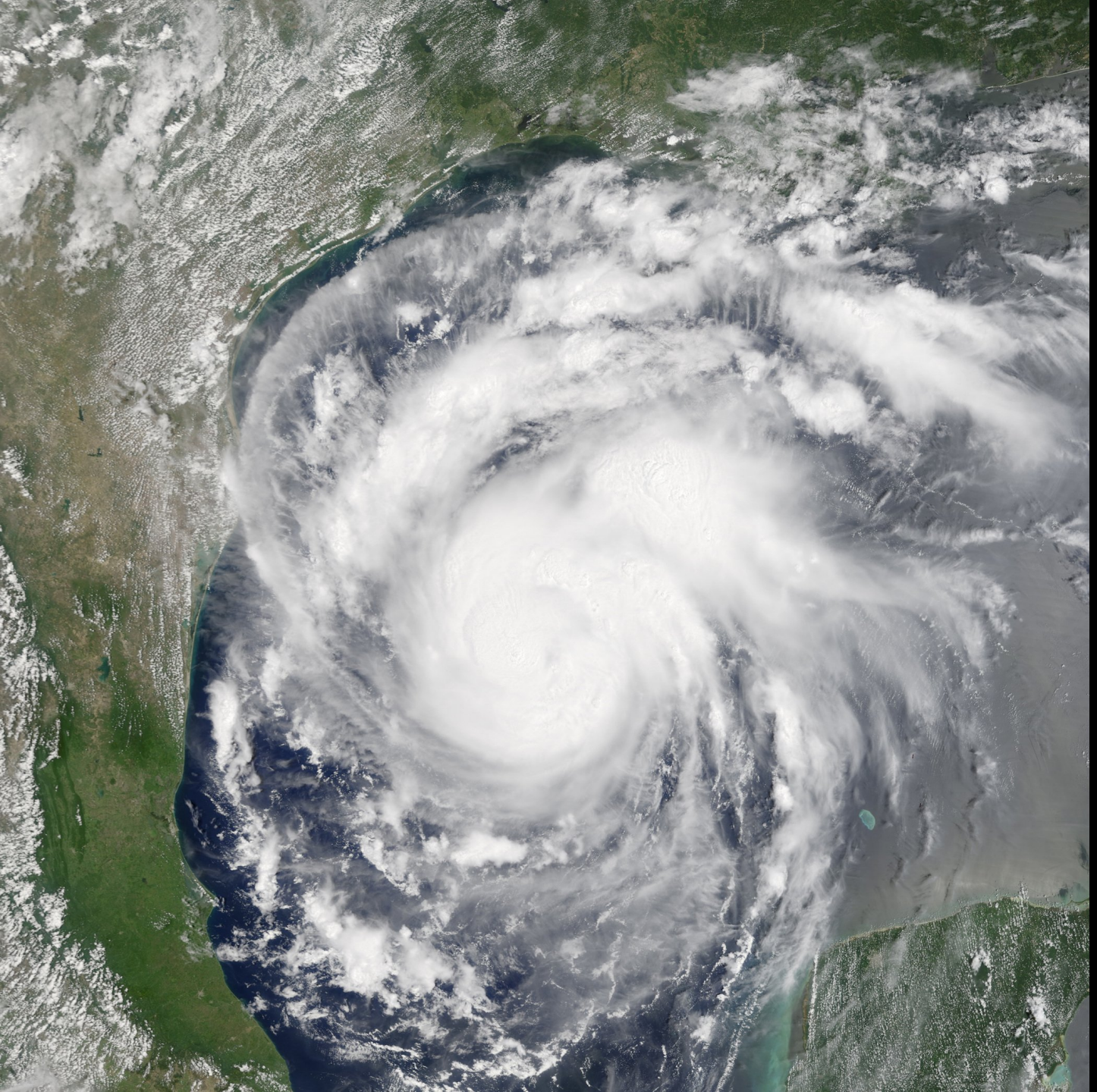

Application of Airborne SAR to Extreme Flooding: A Case Study of the Southeast Texas Rivers During Hurricane Harvey Emergency Response

Cathleen E. Jones[1], Bruce Chapman[1], Yunling Lou[1], Gordon Wells[2]

[1]Jet Propulsion Laboratory, California Institute of Technology

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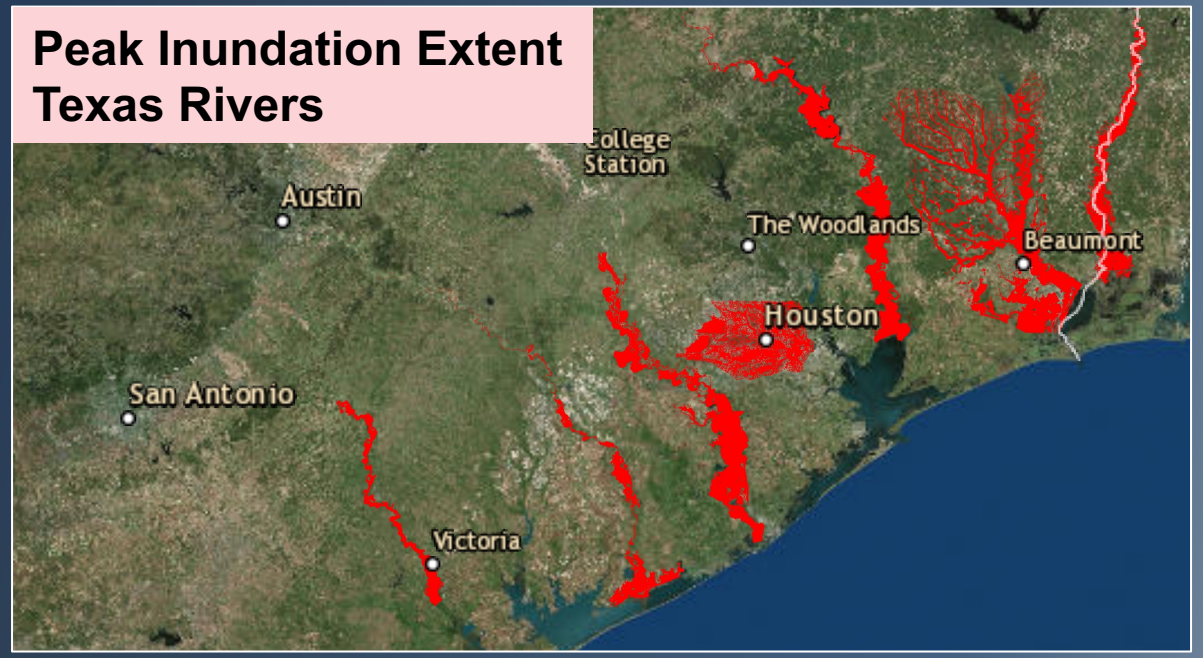
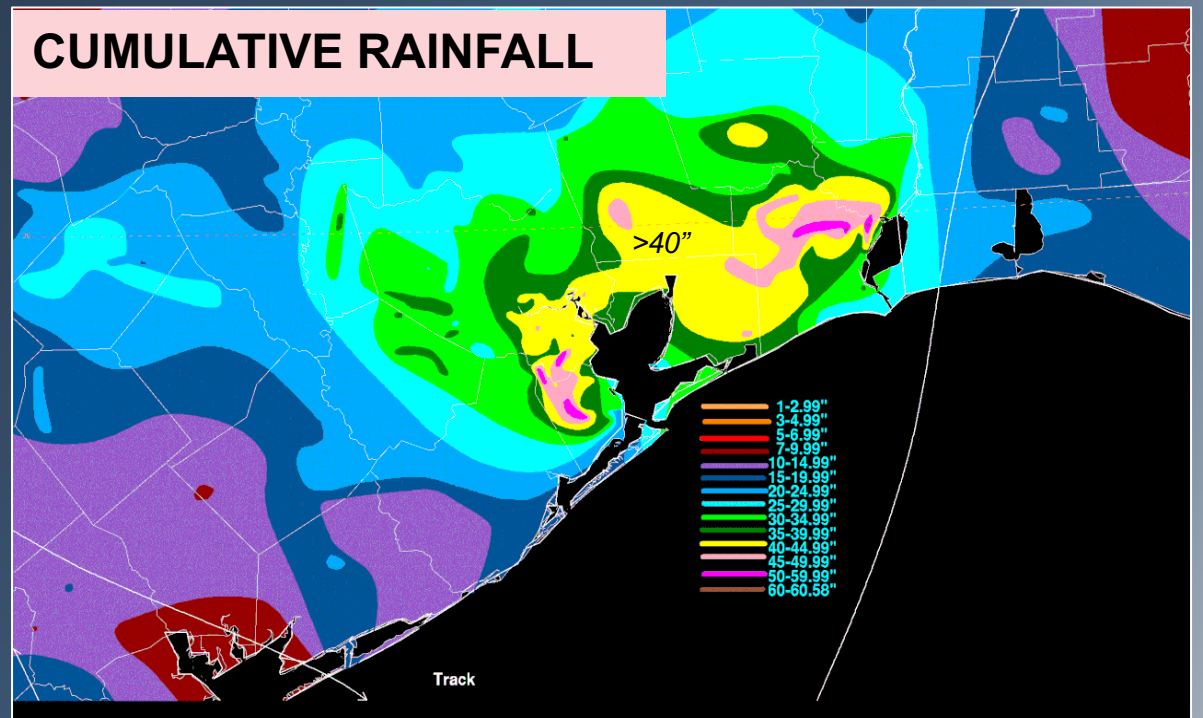
Jet Propulsion Laboratory
California Institute of Technology

HURRICANE HARVEY

CATEGORY 4 HURRICANE
LANDFALL: AUG. 25, 2017
AREA: SOUTHERN TEXAS
WIND GUSTS UP TO 132 MPH
PEAK RAINFALL: 154 CM (60”)
ECONOMIC IMPACT: $125 BILLION
PRIMARY CAUSE: FLOODING



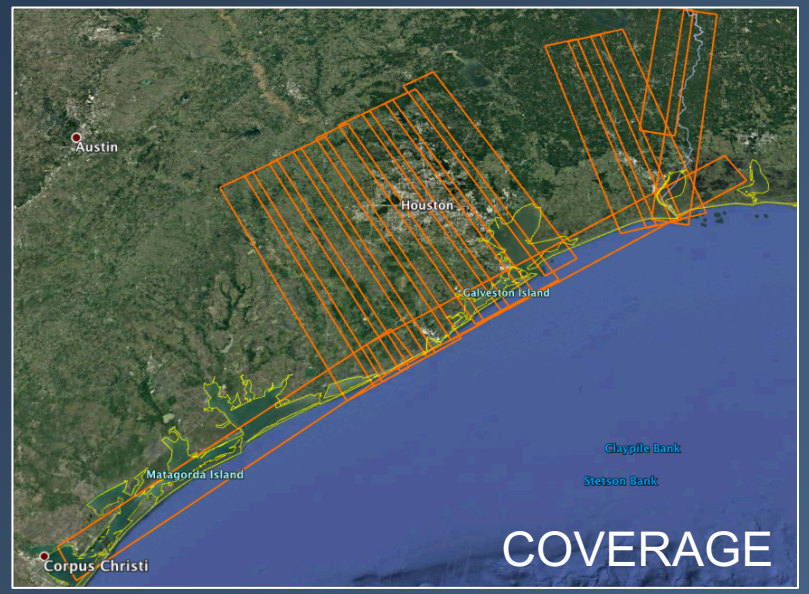


UAVSAR: L-BAND SYNTHETIC APERTURE RADAR

Credit: NASA AFRC

- Left-looking all weather L-band radar
- Repeat-pass polarimetric interferometry for monitoring surface change
- Final product spatial posting: 6 m
- Typical flight lines (orange rectangles in map) in Houston were 22 km wide by 190 km long (programmable)

Parameter	Value
Frequency	L-Band 1217.5 to 1297.5 MHz 23.8 cm wavelength
Resolution	1.7 m x 0.6 m
Operational Altitude	12.5 km (41,000 feet)
Swath Width	22 km (14 mi)
Incidence Angle	25 – 65 degrees
Polarization	Quad-pol (HH, HV, VH, VV)
Radiometric Calib.	1 dB absolute, 0.5 dB relative



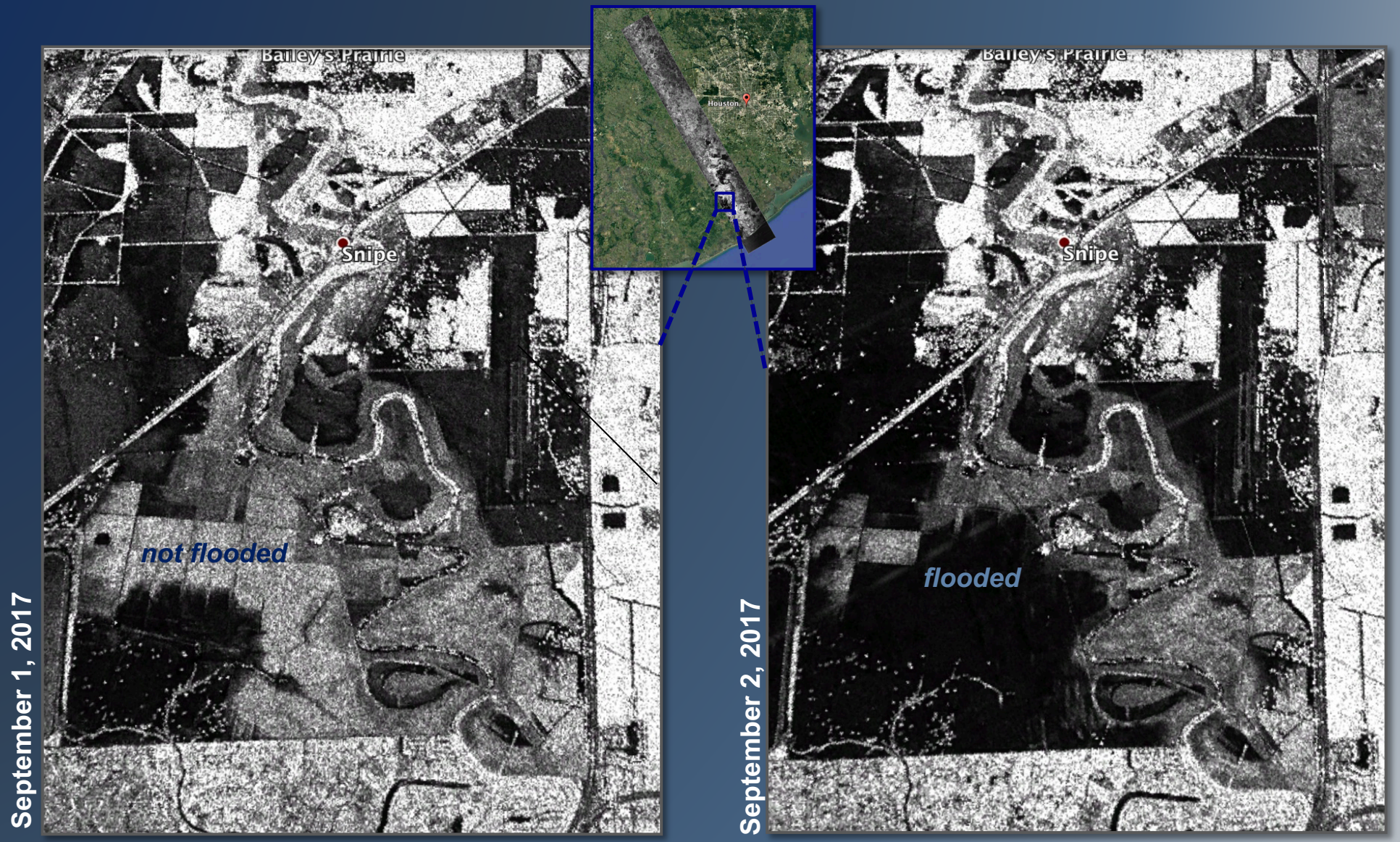
- Support Requested: Aug. 25, 2017
- Hurricane Hit: Aug. 25
- UAVSAR Deployed: Aug. 31
- Base of Operation: Austin, TX
- Four local flights: 8/31 – 9/3 (Thu, Fri, Sat, Sun)

Date	Target Areas	Flight Lines Delivered Upon Landing	Flight Lines Delivered 3-5 hours post-flight
8/31/2017	Greater **Houston** area along the **Colorado, San Bernard, Brazos, San Jacinto,** and **Trinity Rivers**	6	6
9/1/2017	Areas along the **Brazos** (Rosenberg, Sugar Land, Addicks Reservoir), **San Jacinto, Neches** (Beaumont), and **Sabine Rivers**	7	5
9/2/2017	Areas along the lower **Brazos, San Jacinto, Neches** (Beaumont), and **Sabine Rivers, Texas coast** (Galveston, Port Arthur)	9	3
9/3/2017	Lower **Brazos, San Bernard, Colorado Trinity, Neches,** and **Sabine Rivers, Barrier Islands**	8	3

ON-BOARD AND QUICK-LOOK PRODUCTS

- Generated single polarization quick-look products during flight and post-flight
- Provided to Emergency Operation Center 3-6 hours after the flight landed.

UAVSAR HH-polarized quick-look images acquired one day apart showing increased flooding in lower Brazos River basin due to floodwater flowing south into the Gulf of Mexico



ON-BOARD AND QUICK-LOOK PRODUCTS

UAVSAR HH-polarized quick-look images acquired 3 days apart showing flooding and its recession in an area around Wharton, a small town on the Colorado River that experienced severe flooding following Hurricane Harvey.

Wharton Historical Museum

SAR METHODS: POLARIMETRY (POLSAR)

H=horizontal polarization; V=vertical polarization; VV=transmit V, receive V polarization

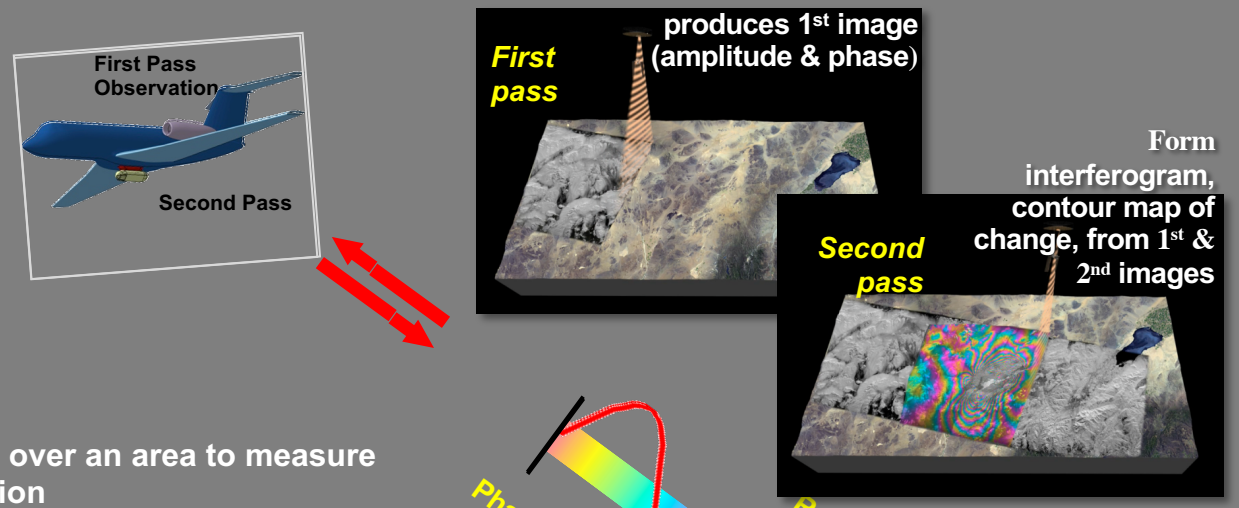
Sacramento Delta / false color UAVSAR POLSAR image / 7 m resolution
FALSE COLOR: Red = HH, Blue = VV, Green = HV

INUNDATION:
- OPEN WATER
- FLOODED VEGETATION

OIL/CHEMICAL SPILLS IN WATER

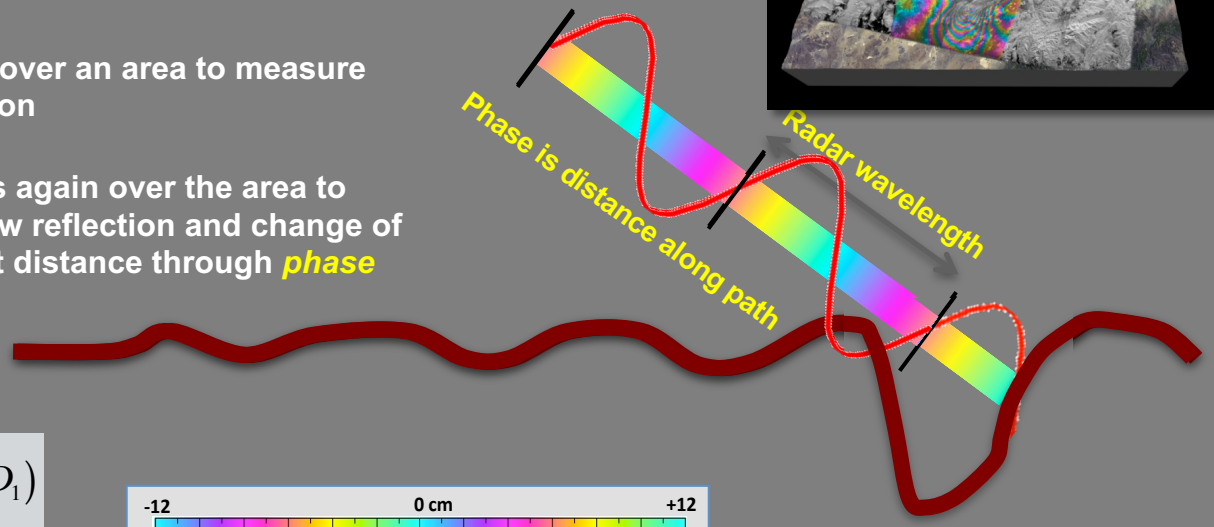
CRITICAL INFRASTRUCTURE STATUS

SAR METHODS: INTERFEROMETRY (INSAR) & COHERENT CHANGE DETECTION (CCD)



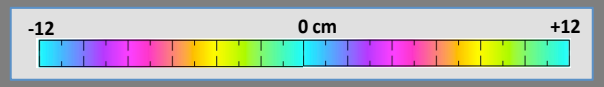
Aircraft flies over an area to measure radar reflection

Aircraft flies again over the area to measure new reflection and change of line-of-sight distance through *phase change*



$$\Delta\phi + N * 2\pi = \frac{4\pi}{\lambda}(D_2 - D_1)$$

$\lambda =$ wavelength of radar



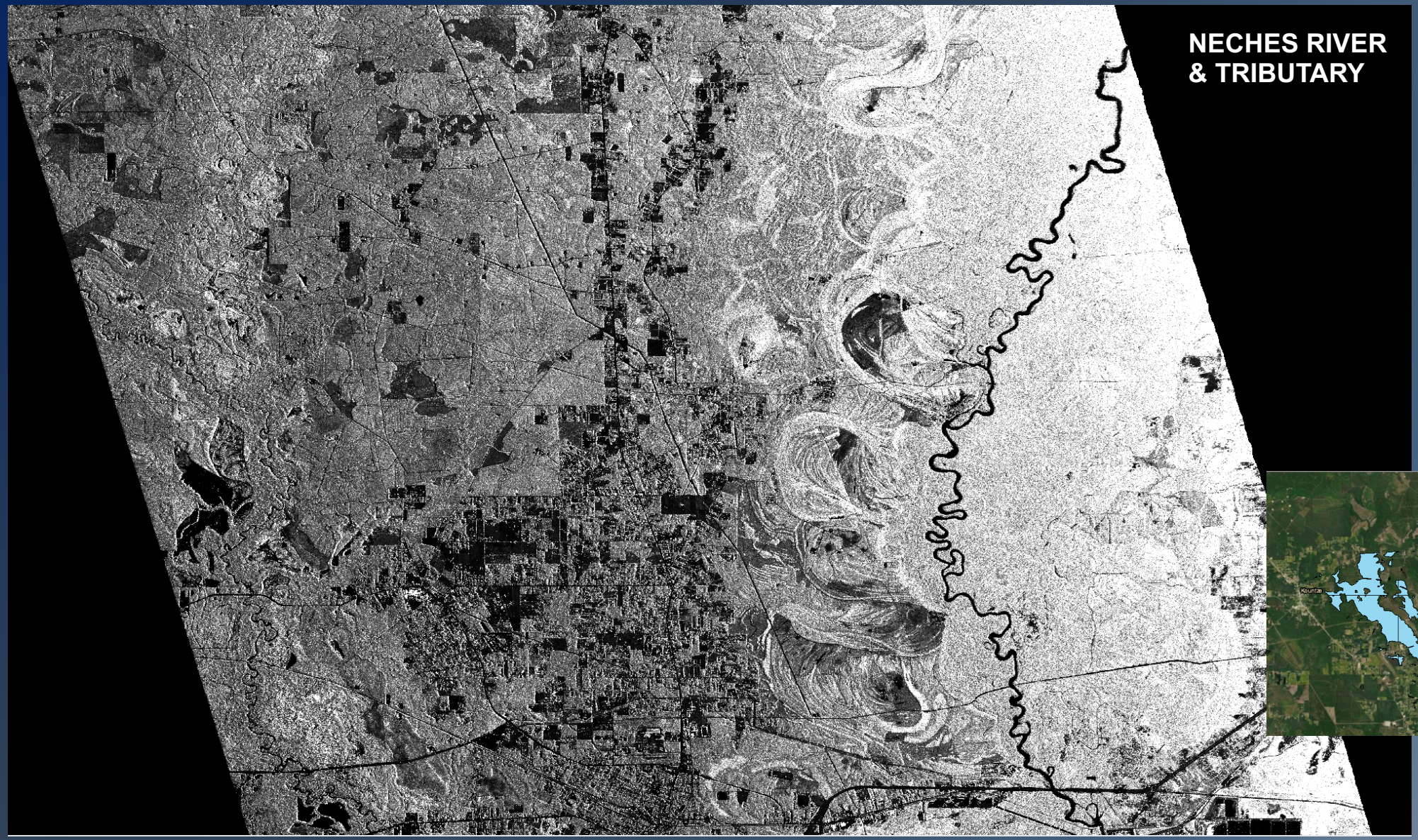
INUNDATION EXTENT (CCD)

WATER LEVEL CHANGE (INSAR)

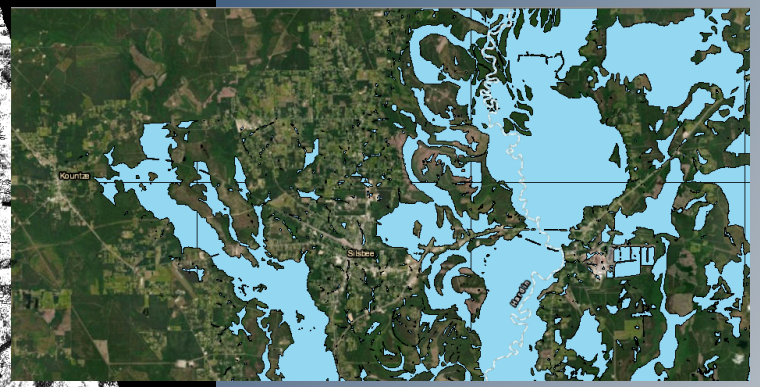
CRITICAL INFRASTRUCTURE STATUS

INUNDATION EXTENT

SAR Intensity-only does not capture full flood extent

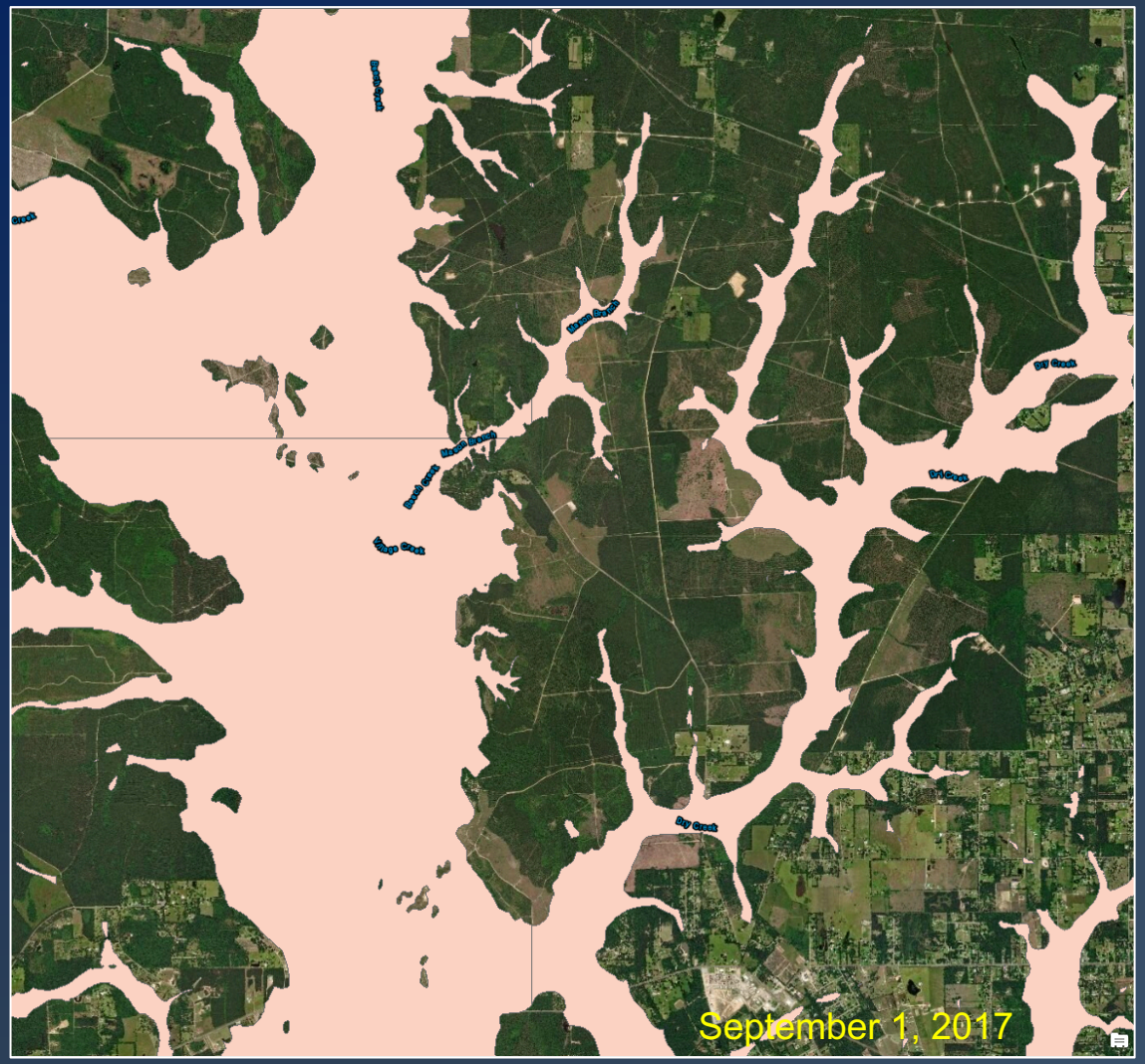


Flood Model

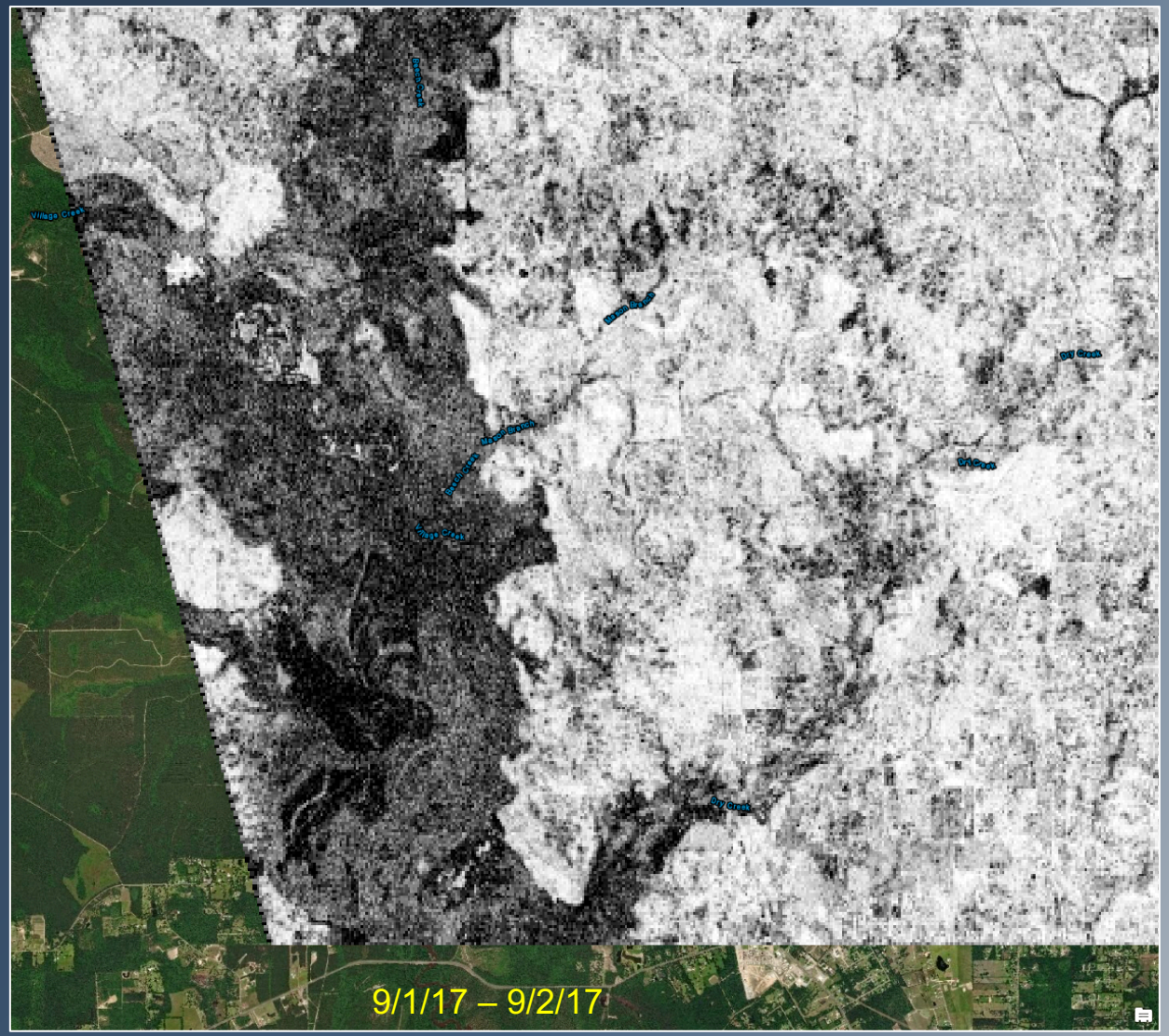


INUNDATION EXTENT

Flood Model



UAVSAR



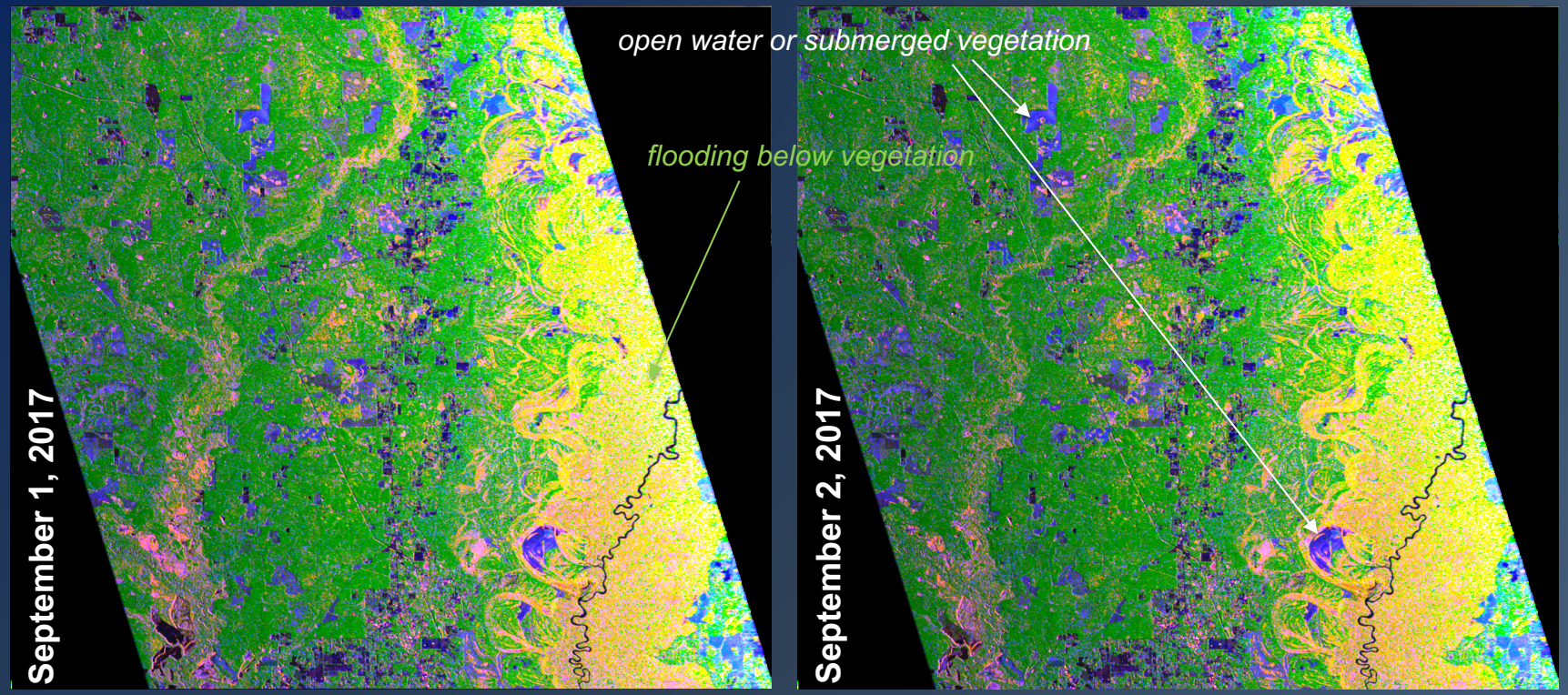
NECHES RIVER & TRIBUTARY

PRODUCT USED:
InSAR Coherence

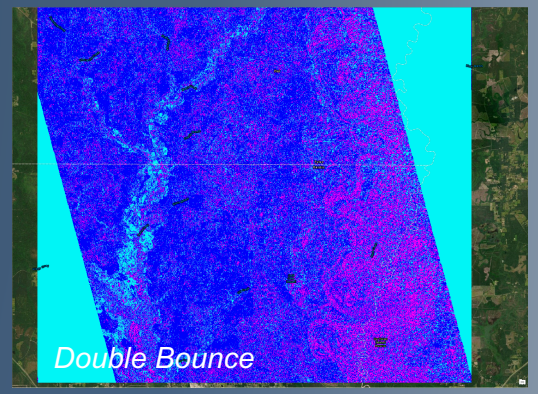
INUNDATION: OPEN WATER VS. BELOW VEGETATION

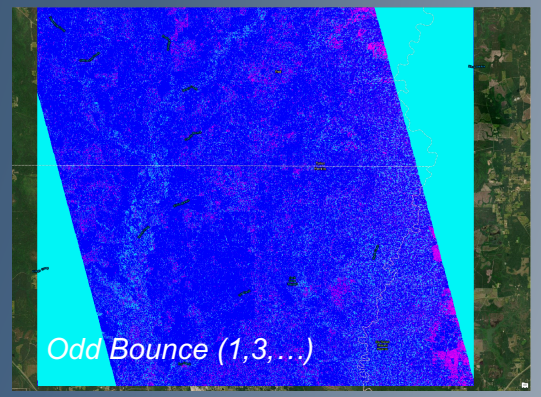
Double bounce scattering can be used to identify floodwater below vegetation
Single/odd bounce scattering identifies open water or water-covered vegetation

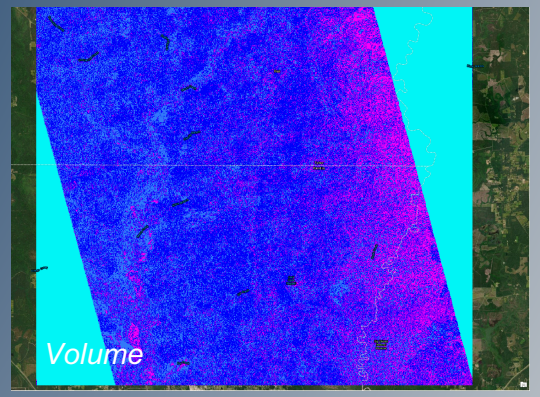
NECHES RIVER & TRIBUTARY



Scattering Mechanism: Red=Double Bounce, Blue=Single/Odd Bounce, Green=Volume





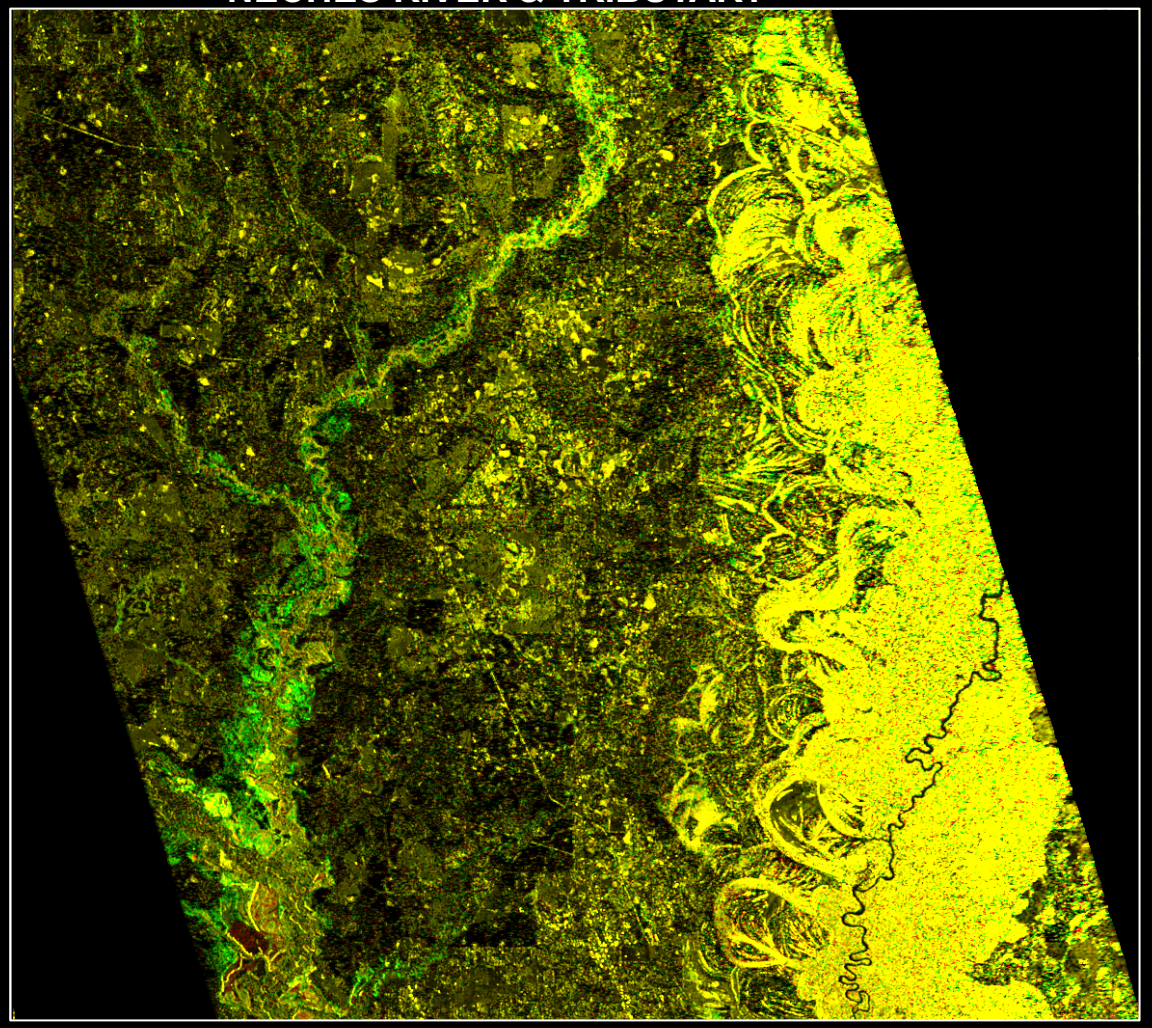


Flood Model: Peak Inundation on Neches River

PRODUCT USED: PolSAR (HH, HV, VH, VV)
(Freeman-Durden Decomposition)

CHANGE IN INUNDATION BELOW VEGETATION

NECHES RIVER & TRIBUTARY

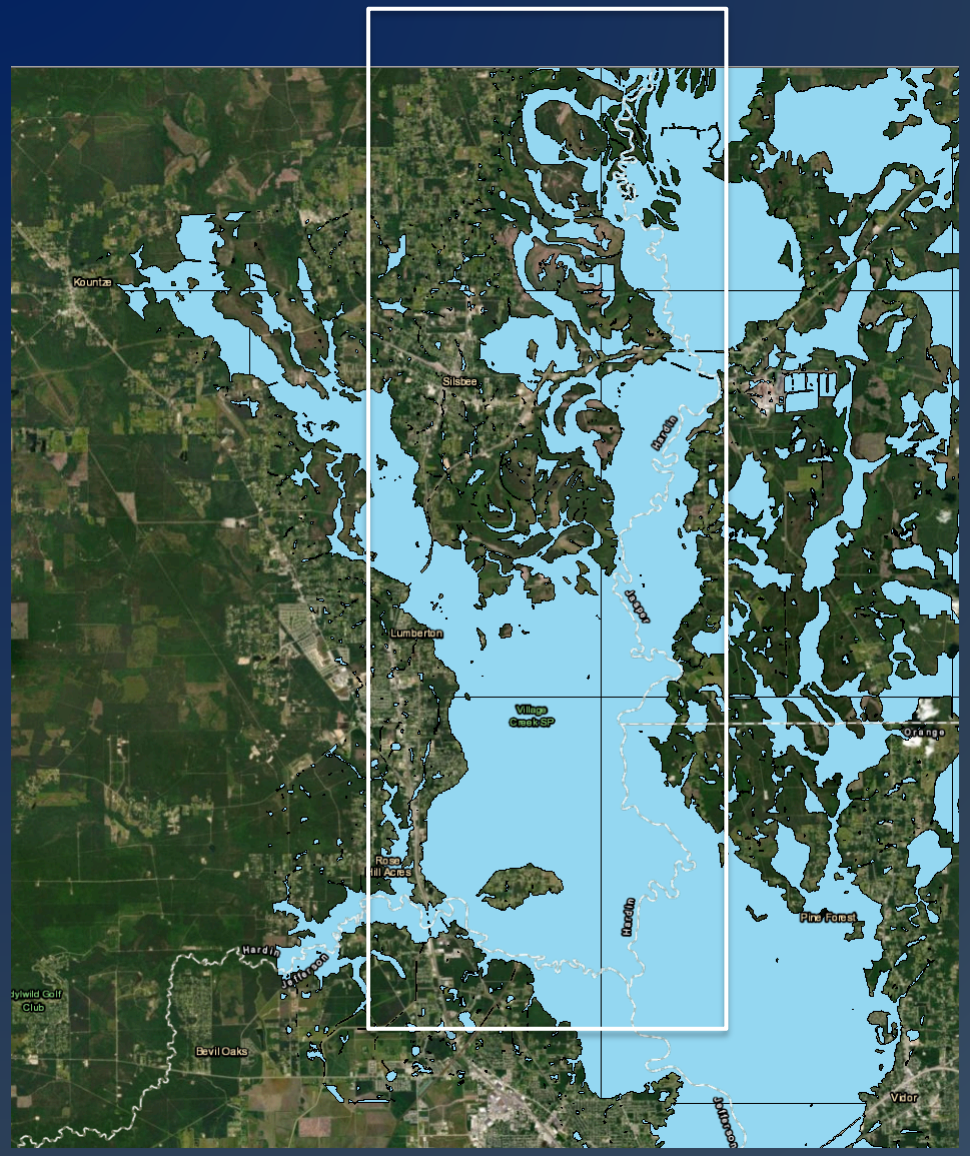


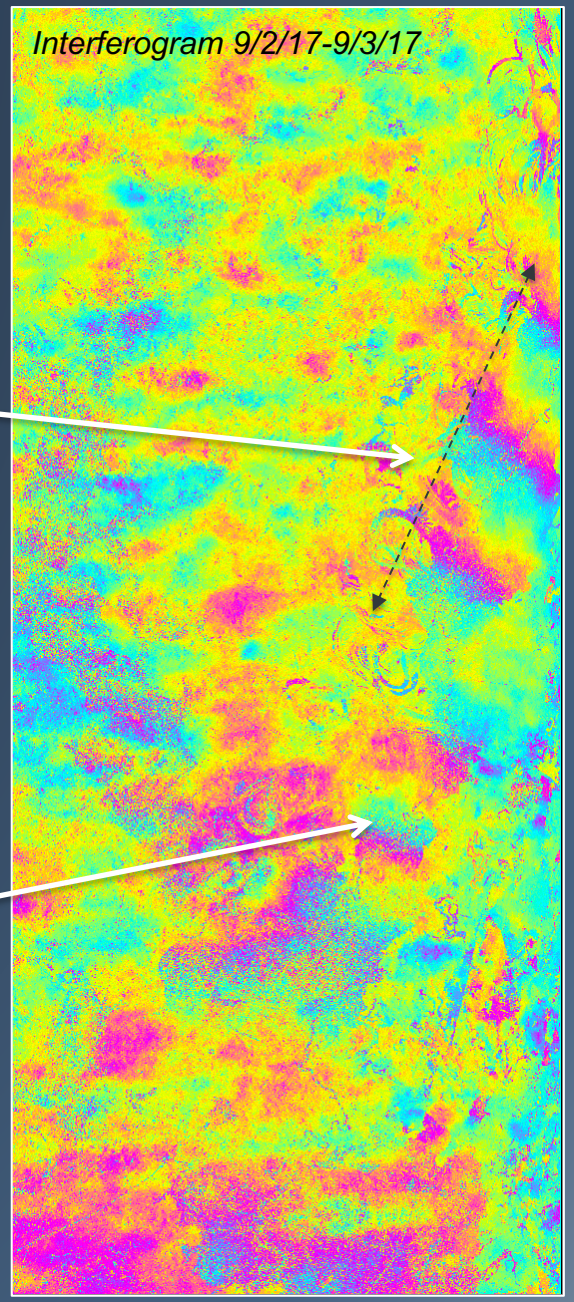
Red=9/2/2017, Green=9/1/2017

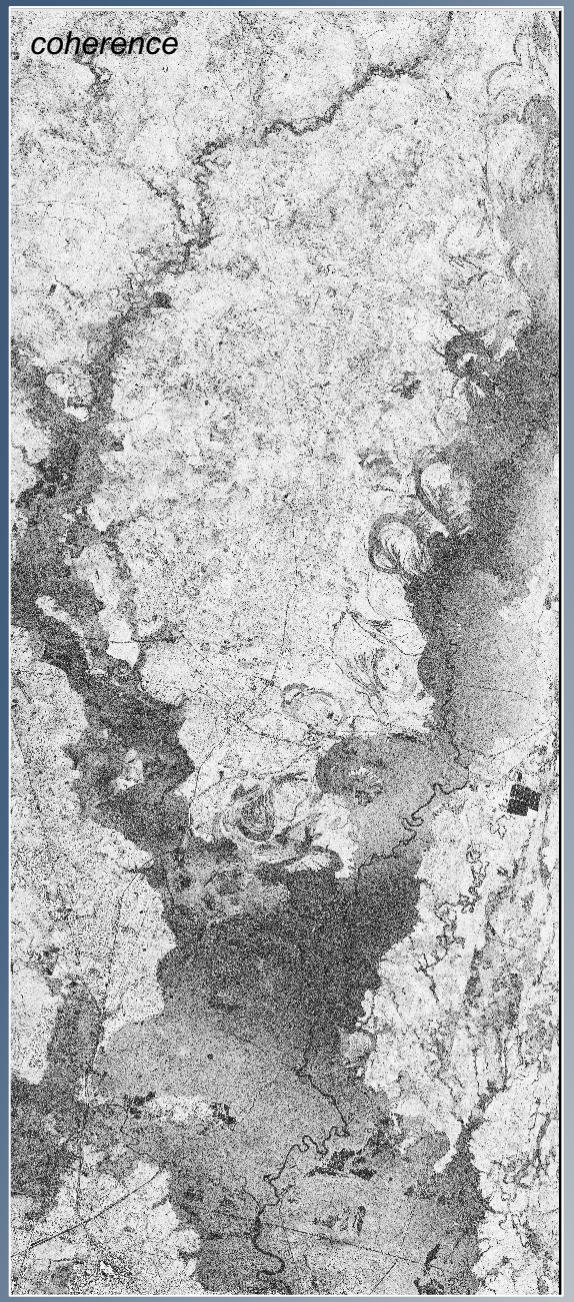
Flood Model:
Peak Inundation on Neches River

PRODUCT USED: PolSAR, double bounce intensity (Freeman-Durden Decomposition)

WATER ELEVATION CHANGE ALONG RIVER







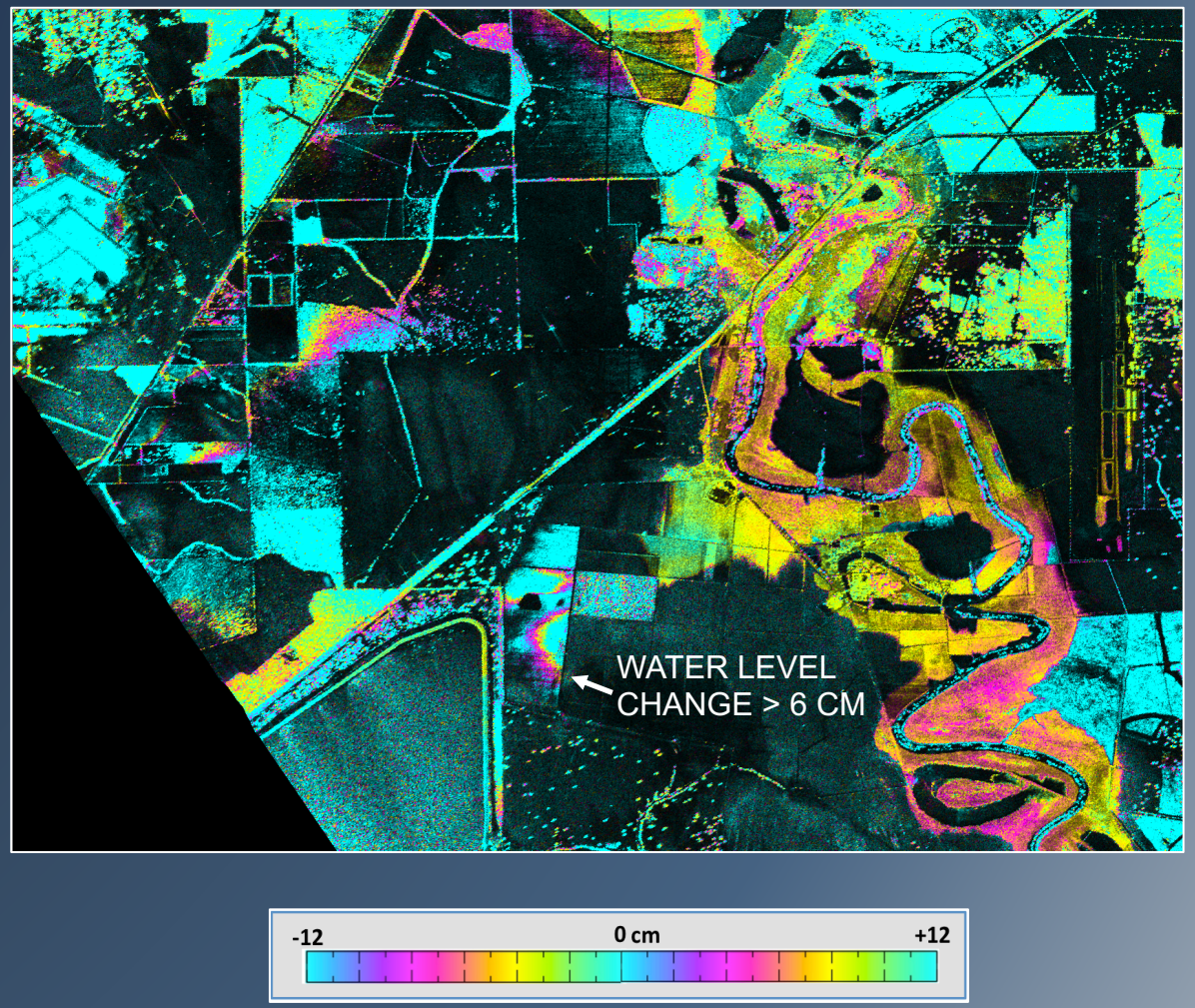
Neches River:
30 cm LOS
change in 12 km

Reverses sign
=> water coming
in from other
branch of river

PRODUCT USED: INTERFEROGRAM

WATER LEVEL CHANGE IN FLOODED FIELDS

LOWER BRAZOS RIVER TRIBUTARIES



PRODUCT USED: INTERFEROGRAM

WATER POLLUTION / INDUSTRIAL DISCHARGE

- Oil and surfactants smooth the water surface, so they appear radar-dark
- Relies on amplitude contrast only (single image)
- Spills are easily detected in the open ocean or large areas of open water under a wide range of meteorological conditions

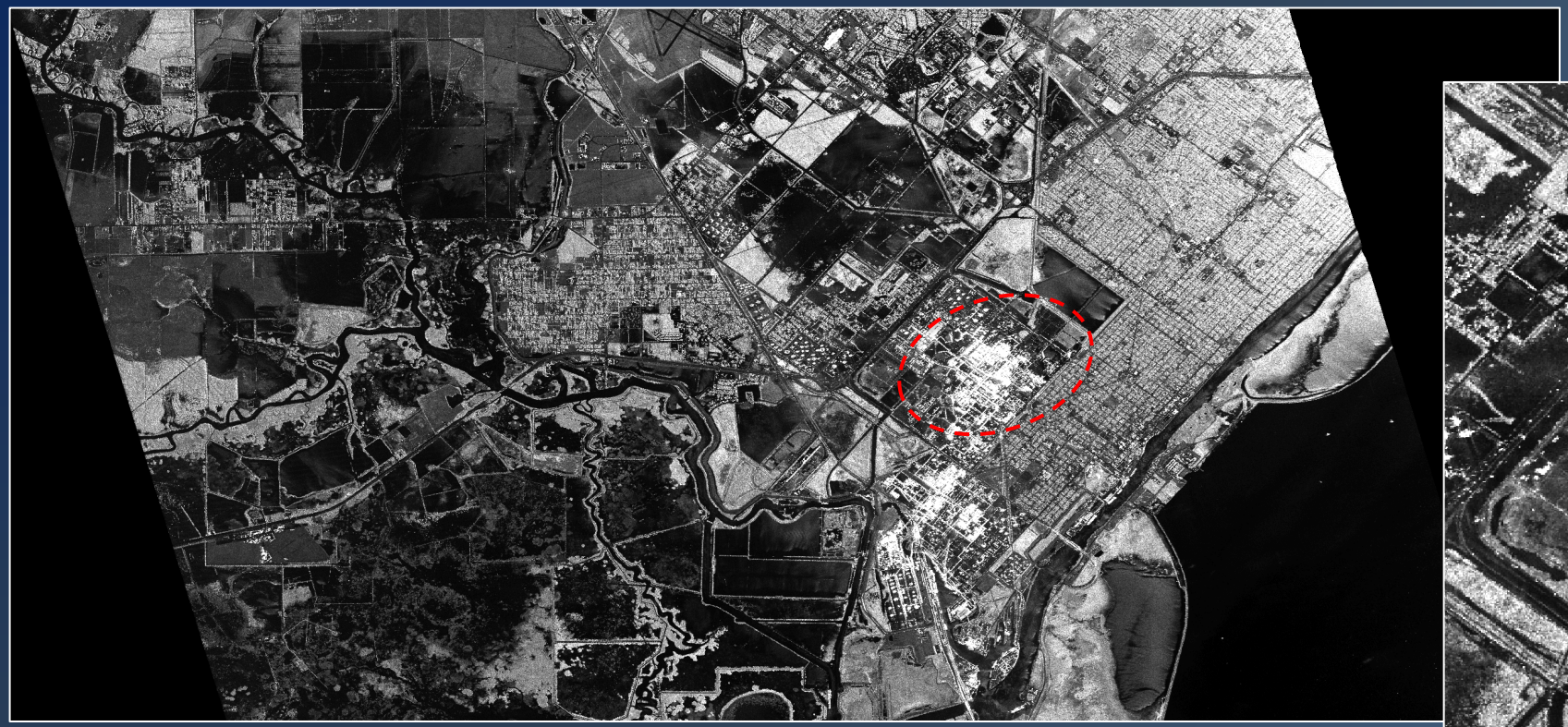
GULF OF MEXICO NEAR THE BRAZOS RIVER OUTLET, 9/2/2017

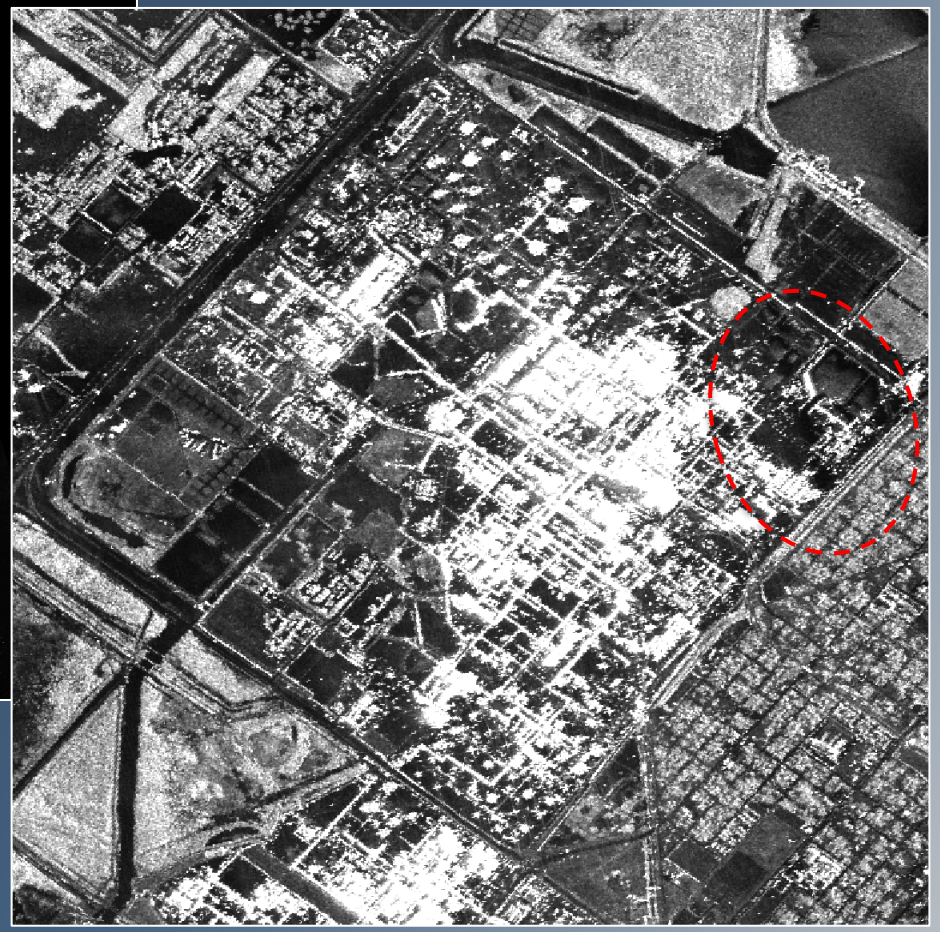
FLOODED LAND, LOWER BRAZOS, 9/2/2017

PRODUCT USED:
VV-INTENSITY IMAGE

WATER POLLUTION / INDUSTRIAL DISCHARGE

Inland small areas of flooded land and flooded rivers display many false-positive signals and can be radar-dark independent of spills.
SAR can be used to detect most-probably source location when there is a reported spill at a particular facility

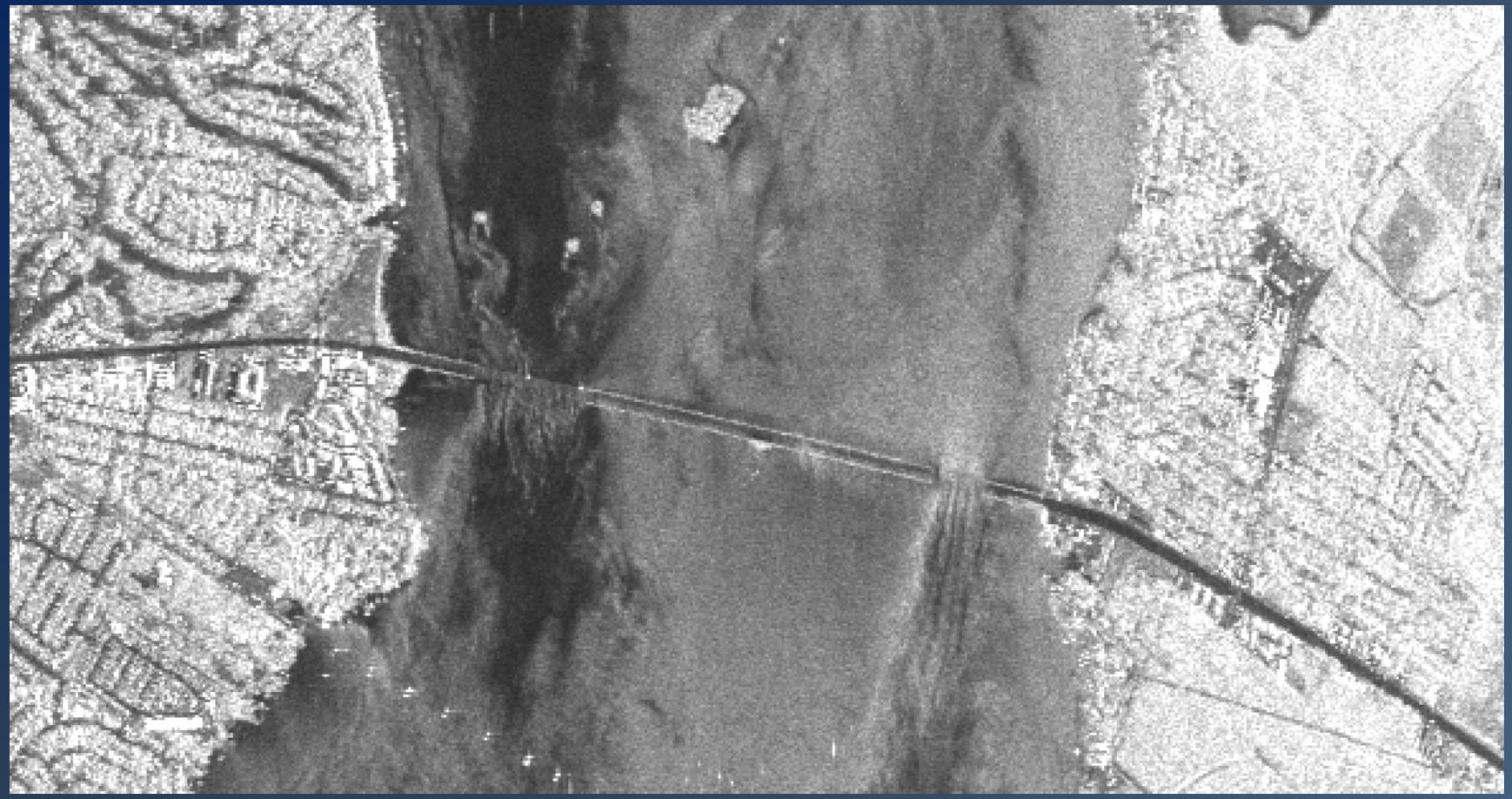


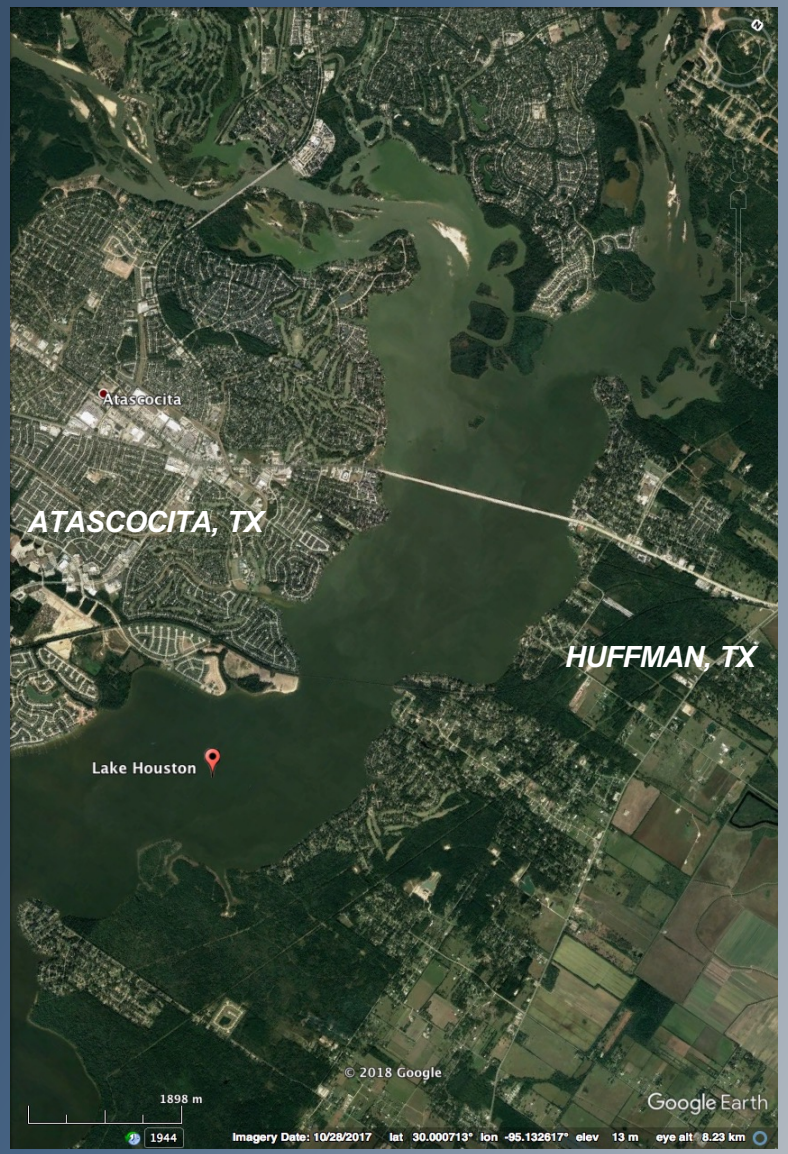


PRODUCT USED:
VV-INTENSITY IMAGE

CRITICAL INFRASTRUCTURE MONITORING - BRIDGES

OVERTOPPING OF BRIDGE ON LAKE HOUSTON (San Jacinto River)

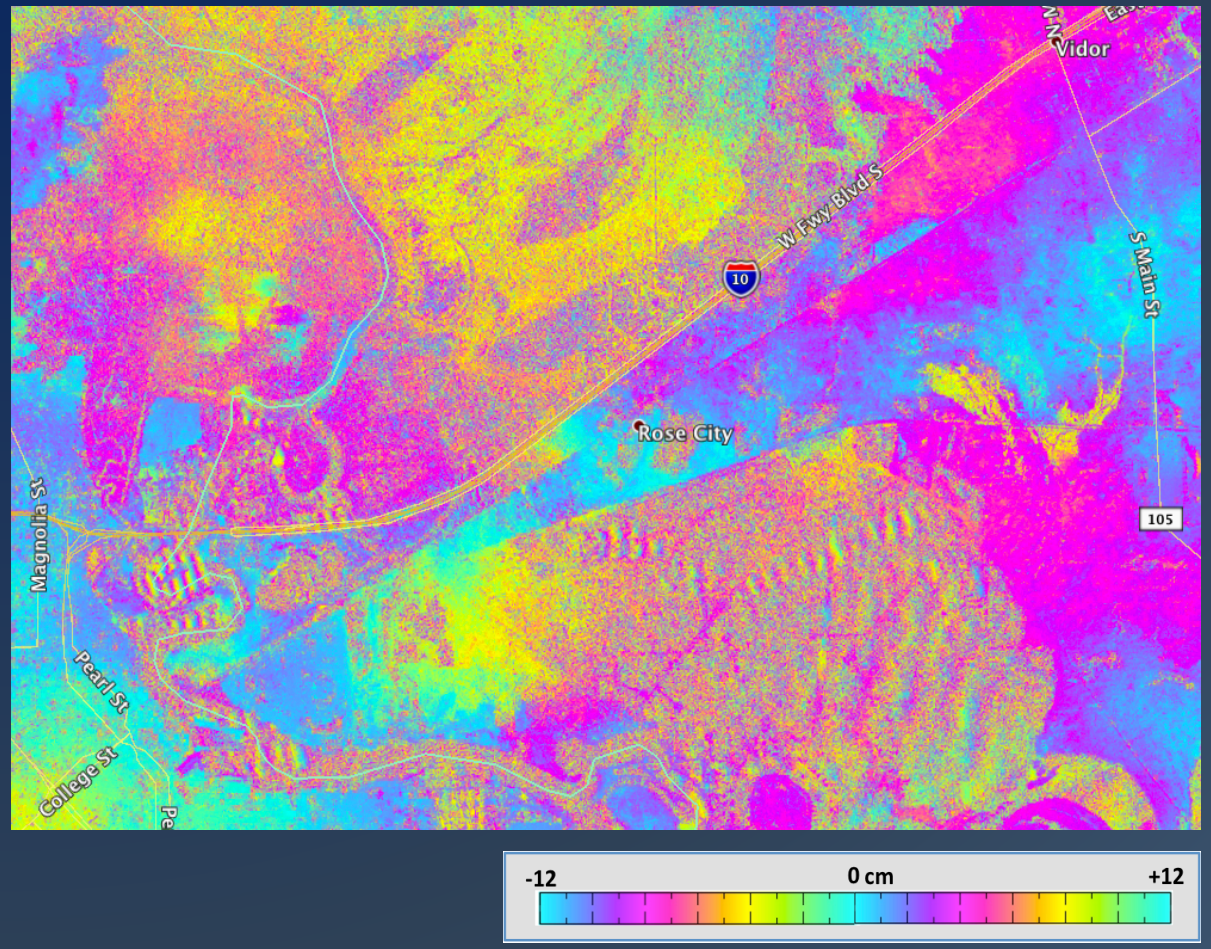


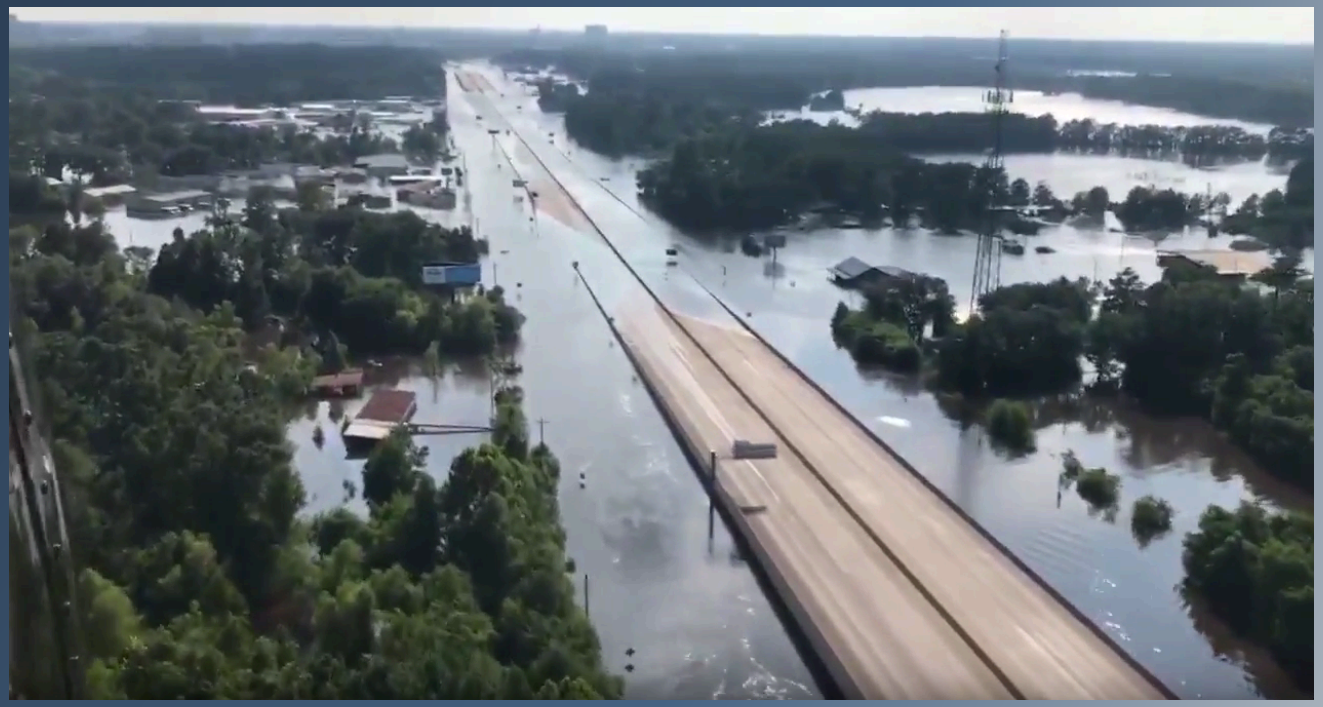


PRODUCT USED: VV-INTENSITY IMAGE

CRITICAL INFRASTRUCTURE MONITORING

FLOODING OF INTERSTATE-10, ROSE CITY, TX (NECHES RIVER)
Interferogram shows water level change across freeway, 9/1 – 9/2/2017





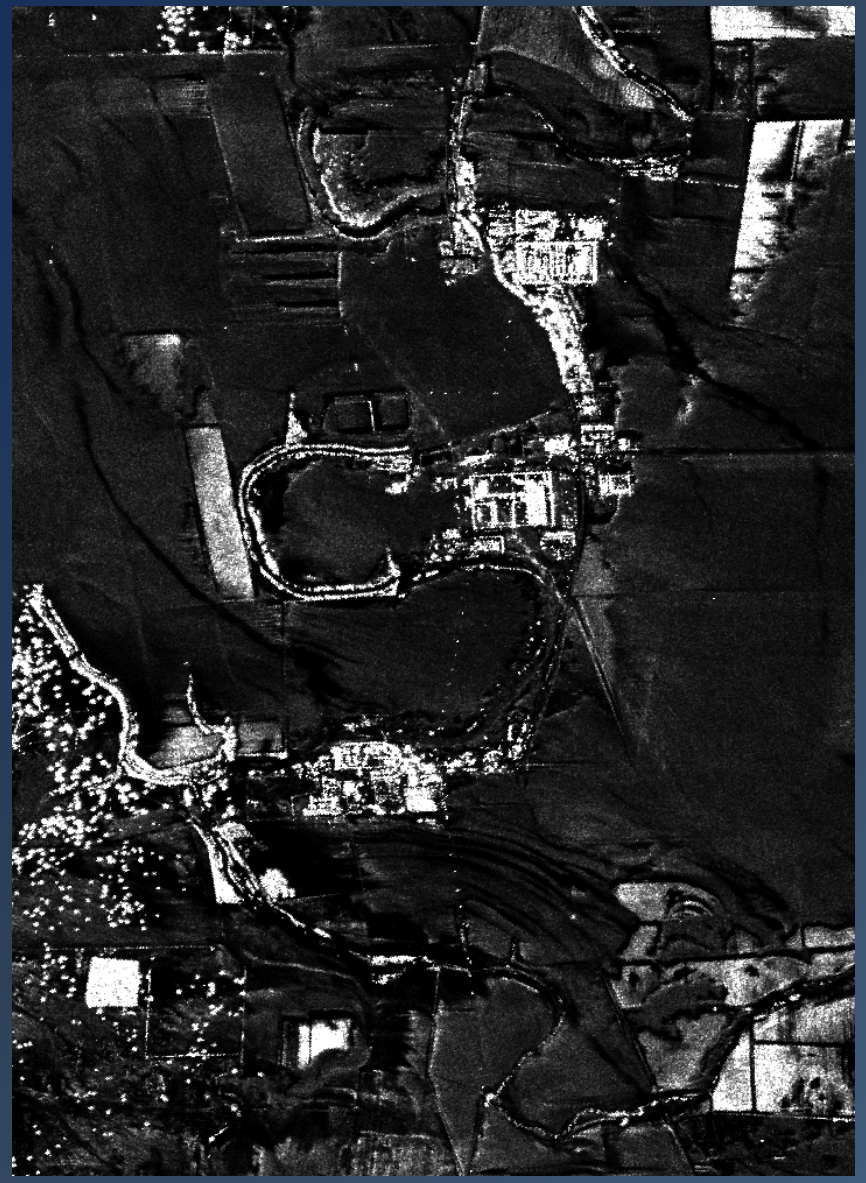
PRODUCT USED: INTERFEROGRAM

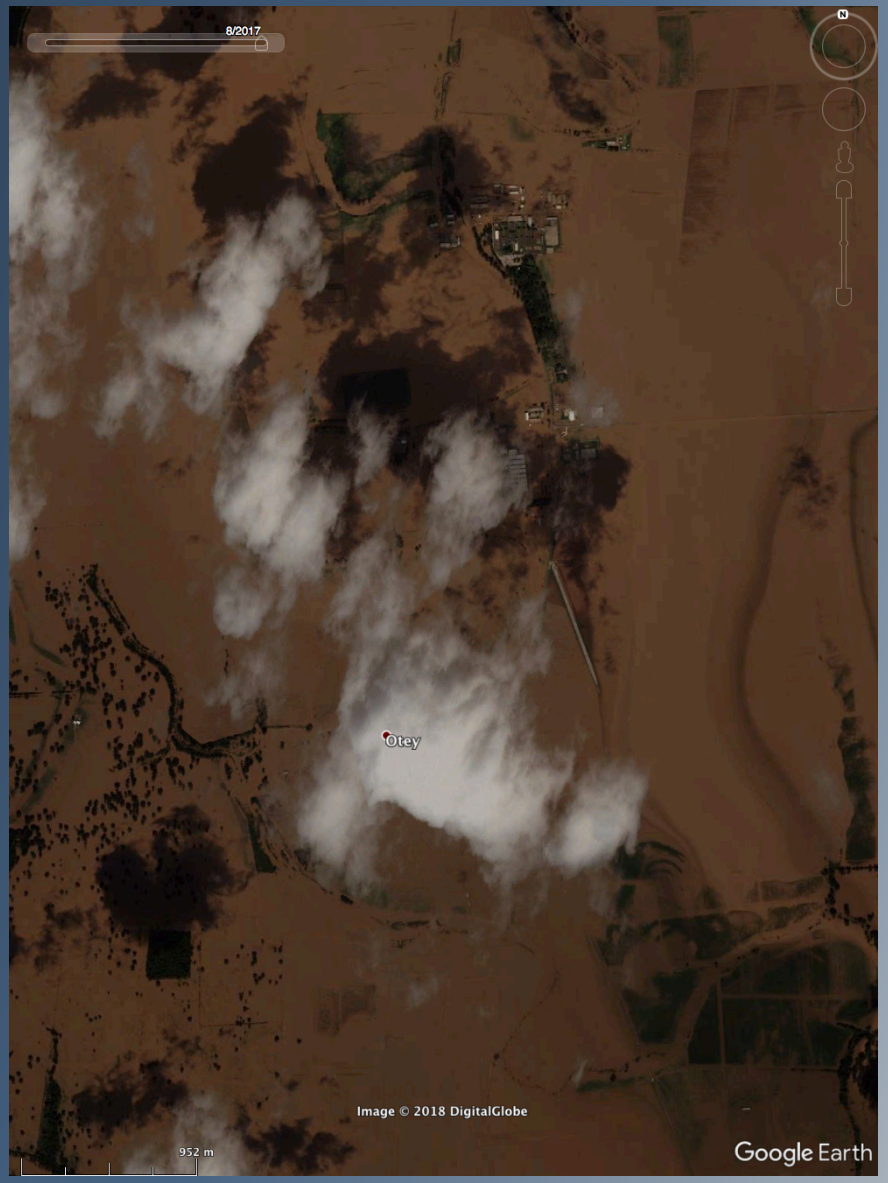
CRITICAL INFRASTRUCTURE MONITORING

FLOODING OF TEXAS PRISONS, 9/1/2017 (Brazos River)

Below-cloud mapping capability can be used to identify evacuation routes.

PRODUCT USED: VV-INTENSITY IMAGE





Summary of UAVSAR CONTRIBUTIONS to Hurricane Harvey Flood Response

UAVSAR quick-look products were used by emergency response staff at the Texas State Operations Center in Austin to:

- Identify levee breaches and levee overtopping around small towns and neighborhoods to direct evacuation and rescue efforts
- Identify flooding in refineries, especially containment breaches and overtopping around the oil tank batteries to direct chemical spill response efforts
- Identify the location of “dry spots” where disaster relief agencies could stage relief centers near flooded towns

The addition of PolSAR & InSAR on-board processing capability would dramatically increase the amount and type of information that could be provided with airborne SAR/InSAR/PolSAR during flood response.

Quoting Gordon Wells (UT Austin Center for Space Research, de facto remote sensing arm of State of Texas emergency response):

“*The efforts of UAVSAR were great; it was great to be able to follow flood waves and fill gaps between radar satellite coverage overpasses. UAVSAR gave us such a good view of where the flood waves were impacting, and allowed us to anticipate where things would be hit next. We could forecast where problems would be, even though this event was well beyond any historical floods. I think we may have previewed the future of flood response.*”

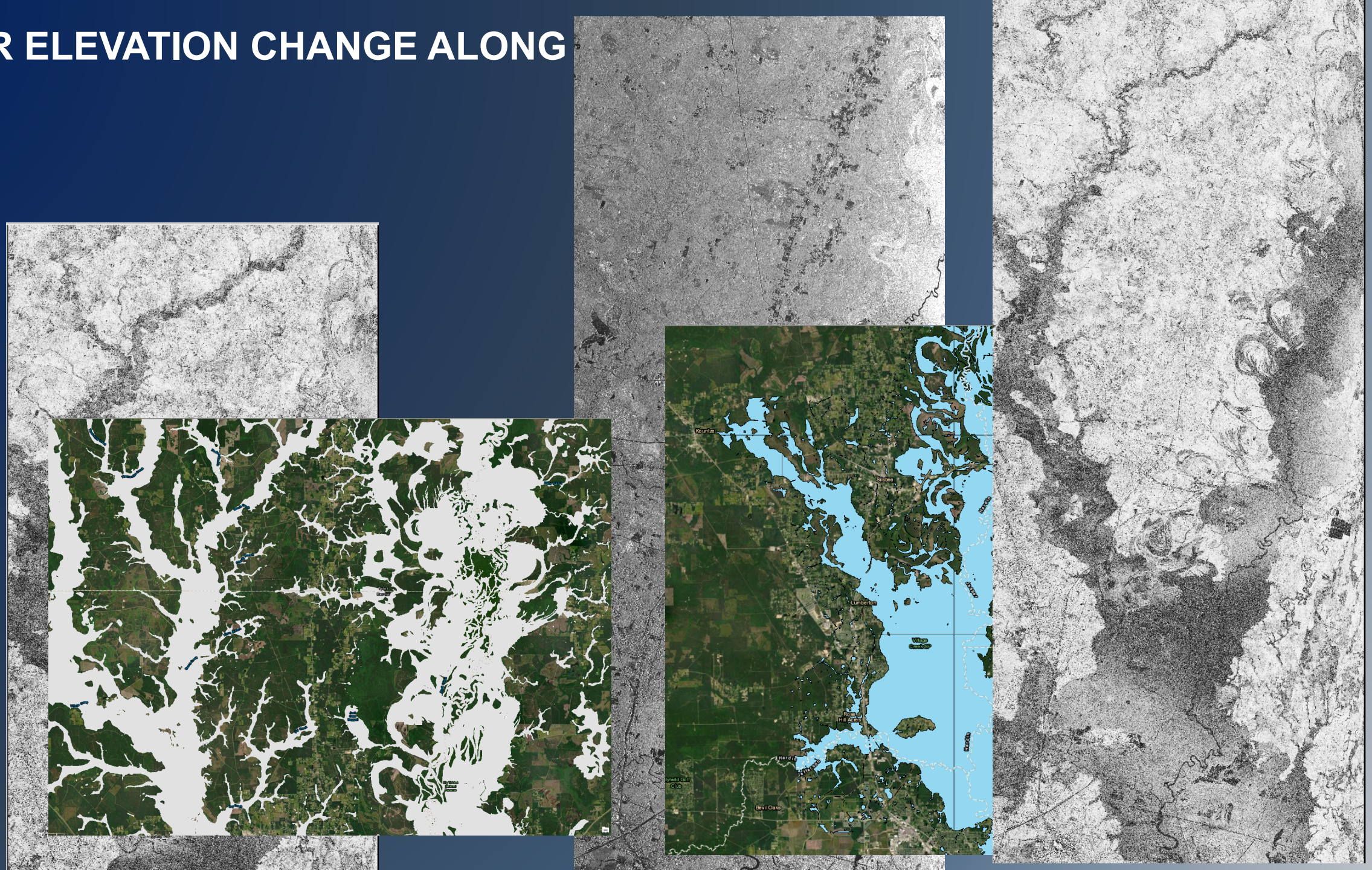
Special thanks to the UAVSAR Teams at Armstrong FRC and JPL who made the response effort possible.

EXTRA SLIDES

OUTLINE

1. Deployment
2. Rapid Response Data Processing
3. SAR Methods
4. Information Provided
    - Inundation extent
    - Floodwater below vegetation
    - Status of critical infrastructure
    - Waterborne pollutants
- Feedback from Responders

WATER ELEVATION CHANGE ALONG



TOPIC