vice chairmanship by Disasters Program Manager David Green. Through the standard CEOS chairmanship process, he will become WGDisasters Chair in 2019. Additional support by Disasters program staff and affiliated partners included co-lead positions in both a landslide pilot and flood pilot.

VI. Disasters Missions Applications

a. The *Cyclone Global Navigation Satellite System* (*CYGNSS*) Mission launched December 15, 2016, and formally ended its mission operations role on December 31, 2018. The Primary Investigator (PI) is Christopher Ruf, University of Michigan. The Deputy Program Applications Lead (DPA) is John Murray, NASA LaRC.

b. The *NASA ISRO Synthetic Aperture Radar* (*NISAR*) Mission is scheduled for launch in 2021. The PI is Paul Rosen, JPL. The DPAs are Sue Owen and Natasha Stavros, JPL.

In 2018 *NISAR* hosted three workshops with applications communities to assess their needs and work together to customize a roadmap for increasing the utility of *NISAR* data prior to launch in January 2022. The three workshops hosted in 2018 included: 1) Forest and Disturbance Applications; 2) Agriculture and Soil Moisture Applications; and, 3) Wetlands Applications.

- At the Forest and Disturbance Applications workshop, the U.S. Forest Service Geospatial and Technology Applications Center, U.S. Geological Survey Earth Resources Observation and Science Center, U.S. Bureau of Land Management, World Wildlife Fund, World Resources Institute, Conservation International, and the USFS/USGS/EPA SilvaCarbon program documented a need for information on disturbance type classification as well as reduced latency for disaster response (e.g., inundation, debris flow, and burn severity).

- The agriculture and soil moisture communities had several organizations tasked with disaster response during flooding including the U.S. Department of Agriculture

National Agricultural Statistics Service, Foreign Agriculture Service, and the Agriculture Research Service, Agrifood Canada, and U.S. Geological Survey Famine Early Warning Systems Network (FEWS NET). These communities also expressed the importance of disaster preparedness and monitoring such as in the event of drought. All of the aforementioned communities monitor drought as well as the U.S. National Drought Mitigation Center and the Group on Earth Observations Global Agricultural Monitoring (GEOGLAM) Initiative. For the agriculture and soil moisture communities the pressing needs in disaster response related to inundation extent mapping using the full SAR constellation and developing a path for using *NISAR* data in response to the international disaster charter.

- For the wetlands community, the primary response to disaster was in post-disaster damage assessment and restoration for conservation purposes.

  In 2018, the *NISAR* Science Team started an Urgent Response Working Group (URWG) to develop a detailed Urgent Response Plan for the mission. The URWG will take a phased approach with sequential groups addressing individual and related sets of the issues. Working group members included science team members from each of the science disciplines and the Science Team Applications Lead, people working on the *NISAR* project at JPL, and a *NISAR* Deputy Program Applications lead (representing NASA Applied Sciences Disaster program). The URWG #1 convened in the fall 2018 to consider the types of events to which *NISAR* should expect to respond; whether an automated mechanism for initiating the response can be developed; and the criteria for response initiation. Events were classified by the degree to which they could be forecast. For example, an earthquake is not forewarned but sensor networks can be used to automate a request for response based on magnitude and proximity to population centers or critical infrastructure. In contrast, flooding from hurricanes can be anticipated and urgent response downlink and processing requested in advance of landfall. The types of events considered covered geological hazards, ecosystem hazards and flooding, maritime hazards, and industrial/human accidents. The findings of the URWG #1 will be documented in a report.

c. The *Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats* (*TROPICS*) Mission is currently postponed pending the identification of a launch opportunity. The *TROPICS* Applications Team is conducting regularly scheduled telecons to address the applications phase. The PI is Bill Blankenship, MIT Lincoln Laboratory. The DPA is Emily Berndt, NASA MSFC.

d. *The Lidar Surface Topography* (*LIST*) Mission. This 2007 Tier 3 Decadal Survey mission remains in a concept design phase. The DPA is David Harding, NASA GSFC. Decadal survey concept: https://cce.nasa.gov/pdfs/LIST.pdf

VII. Abbreviations and Acronyms

ABI:	Advanced Baseline Imager
AGU:	American Geophysical Union
ARL:	Application Readiness Level
ASTER:	Advanced Spaceborne Thermal Emission and Reflection Radiometer
BAER:	Burned Area Emergency Response
CAIR:	Communities and Areas at Intensive Risk
CAL FIRE	California Department of Forestry and Fire Protection
CALIOP:	Cloud-Aerosol Lidar with Orthogonal Polarization
CALIPSO:	Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations
CEOS:	Committee on Earth Observation Satellites
CY:	Calendar Year
CYGNSS:	Cyclone Global Navigation Satellite System
DPA:	Deputy Program Area Lead
EA:	Early Adopter
EC:	European Commission
ECMWF:	European Centre for Medium-Range Weather Forecasts
EO:	Earth Observing
EPA:	Environmental Protection Agency
ESA:	European Space Agency
ESD:	NASA's Earth Science Division
FAO:	UN Food and Agriculture Organization
FEMA:	Federal Emergency Management Agency
FEWS NET:	Famine Early Warning System Network
FWI:	Fire Weather Index
G-LIHT:	Goddard's Lidar, Hyperspectral & Thermal Imager
GEO:	Group on Earth Observations
GEOGLAM:	Group on Earth Observations Global Agricultural Monitoring
GFDRR:	Global Facility for Disaster Reduction and Recovery
GFRM:	Global Flood Risk Monitoring
GFWED:	Global Fire Weather Database
GLISTIN:	Glacier and Ice Surface Topography Interferometer
GOES:	Geostationary Operational Environmental Satellite
GOFC-GOLD:	Global Observations of Forest Cover and Land Dynamics
GPM:	Global Precipitation Measurement
GSFC:	Goddard Space Flight Center
GWIS:	Global Wildfire Information System
HQ:	Headquarters
ISRO:	The Indian Space Research Organisation
ISS:	International Space Station
JPL:	Jet Propulsion Laboratory
JRC:	Joint Research Council
JSC:	Johnson Space Center
LANCE:	Land Atmosphere Near real-time Capabilities for EOS LaRC: Langley Research Center

Lidar:	Light Detection and Ranging
LIST:	Lidar Surface Topography
MASTER:	MODIS/ASTER Airborne Simulator
MISR:	Multi-angle Imaging SpectroRadiometer
MODIS:	Moderate Resolution Imaging SpectroRadiometer
MSFC:	Marshall Space Flight Center
MSG:	Meteosat Second Generation
NASA:	National Aeronautics and Space Administration
NGO:	Non-Governmental Organization
NISAR:	NASA ISRO Synthetic Aperture Radar
NOAA:	National Oceanic and Atmospheric Administration
NPP:	National Polar-orbiting Partnership
NRT:	Near Real-time
OMI:	Ozone Mapping Instrument
OMPS:	Ozone Mapping Profiler Suite
PI:	Principal Investigator
RECOVER:	Rehabilitation Capability Convergence for Ecosystem **Recovery**
RGB:	Red, Green and Blue
ROSES:	Research Opportunities in Space and Earth Sciences
RRNES:	ROSES Rapid Response and Novel Research in Earth Science
SAR:	Synthetic Aperture Radar
SEVIRI	Spinning Enhanced Visible and Infrared Imager
SMAP:	Soil Moisture Active Passive
SMD:	Science Mission Directorate
TROPICS:	Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats
UAVSAR:	Uninhabited Aerial Vehicle Synthetic Aperture Radar
UN:	United Nations
URWG:	Urgent Response Working Group
USDA:	United States Department of Agriculture
USFS:	United States Forest Service
USGEO:	United States Group on Earth Observations
USGS:	United States Geological Survey
VIIRS:	Visible Infrared Imaging Radiometer Suite
WGDisasters:	Working Group Disasters