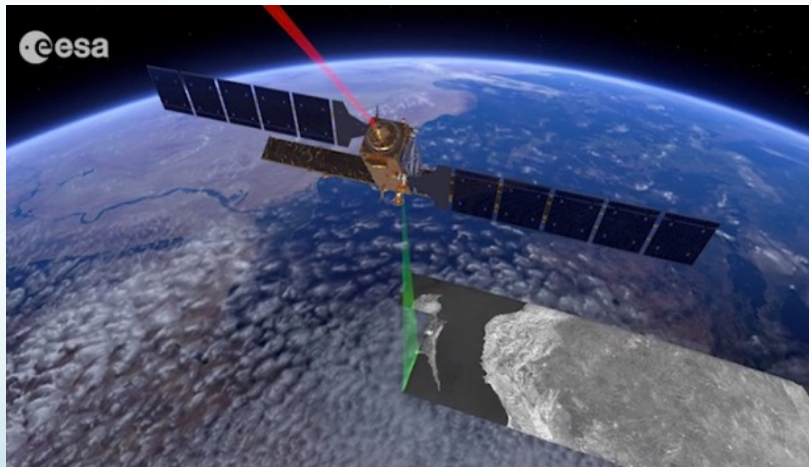
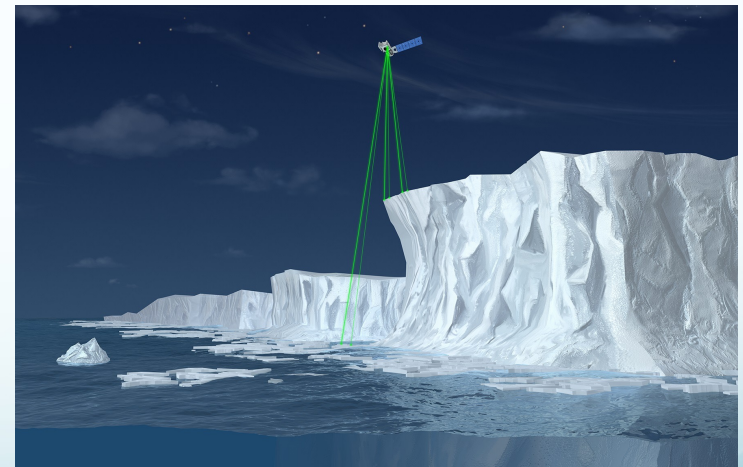


Developing a space-based multi-sensor monitoring system of surface water level changes in wetlands

Shimon Wdowinski, Heming Liao, Boya (Paul) Zhang
Florida International University



Sentinel-1 (ESA)

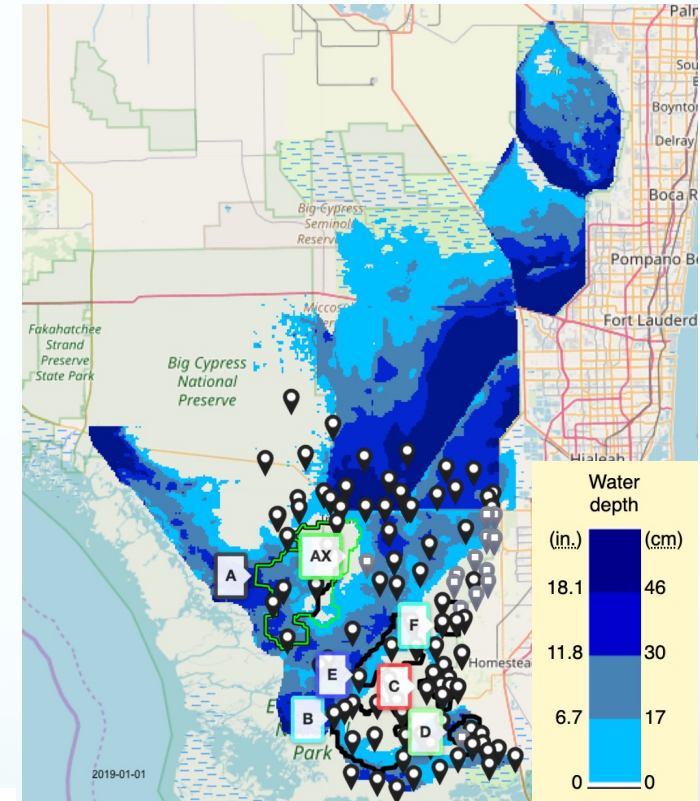
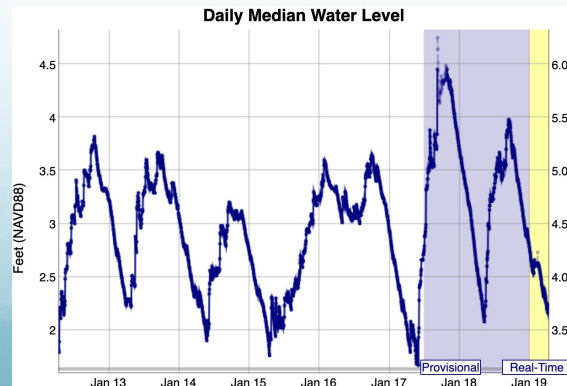
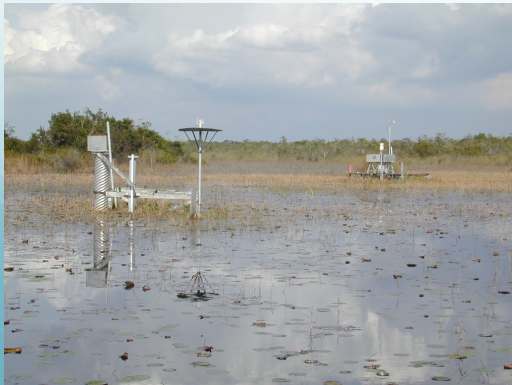


ICESAT-2 (NASA)

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



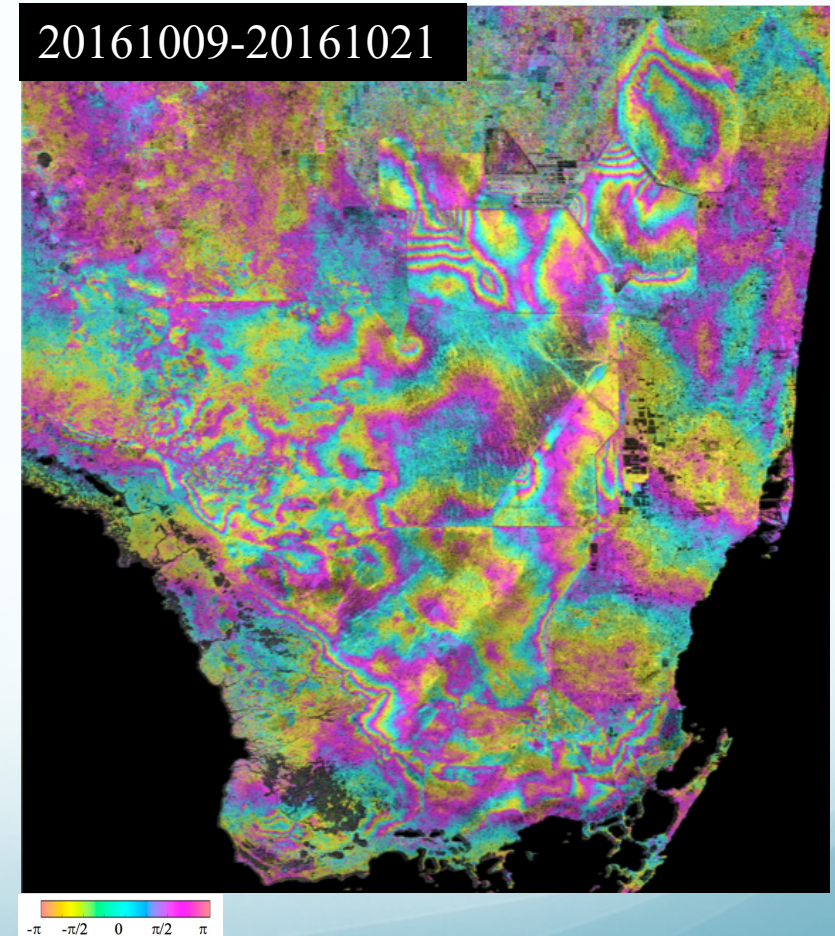
Source:

<https://sofia.usgs.gov/eden>

Space-based hydrological monitoring of the Everglades

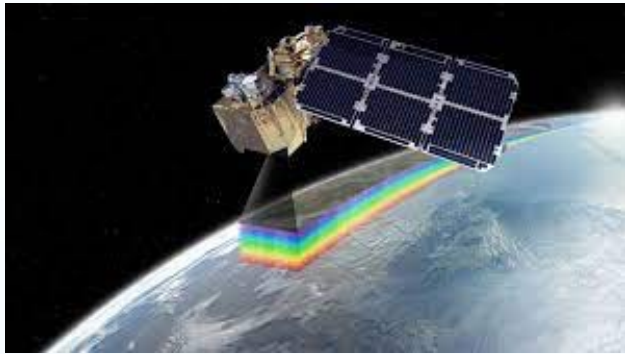
Wetland InSAR

- Measures water level changes between two acquisitions.
- Advantages
 - Works in all weather and illumination conditions.
 - High spatial resolution
 - Wide coverage
- Disadvantages
 - Relative measurements in space and time
 - Requires calibration

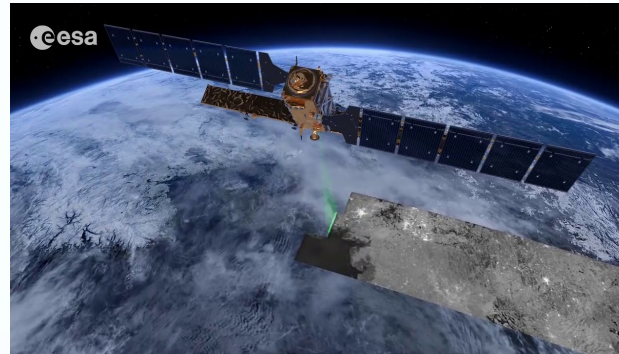


Space-based hydrological monitoring technologies

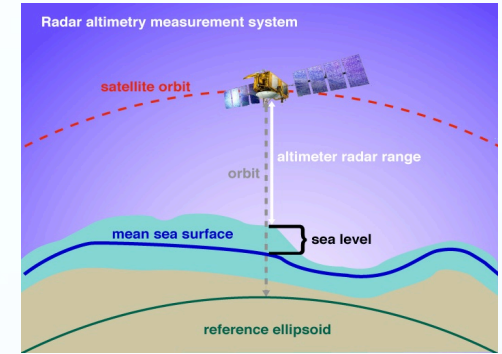
Optical



SAR (Radar)



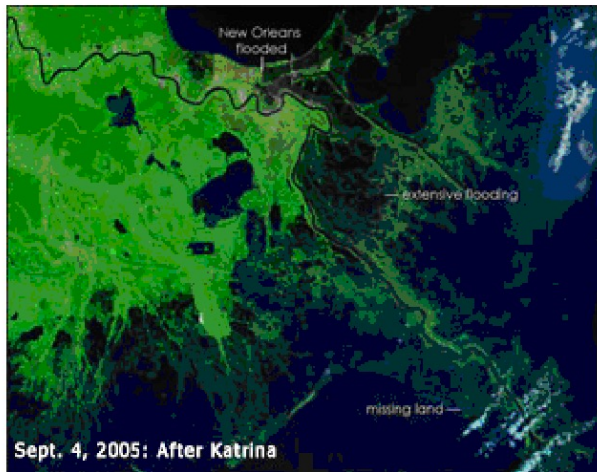
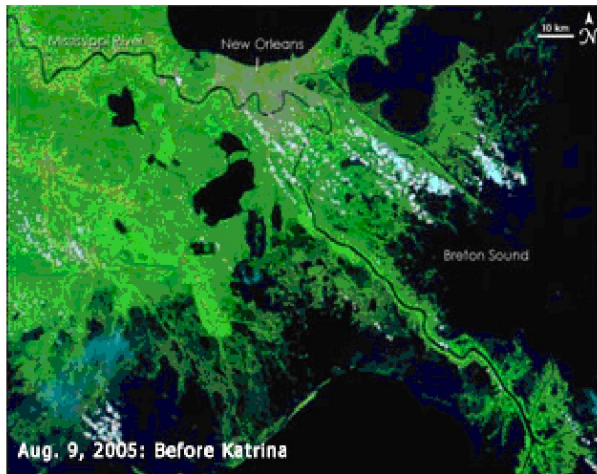
Altimetry



Technology	Mission name	Sensor type	Agency	Time
Optical	Landsat-8	Multi-spectral	NASA/USGS	2013-present
	Sentinel-2	Multi-spectral	ESA	2015-present
SAR	Sentinel-1	C-band	ESA	2014-present
	CRM	C-band	CSA	2018-present
	NISAR	L- and S-bands	NASA/ISRO	Launch date: 2022
Altimetry	ICESat-2	Laser Altimeter	NASA	2018-present
	Sentinel-3	Radar interferometer	ESA	2016-present
	GEDI	Laser Altimeter	NASA	2018-present
	SWOT	Radar interferometer	NASA/CNES	Launch date: 2022

Hydrological monitoring with optical imagery

Before and After Katrina, 2005

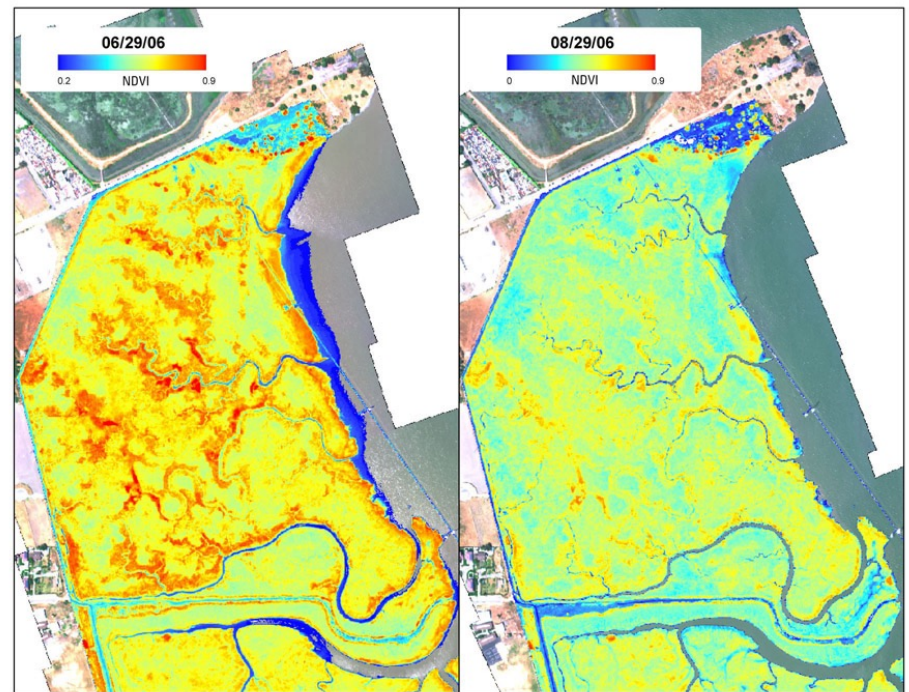


Zaffos 2008

[Renne et al., 2009]

Applications

- Directly - Inundation extent
- Indirect - Impact on vegetation using NDVI



[Credit: Ocean imaging]

Hydrological monitoring with SAR

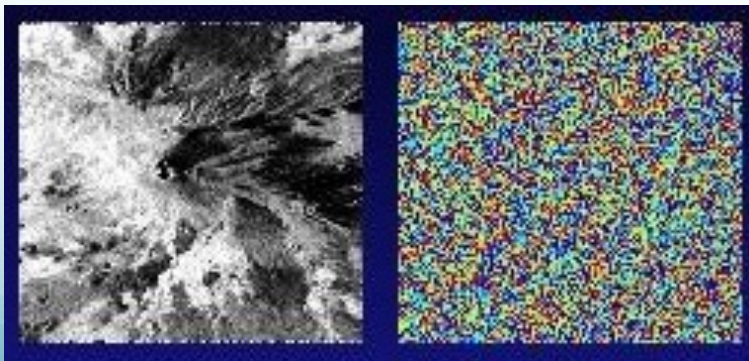
Sentinel-1A (ESA)



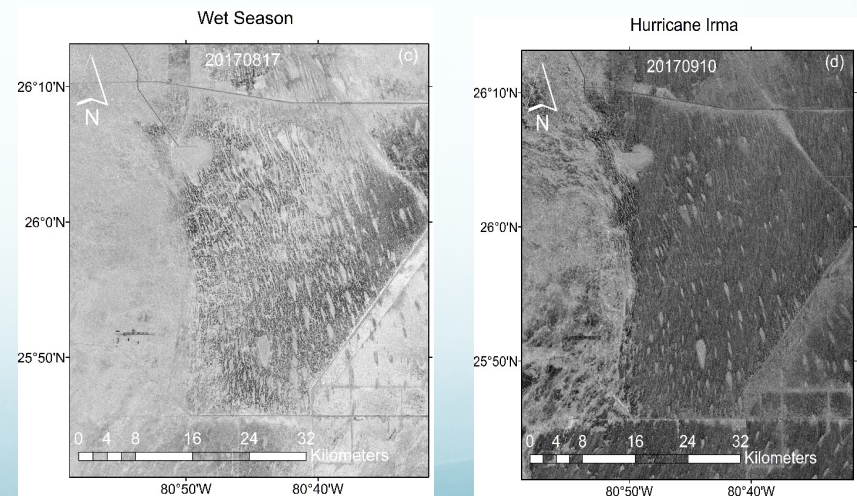
Co-polarization SAR Scattering Mechanisms

Vegetation	No Inundation	Shallow Water	Deep Water	Linear relation between σ_0 and d_w
Woody (RS ⁺)	(a) Ss Weak Db	(b) Ss Moderate Db	(c) Ss Enhanced Db	(d) Yuan et al., 2015 L-HH σ_0 vs d_w
Dense herbaceous (RS ⁺)	(e) Strong Ss Weak Db	(f) Moderate Ss Enhanced Db	(g) Weak Ss Weak Db	(h) Yuan et al., 2015 L-HH σ_0 vs d_w
Sparse herbaceous (RS ⁺)	(i) Strong Ss	(j) Moderate Ss	(k) Weak Ss	(l) Kasischke et al., 2003 C-VV, J.-W. Kim et al., 2014 L-HH σ_0 vs d_w

SAR observables

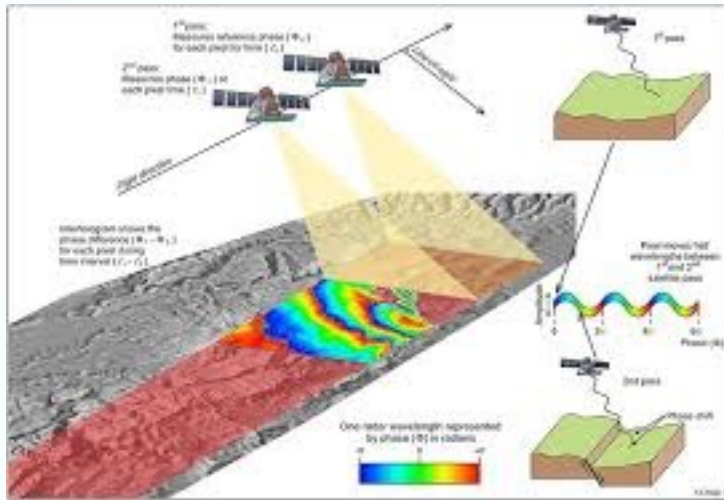


Amplitude Phase



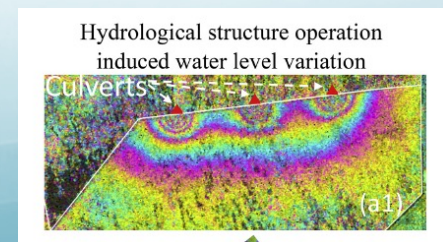
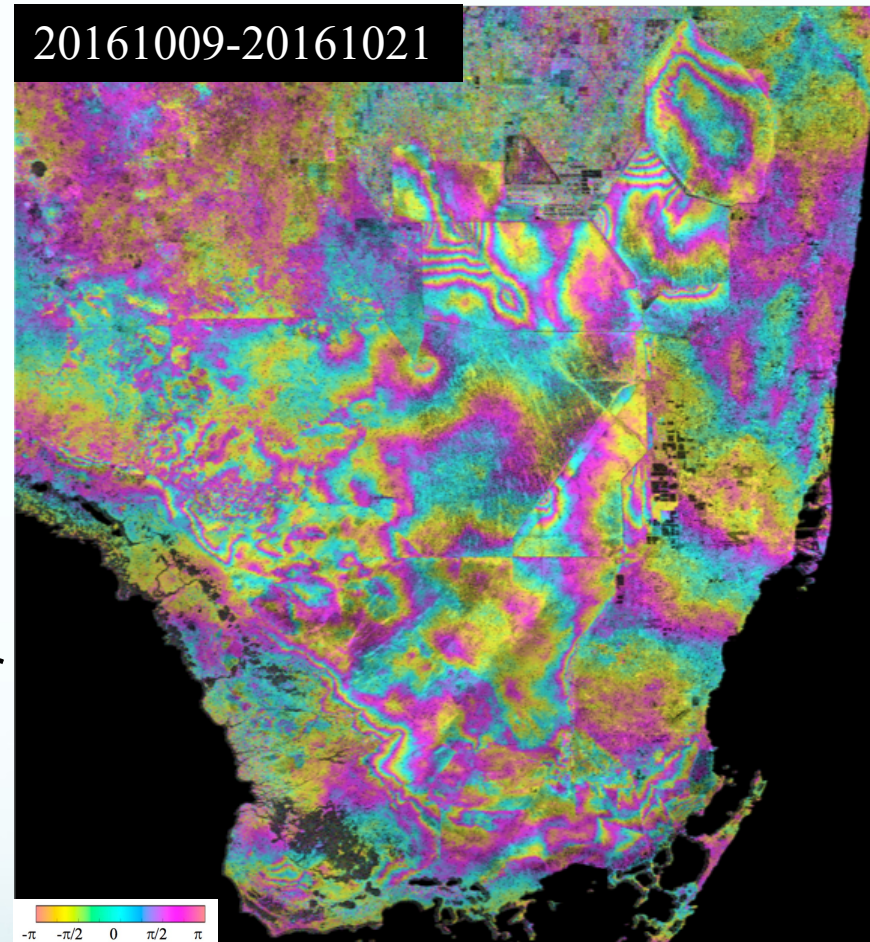
Amplitude changes in the Everglades

Hydrological monitoring with InSAR



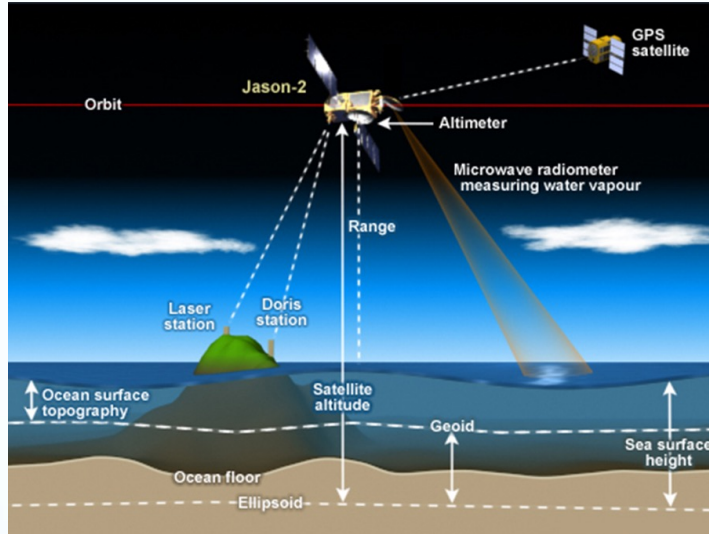
Main characteristics

- 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)



Hydrological monitoring with Altimetry

How does it work?

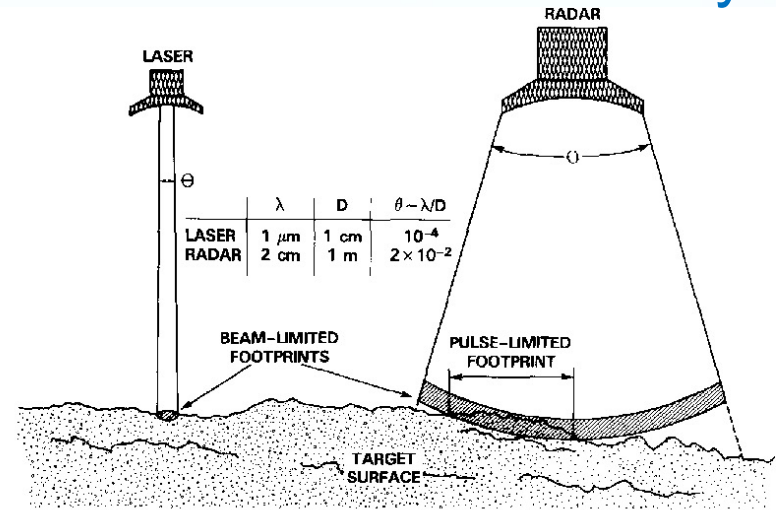


Radar Altimetry



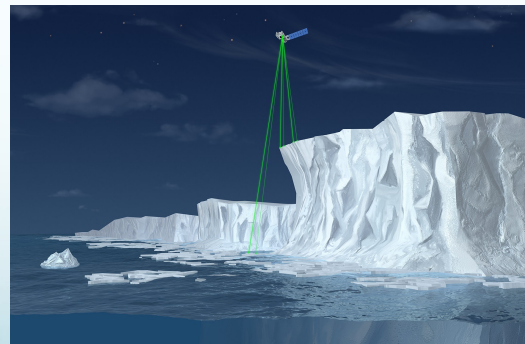
Sentinel-3 (ESA)

Laser vs. Radar Altimetry



laser and radar altimetry.

Laser Altimetry



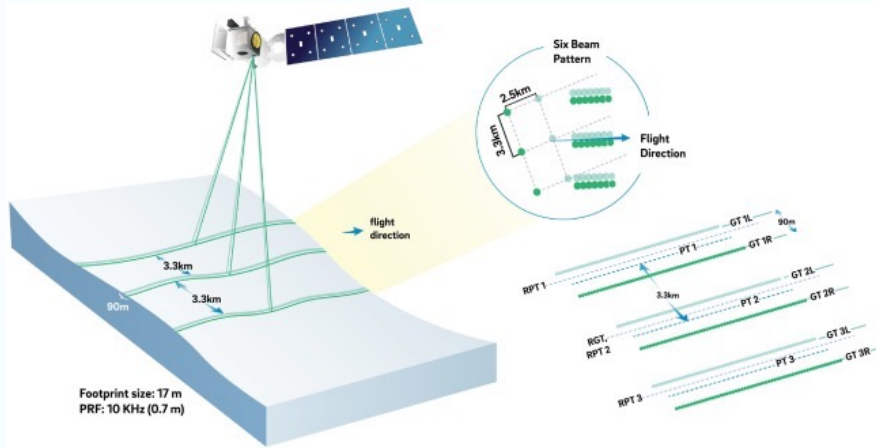
ICESAT-2 (NASA)



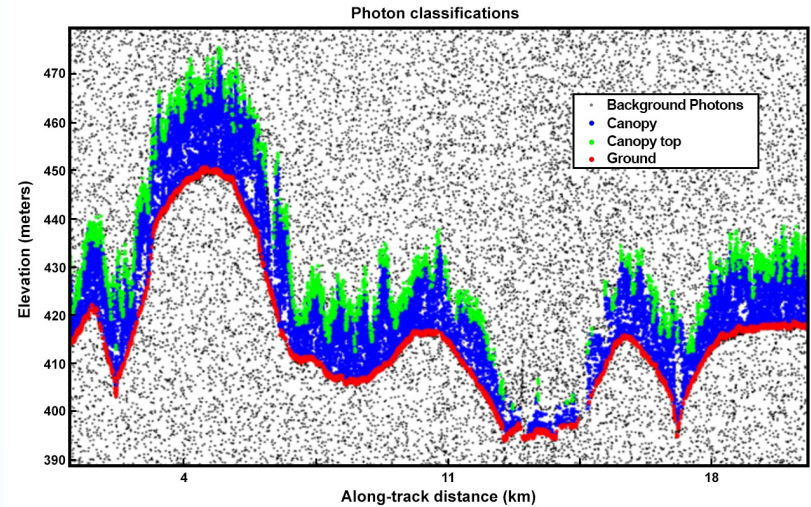
GEDI (NASA)
Laser operated from the ISS

Preliminary results – ICESAT-2

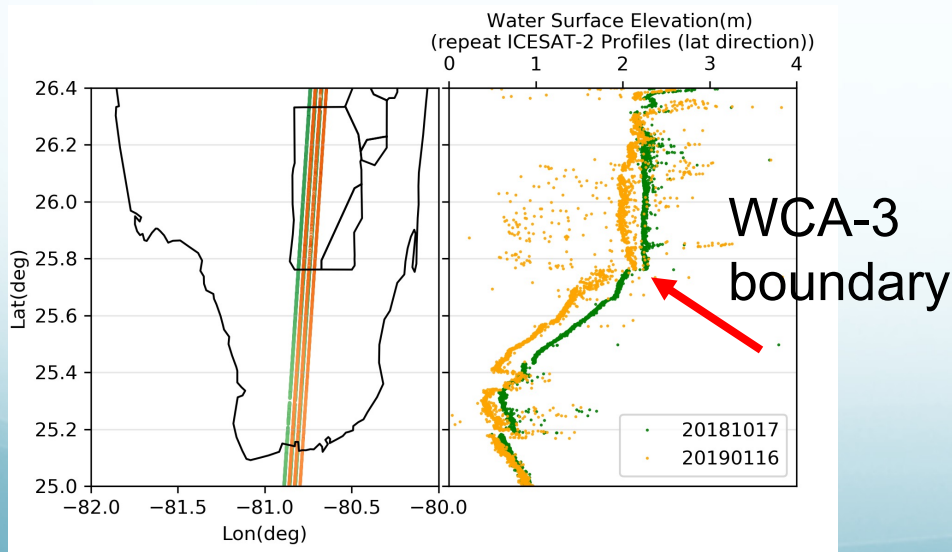
How does it work?



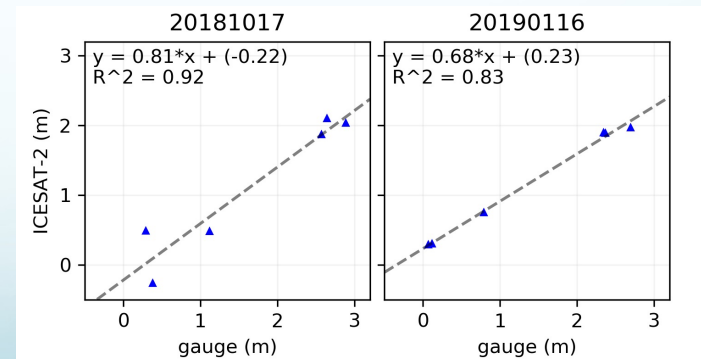
(Credit: NASA)



(Magruder et al, 2019)



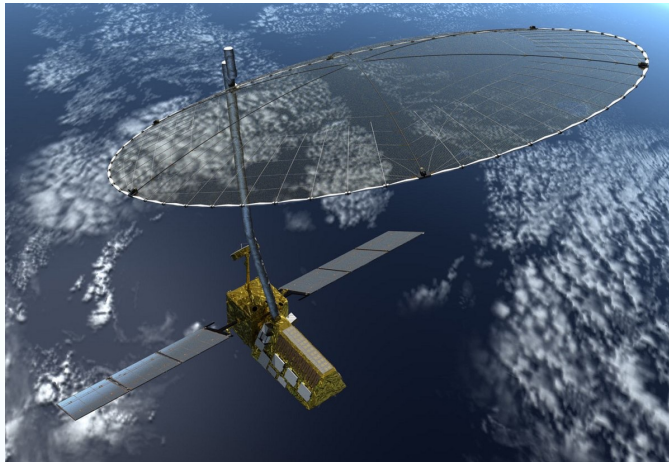
Along track elevation change



Comparison with stage observations

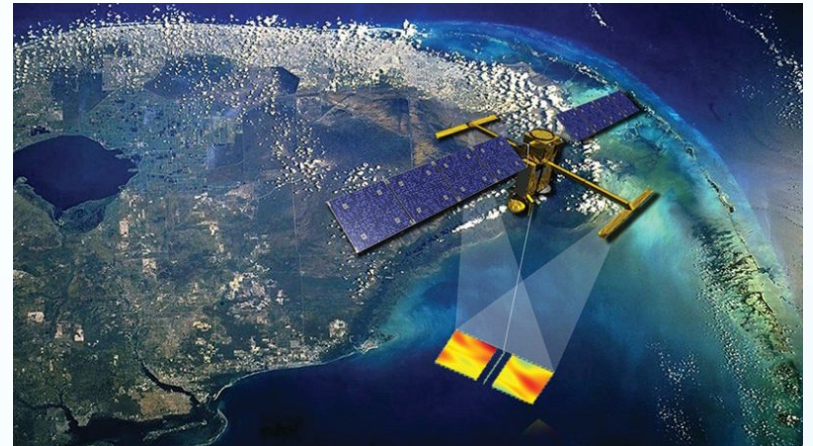
Future mission

NISAR



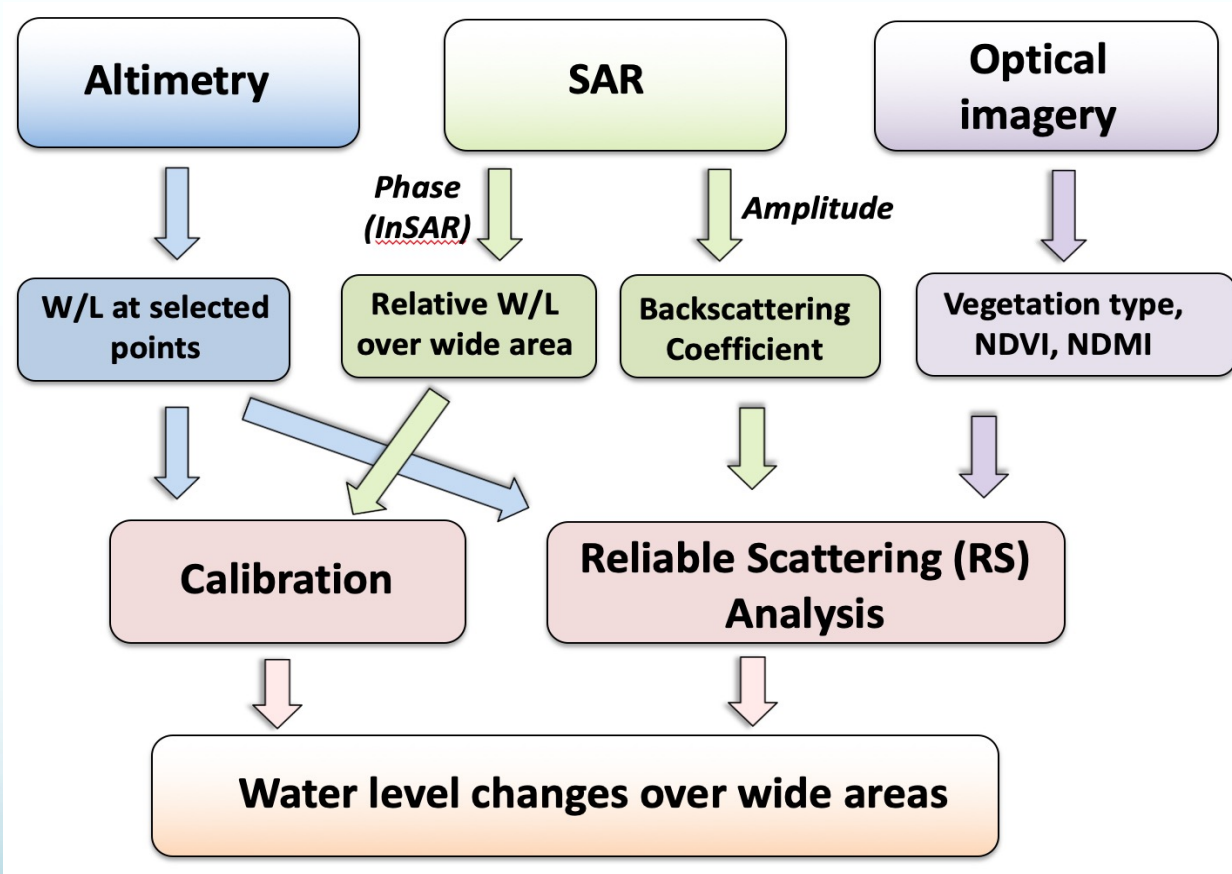
NASA-ISRO-SAR
L+S band SAR mission
Scheduled launch: 05/2022

SWOT

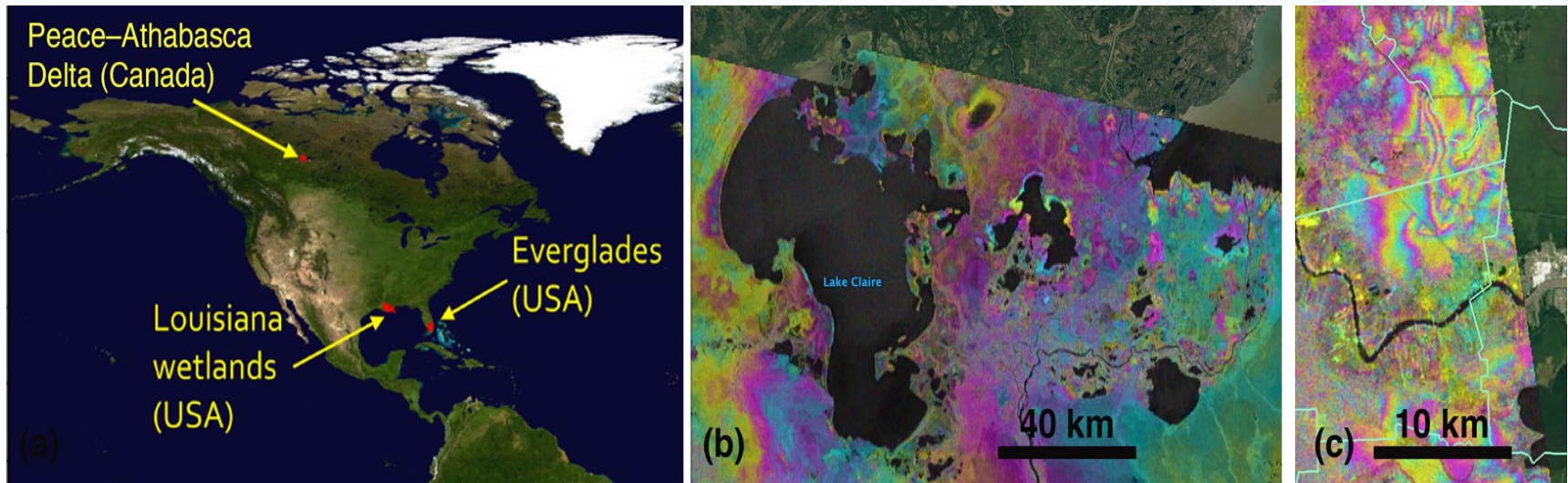


Surface Water Ocean Topography
Ka-band Radar Interferometer
Scheduled launch: 03/2022

A space-based multi-sensor monitoring system



Future research



- Develop the multi-sensor monitoring system over the Everglades (large scale laboratory).
- Apply the multi-sensor monitoring system to two study areas:
 - Louisiana wetlands – Coastal and inland marshes and swamps (some similarity to the Everglades)
 - Peace–Athabasca Delta (Alberta, Canada) - Northern climate wetlands: covered by boreal forest and shrublands in areas of wet marsh soils.

Summary

- Existing and New space technologies provide new tools for monitoring wetland surface water changes
 - Optical
 - SAR
 - Altimetry
- This NASA supported project aims at developing a multi-sensor system that will integrate observations obtained by the different technologies
- The multi-sensor system will be developed over the Everglades and will be expanded to other wetlands.

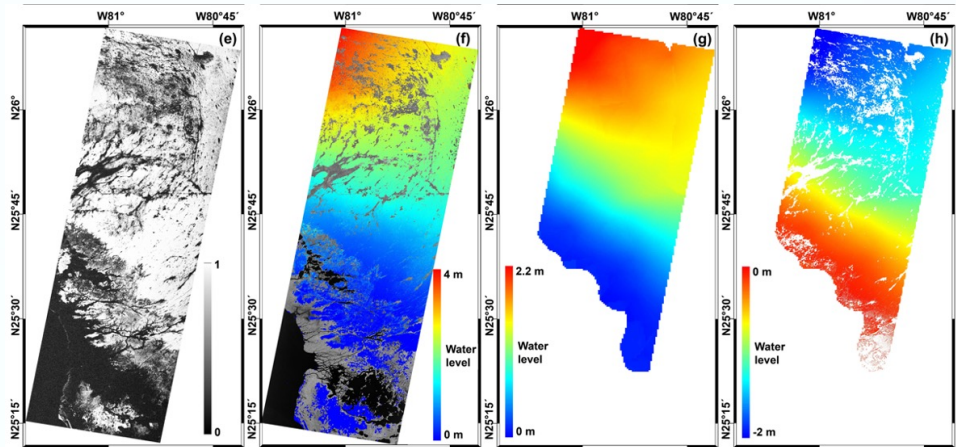
Acknowledgements

- NASA – **Support**
- NASA – **ICESAT-2 data**
- European Space Agency – **Sentinel-1 data**
- EDEN – **stage measurements**

Hydrological monitoring with TanDEM-X

TanDEM-X (DLR)

Water level maps

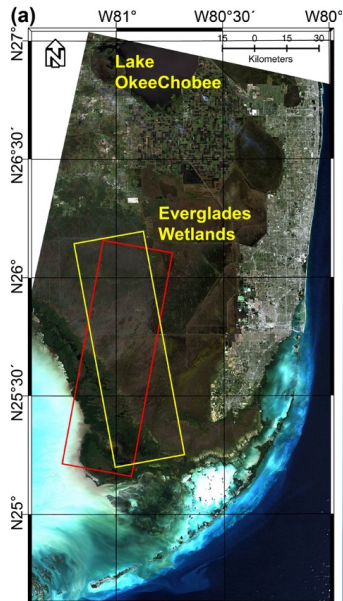


SAR

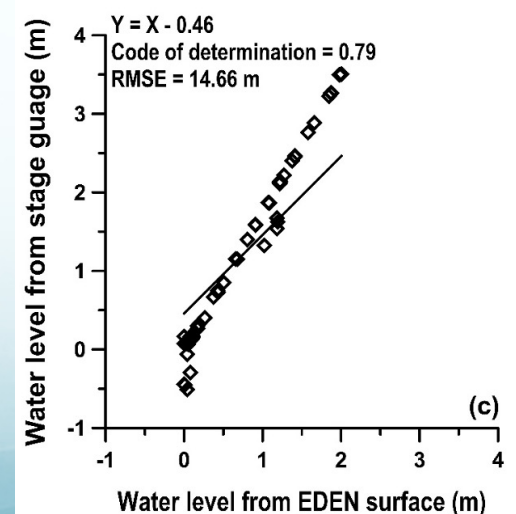
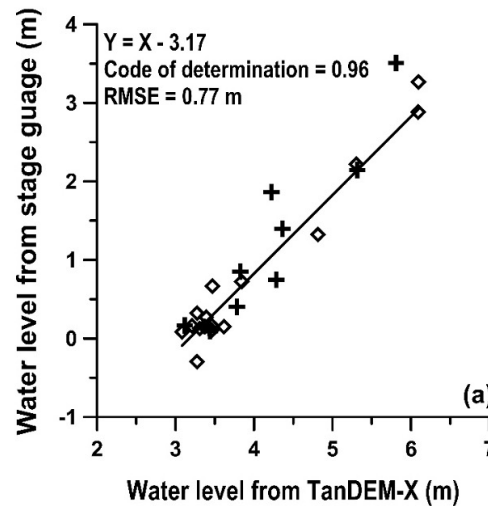
TanDEM-X

TDX-smooth

EDEN



Everglades
Study area



Comparison with stage observations