Space-based hydrological monitoring of the entire Everglades using Sentinel-1 observations

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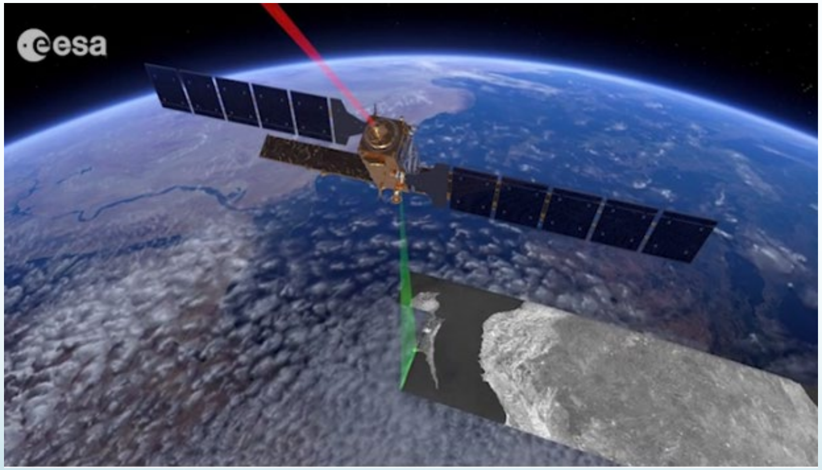
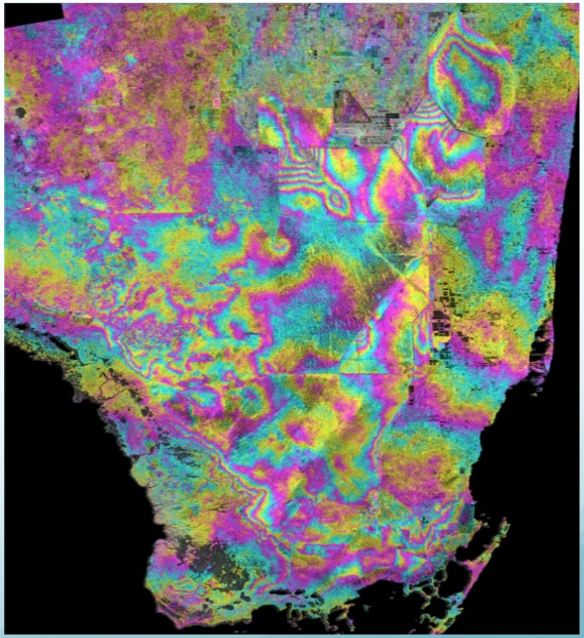
Florida International University



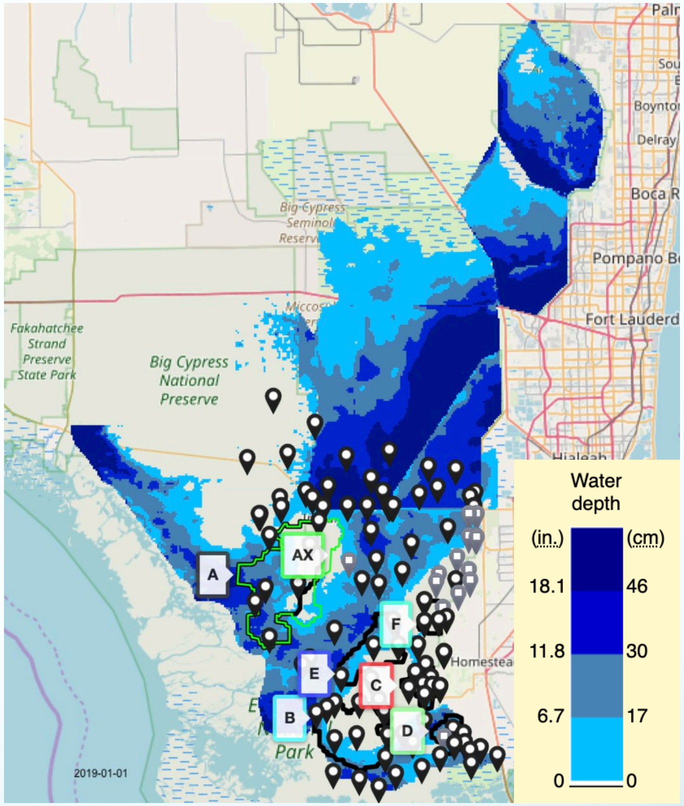
Sentinel-1

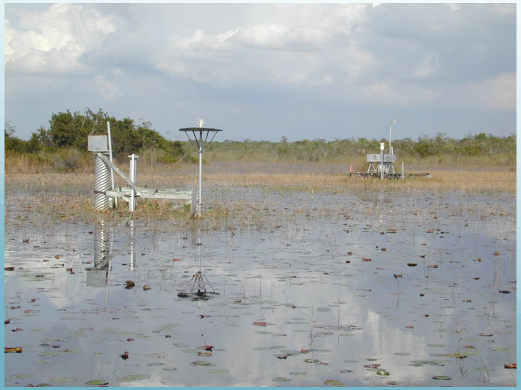


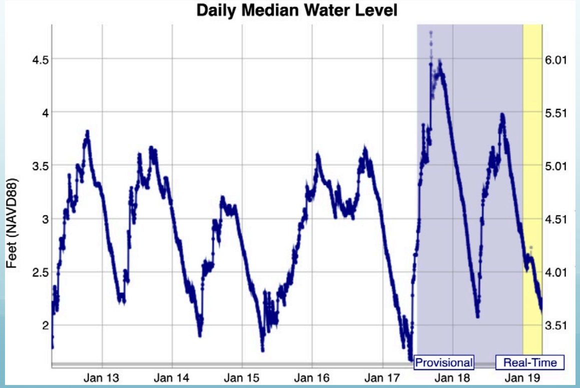
Water level changes

Ground-based hydrological monitoring of the Everglades

- Ground measurements
  - Stage (180 stations)
  - Flow meters
- Advantages
  - High temporal resolution
  - Real-time
- Disadvantages
  - Low spatial resolution (point measurements)
  - Expensive and vulnerable

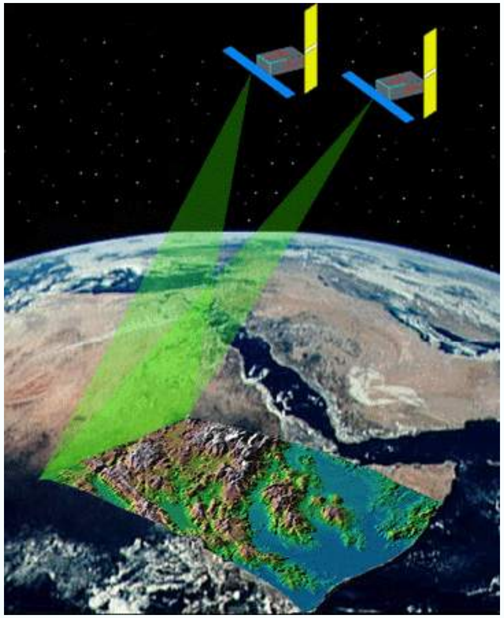






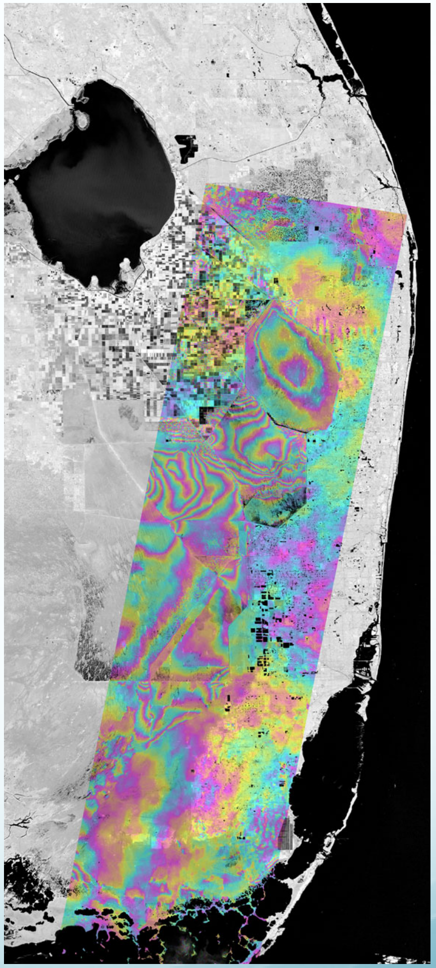
Source: https://sofia.usgs.gov/eden

Space-based hydrological monitoring of the Everglades



Wetland InSAR

- Comparison of phase information acquired by SAR satellites
- Works in wetlands
- Measure water level changes between two acquisitions.



Previous missions

- Limited swath (15-80 km)
- Low temporal resolution (24-45 days)
- Infrequent acquisition plan
- Limited access to data, often requires payment

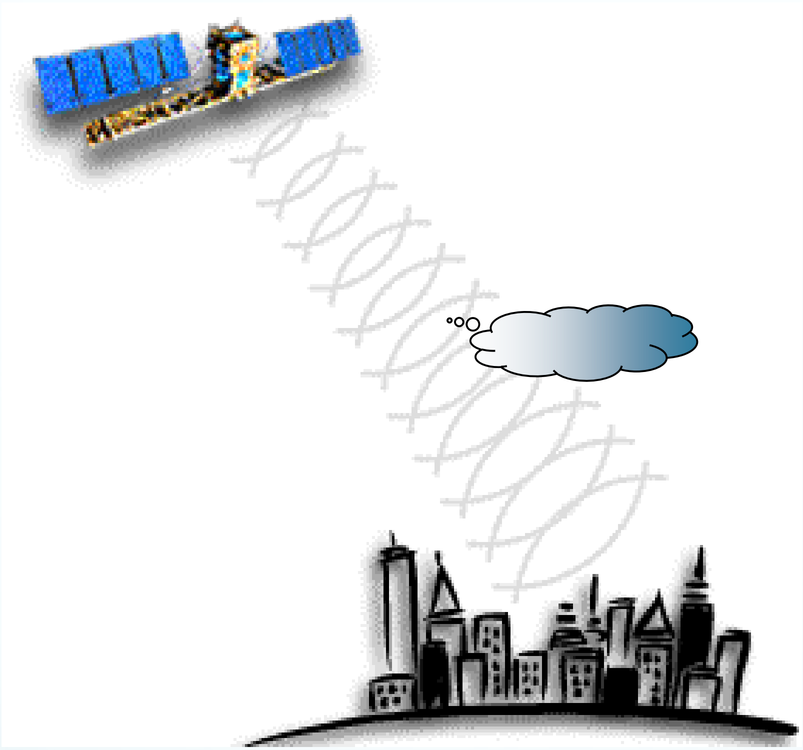
Sentinel-1A/B

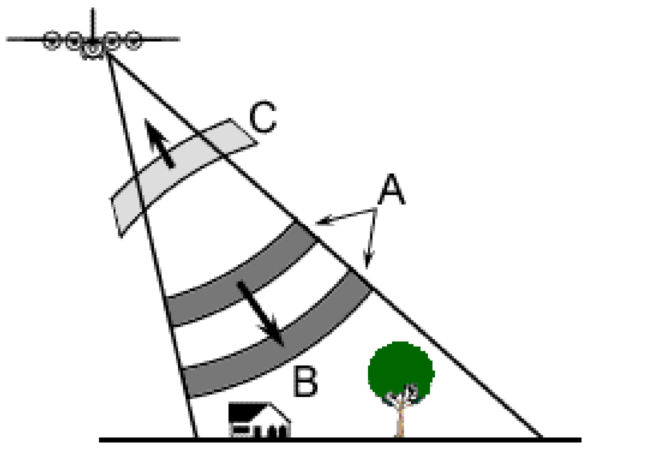
- Launched and operated by the European Spcae Agency (ESA)
- Constellation of 2 identical satellites
- Operational mode

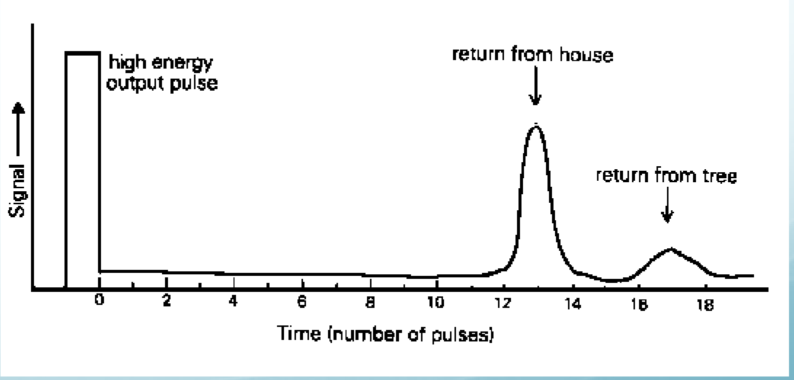
Acquisition characteristics

- Wide swath (250 km)
- Higher temporal resolution (6-12 days)
- Consistent acquisition plan
- FREE

Synthetic Aperture Radar (SAR)







RADAR remote sensing is an `active` imaging technique that utilises the microwave region (~1-100 cm) of the EM spectrum

SAR data

Complex SAR image - The SAR records the amplitude and the phase of the returned signal

amplitude **phase**

Mt. Etna

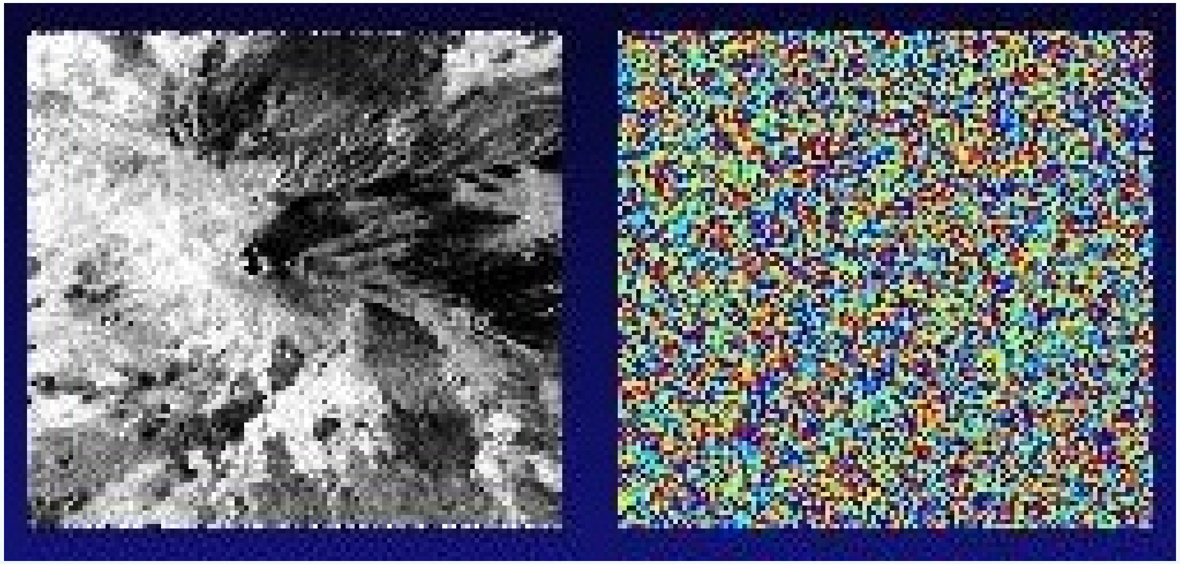
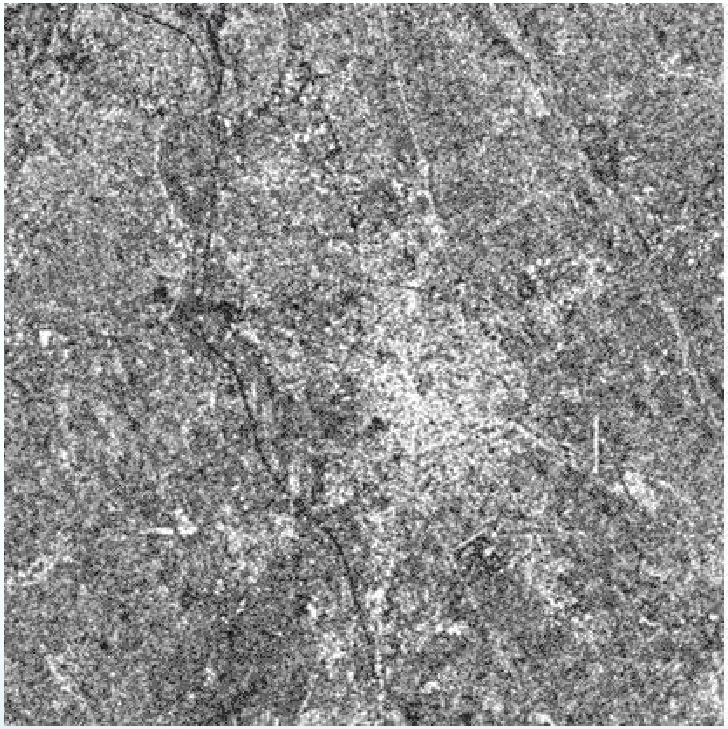


Image from http://epsilon.nought.de/tutorials/insar_tmr/img35.htm

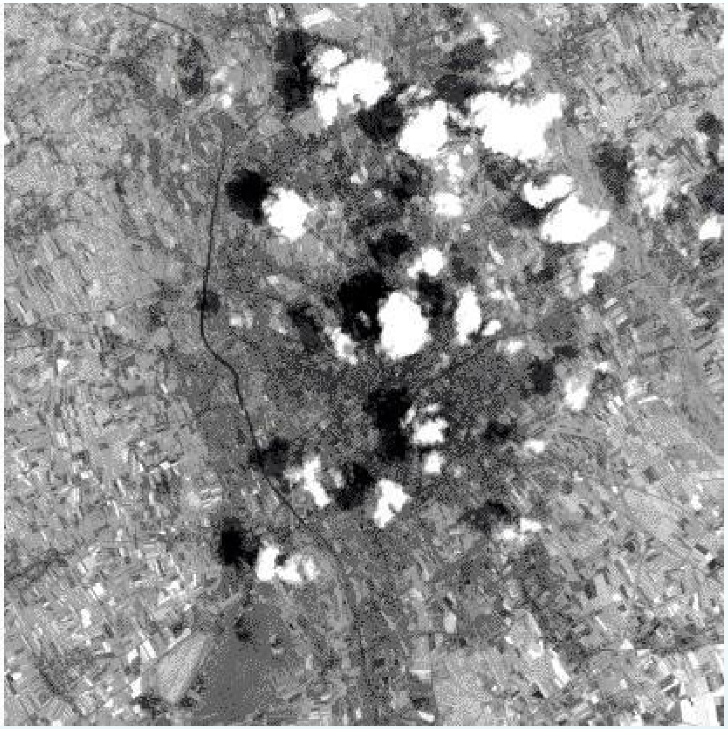
Note that while the amplitude image shows recognizable topographic pattern, the phase image looks random.

SAR amplitude data vs optical images

Acquire data at all weather conditions.



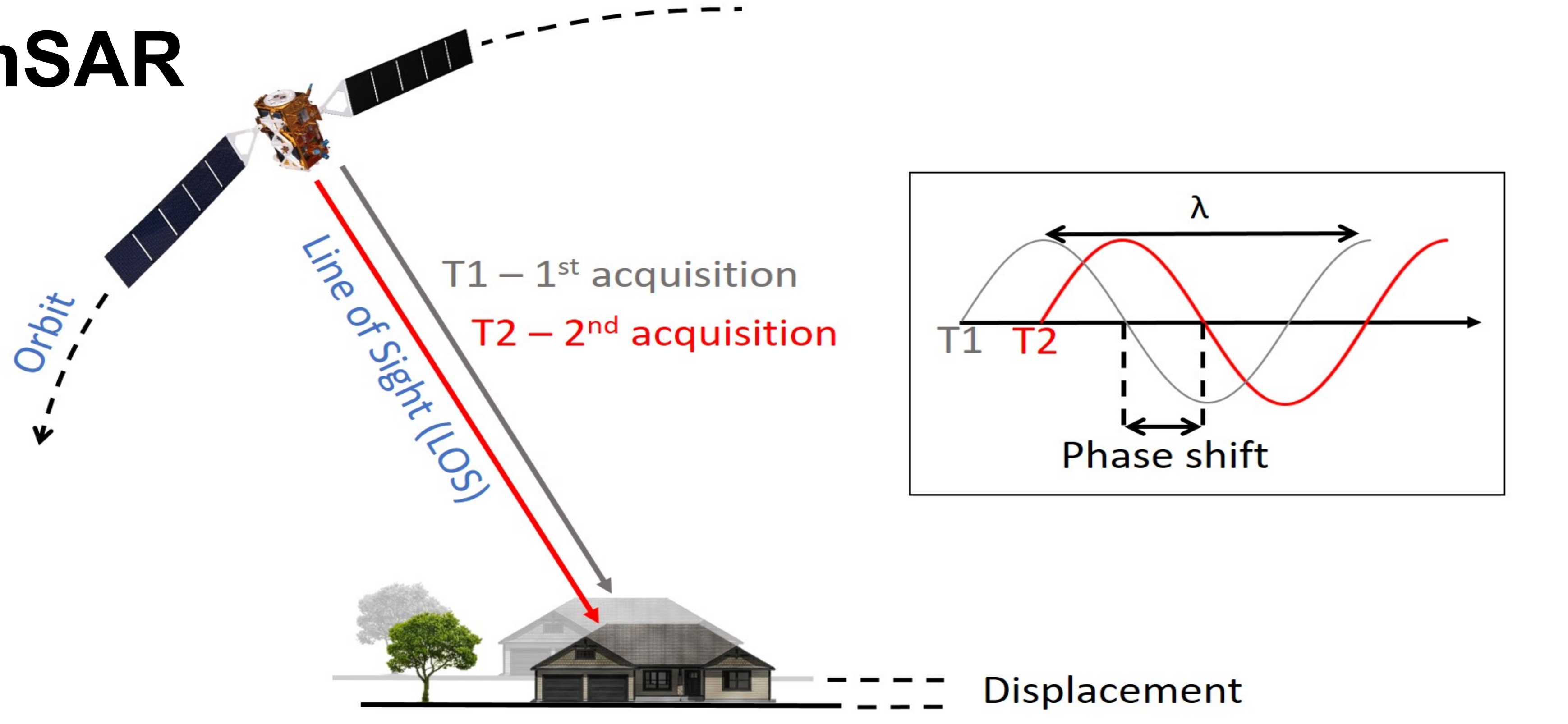
ERS-1



Landsat-5

Both images were acquired over the city of Udine (Italy) roughly during the same time, on 4 July 1993.

InSAR



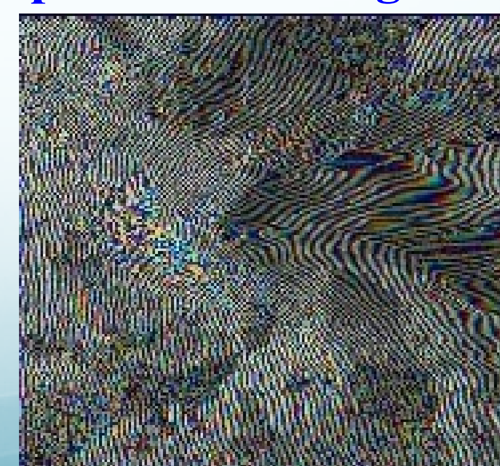
phase “master”

-

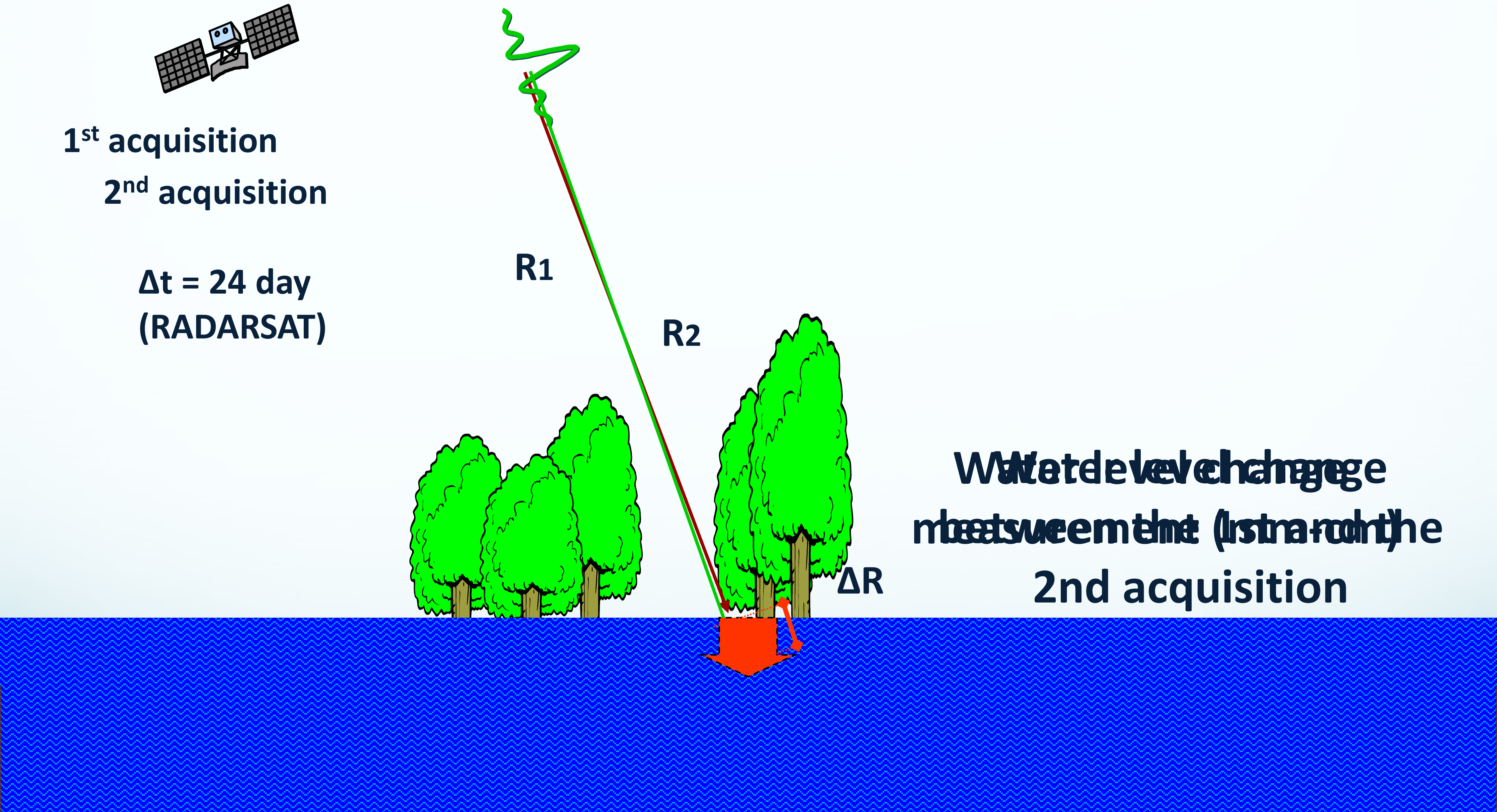
phase “slave”

=

phase interferogram



Water level change measurements

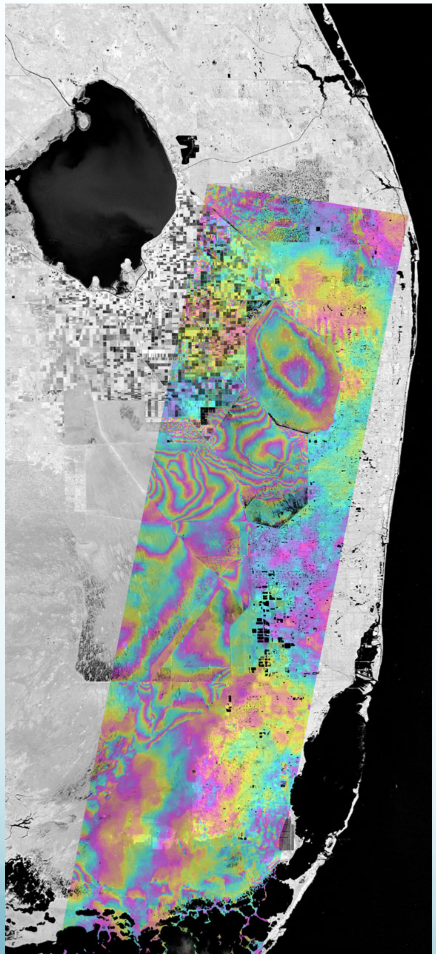


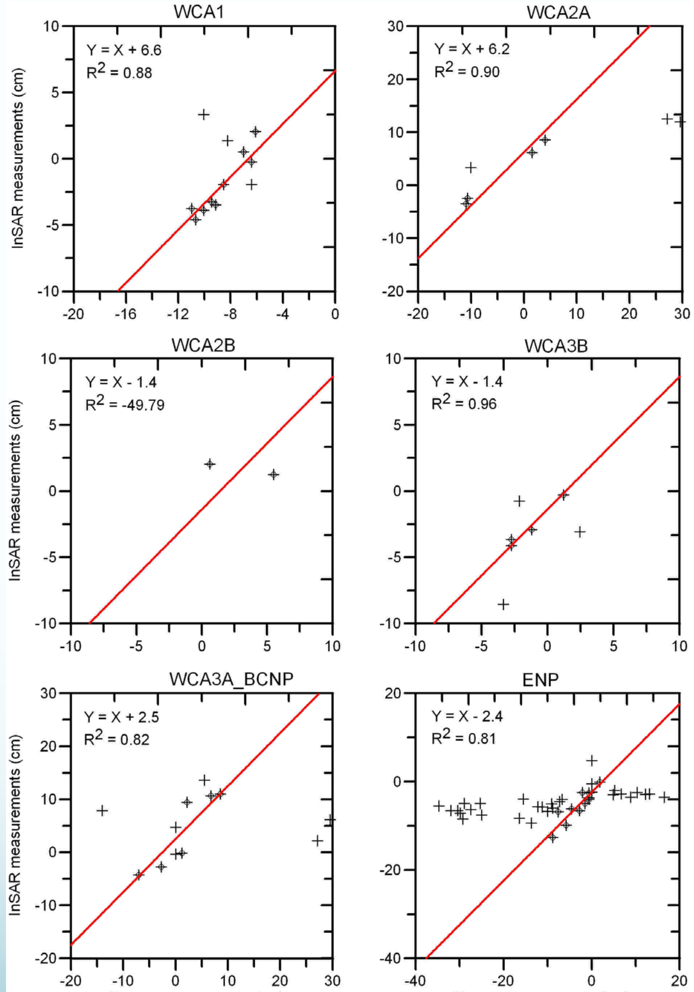
Water level changes

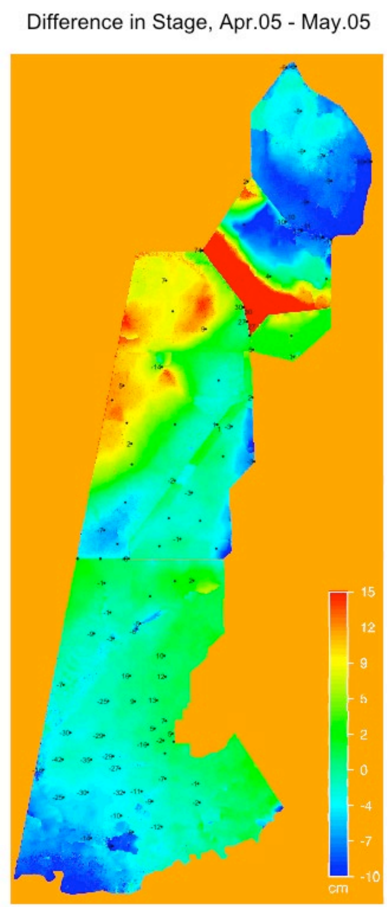
Interferogram

Calibration with stage data

Change maps

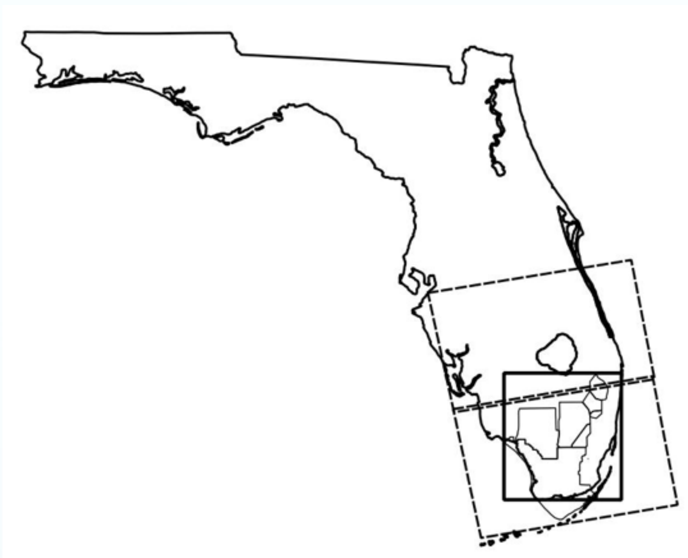






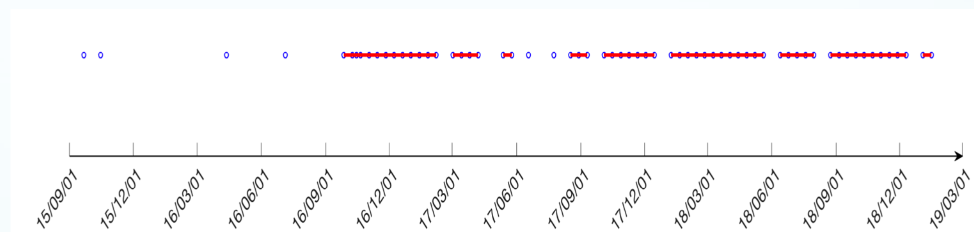
Sentinel-1 data

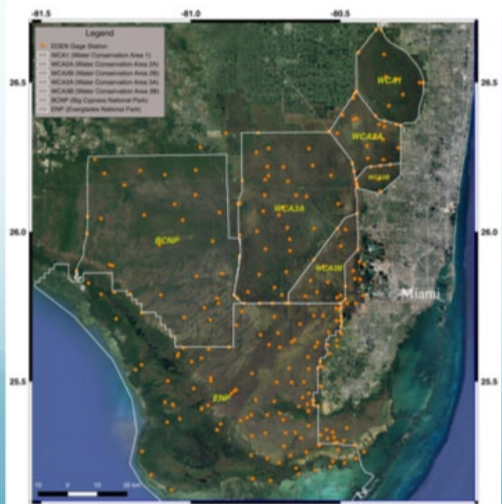
Spatial coverage



Temporal coverage

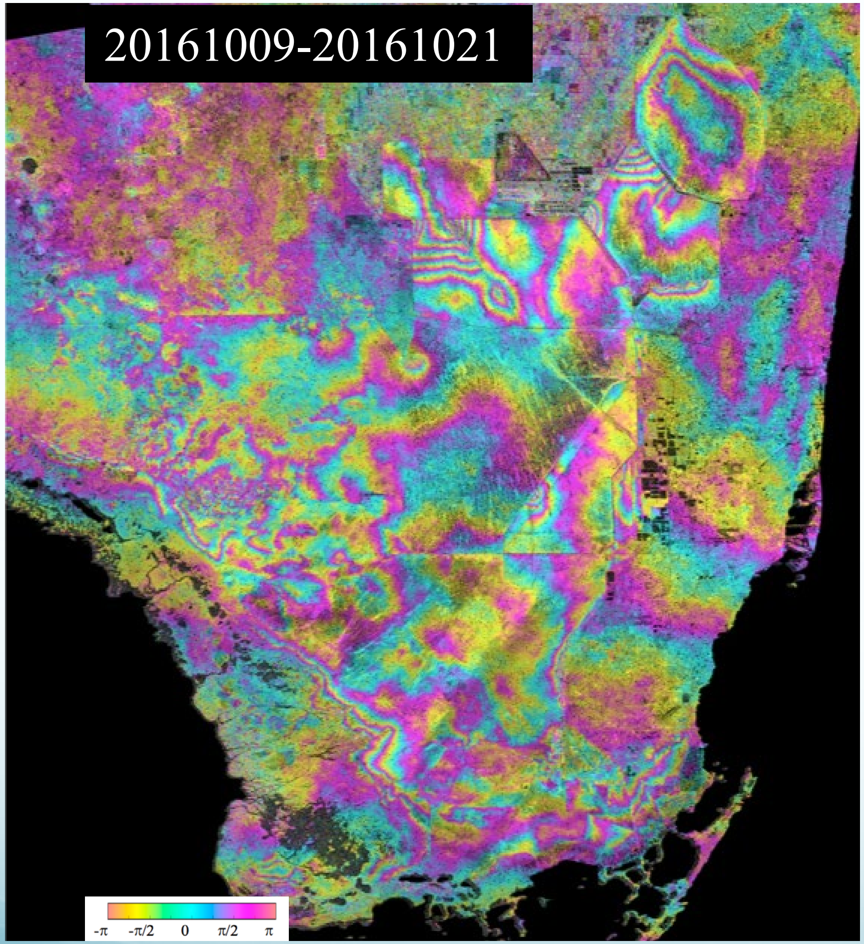
- Sep, 2015 ---- present
- Repeat cycle: 6 or 12 days; some gaps





Stage stations for ground truthing and calibration.

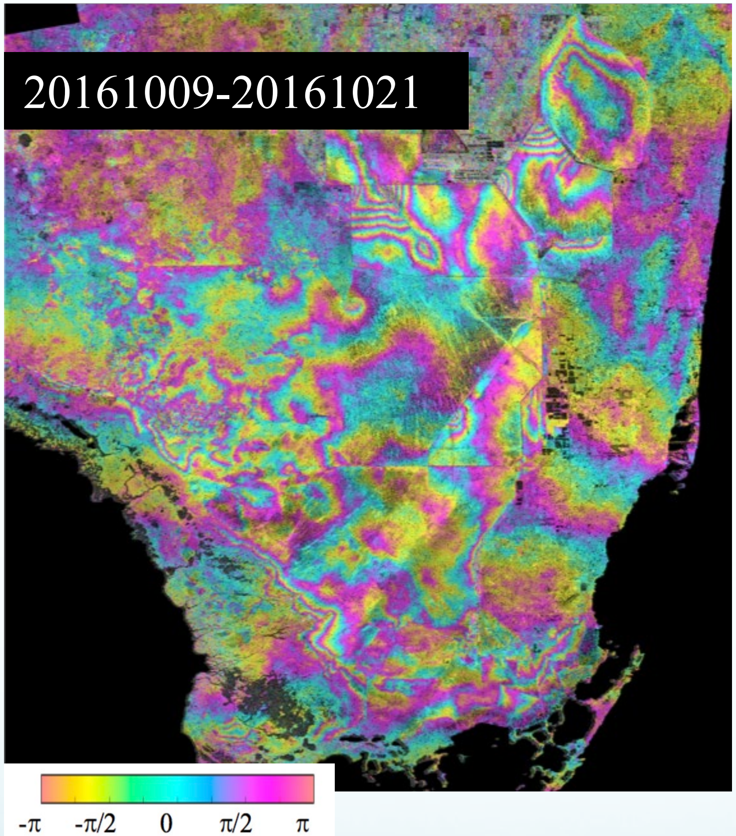
Example Interferograms

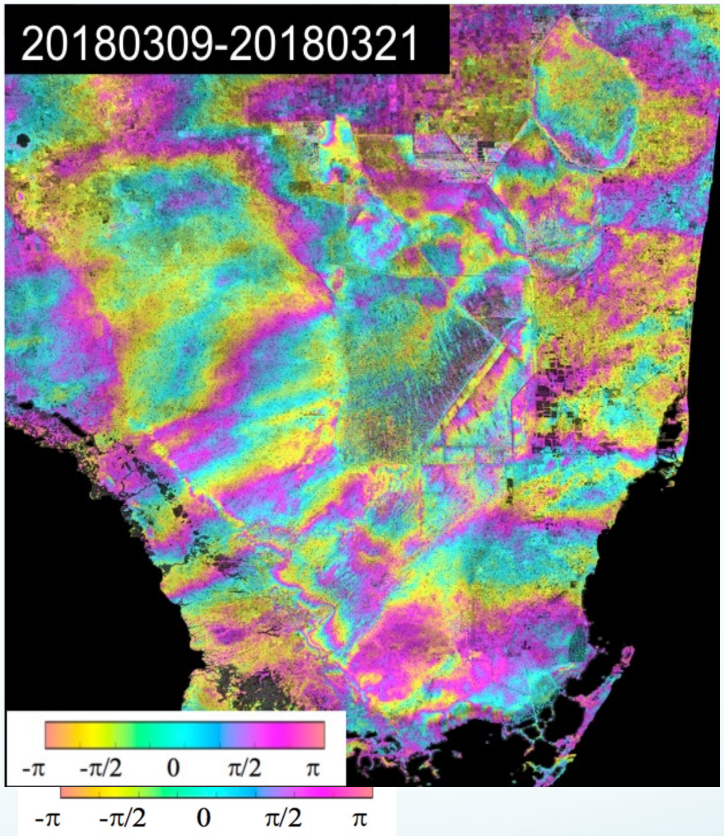


Main characteristics

- Organized phase changes in Water Conservation Areas (WCAs)
- Discontinuous fringes across levees and roads.
- High fringe gradients due to gate operation.
- Less organized changes in naturally flow areas (ENP, Big Cypress)
- Elongated fringe along the fresh- and salt-water transition

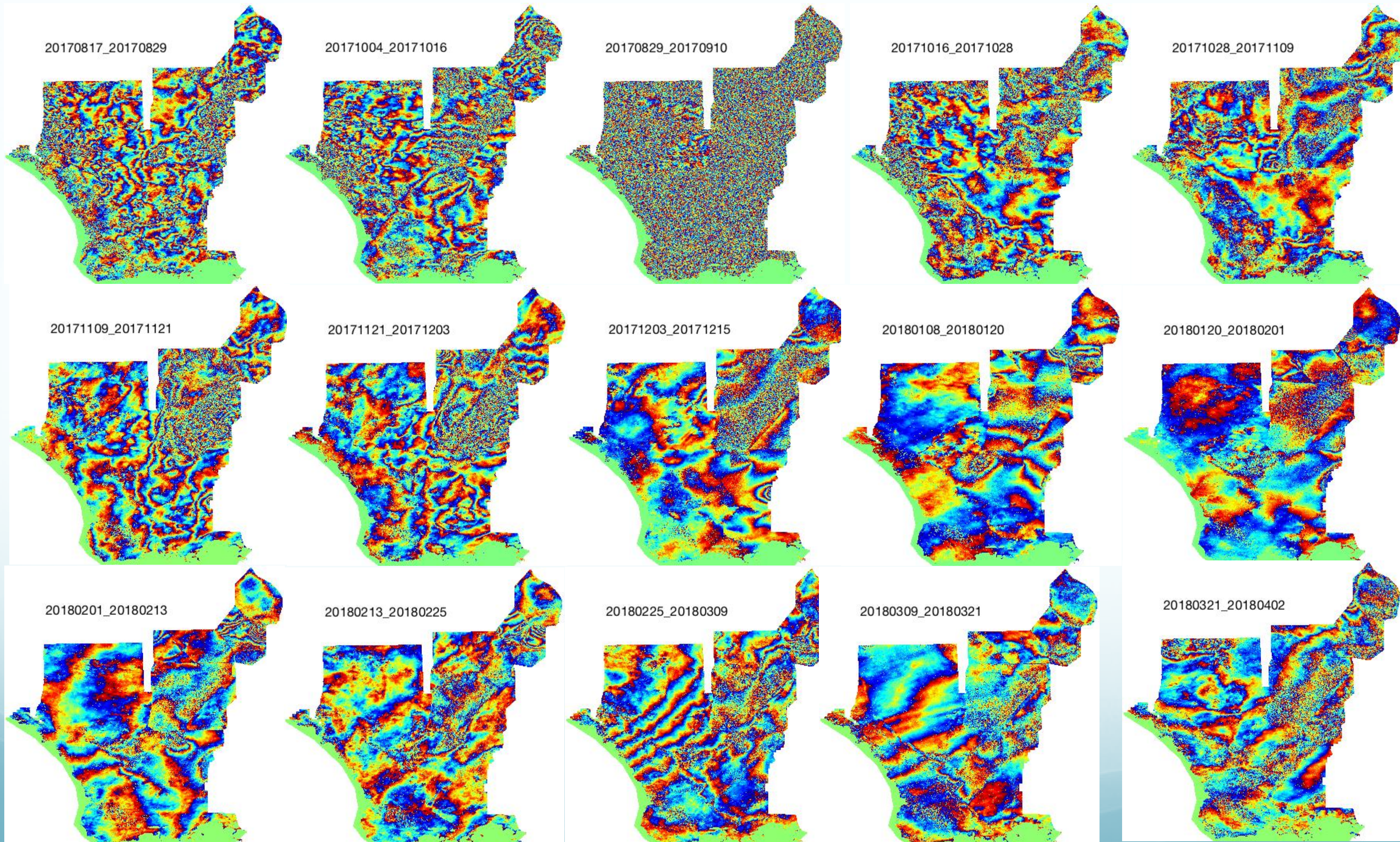
Vegetation transition fringe



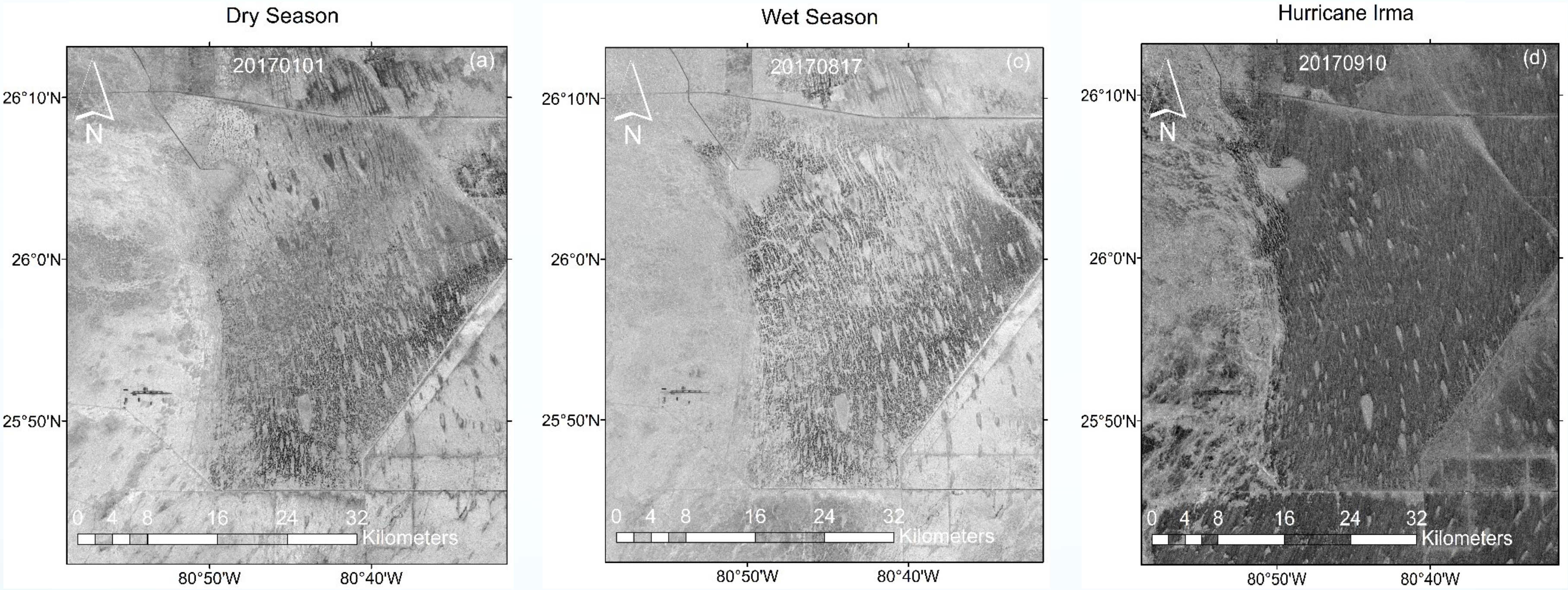


- The elongated fringe follow the transition between brackish and freshwater vegetations
- Number of fringes depends on tide variations (seasonal)
- Lateral seasonal variations are up to 400 m

Time series of water level changes



Amplitude intensity analysis

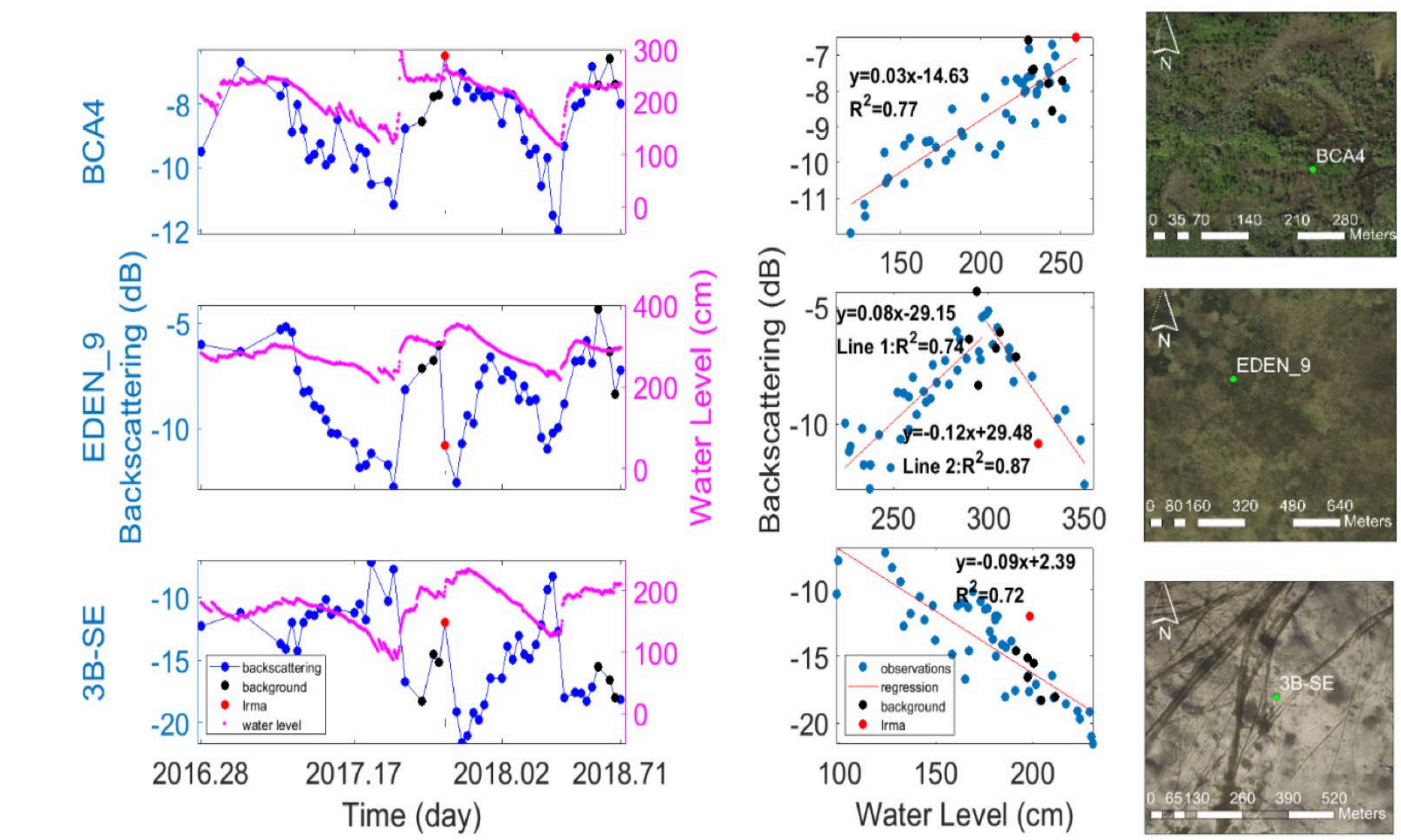


- Intensity level vary depending on vegetation type

  Trees – bright Herbaceous – dark

- Intensity level is sensitive to hydrological conditions. It varies:
  - Seasonally
  - In response to flooding events

Time series analysis of backscatter intensity vs. water levels

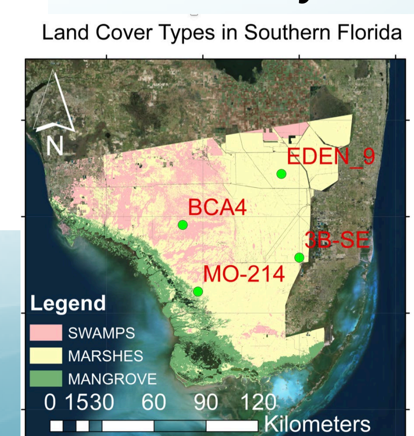


Woody

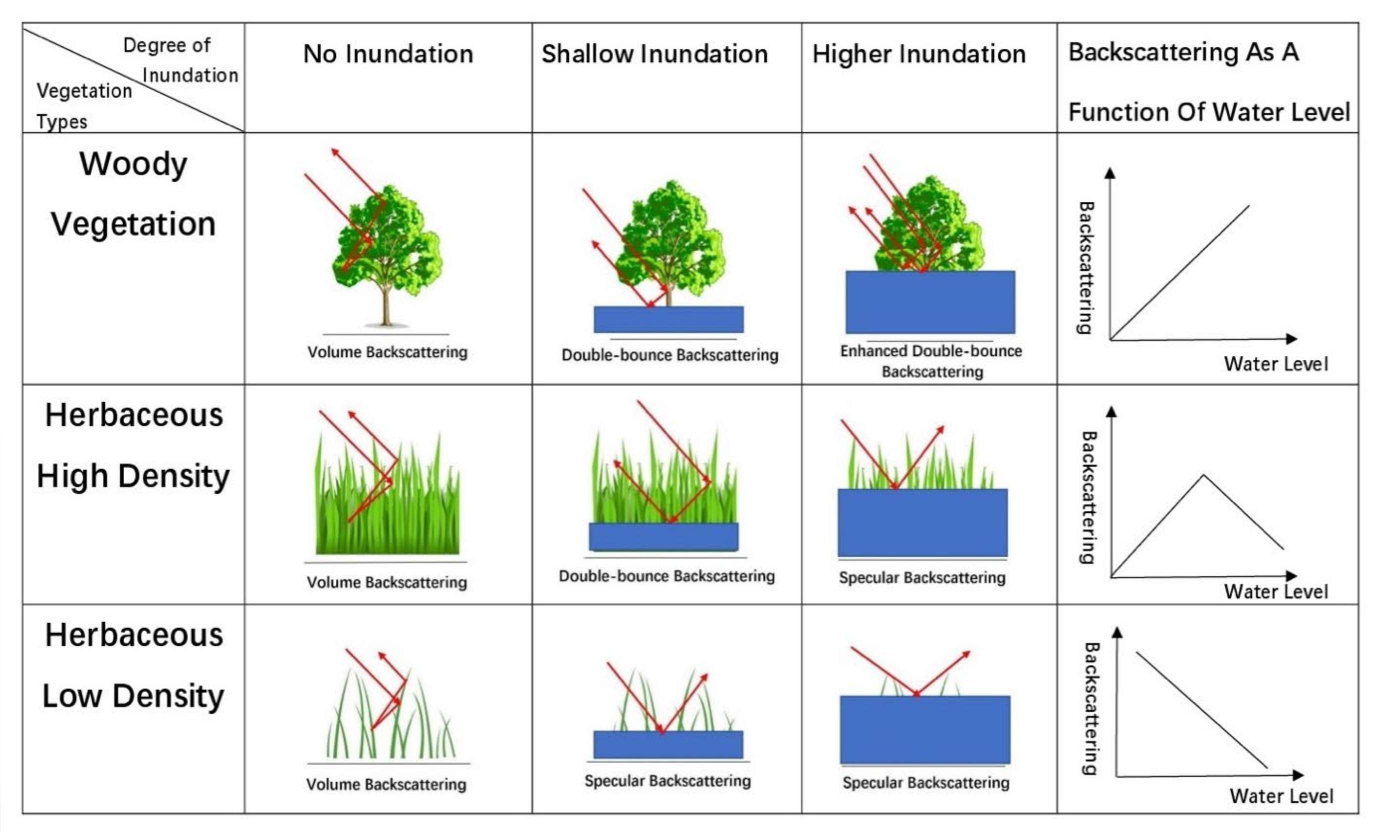
High-density

Herbaceous

Low-density



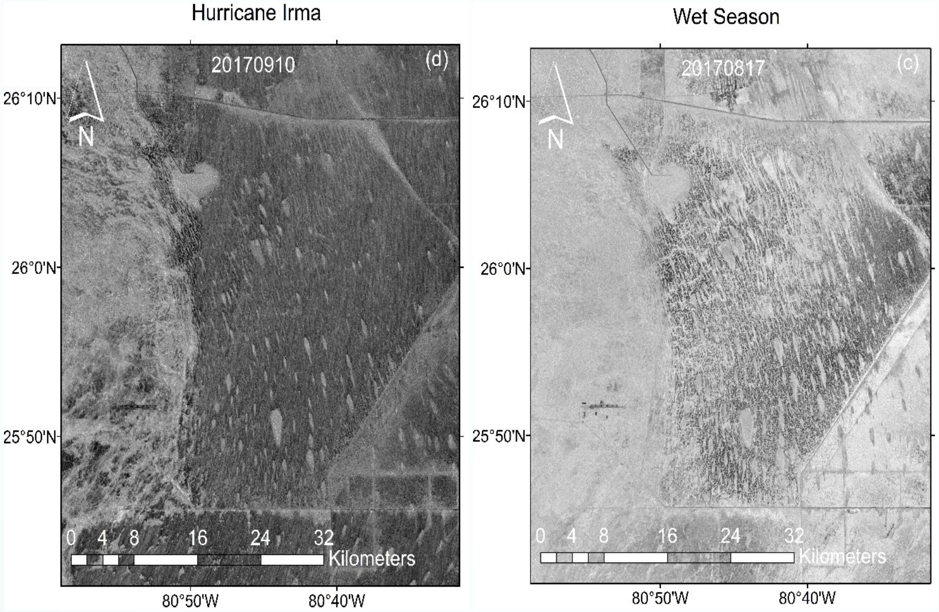
Conceptual model

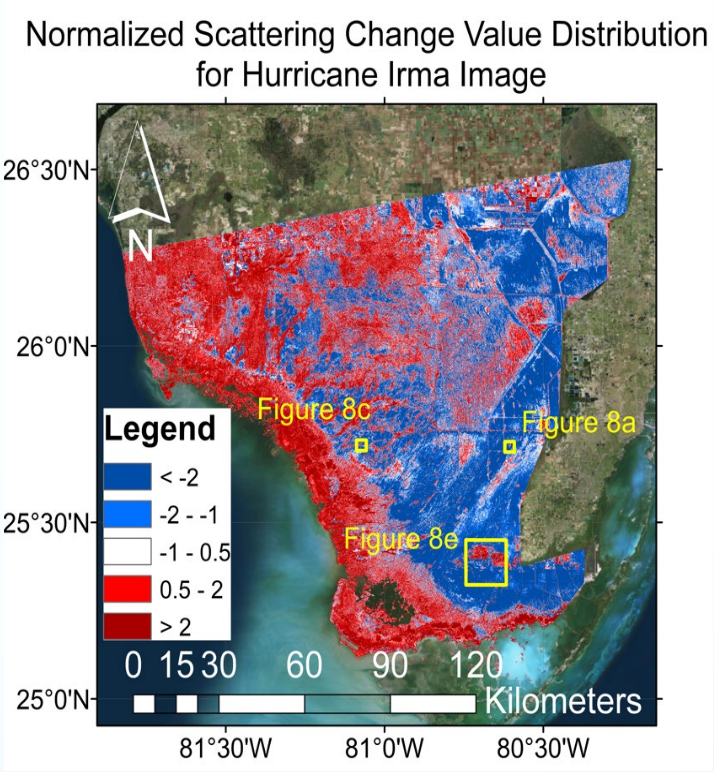


The model explains the observed relations between backscatter intensity and water level in terms of:

- Vegetation type
- Scattering mechanism

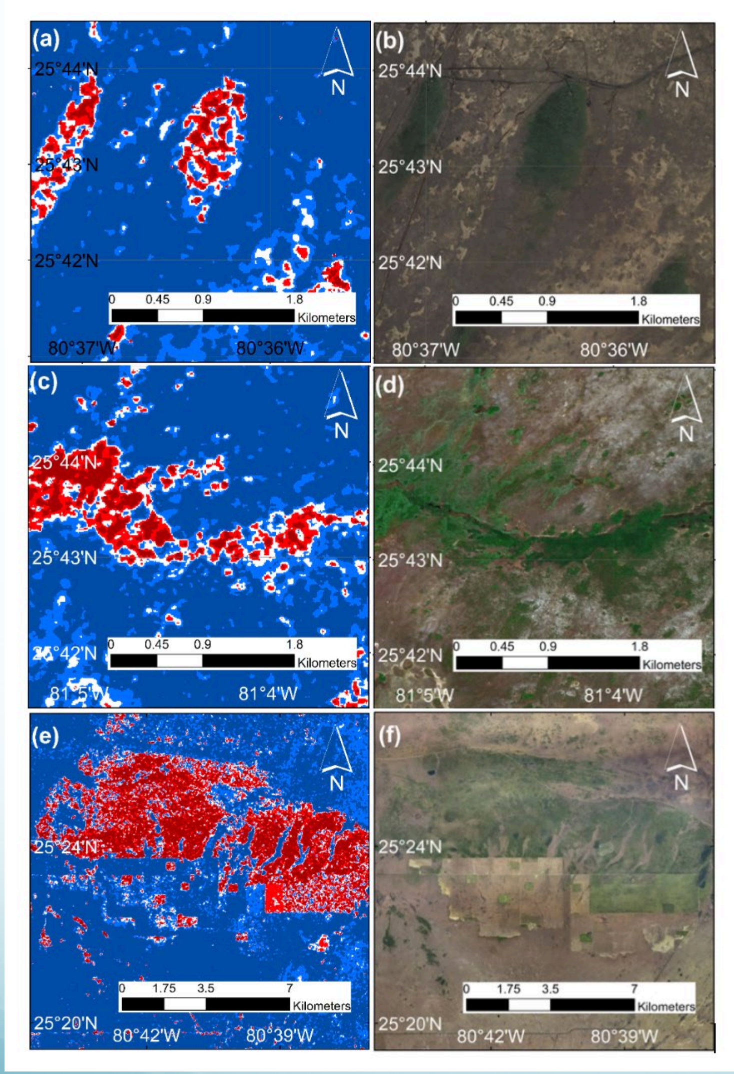
Flood detection analysis





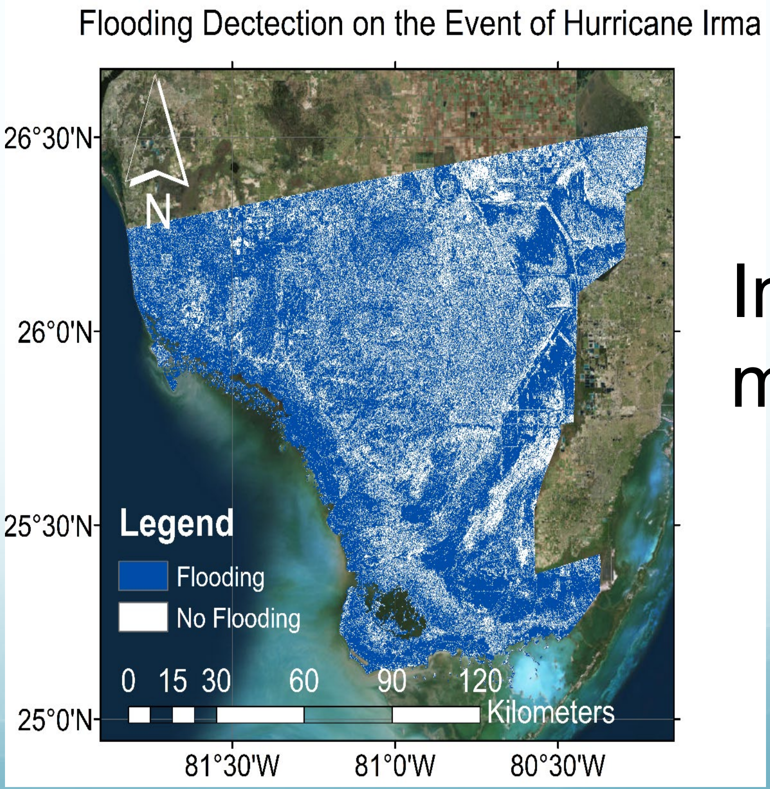
- Hurricane Irma (2017-09-10) caused severe damage in South Florida due to wind, rain and storm surge
- Change detection between SAR images acquired <u>during</u> and <u>before</u> the storm provides map of intensity change due to Irma's rain-induced flooding

Flood detection analysis



Flood conditions:

- Intensity increase (red) in woody vegetation
- Intensity decrease (Blue) in herbaceous vegetation.



Inundation map

Summary

- **SAR has two observables** – Amplitude (intensity) and phase. Both observables are **sensitive to hydrological conditions**
- **Sentinel-1** provides wide swath (250 km), frequent acquisitions (6-12 days), and high spatial resolution (10 m).
- **InSAR (phase)** detects water level changes throughout the Everglades
- **SAR (intensity)** detects (i) water levels, and (ii) inundation due to flooding events

Acknowledgements

- European Space Agency – **Sentienel-1 data**
- EDEN – **stage measurements**

Related presentations

- Boya (Paul) Zhang – Poster No. 18 (Tuesdays) ***Space-Based Monitoring of Temporal Water Level Variations in the South Florida Everglades Ecosystem Using Sentinel-1 SAR Observations***
- Heming Liao – Session 35 – 10:50 am - ***Space-based monitoring of water level changes in everglades with sentinel-1 InSAR observations***