Integration of Synthetic aperture radar imagery and derived products into Severe Weather Disaster Response

Lori A. Schultz[1], Andrew Molthan[2], Jeremy B. Nicoll[3], Jordan R. Bell[1],

Rudiger Gens[3] and Franz J. Meyer[4]

[1]Earth System Science Center, University of Alabama Huntsville,

[2]Earth Science, Marshall Space Flight Center

[3]Alaska Satellite Facility, University of Alaska Fairbanks, Fairbanks, AK

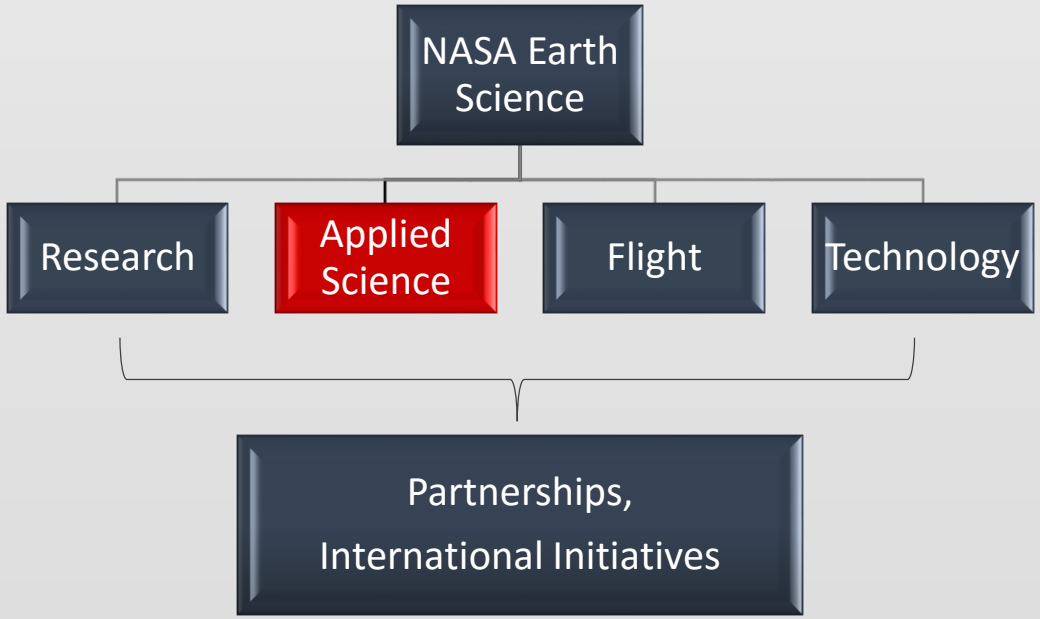
[4]Geophysical Institute, University of Alaska Fairbanks, Fairbanks, AK

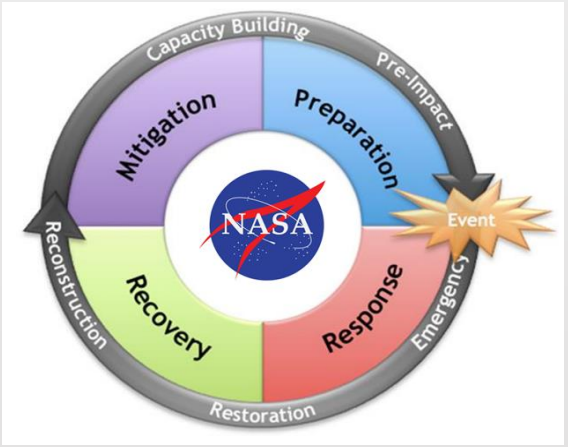
NASA SPORT Short-term Prediction Research and Transition Center

NASA's Earth Science DISASTERS

Applied Science and Disaster Response at NASA

Science Mission Directorate
Earth Science Division





- *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	Tier 1	Tier 2	Tier 3
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*	**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*	**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)*	**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 SPORT
Short-term Prediction Research and Transition Center

The SPoRT Paradigm

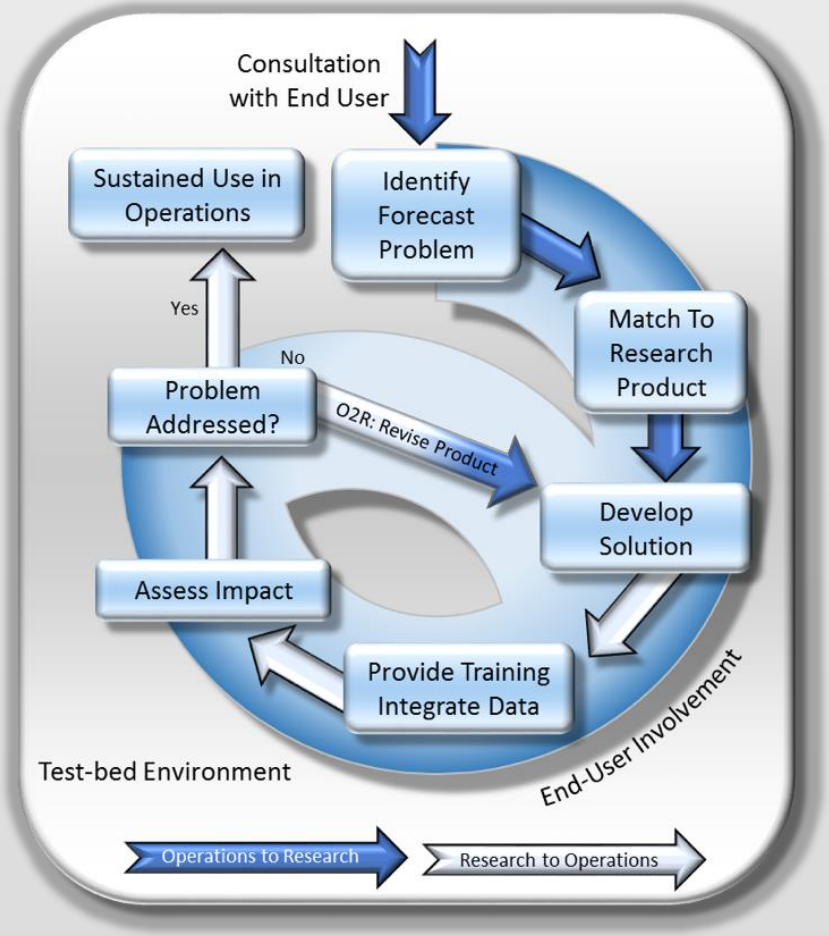
Short-term Prediction Research and Transition Center (SPoRT)

Keys to success

- **Involve** end users throughout the entire process.
- **Develop** end-user appropriate training on how to understand and correctly use the solution that has been developed
- **Assess** impact of solution on operations

A successful transition occurs when a new capability has a predominately positive impact on the forecast problem and is used “operationally” in the end users decision support system.

“Operational” use means regular or sustained use of data / products to make decisions



NASA SPORT Short-term Prediction Research and Transition Center

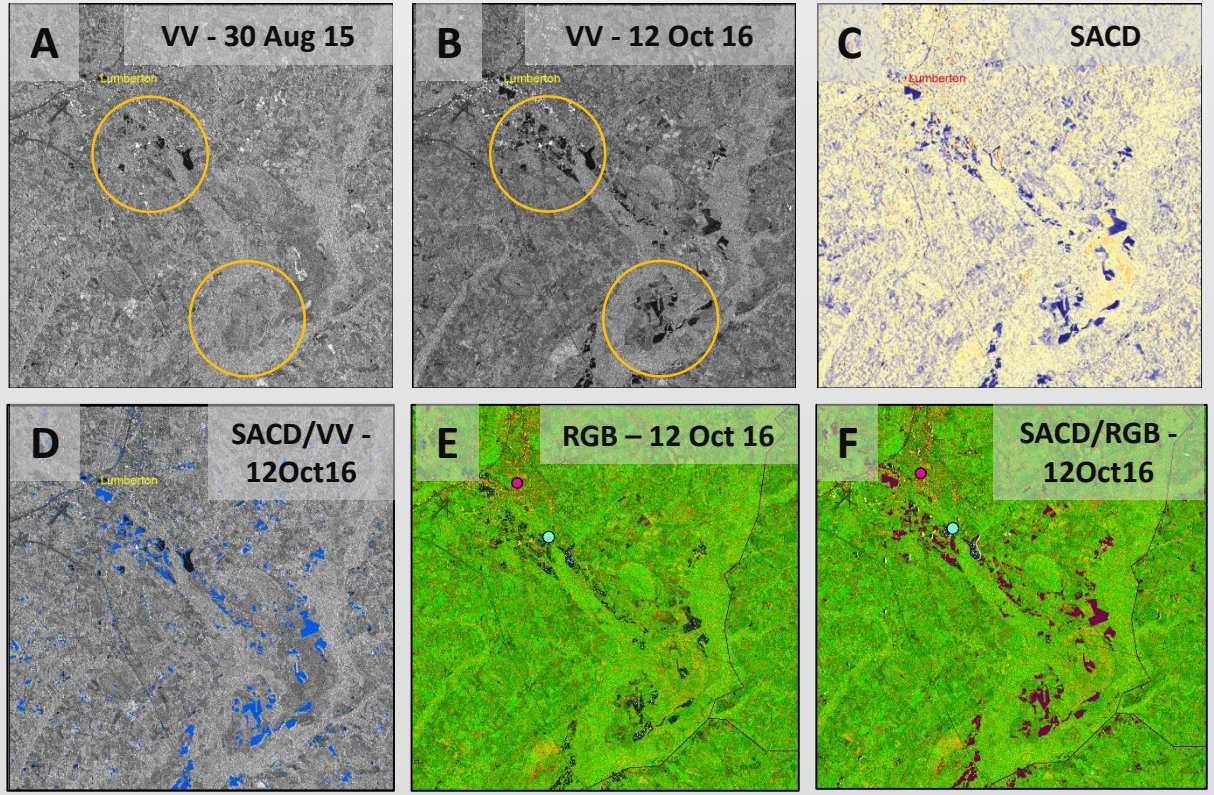
https://weather.msfc.nasa.gov/sport/

NASA's Earth Science DISASTERS

Collaborations with ASF

NASA SPoRT and ASF collaborations to further end-user SAR application use started with a two-week visit to the Alaska Satellite Facility (ASF) to work with scientists and developers directly.

- This in-depth engagement allowed for both parties to learn and better understand processing requirements, capabilities and limitations of SAR imagery, especially the Sentinel 1A/B instruments from both the processing and end-user perspectives.



Hurricane Matthew case study. A) VV-polarization RTC image from 30 Aug 15. B) VV-polarization RTC image from 12 Oct 16. C) Simple Algorithm Change Detection (SACD) output. D) Threshold applied to SACD (C) and overlaid on post VV-image (Blue). E) RGB from 12 Oct 16. F) RGB with change detection overlaid.

NASA SPORT Short-term Prediction Research and Transition Center

ASF DAAC 2017, contains modified Copernicus Sentinel data 2016.

NASA's Earth Science DISASTERS

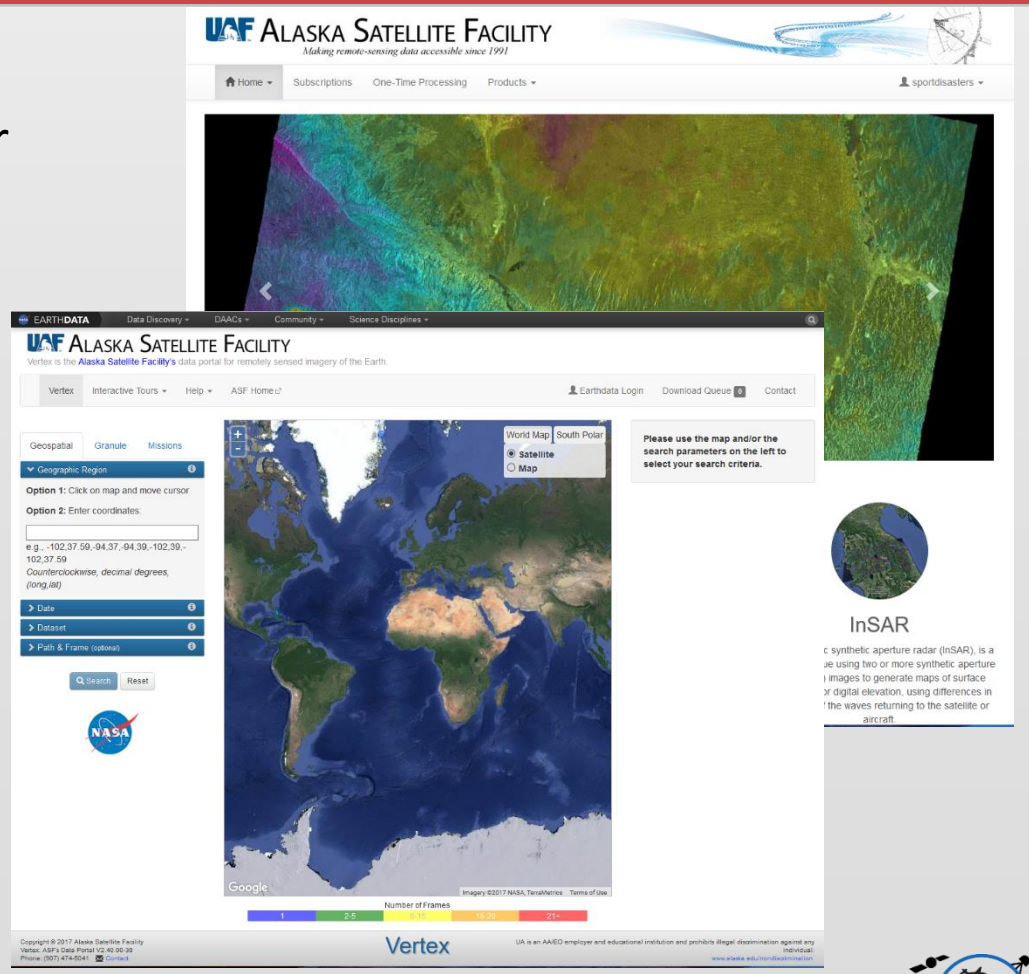
ASF Hybrid Pluggable Processing Pipeline (HyP3)

Vertex (https://vertex.daac.asf.Alaska.edu) is the Alaska Satellite Facility's data portal for remotely sensed Synthetic Aperture Radar (SAR) imagery.

- Using a NASA Earthdata login, a user can access SAR imagery from multiple instruments and missions dating back to 1978.
- Data is available in multiple formats, depending on sensor.
- Additional information is provided on additional processing options, software packages and other training topics.

ASF's HyP3 system is a collaboration tool for prototyping tools and recipes.

- HyP3 offers users SAR derived products, calibrated and processed using known scientific algorithms for specific tasks:
  - False color Composites (RGB images)
  - Interferometric SAR
  - Change Detection

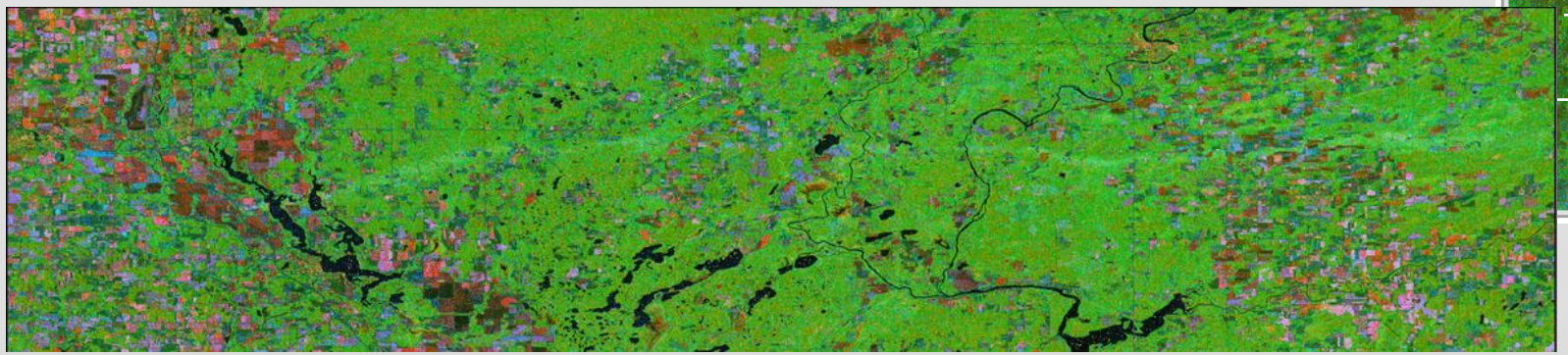


Tornado Track Detection

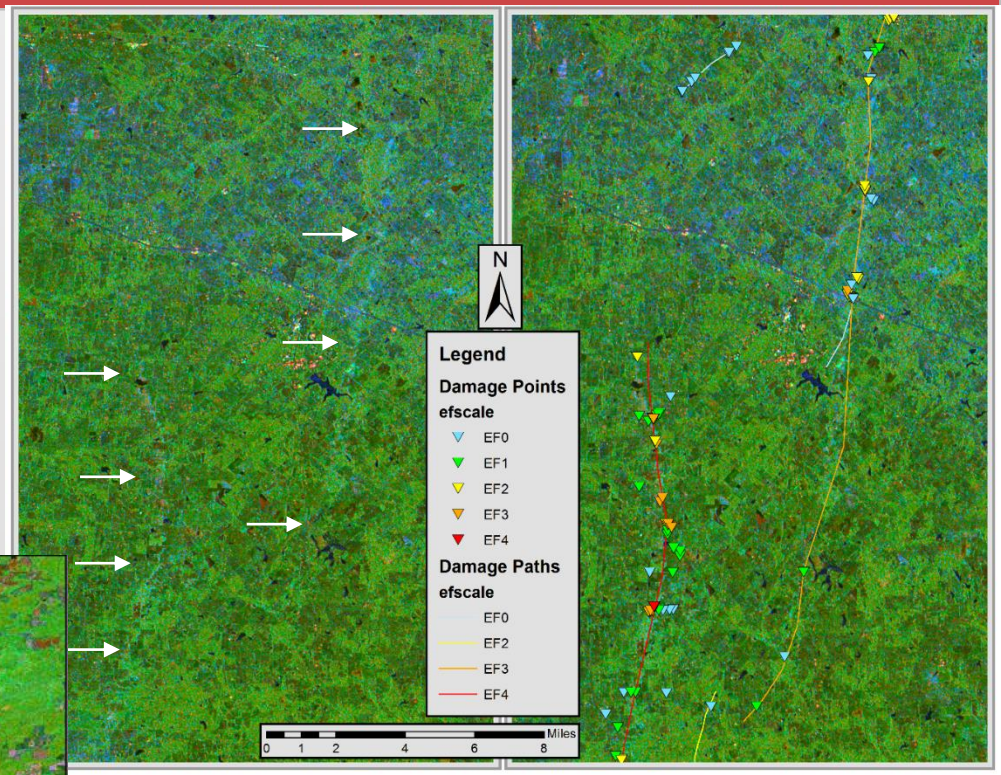
Sometime, acquiring a cloud free look over a damaged area is difficult, making optical satellite imagery difficult to rely on for storm surveys.

Here, false color composites *focused on change detection*, look at differences in VH-polarization returns pre- and post-storm to visually identify tracks.

- Red channel: co-pol – post image
- Green channel: cross-pol – post image
- Blue channel: cross-pol -> pre - post



Sentinel 1A Change RGB: Clear Lake, Wisconsin – EF-3 tornado



Sentinel 1A Change RGB:
Canton, Texas – EF-4 tornado

NASA SPORT Short-term Prediction Research and Transition Center

ASF DAAC 2017, contains modified Copernicus Sentinel data 2017.

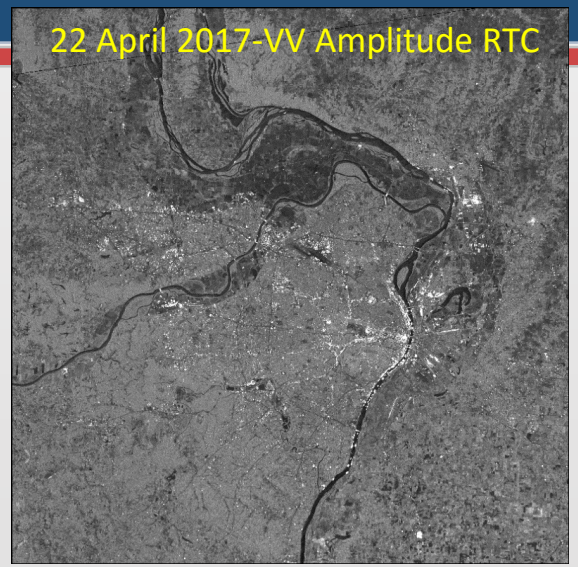
NASA's Earth Science DISASTERS

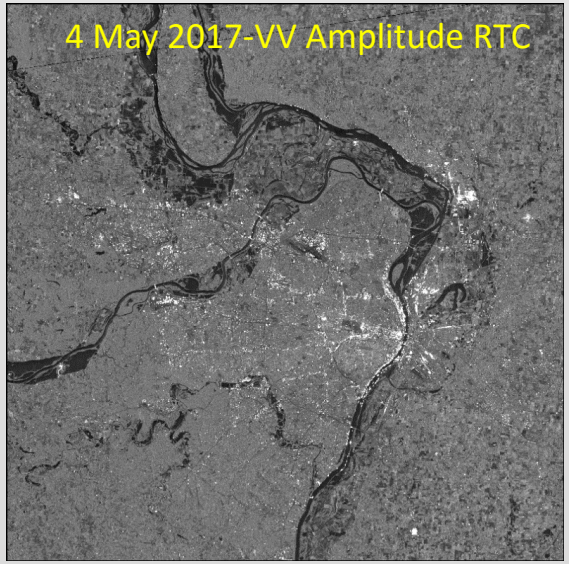
Missouri Floods of Spring 2017

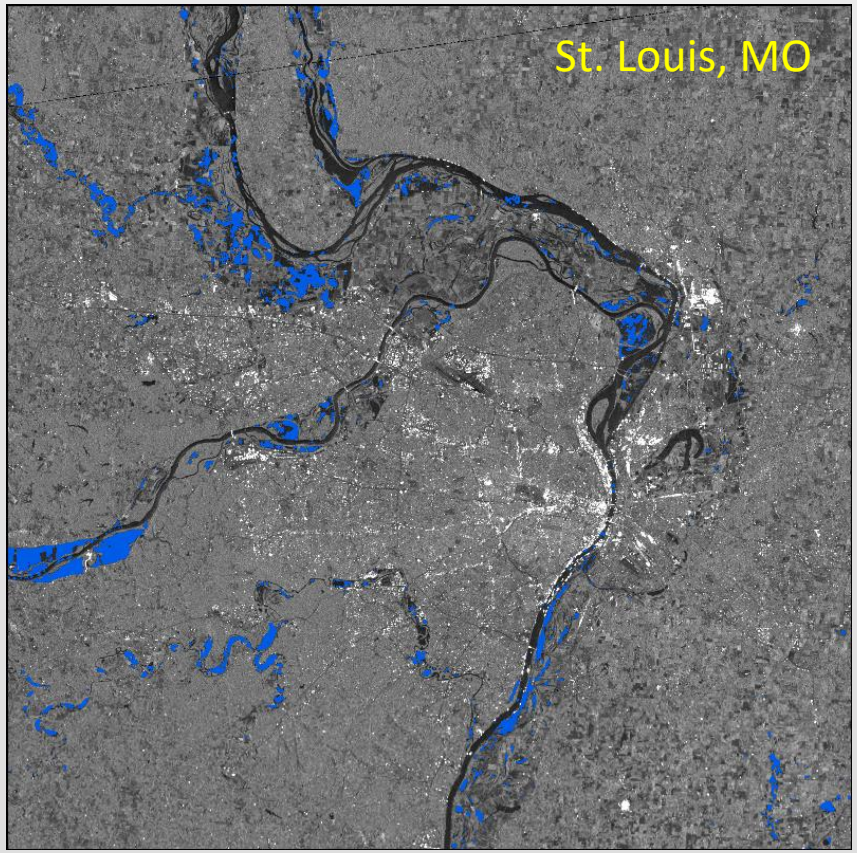
SAR products from Sentinel 1A/1B are useful for the visualization of flood water, urban area, and vegetation given unique appearances in co- and cross-pol returns.

Collaborations with the University of Alaska Fairbanks and the Alaska Satellite Facility provide RTC , change detection and false color combinations to aid in interpretation.

In late April 2017, portions of the Midwest received heavy rainfall over the course of multiple days. This caused the rivers to rapidly swell and begin flooding. Several federal agencies responded to the river flooding, including the Federal Emergency Management Agency (FEMA) and the National Guard Bureau







The change detection algorithm identifies areas of change (blue pixels) between the two images that meet a certain threshold. The change identified in this image, is consistent with water being present in the later image, where it wasn't in the early image, flagged as potential flooding.

NASA SPORT Short-term Prediction Research and Transition Center

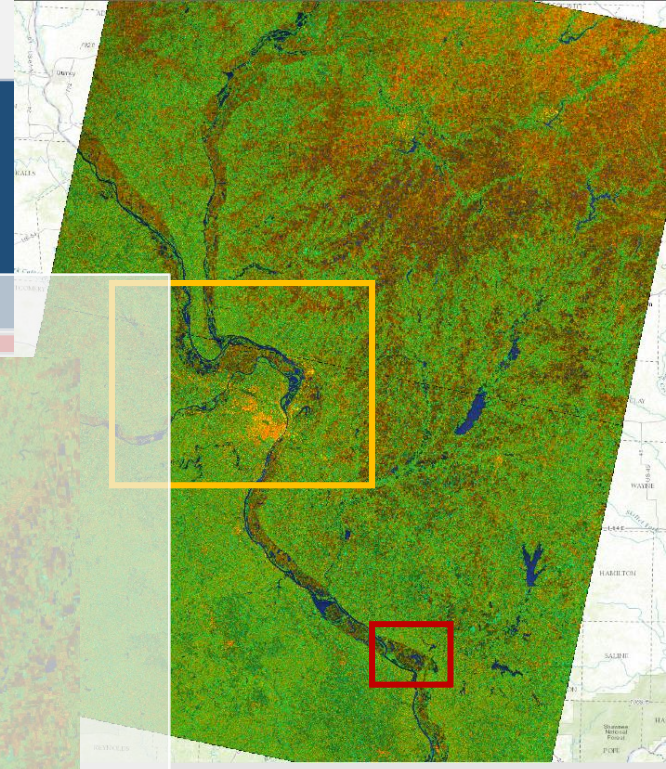
ASF DAAC 2017, contains modified Copernicus Sentinel data 2017.

Missouri Floods of Spring 2017

False color compositing allows for rapid, visual identification of key features.

Visual changes in false color composites in subsequent images/passes help to visually interpret and confirm changes in water extent as flooding progresses downstream, and other flood waters recede.

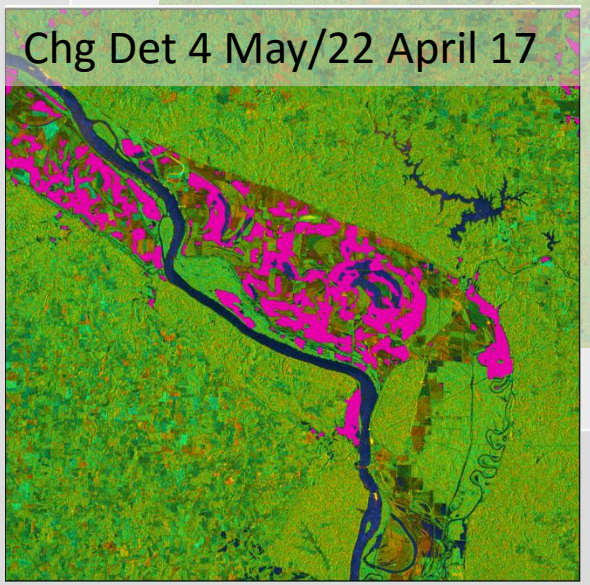
SAR products can be used in combination with optical imagery to improve understanding of current conditions.

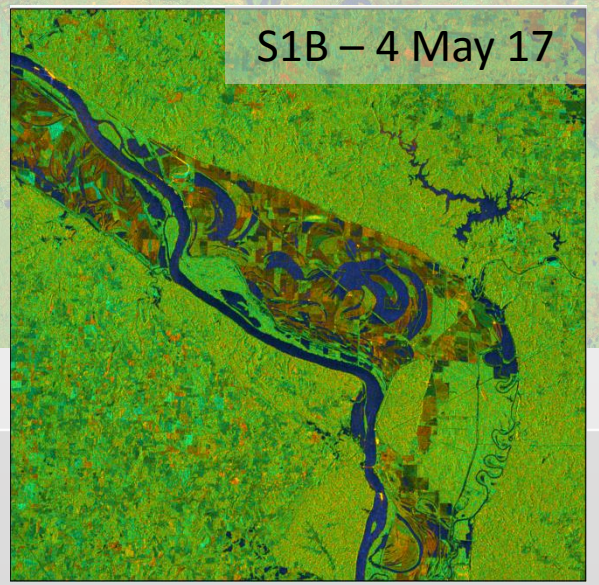


Sentinel 1B – 4 May 2017

Mississippi River

ASF DAAC 2017, contains modified Copernicus Sentinel data 2017.



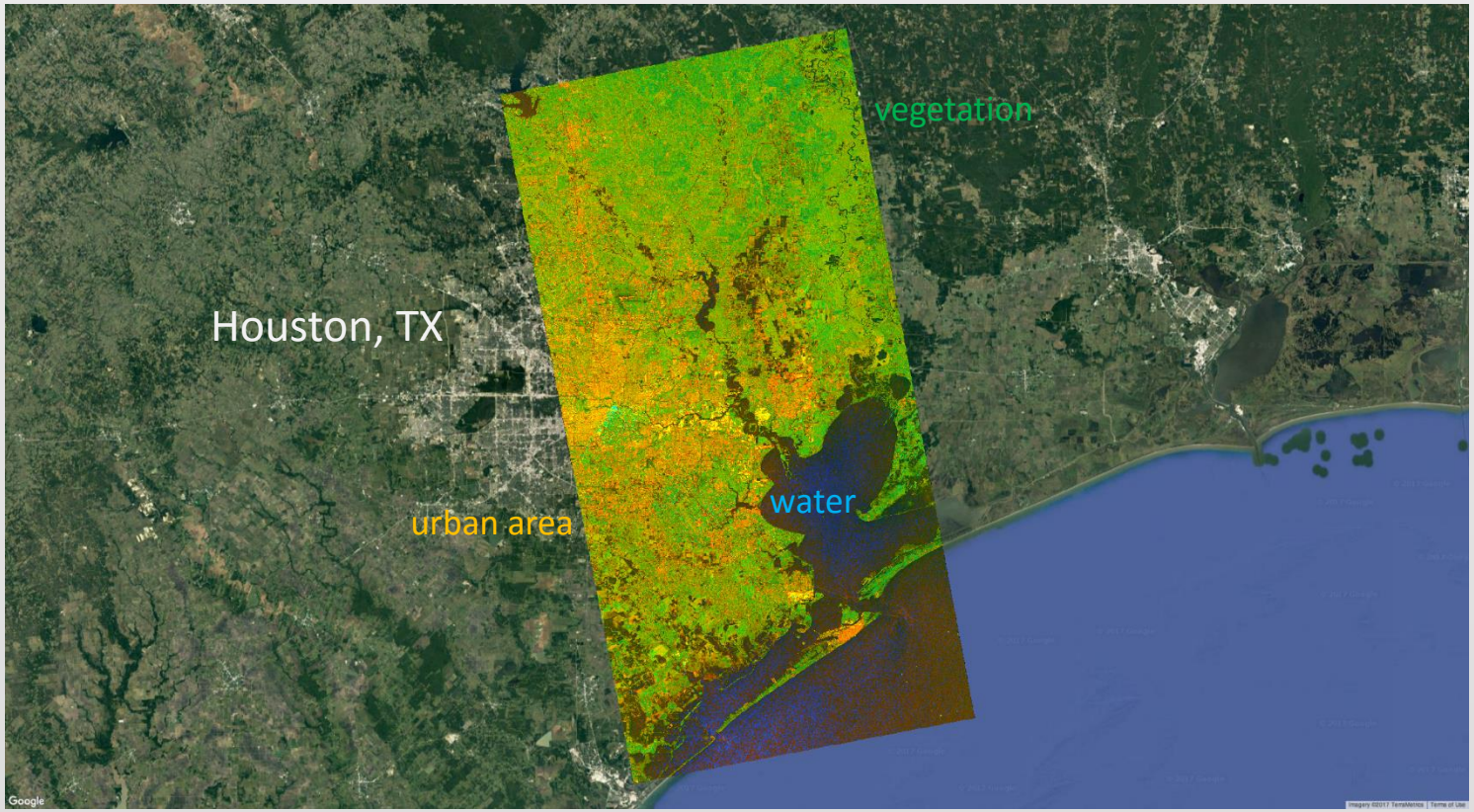


NASA SPORT
Short-term Prediction Research and Transition Center

Flooding from Hurricane Harvey

Applications of SAR imagery have been extensive following major hurricane landfalls in the United States and Caribbean.

In this image, S1B stripmap mode imagery of the Houston, TX area captures coastal and inland flooding in dark shades of blues and browns.



Sentinel 1B false color composite obtained on August 30, 2017 at 0017 UTC.

NASA SPORT Short-term Prediction Research and Transition Center

NASA's Earth Science DISASTERS

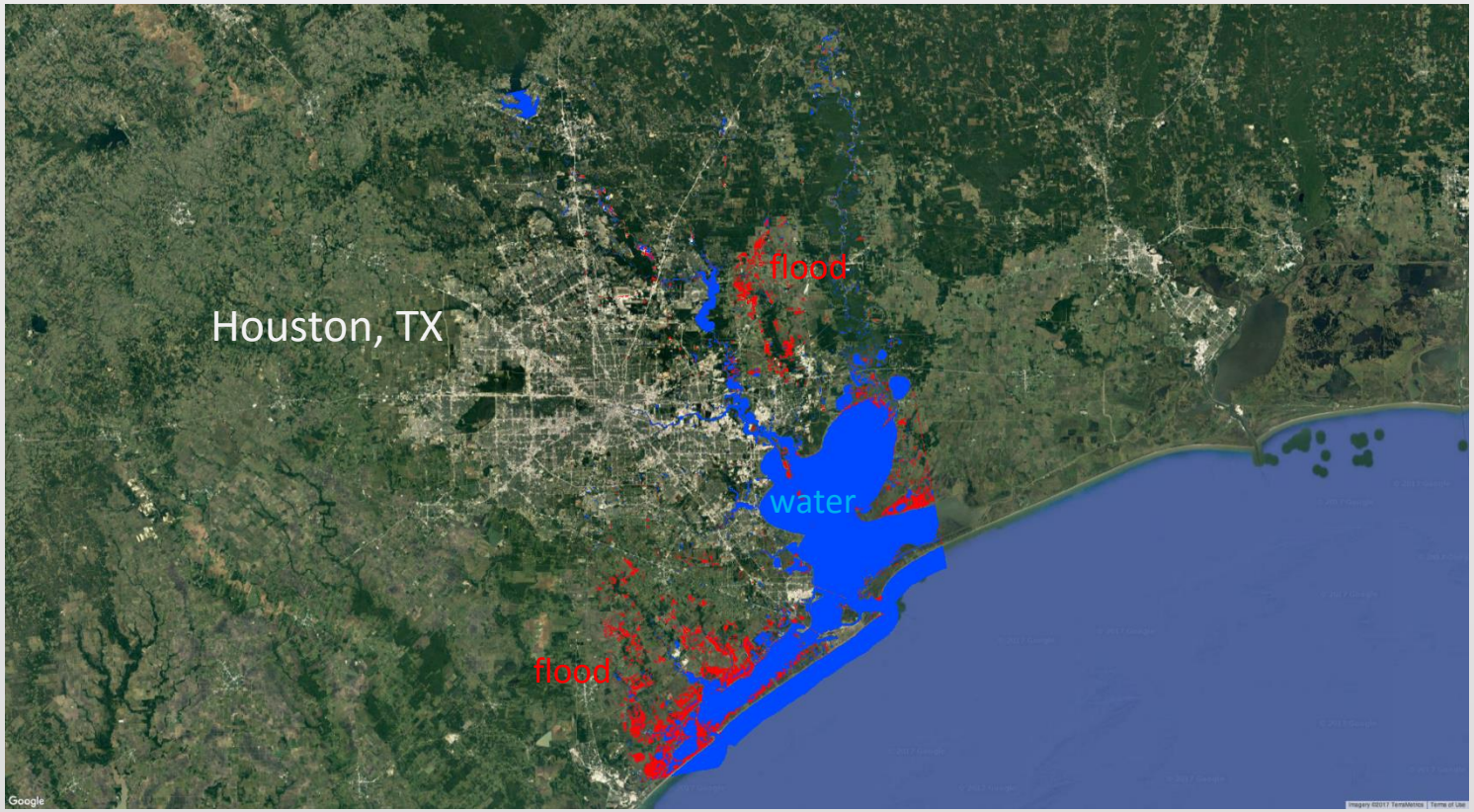
Flooding from Hurricane Harvey

Single, post-event scenes can be used with thresholding approaches to quickly mask water.

Statistics for known, open water in the area were used as guidance to select a threshold.

With threshold selected, flood is identified as water outside of known water areas.

Identifying flooding that occurs beneath vegetation and rapid, robust change detection work continues.



Sentinel 1B single-image, threshold-based flood detection from August 30, 2017 at 0017 UTC.

NASA SPORT
Short-term Prediction Research and Transition Center

NASA's Earth Science DISASTERS

Summary / Conclusions

- Optical and synthetic aperture radar remote sensing provide numerous application opportunities to map the impacts of disasters
  - Flooding, severe weather, tropical cyclones, and other impacts have been used by U.S. partners including FEMA, the National Guard, and the National Weather Service
- Efforts will continue to evolve towards automated change detection and anomaly-based products that provide detailed mapping in addition to visual interpretation
- Collaborations with ESA on access to data and products is extremely helpful, and we look forward to working with others on new product concepts, development, and training