National Aeronautics
and Space Administration

NASA EARTH SCIENCE

APPLIED SCIENCES PROGRAM

DISASTERS

2017

NASA Disasters Program 2017 Annual Summary

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https://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 2017

A portfolio of diverse Disaster research projects are at the program's core. These projects stem from three primary vehicles which include responses to dedicated NASA ROSES Disasters solicitations, Rapid Response and Novel Research in Earth Science (NNRES) solicitations, and Topical Workshops Symposia and Conference (TWSC) solicitations. Results from the first two areas are detailed in section 2 of this summary. This includes 10 NASA ROSES 2011 A.33 Projects which were completed at the end of 2017. Two 2017 TWSC awards supported applications workshops for the NASA Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats (TROPICS) and Cyclone Global Navigation Satellite System (CYGNSS) Missions.

For 2018, the NASA ROSES Earth Science Applications: Disaster Risk Reduction and Response Solicitation NNH18ZDA001N-DISASTERS will support new Disaster research. Details may be found at: https://nspires.nasaprs.com/external/solicitations/summary!init.do?solId={9CEF8BAC-CBF7-809C-51BD-8334579799C8}&path=open

c. Disaster Response for 2017

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 is comprised of disaster coordinators who are physically located at all NASA Centers across the country. Each Center has one or more assigned coordinators who work 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 both within individual NASA Centers as well as in relevant fields is critical. Bringing these relationships and bodies of knowledge together across centers promotes and strengthens the Program's effectiveness and reach. This 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 89 events in CY17. These are detailed in section 3.

NASA Applied Sciences Disasters Program Responses

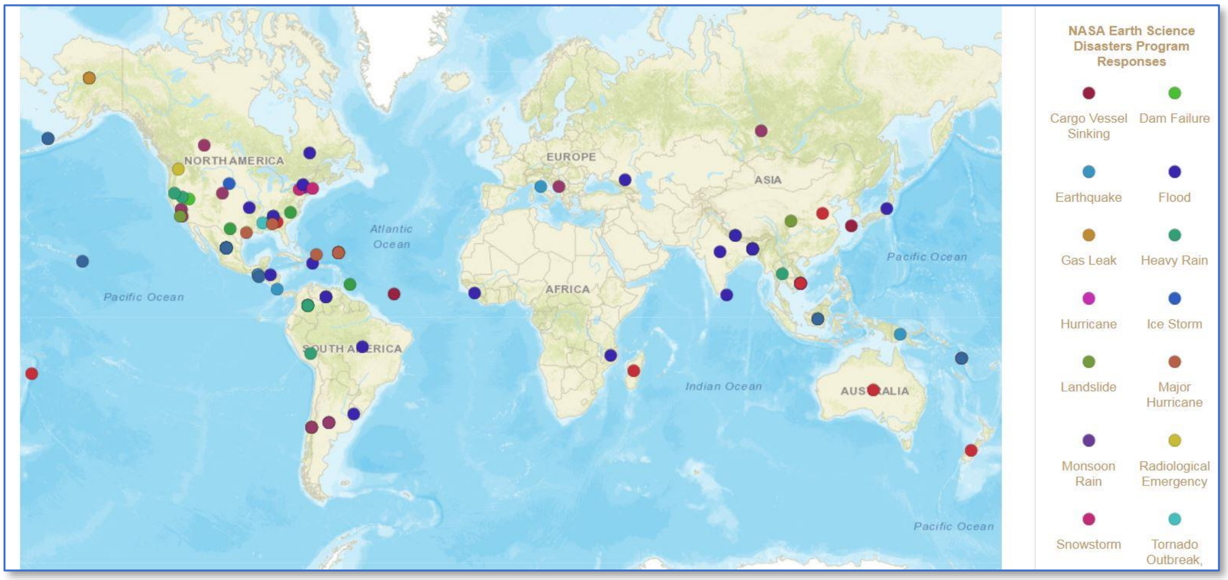


Figure X. 2017 Hazards that activated the Disasters Program. Hazards type symbolized by color.

d. Disaster Resiliency

In 2017, the NASA Disasters Program began a new focus centered on Communities and Areas at Intensive Risk (CAIR). Disaster risk reduction and the building of community resilience have emerged as key priorities of governments, businesses (the insurance sector in particular), and national and international communities. While the increasing frequency and intensity of weather-related hazards share part of the responsibility for this emergence, it is also attributable to the increased exposure and vulnerability of communities. Factors contributing to this vulnerability and exposure arise from human choices, and therefore, may be mitigated by strategic planning. These are detailed in section 4.

e. Disaster Mission Applications

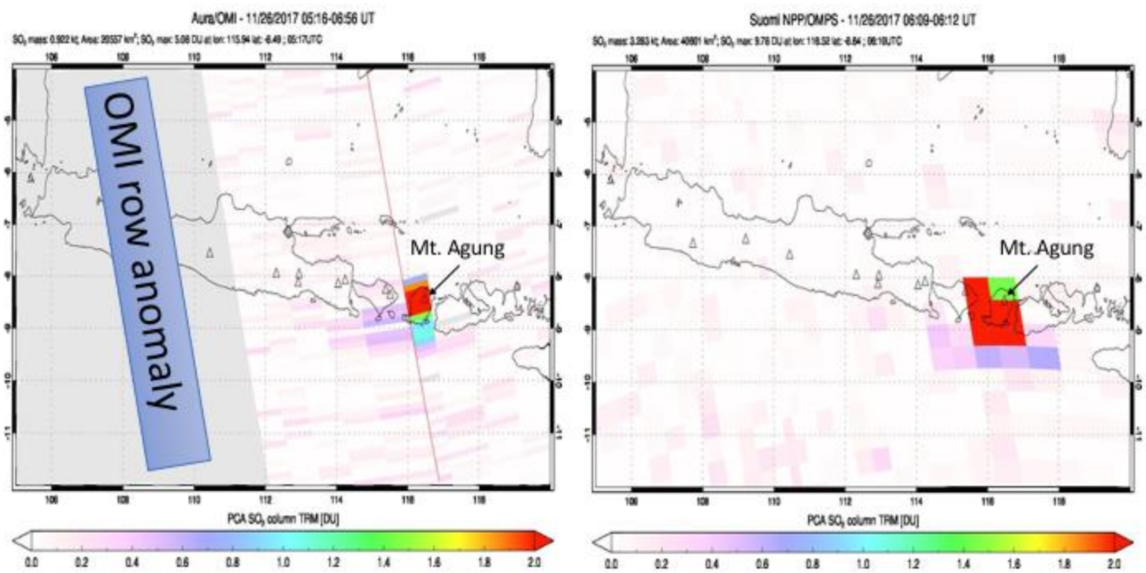
Until a new mission applications paradigm was promulgated Applied Science Program area managers were assigned as Program Applications (PA) leads with applications development readiness responsibilities for upcoming NASA Earth Science satellite missions. These were generally performed by a deputy (DPA). Four NASA Missions have been assigned to the Disasters Program to date. These are detailed in section 5.

- The Cyclone Global Navigation Satellite System (CYGNSS) Mission launched December 15, 2016. Primary Investigator (PI) Christopher Ruf, University of Michigan. DPA John Murray, NASA LaRC.
- The NASA ISRO Synthetic Aperture Radar (NISAR) Mission 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) Mission scheduled for launch in 2022. PI Bill Blankenship, MIT Lincoln Laboratory. DPA Brad Zavodsky, NASA MSFC.
- Lidar Surface Topography (LIST). Tier 3 Decadal Survey mission remains in concept design phase. DPA David Harding, NASA GSFC.

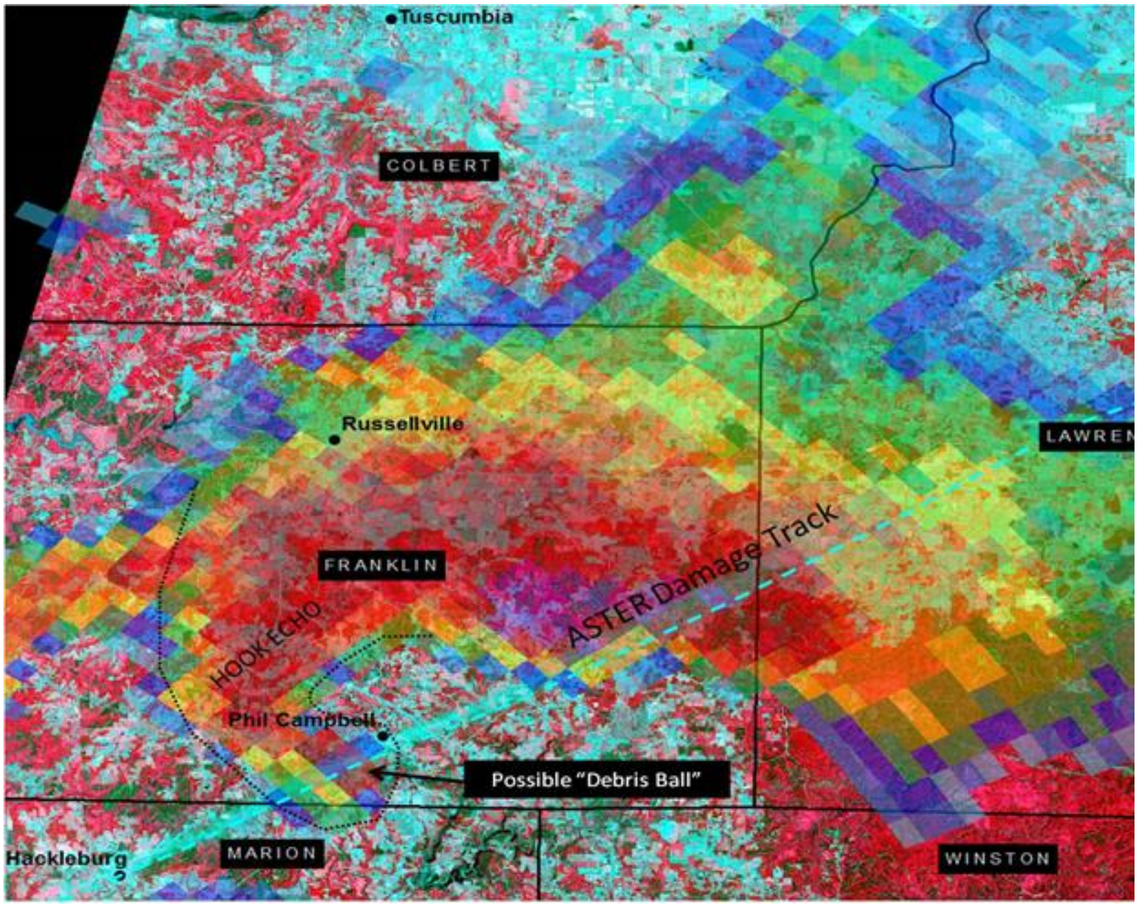
II. Disasters Research Project Portfolio for 2017

f. Real-Time Volcanic Cloud Products and Predictions for Aviation Alerts

Volcanic eruptions can inject significant amounts of sulfur dioxide (SO_2) and particulate matter (ash) into the atmosphere, posing a substantial risk to aviation safety. NASA volcanic NRT products from the Aura/OMI and Suomi/NPP/JPSS OMPS UV sensors can be currently accessed through a NOAA operational volcanic SO_2/ash web site to inform global Volcanic Ash Advisory Center advisories. Such daily volcanic SO_2 (VSO_2) maps are automatically created at NASA's Atmospheric Chemistry Processing System (ACPS) for volcanic regions worldwide (https://so2.gsfc.nasa.gov). Both OMI and OMPS NRT VSO_2 data are injected into multi-satellite European Support to Aviation Control Service (SACS): http://sacs.aeronomie.be/ (link is external). OMPS Direct Readout VSO_2 data also available for local processing by users worldwide (e.g., http://sampo.fmi.fi/volcanic.html (link is external)) supported by NASA Direct Readout Laboratory's International Polar Orbiter Processing Package (IPOPP): https://directreadout.sci.gsfc.nasa.gov/ . This project achieved an ARL (Applications Readiness Level) of 8 and was given a no-cost extension until the end of 2018 to completed transition to operations and achieve its goal ARL of 9.

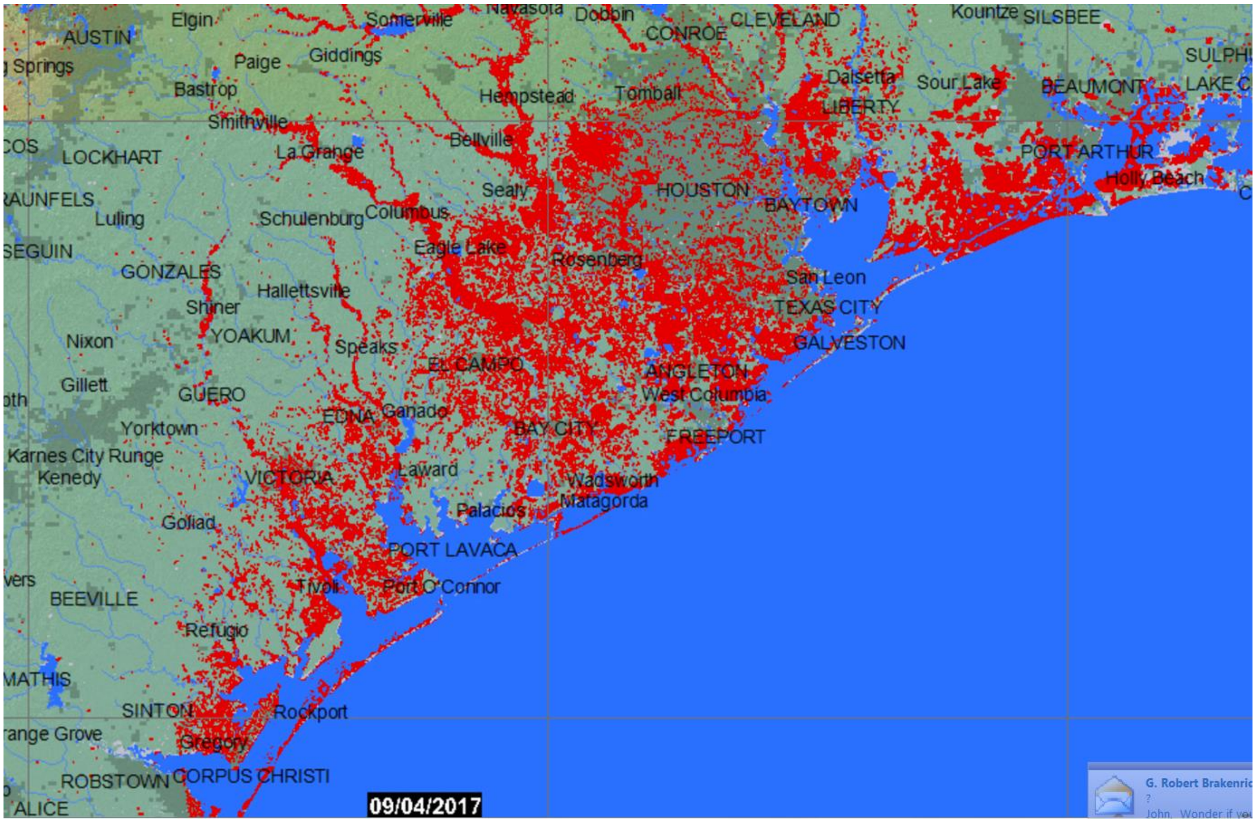


g. Enhancement of the NWS Storm Damage Assessment Toolkit with Earth Remote Sensing Data



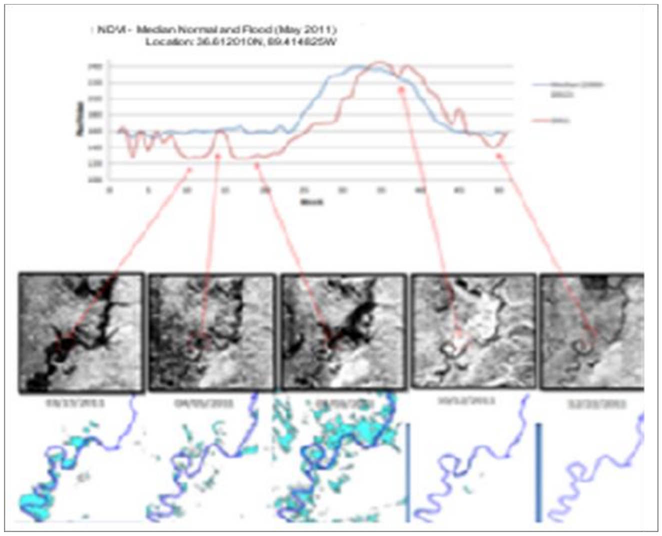
This Storm Damage Assessment project incorporates Earth remote-sensing imagery from NASA/NOAA and commercial satellites into the NOAA/NWS app used in severe weather damage surveys to complement ground-based assessments by NWS meteorologists. The team has successfully integrated Earth remote-sensing products and demonstrated with partners how the imagery can be of high value for refining tornado and other damage surveys used by downstream partners and other scientists. They've built new partnerships within the NOAA/NWS Training Division, folded their work into upcoming NWS Directives for the damage survey process, and increased visibility for the use of remote sensing by participating in committees developing EF-scale refinements. Success has led to other partnerships with UAF, USGS, and others, and valuable experience in R2O has spinoff value in Disasters Program collaborations with FEMA and National Guard. Final report was received 5/30/2017, however, it was updated and res-submitted on 10/25/2017 to reflect achieving the project goal ARL 9.

h. Near Real Time Flood Inundation Prediction and Mapping for the World Food Programme



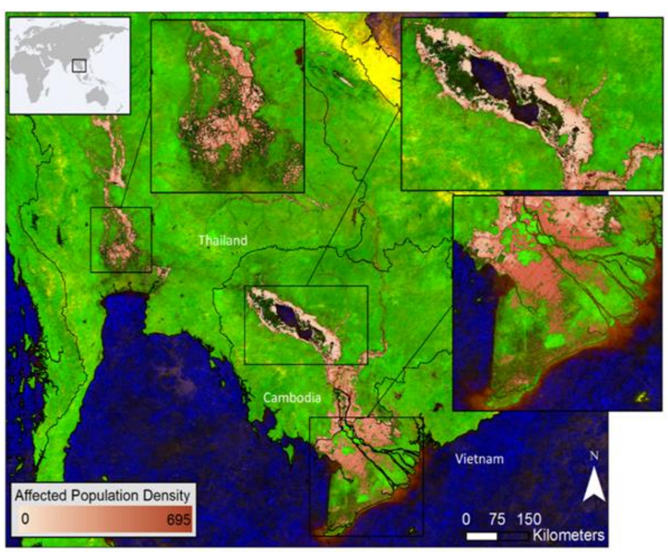
This figure illustrates Sentinel 1 SAR, and MODIS, GIS (.shp) files which were widely used by the media via this flood observatory project to illustrate flooding from Harvey (red area in attached screen shot). The World Food Programme, WFP is the world's largest disaster response organization, and the U.S. Government is its largest donor ($1.2 billion USD, 2011, out of the total budget of $3.1 billion). The project is transitioning four NASA-related flood data products to operational use by end users, who include a major international geospatial data consortium (the GeoSUR project, funded by the Development Bank for Latin America) and, for disaster preparedness and response, the World Food Program (WFP). Other end users (the World Bank, UN FAO) are also connected. This project has achieved and ARL of 7, and a no-cost extension has been granted to reach ARL 9 while aligning the project with a NASA GEO Flood project awarded this past fall.

i. A Remote-sensing-based Flood Crop Loss Assessment Service System (RF-CLASS) for Supporting USDA Crop Statistics and Insurance Decision Making



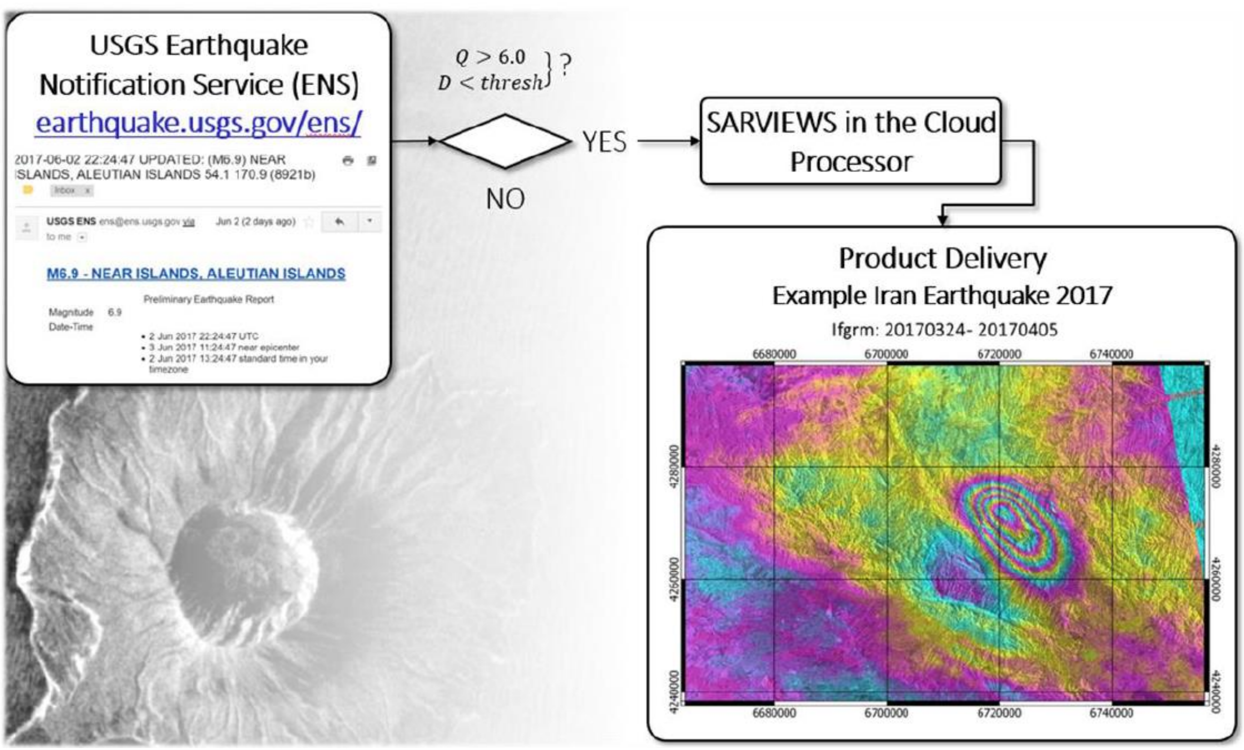
RF-CLASS improves the objectiveness, timeliness, and accuracy of flood-related decision making at USDA/NASS and USDA/RMA through a web-based service system (RF-CLASS) using Earth observations from multiple NASA and non-NASA sensors. The prototype system is fully integrated and tested with USDA. All modules have been validated except the crop area product, so a no-cost extension has been granted to explore substitution of higher fidelity data than MODIS Flood Mapping.

j. Enhancing Floodplain Management in the Lower Mekong River Basin Using NASA Vegetation and Water Cycle Satellite Observations



MODIS observations, together with socioeconomic and historical flooding data, are being used by regional stakeholders to rapidly identify floods and associated impacts to people and infrastructure in near real-time in the Lower Mekong region. Delivered Land Use Land Cover (LULC) product for six of eight basins to Mekong River partners. Also integrated operational flood inundation product. The project is complete and has obtained its goal ARL of 8.

k. SAR-VIEWS: SAR Volcano Integrated Early Warning System
Volcanic eruptions are among the most significant hazards to human society, capable of triggering natural disasters on regional and global scales. Recent eruptions also indicated their potential to disrupt air traffic and cause significant damage to the global economy. Optical and thermal imagery is currently used to identify precursor signals, detect eruption plumes/clouds, and map lahars and lava flows. For many areas, remote sensing is the only source of information for determining a volcano s pre-eruptive activity and coordinate responses to volcanic eruptions. However, the presence of clouds and a dependence on solar illumination are limiting the performance of current systems. This project advances the accuracy and reliability of volcanic hazard mitigation through the addition of spaceborne radar to AVO's operational monitoring.



The project has also fully automated the SARVIEWS production chains for seismic and volcanic hazards by integrating SARVIEWS with the USGS earthquake notification service (ENS) and the USGS eruption alert system. SAR based early warning has thus been fully integrated by USGS, Volcanic Ash Detection, Avoidance, and Preparedness for Transportation (V-ADAPT), Inc., and the Alaska Satellite and has provided the basis for recently implementing a major Disaster Community SAR Portal at the Alaska Satellite Facility /NASA SAR DAAC which greatly expands global scientific and operational use off the data and applications. The project is complete and has obtained its goal ARL of 9.

l. Deformation monitoring of volcanoes in the Caribbean and Latin America using ALOS-PALSAR and Sentinel-1 interferometry

PI: Falk Amelung

Multi-sensor SAR data are used for ground deformation monitoring of Latin American volcanoes with the aim of detecting subsurface magma accumulation under active volcanoes (current emphasis: Ecuador). In addition to analyses of a number of volcanoes including Cotopaxi and Guangua Pincha, this project has also developed a software system for processing and displaying Sentinel-1 SAR interferograms in order to expedite research. This project was funded based on a proposal to the ROSES GEOIM 2010 call for three years starting in 2014 and is being continued into 2018 with a no-cost extension in order to continue student support and further develop automated processing.

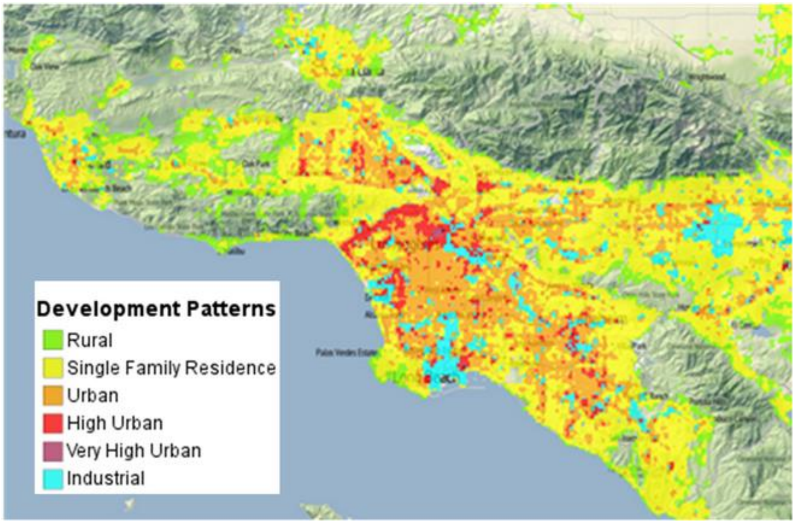
m. SAR-VIEWS Real-Time GPS/Seismic Displacements to Improve Disaster Management and Decisions

PI: Yehuda Bock

Using Earth science data to enable decision making for targeted end users by integrating in situ seismogeodetic observations into engineering practice for improved structural health monitoring and damage prognosis. The project is developing protocols for effective transmission of information from researcher to users such as Caltrans and Offices of Emergency Services to guide preparedness, mitigation and response. The project has integrated monitoring equipment in the Theodore Geisel Library at UCSD and is working with facilities to provide information in the case of an earthquake. They have also instrumented a parking garage with partners at Universidad Autónoma de Baja California, Ingeniería Civil. The project reached an ARL of 6 with prototypes installed in an operational environment and is at the cusp of ARL 7 at UCSD. In addition, their hard work transferring their algorithms and encouraging seismogeodetic data use at the NOAA Tsunami Warning Centers (TWCs) may result in the adoption of this unique data stream into an operational environment.

n. Developing global building exposure for disaster forecasting, mitigation, and response

PI: Ron Eguchi



This project addresses the Applied Sciences Program goal of integrating Earth science data and information for disaster forecasting, mitigation and response, specifically by delivering EO-derived built environment data for use in CAT models and loss estimation tools. CAT (catastrophe) models and loss estimation tools are essential for assessing risk from natural disasters and pricing insurance products, but these tools depend on GIS databases to characterize building exposure. This project has achieved an ARL of 8 and has fully demonstrated in relevant environment (re-insurance industry). Work completed for World Bank. They have been given a no cost extension and additional funding to develop exposure maps for Los Angeles basin and other U.S. metro areas to support the Disaster Program response efforts.

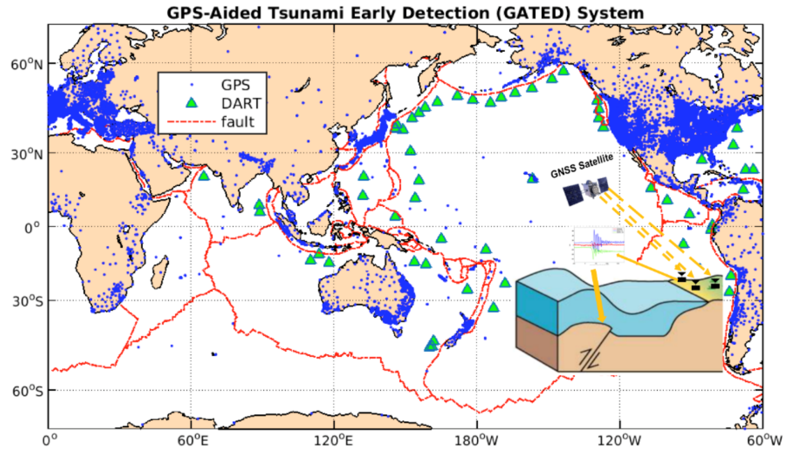
o. Disaster Response and Analysis Through Event-Driven Data Delivery (ED3) Technology

PI: Sara Graves

ED3 provides a cyber framework to facilitate the execution of user or system defined data processes in response to the real-time notification of disaster events, supporting any type of data process in response to any type of event. The framework supports an API that supports the addition of loosely-coupled, distributed event handlers and data processes. This approach allows the easy addition of new events and data processes so the system can scale to support virtually any type of event or data process. REACT (Rapid Event Album CollecTions) is an ED3 demonstration web application that provides a user the ability to subscribe to data processes (data access, model execution, product generation, sensor tasking, social media filtering, etc.) and define what type of event should trigger the execution of the subscription. The ED3 team has worked closely with the ESIP Federation and installed a prototype at the GHRC Innovation Lab advancing their system to ARL 7.

p. GPS-Aided and DART-Ensured Real-time(GADER) Tsunami Early Detection System

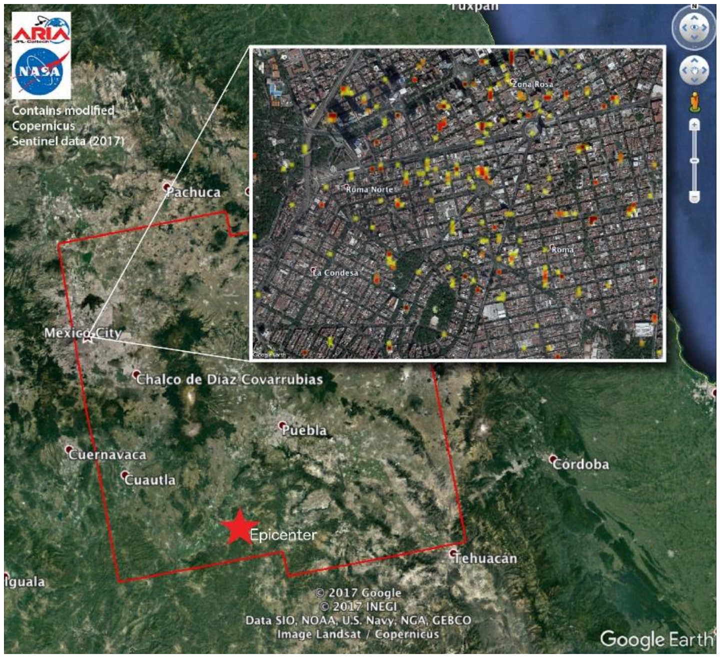
PI: Tony Song



The project exploits NASA real-time GPS data to enable more accurate and timely assessment of the magnitude and structure of earthquakes, as well as the magnitude and direction of resulting tsunamis. We combine GNSS information with NOAA's DART buoys in order to provide early forecast and warning and early cancellation of tsunami warnings to avoid unnecessary false alarms. Algorithms and real-time GNSS data from this project are being used as part of our demonstration project with the NOAA National and Pacific Tsunami Warning Centers. This work has reached an ARL of 7, but should advance to ARL 8 during a no-cost extension continue the work with NOAA.

q. Damage Assessment Map from Interferometric Coherence

PI Sang-ho Yun



This project develops algorithms to produce reliable damage detection maps of natural disasters using Interferometric Synthetic Aperture Radar (InSAR) coherence, which will guide decision making, disaster assessment, response and recovery activities of international, federal, state and local agencies, including the World Bank and USGS. The Damage Proxy Maps (DPM) produced by this projects have been among our most prolific, requested, and useful response products. Initially developed for earthquake damage, the they have been responsive and produced much needed flood response products, as well. This capability is not specific to a particular InSAR sensor and will be ready for NISAR when launched. The project has been given a no cost extension into fiscal year 2018 to continue support for a post-doctoral fellow and further develop their algorithms and automation.

III. 2017 Disaster Response

The Disasters Program, within Applied Science, supports Earth Sciences within the Science Mission Directorate (SMD) which along with all of NASA, is non-operational. The Program's focus is to apply the appropriate methods of science 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 has updated its activation criteria to ensure that response efforts have maximum impact, considering the amount 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 if NASA can or should respond or support an event, as well as what level of support is warranted. This response tier structure continues to evolve, and is thus still considered to be draft language.

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 if 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: 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 Associate Administrators.

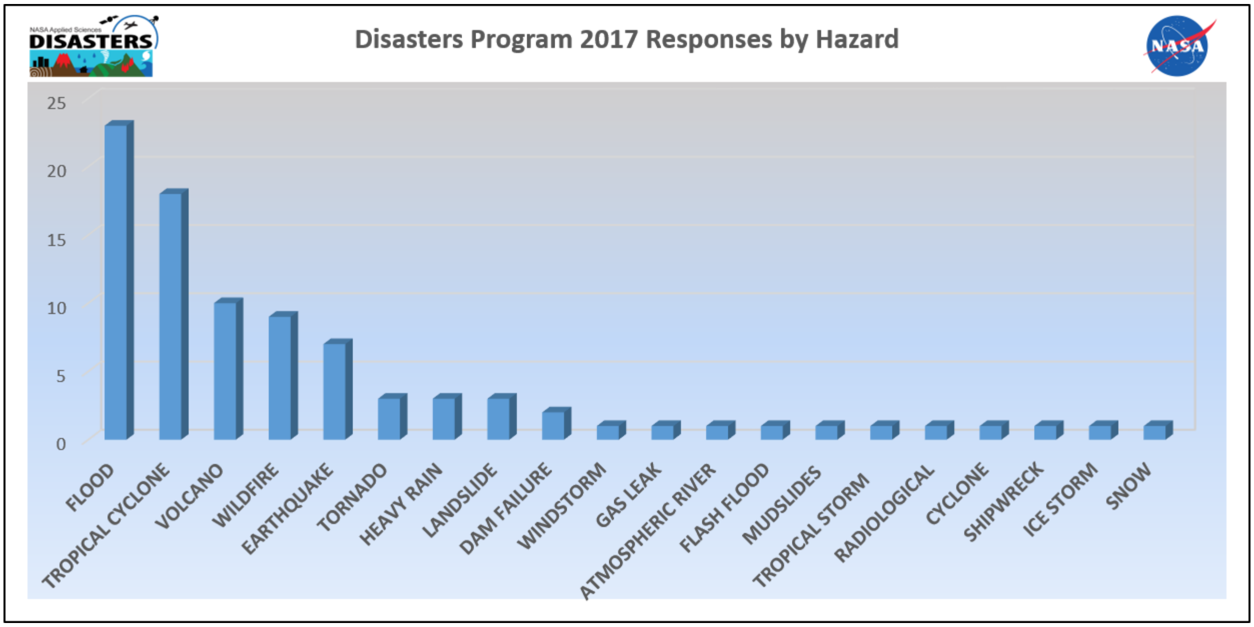


Figure X. Flood, Tropical Cyclone, Volcano, Wildfire and Earthquake constitute the most frequent Program hazard responses.

The Disasters Program responded to 89 events in CY17. These responses included 20 unique hazard categories which developed into disasters based on their impacts to human infrastructure. Flood events were the most common hazard, accounting for 23 of the 89 Program responses. Tropical cyclone responses occurred 18 times, while there were 10 volcano-related responses and 9 separate wildfire responses. Additional information regarding specific event responses conducted in CY17, including examples of data provided to end users, can be found on the Disasters Program website.

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IV. Disasters Resiliency

Communities and Areas at Intensive Risk (CAIR)

It is widely accepted that natural hazards do not create disasters without human risk and exposure. In other words, humans and human institutions can contribute greatly to their own risk—and to their protection—from disasters. Remote sensing has become invaluable in hazard monitoring, mitigation, disaster response, and recovery. Providing heightened awareness of risk and vulnerability through improved understanding of communities, key infrastructure (e.g., oil and gas pipelines, roads and highways, bridges, electrical grids and networks, and hospitals), and the climate-related processes that contribute to risk can strengthen and support community-level interventions.

Data is not the same as information, nor does understanding of processes necessarily translate into decision-support for hazard mitigation, disaster preparedness, response, and recovery. Accordingly, NASA is engaging the scientific and decision-support communities to develop community groups focused on applying remote sensing, modeling, and related applications in areas at intensive risk. These areas include coastal regions vulnerable to coastal erosion, sea-level rise coupled with land subsidence, severe storms, earthquakes and tsunamis; mountainous regions that expose communities to unstable landscape elements such as flash flooding, landslides, and glacial movements; and small island regions that face sea-level rise, tropical cyclones and storm surge, and subsidence. Provided below are short descriptions of each CAIR project and associated region, along with the overarching programmatic goals and relevant actors.

Coastal Regions:

Sea-level rise, severe storms, subsidence, earthquakes, and tsunami risks are complex hazards to coastal landscapes. Presently, approximately 200 million people worldwide live along coastlines less than five meters above sea level. These populations and related economic activities are exposed to low- to mid-frequency events, but of particularly high severity. For example, though hurricane impacts to the U.S. coastline are relatively uncommon (compared to, for example, tornadoes elsewhere in the U.S.), a single land falling hurricane brings combined hazards of heavy rainfall, flooding, destructive storm surge, and high winds that impact a large area. Vulnerable persons and property in these areas may be subject to catastrophic disaster impacts with high mortality and asset loss. Two demonstration projects exist to represent the distinct characteristics of risk for coastal regions, with exposure and vulnerability reflected along various continental coastline areas, one focused on the mid-Atlantic and the other on the U.S. Pacific coast.

The mid-Atlantic CAIR project demonstrates the ability to integrate satellite-derived Earth observations and physical models into actionable, trusted knowledge. Severe storms and associated storm surge, sea-level rise, and land subsidence coupled with increasing populations and densely populated, aging critical infrastructure often leave coastal regions and their communities extremely vulnerable. The integration of observations and models allow for a comprehensive understanding of the compounding risk experienced in coastal regions and enables individuals in all positions make risk-informed decisions. This team uses a representative storm surge case as a baseline to produce flood inundation maps. These maps predict building level impacts at current day as well as for SLR and subsidence scenarios of the future with the intent of informing critical decisions. The next step in the process is to compare physical model output to current remote sensing capabilities in order to understand where predictions can best be improved and work with policy-makers to determine when predictions becomes actionable. Looking to the future, the team can then begin developing methodologies and applications for advanced remote sensing capabilities such as SAR and Lidar. Current team members include Virginia Institute of Marine Science, George Mason University, Hampton University, the University of Alabama and Old Dominion University.

The Pacific CAIR project uses coastal Global Positioning System networks to infer seafloor displacement due to large earthquakes. Rapid observation of these displacements will improve understanding of the power and scale of a potential tsunami to guide emergency warnings before they reach coastal areas. The initial phase of this project tested successfully on two independent platforms, and received confirmation of the feasibility and reliability to offer the best solution for early detection. Future actions include engagement with local stakeholders and demonstrations of the applicability of these geospatial tools by emergency managers and other decision-making agencies. Promotion of the access and availability of this data also needs to occur, along with potential for testing, and integration into planning and program management.

Multiple locations are included in the Pacific region scenario – Cascadia: coastal regions of California, Oregon, and Washington, Hawaii, and Alaska. To date, this team is comprised of actors from NASA: Jet Propulsion Lab, Scripps Institute of Oceanography, Central Washington University, University of Washington, and University of Oregon, and National Oceanographic and Atmospheric Administration: both the Pacific and National Tsunami Warning Centers. Immediate next steps for this team are to: 1) determine a specific region to focus activities, and 2) increase the network of partners and stakeholders to ensure end-user integration of these activities into regular activities.

High Mountain Regions:

High mountain areas, glaciers, rocks, and permafrost exist in various configurations of unstable landscape elements (e.g., landforms, bedrock, debris, and water bodies) often located near vulnerable human populations and infrastructure. This project intends to integrate satellite remote sensing with ground data to increase the knowledge and understanding of hazards in high mountain areas due to atmospheric and Earth-surface dynamics.

This team will focus on four key regions: Cascadia, Alaska, the Northern Andes, and Himalayas. While the physics of hazardous events may be similar, the geography is different; therefore, knowledge gained in one region may not be readily applicable elsewhere. For example, glacial surges or advances often trigger glacial lake outburst floods in Alaska; however, in the Himalayas, landslides or glacial calving into lakes, or piping through glacial or ice-cored moraine dams are the primary triggers. For this reason, improved representation of glacier boundary conditions in numerical modeling, better characterization of thermal conditions, interactions with subglacial material, and knowledge of subglacial plumbing are required to understand these hazards.

Transferring knowledge of these landscapes and intensive risk scenarios requires collaboration, establishing trust between scientists and emergency managers, exchange of expertise and understanding, and collaborations focused on local community actors and emergency planners. This demonstration will include selection of a pilot location, determining the needs and vulnerabilities of the pilot area by working with local actors, and developing ensemble approaches (i.e., the use of multiple data from satellites and sensors) needed to identify and address the risks associated with this region.

Small Island Regions:

This project is in the research phase. Focus areas under consideration include Puerto Rico and the U.S. Virgin Islands, and the Federated States of Micronesia. This project seeks to characterize the risks from tropical cyclones, earthquakes, volcanoes, and tsunamis to low-lying communities often isolated and have limitations in their economic and distributive capacities. Possible concepts include the use of Data Cubes—a data processing platform for Earth science data with a focus on remote sensing—and case studies reflecting on efforts in reconstruction and recovery.

V. Disasters Mission Applications

a. The Cyclone Global Navigation Satellite System (CYGNSS) Mission launched December 15, 2016. Primary Investigator (PI) Christopher Ruf, University of Michigan. DPA John Murray, NASA LaRC.

For mission applications, the highlight of 2017, was a CYGNSS Applications Workshop conducted from October 31 through November 2 in Monterey, Calif. This workshop was convened post-launch with four primary objectives:

a. Mission status update with a summary of routine and major operations and observations. This was delivered by the mission PI, Dr. Chris Ruf, University of Michigan.

b. Applications community engagement to provide opportunity to fully develop applications science and data assimilation for CYGNSS observations. This first entailed a review of applications development projects that were awarded to extended CYGNSS Science Team members via NASA ROSES solicitations. Many of these projects focused on applications concepts identified in a June 2015, a pre-launch applications development workshop in Silver Spring, Md., whose plenary and breakout sessions identified applications related to tropical cyclones, large and small scale tropical and non-tropical oscillations, terrestrial applications such as soil moisture detection and water mapping, oceanographic applications for ocean currents and wave modeling, and data assimilation considerations related to all of these phenomena. The extensive report from the 2015 pre-launch workshop report including detailed Applications Traceability Matrices is still available for review here. Other new and innovative applications projects such as ocean surface topography and tsunami detection were also reviewed at the Monterey workshop.

c. End-user community engagement to address the development of specific applications for CYGNSS observations. This entailed breakout sessions to narrow down and prioritize the full spectrum of thematic applications using the three unique classes of CYGNSS data:

- (Level 1 Oceanic DDM's) Raw Delay Doppler Maps for direct assimilation into weather and ocean models
- (Level 2 and 3 Winds) Un-gridded and gridded oceanic surface wind speeds used for wind, weather, oceanographic and hybrid applications

- Terrestrial Level 1 data for soil moisture, surface water and wetland mapping

d. Broad stakeholder engagement to address issues such as data latency and the complementarity of CYGNSS with current and future satellite and non-satellite missions. This began with the inclusion of complimentary missions (SMAP and TROPICS) and focused on affiliating and leveraging the applications efforts for those missions. The SMAP PI, Dara Entakabi, also presented a targeted presentation proposing to use CYGNSS to fill key data gaps for his mission and to work with the CYGNSS applications team to cross-pollinate towards this end, and to share applications development expertise. The workshop also focused on improving small sat applications paradigms in general with a superb industry panel conducted for that purpose.

Now that the CYGNSS constellation is in orbit, collecting data and producing science data products, exciting new opportunities and some challenges have arisen to realize the full applications potential of the mission. A critical challenge is the production and validation of the primary mission data set – oceanic surface wind fields for hurricane forecast improvement (and the majority of the many other applications identified in both workshops). At the time of this writing, the CYGNSS science team continues its attempt to decouple the combined wind and wave signal in the data. Until this is accomplished, wind values over 12 m/sec (25kt) are not yet accurate. Unless this is resolved, it will hamper the ability of most CYGNSS applications to advance beyond Applications Readiness Level (ARL) 3 – proof of applications concept. Due to this, alternate strategies for weather (especially hurricane) and oceanography model assimilation such as direct assimilation of the raw data are being explored. Despite this, very promising results for the terrestrial and ocean applications continue to bear fruit. Further details are available in the second workshop report, on a separate tab/link on the CYGNSS Mission webpage. 2018 plans are to expand applications developer and stakeholder engagement through that dedicated applications page and to document further results and advance quarterly applications team meeting actions.

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

In 2017, the NISAR application team worked with the NISAR project to reduce the planned latency of Level 2 products, since many applications users value lower latency data. The NISAR application team engaged with decision makers and end users through several types of activities. The NISAR team held its first two application area-focused workshops. The first, a workshop on critical infrastructure organized jointly with the Department of Homeland Security, found that routine monitoring is the primary game-changing value of NISAR for both their strategic and tactical information needs. The second, a workshop on ocean applications organized jointly with the National Oceanic and Atmospheric Administration, found that NISAR data will be very important for sea ice characterization, and defined the regions and observation modes most important for that application. The reports for these two workshops are available on the NISAR applications page (https://nisar.jpl.nasa.gov/applications/). Lead by the Applications Co-Lead Cathleen Jones, the NISAR Science Team developed 20 application specific information sheets that describe the applications value of SAR and NISAR, also available on the NISAR applications webpage. A special session on NISAR was organized and held at the Society of American Foresters, which started a discussion with the forestry community that will continue in at the 2018 workshop. The NISAR applications team also finished drafting the NISAR Utilization Plan, a plan for activities that will increase the utility of NISAR data before launch in 2021.

In 2018, the NISAR applications team will continue to engage with different application communities at workshops and professional meetings, as well as convening an Urgent Response Working Group, and conducting feasibility studies and demonstrating proof of concept of SAR for different applications. There are two workshops scheduled for June (Forests and Disturbance Applications, and Agriculture and Soil Moisture Applications) and two workshops being planned for the fall (Wetlands Applications and Landslide Applications). The Urgent Response Working Group will help inform the NISAR project on how to meet the NISAR Level 1 urgent response capability requirement. Lastly, four feasibility studies will be conducted in coordination with NASA DEVELOP for the: 1) Federal Emergency Management Agency (FEMA), 2) National Wetlands Inventory (NWI), 3) USDA Agricultural Research Service (USDA ARS), and 4) Bureau of Land Management (BLM).

c. Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats (TROPICS) Mission scheduled for launch in 2022. PI Bill Blankenship, MIT Lincoln Laboratory. DPA Brad Zavodsky, NASA MSFC.

The primary accomplishment for the Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats (TROPICS) mission in 2017 was the convening of the First TROPICS Applications Workshop in Miami, Fla., on May 8-10. The meeting consisted of panel discussions, invited presentations, and breakout discussions to begin formulating a set of potential application areas related to the mission data. Quarterly applications teleconference calls were initiated in the third quarter of 2017 to continue user engagement related to mission updates and new application areas. The workshop produced a report summarizing the outcomes of the meeting, which included specific targets for the temporal resolution (threshold: less than 3 hours; optimal: less than 1 hour) and data latency (threshold: less than 3 hours; optimal: less than 1 hour). These design requests from the applications community were used as part of the mission preliminary design review. The report also summarizes key application areas in four categories: terrestrial, analysis and nowcasting, modeling and data assimilation, and tropical dynamics. The report can be viewed here. The applications team also produced an article for the NASA Earth Observer, which was featured in the November/December 2017 issue and can be viewed here. An applications-focused website was launched in December.

In 2018, the focus will remain on recruitment of new applications users and the start of user engagement through the dissemination of proxy data products from the mission. Quarterly calls with the growing applications community will continue in 2018. Early in 2018, two MicroMAS-2 satellites—the instrument used by TROPICS—will be launched. These instruments, along with a hurricane nature run, will allow the mission science team to produce a set of proxy data products by the end of the year. The applications website will be updated and integrated into the primary TROPICS mission website with new features and articles highlighting groups working with TROPICS on applications. To fill in these details, the mission plans to start an Early Adopter (EA) program to formalize the participation of specific end-user groups for using TROPICS data as part of their activities. This list of EAs will drive the list of known/trusted users for obtaining the proxy data described above. The goal is to have a list of known users with proxy data in hand by the end of 2018 in order to host a Second TROPICS Applications Workshop early in 2019. In addition to work with end users and proxy datasets, the TROPICS mission plans to continue conversations with management from NASA and the National Oceanic and Atmospheric Administration (NOAA) on solutions to reduce data latency for the mission in order to improve user application.

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

VI. Appendix

A. Abbreviations and Acronyms

ARL: Application Readiness Level
AVO: Alaska Volcano Observatory
CAIR: Communities and Areas at Intensive Risk
CALIOP: Cloud-Aerosol Lidar with Orthogonal Polarization
CALIPSO: Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations
CAT: catastrophe
CY: calendar year
CYGNSS: Cyclone Global Navigation Satellite System
DART: Deep-ocean Assessment and Reporting of Tsunami system
DAT: Damage Assessment Toolkit
DHS: Department of Homeland Security
DoD: Department of Defense
DOT: Department of Transportation
DPM: Damage Proxy Maps
EA: Early Adopter
EC: European Commission
ED3: Event-driven Data Delivery
EOS: Earth Observing System
ESA: European Space Agency

ESIP: Federation of Earth Science Information Partners
FEMA: Federal Emergency Management Agency
GADER: GPS-Aided and DART-Ensured Real-time
GEO: Group on Earth Observations
GPM: Global Precipitation Measurement
GPS: Global Positioning System
GSFC: Goddard Space Flight Center
HQ: headquarters
InSAR: Interferometric Synthetic Aperture Radar
JPL: Jet Propulsion Laboratory
LaRC: Langley Research Center
LIST: Lidar Surface Topography
LULC: Land Use Land Cover
MODIS: Moderate Resolution Imaging Spectroradiometer
MSFC: Marshall Space Flight Center
NASA: National Aeronautics and Space Administration
NISAR: NASA ISRO Synthetic Aperture Radar
NOAA: National Oceanic and Atmospheric Administration
NPP: National Polar-orbiting Partnership
NRT: near real-time
NWS: National Weather Service
OMI: Ozone Mapping Instrument
OMPS: Ozone Mapping Profiler Suite
PI: principal investigator
RF-CLASS: Remote-sensing-based Flood Crop Loss Assessment Service System
ROSES: Research Opportunities in Space and Earth Sciences
SAR VIEWS: SAR Volcano Integrated Early Warning System
SAR: Synthetic Aperture Radar
SMAP:
SMD: Science Mission Directorate
SPoRT: Short-term Prediction Research and Transition
TROPICS: Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats
TWSC: Topical Workshops Symposia and Conference
USDA: United States Department of Agriculture
USGS: United States Geological Survey