# Sizing Up Floods from Space
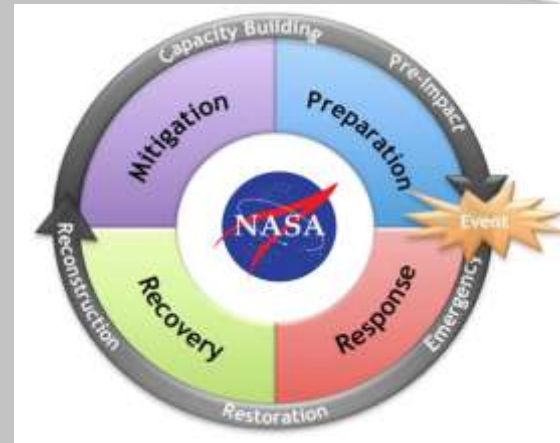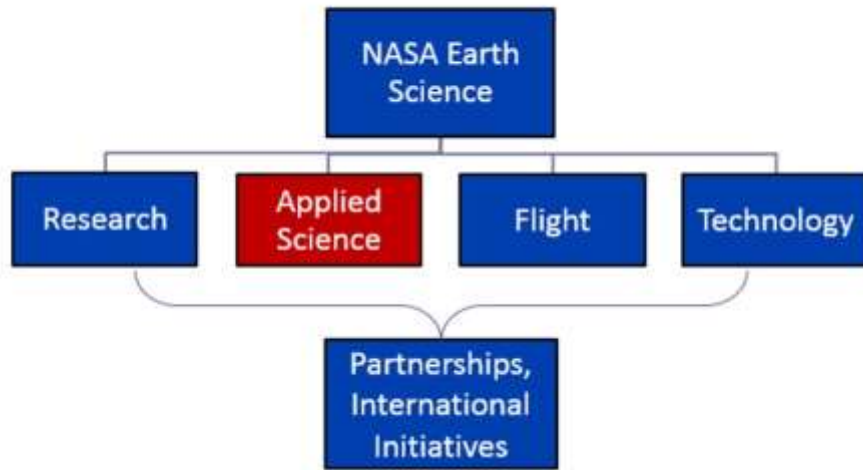
**J. Carver Struve, CFM, AEM, ABCP**
**Emergency Manager**
**Science Mission Directorate**
**Earth Science Division**

*Association of State Floodplain Managers*

*June 20, 2018*

*Phoenix, AZ*

# 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)*



**Assessment**

**Rapid Hazard Assessment Expected**

- Centers and program experts to contribute within scope of daily activity
- Guidance to elevate to Tier response, direct to research or no action
- Days

E.g.: media report

## Tier 1

**Response and Recovery Short Term and Best Effort**

- Centers and programs respond as available with only minor impact to existing/on-going activities
- Detailed assessment and products scaled to modest response
- Weeks to Month(s)

E.g.: Napa Earthquake (2014), Chile Earthquake (2015), Oklahoma tornadoes, yearly floods

## Tier 2

**Significant Contributions Over Extended Period**

- Contributions are considerable given continual assessment of size and scale of impact
- Personnel relevant to disaster type (s) expected, tasked, and assigned to support
- Data and products adapted into recovery
- Weeks to Month(s)

E.g.: Nepal Earthquake (2015), Deep Horizon (2010), Eyjafjallajökull Eruption (2015)

## Tier 3

**Disaster is of major national importance**

- All relevant personnel expected to review activities for level of support to the disaster and/or be on-call
- Assets and personnel may specifically assigned and tasked for lengthy time period (Months into recovery).

E.g.: Super Storm Sandy (2012), Hurricane Katrina (2005), September 11, 2001 attacks

# NASA Operating Missions

# 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
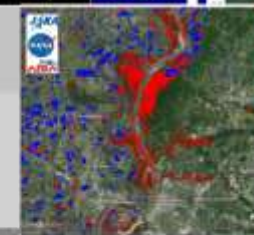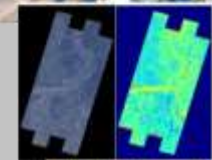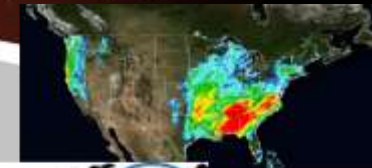
# Challenges in Responding to Harvey, Irma, and Maria

- *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.*
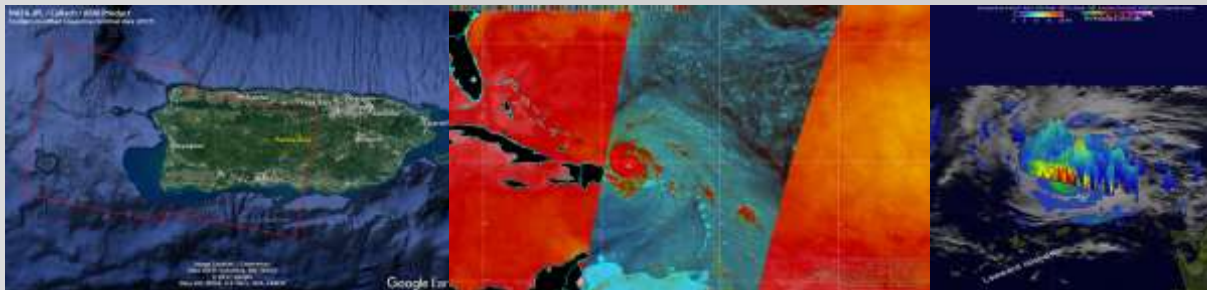
■ Generated targeted and complementary products including:

- 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.

BREAKING NEWS
FLURRY OF STORMS: A RESULT OF CLIMATE CHANGE? MSNBC
CATEGORY 3 | WIND SPEED 125 MPH | WIND GUSTS 155 MPH | DIRECTION/SPEED MOVING W @ 9MPH | 175 MILES SE OF KEY WEST

## 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



DEVELOPING STORY — 28 PEOPLE KILLED IN CARIBBEAN AFTER IRMA STRUCK — CNBC



OUR WEATHER-PREDICTION MODELS KEEP GETTING BETTER, AND HURRICANE IRMA IS THE PROOF

By Alan Burdick    September 6, 2017

**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

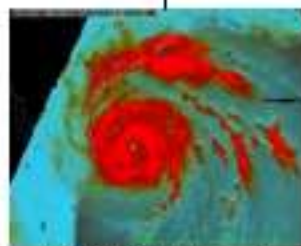NASA, NOAA, ESA, International Space Station, and Charter data used collaboratively to map flooding from SAR/optical
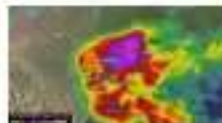
Charter/RadarSat-2 Flood Map

Sentinel 1A ARIA Flood Proxy Map (Hurricane Harvey)

ALOS-2 Flood Proxy Map

Modeling disaster impacts in Houston metro

NASA's Earth Science **DISASTERS**

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

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

| NASA Response Tier | 0 | 1 | | [Numerous Flood Maps from NASA Teams → | | 2 | | 1 | 0 |
|---|---|---|---|---|---|---|---|---|---|
| | Day 1 | Day 4 | Day 6 | Day 7 | Day 9 | Day 10 | Day 11 | ←UAVSAR Flights→ | Day 11 | Day 19 |
| | August 23 | August 27 | August 27 | August 28 | August 30 | August 31 | September 1 | | September 4 | September 9 |

Daily calls begin to coordinate NASA team in generation of products, engagement of funded PIs, and coordination with federal end user partners including FEMA, USGS, National Guard, and others.

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

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

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

increased flooding from 9/1-2
9/1/17    9/2/17

NASA provides daily flights of UAVSAR from September 1-4 to rapidly map evolving flood impacts

# Mapping Progression of Harvey Flood Impact

**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.

*"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.*

**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

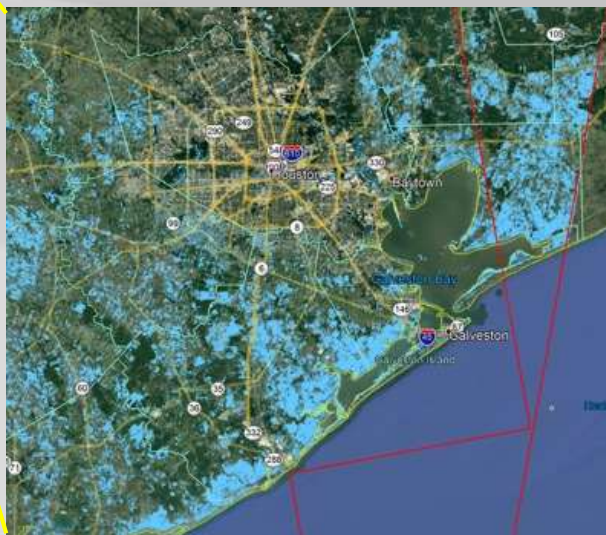- **Identify "dry spots" for relief agencies** to stage centers

# Flood Maps For Hurricane Harvey



**August 27th**

## 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.
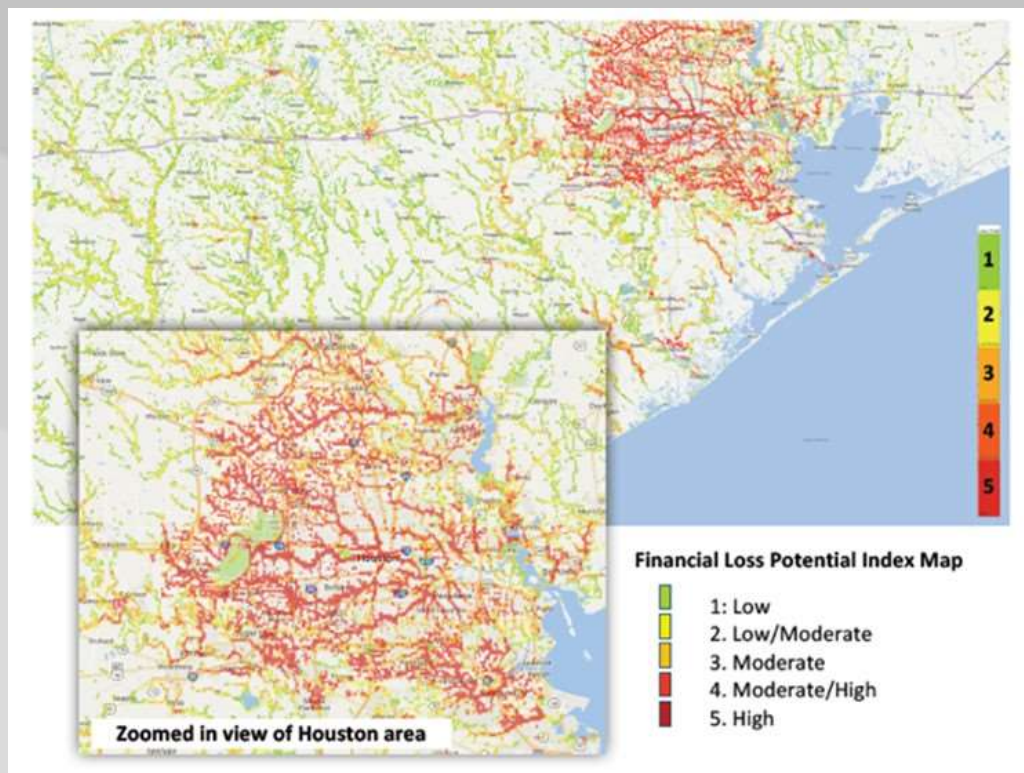


*Products were posted and provided to FEMA, USGS, International Charter, and State of Texas.*

# Assessing Financial Loss Potential for Hurricane Harvey

## Where and what is the extent of insured loss?



**Financial Loss Potential Index Map**

- 1: Low
- 2. Low/Moderate
- 3. Moderate
- 4. Moderate/High
- 5. High

Zoomed in view of Houston area

Disasters Program PI, ImageCat combined flood extent maps and depth information to create overlays with exposed property values in the flooded areas.
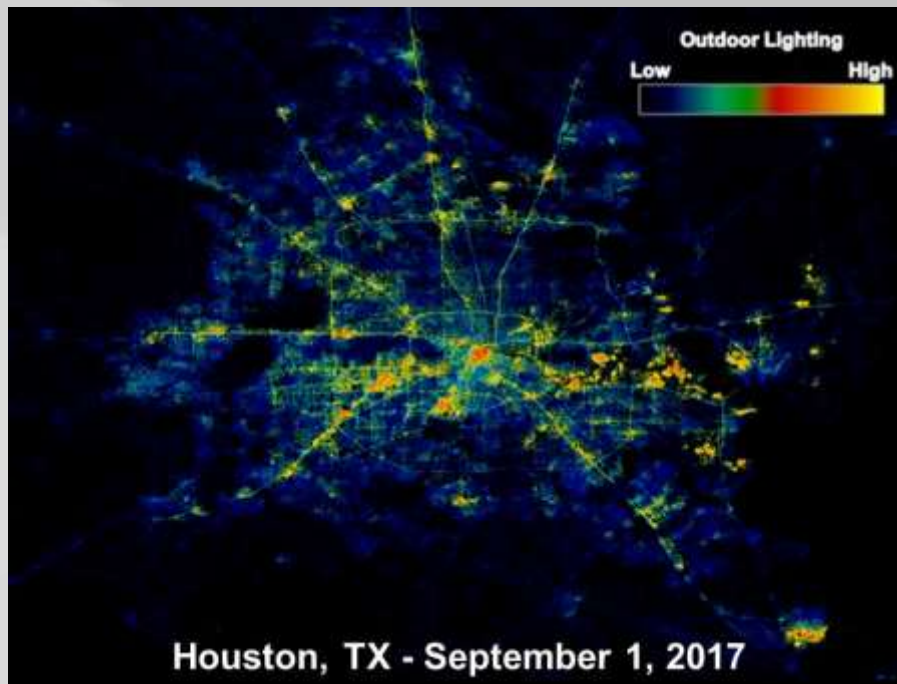
Products were provided to FEMA and the state of Texas to help estimate financial loss

# Night-time Satellite Data

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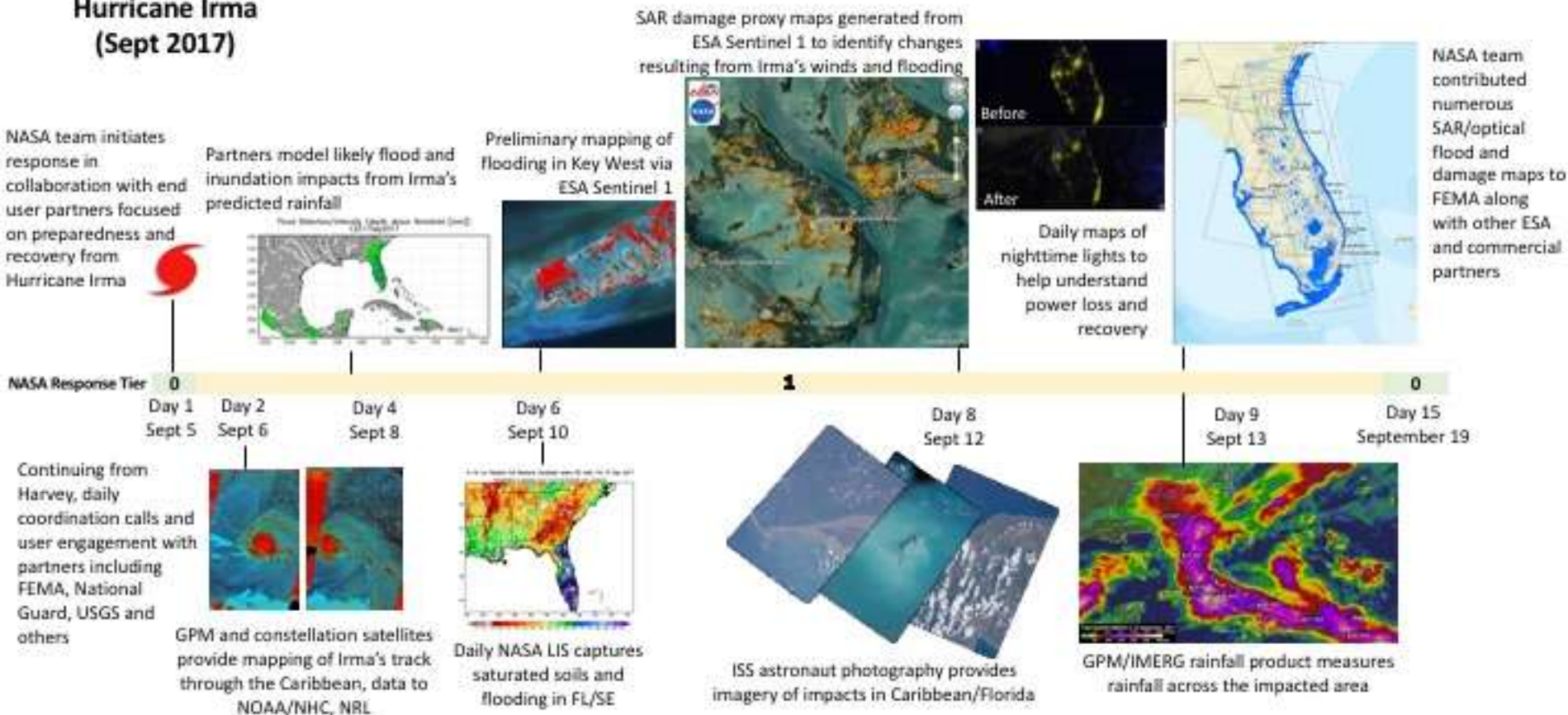




Houston, TX - September 1, 2017

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
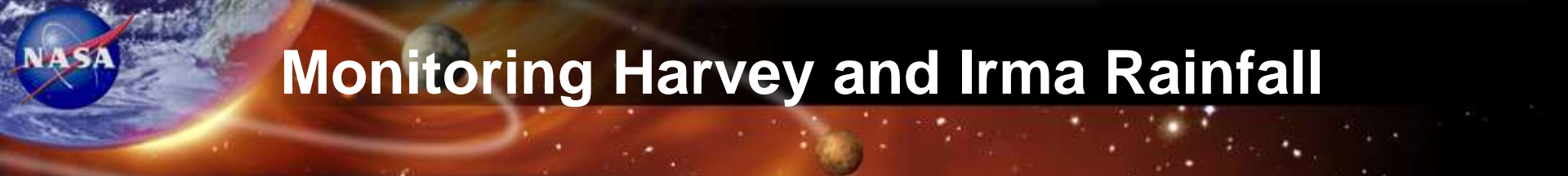
**NASA Response and Engagement Timeline**

**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 | 0 | | | 1 | | | 0 |
|---|---|---|---|---|---|---|---|
| | 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

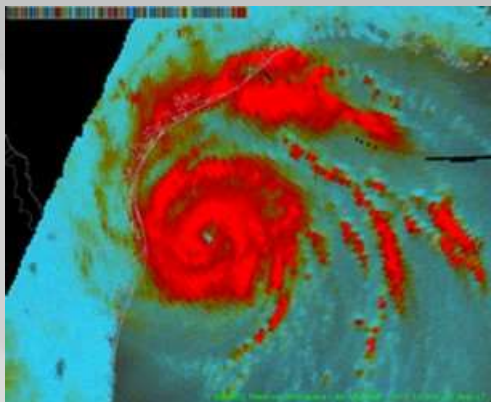GPM/IMERG rainfall product measures rainfall across the impacted area

# 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.
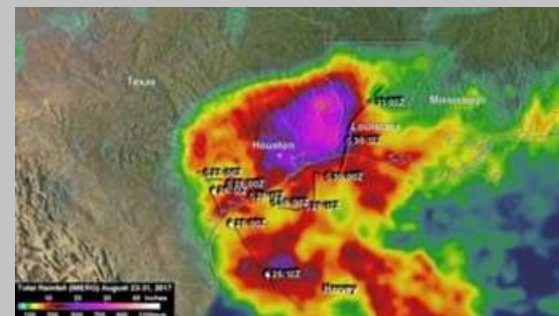


Hurricane Irma Discussion Number 37
NWS National Hurricane Center Miami FL      AL112017
500 AM EDT Fri Sep 08 2017

Microwave images and data from an Air Force Reserve Hurricane Hunter aircraft indicate that Irma is currently undergoing an eyewall replacement cycle. A recent GMI overpass showed an 50 nmi wide outer eyewall, with the inner eyewall weakening. The Hurricane Hunter aircraft reported peak 700-mb winds of 147 kt in the outer eyewall near 0500 UTC, and maximum SFMR winds were in the 125-130 kt range. Based on these data, the initial intensity is reduced to 135 kt.
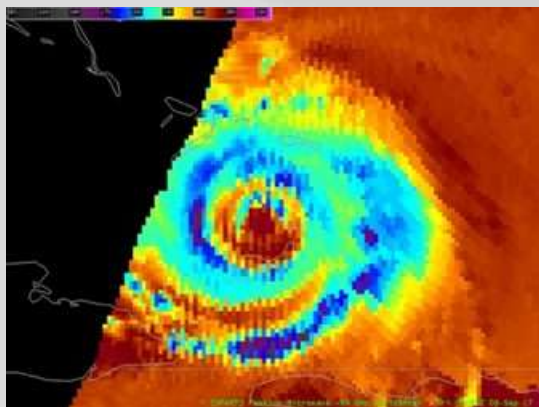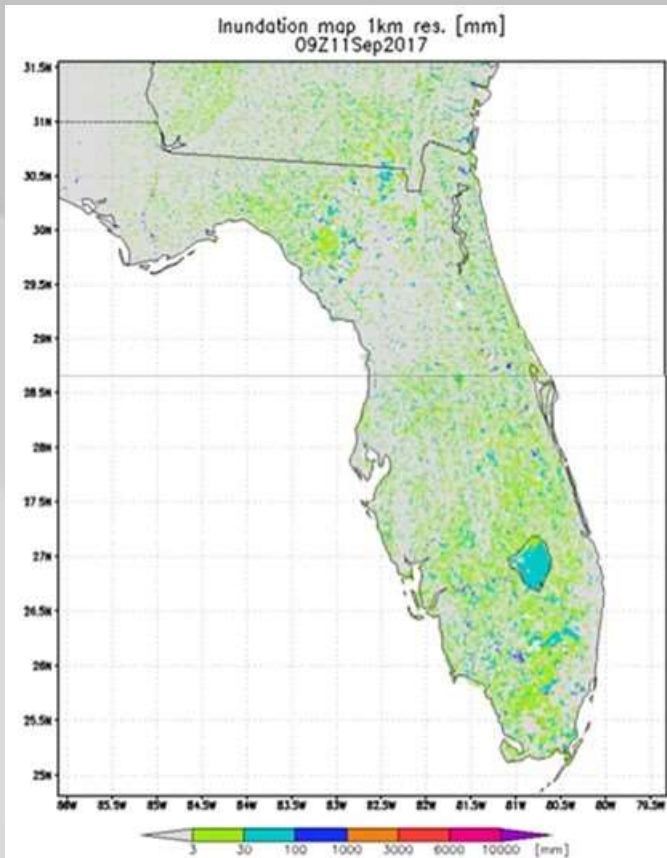


NASA imagery cited and used by the National Hurricane Center to help understand and describe the state of Irma as it moved north of Cuba and then over the Florida Keys and inland.

## Where is substantial and damaging flooding expected?



Inundation map 1km res. [mm]
09Z11Sep2017

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).
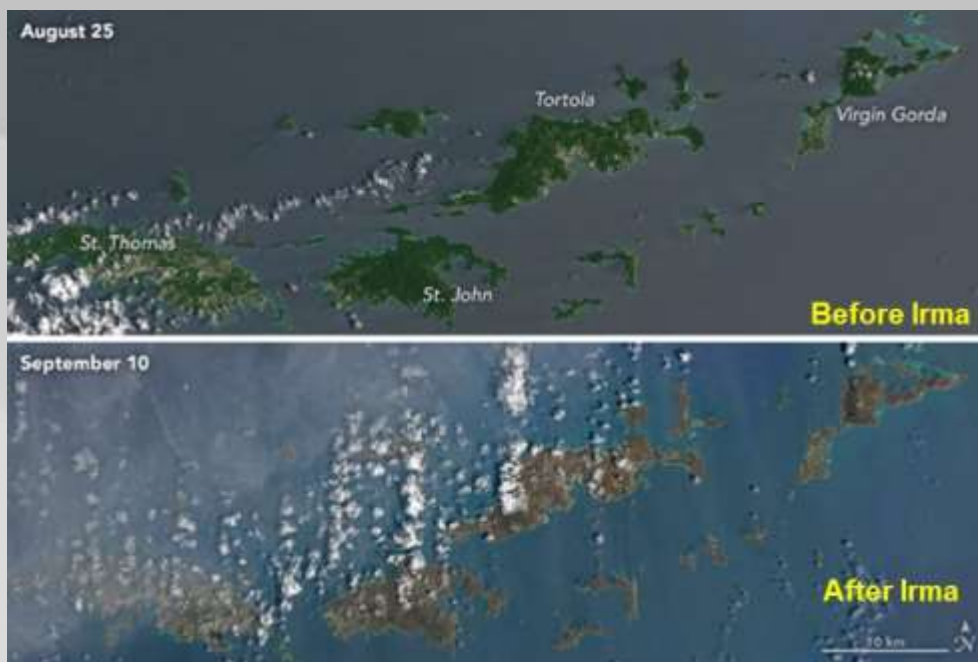
GFMS guidance provided FEMA and other end users a rapid estimate of areas of concern and triggered actions

16

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



Courtesy of NASA's Earth Observatory:

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**
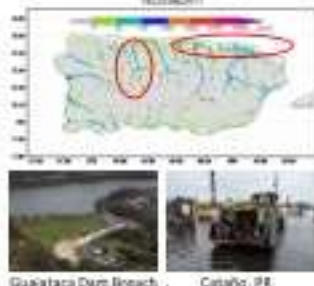
## NASA Response and Engagement Timeline

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

Remote Sensing

NASA's Earth Science DISASTERS

### Hurricane Maria (Sept-Oct 2017)

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

Flood modeling by partners for impacts in Puerto Rico

Guajataca Dam Breach    Cataño, PR

ESA Sentinel SAR imaging used to produce damage proxy maps for affected regions in Puerto Rico

Puerto Rico Damage Proxy Map (Hurricane Maria)

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
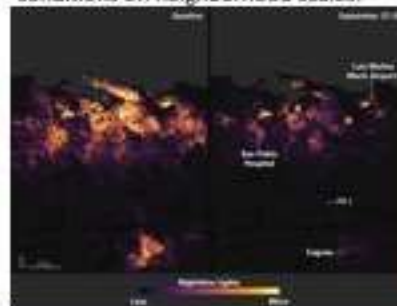
**NASA Response Tier    0**                                                                 **1**    **Daily Power and Light Analysis w/Black Marble →    0**

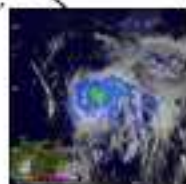| Day 1 Sept 18 | Day 3 Sept 20 | Day 4 Sept 21 | Day 5 Sept 22 | Day 7 Sept 24 | Day 10 Sept 27 | Day 13 Sept 30 | Day 14 Oct 2 | Day 15 Oct 3 |

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

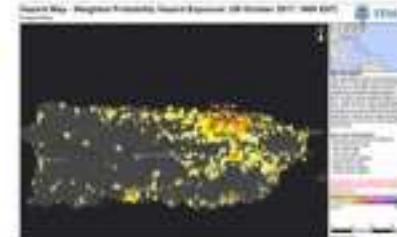GPM and constellation satellites map Maria, data for NOAA/NHC and NRL

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

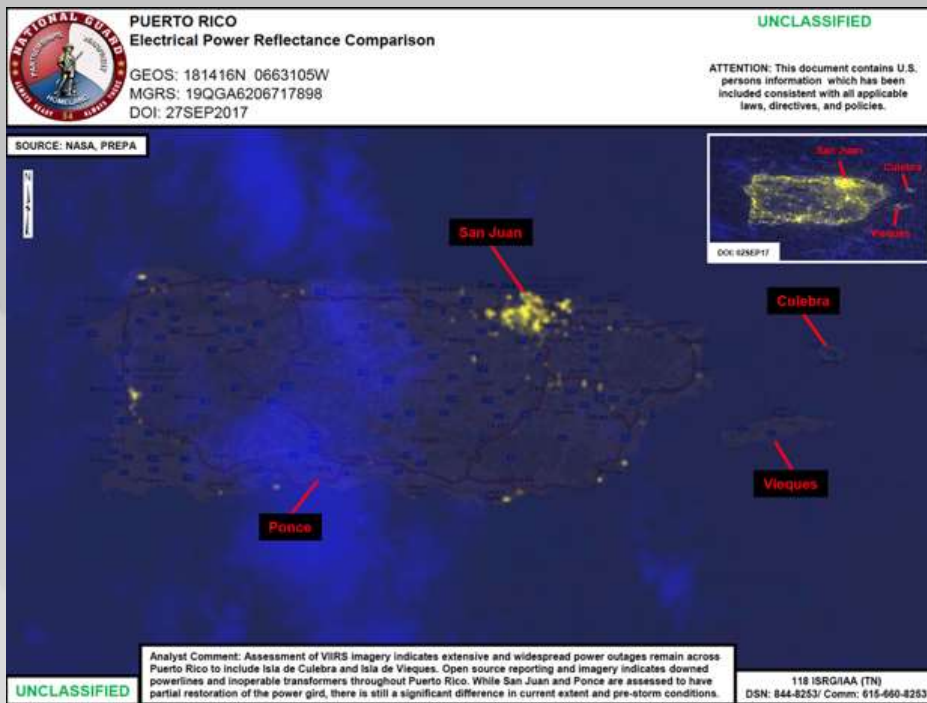NASA Black Marble by National Guard teams for daily situational awareness.

NASA team damage proxy and flood information synthesized with other FEMA data to map impacts

NASA

# Pinpointing Where Lights Went Out in Puerto Rico



PUERTO RICO
Electrical Power Reflectance Comparison

UNCLASSIFIED

GEOS: 181416N  0663105W
MGRS: 19QGA6206717898
DOI: 27SEP2017

ATTENTION: This document contains U.S. persons information which has been included consistent with all applicable laws, directives, and policies.

SOURCE: NASA, PREPA

Analyst Comment: Assessment of VIIRS imagery indicates extensive and widespread power outages remain across Puerto Rico to include Isla de Culebra and Isla de Vieques. Open source reporting and imagery indicates downed powerlines and inoperable transformers throughout Puerto Rico. While San Juan and Ponce are assessed to have partial restoration of the power grid, there is still a significant difference in current extent and pre-storm conditions.

UNCLASSIFIED

118 ISRG/IAA (TN)
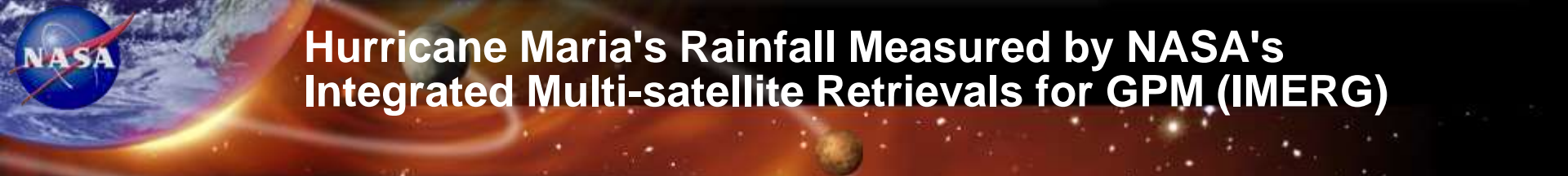DSN: 844-8253/ Comm: 615-660-8253

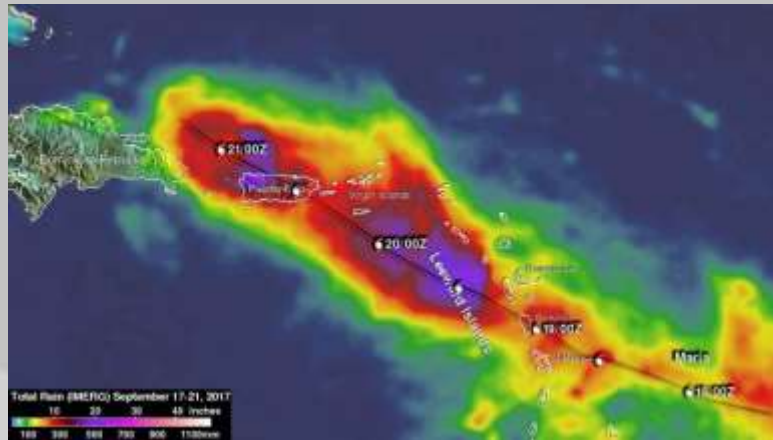**(Sources: U.S. National Guard Bureau Analysts/S-NPP VIIRS)**

**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.)
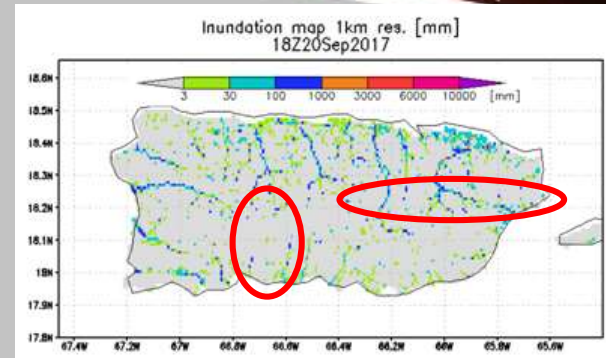
**Total Rainfall (IMERG) Sept 17-21, 2017**



**(GFMS) Hurricane Maria Impacts Sept 20, 2017; 200-400 mm water depth**



**Guajataca Dam Breach**



**Cataño, PR**

- 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.

# SAR Response Support for Three Hurricanes



**Texas Flood Proxy Map (Hurricane Harvey)**

**Puerto Rico Damage Proxy Map (Hurricane Maria)**

Texas (Harvey)  Florida (Irma)

**FEMA combined DPM data with other information to estimate damage impacts and target response efforts**
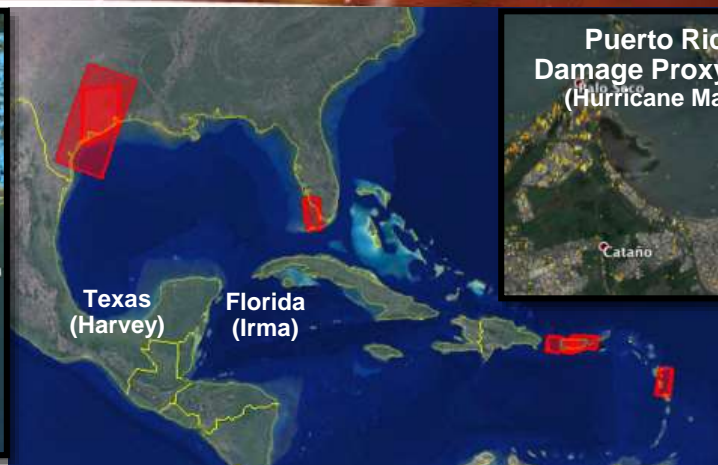
**Satellite SAR made an early flood map of Texas**

**ARIA flood and damage maps for Hurricane Harvey, Irma, and Maria**

- 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

**https://maps.disasters.nasa.gov**

- 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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https://disasters.nasa.gov/
https://maps.disasters.nasa.gov/arcgis/home/