UAVSAR

Uninhabited Aerial Vehicle Synthetic Aperture Radar

Recent Airborne SAR Demonstrations for Monitoring and Assessment of Volcanic Lava Flow and Severe Flooding

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July, 2019

IGARSS 2019

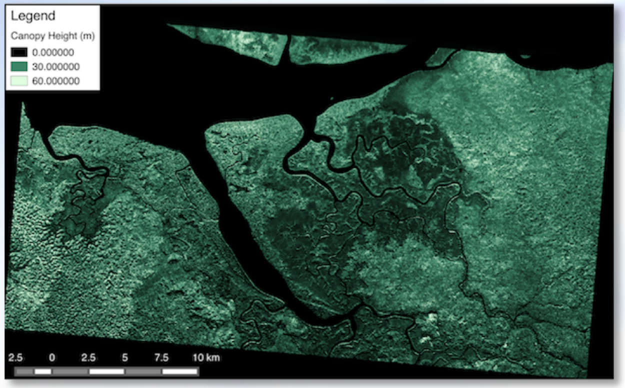
Yokohama, Japan

Agenda

- Overview of UAVSAR Instrument Suite
- Kilauea Volcano Rapid Response with GLISTIN-A
- Hurricane Florence Rapid Response with UAVSAR
- Summary

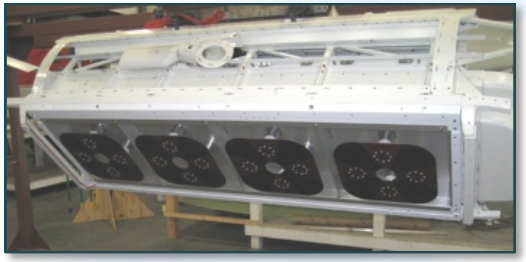
UAVSAR Instrument Suite

UAVSAR, NASA Earth Science Division's airborne imaging radar, first began L-band science demonstration in 2009 aboard a NASA G-III jet and later augmented to operate in P-band and Ka-band to demonstrate new applications.

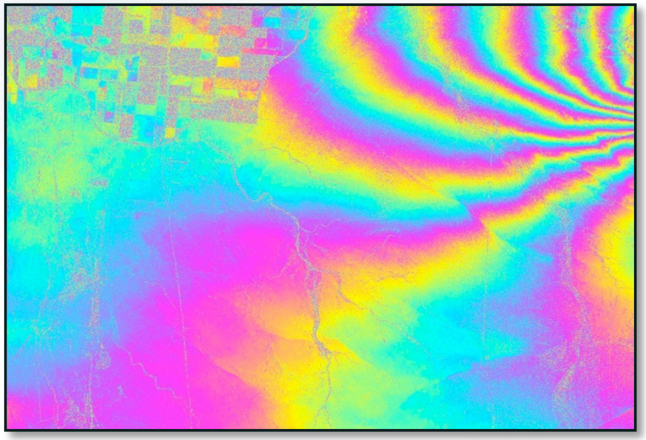


PolInSAR forest height over Pongara, Gabon, estimated from single-baseline Random Volume over Ground model. (acquired in February, 2016)

P-band POLSAR (AirMOSS) for measuring subsurface and subcanopy soil moisture

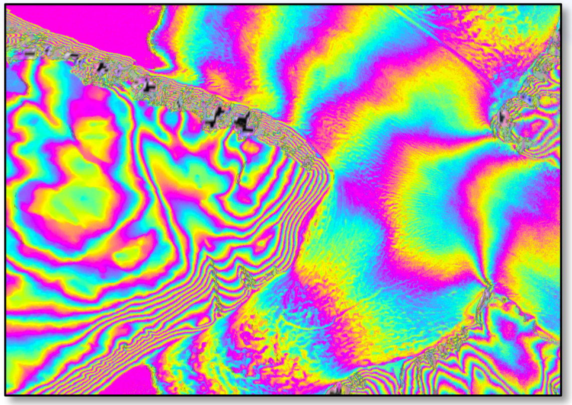


L-band repeat-pass DInSAR



Mexicali earthquake deformation captured by UAVSAR using data acquired on October 21, 2009 and April 13, 2010. Major deformation (multiple color wraps) and subtle faulting are visible in the interferogram.

Ka-band single-pass InSAR for observing glacier and land ice topography



Calibrated height map at 50 m height wrap of Greenland's Leidy Gletscher (top) & Marie Gletscher. (acquired on March 21, 2017)

First GLISTIN-A study of an Eruption

UAVSAR-Ka (GLISTIN-A)

The Ka-band single-pass interferometric synthetic aperture radar is designed to map land surface topography.

- Horizontal pol. with center frequency at 35.66 GHz
- Left-looking, from 15º - 50º look angle, ~10 km swath
- The all weather radar measures land topography with height precision ~ 0.3-3 m (3x3 m posting)
- Successfully flown in several campaigns to measure glacier and ice surface topographic changes over time (OMG 2016-19, SnowEx 2016-17, Hawaii 2017-18)

Radar pod which houses the radar electronics and two Ka-band slotted waveguide antennas for single-pass interferometry

Takeoff for Greenland deployment

https://uavsar.jpl.nasa.gov/technology/ka-band.html

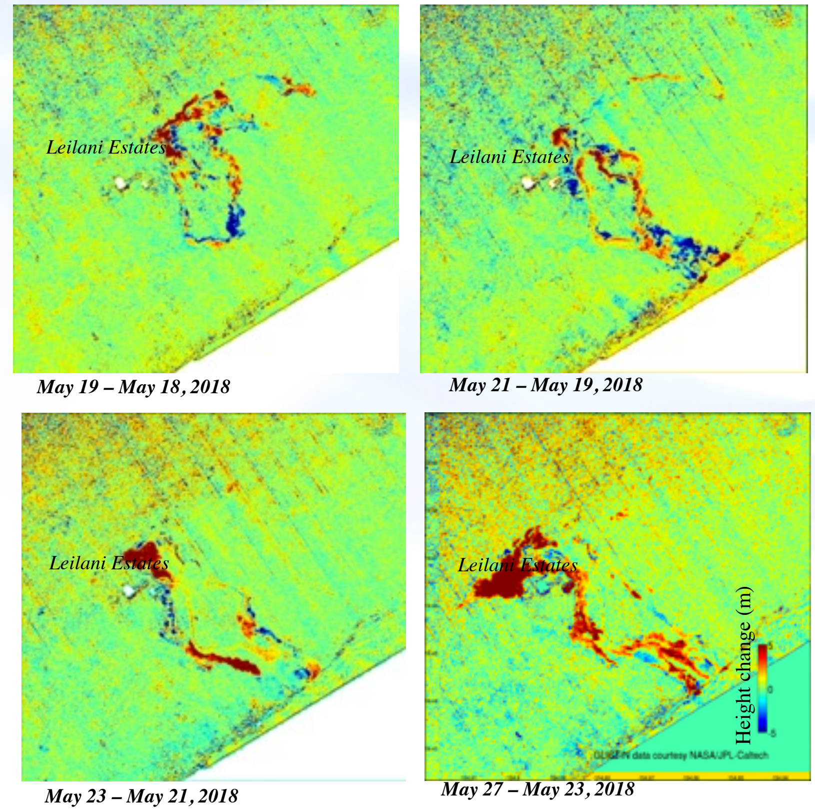
GLISTIN-A Kilauea Deployment

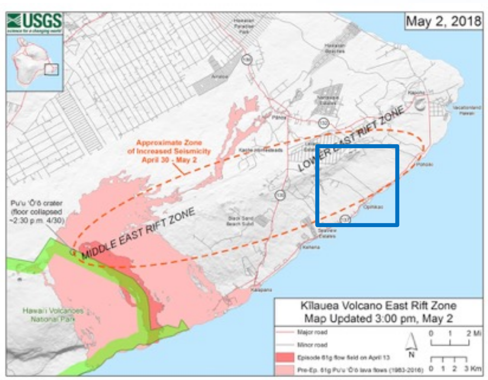
- Monitor Kilauea summit topography changes to map the enlargement of the center caldera crater
- First science demonstration of volcano dynamics study with the all weather Ka-band InSAR
- Ka-band radar was able to image lava flow through volcano plumes and clouds, and over wide coverage, while lidars and optical sensors were grounded

June 18 summit overflight photo of Halema‘uma‘u. Estimated total volume loss is about 260 million cubic meters as of June 15th

GLISTIN-A 2018 Kilauea Eruption Campaign

- GLISTIN-A arrived in Hawaii May 16, 2018
- Three sets of observations:
  - May 18, 19, 21, 23, 27
  - June 18
  - September 14, 15
- Data were processed by the UAVSAR Project at JPL
- Lava flow topography height and volume estimates were computed by GLISTIN-A Kilauea Response PI Paul Lundgren
- Collaboration across NASA centers (JSC, AFRC)





Topographic difference map over a +/- 5 m scale – the difference in topography is caused by lava movement. In areas where lava moves through forests, negative (blue) topography changes are observed due to tree canopy loss.

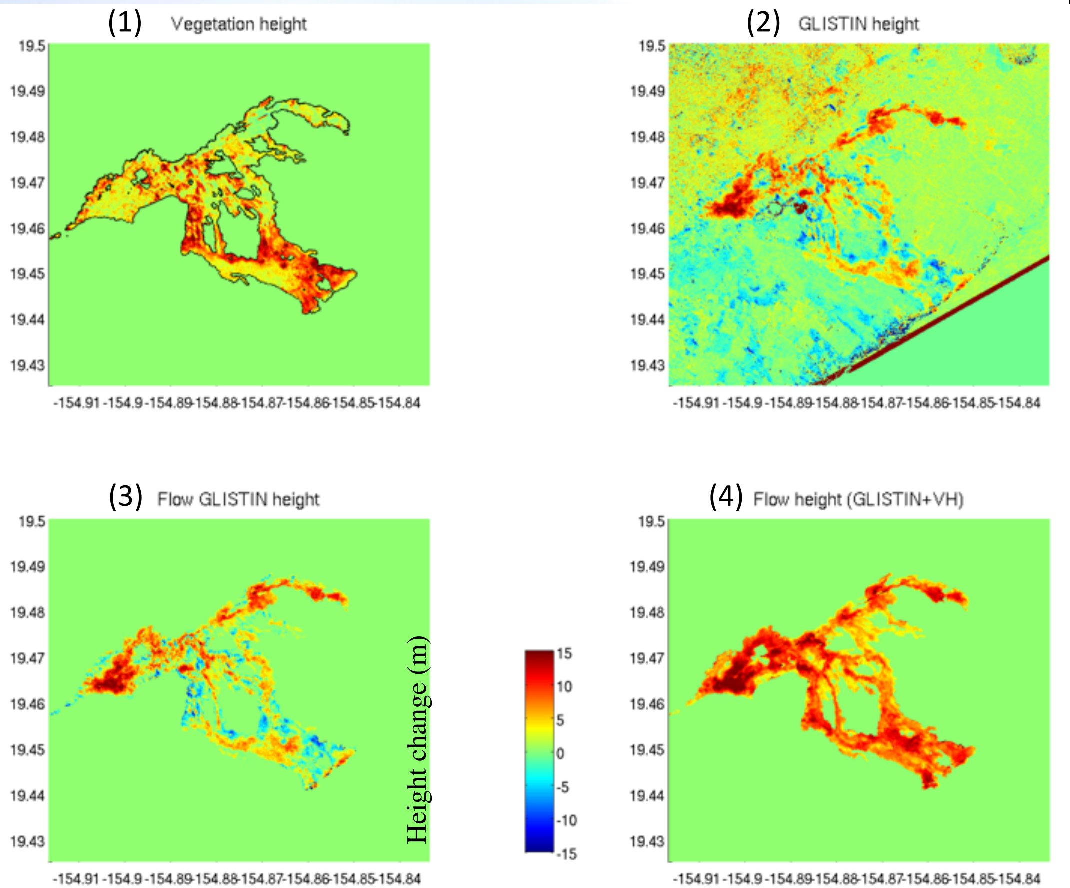
GLISTIN-A lava flow topography change and volume estimation workflow

1. Use a 2017 GLISTIN DEM relative to a bare-earth LIDAR DEM (from HVO) to estimate the vegetation height

2. GLISTIN co-eruption and pre-eruptive (Feb 2017) DEMs are differenced, giving the GLISTIN height change

3. A USGS lava flow shapefile is used to select only the Vegetation and GLISTIN heights for the flows

4. These two are summed to give the flow height (or thickness)

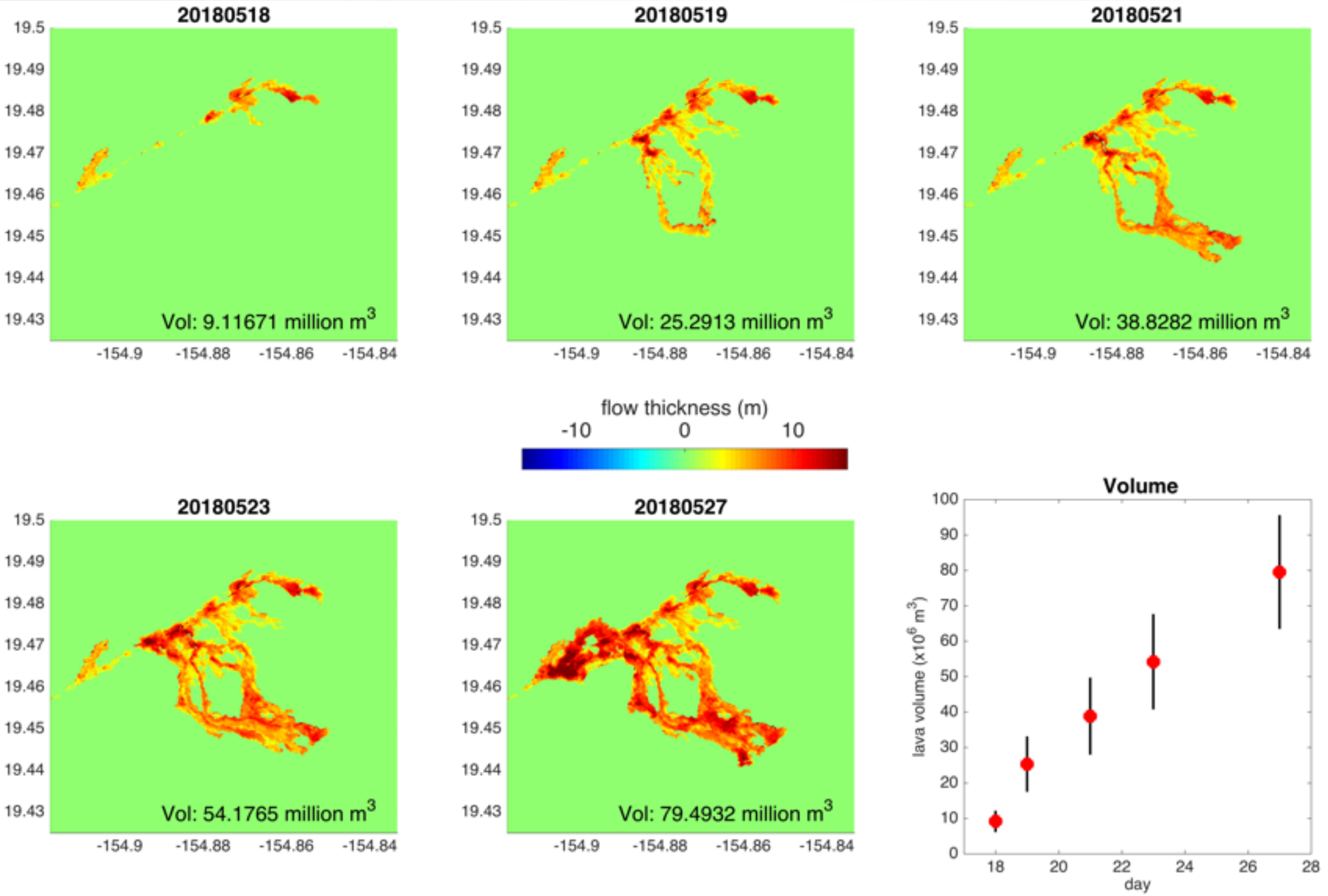


Note: In areas where lava moves through forests, negative (blue) topography changes are observed due to tree canopy loss (see 2 and 3)

Credit: Paul Lundgren (JPL)

GLISTIN-A flow thickness and volume change

Lava effusion volume time series used to constrain dynamic volcano models

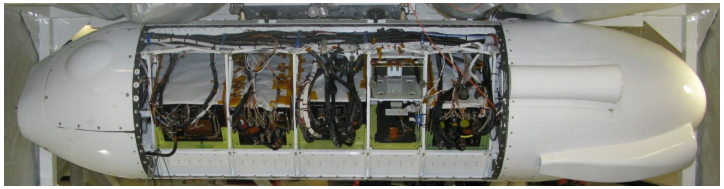


UAVSAR-L Instrument and Coverage

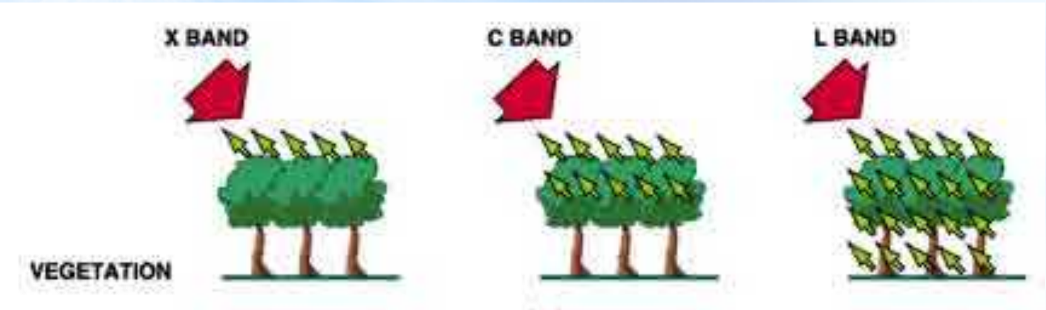
- Platform: NASA G-IIIs based at AFRC and JSC
- Nominal altitude: 12.5 km (41,000 ft)
- Nominal velocity: 221 m/s (430 knots)
- Nominal flight duration: 5.5 hours
- Platform precision autopilot: < 10 m tube

- Left-looking all weather L-band radar
- Repeat-pass polarimetric interferometry for monitoring cm-level surface change
- Typical spatial posting: 7 m
- Nominal range swath: 22 km
- Quick-look processing with short latency (0-6 hours) post-landing

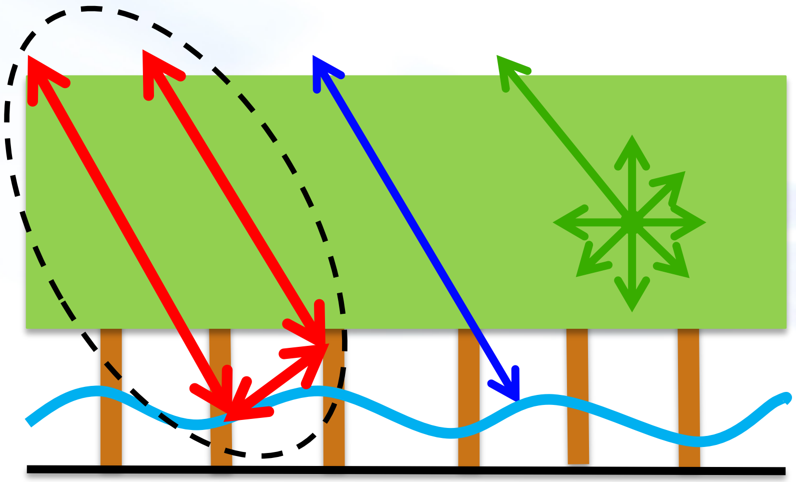
L-band radar pod



L-band POLSAR Detecting Flooding Under Canopy



UAVSAR is an active microwave sensor whose signal can travel through clouds. The L-band signal can also **penetrate dense vegetation** cover to reveal soil conditions under tree canopies.

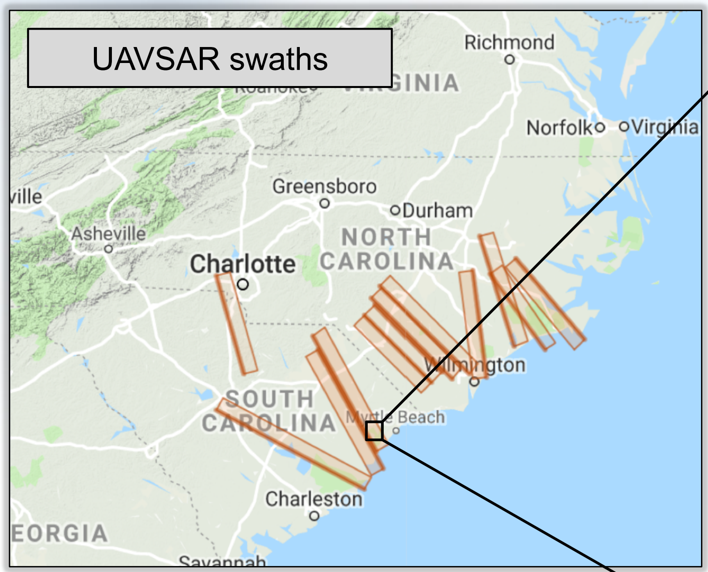


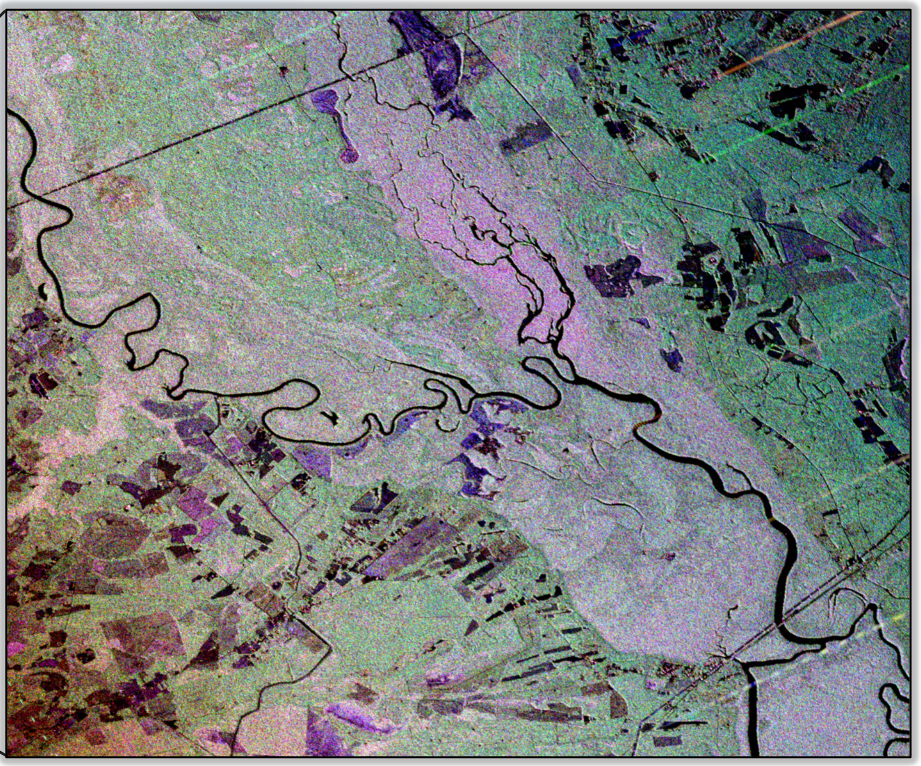
Polarimetric scattering signatures allow flooding to be detected by UAVSAR even underneath dense forest canopy, due to the “double-bounce” radar returns shown in red.

UAVSAR Hurricane Florence Flood Response

Sept 17-23, 2018

- **UAVSAR conducted 6 flights to observe the flood water cresting and receding over floodplain sites identified by emergency responders. False color polarimetric quick-look images were delivered post-flight and posted at the NASA Disasters data portal.**
- **UAVSAR images filled gaps between radar satellite coverage overpasses so flood responders can determine and predict where neighborhoods and key facilities were impacted by flood waves.**





UAVSAR false color quick-look polarimetric image over the Pee Dee River
HH HV VV
(Pink areas are likely inundated vegetation)

UAVSAR Hurricane Florence Flood Response

Sept 17-23, 2018

UAVSAR precision processed polarimetric image over the Pee Dee River used to track flood extent

HH HV VV (UAVSAR images together with other image sources were used to look for isolated communities cut off by flood water)

Black: flooded ground, smooth bare ground (e.g. roads), or open water (e.g. river)

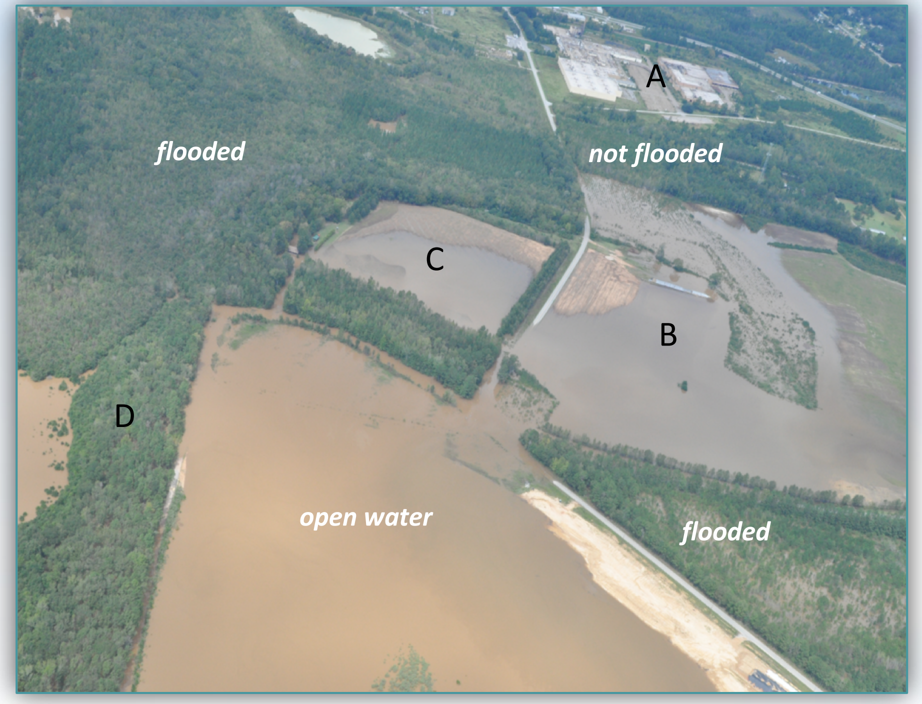
Pink: flooded vegetation

Green: vegetation

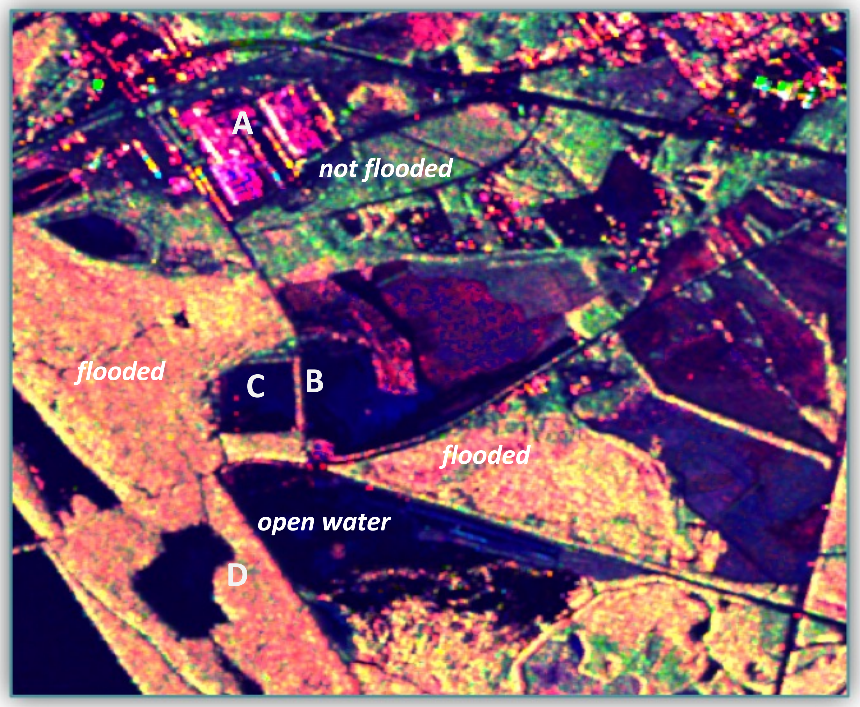
Brightness: strength of radar backscatter

Comparison between Civil Air Patrol photograph and UAVSAR classified quad-polarimetric image near Cheraw, SC

Civil Air Patrol photo (Sept 18th)



UAVSAR polarimetric decomposition image (Sept 17th)



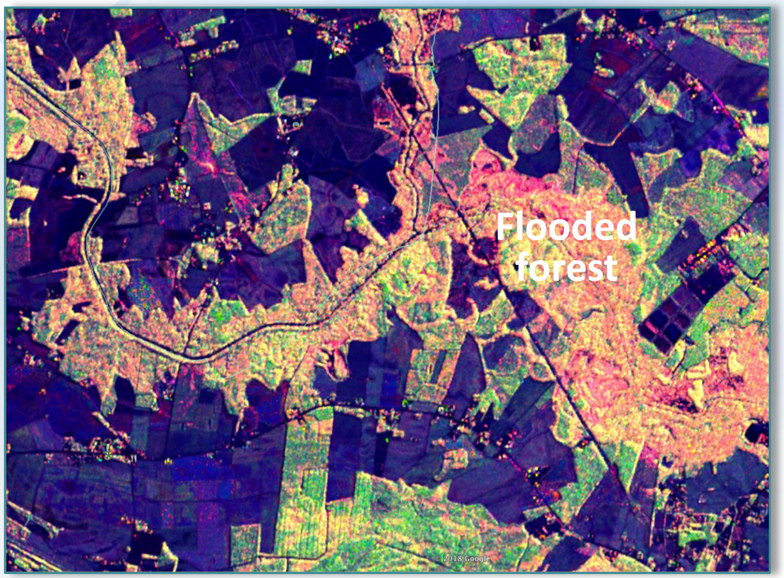
Interpretation of UAVSAR result:

Pink denotes urban areas whereas red/orange/yellow denote inundated forests. **Dark blue** or **black** are flooded open water; roads can be black even if not flooded. **Green** and **light blue** denote not flooded.

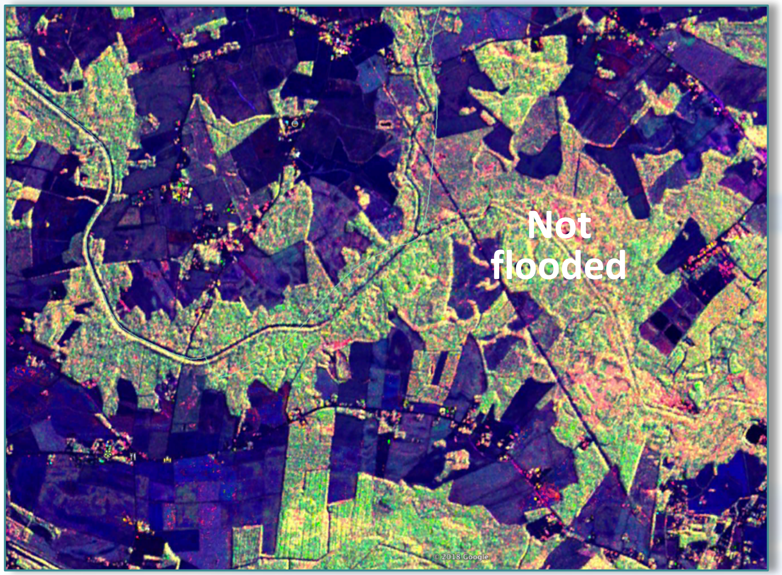
Note: Red -- Double bounce scattering (flooded forests and urban); Green – Volume scattering (unflooded forests); Blue – Specular scattering (dry bare ground, open water)

Detecting flood level change northwest of Vanceboro, NC with UAVSAR classified quad-polarimetric images

UAVSAR polarimetric decomposition image (Sept 18th)



UAVSAR polarimetric decomposition image (Sept 23th)



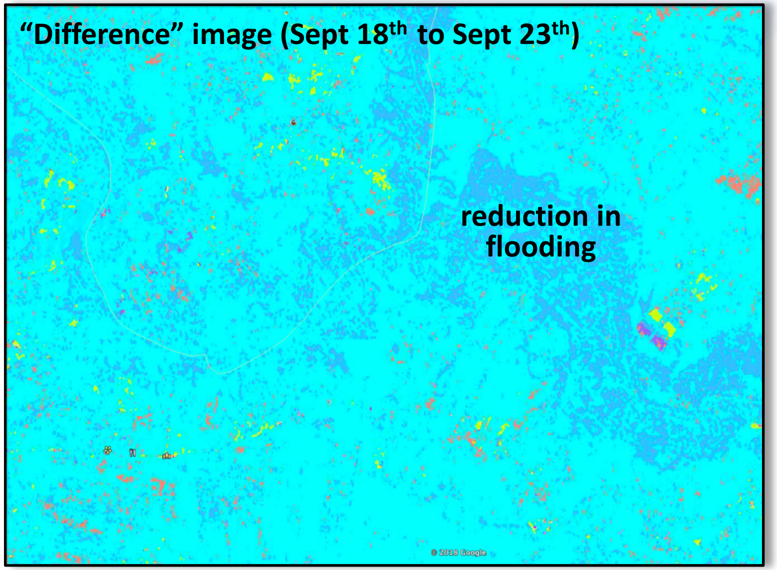
Interpretation of UAVSAR result

Above images:

Pink denotes urban areas whereas red/orange/yellow denote inundated forests. **Dark blue** or **black** are flooded open water; roads can be black even if not flooded. **Green** and **light blue** denote not flooded.

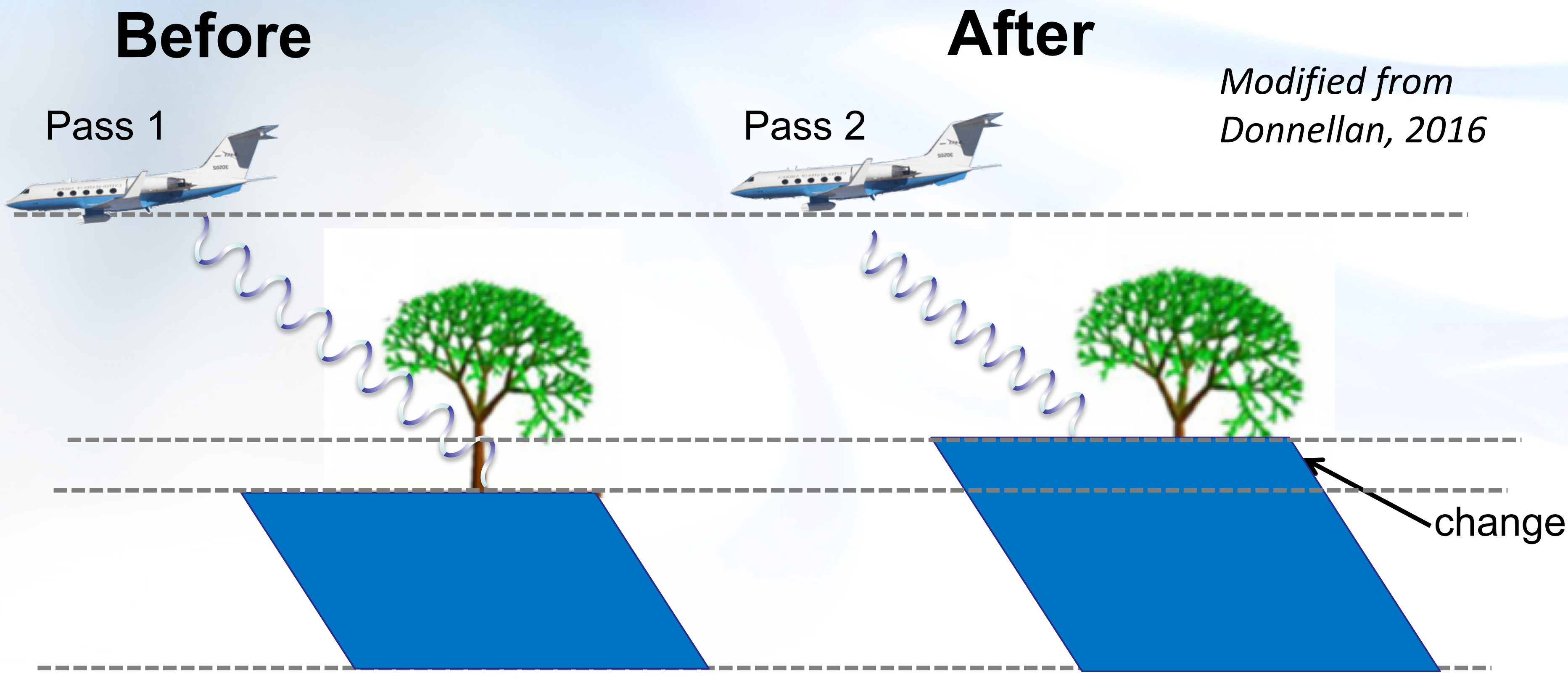
"Difference" image to right →

Light blue denotes no change and **darker blue** denotes reduction in flooding over 5 days.



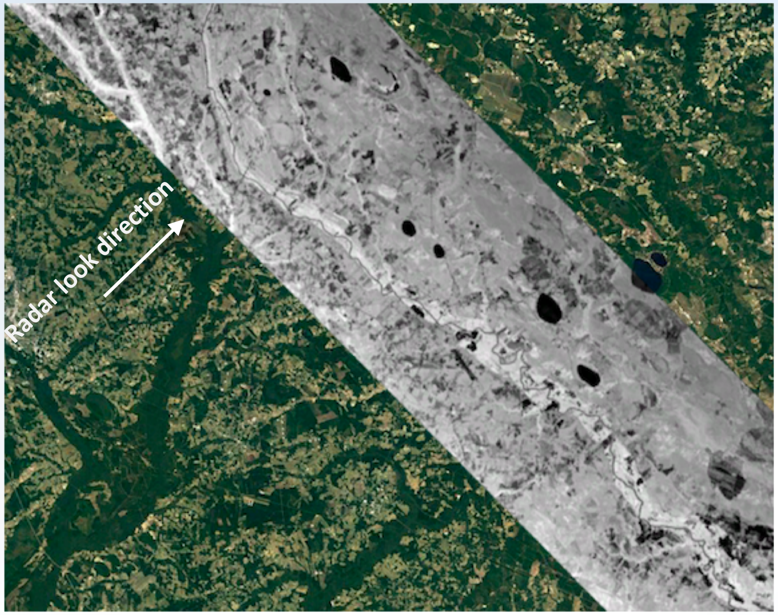
Repeat-Pass Interferometry for Water Level Change

By comparing the phase between two passes, it is possible to estimate water level changes under tree canopies.



This approach is being employed by Univ. South Carolina researchers to parameterize hydrological models that predict flood dynamics.

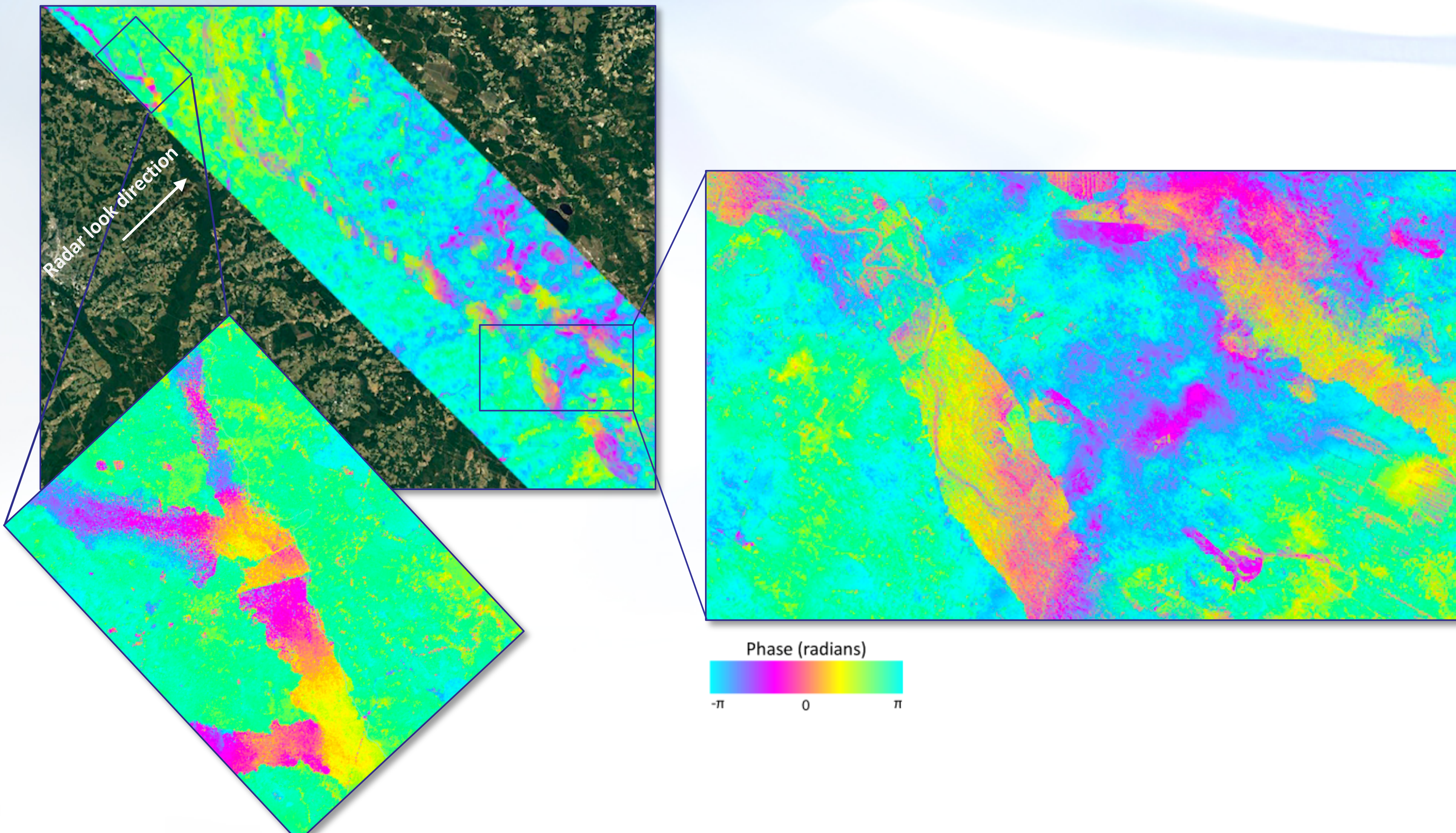
Interferogram Showing Water Level Change



HH amplitude image showing the bright river floodplain due to the double-bounce effect of inundation under tree canopies

Interferogram Showing Water Level Change

Interferogram of UAVSAR data acquired one day apart over Cape Fear River, North Carolina
Color fringes represent water level change over the heavily vegetated river floodplain



Future Work on Flood Response

- For storm flood response applications, continue to develop UAVSAR's polarimetric and DInSAR processing capabilities to provide information about
  - flood extent and water level change
  - Small-scale movement of structures
  - Presence and location of water-borne contaminants that take the form of slicks on water surface
- Use machine learning techniques to help improve and automate flood extent detection, which is time-consuming and often error prone
- Help hydrologists refine and adapt hydrologic models to improve short-term forecasting of flooding