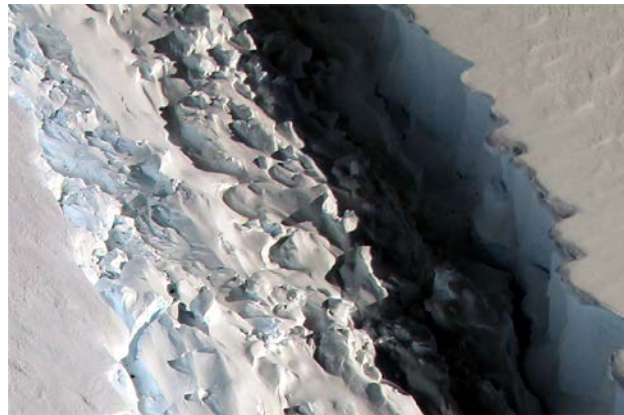
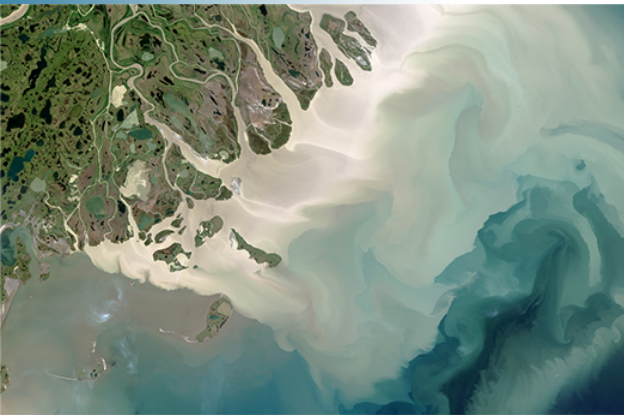




# SCIENCE



ASFPM B7-Post Disaster Tech

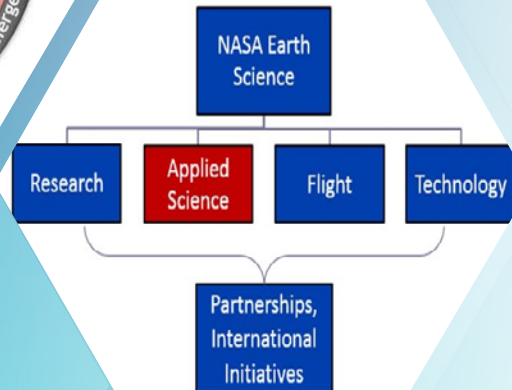
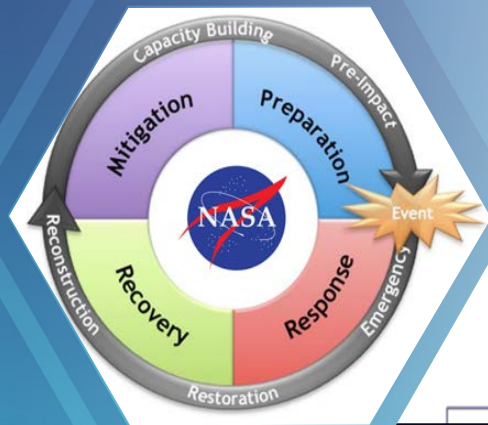
## NASA Disasters Program Support of Hurricane Florence Response

Garrett Layne

NASA Disasters Program  
NASA Headquarters  
[garrett.w.layne@nasa.gov](mailto:garrett.w.layne@nasa.gov)

May 21, 2019





# 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.

Assessment	Tier 1	Tier 2	Tier 3
<b>Rapid Hazard Assessment Expected</b> <ul style="list-style-type: none"> <li>- Centers and program experts to contribute within scope of daily activity</li> <li>- Guidance to elevate to Tier response, direct to research or no action</li> <li>- Days</li> </ul> <i>E.g.: media report</i>	<b>Response and Recovery Short Term and Best Effort</b> <ul style="list-style-type: none"> <li>- Centers and programs respond as available with only minor impact to existing/on-going activities</li> <li>- Detailed assessment and products scaled to modest response</li> <li>- Weeks to Month(s)</li> </ul> <i>E.g.: Napa Earthquake (2014), Chile Earthquake (2015), Oklahoma tornadoes, yearly floods</i>	<b>Significant Contributions Over Extended Period</b> <ul style="list-style-type: none"> <li>- Contributions are considerable given continual assessment of size and scale of impact</li> <li>- Personnel relevant to disaster type (s) expected, tasked, and assigned to support</li> <li>- Data and products adapted into recovery</li> <li>- Weeks to Month(s)</li> </ul> <i>E.g.: Nepal Earthquake (2015), Deep Horizon (2010), Eyjafjallajökull Eruption (2015)</i>	<b>Disaster is of major national importance</b> <ul style="list-style-type: none"> <li>- All relevant personnel expected to review activities for level of support to the disaster and/or be on-call</li> <li>- Assets and personnel may specifically assigned and tasked for lengthy time period (Months into recovery).</li> </ul> <i>E.g.: Super Storm Sandy (2012), Hurricane Katrina (2005), September 11, 2001 attacks</i>

# Contributions from NASA Earth Science Elements

- Applied Sciences
  - Earth Science Disasters Program brought together NASA and sponsored investigators to support analysis of pre-landfall and recovery efforts. Included multi-Center and institutional effort to map damage and flooding, along with in-person support at FEMA HQ to better understand their immediate and longer-term remote sensing needs.
- Research and Analysis (R&A)
  - Ongoing research regarding tropical cyclones, intensification, modeling, and use of NASA tools to map cyclone impacts, and sharing of data with the weather community via SPoRT Project
- Satellite and Airborne Science
  - With R&A and Applied, deployed G-III aircraft and UAVSAR instrument to the Carolinas to support immediate flood mapping, response activities, and collect data for longer-term science
- Earth Science Technology Office (ESTO)
  - Developed UAVSAR instrument, supports investment in NASA remote sensing and data systems technologies to support rapid acquisitions and sharing of information



# Response and Engagement Timeline: Hurricane Florence



## Integrated Sharing of Data via Esri Services

### NASA Disasters Mapping Portal

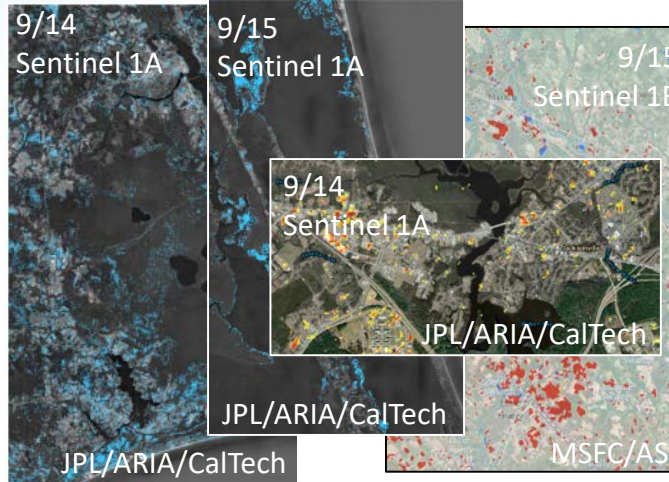
TOOLS TRAINING NEWS

Sharing of imagery, products, and training through uniform services to improve integration

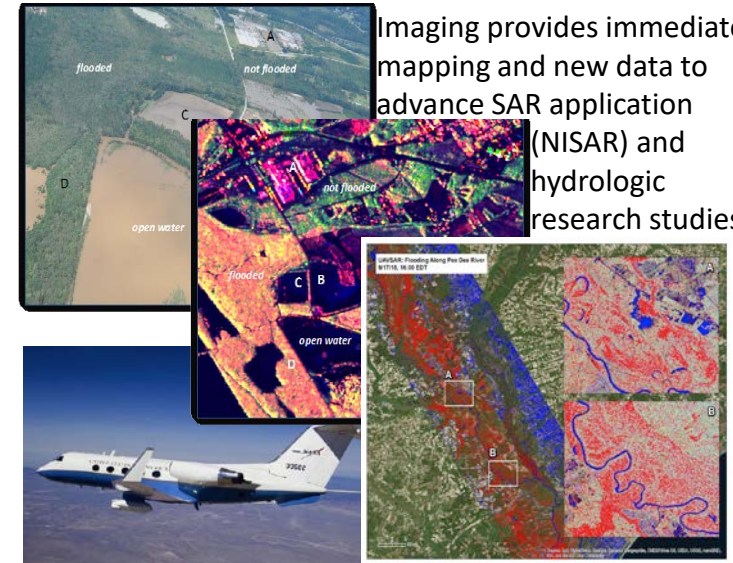


Photos from the ISS demonstrate the storm's intimidating size and intensity, capturing the attention of the public and media

**Flood Mapping:** Team members generate flood and damage proxy maps via ESA and International Charter contributions to SAR imaging



## UAVSAR Flights Support Research and Response Efforts



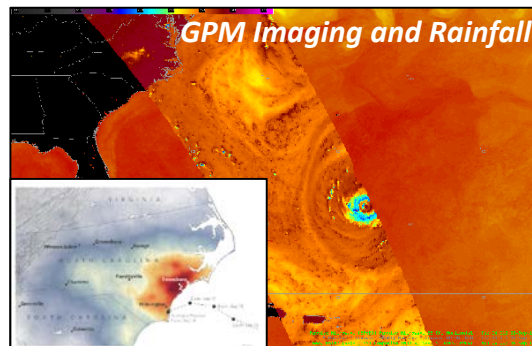
Imaging provides immediate mapping and new data to advance SAR application (NISAR) and hydrologic research studies

Forecasts for Florence identify likely, significant impacts to the southeastern U.S., and NASA team activates for coordination calls, product generation, and end-user engagement

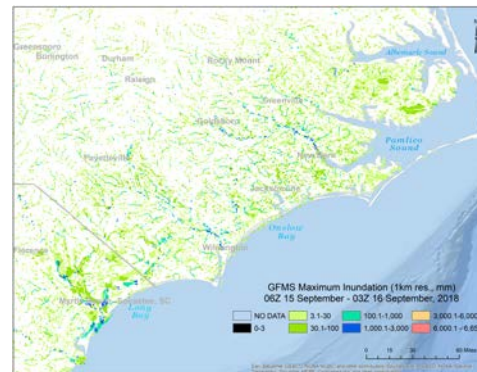
NASA Response Tier 0 Day 1: Sept 9  
 Tier 1: 9/10  
 Tier 2: 9/14  
 9/13 – NASA Team Member Supports at FEMA HQ – 9/20  
 9/14 – UAVSAR and Team Receive FEMA Mission Assignment  
 9/17 – NASA UAVSAR Flights to Support Science and Response – 9/24  
 Tier 1: 9/24  
 0  
 Day 20: Sept 28

**Team Coordination:**  
 Daily calls begin to coordinate NASA team:  
 • Flood Mapping  
 • Other Products  
 • UAVSAR

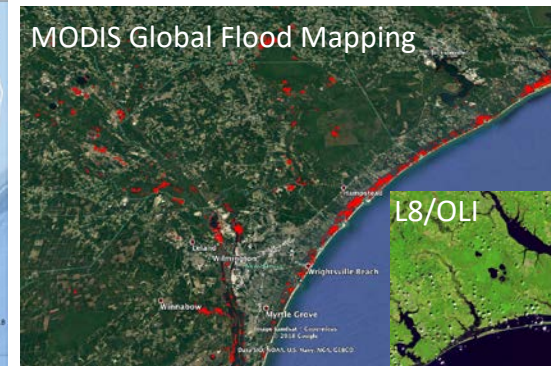
**Pre-Existing Partners**  
 • FEMA, USFS, NOAA/NWS and NWC, USGS, National Guard,  
 • Research/Academia



**Monitoring the Storm:** NASA's SPoRT Center, via R&A, ensures mission data support operational forecasting

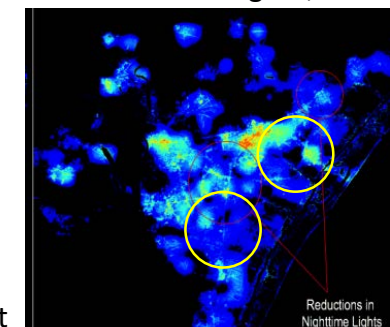


**Global Flood Monitoring System** estimates extent of inundation



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

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



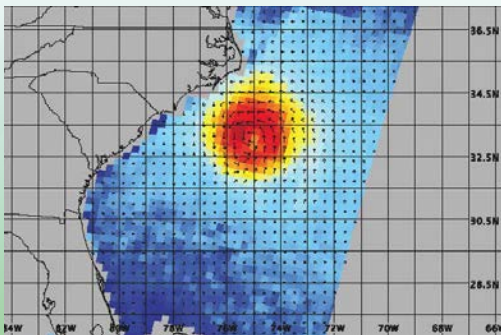
Decreased illumination compared to pre-event composite



# NASA Mission Insights: Structure and Evolution

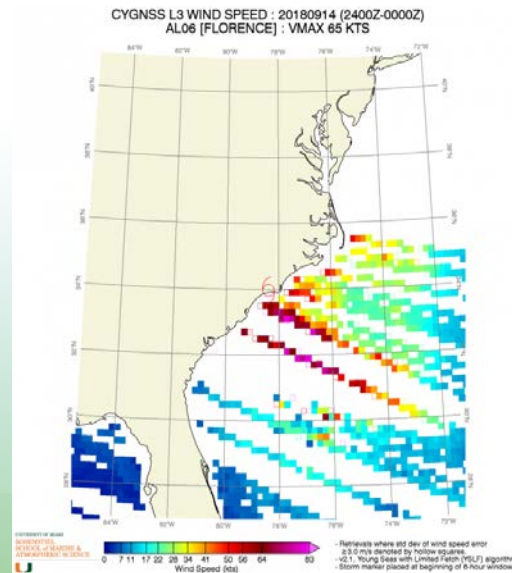
## Ocean Surface Winds from SMAP

- SMAP observations are being used to estimate cyclone wind speeds, helpful for diagnosing and documenting the intensity and extent of impacts



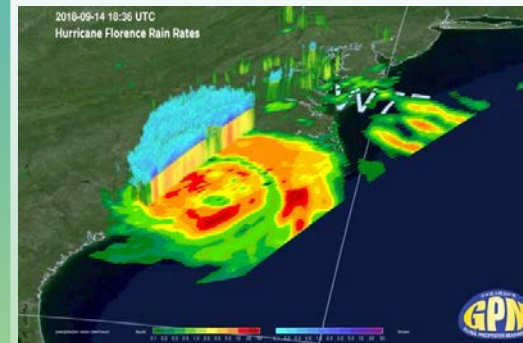
## CYGNSS Wind Speed Measurement

- CYGNSS wind speeds capture higher spatial and temporal details of cyclone intensity



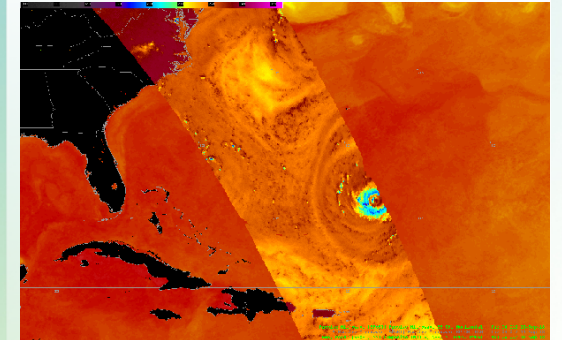
## Monitoring Precipitation with GPM

- GPM Core and supported constellation provide routine mapping of torrential rains and storm structure, particularly valuable in offshore and radar-sparse locations



## Supporting Operational Weather Forecasting

- Imagery from GPM, including views of storm structure and rainfall, provided along with other NASA mission data to the weather community through the SPoRT Center



# NASA Mission Insights: Land Surface and Hydrology

## Imaging the Earth to Capture Flooding

- Routine imaging by Landsat 8 and comparisons to historical record provide visual confirmation of flood extent and potential impacts



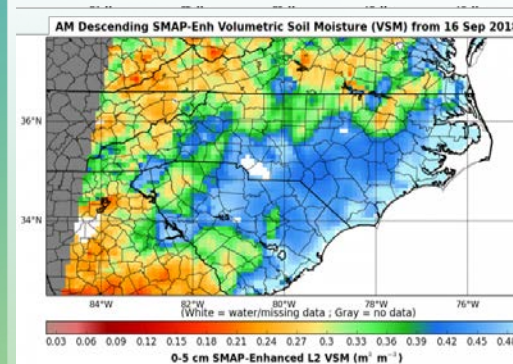
## Coastal Impacts from Flood and Runoff

- Imaging captures sediment plumes and coastal pollution from inland runoff



## Mapping Soil Moisture and Flood Risk

- Observations from the SMAP instrument capture wet soils, increased runoff, and longer-term impacts to agriculture and flood risk in the Carolinas



## Soil Moisture Modeling and Climatology

- Inclusion of SMAP, rainfall, and other information helps real-time predictions for understanding flood risk and improving streamflow models

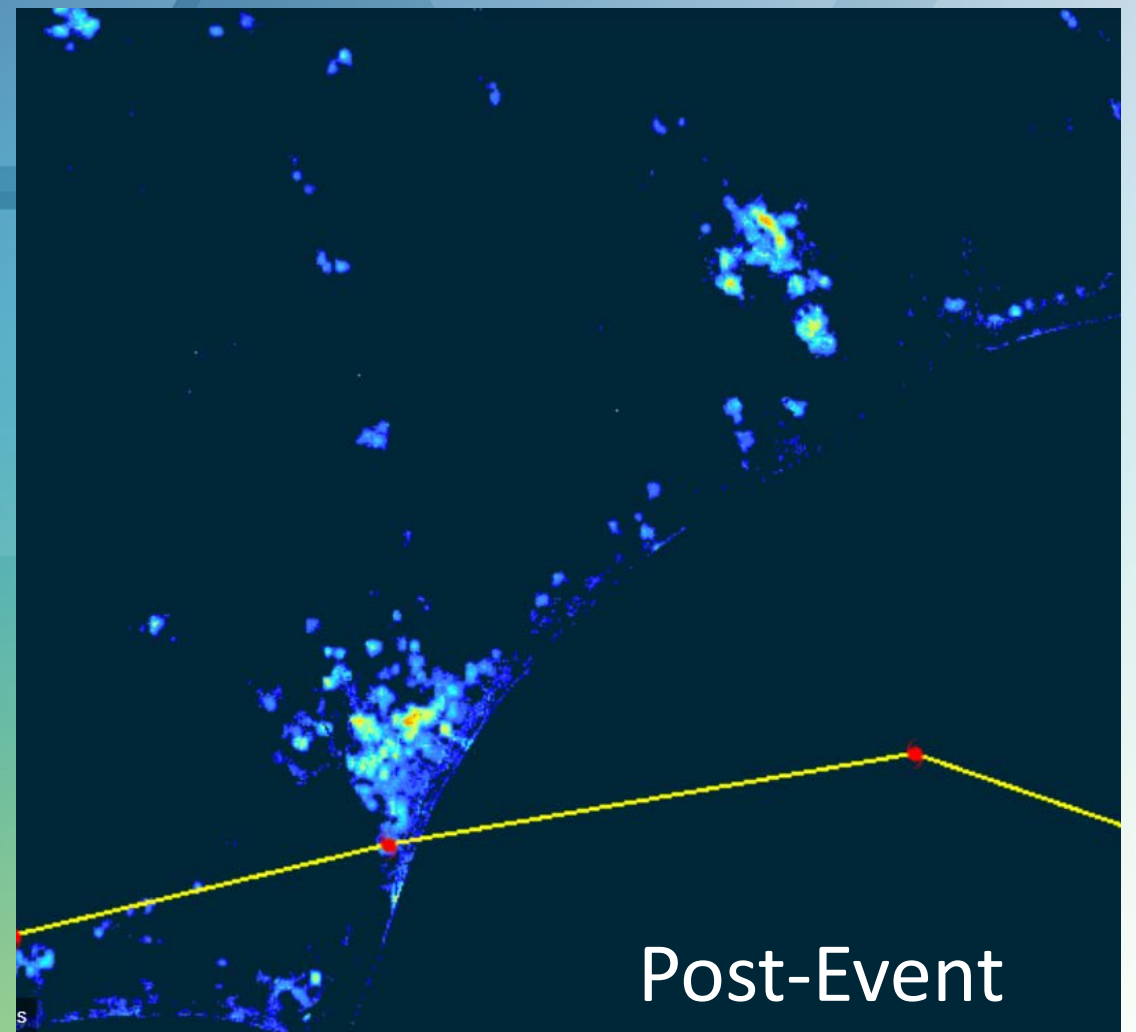
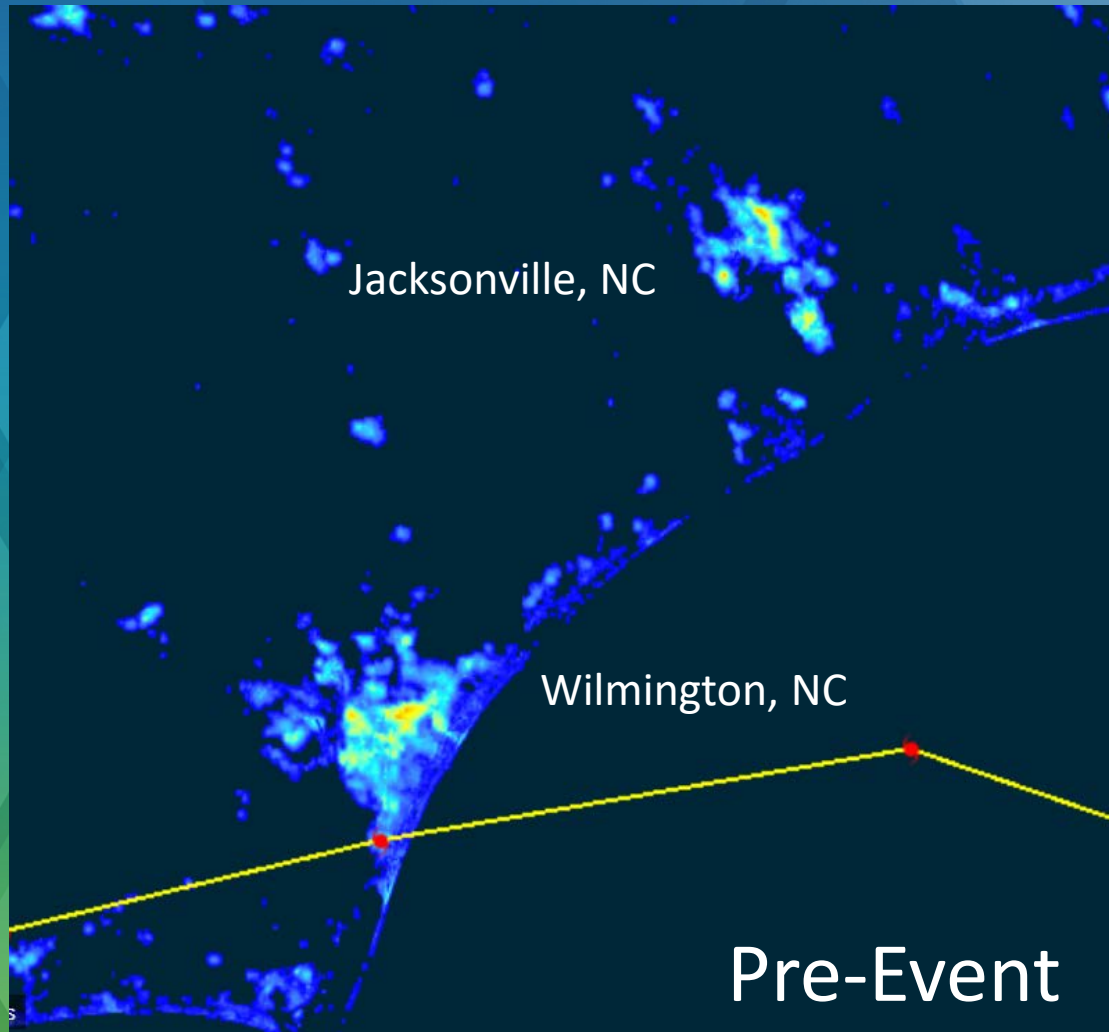




# Products Created for Hurricane Florence

- Flood Products
  - Sentinel-1 Water Extent
  - ARIA Flood Proxy Map
  - Landsat 8 mNDWI
  - MODIS Near Real-Time Flood Product
- Flood Modeling
  - GFMS Inundation Estimate
  - Floodwater Maximum Depth Estimate (National Water Center)
- Soil Moisture
  - Land Information System (LIS) Relative Soil Moisture
- Rainfall Accumulation
  - GPM Precipitation Accumulation (30min, 3hr, 1 day, 7 day)
- Damage Detection
  - ARIA Damage Proxy Map
- Power Outage Detection
  - Black Marble HD
  - Black Marble
  - VIIRS Day/Night Band
- Situational Awareness
  - Sentinel-1 RGB
  - Landsat 8 RGBs

# Black Marble HD Power Outages

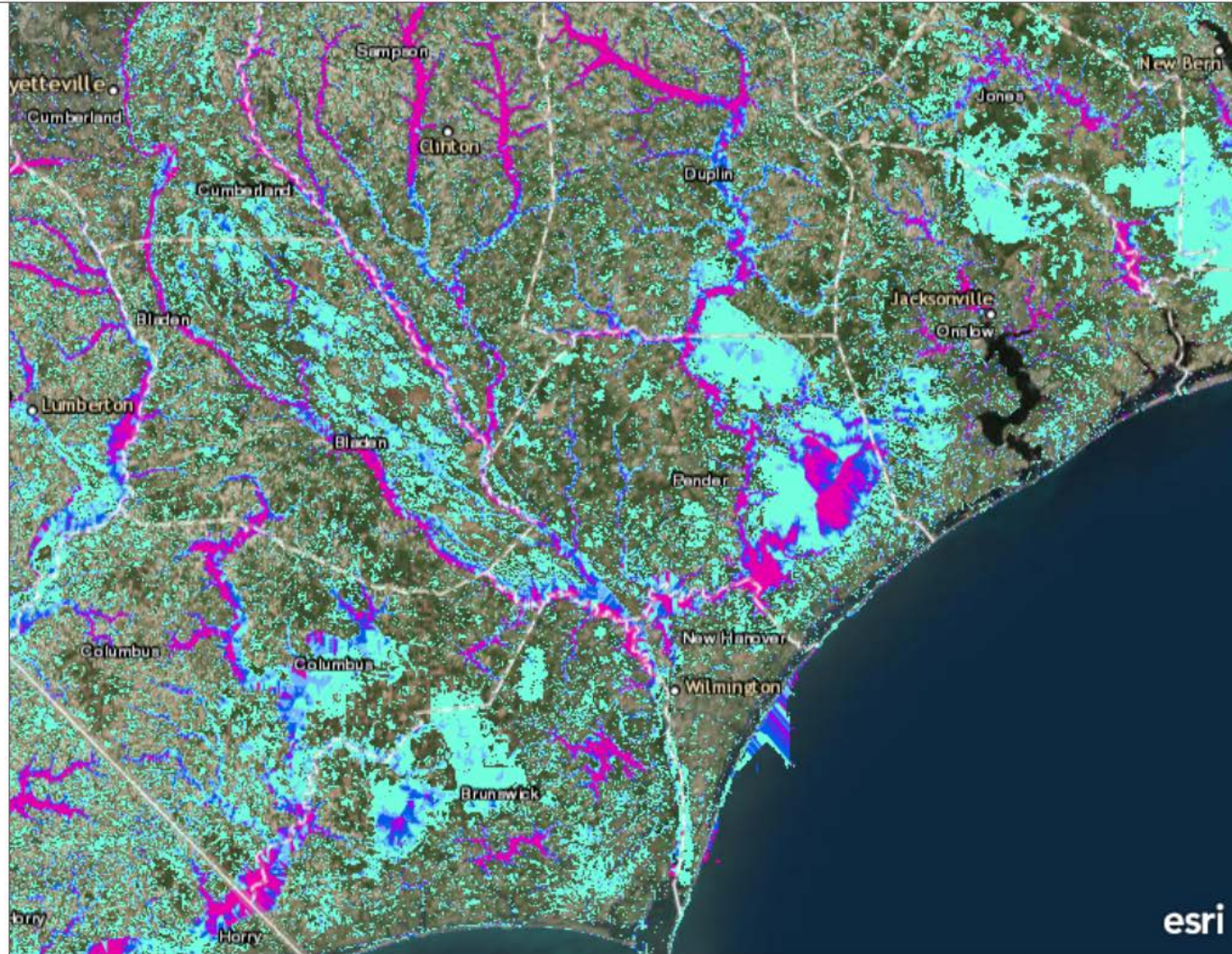
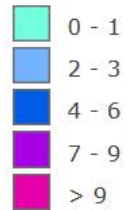




# Floodwater Maximum Depth Estimate

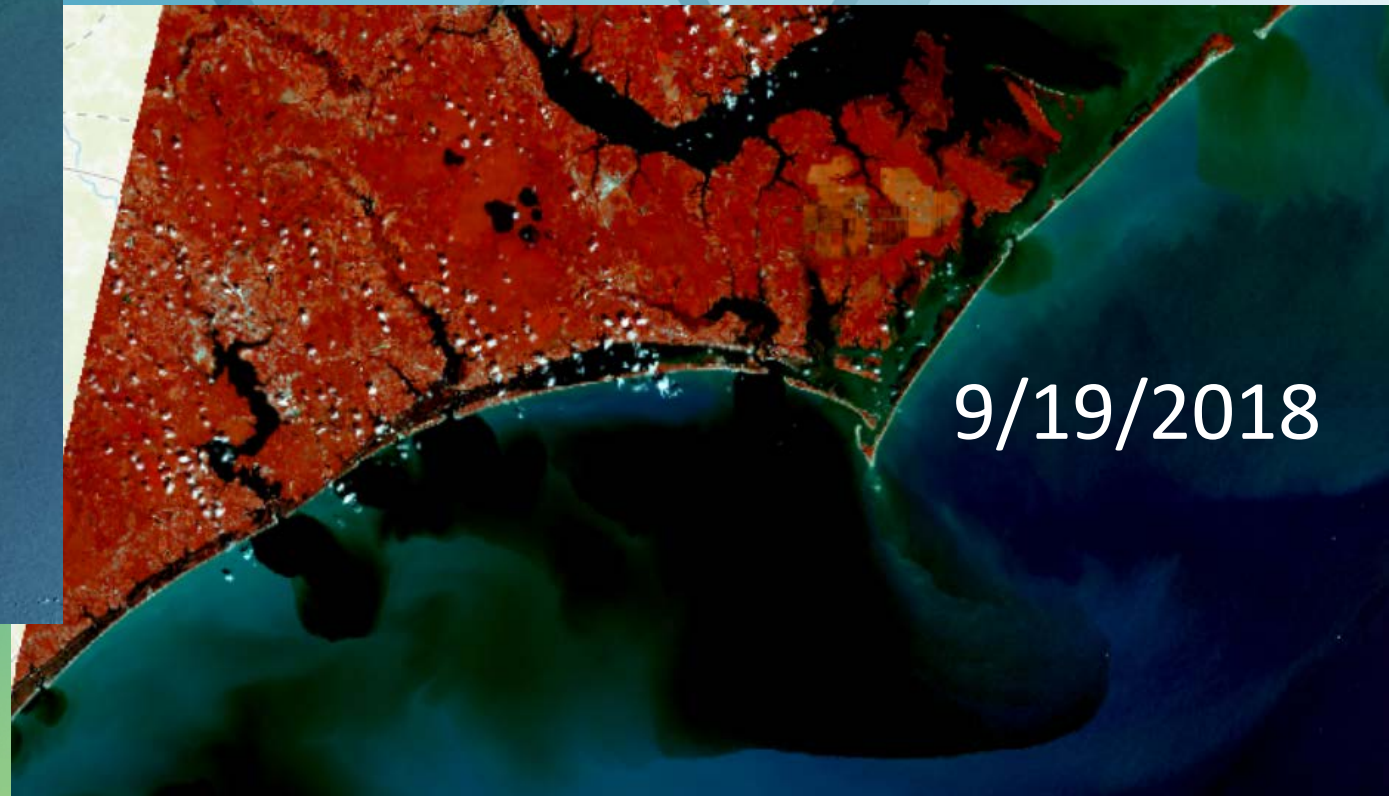
Floodwater Maximum Depth Estimate for Hurricane Florence on 9/18/2018 (NWC)

Floodwater Maximum  
Depth Estimate for  
Hurricane Florence on  
9/18/2018 (NWC)





# Flooding Runoff from Landsat-8



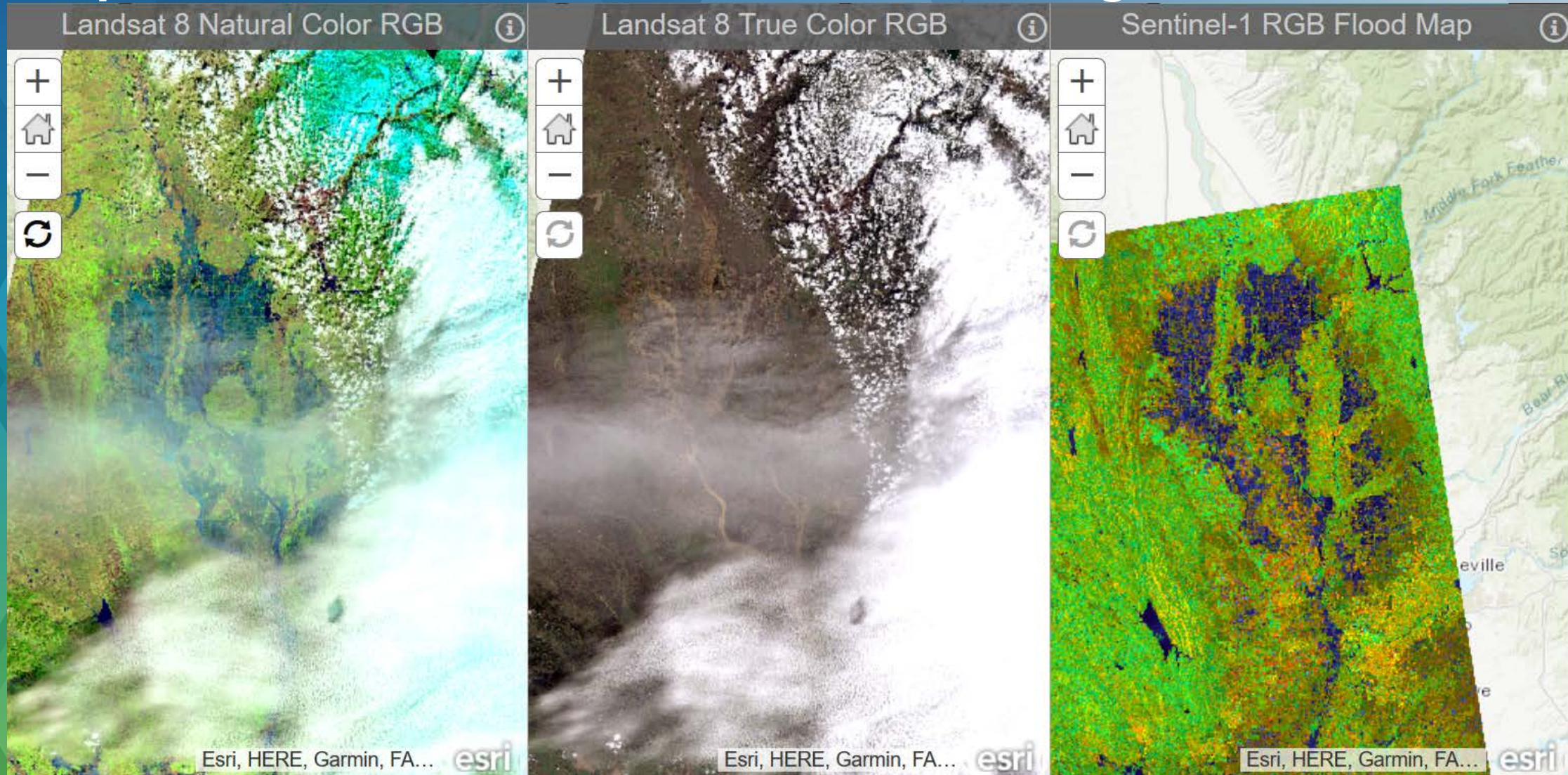


# Optical vs. SAR

- Optical Sensors are passive sensors that captures in the visible spectrum, but are unable to see through clouds and at night
  - Ex: MODIS, Landsat-8, GOES
  - Similar to a traditional camera
  - NASA/USGS/NWS operated
  - More frequent overpasses
- Synthetic aperture radar (SAR) is another way to view Earth's surface through the use of active remote sensing, which allows for capturing images at night and through clouds, rain and smoke
  - Ex: Sentinel-1 (ESA), ALOS-2 (JAXA). UAVSAR
  - Different wavelengths allow for detection of different features
  - Non-NASA operated
  - Less frequent overpasses



# Optical vs. SAR – California Flooding 2019

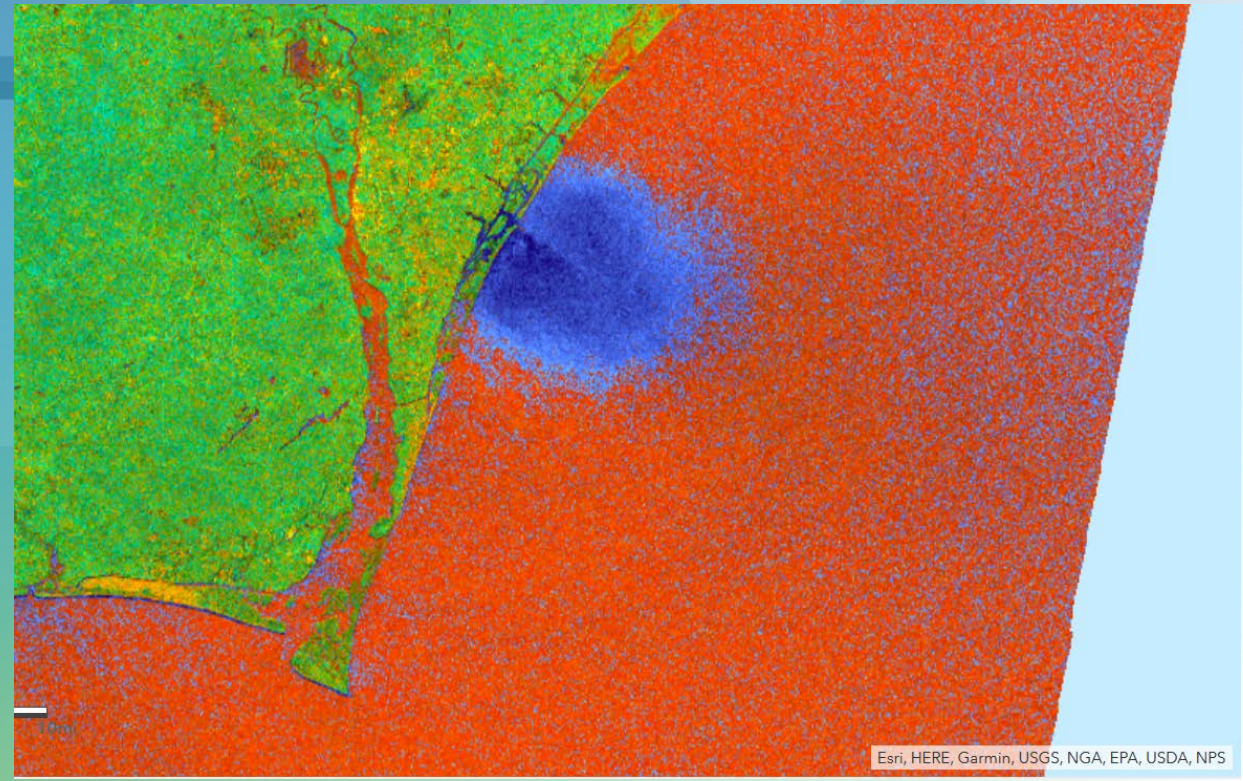




# Optical vs. SAR – Hurricane Florence



MODIS 9/14/2019



Sentinel-1 9/14/2019



# SAR Flood Products

MSFC Water Extent  
9/15/2019

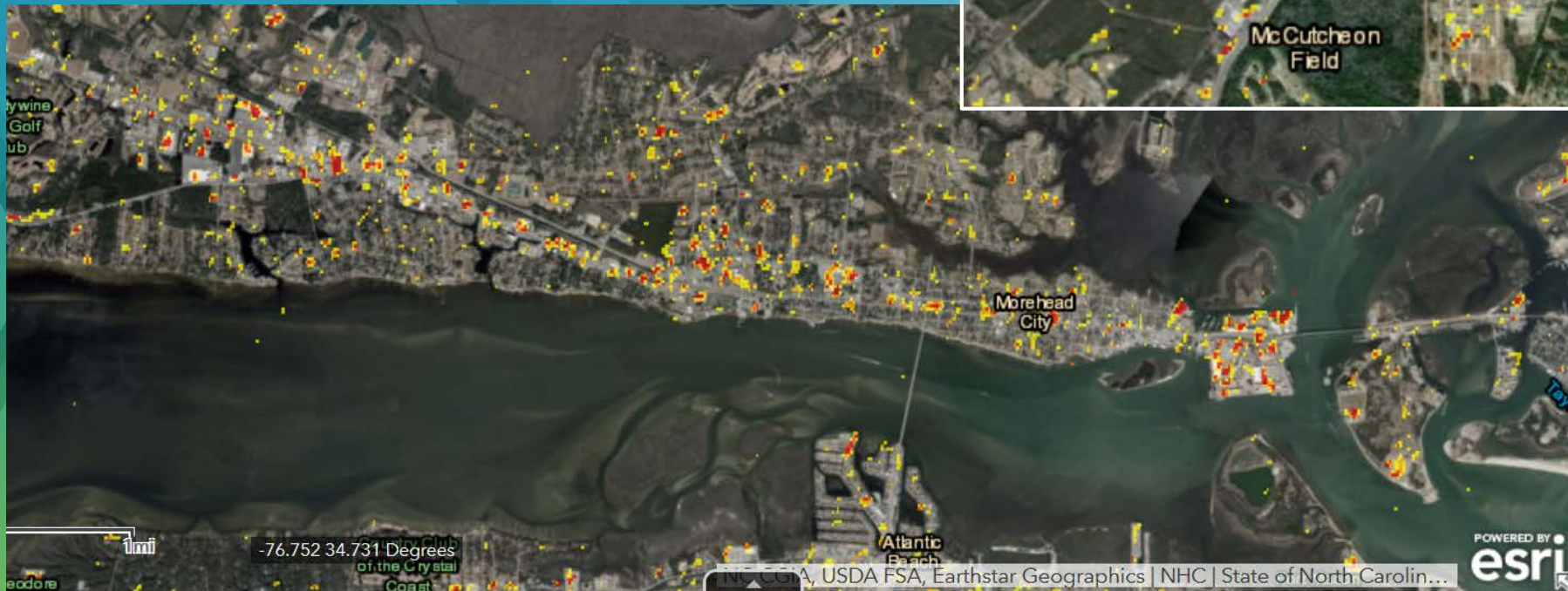
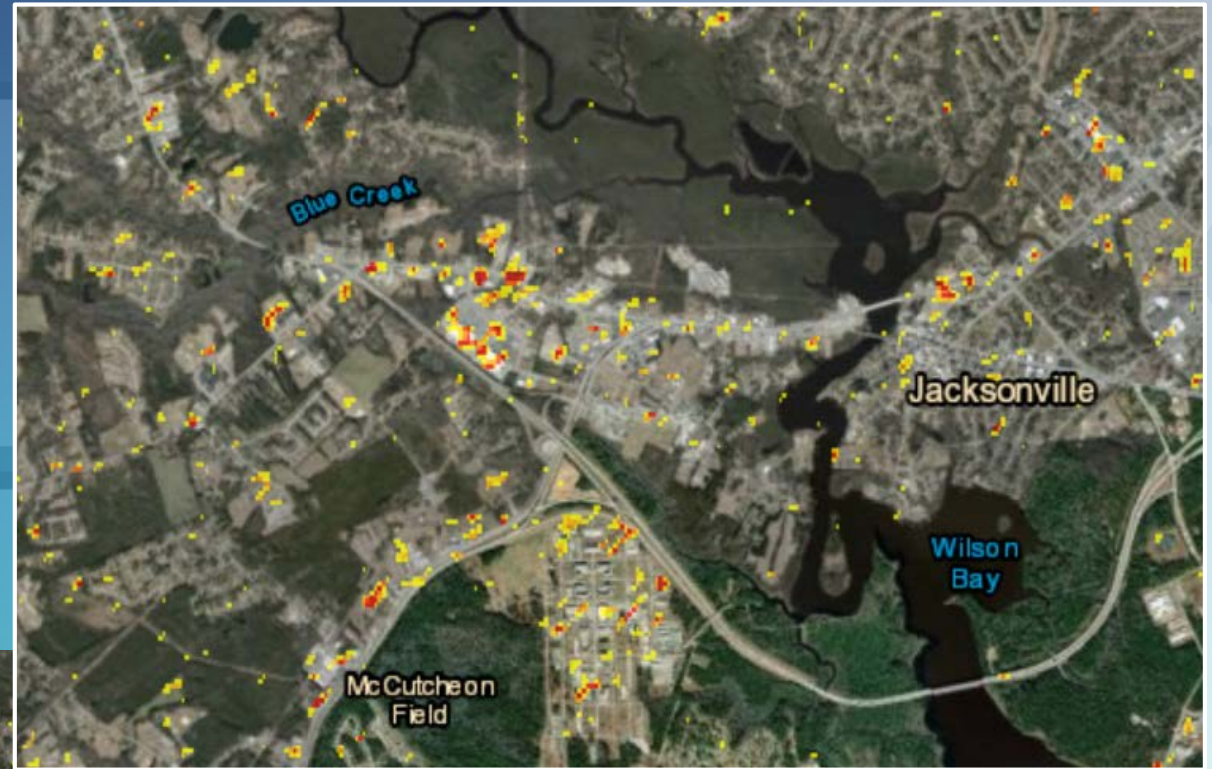


ARIA Flood Proxy Map  
9/14/2019



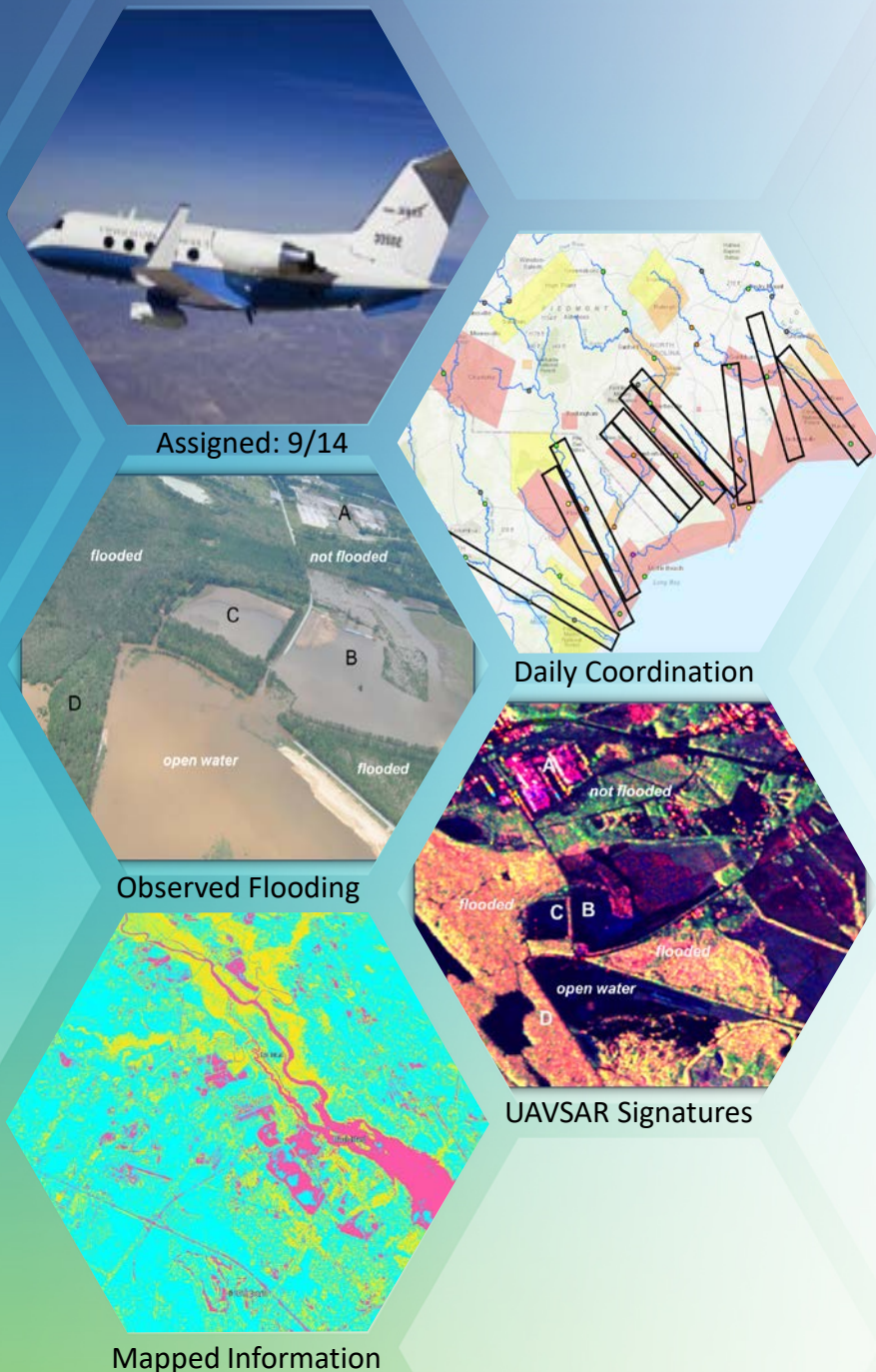
# SAR Damage Mapping

ARIA Damage Proxy Map  
9/14





# UAVSAR Mission Assignment

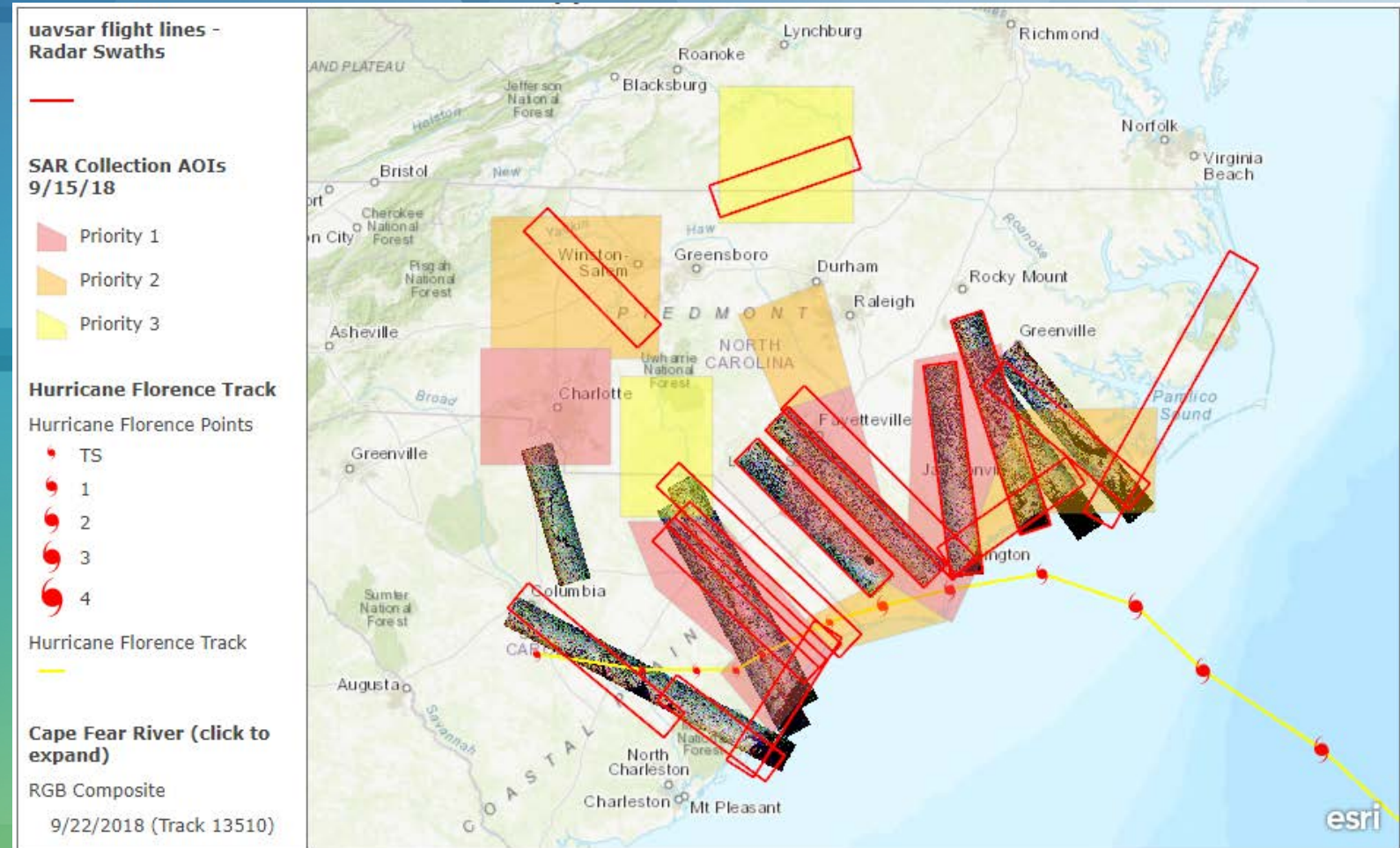


- FEMA requested mission assignment of the Gulfstream-III and UAVSAR instrument for repeat collection of L-band SAR over the affected areas
- Daily coordination calls targeted UAVSAR collections where significant river flooding was ongoing or expected, and where populations were at risk from rising flood waters
- UAVSAR collections supported rapid mapping of flood extent through false color composites and extraction of visual signatures
- 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 2021



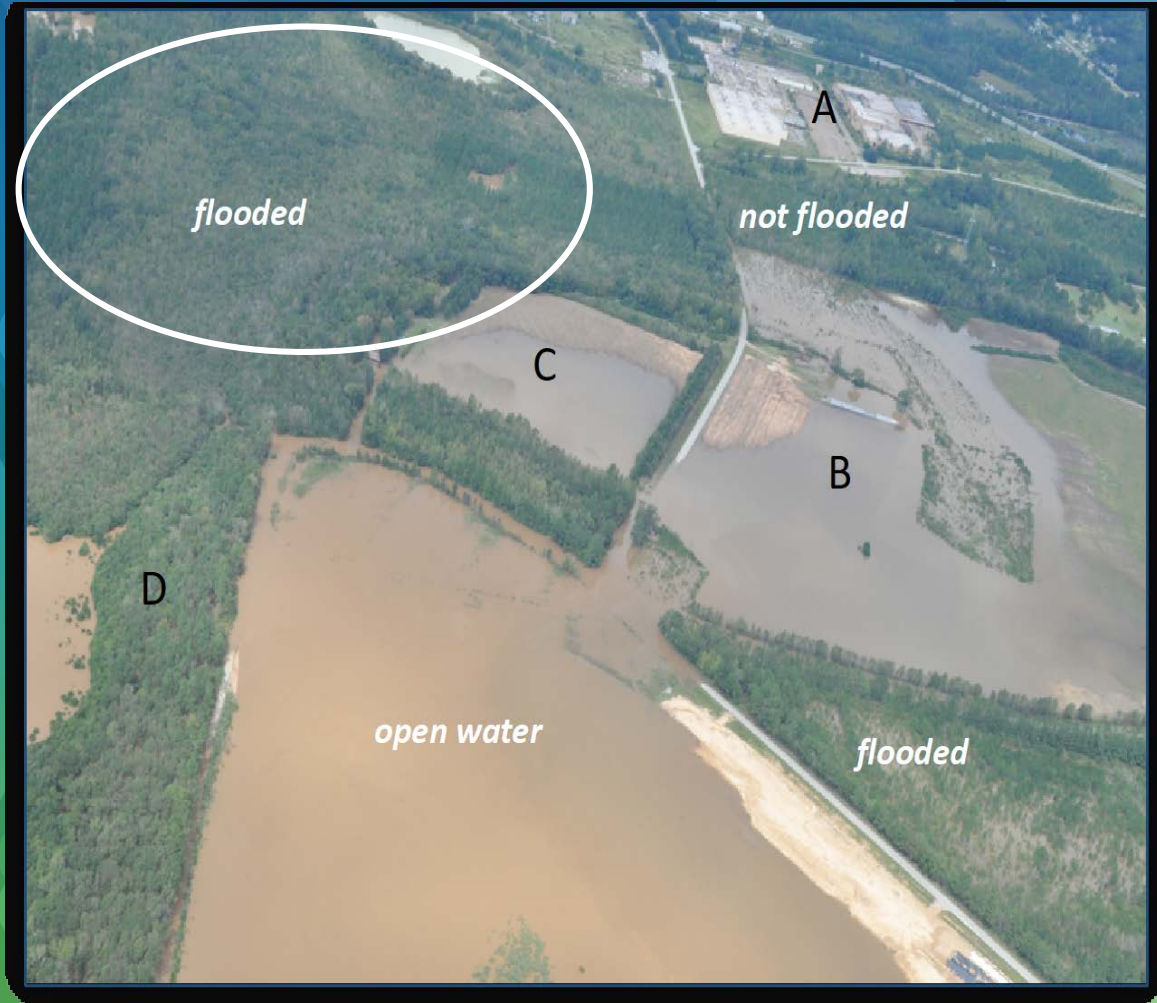
# Rivers and Dates Covered

- Cape Fear River (2 lines)
  - 9/18, 9/19, 9/20, 9/22
- Catawba River
  - 9/17
- Congaree River
  - 9/18, 9/20, 9/22
- Croatan National Forest
  - 9/22
- Jackson River
  - 9/18, 9/19
- Lumber River
  - 9/18 (2 lines), 9/19 (2 lines), 9/20, 9/22
- Neuser River
  - 9/18, 9/19, 9/20, 9/22
- Pee Dee River (2 lines)
  - 9/17 (1 line), 9/18, 9/19, 9/20, 9/22





# UAVSAR Water Detection





# UAVSAR – Cape Fear River

- V

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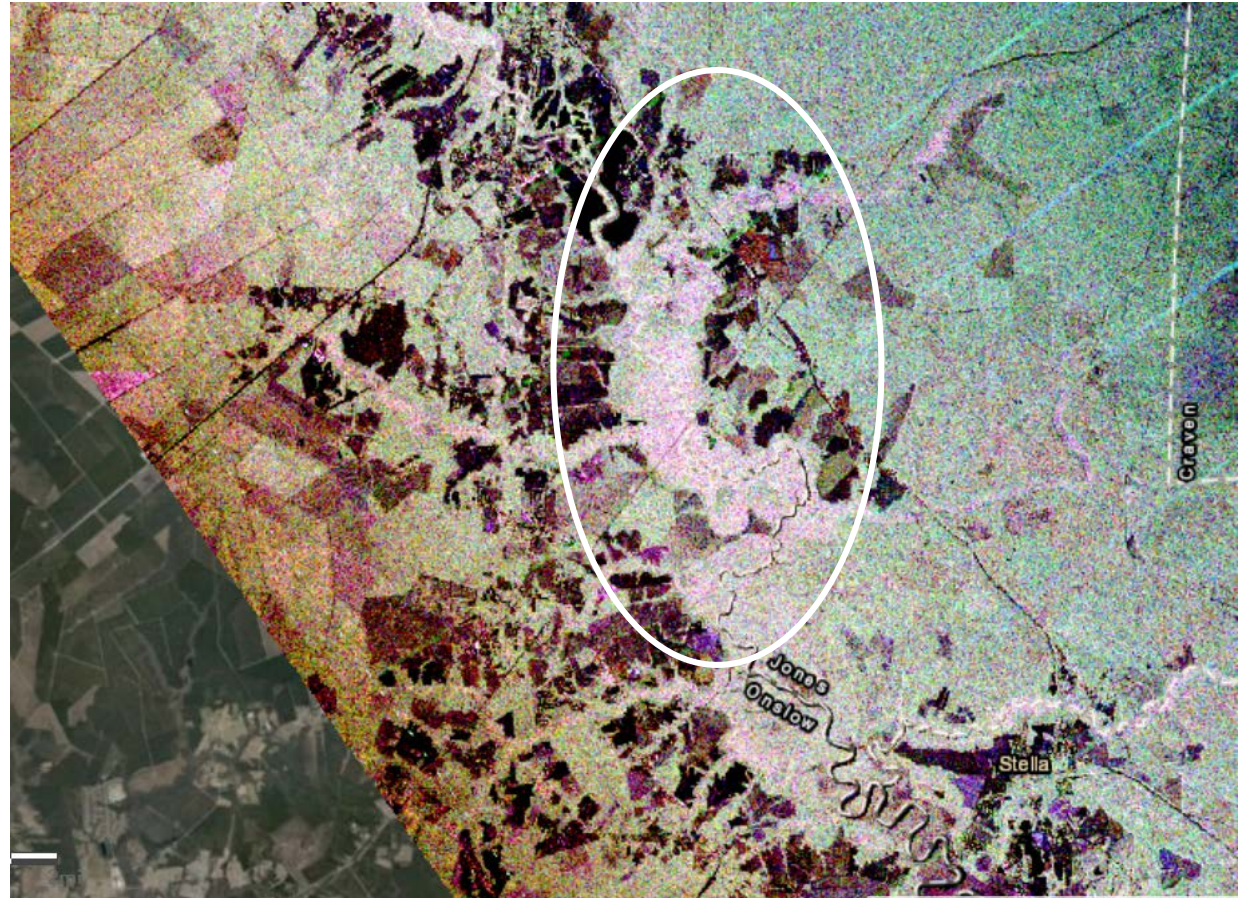
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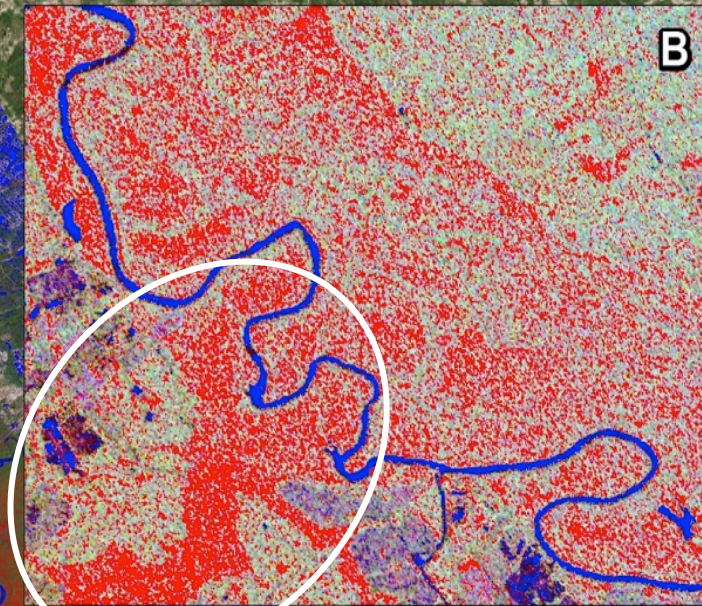
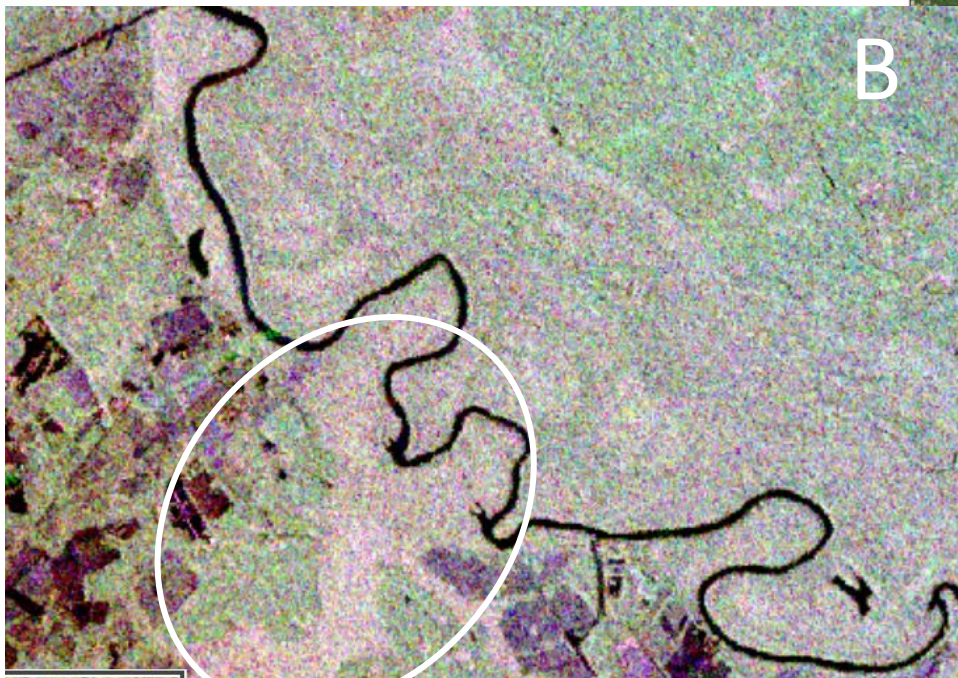
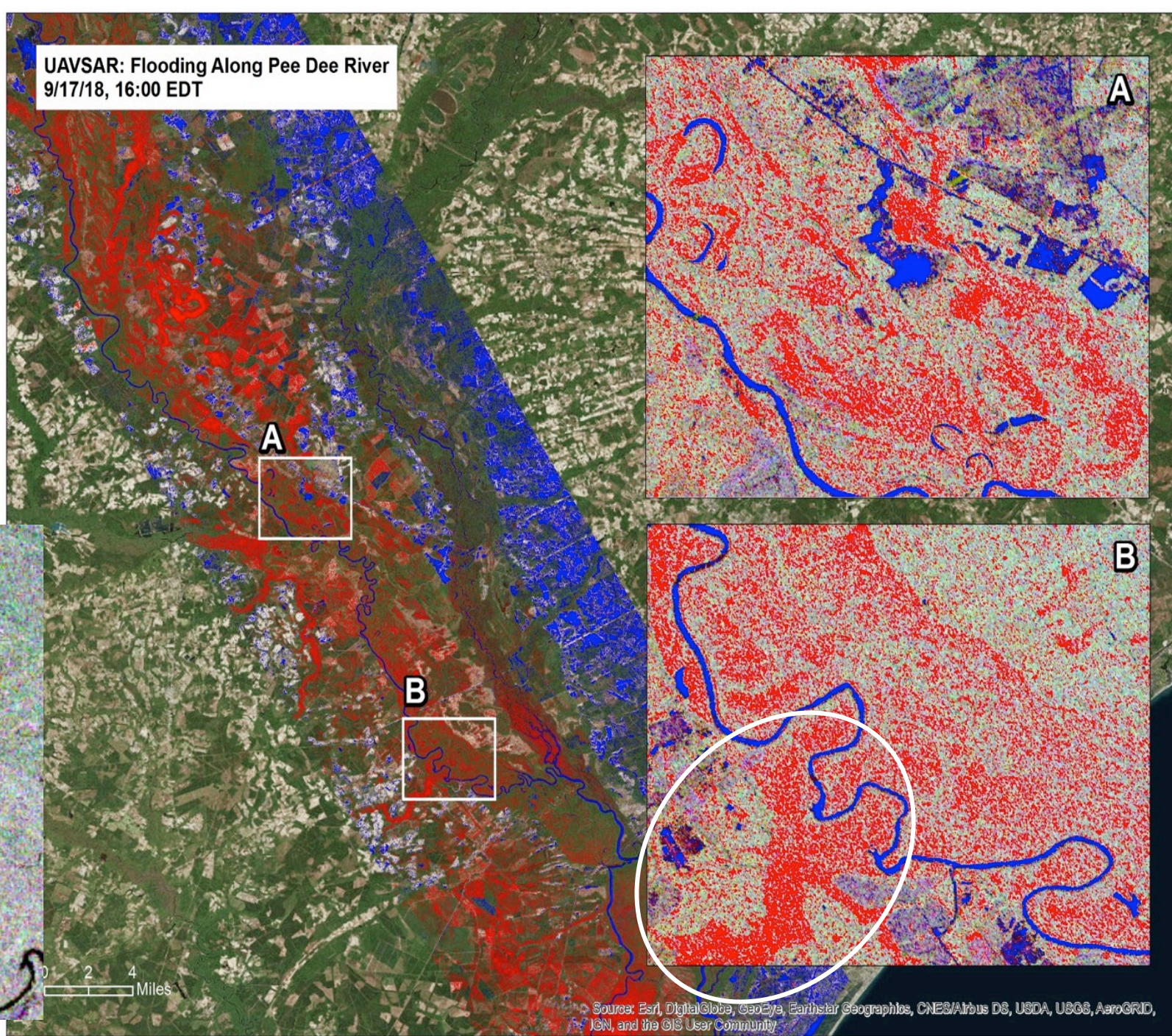
HV

RGB

# UAVSAR – Croatan National Forest









# Conclusions

- Hurricane Florence was a Tier 2 response
- 40+ products/images published to the Disasters Mapping Portal
- Mission assigned by FEMA to fly UAVSAR over the affected regions
- The benefits of the acquisition of this imagery were three-fold. They
  - 1) share UAVSAR imagery in near real-time or reduced latency for local, state, and federal benefits to the immediate needs to response and recovery,
  - 2) provided a scientific opportunity to better understand the signals observed in UAVSAR and complementary SAR imagery as they relate to surface change and structural damage, and
  - 3) opportunities to further develop change/damage products and mapping from UAVSAR and other on-orbit platforms.
- Built on existing and created new relationships with stakeholders and end users



# Where to Get Data and Information

- Disasters Program Website
  - <https://disasters.nasa.gov>
  - Contains information about the program
  - Information about the Risk and Resilience aspects
  - Additional resources
  - Non-GIS data
  - Blog-like posts about responses
- Disasters Mapping Portal
  - <https://maps.disasters.nasa.gov>
  - Primary source for data produced during a response
  - GIS-enabled for both Esri and open source software



# Questions?

Garrett Layne

[garrett.w.layne@nasa.gov](mailto:garrett.w.layne@nasa.gov)

<https://maps.disasters.nasa.gov>

<https://disasters.nasa.gov>



# Results, Findings, and Recommendations

- Based upon recent experiences with Hurricane Florence:
  - Coordination with other federal agencies and partners (FEMA, NOAA/NWS, USGS, National Guard, USFS, and others) is critical to understanding data needs, response and future research or applications questions, and to identify future opportunities
    - Participation at FEMA helped NASA to understand the types of questions being asked, methods for best use of data, limitations of various platforms, and paths forward on research and applications
    - Routine coordination with other partners on calls are similarly helpful. To sustain engagement and improve for future events, participate in after-action reviews and work with partners on product, training, and delivery needs
  - Mission assignment of UAVSAR helps NASA to practice and refine internal policies and procedures for rapid airborne deployment. Partnerships refined with scientists to produce reduced latency analyses, along with follow-on products of greater accuracy and detail
    - For example, collection of SAR imagery from ESA, International Charter, and other partners, delivery of output mapping and UAVSAR information to HDDS and other portals, training, etc.

# Response and Engagement Timeline: Hurricane Florence



Forecasts for Florence identify likely, significant impacts to the southeastern U.S., and NASA team activates for coordination calls, product generation, and end-user engagement



NASA Response Tier 0 Tier 1: 9/10

Day 1: Sept 9

## NASA Team Activation for Florence Response Efforts

In consultation with partners, NASA team activates to begin coordination of response activities. Team Lead Jordan Bell (MSFC/UAH), HQ staff (Struve/Seepersad), GIS specialists (Kirkendall/Layne/Borges), and other Center coordinators (Glasscoe/JPL, Osmanoglu/GSFC, Stefanov/JSC) begin to sketch timelines for product generation, delivery, and end-user collaborations.

**Pre-Existing Partners:** FEMA, USFS, NOAA, USGS, NGB

## NASA Team Member Supports at FEMA HQ

Andrew Molthan (MSFC) traveled to DC to support FEMA's Geospatial Team with interpretation of products and to help coordinate UAVSAR mission tasking and flight efforts.

In the Subcommittee on Disaster Reduction (SDR) review of Florence (10/4), FEMA stated "NASA provided a visiting scientist who helped process and integrate UAV SAR data into our existing, time-sensitive flood detection and structural damage assessment workflows."

9/18: 10 9/19: 9 9/20: 8

9/17: UAVSAR Arrives + 2 Legs

Tier 2: 9/14

## UAVSAR and Team Receive FEMA Mission Assignment

FEMA provides mission assignment designation to the G-III/UAVSAR team out of the Airborne Science Program. Yunling Lou (JPL), Naiara Sardinha Pinto (JPL), John McGrath (AFRC), Randy Albertson (AFRC) and others join in collaborations with other NASA team members to target collections en route and in subsequent days of flight assignments.

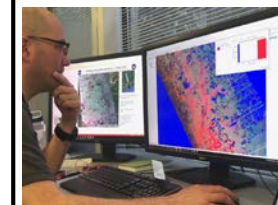
## New Experiences Gained by NASA and FEMA Teams

"This was the first time FEMA implemented our Automated Area of Interest Designation application to nominate regions for further airborne data collection by analyzing social vulnerability of communities and their probability of exposure to unfolding hazards." – FEMA Response GIS

9/22: 8 9/23: 8 UAVSAR Collections

Tier 1: 9/24 0

Day 20: Sept 28



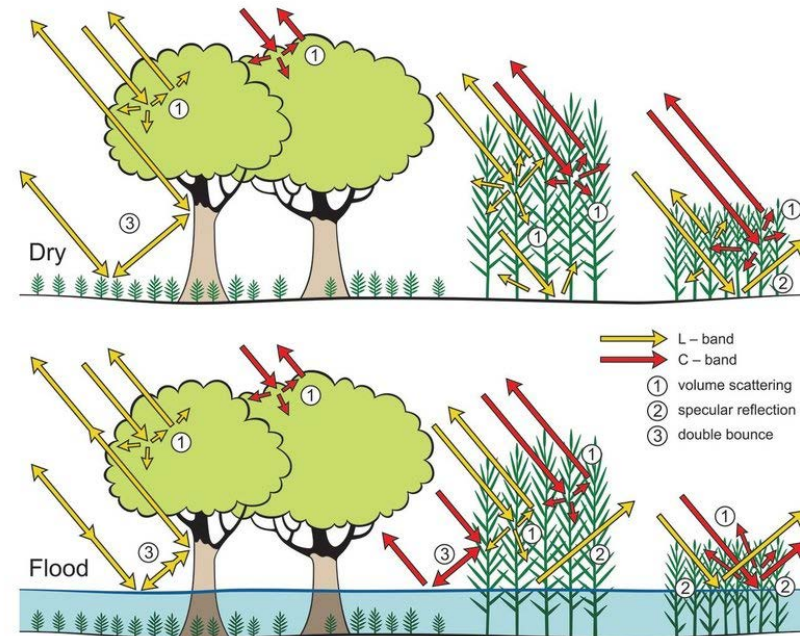
## Leveraging UAVSAR Data Collections for Analysis

FEMA looks forward to continuing this close partnership with NASA teams to jointly develop methods for synthesizing near-real time airborne SAR data, elevation data, rainfall observations, and high-resolution visible images in support of enhanced situational awareness and rapid damage assessments.



# How SAR Works

- Amplitude or intensity images from SAR of a vegetated or crop covered area is affected by the wavelength of the sensor (how deep the radiation can penetrate the top surface (leaves and branches)), geometry of the object (structure and orientation in the case of vegetation), surface roughness, and water content on the surface.



# UAVSAR Flight Lines

