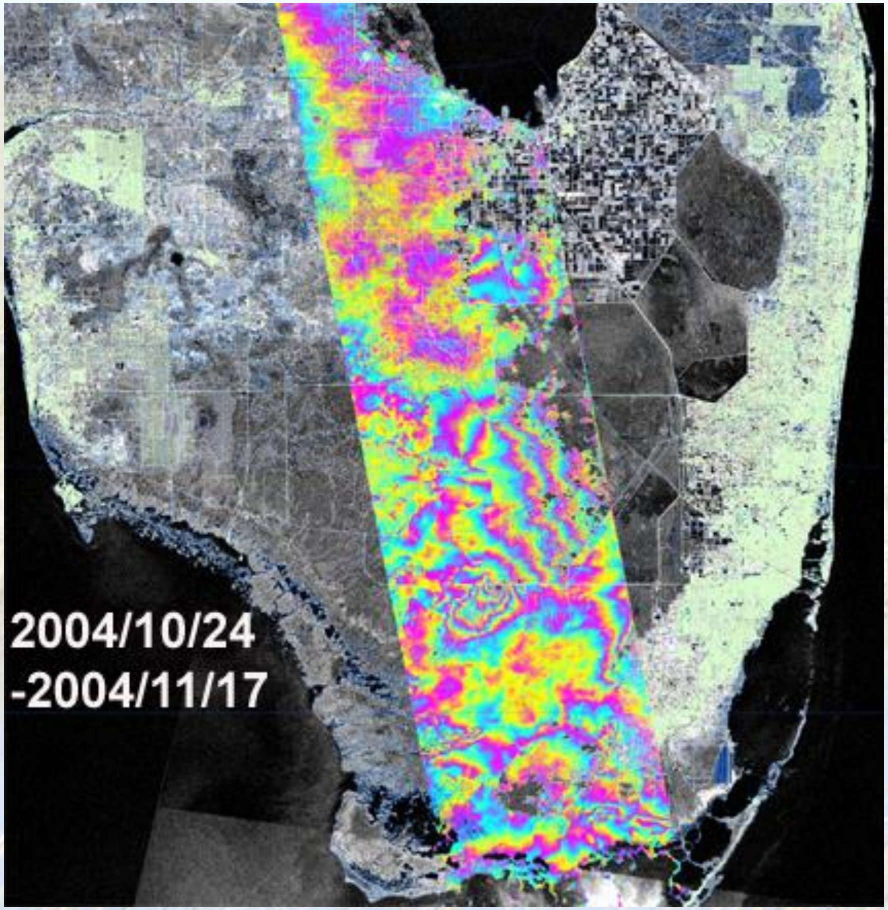
Suitability of the new generation of SAR satellites to the wetland InSAR application

Shimon Wdowinski[1], San-Hoon Hong[2], Brian Brisco[3]

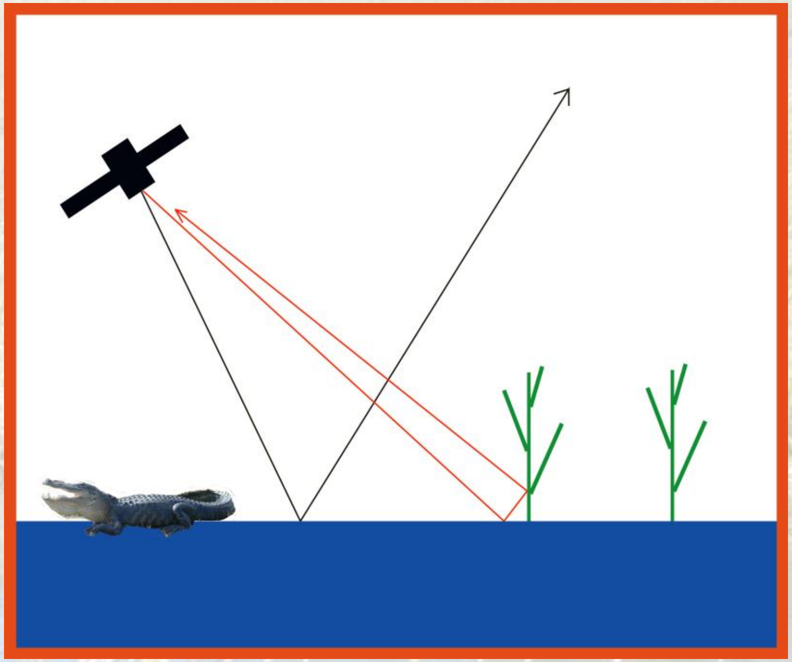
1. **University of Miami**
2. **Korea Aerospace Research Institute**
3. **Canada Centre for Remote Sensing**

- Wetland InSAR
- The new generation of SAR satellites
- New observations
- Summary & acknowledgements

Wetland InSAR

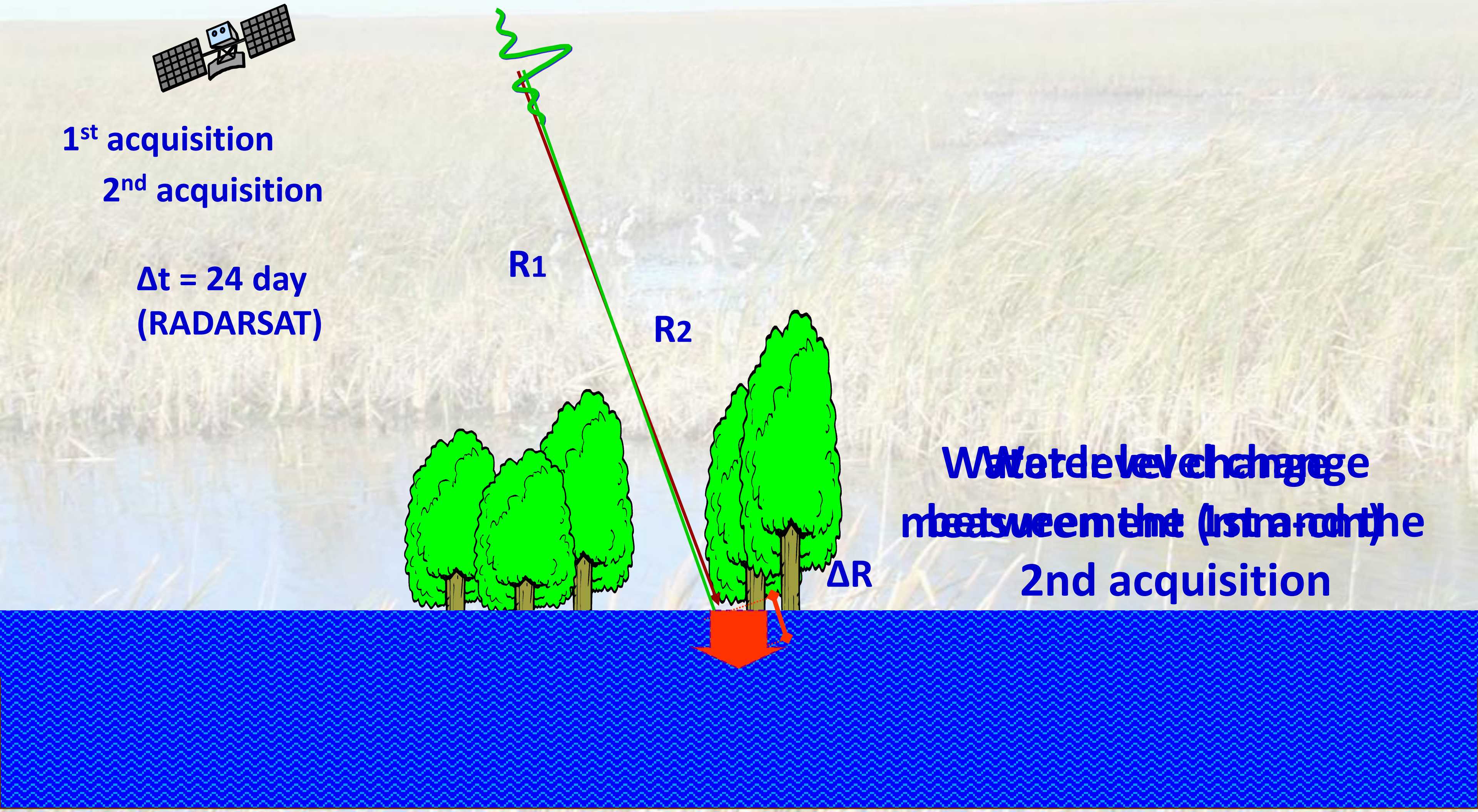


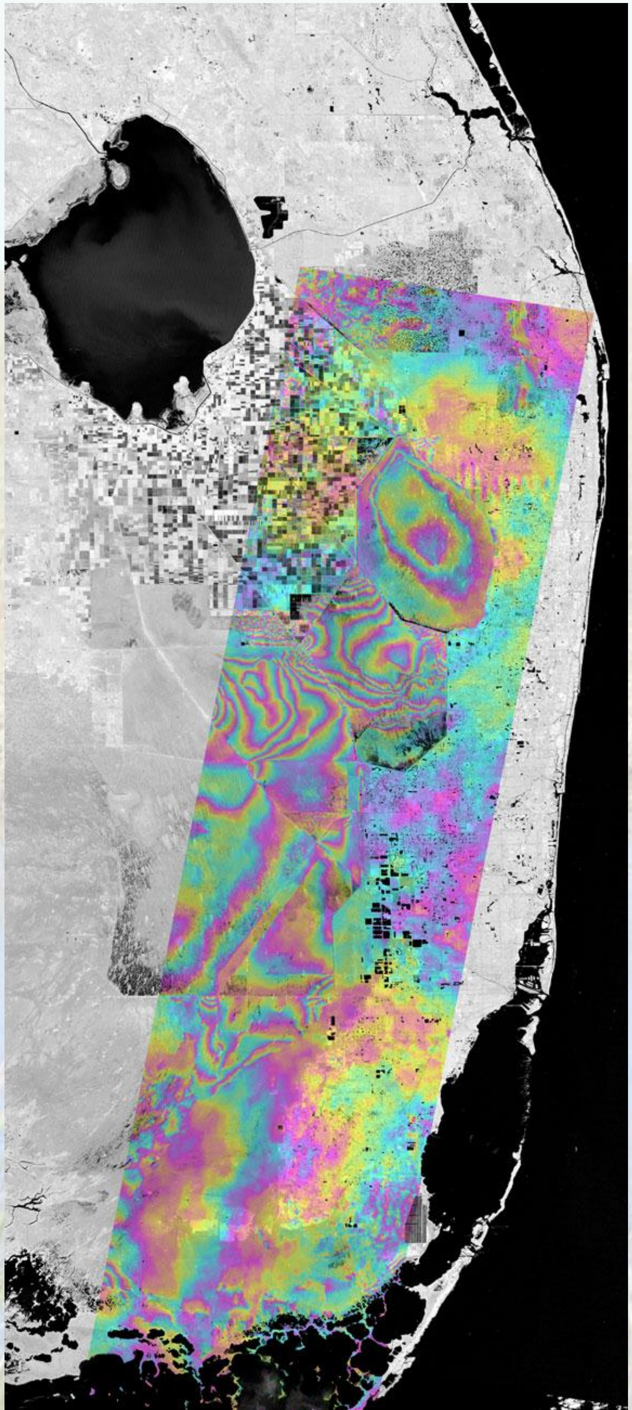
Double bounce effect



Using InSAR observations to detect surface water level changes in wetlands

Water level change measurements



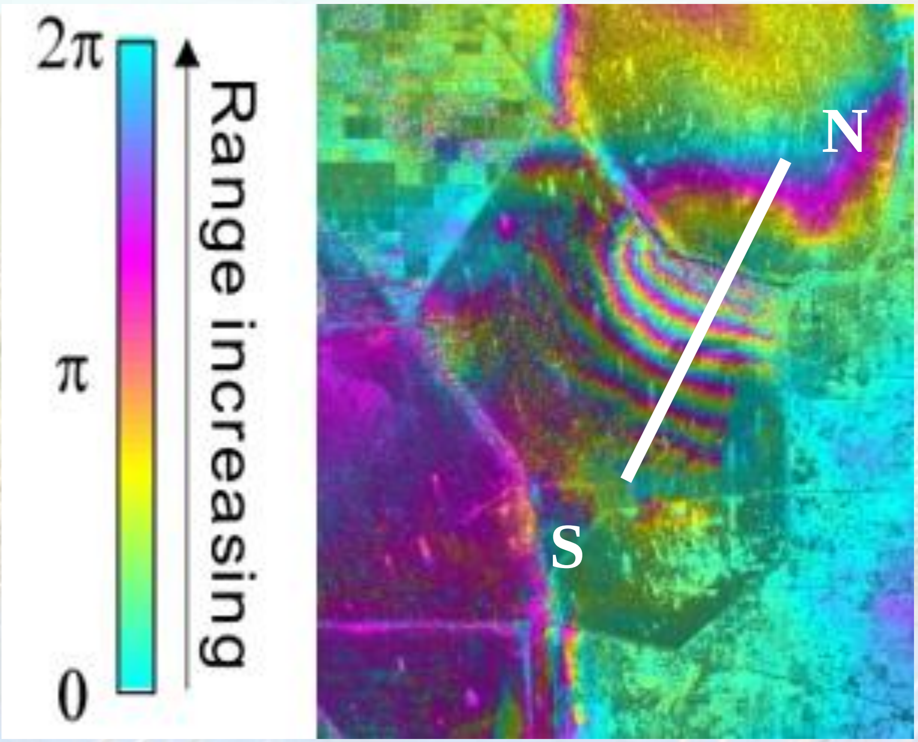


Interferograms

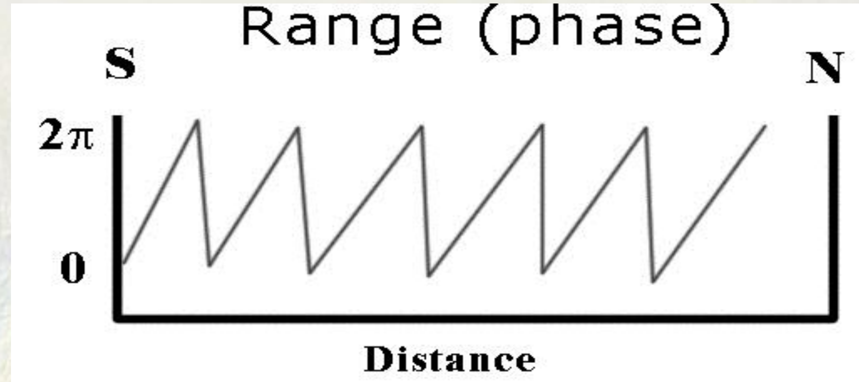
Interferogram shows phase change information in the range 0-2π.

Translation of phase information (interferogram) to water level change map requires:
1. phase unwrapping.
2. calibration with stage data.

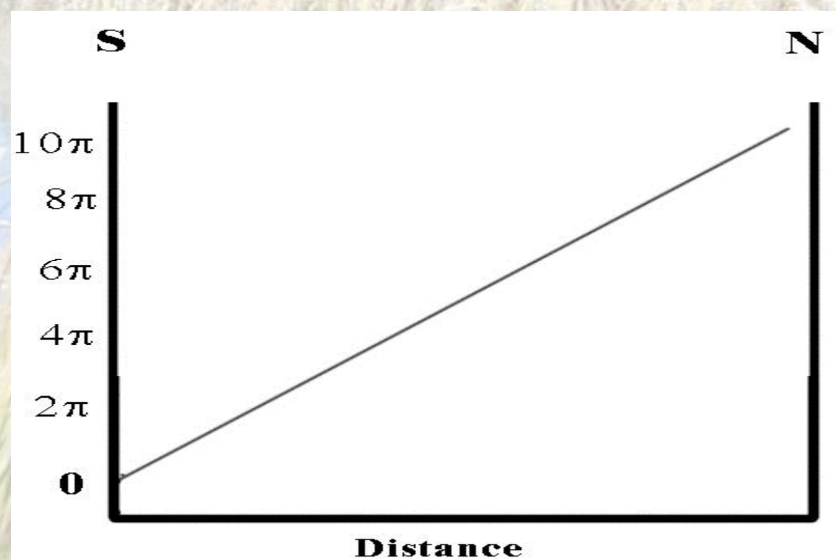
Phase unwrapping



Wrapped phase



Unwrapped phase



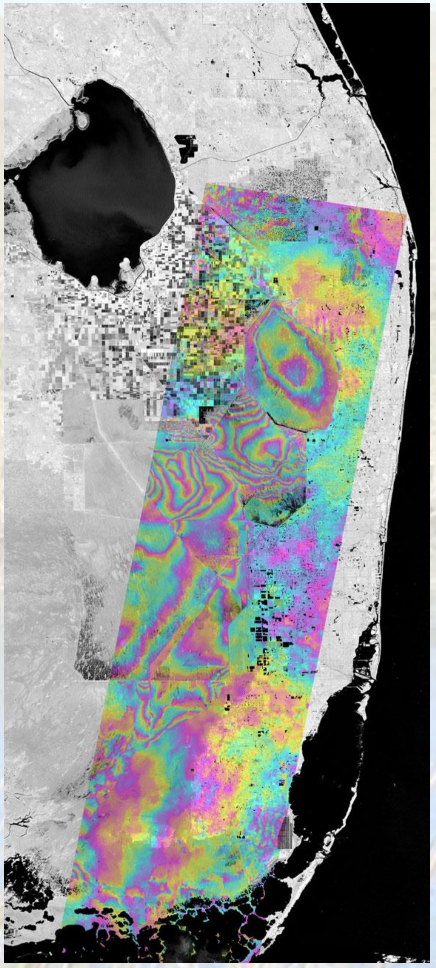
InSAR measures phase change along the line-of-sight (LOS) between the satellite and the surface.

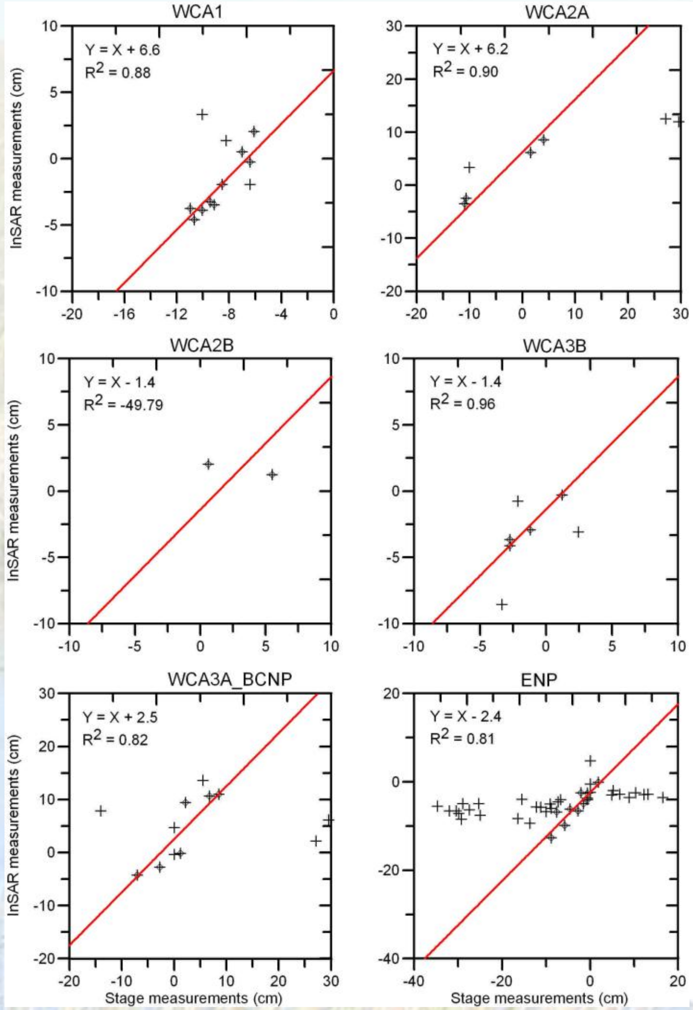
Water level changes

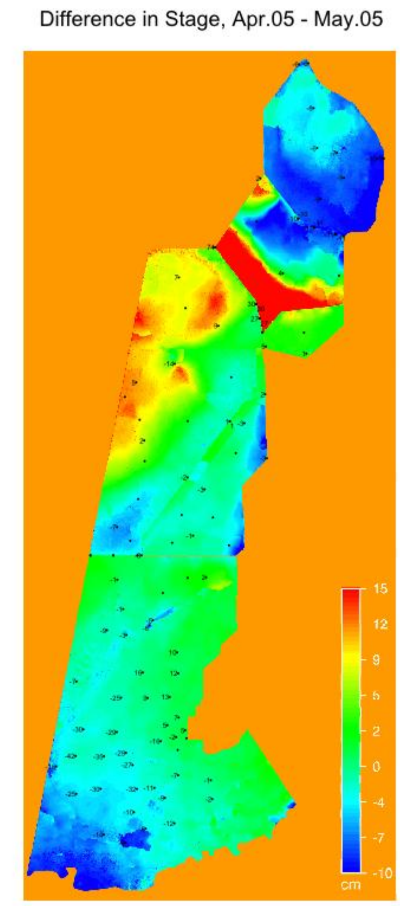
Interferogram

Calibration with stage data

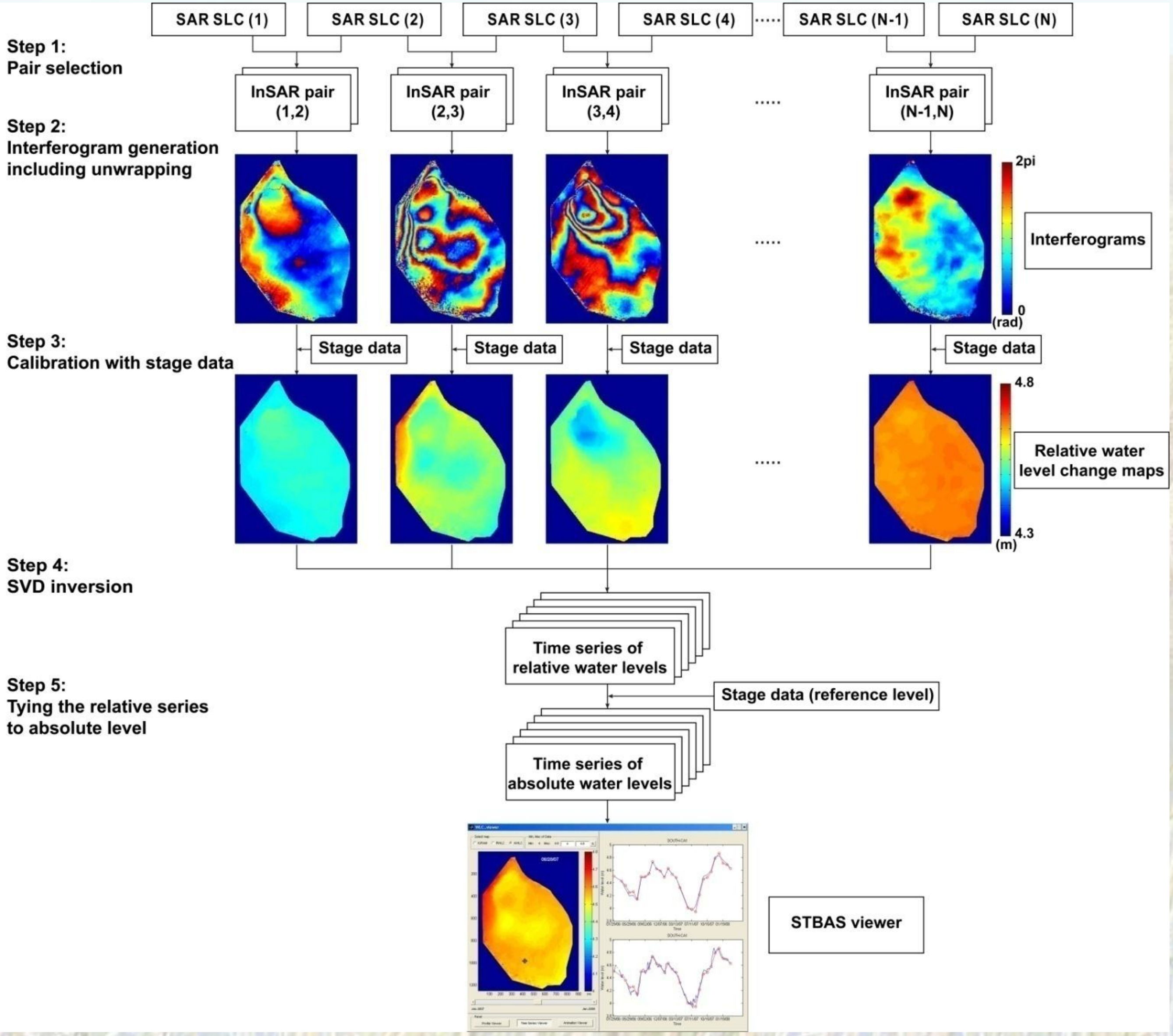
Change maps



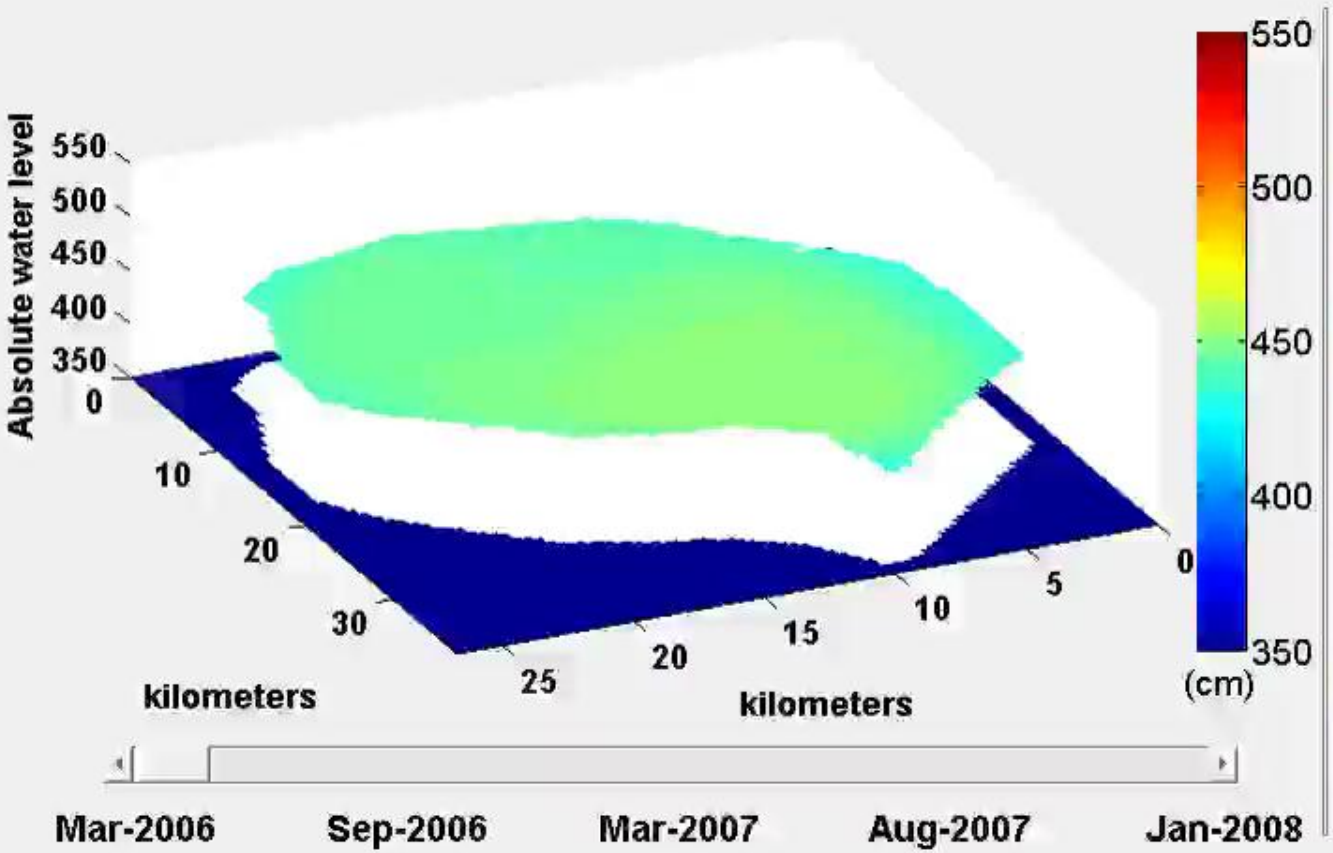


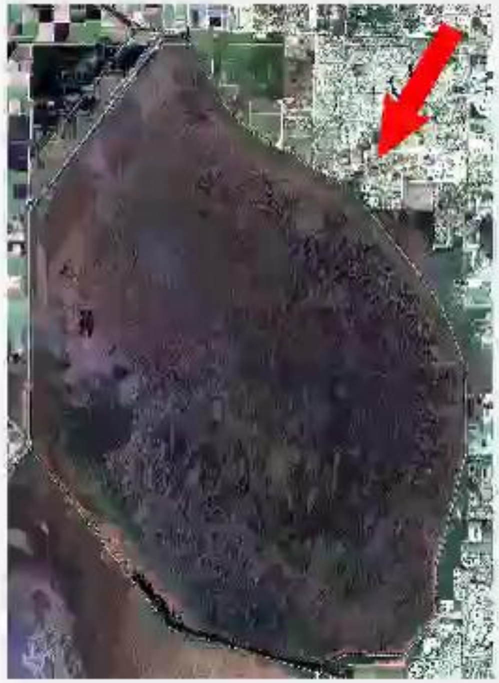


InSAR time series (STBAS)



Time series of water levels





SAR satellites

First generation (1990 - 2005):

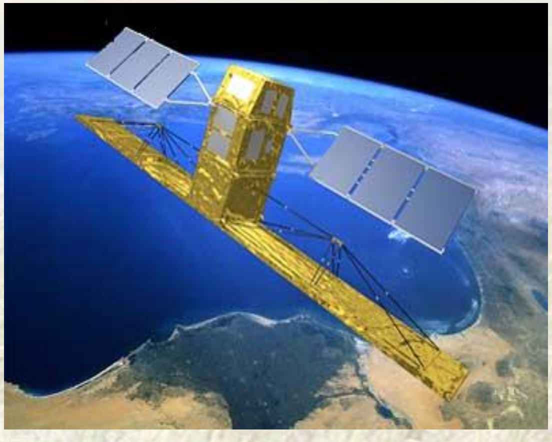
- (SEASAT - 1979)
- ERS-1/2
- JERS-1
- RADARSAT-1
- ENVISAT

Second generation (2005 – present):

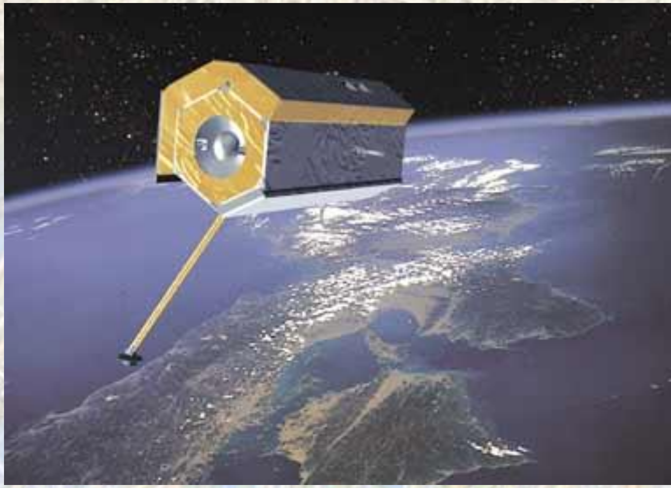
- ALOS/PALSAR
- TERRASAR-X/TANDEM-X
- CosmoSky-Med (4 satellites)
- RADARSAT-2

Planned missions:

- Sentinel-1
- ALOS-2
- Canadian Radarsat Mission
- DESDynI



RADARSAT-1



TerraSAR-X

SAR acquisition parameters

Sensor type (Radar wavelength):

- L-band (24 cm)
- C-band (5.6 cm)
- X-band (3.1 cm)

Polarization:

- Single: HH, VV
- Dual: HH+HV, VV+HV, HH+VV
- Quad: HH+VV+HV+VH
- Compact Polarimetry:
  - Circular transmission, linear reception

Spatial resolution & swath width:

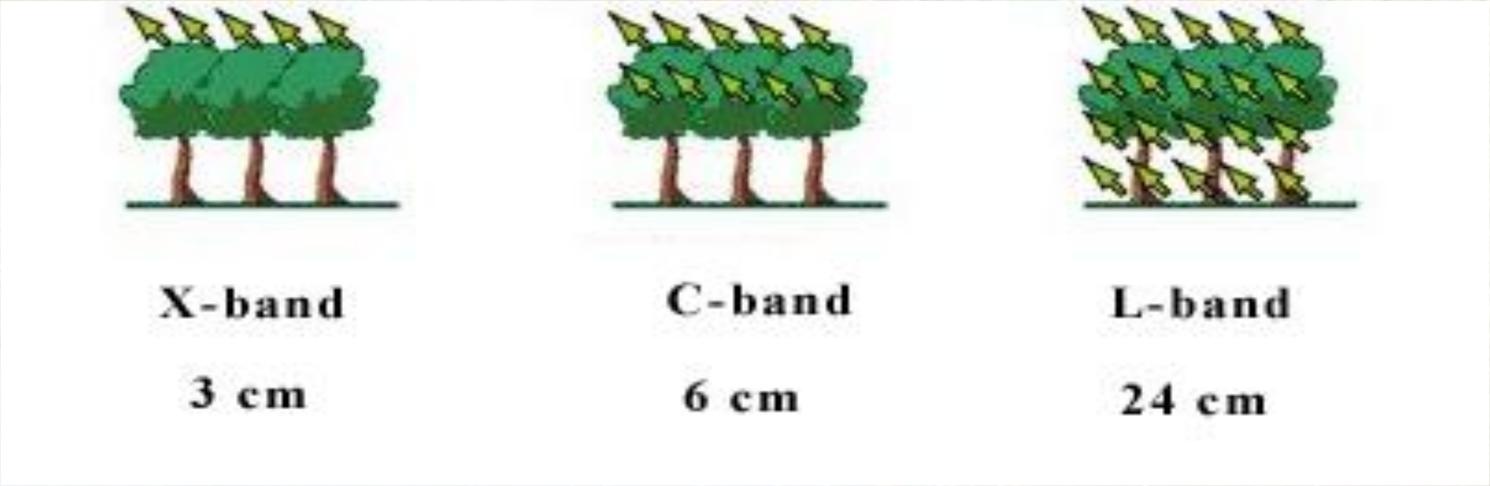
- Scan SAR: 20-50 m – 100-200 km
- Standard: 10-20 m – 30-100 km
- Fine/ultra: 1-5 m – 10-30 km
- Spotlight: sub-meter – 5 km

Temporal resolution:

- 11, 24, 35, 46 days; Constellation – 1, 7, 8, 16 days

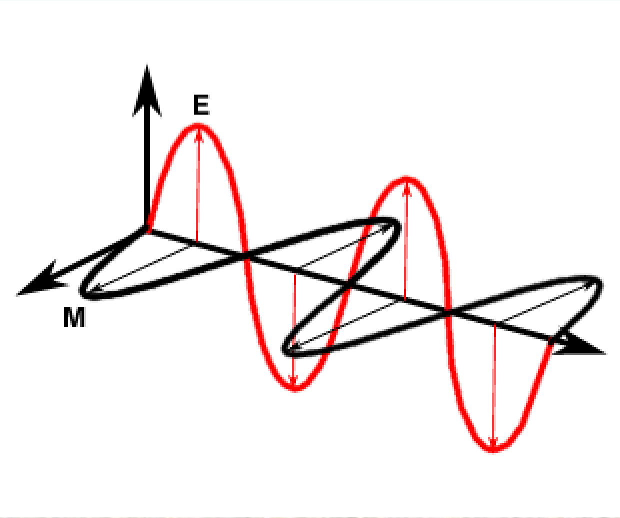
SAR sensor and vegetation

Short wavelength radar signal interacts more with vegetation and tends to back-scatter from tree canopies

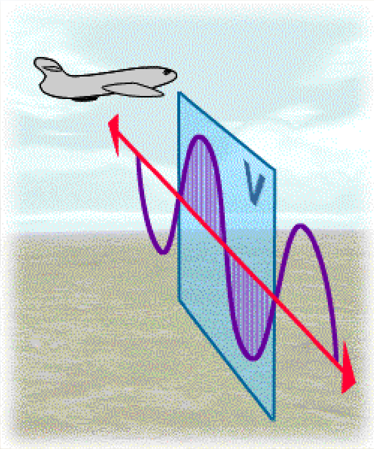


- L-band data is most suitable for wetland InSAR.
- C-band also works fairly well, especially with HH polarization and short temporal baseline.
- X-band – Surprisingly also works very well.

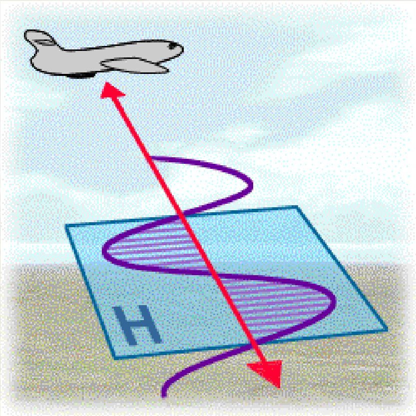
SAR Polarization



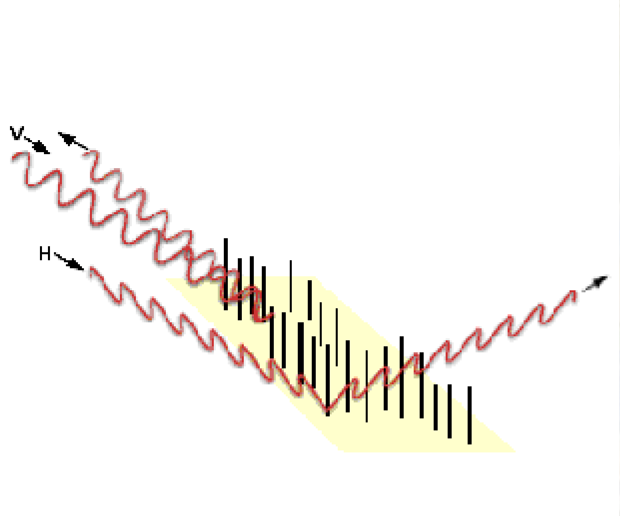
Electromagnetic wave



VV-Polarization

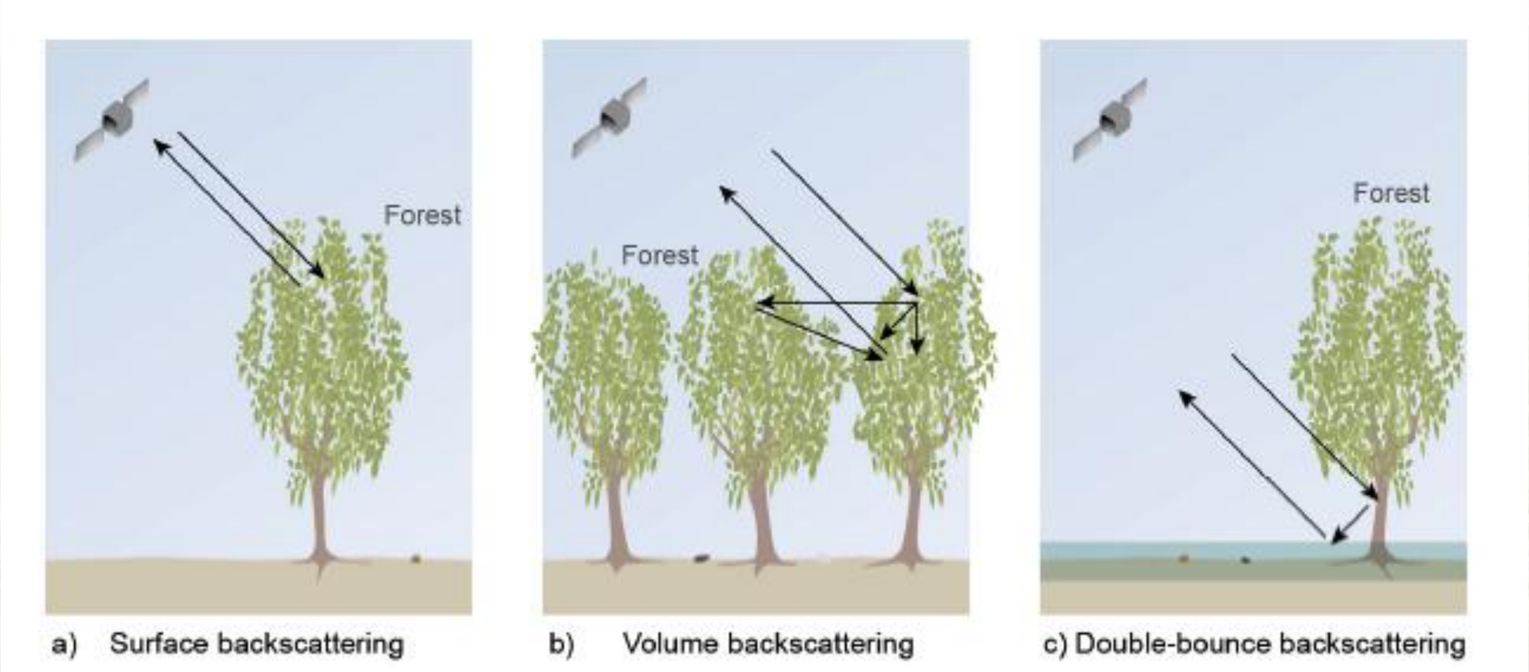


HH-Polarization



V-polarized wave is backscattered by vertical dipoles. The H-polarized wave is scattered away.

SAR vegetation scattering theory



Gondwe (2010)

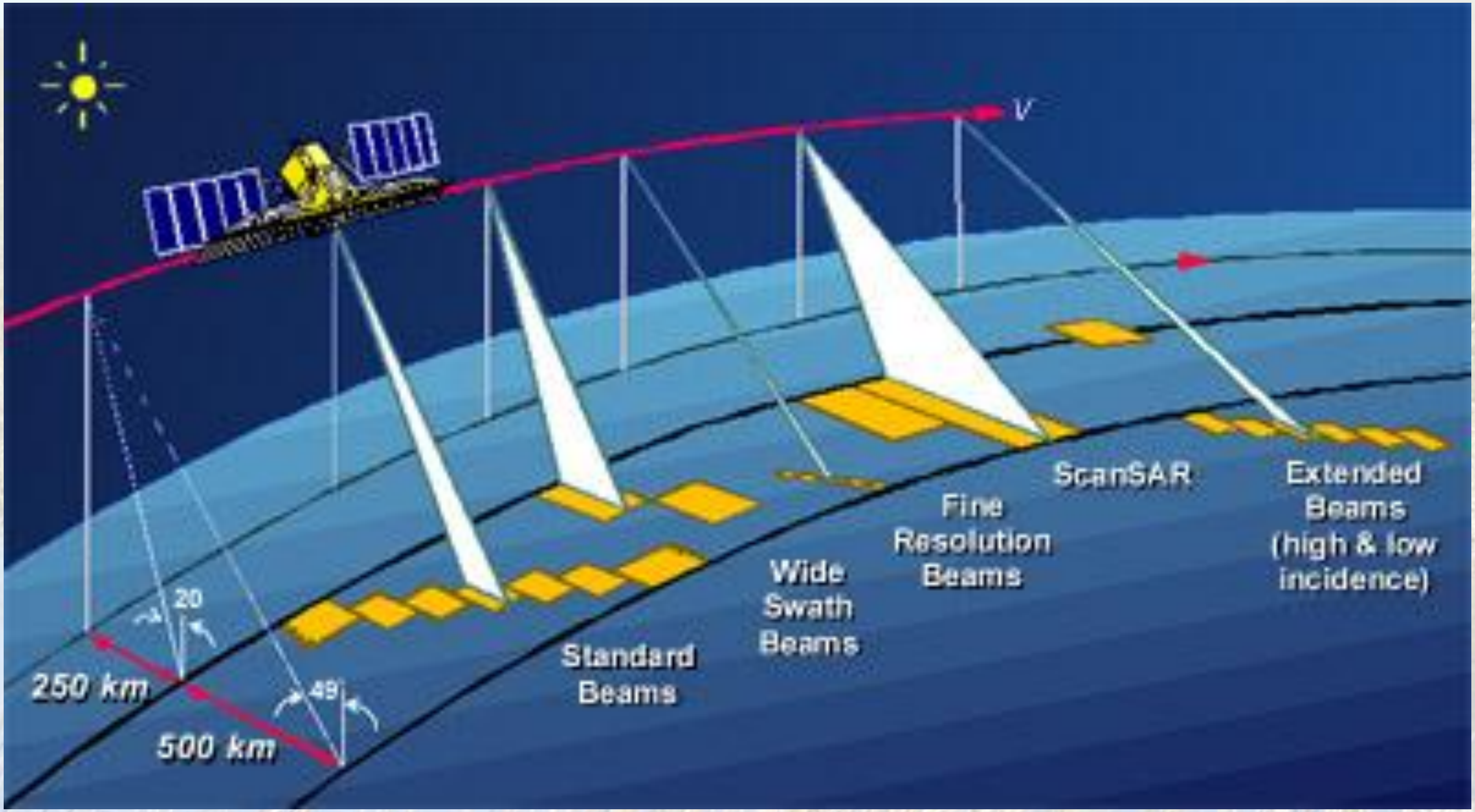
<u>Current assumption:</u>

Double bounce = HH-VV

Single bounce = HH+VV

Volume scattering = HV

Spatial resolution and swath width



Spatial resolution: 1-50 m
Swath width: 5 – 200 km

SAR satellites

First generation:

(SEASAT)
ERS-1/2
JERS-1
RADARSAT-1
ENVISAT

C-, L-band
Single/dual polarization
10-50 m resolution
24, 35, 46 day repeat path

Second generation:

ALOS/PALSAR
TSX/TDX
CosmoSky-Med
RADARSAT-2

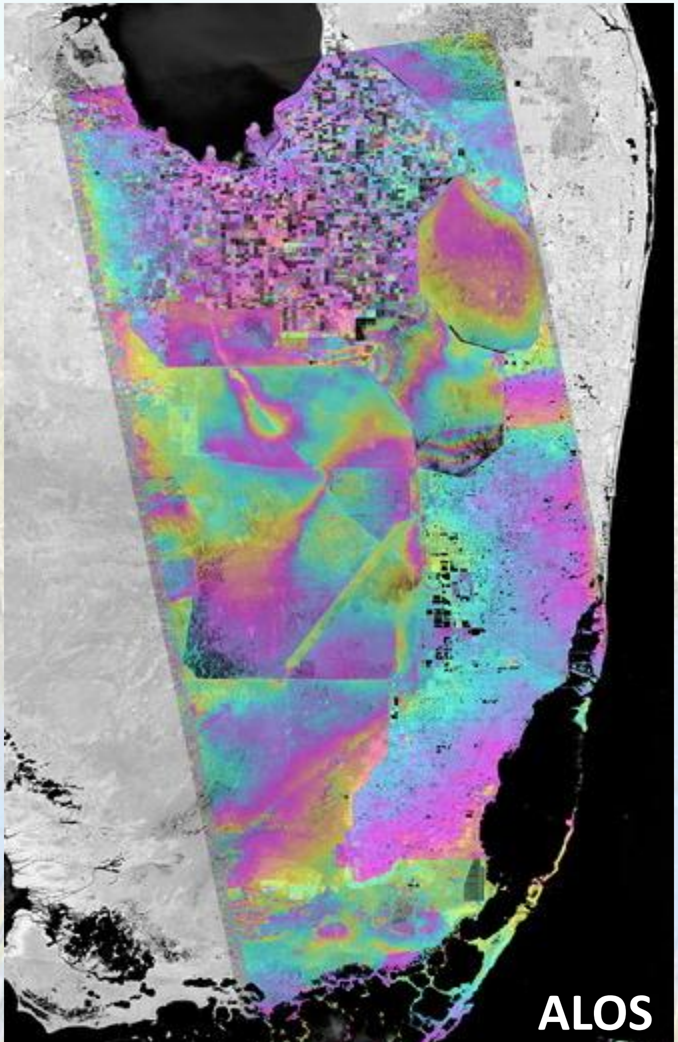
X-, C-, L-band
Dual/Quad polarization
1-50 m resolution
1-46 day repeat path

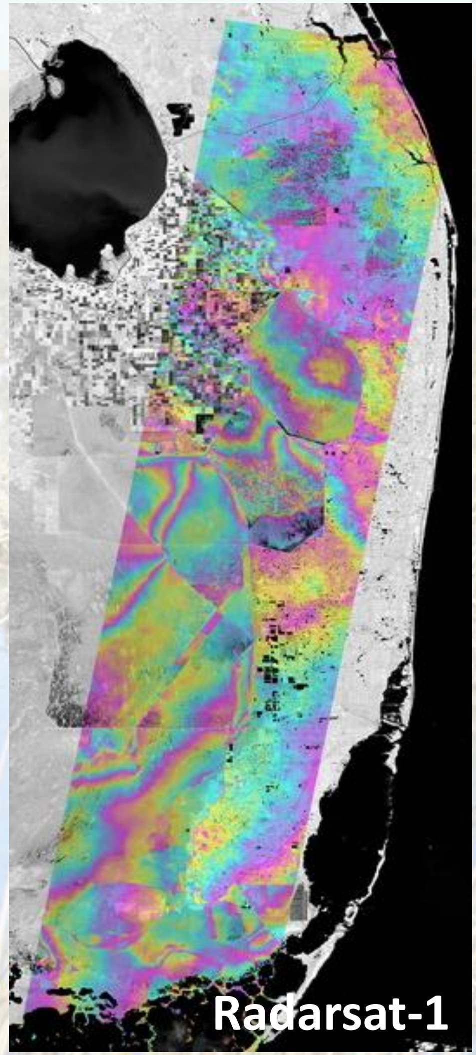
Planned missions:

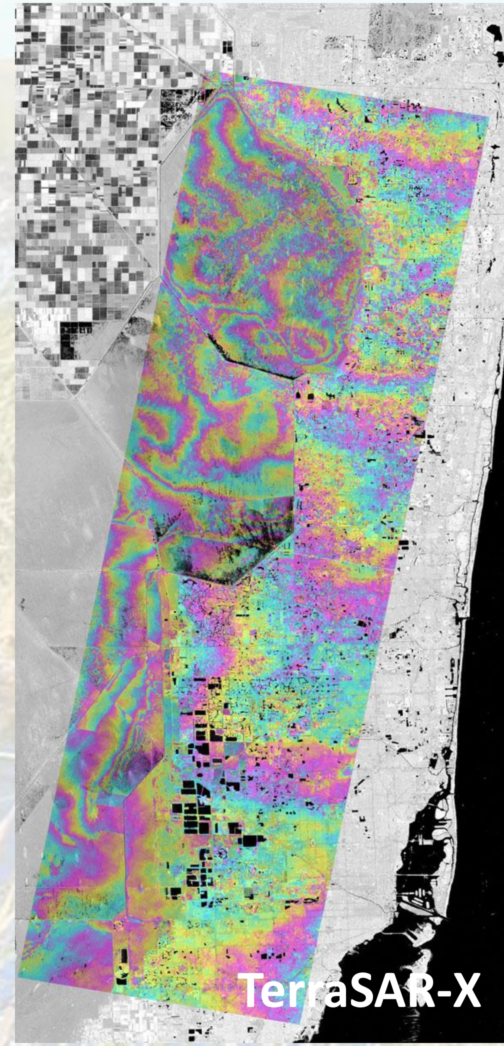
Sentinel-1
ALOS-2
CRM
DESDeNI

C-, L-band
Dual/Quad/Compact pol.
1-50 m resolution
Constellations

L-, C-, and X-band Interferograms

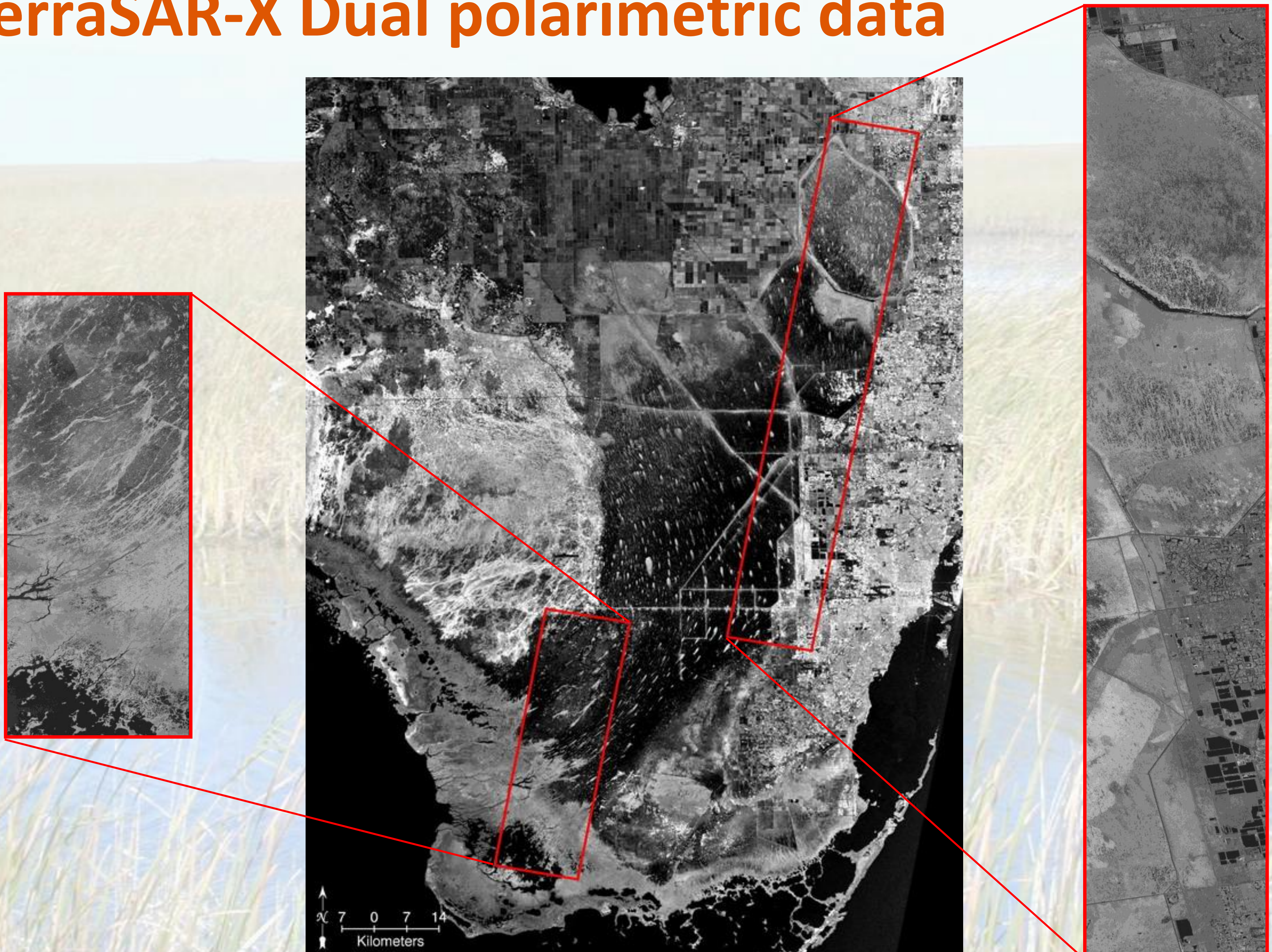






High spatial resolution maps of water level changes.
Vertical change (fringes): L-band – 15 cm; C-band – 4 cm; X-band – 2 cm

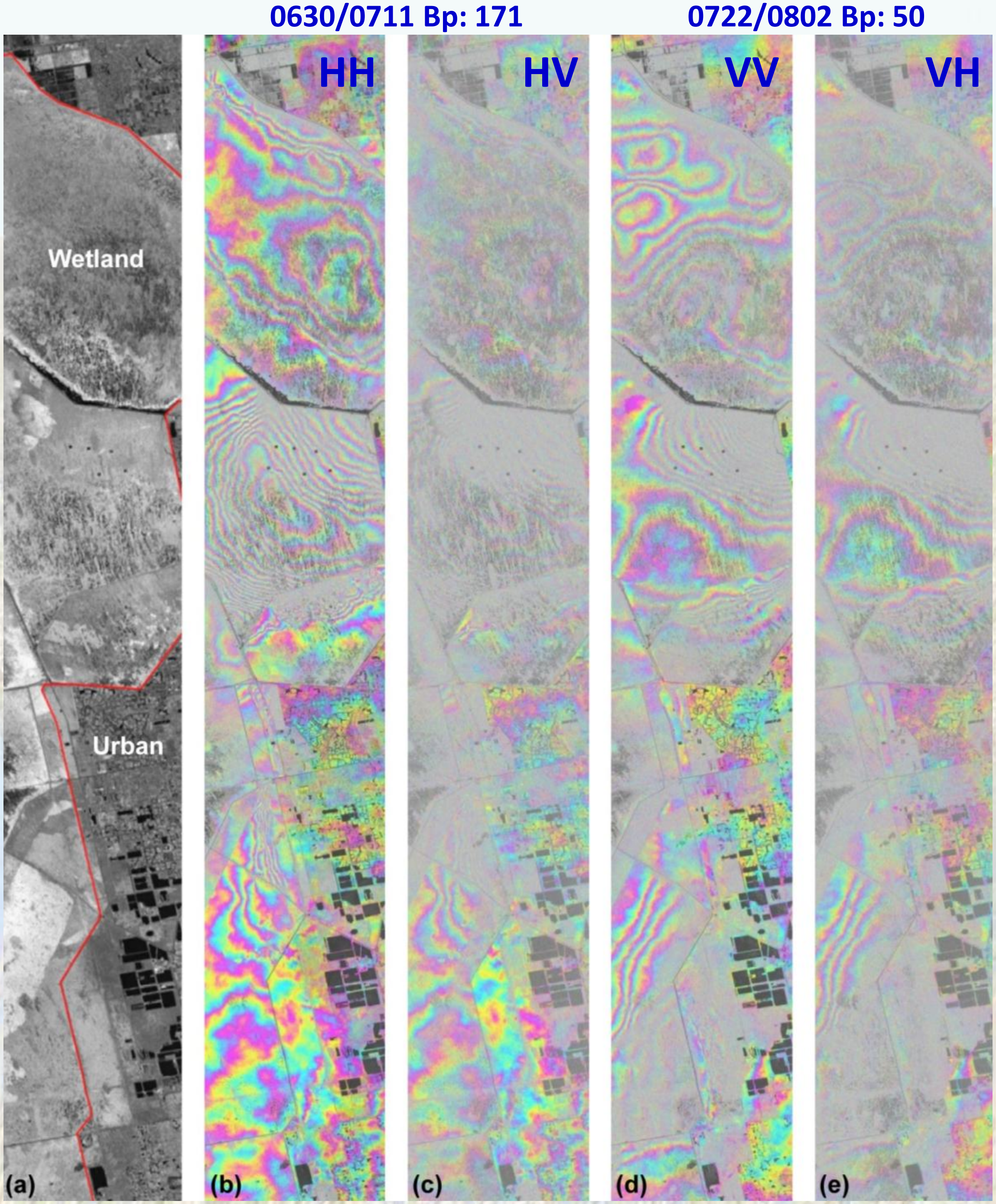
TerraSAR-X Dual polarimetric data



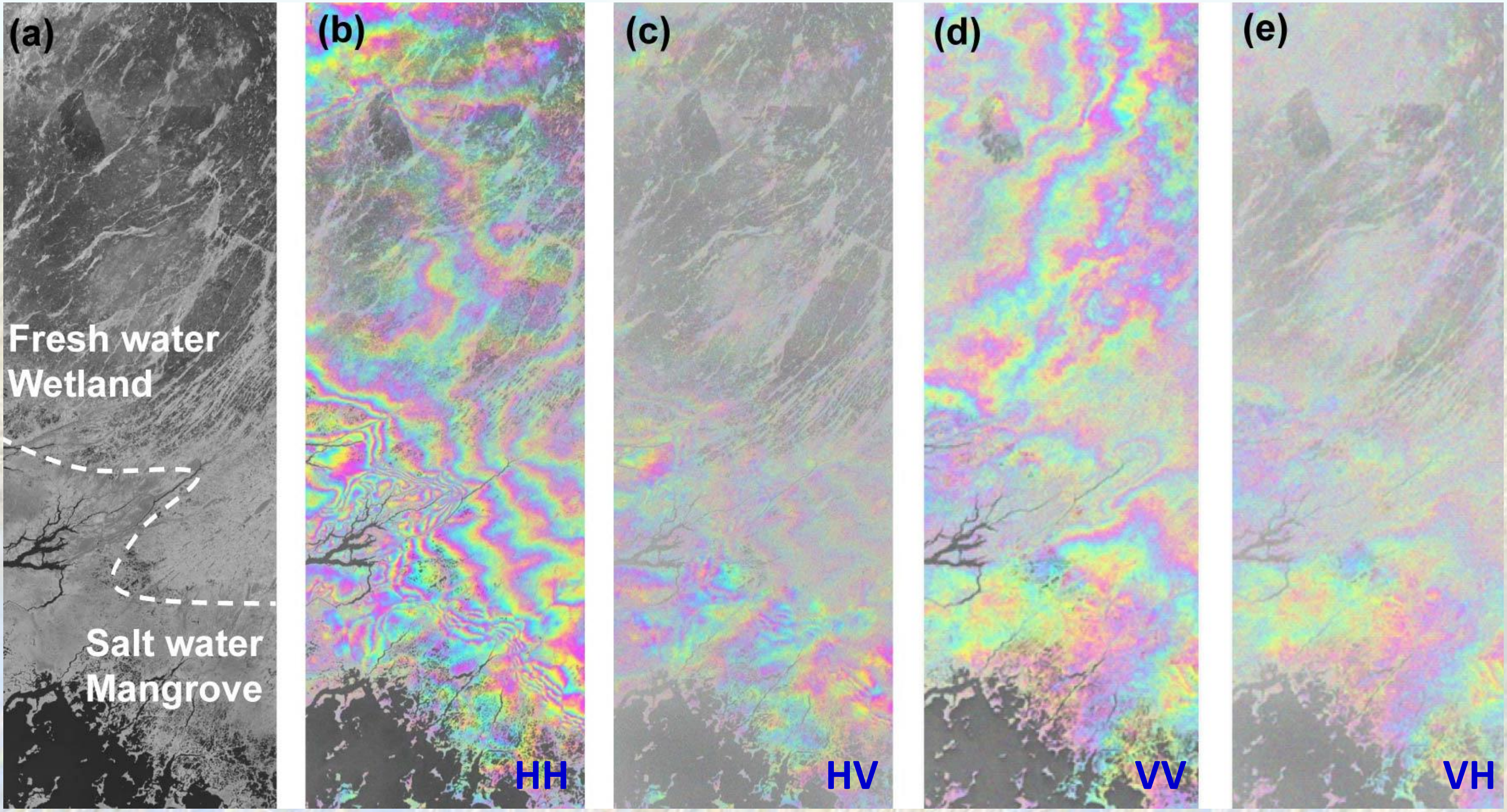
Water Conservation Area (WCA) Managed wetland

Water level changes can be - detected at all polarimetric data.

The coherence are the best in - HH-pol, and VV is the next. The cross-pol has the lowest coherence.



Freshwater wetland v.s. Saltwater mangrove

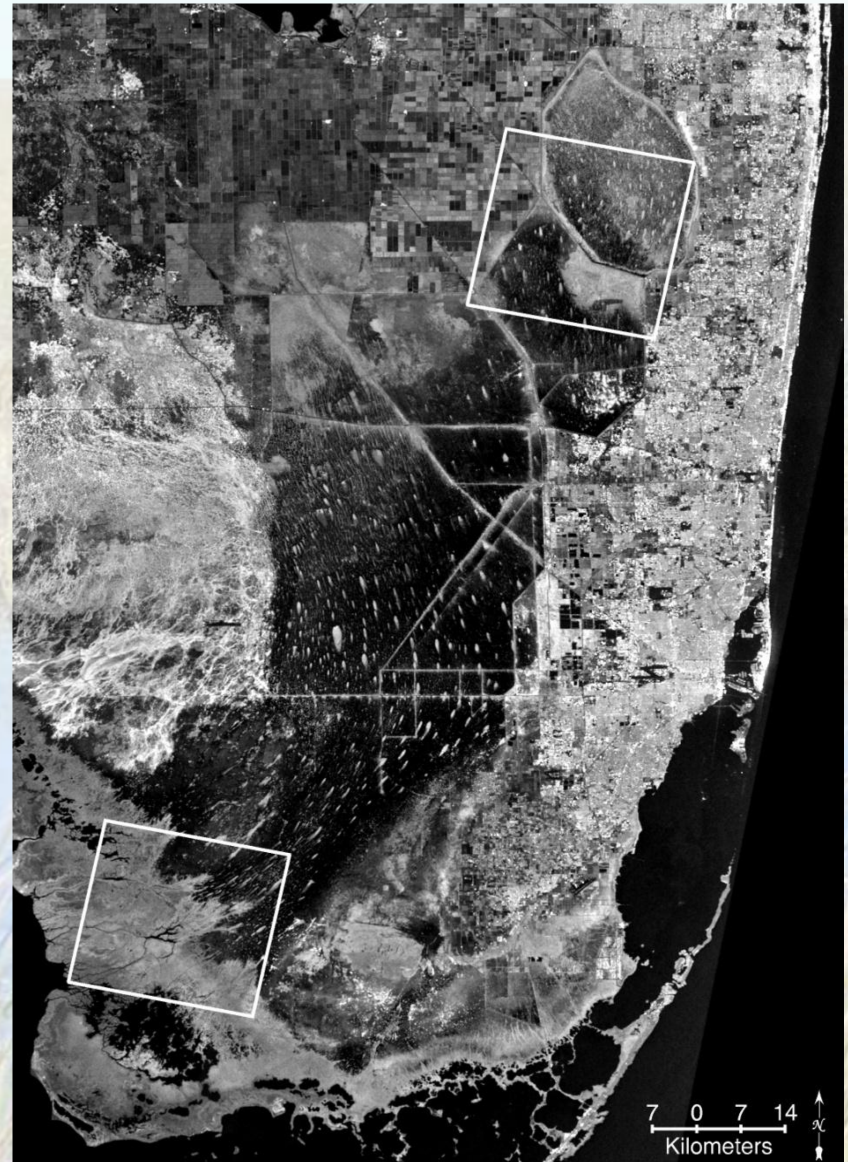


0926/1007 Bp: 77

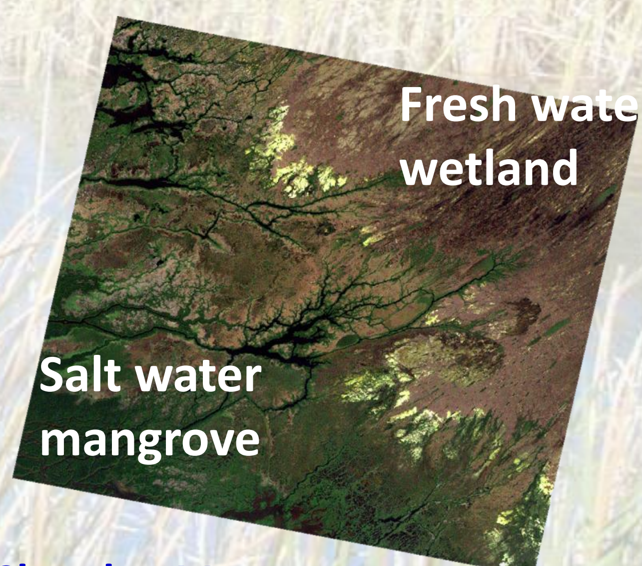
1109/1120 Bp: 147

Cross-pol acts like double bounce scattering as well as volume scattering

Radarsat-2 Quad-pol, Fine beam mode (5 m)

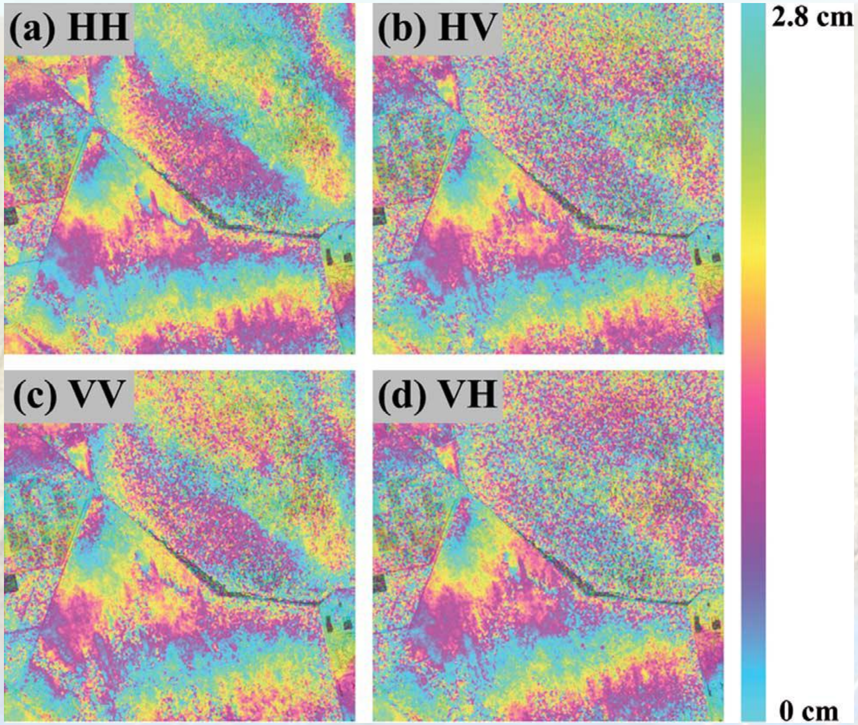


Managed wetland

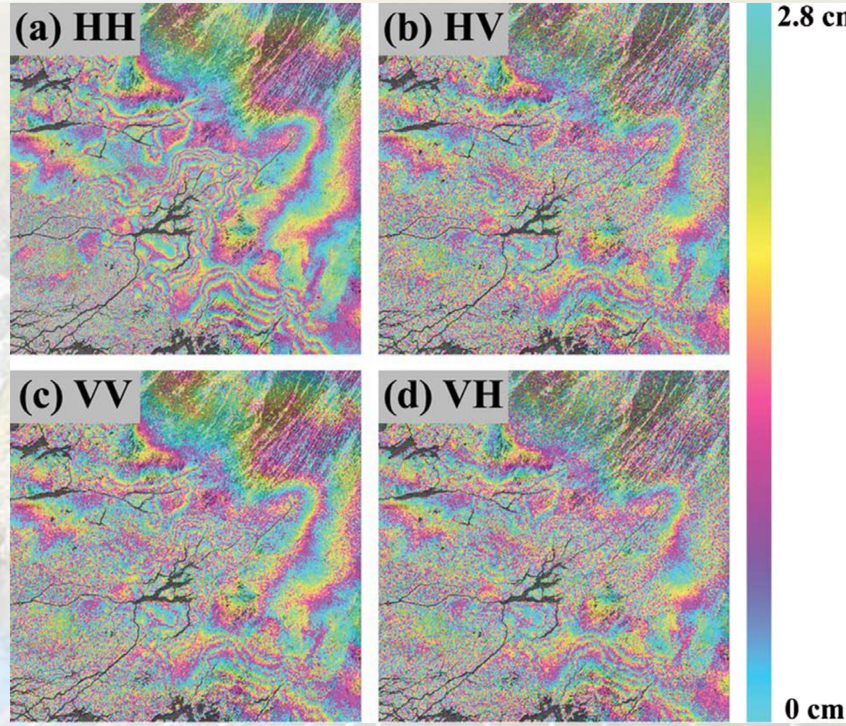


Slough + Mangrove

Radarsat-2: Fine Quad-pol mode (5 m)



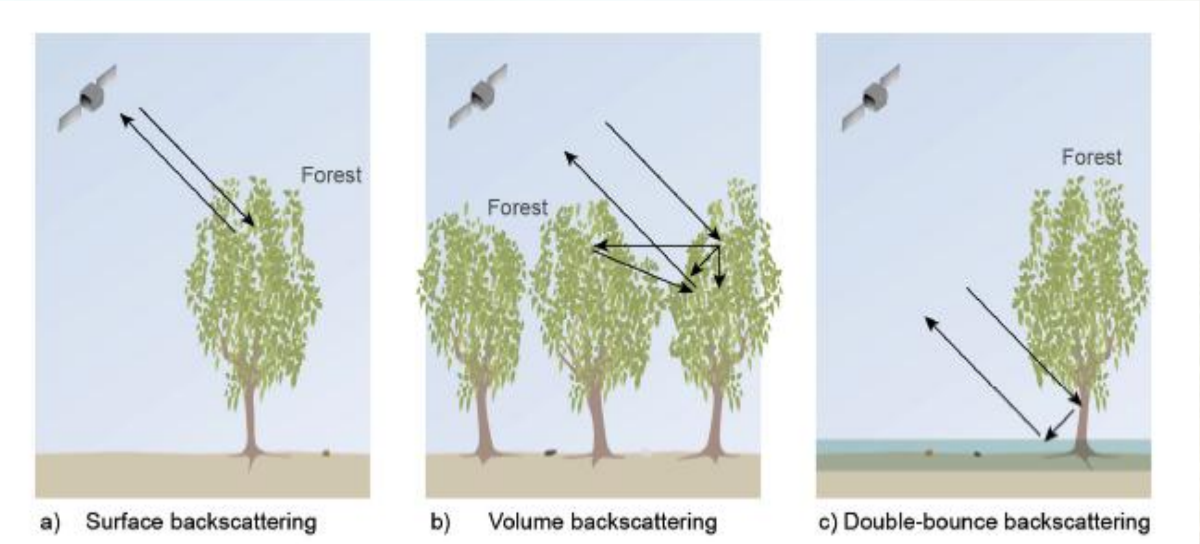
Managed wetlands

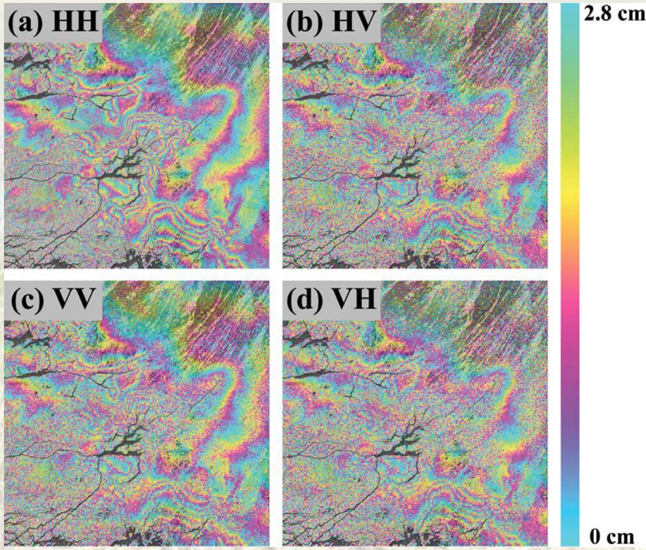


Rural wetlands

Surprising result: Cross-pol interferograms (volume scattering ?) show fringes due to water level changes (double bounce)

SAR vegetation scattering theory





Gondwe (2010)

<u>Current assumption:</u>

Double bounce = HH-VV

Single bounce = HH+VV

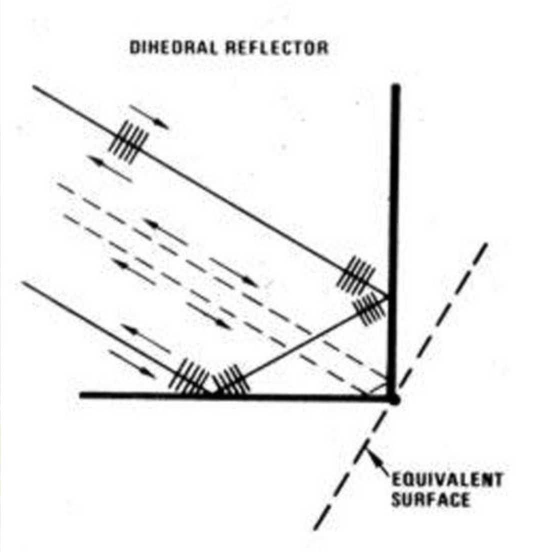
Volume scattering = HV

<u>Observations:</u>

Cross-polarization (HV) interferograms show water level changes

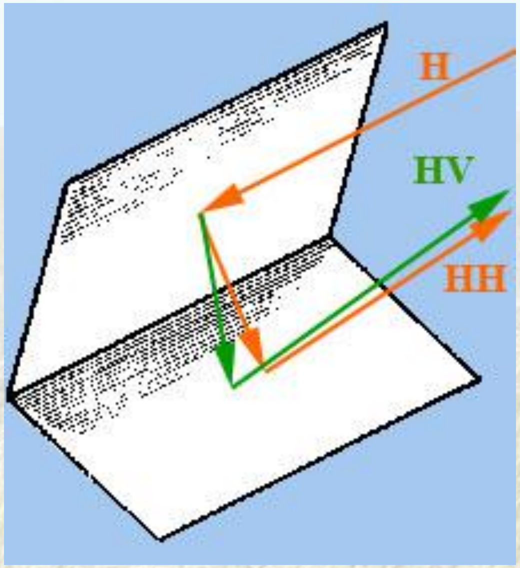
=> *HV has a double bounce component*

Revising vegetation scattering theory



Dihedral

Hong and Wdowinski (2012)

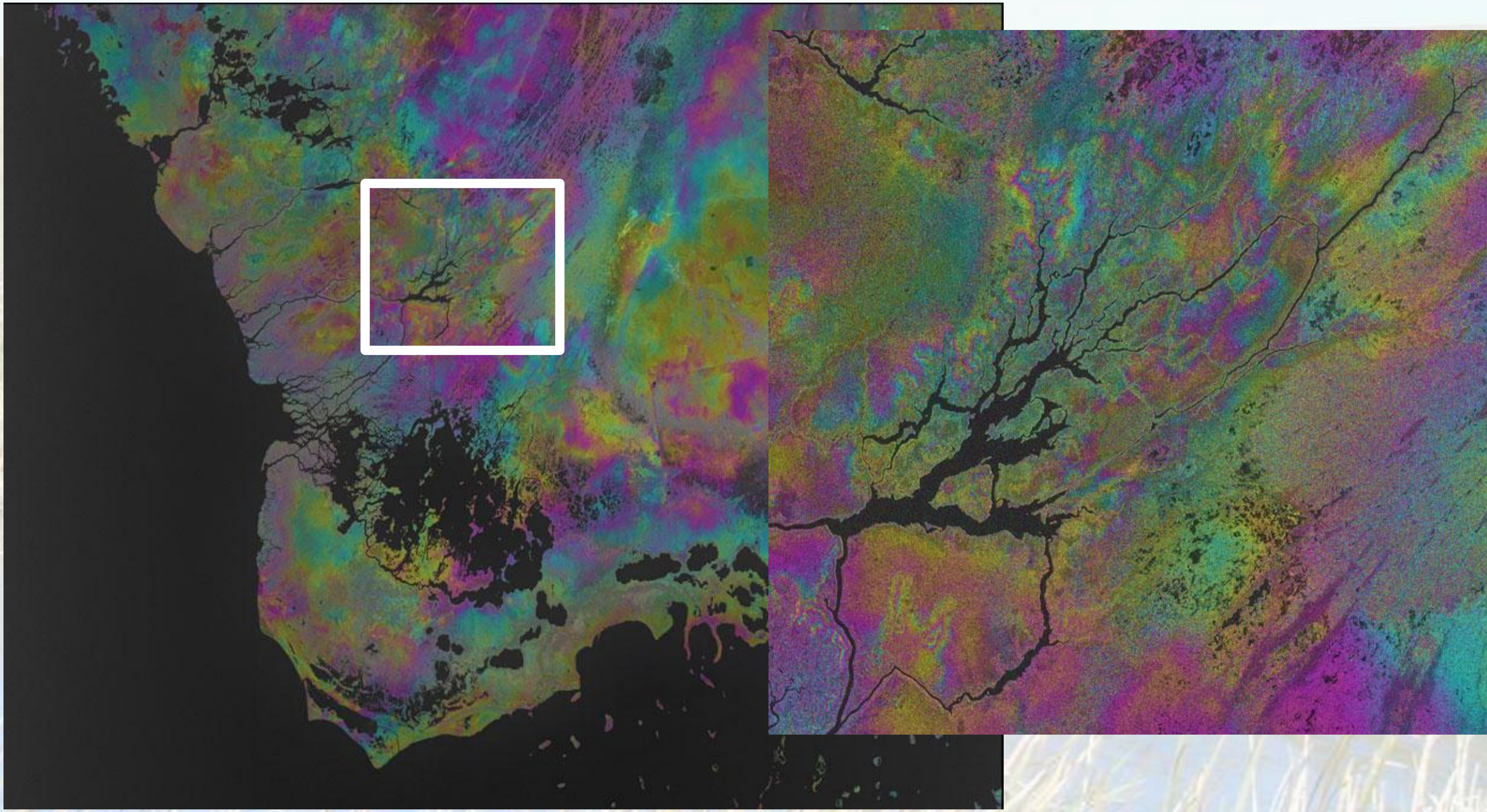


Rotated Dihedral

Cypress

Mangroves

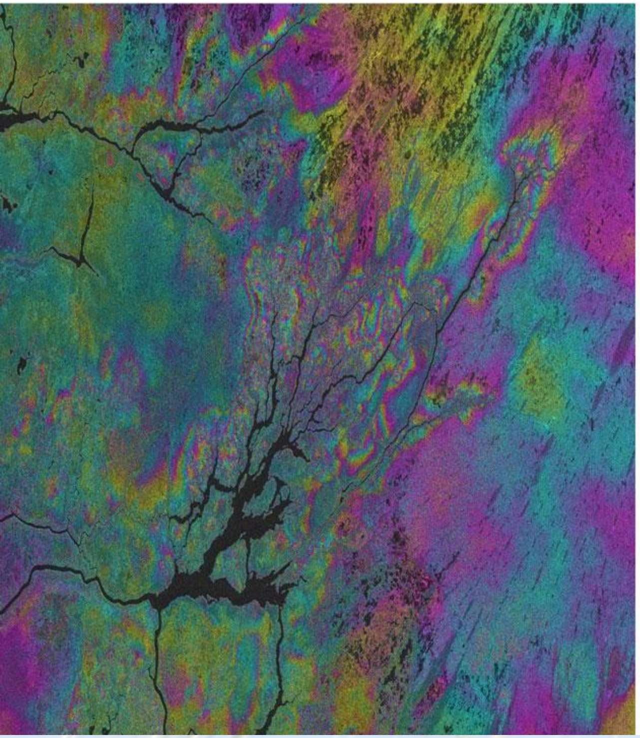
Radarsat-2 HH, Wide Ultra Fine mode (3 m)



Advantage: 90 km wide swath

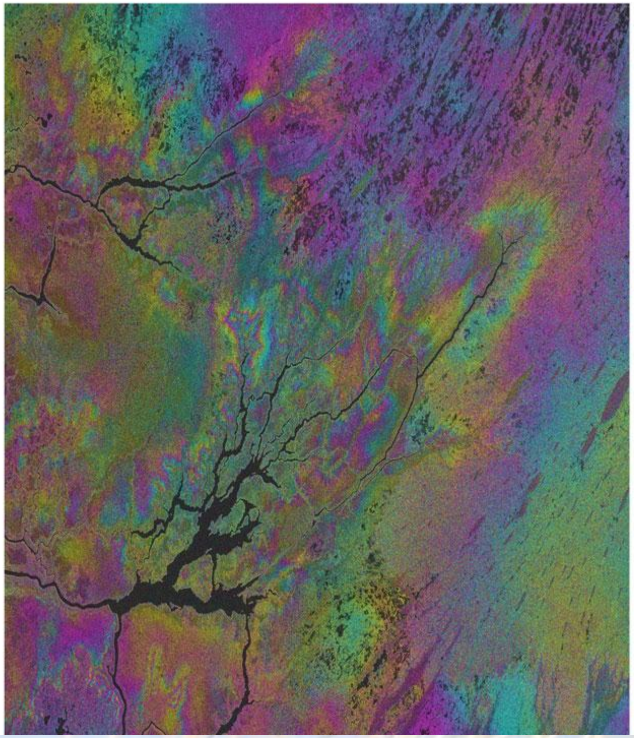
Radarsat-2: Wide Ultra-fine vs. Fine modes

2011/11/26-2011/12/20



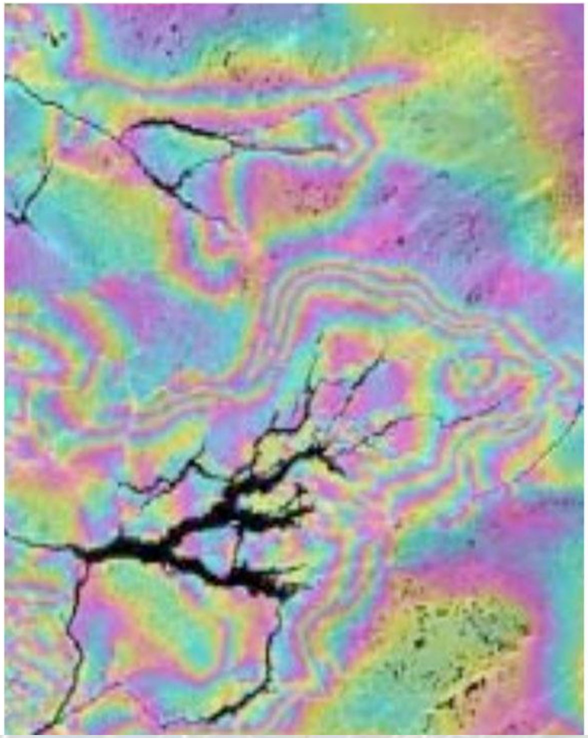
Wide Ultra-fine

2011/11/23 - 2011/12/17



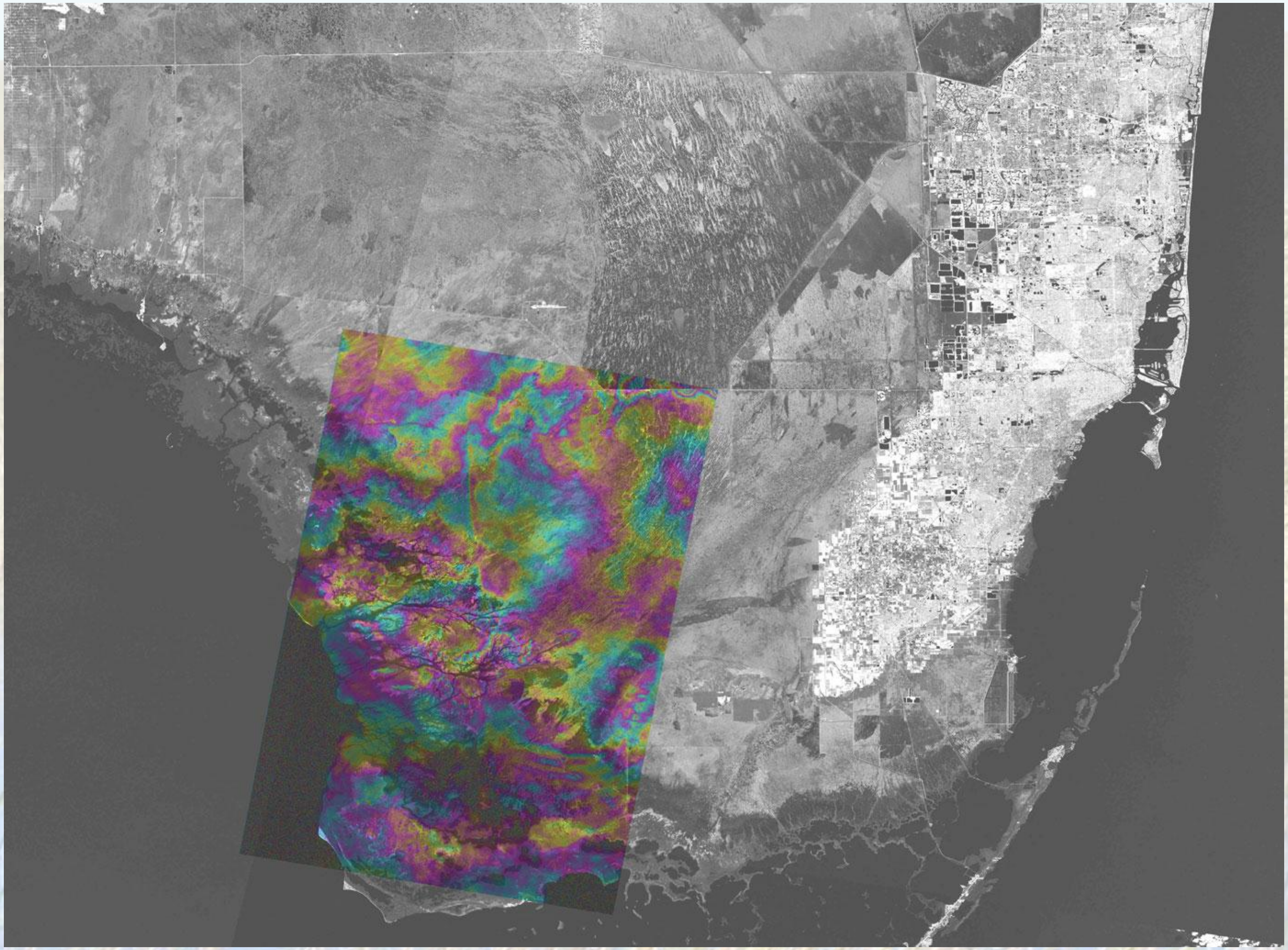
Wide Ultra-fine

2008/09/23-2008/10/17

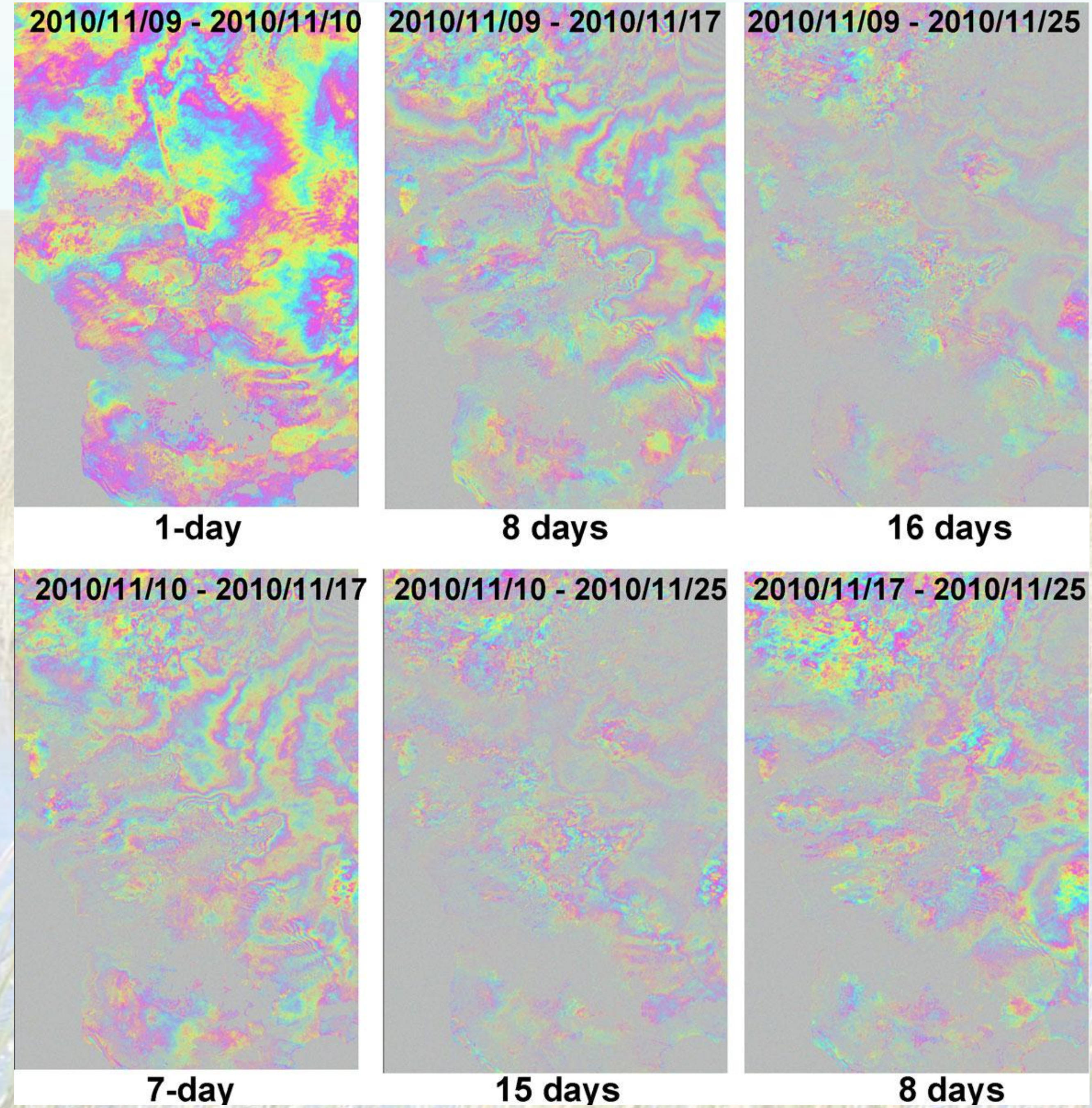


Quad-fine

Cosmo-SkyMed



1-day interferogram (2010/11/09 – 2010/11/10)



Cosmo-SkyMed

Fast coherence decay with time

No dual-pol phase observations

Summary

- The new generation of SAR satellites can acquire data with significantly improved spatial (1-5 m) and temporal (1, 7, 8, 11… days) resolutions.
- The high temporal resolution observations provide high coherence with all sensor types, even X-band.
- The high spatial resolution observations provide very detailed information on water level changes and wetland surface flow through vegetation.
- The new dual- and quad-pol observations indicate that cross-pol radar signal samples the water surface beneath the vegetation, which led to the revision of vegetation scattering theory.

Acknowledgements

SAR data

- JAXA – ALOS, L-band data
- CSA – RADARSAT-2, C-band data
- DLR – TerraSAR-X, X-band data
- ASI– Cosmo-SkyMed, X-band data

Support

- National Institute for Water Research (USGS)
- NASA
- ONR
- SFWMD