Disaster Response
from a NASA Perspective

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Silver Jackets Interagency Flood
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What is the NASA Earth Science Disasters Program?

- Utilizing the various NASA centers and their resources, a robust response program has been assembled to respond to various disasters worldwide
  - Meteorological (hurricanes, tornadoes)
  - Hydrological (heavy rain/flood)
  - Geophysical (earthquakes, volcanoes)
Approach and Principles of the Disasters Program

- **Global to Local Reach on Extreme Events**
  - Tiered Mobilization
  - Best effort following hazard-based playbooks
- **Harvesting and Exploiting Data**
  - NASA and Non-NASA data and processing systems
  - Infrastructure and natural resource impact maps and models
  - Near real-time and direct readout data/product access and visualization systems
  - Geospatial platform, GIS and web services
- **Convergent and Integrated Research**
  - Basic and applied, technology and flight
- **Human Capital**
  - Center coordinators, Event Leads, and Engagement
  - Integrated workforce of scientists, technologists, communication and emergency management specialists
  - Principal Investigators, Users, and Volunteer Networks
  - Partnerships
Challenges in Responding to Harvey, Irma, and Maria

• **The Challenge:**
  - Hurricanes Harvey, Irma, and Maria presented unique challenges, needs, and opportunities for end-user engagement
  - Playbooks used to provide continued support from late August through early October
  - Uniform coordination with end-user partners:
    - FEMA, National Guard Bureau, USAID Office of Federal Disaster Assistance, USGS/HDDS
  - NASA Event Leads at Marshall Space Flight Center worked with other NASA Centers, scientists, and partners to coordinate response efforts.
    - *Multiple daily interagency calls 24/7, provided support to end users, supported by other scientists to publicize activities, and share science stories*

• **The Result:**
  - *Focused coordination with FEMA and the National Guard led to extensive use of NASA-provided information in response and recovery activities.*
Generated targeted and complementary products including:

- NASA and NOAA LEO and GEOsat imagery for storm monitoring and tracking and power outages.
- GPM and SMAP products showing precipitation and soil moisture needed for flood potential and rainfall quantification.
- Flood mapping, forecasting and damage assessment products based on VIIRS imagery and on satellite and airborne SAR data.
- Socioeconomic impact assessments based on composites of the above.
What is the situation?

Public and Media ask about event as well as role of NASA

Scientists, engineers and PA fielded interviews and print media on hurricane intensification and impacts
Hurricane Harvey Response Timeline

NASA Response and Engagement Timeline

Hurricane Harvey (Aug-Sept 2017)

Forecasts for Harvey identify impacts to U.S. mainland, NASA team activates for coordination calls, product generation, and end-user engagement.

NASA Response Tier

Day 0
August 23

Day 1
August 27

Day 2
August 27

Day 3
August 28

Day 4
August 30

Day 5
August 31

Day 6
September 1

Day 7
September 4

NASA’s GPM helps track Harvey with data provided to NOAA/NWS and NHC

Nighttime Lights: Tracking Power Outages
Houston, TX – Post-Harvey

Use of NASA Black Marble HD product to explore power outages during post-Harvey flooding

ALOS-2 Flood Proxy Map

NASA, NOAA, ESA, International Space Station, and Charter data used collaboratively to map flooding from SAR/optical

Modeling disaster impacts in Houston metro

Sentinel 1A ARIA Flood Proxy Map (Hurricane Harvey)

Numerous Flood Maps from NASA Teams

GPM maps the record-setting rainfall in SE Texas from Harvey

Increased flooding from 9/1-2

9/1/17

9/2/17

NASA team collaborations provide over a dozen detailed flood maps from SAR used by FEMA’s geospatial team

NASA provides daily flights of UAVSAR from September 1-4 to rapidly map evolving flood impacts
“I think we may have seen the future of flood response” - Gordon Wells, Texas Center for Space Research and Special Advisor to the TX Natural Disasters Working Group.

When and where will floods crest and risks change across 4 major river basins as waters drain to the Gulf? Where and when should action be taken?

NASA deployed UAVSAR over 4 days from base operations in Austin, TX, conducting local flights to fill information gaps and generated single channel quick-look products during flight and post-flight for state and local officials.
Flood Maps For Hurricane Harvey

Where is potential flood damage?

JPL’s Advanced Rapid Imaging and Analysis (ARIA) used Synthetic Aperture Radar from JAXA to create Flood Proxy Maps for Southeastern Texas that are likely flooded as a result of Hurricane Harvey.

August 27th

Products were posted and provided to FEMA, USGS, International Charter, and State of Texas.
Imaging Flood Retreat

Where are the risks from infrastructure failure and where do we stage relief efforts?

UAVSAR data and quicklook products were used by the Texas State Operations Center to:

- **Identify levee breaches** and levee over tops around small towns to direct evacuation and rescue efforts
- **Identify flooding in refineries**, to direct chemical spill response
- **Identify “dry spots” for relief agencies** to stage centers
Assessing Financial Loss Potential for Hurricane Harvey

Where and what is the extent of insured loss?

Disasters Program PI, ImageCat combined flood extent maps and depth information to create overlays with exposed property values in the flooded areas.

Products were provided to FEMA and the state of Texas to help estimate financial loss.
Night-time Satellite Data

What are the night-time conditions for Search & Rescue?

High resolution night time maps combined data from six satellites (Suomi-NPP, Landsat-8, Sentinel 2A & 2B, TerraSAR-X/TanDEM-X) to enable first-ever daily monitoring of affected areas at neighborhood scales (< 30 meters) for S&R.

Houston, TX - September 1, 2017
Hurricane Irma Response Timeline

NASA Response and Engagement Timeline

Hurricane Irma (Sept 2017)

NASA team initiates response in collaboration with end user partners focused on preparedness and recovery from Hurricane Irma.

Partners model likely flood and inundation impacts from Irma’s predicted rainfall.

Preliminary mapping of flooding in Key West via ESA Sentinel 1.

SAR damage proxy maps generated from ESA Sentinel 1 to identify changes resulting from Irma’s winds and flooding.

Before

After

Daily maps of nighttime lights to help understand power loss and recovery.

NASA team contributed numerous SAR/optical flood and damage maps to FEMA along with other ESA and commercial partners.

NASA Response Tier

Day 1
Sept 5

Day 2
Sept 6

Day 4
Sept 8

Day 6
Sept 10

Day 8
Sept 12

Day 9
Sept 13

Day 15
September 19

Continuing from Harvey, daily coordination calls and user engagement with partners including FEMA, National Guard, USGS and others.

GPM and constellation satellites provide mapping of Irma’s track through the Caribbean, data to NOAA/NHC, NRL.

Daily NASA LIS captures saturated soils and flooding in FL/SE.

ISS astronaut photography provides imagery of impacts in Caribbean/Florida.

GPM/IMERG rainfall product measures rainfall across the impacted area.
Monitoring Harvey and Irma Rainfall

What is the circulation? Where are the strong thunderstorms? Where is the rain maxima in the impacted areas of Texas, Louisiana and Florida?

Global Precipitation Measurement (GPM) provided products used by the National Hurricane Center, NOAA/NWS weather Forecast Offices, and NRL.

NASA imagery cited and used by the National Hurricane Center to help understand and describe the state of Irma as it moved north of Cuba and then over the Florida Keys and inland.
Where is substantial and damaging flooding expected?

Disasters Program PI at the University of Maryland provided results from the Global Flood Mapping System (GFMS), which uses NASA satellite-based rainfall (GPM) and other model information to predict river flows and resulting flooding (inundation).

GFMS guidance provided FEMA and other end users a rapid estimate of areas of concern and triggered actions.
Observing Damage from Hurricane Irma

Where is hurricane wind damage expected for Island nations and communities?

Natural-color images, from the Operational Land Imager (OLI) on Landsat 8, showed Irma’s effect on the U.S. and British Virgin Islands.

Imagery posted and made readily available informed restoration planners and ecosystem managers of likely defoliation of trees and related impacts.

Courtesy of NASA’s Earth Observatory:
Hurricane Maria Response Timeline

**NASA Response and Engagement Timeline**

**Hurricane Maria**  
*(Sept-Oct 2017)*

- **GPM and constellation satellites map Maria, data for NOAA/NHC and NRL**
- **Flood mapping by the NASA team using ESA and Charter SAR and optical assets**
- **Multiple flood-mapped scenes from NASA and commercial partners combined by FEMA to assess flood extent**
- **NASA Black Marble by National Guard teams for daily situational awareness.**

**NASA Response Tier 0**

- **Day 1**  
  Sept 18
- **Day 3**  
  Sept 20
- **Day 4**  
  Sept 21
- **Day 5**  
  Sept 22
- **Day 7**  
  Sept 24
- **Day 10**  
  Sept 27
- **Day 13**  
  Sept 30
- **Day 14**  
  Oct 2
- **Day 15**  
  Oct 3

**Daily:** FEMA Remote Sensing and Geospatial Teams incorporate NASA information into daily briefings and use analysis to understand recovery needs.

**NASA Black Marble HD captures Puerto Rico outages, used by partners and major media to keep public informed of local power conditions on neighborhood scales.**

**Damage proxy maps extended to Dominica using ESA S1 data**
Pinpointing Where Lights Went Out in Puerto Rico

(Sources: U.S. National Guard Bureau Analysts/S-NPP VIIRS)

The Solution: Routine distribution of pre-event (upper right) and post-event (center) nighttime scenes to the US National Guard Bureau team members assisted in their detailed analysis of power conditions and response activities.

- The Challenge: End-users highly value quantitative analyses, along with rapid assessments that can improve interpretation of outage conditions. Satellite products are more useful when science teams, and affiliated members, assist with guidance and interpretation.

- Unique Features: NASA’s Black Marble standard products combine “night vision” imagery with thermal infrared data; allowing for easy-to-interpret false color composites. Reduction of aerosols, air-glow, and moonlight contamination dramatically improves temporal coverage (from monthly- to daily updates.)
NASA's Integrated Multi-satellite Retrievals for the Global Precipitation Mission (IMERG) were used to estimate the total amount of rain that Hurricane Maria dropped from September 17 to early September 21, 2017.

During that period Maria dropped heavy rain in the Leeward Islands, Virgin Islands and Puerto Rico (PR).

- GPM rainfall accumulation products are provided routinely via R&A activities within SPoRT and were used to monitor rainfall amounts after the San Juan WSR-88D Doppler radar failed during Hurricane Maria.
- The International Red Cross used data from the UMD Global Flood Mapping System (GFMS) to determine potential flooding due to Hurricane Maria for parts of the southeast, northeast, and northern coasts of PR.
ARIA team flood and damage proxy maps using satellite SAR imagery.

ARIA flood map from SAR data acquired by the Japan Aerospace Exploration Agency’s ALO data using S-2 satellite.

The flood map, delivered to FEMA and the state of Texas, covered a wide area including Houston (and provided a synoptic cloud-free view, when Civil Air Patrol was limited by weather conditions, and no satellite optical sensors were able to image the area due to lingering clouds of Hurricane Harvey.

A damage proxy map of Puerto Rico devastated by Hurricane Maria was generated using SAR data from the Copernicus Sentinel-1 satellites (operated by the European Space Agency) and delivered to FEMA.

FEMA created a damage density map derived from the ARIA damage proxy map and multiple, other data sources and used DPM information to estimate damage and guide response and recovery activities.
NASA Disasters Mapping Portal

- Portal officially launched in March 2018
- Central location for finding disaster science
- Near Real-Time and event specific products and services
- Geo-enabled and easily discoverable, accessed and utilized by end-users in their own platforms.
- Capability to feed NASA data into other platforms, including FEMA geoportal
- will move NASA disasters data into the hands of end-users around the world.

Access the Portal at https://maps.disasters.nasa.gov
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