NASA Earth Science Disasters Program Response Activities During Hurricanes Harvey, Irma and Maria in 2017

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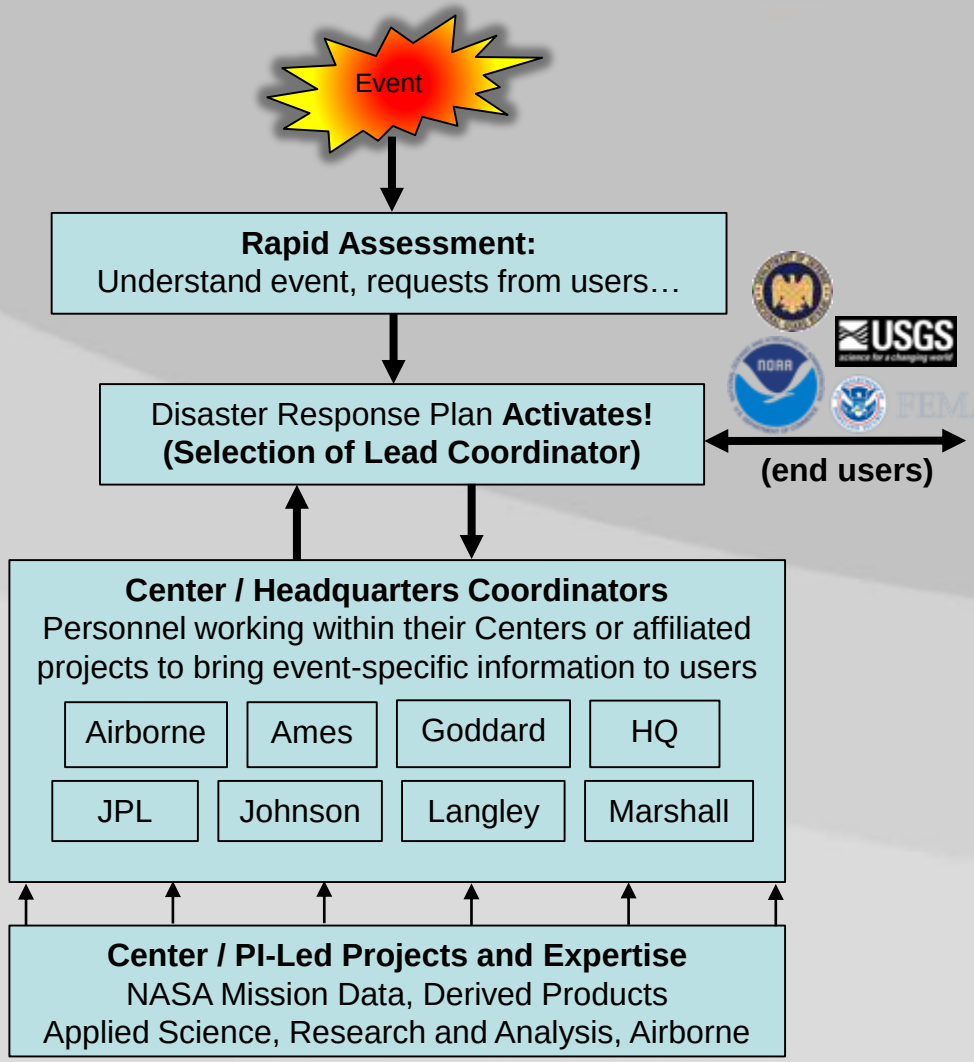
Other partners: USGS/Hazards Data Distribution System, International Charter on Space and Major Disasters, end user collaborators within DHS/FEMA, U.S. National Guard, and other partners.	

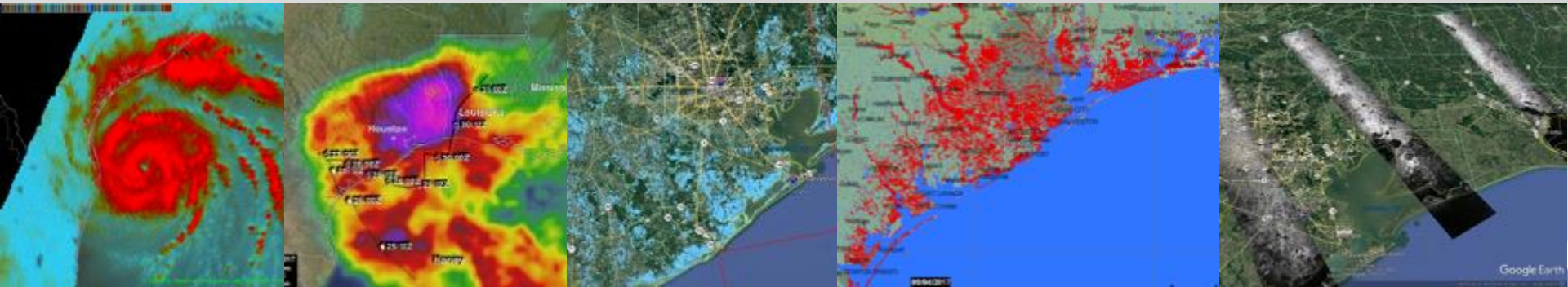
Disaster Response Team Process



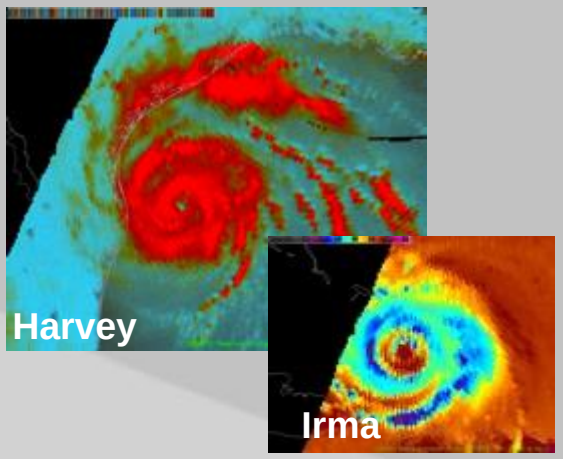
- **Following a disaster event, NASA personnel at HQ evaluate to determine an appropriate degree of response from NASA Centers and partners.**
- **When activated, NASA Centers contribute an event coordinator to help bring together efforts throughout the agency and academic or industry partners.**
- **Response activities focus on providing information and products requested by partners, helping to integrate information into their decision-making process.**

2017 Hurricane Response Activities

- NASA's Earth Science Disaster Response Team provided numerous products and assistance during Hurricanes Harvey, Irma, and Maria
- Efforts focused on partnerships with USGS/HDDS, Charter activities, and other data sources to address remote sensing needs of state, federal, and international partners.
- Examples include:
  - Using NASA data to support weather analysis and forecasting
  - Synthetic aperture radar, including airborne UAVSAR, and optical remote sensing to help map flooding in affected states, Puerto Rico, and Caribbean islands.
  - Longer-term remote sensing efforts to map recovery, with specific focus on loss and recovery of light following Hurricane Maria

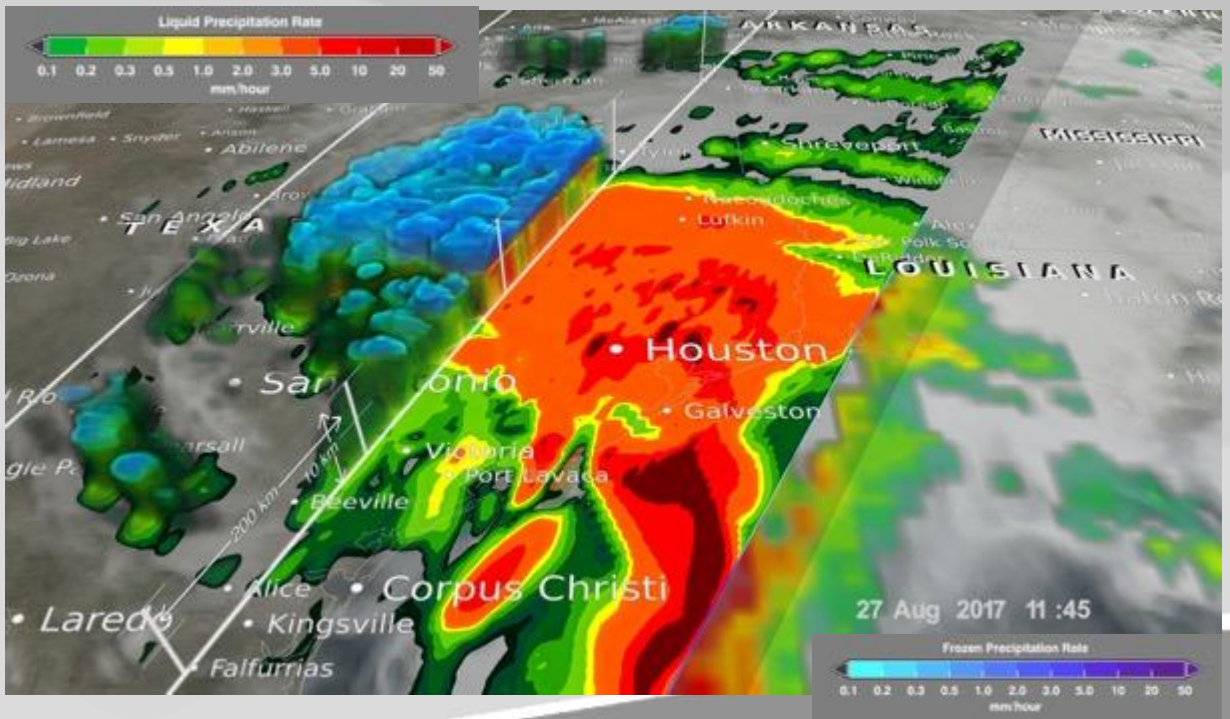


Monitoring Hurricanes with GPM

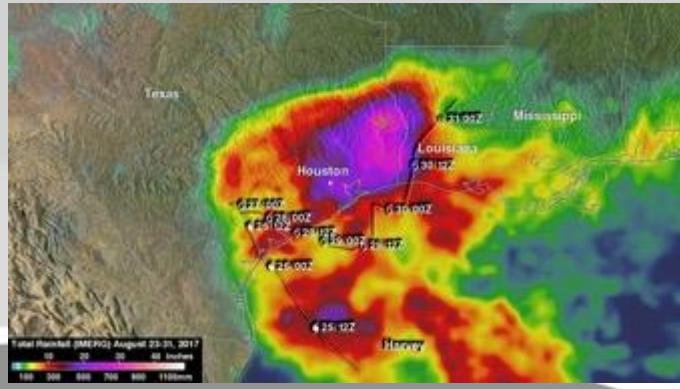


GPM and Constellation Imagers Map Cyclone Positions and Help Measure Rainfall

- The Global Precipitation Measurement (GPM) Microwave Imager (GMI) and other constellation sensors provide passive microwave imaging of tropical cyclones.
- NASA partnerships help to distribute this imagery to colleagues at NOAA/NWS National Hurricane Center and Naval Research Lab, where imagery is used to help identify center of location and internal structure.

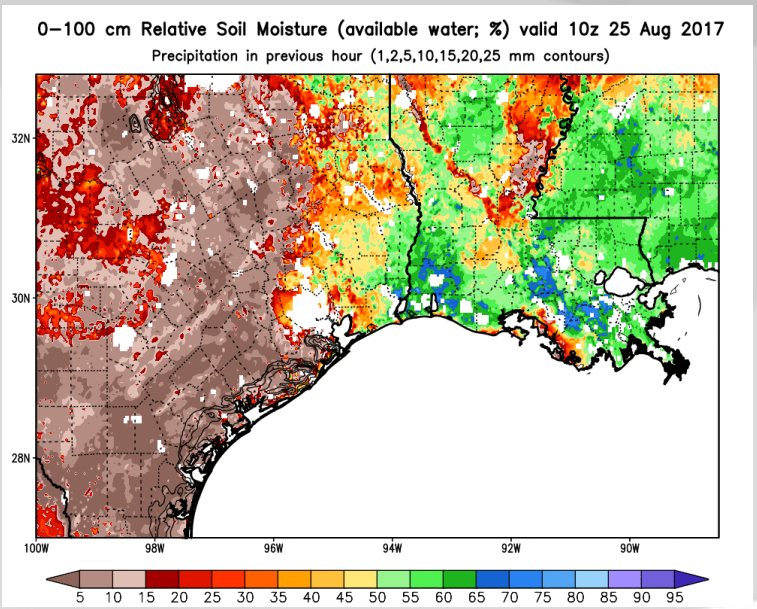


GPM also reveals three-dimensional structure and IMERG integrates rainfall over time to assess scope and impact of inland flooding, particularly where radar is not available.



Soil Moisture

JPL/CalTech and NASA Earth Observatory



NASA Marshall / Short-term Prediction Research and Transition (SPoRT) Center

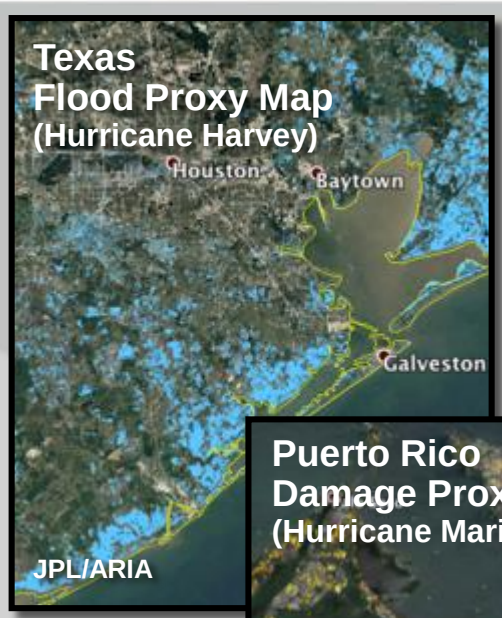
NASA mission data and models capture impacts of rainfall on soil moisture and greater likelihood of flooding

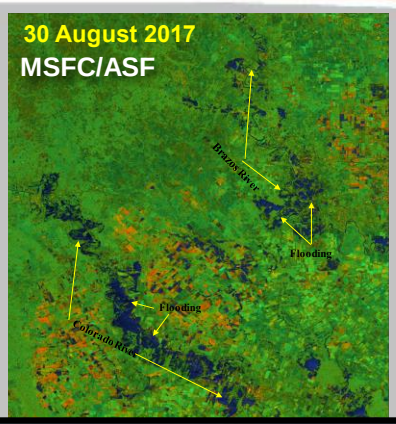
Data from the Soil Moisture Active Passive (SMAP) mission (top) capture significant increases in soil moisture across southeastern Texas following Harvey, with similar observations available for other tropical cyclones.

Combined with other atmospheric forcing and rainfall data sets, the NASA Land Information System (LIS) to create higher spatial resolution maps of soil moisture prior to and during Hurricane Harvey.

Soil moisture increases are used by partners to assess flood-prone areas and other agricultural applications.

Synthetic Aperture Radar Mapping





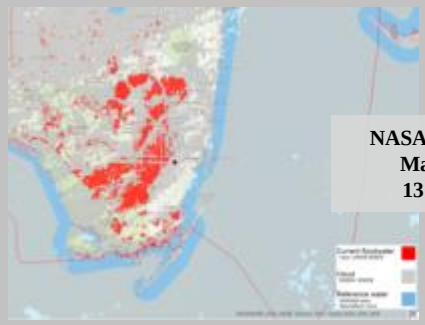
Multiple SAR scenes used in partner analysis

NASA scientists apply SAR remote sensing techniques to map flood extents to inform partner damage analysis

Teams across NASA including the JPL Advanced Rapid Imaging and Analysis (ARIA) team, NASA Marshall in partnership with the Alaska Satellite Facility, NASA Goddard, and others provided SAR analysis for flood extent and damage mapping shared with partners including USGS, the Charter, FEMA, National Guard, and others.

Specific to Harvey, NASA provided flights of UAVSAR led by JPL that assisted the State of Texas with rapid mapping of flood evolution in the Houston metro area.

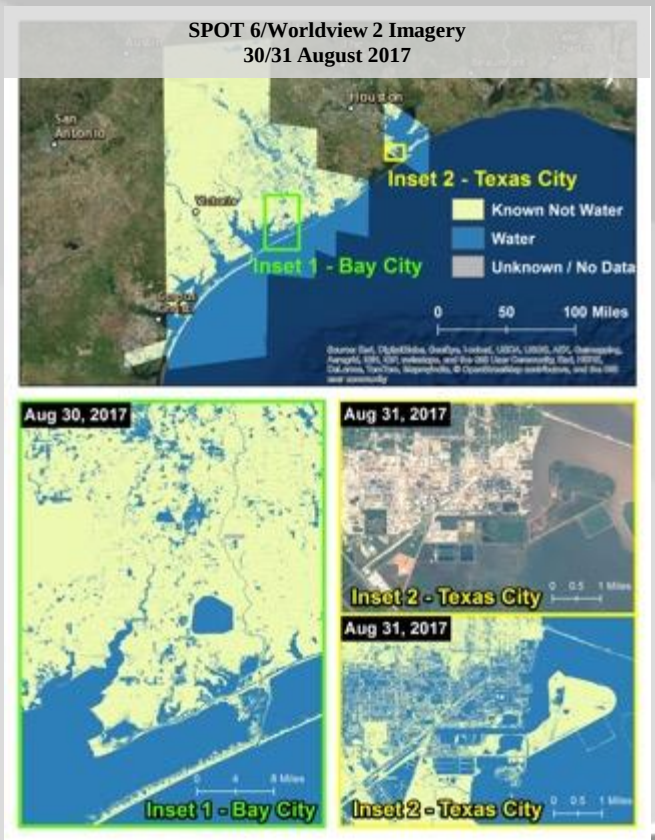
Optical Remote Sensing and Mapping



NASA NRT Global Flood Mapping via GSFC
13 September 2017

NASA team members leverage routine mapping from MODIS for mapping flood extent, and remote sensing expertise to provide additional mapping through HDDS and other providers.

SPOT 6/Worldview 2 Imagery
30/31 August 2017

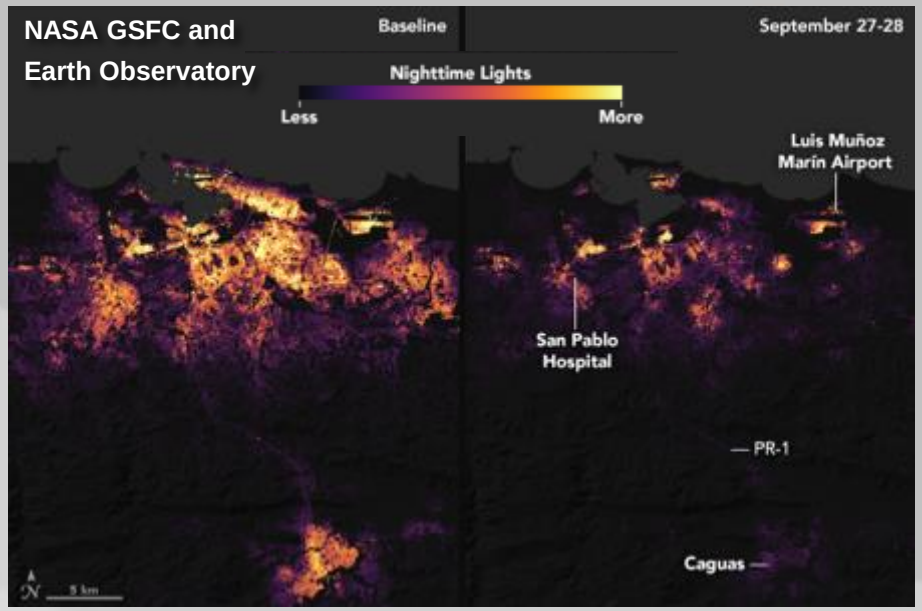


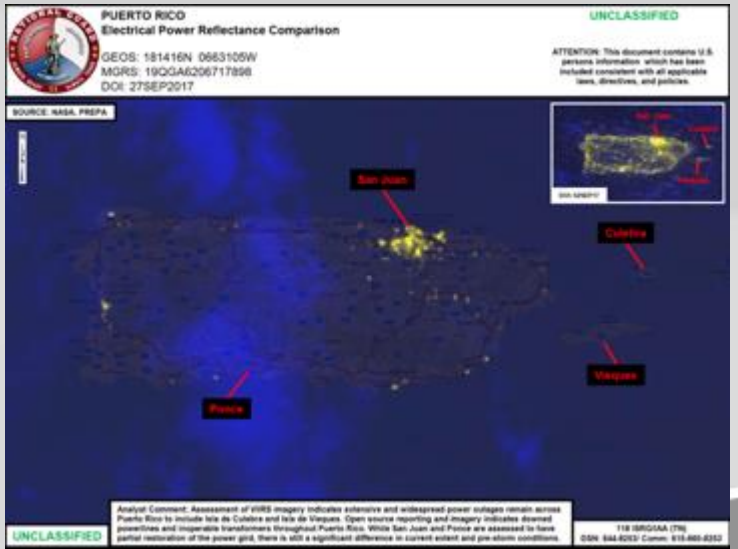
Worldview 2
30 August 2017

- Routine remote sensing of flood extent via MODIS provided by team members at NASA Goddard
- Other optical data including SPOT, DigitalGlobe Worldview, and others provided by HDDS used to derive various indices and map floods to build upon SAR and other analysis for end users partners

MSFC/UAH and SERVIR collaboration

Monitoring Nighttime Lights





NASA/NOAA Suomi-NPP VIIRS data and nighttime light imaging documents extensive loss of light across Puerto Rico, providing situational awareness and opportunity to monitor recovery.

NASA's Black Marble (below) and Black Marble HD (above) combine VIIRS data and analysis over time to capture departures from normal and current light conditions in the context of real-time cloud cover.

Delivery of products to partners, along with guidance on interpretation, assists with situational awareness and other response decision-making.

Response Timeline: Harvey

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

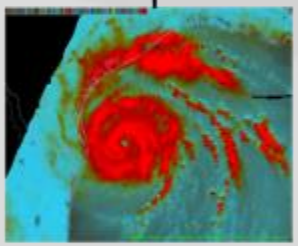
NASA, NOAA, ESA, International Space Station, and Charter data used collaboratively to map flooding from SAR/optical

Modeling disaster impacts in Houston metro

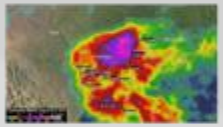
Use of NASA Black Marble HD product to explore power outages during post-Harvey flooding

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

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

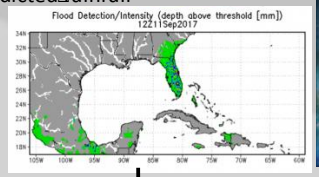
Response Timeline: Irma

NASA Response and Engagement Timeline

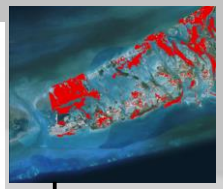
Hurricane Irma (Sept 2017)

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

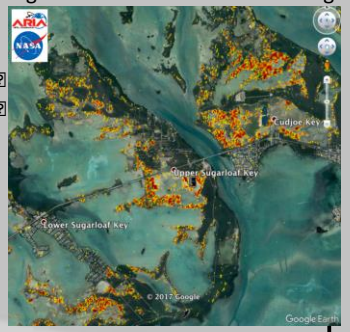
Partners model likely flood and inundation impacts from Irma's predicted rainfall

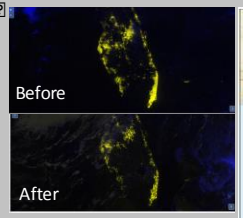


Preliminary mapping of flooding in Key West via ESA Sentinel-1

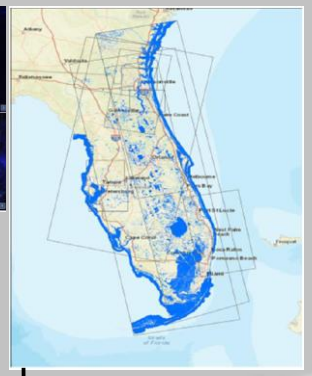


SAR damage proxy maps generated from ESA Sentinel-1 to identify changes resulting from Irma's winds and flooding





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

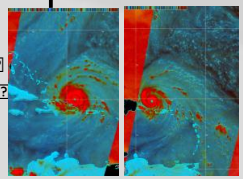


NASA team contributed numerous SAR/optical flood and damage maps to FEMA along with other ESA and commercial partners

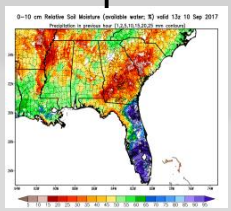
NASA Response Tier 0 — 1 — 0

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

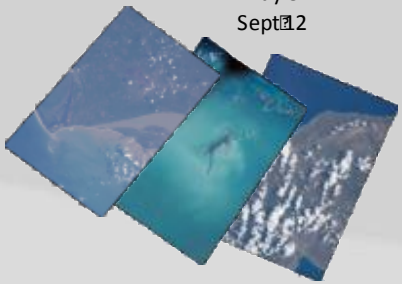
Continuing from Harvey, daily coordination calls and user engagement with partners including FEMA, National Guard, USGS and others



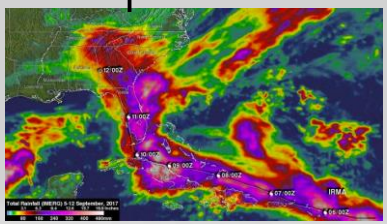
GPM and constellation satellites provide mapping of Irma's track through the Caribbean, data to NOAA/NHC, NRL



Daily NASA ISS captures saturated soils and flooding in FL/SE



ISS astronaut photography provides imagery of impacts in Caribbean/Florida



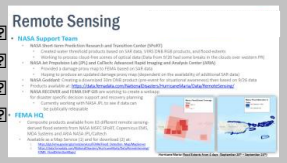
GPM/IMERG rainfall product measures rainfall across the impacted area

Response Timeline: Maria

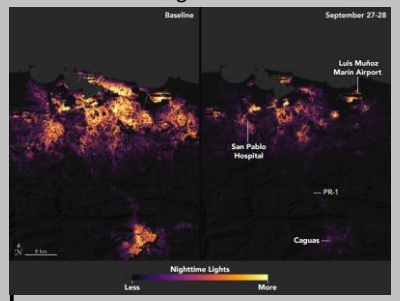
NASA Response and Engagement Timeline

Hurricane Maria (Sept-Oct 2017)

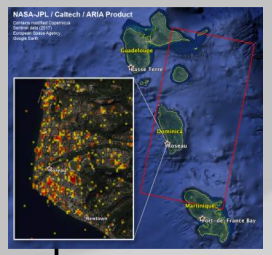
Daily: FEMA Remote Sensing and Geospatial Teams incorporate NASA information into daily briefings and use analysis to understand recovery needs.



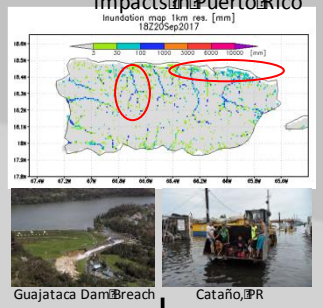
NASA Black Marble HD captures Puerto Rico outages, used by partners and major media to keep public informed of local power conditions on neighborhood scales.



Damage proxy maps extended to Dominica using ESA S1 data



Flood modeling by partners for impacts in Puerto Rico



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

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

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

Day 1 Sept 18

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

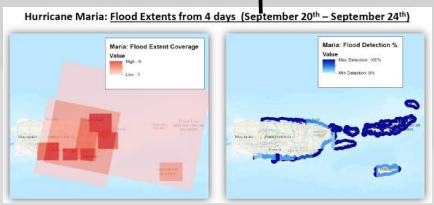
Day 3 Sept 20

Day 4 Sept 21

Flood mapping by the NASA team using ESA and Charter SAR and optical assets

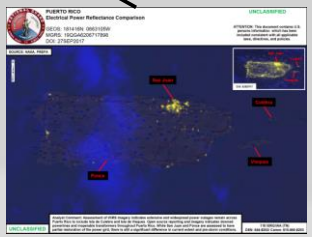
Day 5 Sept 22

Day 7 Sept 24



Multiple flood-mapped scenes from NASA and commercial partners combined by FEMA to assess flood extent

Day 10 Sept 27

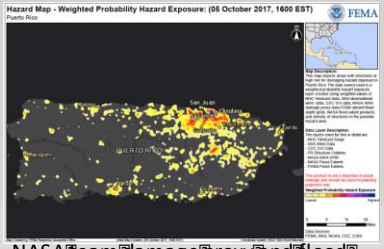


NASA Black Marble by National Guard teams for daily situational awareness.

Day 13 Sept 30

Day 14 Oct 2

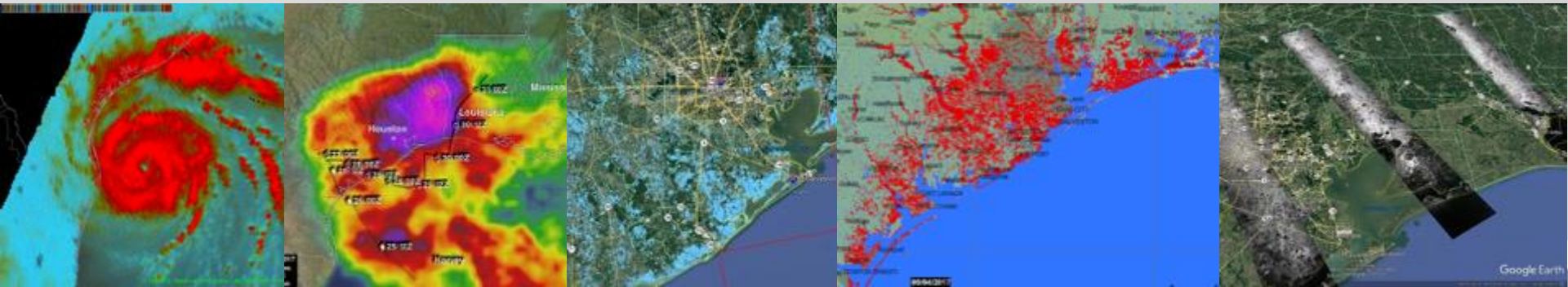
Day 15 Oct 3



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

Summary

- NASA's Earth Science Disaster Response Team provided numerous products and assistance during Hurricanes Harvey, Irma, and Maria
- Through collaboration across NASA Centers and partners, the broader team provided numerous remote sensing and modeling capabilities to end user partners, along with close end-user collaborations that assisted end users with incorporating those products and maps into their decision-making and analysis process.
- Ongoing and future activities will continue to bolster collaborations with end users including GIS services for delivery of data and training, continued after-action reviews, and further improvements in event coordination.



Questions?