NASA Disasters Program: A Partner for Coastal Disaster Response, Resiliency, and Risk Reduction

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17\textsuperscript{th} Annual Climate Prediction Applications Science Workshop
Disasters Program Mission and Goals

- **Program Mission:** The Disasters Program mission is to use Earth observation to inform disaster risk reduction and resilience across the disaster cycle from local to global scales.

- **Program Goals:**
  - Harness NASA Capabilities for Disaster Risk Reduction (DRR) and resilience.
  - Engage stakeholders in the use of Earth Observations (EO) throughout the disaster lifecycle.
  - Demonstrate the value and impact of EO to support decision making and actions.
  - Grow as a trusted source for delivering useful results.
Communities at Intensive Risk
Mid-Atlantic Resiliency Demonstration Study

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Background

• In FY17, NASA’s Applied Sciences: Disasters Program began a small pilot project titled “Mid-Atlantic Resiliency Demonstration Study, Communities at Intensive Risk”

• Strategic Goals and Objectives:
  • Demonstrate how coupling diverse models, data and predictions enable us to develop and extend our collective knowledge of compounding risk
  • Collaborate with partners to understand their data-driven needs for decision making in coastal communities with intensive risk
  • Demonstrate how various tools, ranging from modeling to remote sensing, can help to identify current and future areas of risk.
  • Engage with key external partners to understand their goals for improving disaster resilience and participate as a key collaborator.

• Focus:
  • Holistic, interdisciplinary research and integrated application outcomes focused on improving resilience for coastal communities.

• Areas of Interest
  • Portsmouth, VA
  • Norfolk, VA
  • Pamlico County, NC
Technical Components

- **WX Forcing**
  - NASA-Unified WRF Model
  - Simulate the hazard

- **Large-scale model**
  - SCHISM – open-source coastal ocean model
  - Robust Storm Tide Predictions

- **Sub-grid model**
  - Street level flood visualization

- **Bldg. Footprints**
  - Water flow and friction
  - Digital Elev. Models
    - Topography

- **SLR Rate**
  - Influence of long-term hazard

- **First Floor Elevation**
  - Predicted water depth relative to flooded structure

- **3D Hydrodynamic Model**
  - Map larger hazards to local-scale impacts – depicts time-relevant flood extent and depth

- **Local Subsidence Rates**
  - Influence of long-term hazard

- **10m MODIS Footprint Maps**
  - Remote Sensing Flood and Depth Maps
    - Validate and improve modeling based upon observations

- **30m Landsat Depth Maps**

Results in

Building-level impact analysis in areas of intensive risk
2011 Irene Simulations

• Using the NASA-Unified WRF Model to create a reanalysis of an Irene-like storm, based upon GFS analysis data available from 2011.

• Early issues with simulating the storm from GFS analyses: landfall was too early, storm was too intense. Exploring solutions through various initialization times, parameterizations, TC initial conditions, perhaps switch to HWRF.

• For exploratory work and fitting to other models, track and timing are reasonable for approach to NC/VA. ECMWF also provides good Irene simulations
Large-Scale Storm Tide Modeling
Z. Liu, H. Wang, Virginia Institute of Marine Science

- **SCHISM** (Semi-implicit, Cross-scale, Hydro-science Integrated System Model)
  - Operationally tested and proven (NOAA, DWR, CWB...)

SCHISM Simulation Results Driven with ECMWF Wind and Pressure Data

*Reasonable comparison by SCHISM with observations using ECMWF forecast data, while WRF simulation improves*

Animation of Model Output near Chesapeake Bay

**Goal:** Establish confidence in model capabilities for predicting coastal hazards when combined with supporting numerical weather prediction inputs, then explore with varying intensity and other types of coastal change (sea level, subsidence).
Street-Level Flood Modeling

J.D. Loftis, Virginia Institute of Marine Science

- Driven with water levels and atmospheric forecasts from Large-Scale SCHISM model
- Compares well with local sensor data

**2011 Hurricane Irene Max. Flood Extent Forecast: Contour Map in Norfolk’s Larchmont Neighborhood**

**Goal:** Develop dynamic flood forecast maps to effectively and quickly communicate inundation risk; further aid prediction of long-term coastal storm hazards with sea level rise & subsidence predictions.

**SCHISM Model Domain**

- RMSE = 3.7 cm
- RMSE = 4.8 cm
- RMSE = 5.3 cm

- Driven with water levels and atmospheric forecasts from Large-Scale SCHISM model
- Compares well with local sensor data
Geospatial Integration for Hurricane Irene Reanalysis

Dr. Tom Allen, Geography Program and Commonwealth Center for Recurrent Flooding Resiliency (CCRFR)
Old Dominion University, Norfolk, VA

- Demonstrate geospatial analysis and integration for flood impacts from storm surge models, SAR, and LiDAR

- Source and provide supporting data for Irene
  - NC Flood Inundation Mapping and Alert Network
  - High Water Marks (NWS and USGS)
  - Dasymetric population demographics
  - NHC Hurricane forecast track, cone, watches, warnings, and surges
  - SLOSH surge MOMs and MEOWS, NC-CERA/Renci ADCIRC

- Engage stakeholders for needs and applications
  - NWS, cities, and Hampton Roads Planning District Commission
  - Hampton Roads Coastal Resiliency Working Group
  - Leverage modeling and remote sensing for time-dependent planning, response, and resiliency

- Develop lessons learned, uncertainties, and improvements for future research
  - Sentinel, NISAR, other platforms and data sets

https://fiman.nc.gov/fiman/

http://nc-cera.renci.org/
Revisiting Flood Maps with new VIIRS Flood Mapping Capability

Dr. Lillian Sun, George Mason University

- Team from George Mason University is revisiting MODIS and Landsat remote sensing adopting new techniques developed for VIIRS:
  - Reduced impact of terrain shadows, cloud shadows, and other potential errors

Improving Access to Flood Mapping

Dr. W.B. Moore, Hampton University

- Incorporating VIIRS algorithm for processing of NRT MODIS and other imagery
  - Share with partners to improve flood mapping capabilities from NASA MODIS sensors
Floodwater Depth Estimates from Remote Sensing of Flood Water

Dr. Sagy Cohen, Surface Dynamics Modeling Lab, University of Alabama

• Estimate floodwater depth based on remote sensing inundation maps and a DEM:
  • *Landsat imagery classification and 10m NED DEM*

• Assess accuracy and feasibility of the methodology for coastal flooding:
  • *Hydrodynamic model flood extent and 1m LiDAR*
Summary

• The NASA Applied Sciences: Disasters Program has kicked off a pilot project as “Mid-Atlantic Resiliency Demonstration Study, Communities at Intensive Risk” in FY17 and FY18

• Efforts focus on a holistic, interdisciplinary approach to integrate a full suite of capabilities from numerical weather prediction, tide and surge modeling at high spatial resolution and urban/neighborhood scales, and remote sensing capabilities for water detection and depth estimation.

• Future efforts:
  • Partner with Federal Agencies, academia professional societies to complement and augment ongoing work using Earth observations unique to NASA
  • Translate hazards to risk in order to understand local and regional impacts and minimize vulnerability
NASA Disaster Programs
Response Efforts
### Response and Engagement Timeline: Hurricane Florence

#### Integrated Sharing of Data via Esri Services

**NASA Disasters Mapping Portal**
- Sharing of imagery, products, and training through uniform services to improve integration

**Modex**
- Recent NASA Products: Hurricane Florence

**GPM Imaging and Rainfall**
- Images from GPM Imaging and Rainfall services to improve operational forecasting

**MODIS Global Flood Mapping**
- Early detection of flooding and damage proxy maps via ESA and International Charter contributions to SAR imaging

**Mapping Floods as Skies Clear:**
- Clear skies and views from MODIS/Landsat, demonstrating the extent of inundation

### Flood Mapping:
- Team members generate flood and damage proxy maps via ESA and International Charter contributions to SAR imaging:
  - **9/14**: Sentinel 1A
  - **9/15**: Sentinel 1A
  - **9/17**: UAVSAR Arrives + 2 Legs
  - **9/18**: 10
  - **9/19**: 9
  - **9/20**: 8
  - **9/22**: 8
  - **9/23**: 8 UAVSAR Collections

- **NASA Response Tier**:
  - **Tier 0**
  - **Tier 1: 9/10**
  - **Tier 2: 9/14**
  - **Tier 1: 9/24**

- **Day 1: Sept 9**
  - **Tier 1: 9/10**
  - **Tier 2: 9/14**

- **Day 20: Sept 28**
  - **Tier 1: 9/24**

#### NASA Black Marble HD
- Black Marble HD: Captures lights missing in coastal Wilmington, NC

#### Team Coordination:
- Daily calls begin to coordinate NASA team:
  - Flood Mapping
  - Other Products
  - UAVSAR

#### Pre-Existing Partners
- FEMA, USFS, NOAA/NWS and NWC, USGS, National Guard,
- Research/Academia

#### Civil Air Patrol photo (Sept 18th)

**UAVSAR Flights Support Research and Response Efforts**
- Imaging provides immediate mapping and new data to advance SAR application (NISAR) and hydrologic research studies

### Civil Air Patrol photo (Sept 18th)

- **UAVSAR polarimetric decomposition image (Sept 17th)**
  - Flooded
  - Not flooded
  - Flooded
  - Flooded
  - Open water
  - Open water

### GPM Imaging and Rainfall
- Images from GPM Imaging and Rainfall services to improve operational forecasting

### MODIS Global Flood Mapping
- Early detection of flooding and damage proxy maps via ESA and International Charter contributions to SAR imaging

### Mapping Floods as Skies Clear:
- Clear skies and views from MODIS/Landsat

### GPM Imaging and Rainfall
- Images from GPM Imaging and Rainfall services to improve operational forecasting

### Global Flood Monitoring System
- Estimates extent of inundation

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UAVSAR Mission Assignment

- FEMA requested mission assignment of the Gulfstream-III and UAVSAR instrument for repeat collection of L-band SAR over the affected areas.
- Daily coordination calls targeted UAVSAR collections where significant river flooding was ongoing or expected, and where populations were at risk from rising flood waters.
- UAVSAR collections supported rapid mapping of flood extent through false color composites and extraction of visual signatures.
- Mission data were also collected to support an EPSCoR* research activity examining predictions for the Congaree River.
- UAVSAR provided immediate value in near-term mapping and longer-term value through repeated collections in flooded rivers and basins that will support further study of rivers, hydrology, streamflow, and inundation.
- Collections of L-band and polarized SAR provide new data sets to build experience and applications around the NASA-ISRO SAR (NISAR) mission expected in 2022.

* Experimental Program to Stimulate Competitive Research (EPSCoR)
Contact Information

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• Program Website: https://disasters.nasa.gov/

• Program’s Mapping Portal (GIS): https://maps.disasters.nasa.gov/
Backup Slides
Areas of Interest: Virginia

- Preliminary focus in Virginia based upon previously established partnerships in these areas and significant impacts from past events.

**Portsmouth, VA**
- Craney Island Naval Supply Center
- Norfolk Naval Shipyards

**Norfolk, VA**
- Naval Station Norfolk
- NATO Strategic Command HQ

[Sea Level Rise Scenarios](https://coast.noaa.gov/floodexposure)
Areas of Interest: N. Carolina

• Preliminary focus in N. Carolina focused on partnerships as well as unique access to high-resolution data for analysis.

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

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.

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

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

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

Modeling disaster impacts in Houston metro

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

**NASA Response and Engagement Timeline**

**Hurricane Harvey**

(Aug-Sept 2017)

<table>
<thead>
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<th>NASA Response Tier</th>
<th>Day 1</th>
<th>Day 4</th>
<th>Day 6</th>
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<td>August 28</td>
<td>August 30</td>
<td>August 31</td>
<td>September 1</td>
<td>September 9</td>
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**Numerous Flood Maps from NASA Teams**

Charter/RadaSat-2 Flood Map

Sentinel 1A ARIA Flood Proxy Map (Hurricane Harvey)

ALOS-2 Flood Proxy Map

Day 19

Day 9

Charter/RadaSat-2 Flood Map

Modeling disaster impacts in Houston metro

Nighttime Lights: Tracking Power Outages

Houston, TX – Post-Harvey

9/1/17

9/2/17

Increased flooding from 9/1-2
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.

- **Day 1** Sept 5: GPM and constellation satellites provide mapping of Irma's track through the Caribbean, data to NOAA/NHC, NRL.
- **Day 2** Sept 6: Continuing from Harvey, daily coordination calls and user engagement with partners including FEMA, National Guard, USGS and others.
- **Day 4** Sept 8: Partners model likely flood and inundation impacts from Irma’s predicted rainfall.
- **Day 6** Sept 10: Preliminary mapping of flooding in Key West via ESA Sentinel 1.
- **Day 8** Sept 12: ISS astronaut photography provides imagery of impacts in Caribbean/Florida.
- **Day 9** Sept 13: Daily NASA LIS captures saturated soils and flooding in FL/SE.
- **Day 15** September 19: GPM/IMERG rainfall product measures rainfall across the impacted area.

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.

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

Preliminary mapping of flooding in Key West via ESA Sentinel 1.
**NASA Response and Engagement Timeline**

**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**
- **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**

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

**Daily Power and Light Analysis w/Black Marble**

- **Day 0**
  - **Sept 18**
  - **Sept 19**
  - **Sept 20**
- **Day 1**
  - **Sept 19**
- **Day 2**
  - **Sept 21**
- **Day 3**
  - **Sept 22**
- **Day 4**
  - **Sept 23**
- **Day 5**
  - **Sept 24**
- **Day 6**
  - **Sept 25**
- **Day 7**
  - **Sept 26**
- **Day 8**
  - **Sept 27**
- **Day 9**
  - **Sept 28**
- **Day 10**
  - **Sept 29**
- **Day 11**
  - **Sept 30**
- **Day 12**
  - **Oct 1**
- **Day 13**
  - **Oct 2**
- **Day 14**
  - **Oct 3**
- **Day 15**
  - **Oct 4**

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

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

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

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

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

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

**Guajataca Dam Breach, Cataño, PR**

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

**Damage proxy maps extended to Dominica using ESA S1 data**

**NASA team damage proxy and flood information synthesized with other FEMA data to map impacts**
Response and Engagement Timeline: Hurricane Michael

Team coordination began prior to 10/10 and continued daily throughout the event Partners/Stakeholders engaged prior to and throughout storm’s impact: FEMA, NGB, NOAA, USFS, USGS, US Army Geospatial Center, Department of Interior

Monitoring the Storm: GPM data provided to support operational forecasting

Damage Mapping: Damage proxy maps capture structure damage on immediate coastline

Flood Mapping: Identifying coastal and inland flooding from SAR imagery

NASA Black Marble HD: Black Marble HD: Captures lights missing in Florida’s Energy Sector

NASA Data/Product portal available via Esri Services http://maps.disasters.nasa.gov