

# High-Resolution Wetland Water Level Monitoring Towards Everglades Restoration Integrating Synthetic Aperture Radar Interferometry and Satellite Radar Altimetry

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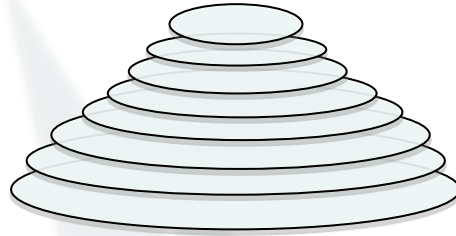
<sup>3</sup>US Geological Survey, Reston, VA

<sup>4</sup>US Geological Survey, Vancouver, WA

**Acknowledgement: USGS**

**GRACE**  
( $\Delta g$ )

**InSAR**  
( $dh/dx$ )

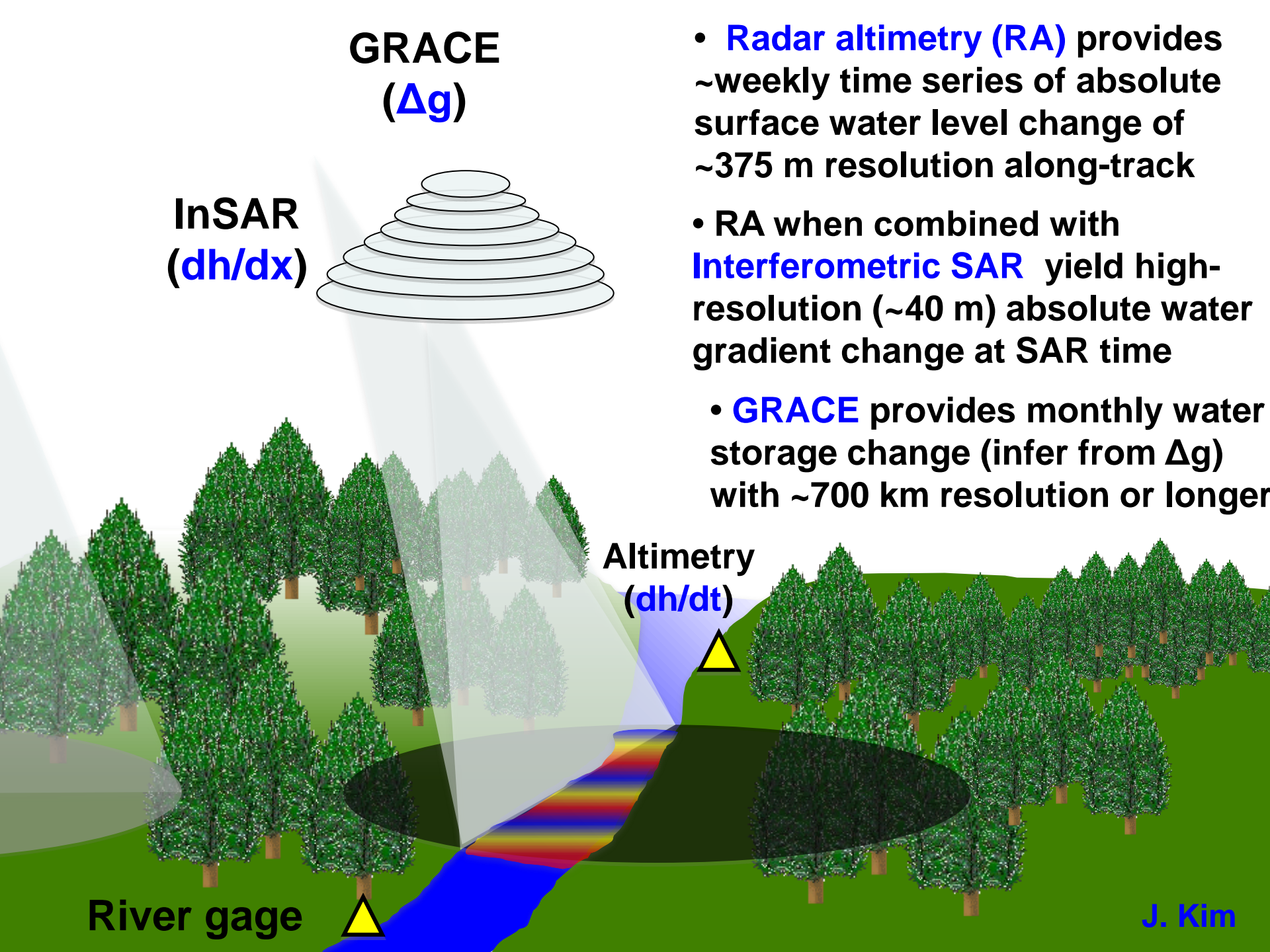


- **Radar altimetry (RA)** provides ~weekly time series of absolute surface water level change of ~375 m resolution along-track
- RA when combined with **Interferometric SAR** yield high-resolution (~40 m) absolute water gradient change at SAR time
- **GRACE** provides monthly water storage change (infer from  $\Delta g$ ) with ~700 km resolution or longer

**Altimetry**  
( $dh/dt$ )

**River gage**

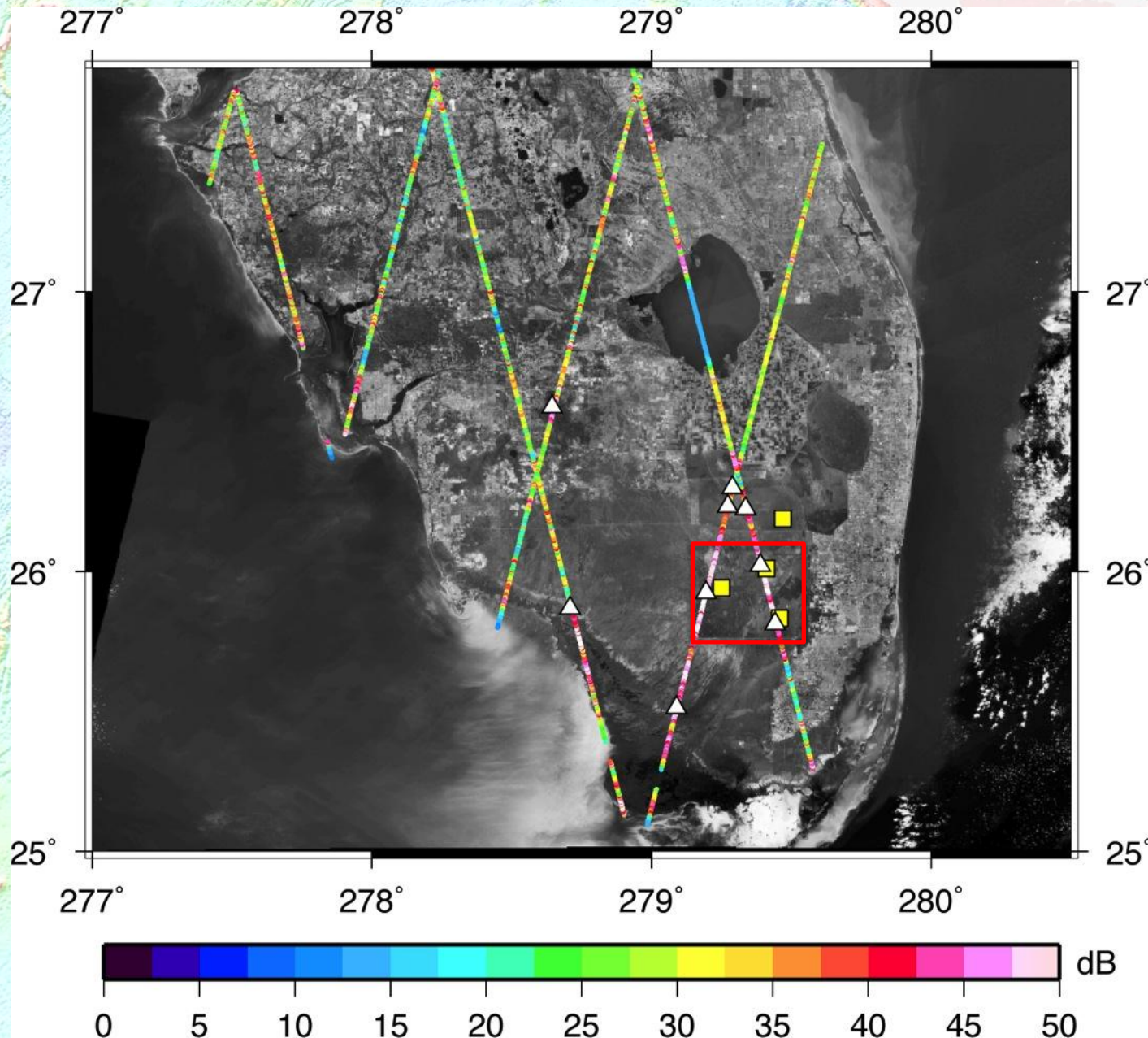
**J. Kim**

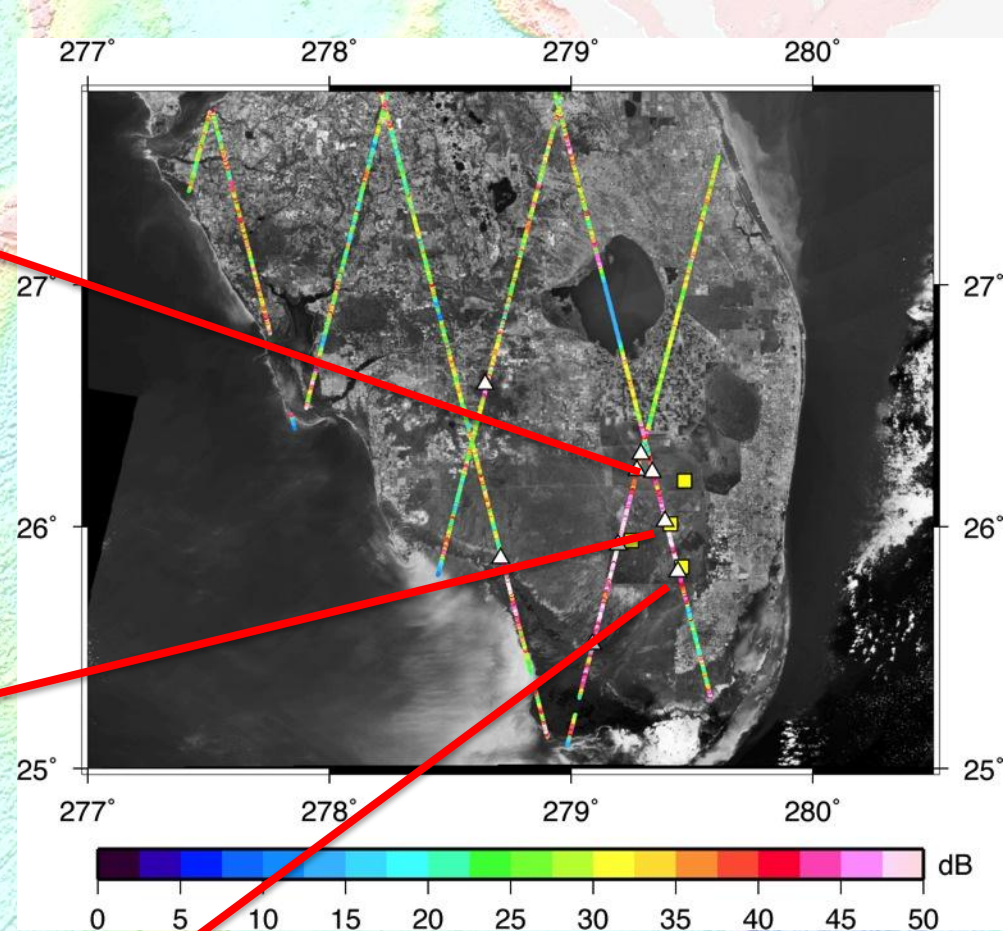
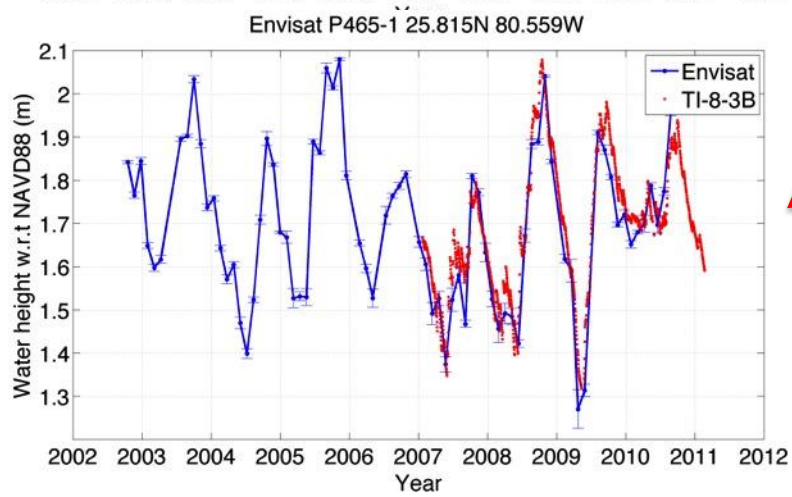
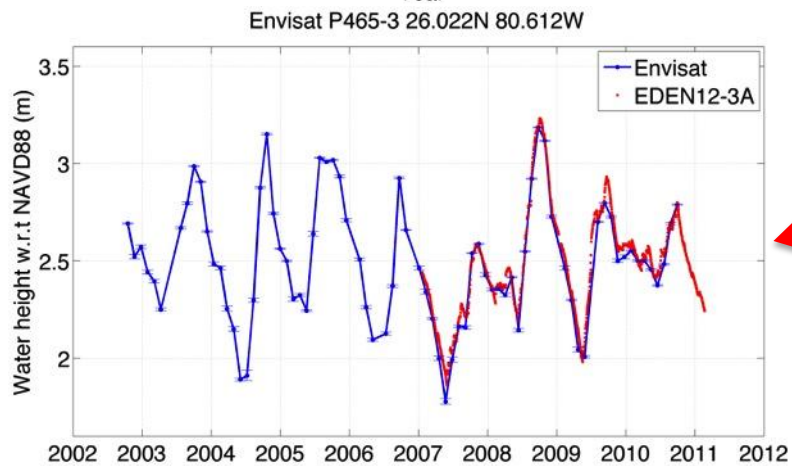
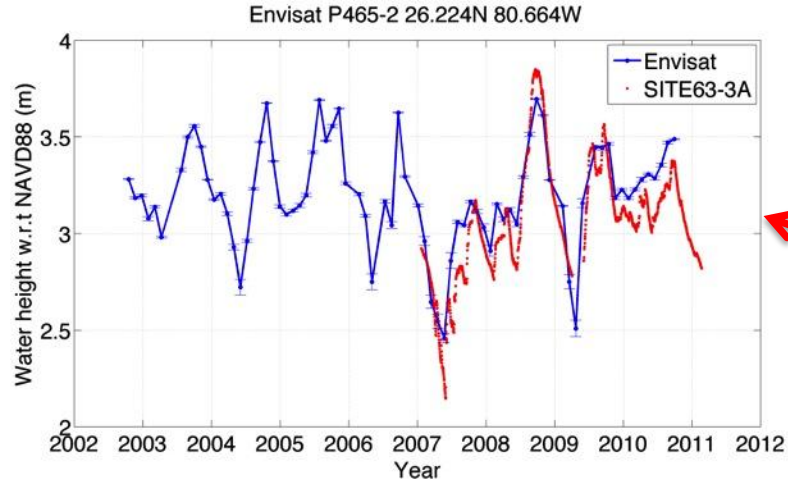


# Envisat altimeter over Everglades

Higher backscatter from Everglades wetlands → potential water height extraction

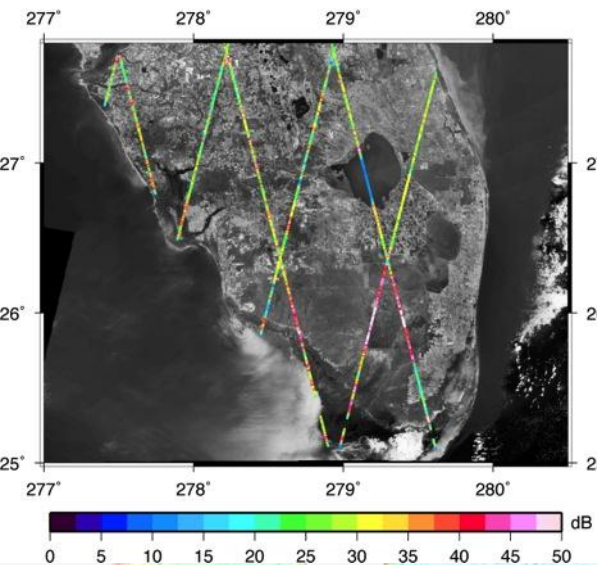
white triangles: altimeter sites  
yellow rectangles: water gauges



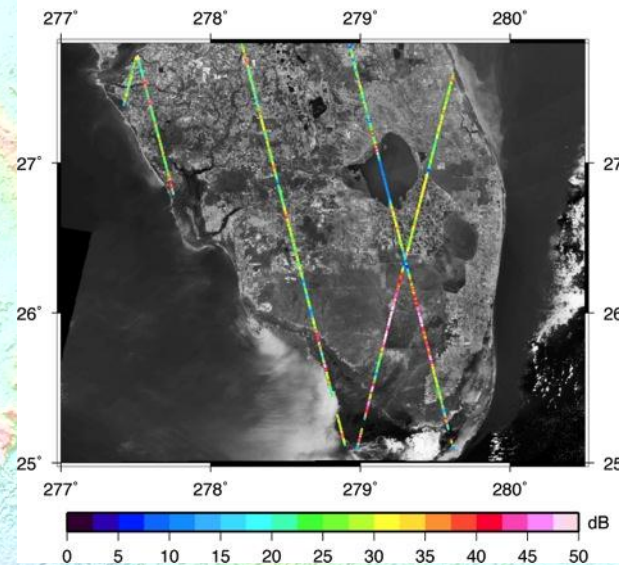


**Excellent agreement  
between Envisat altimeter  
and nearby daily water  
gauge measurement  
(USGS)**

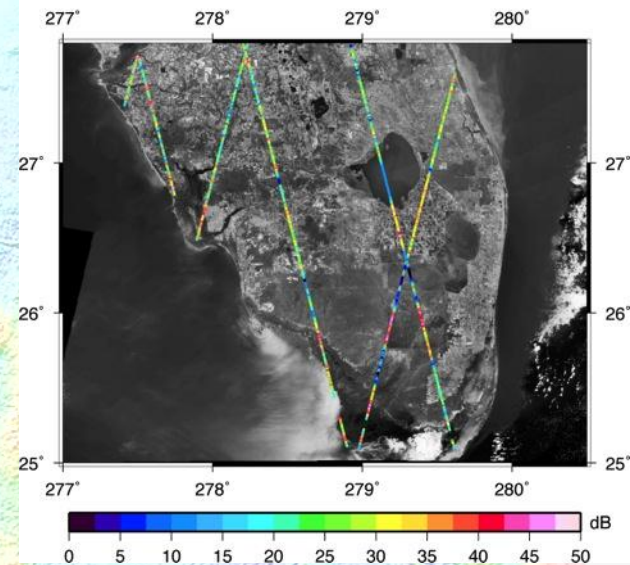
03/09/2004-04/12/2004



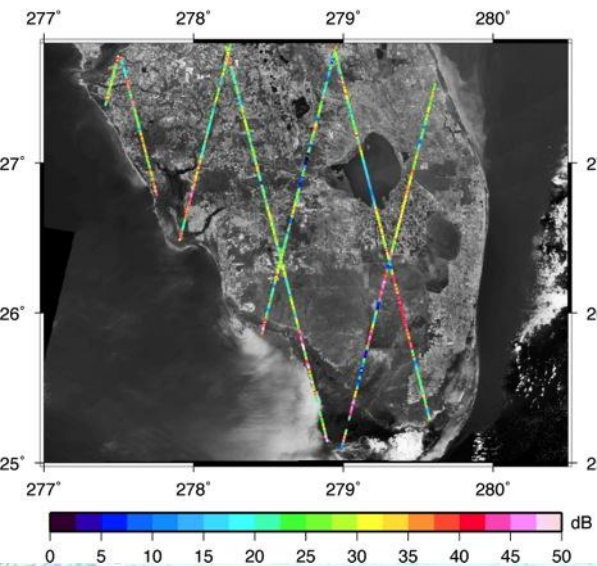
04/13/2004-05/17/2004



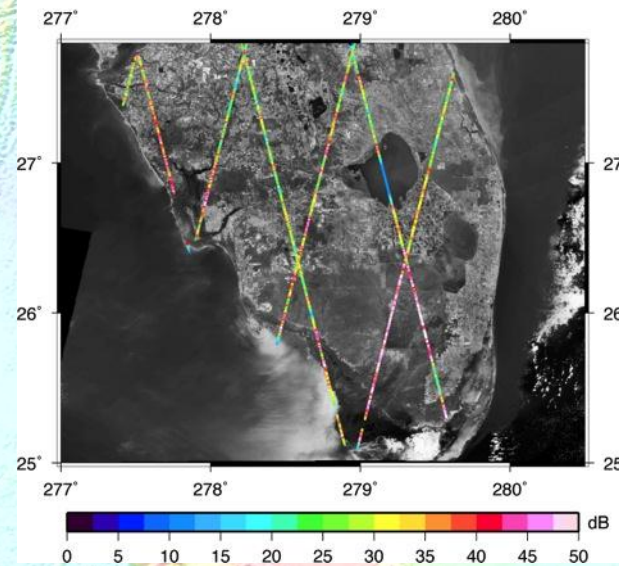
05/18/2004-06/21/2004



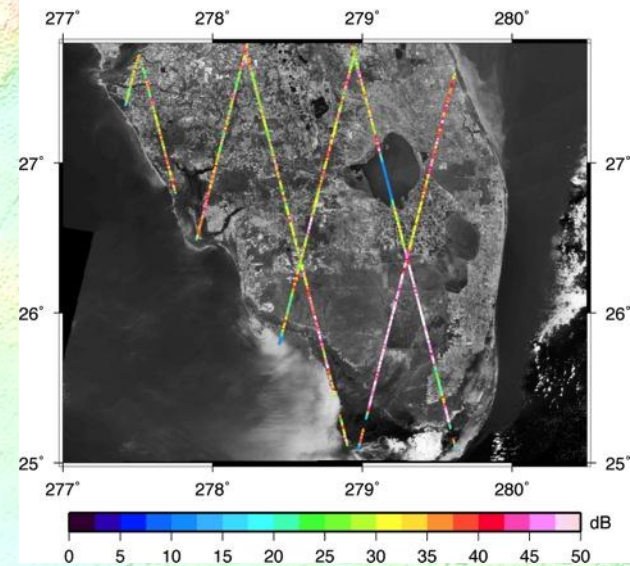
06/22/2004-07/26/2004

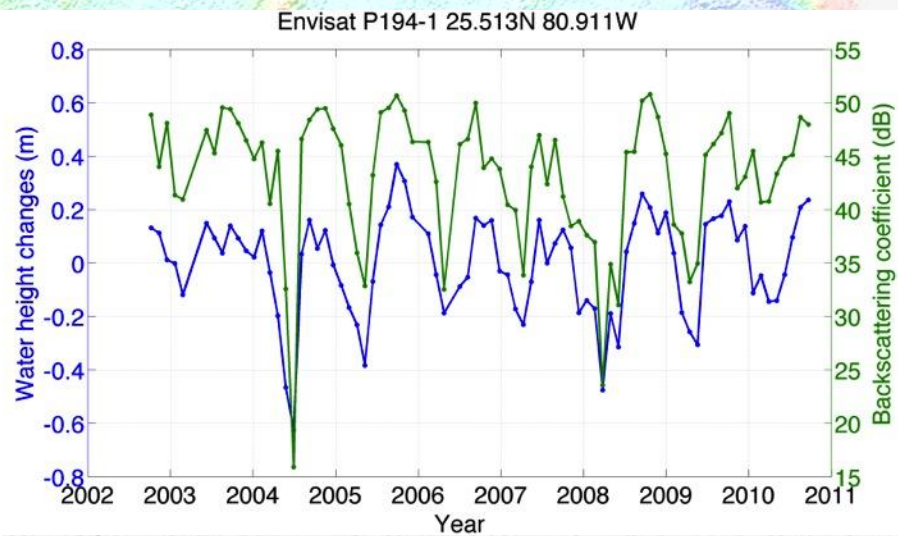
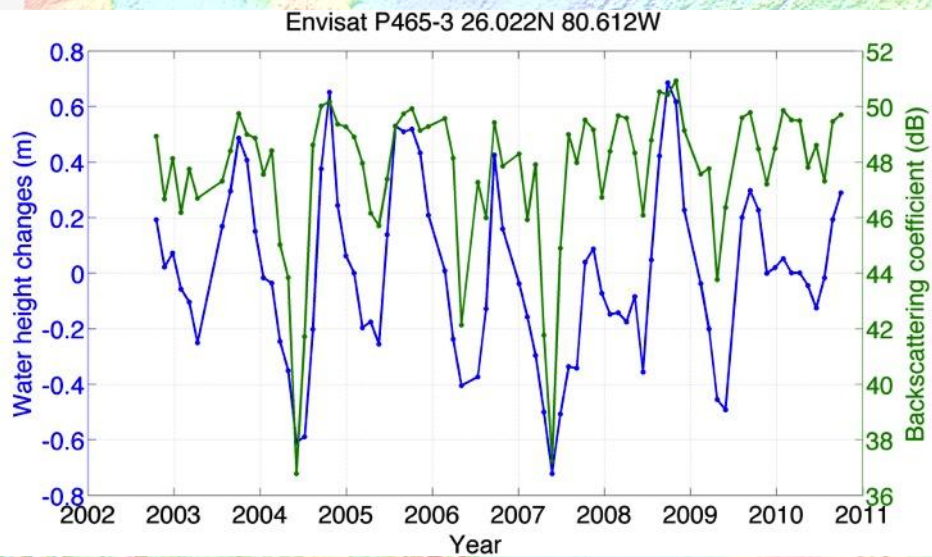
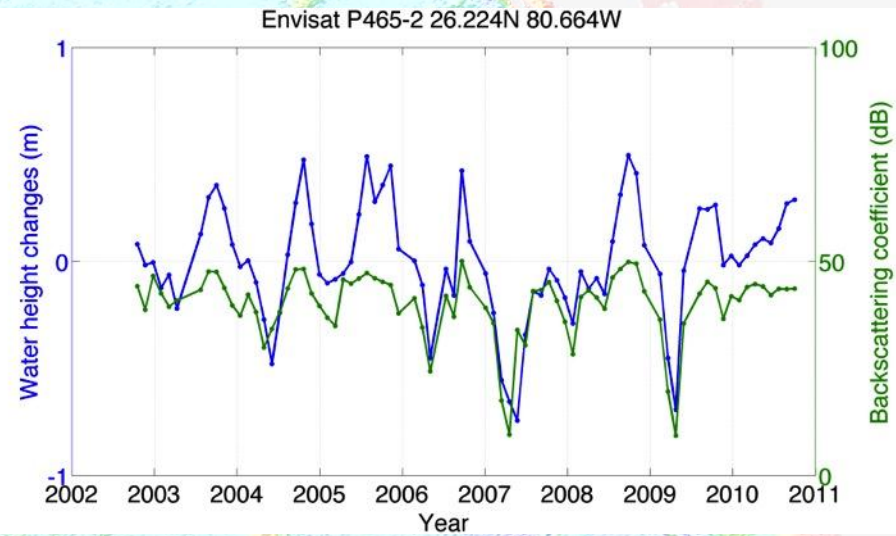
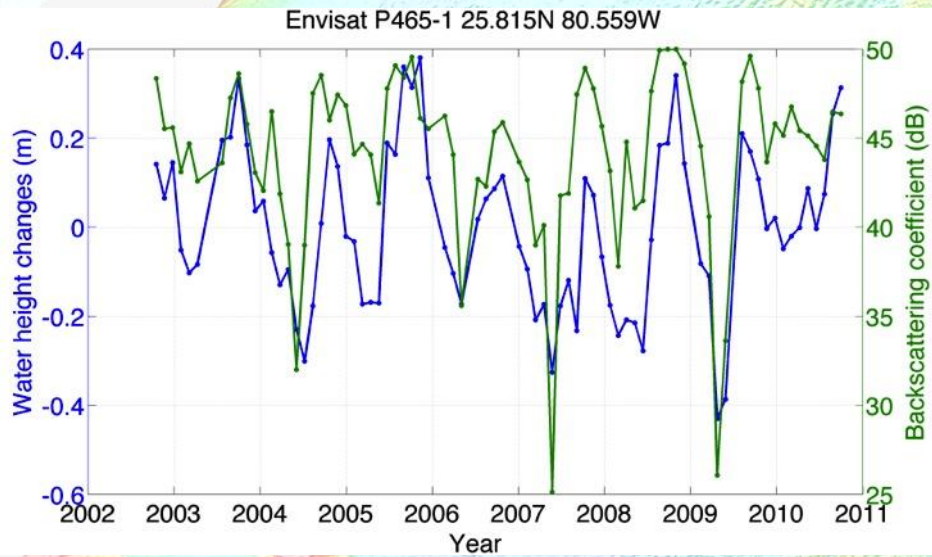


07/27/2004-08/30/2004

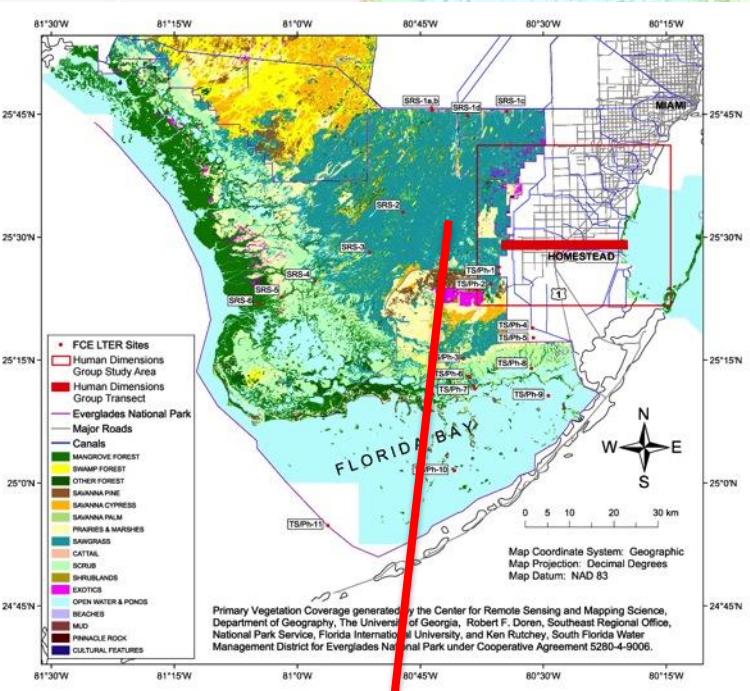


08/31/2004-10/04/2004





**Excellent correlation between water height and radar backscatter**

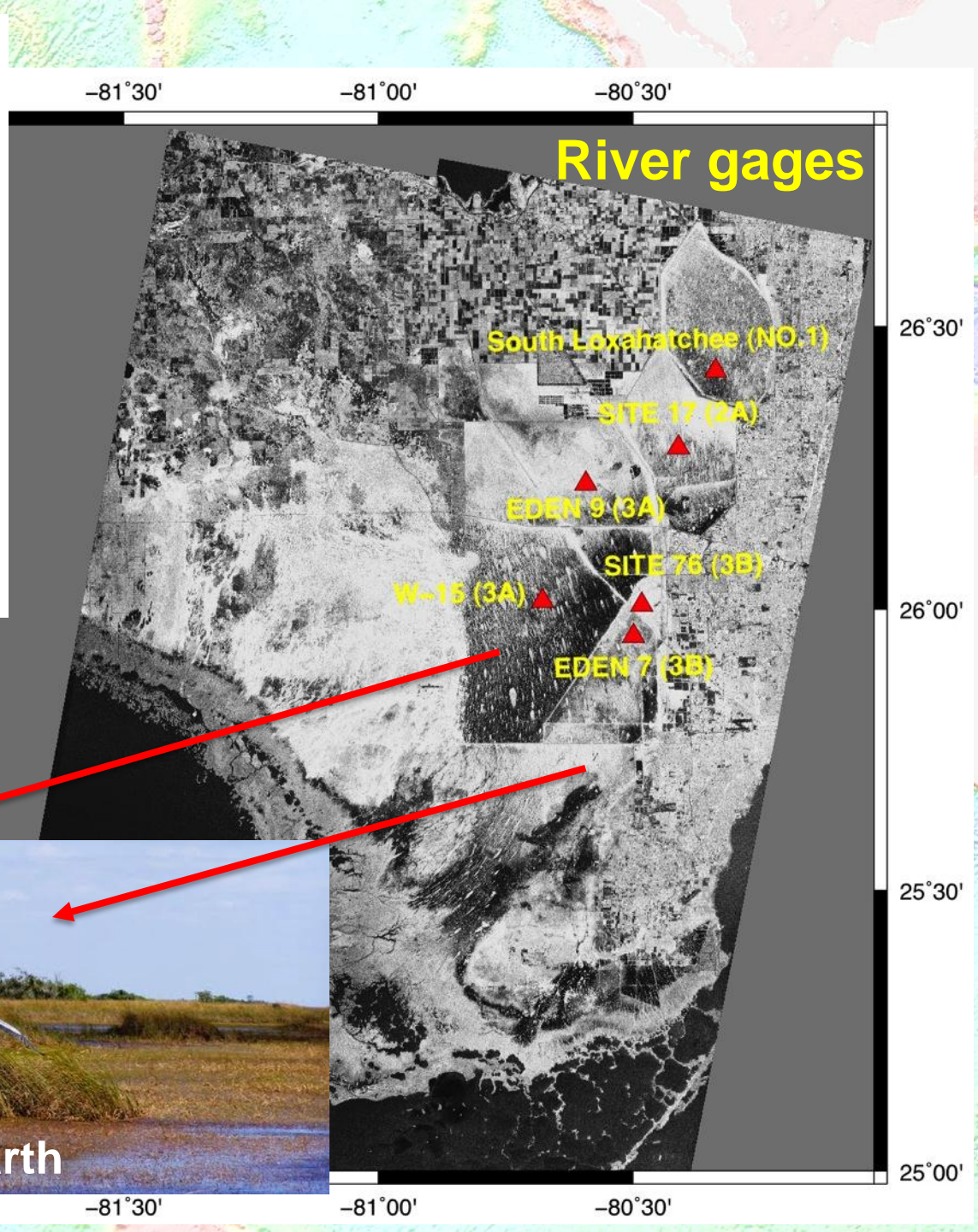


# Land cover in Southwestern Everglades

## Sawgrass

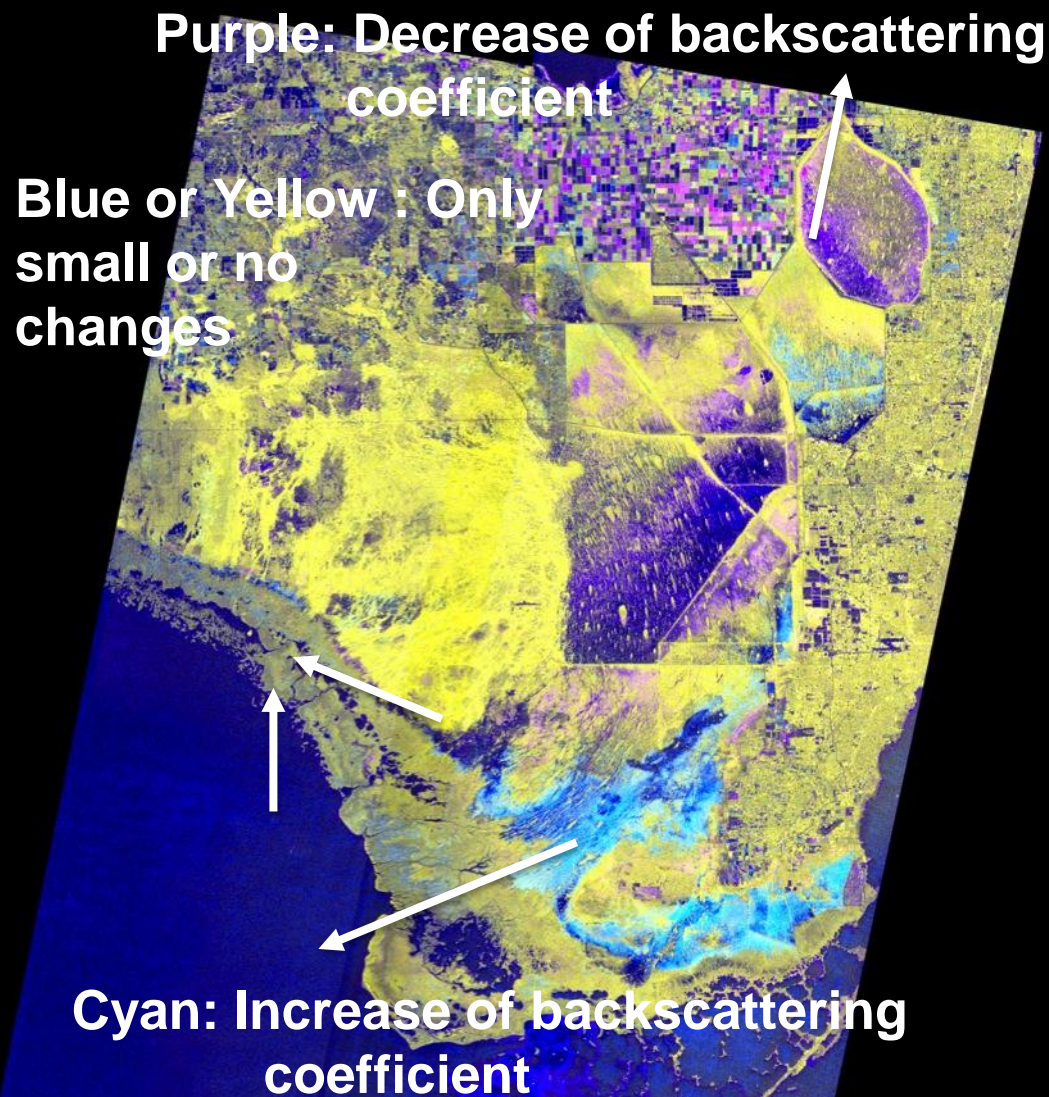
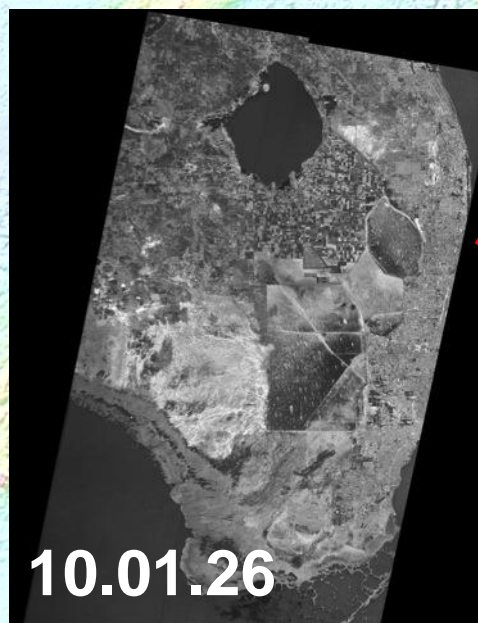


From Google Earth



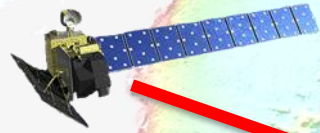
# P464 Backscattering coefficient change (ScanSAR, 09.12.11~10.01.26)

R: 09.12.11, G: 10.01.26, B: 09.12.11-10.01.26





# Double bounce scattering in saw grass regions



**Specular scattering:  
Dominant**

**High  
water**



**Weak return**

**Double bounce scattering:  
Dominant**

**Low  
water**

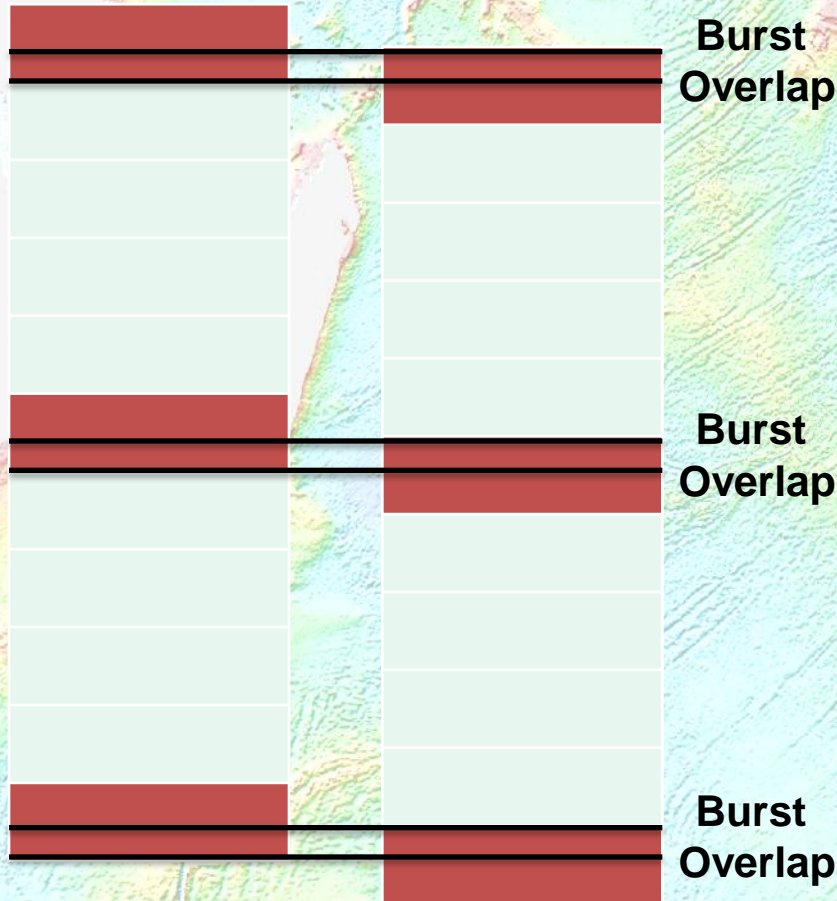


**Strong return**

**Relatively low grass height and no-canopy condition cause different scattering mechanism. The change map of sigma naught helps to monitor the wetland condition.**

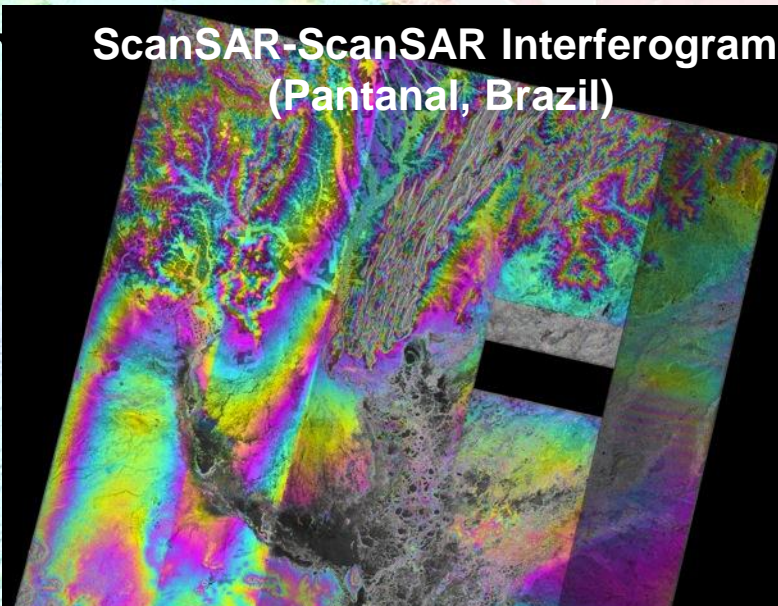
# ScanSAR-ScanSAR Interferogram

Subswath 4 (Day 0)    Subswath 4 (Day 46)

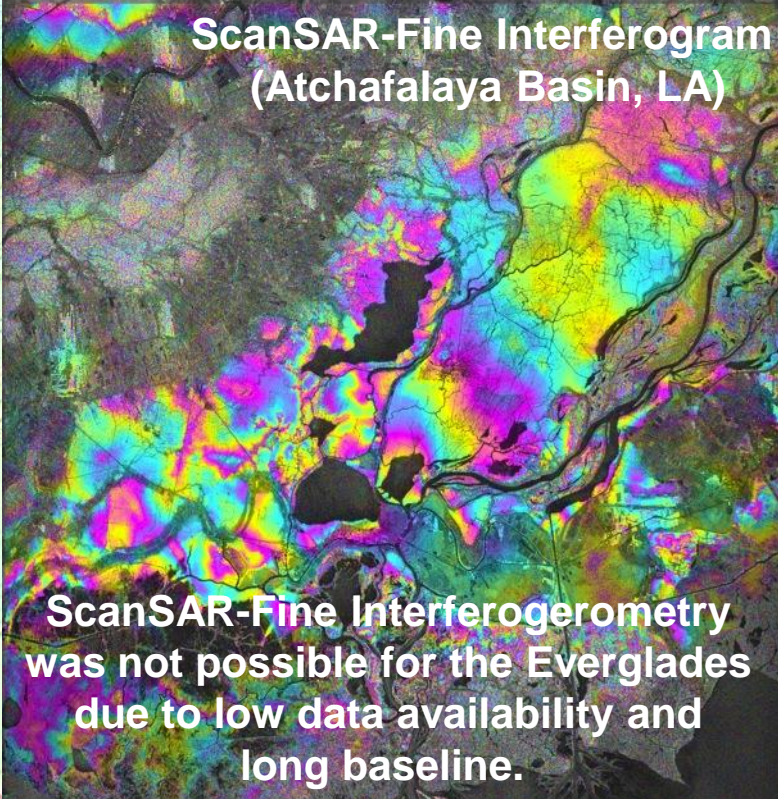


**PALSAR ScanSAR has a problem with wrong burst alignment. Small burst overlap causes the loss of coherence for InSAR.**

# ScanSAR-ScanSAR Interferogram (Pantanal, Brazil)



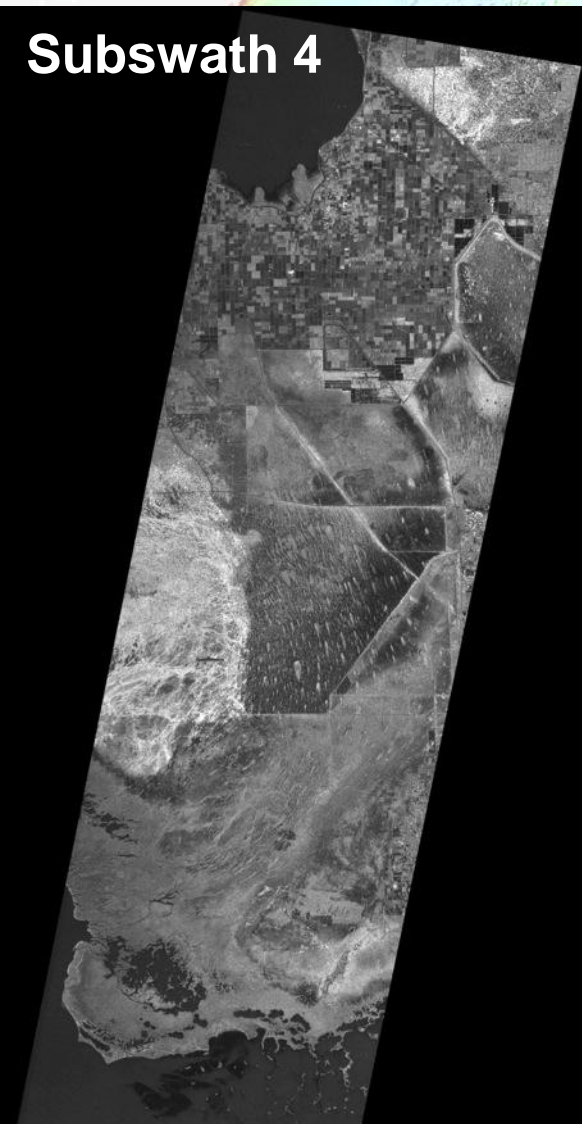
# ScanSAR-Fine Interferogram (Atchafalaya Basin, LA)



**ScanSAR-Fine Interferometry was not possible for the Everglades due to low data availability and long baseline.**

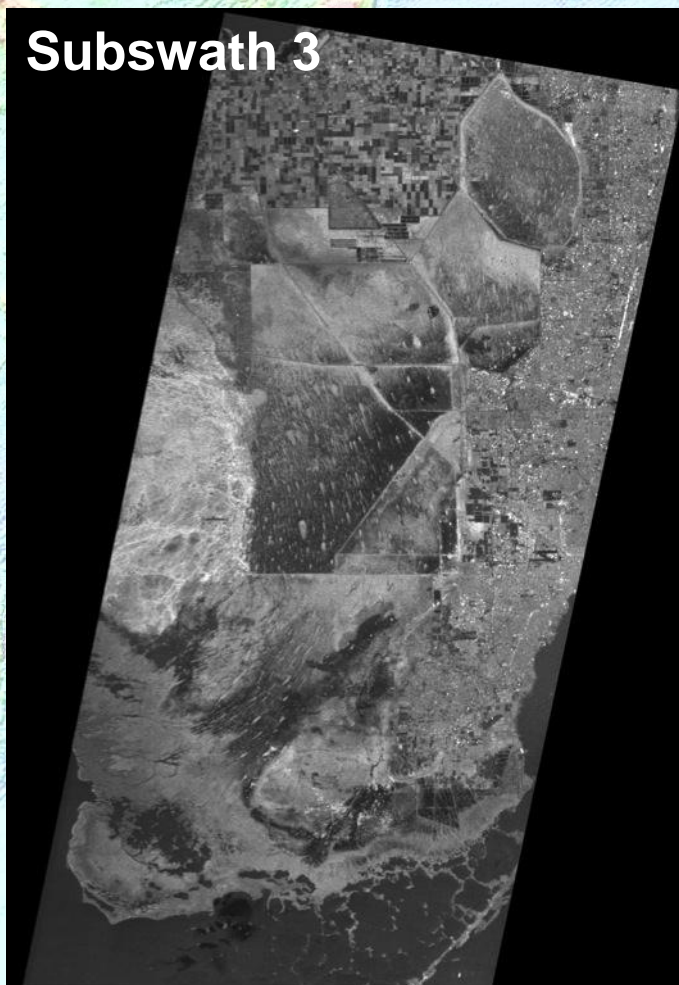
# Available ScanSAR Interferometry pairs (Descending track)

**Subswath 4**



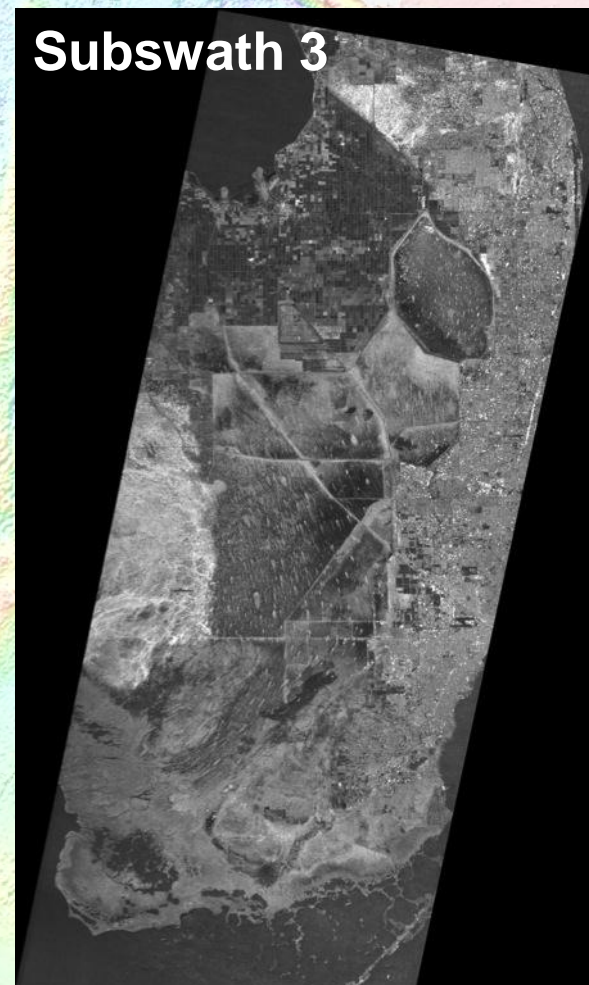
**P465: 2008.02.19 ~  
2008.04.05**

**Subswath 3**



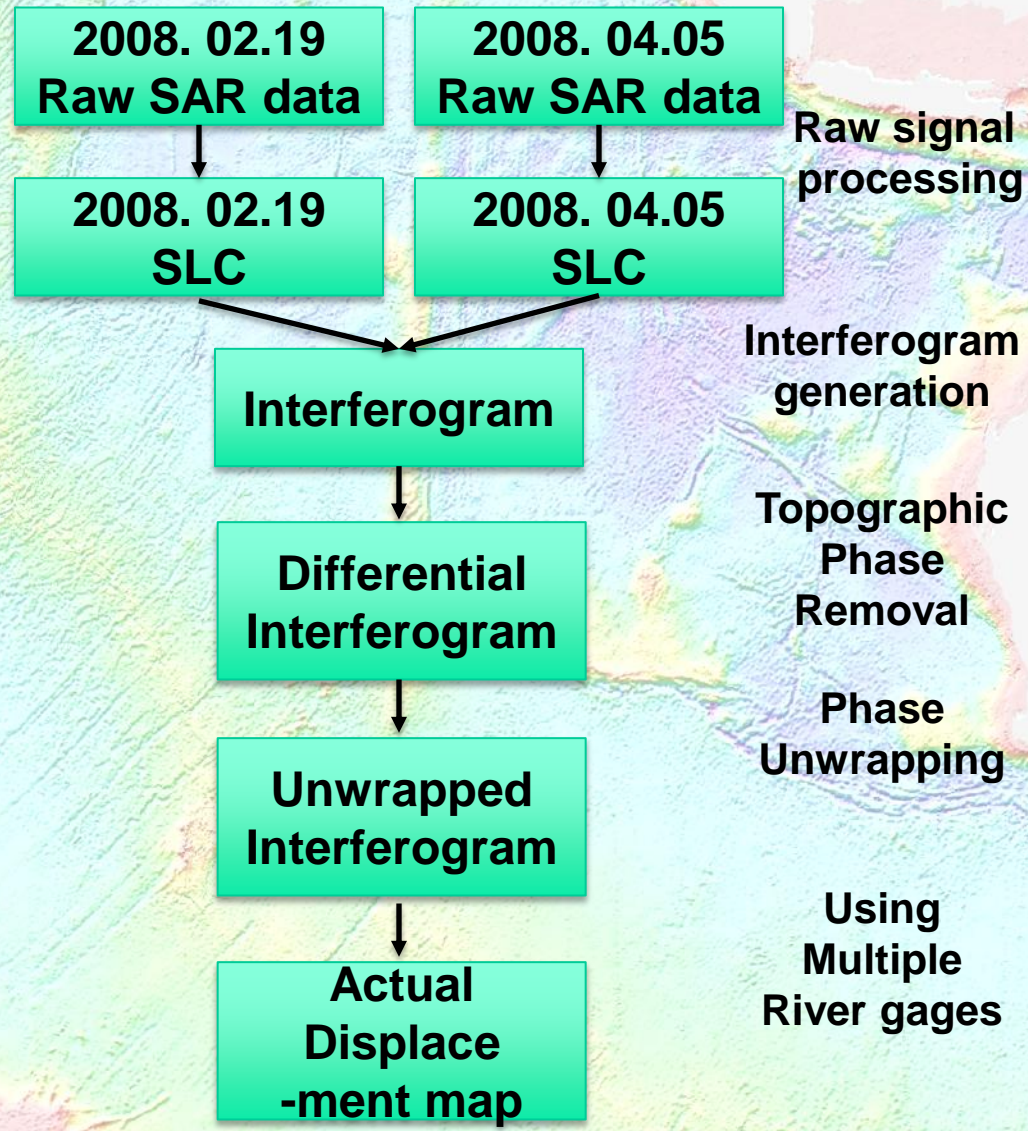
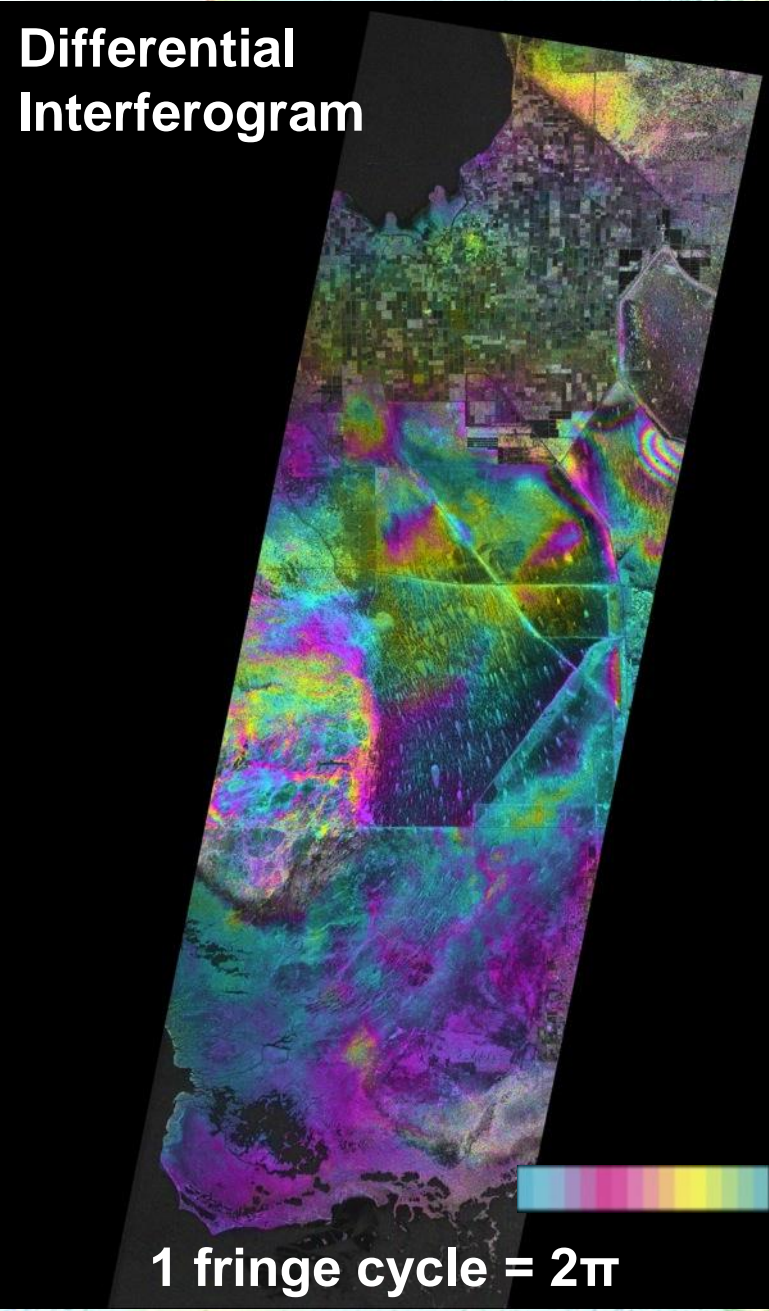
**P466: 2009.12.11 ~  
2010.04.28**

**Subswath 3**



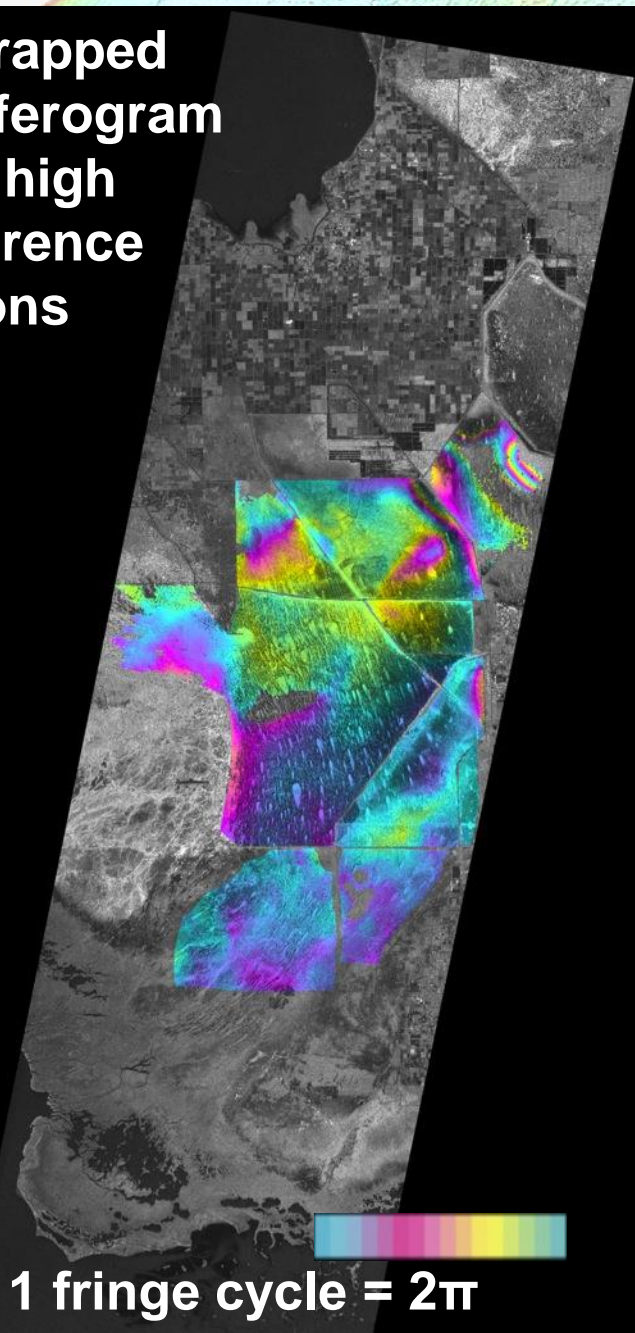
**P466: 2010.03.13 ~  
2010.07.29**

# 1. P465: 2008.02.19 ~ 2008.04.05



Temporal baseline: 46 days  
Perpendicular baseline: 157.62 m

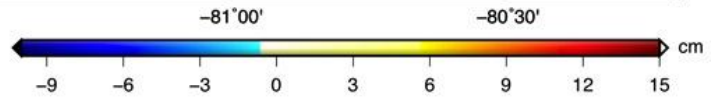
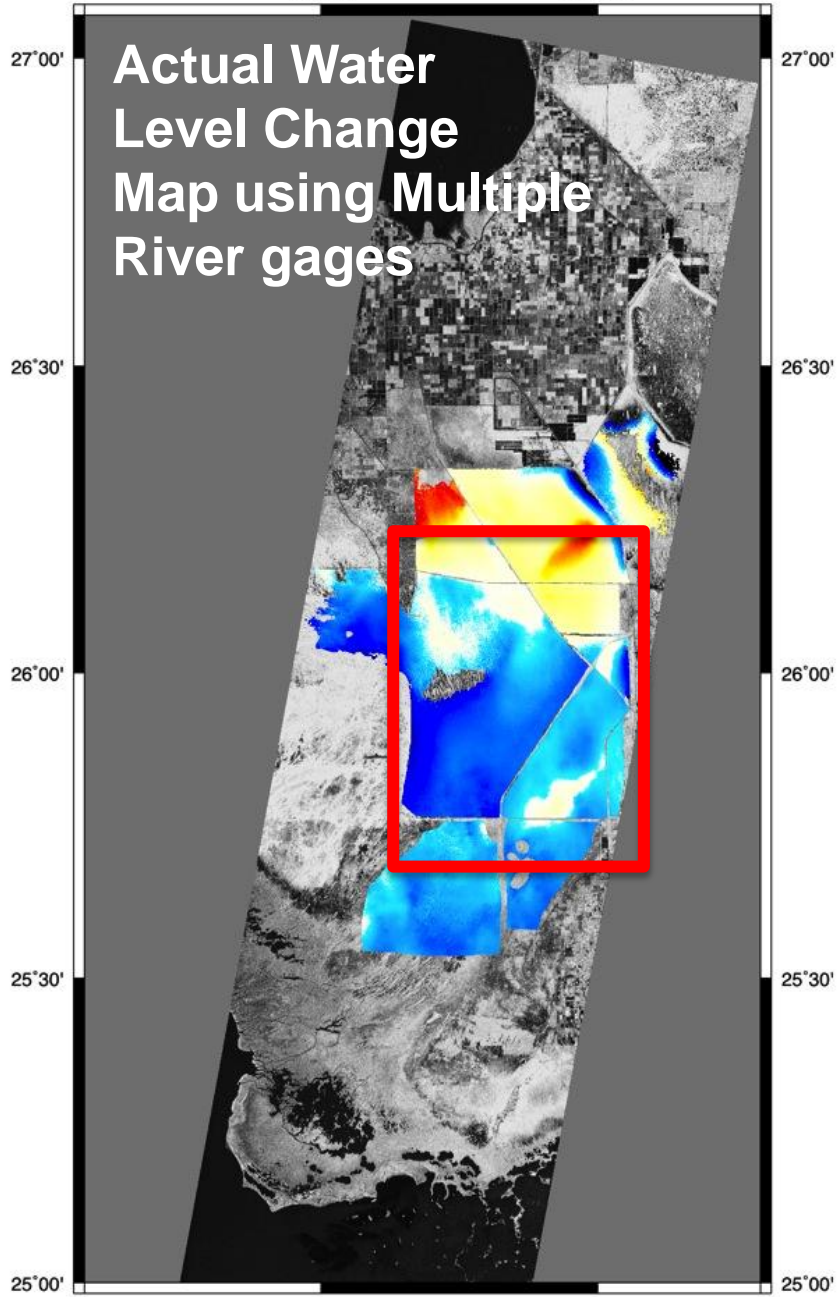
**Unwrapped  
Interferogram  
over high  
coherence  
regions**



**1 fringe cycle =  $2\pi$**

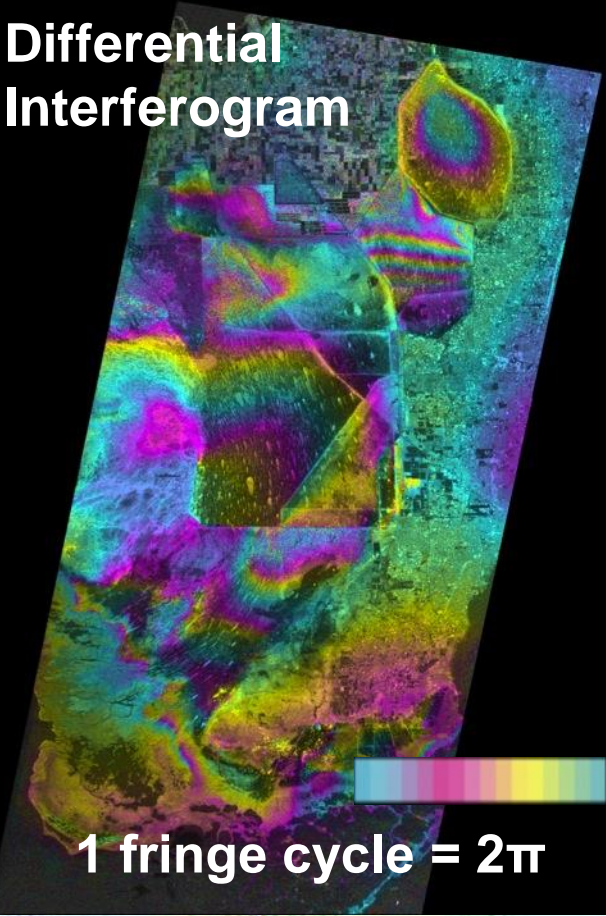


**Actual Water  
Level Change  
Map using Multiple  
River gages**

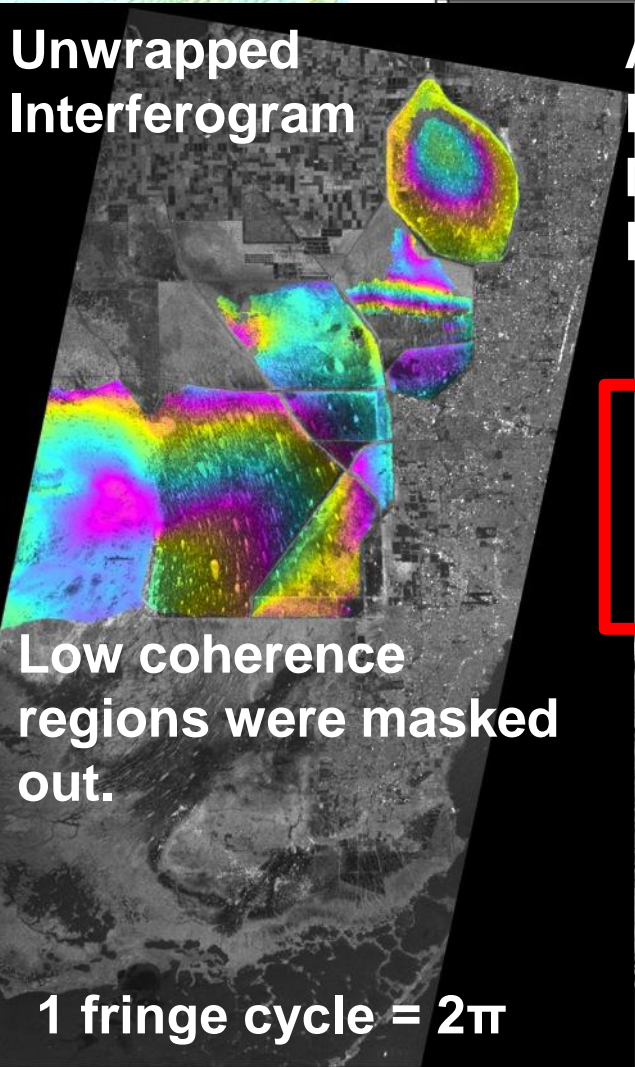


# 2. P466: 2009.12.11 ~ 2010.04.28

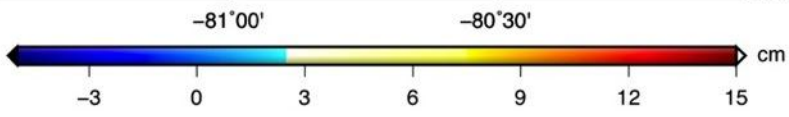
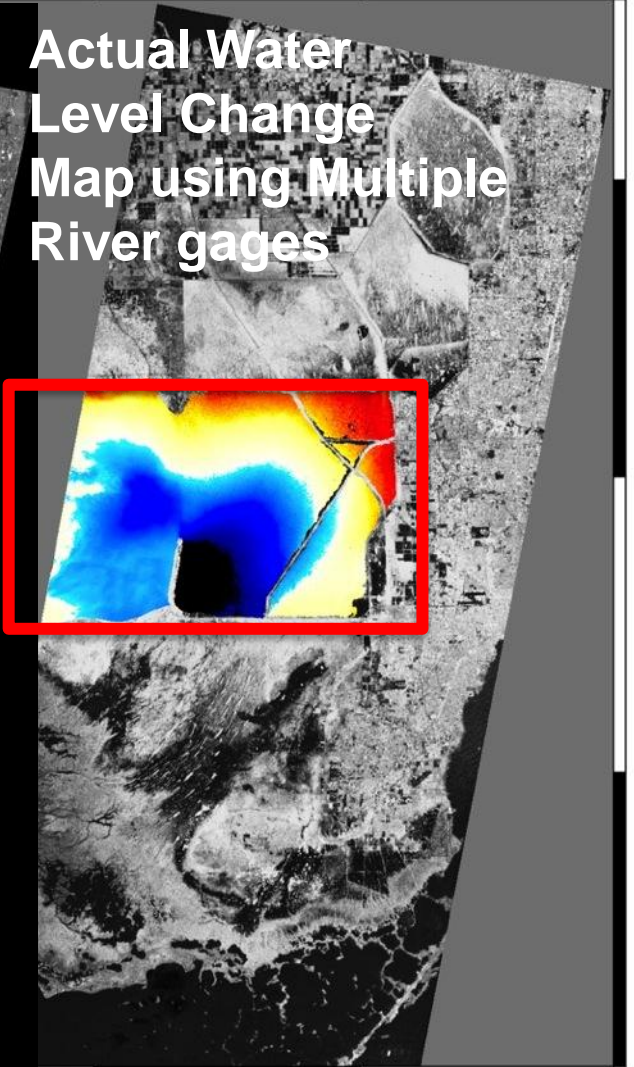
Differential Interferogram



Unwrapped Interferogram



Actual Water Level Change Map using Multiple River gages



Temporal baseline: 138 days  
Perpendicular baseline: 832.11 m

### 3. P466: 2010.03.13 ~ 2010.07.29

Differential Interferogram

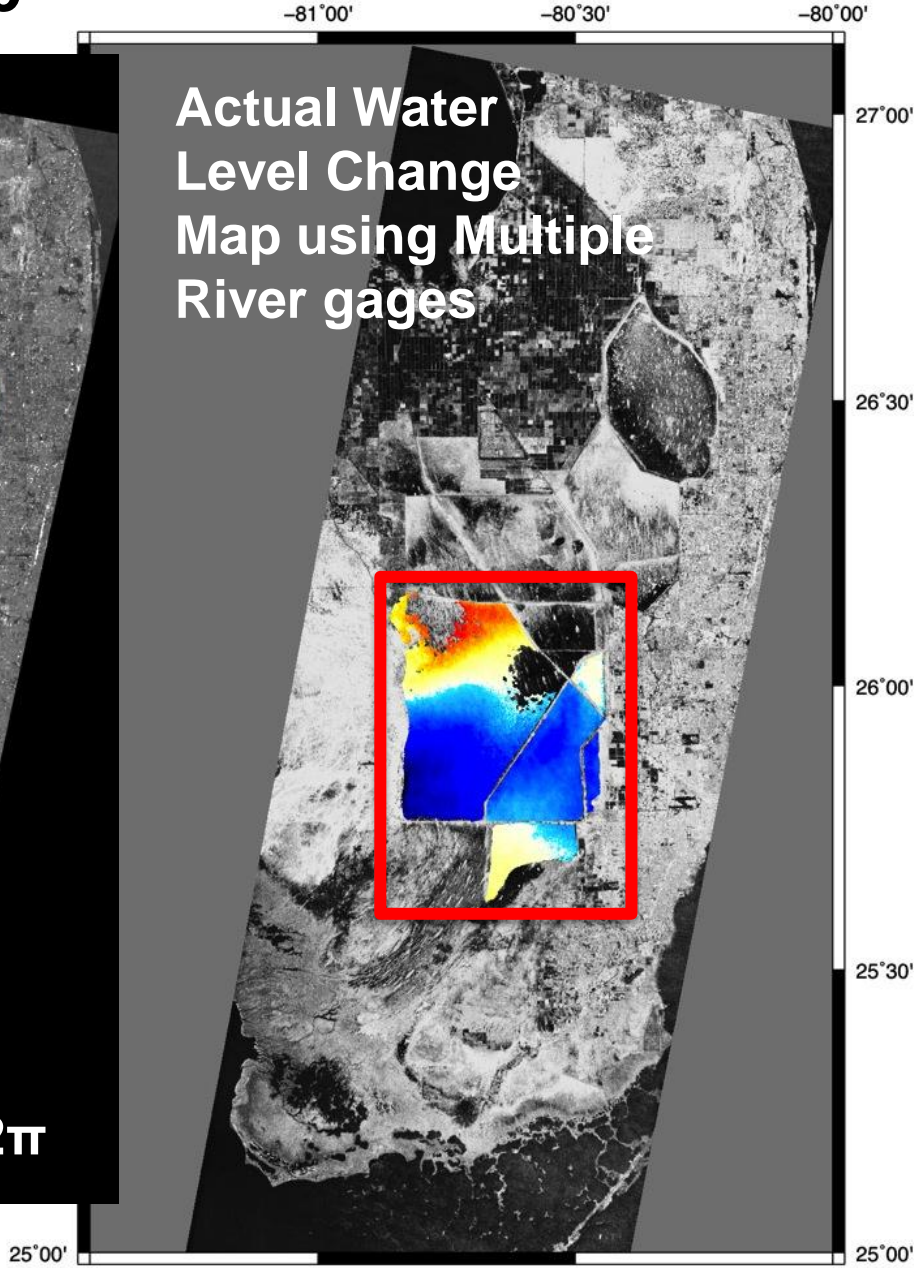
1 fringe cycle =  $2\pi$

Unwrapped Interferogram

1 fringe cycle =  $2\pi$

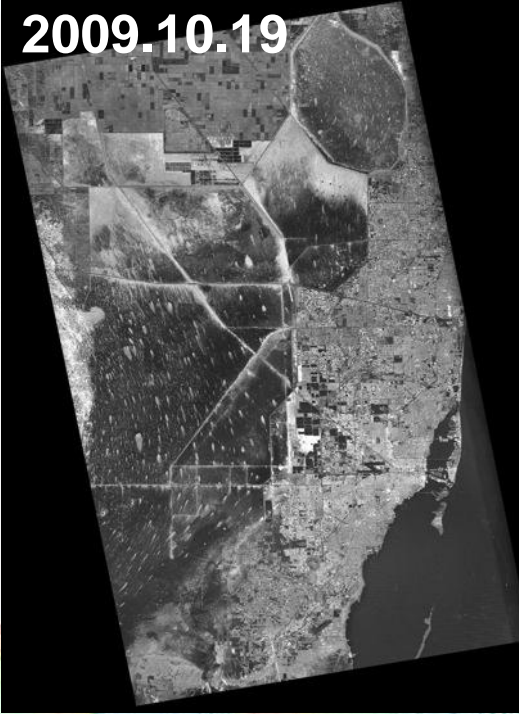
Actual Water Level Change Map using Multiple River gages

Temporal baseline: 138 days  
Perpendicular baseline: 436.3 m



# Available Fine-Beam Interferometry pairs (Ascending track)

**2009.10.19**



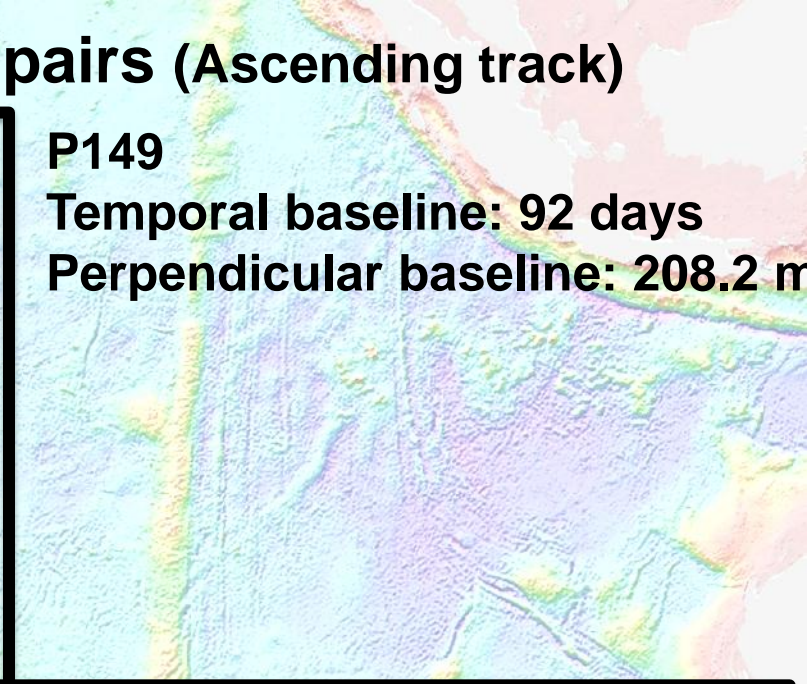
**2010.01.19**



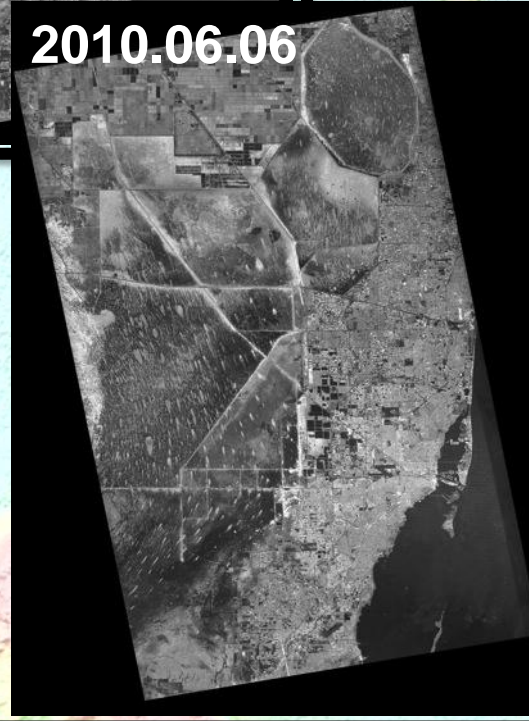
**P149**

**Temporal baseline: 92 days**

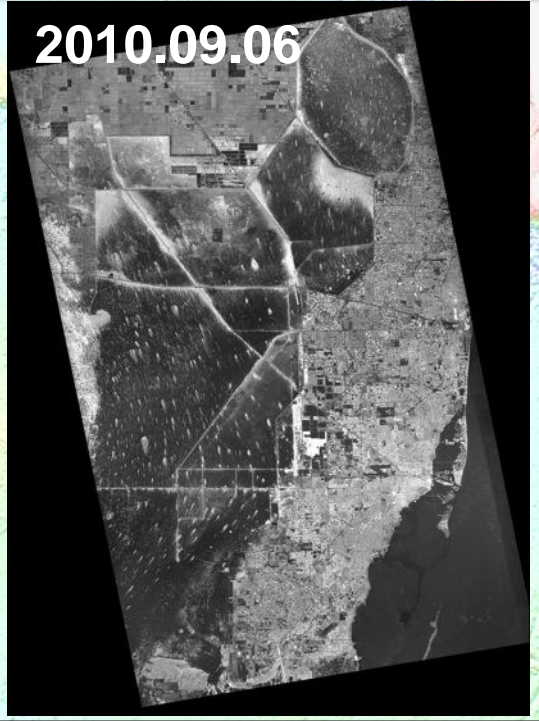
**Perpendicular baseline: 208.2 m**



**2010.06.06**



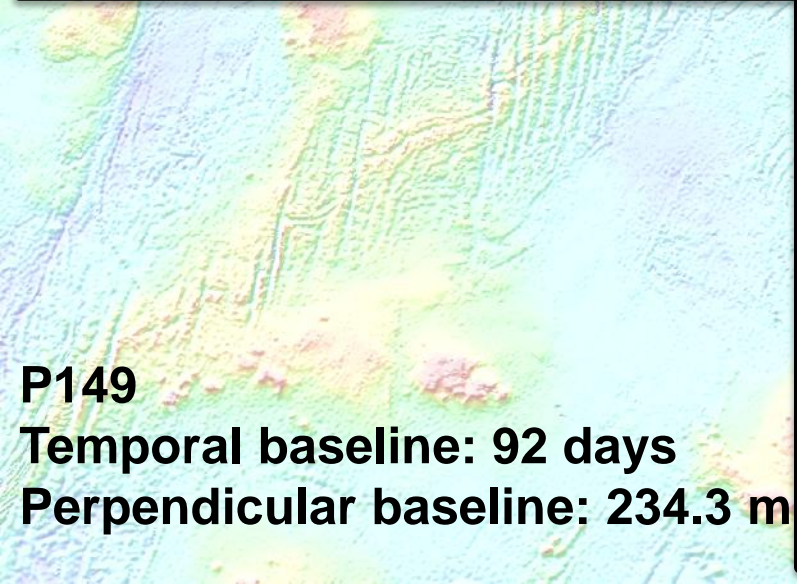
**2010.09.06**



**P149**

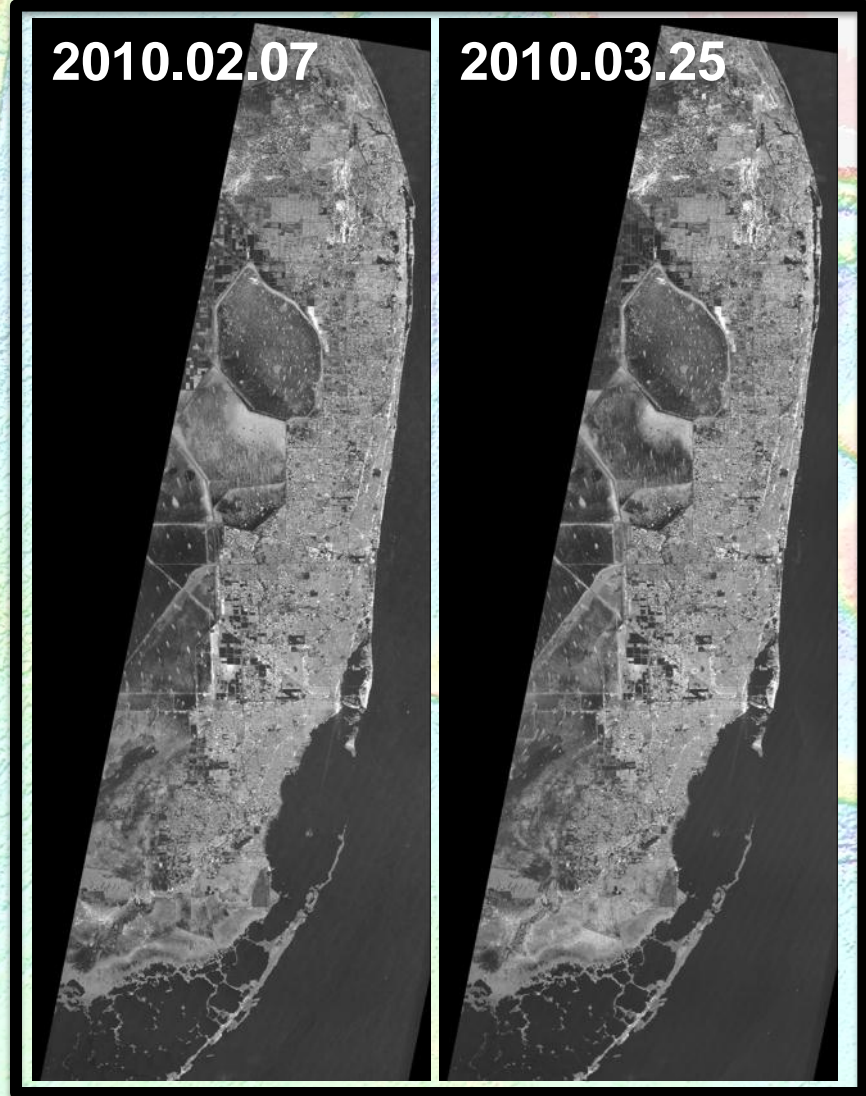
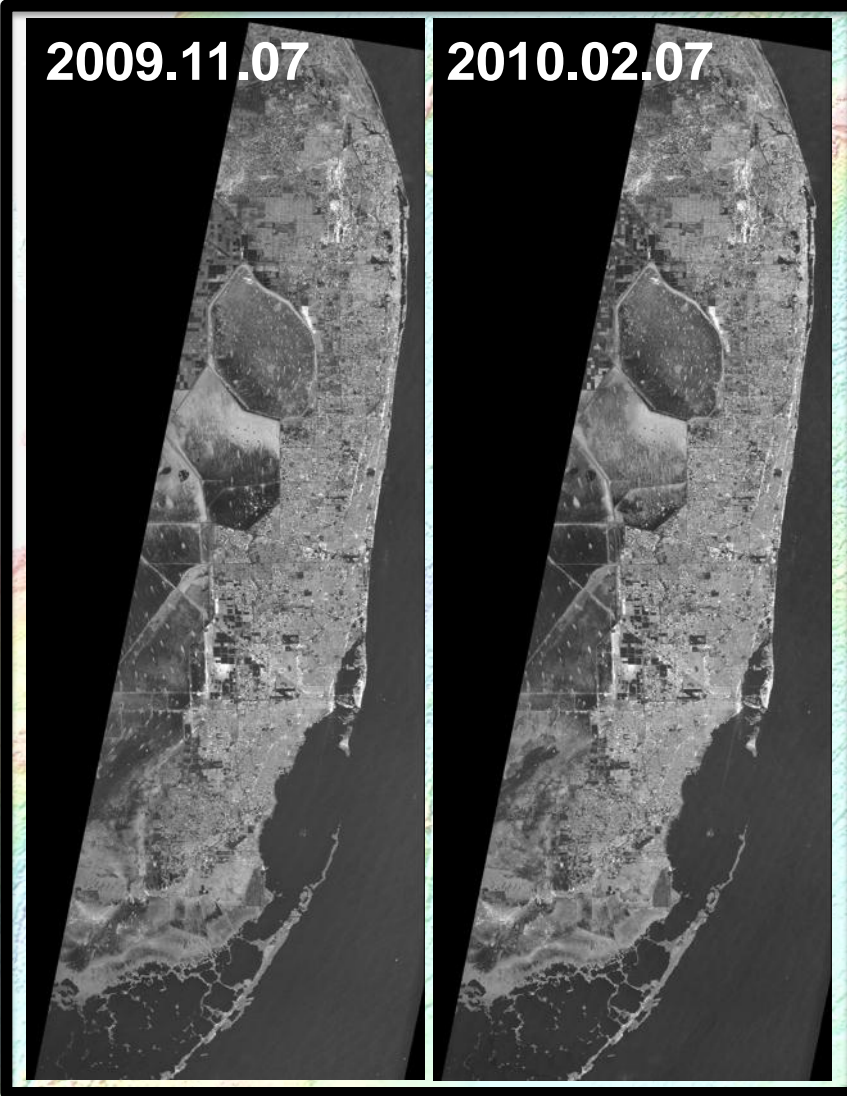
**Temporal baseline: 92 days**

**Perpendicular baseline: 234.3 m**





# Available Fine-Beam Interferometry pairs (Descending track)

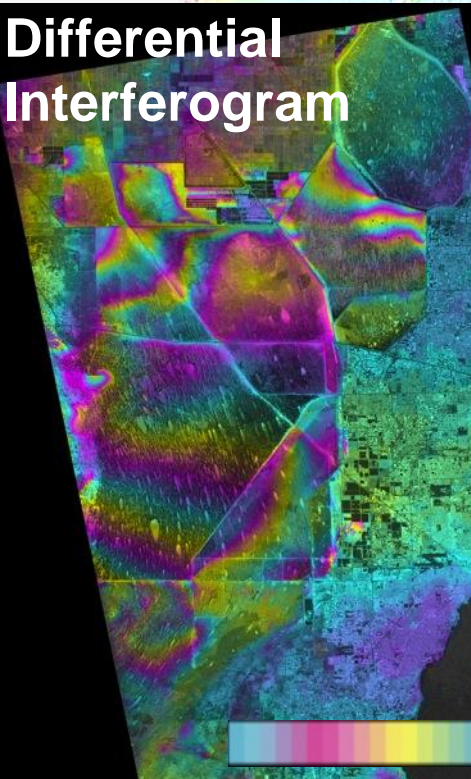


**P464** Temporal baseline: 92 days  
Perpendicular baseline: 474.5 m

Temporal baseline: 46 days  
Perpendicular baseline: 301.36 m

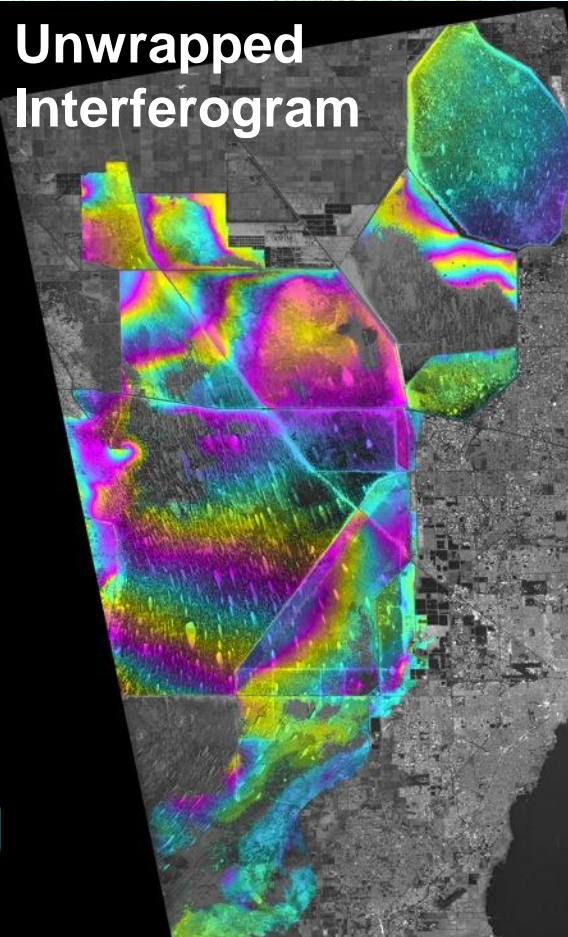
# 1. P149: 2009.10.19 ~ 2010.01.19

Differential Interferogram

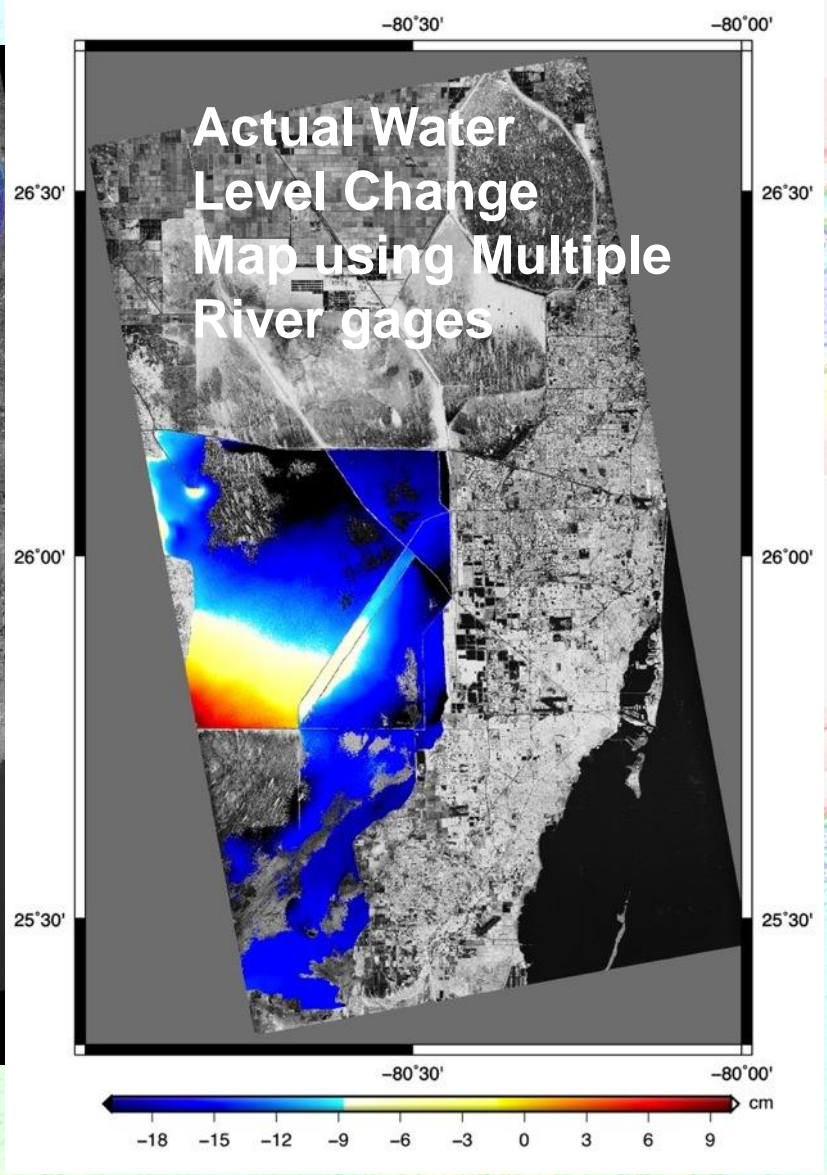


1 fringe cycle =  $2\pi$

Unwrapped Interferogram

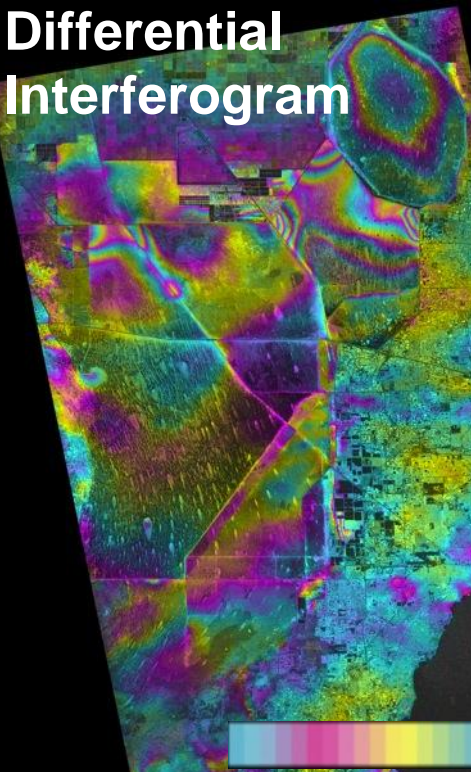


1 fringe cycle =  $2\pi$



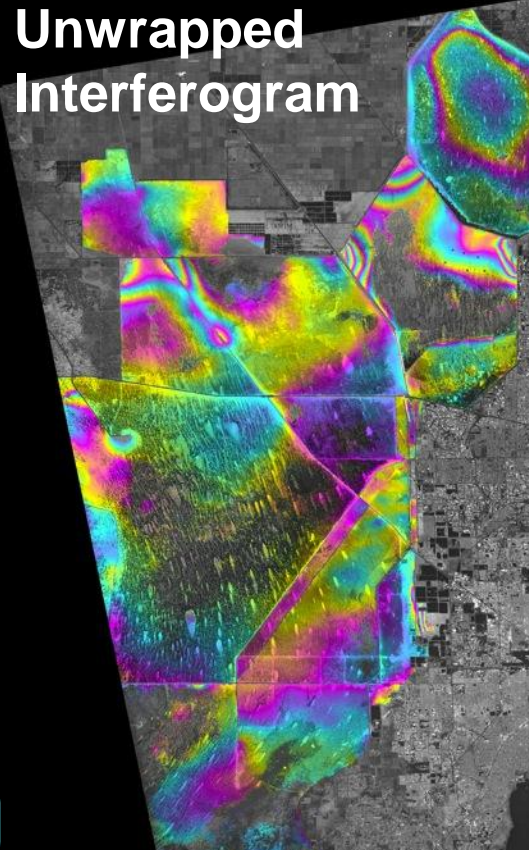
# 2. P149: 2010.06.06 ~ 2010.09.06

Differential Interferogram

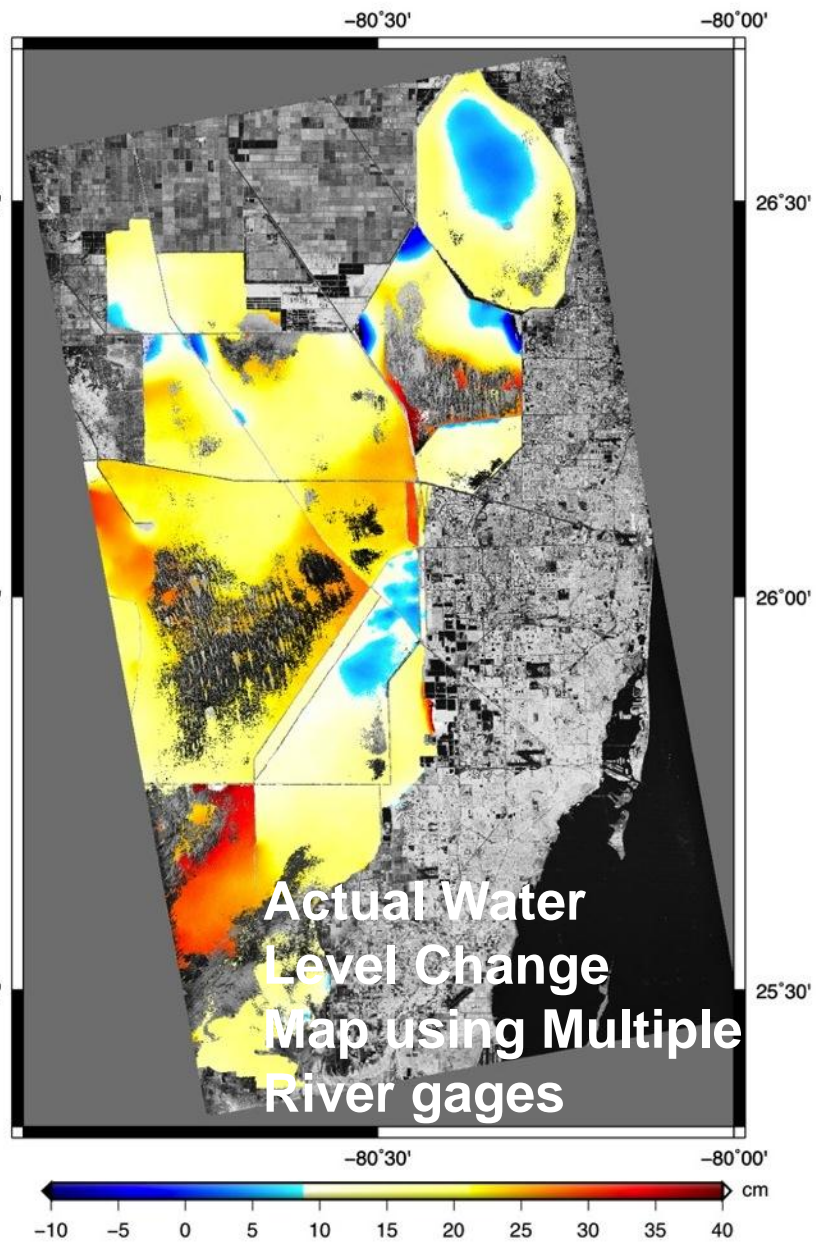


1 fringe cycle =  $2\pi$

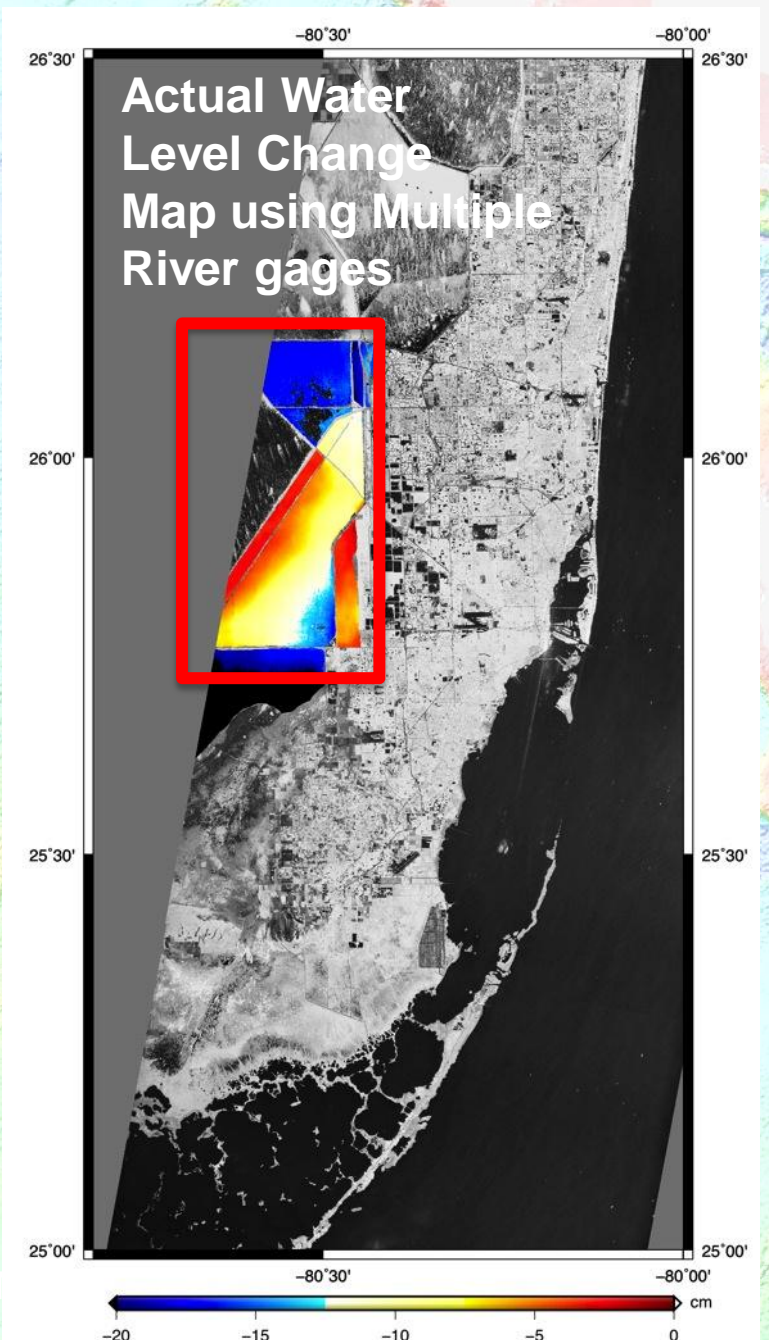
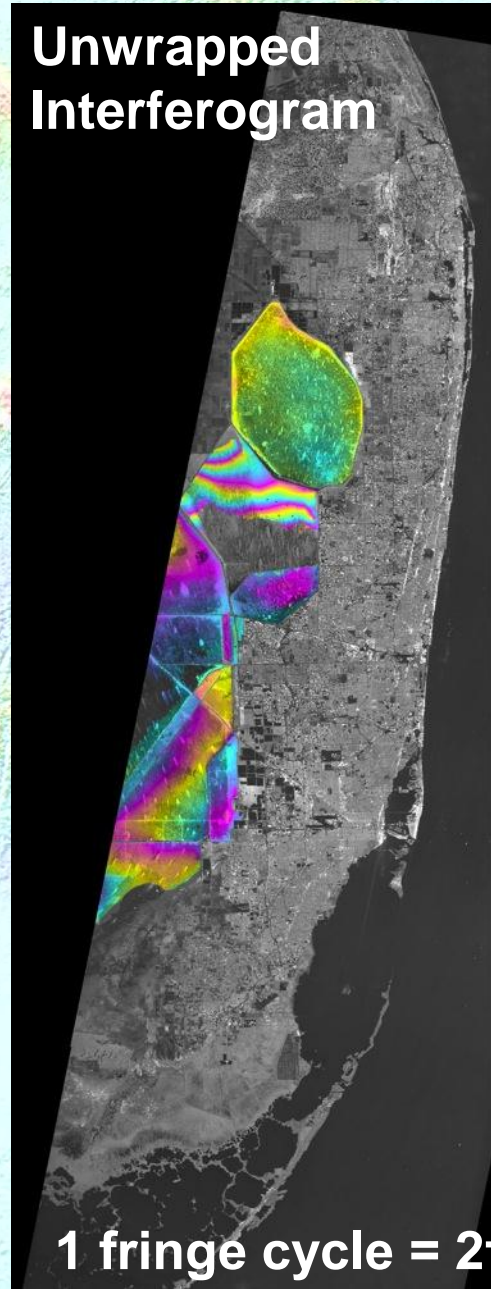
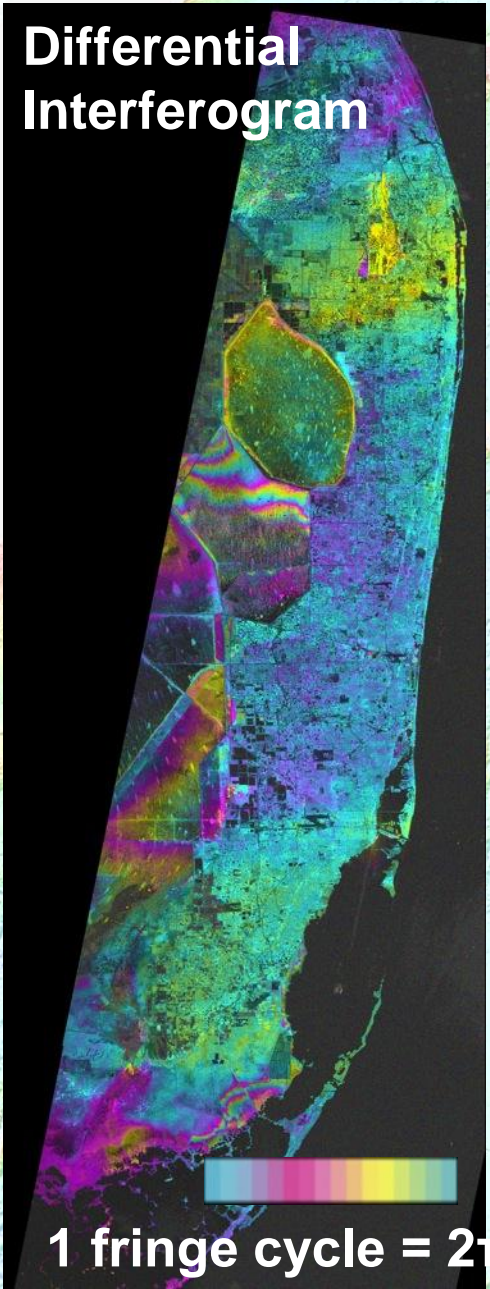
Unwrapped Interferogram



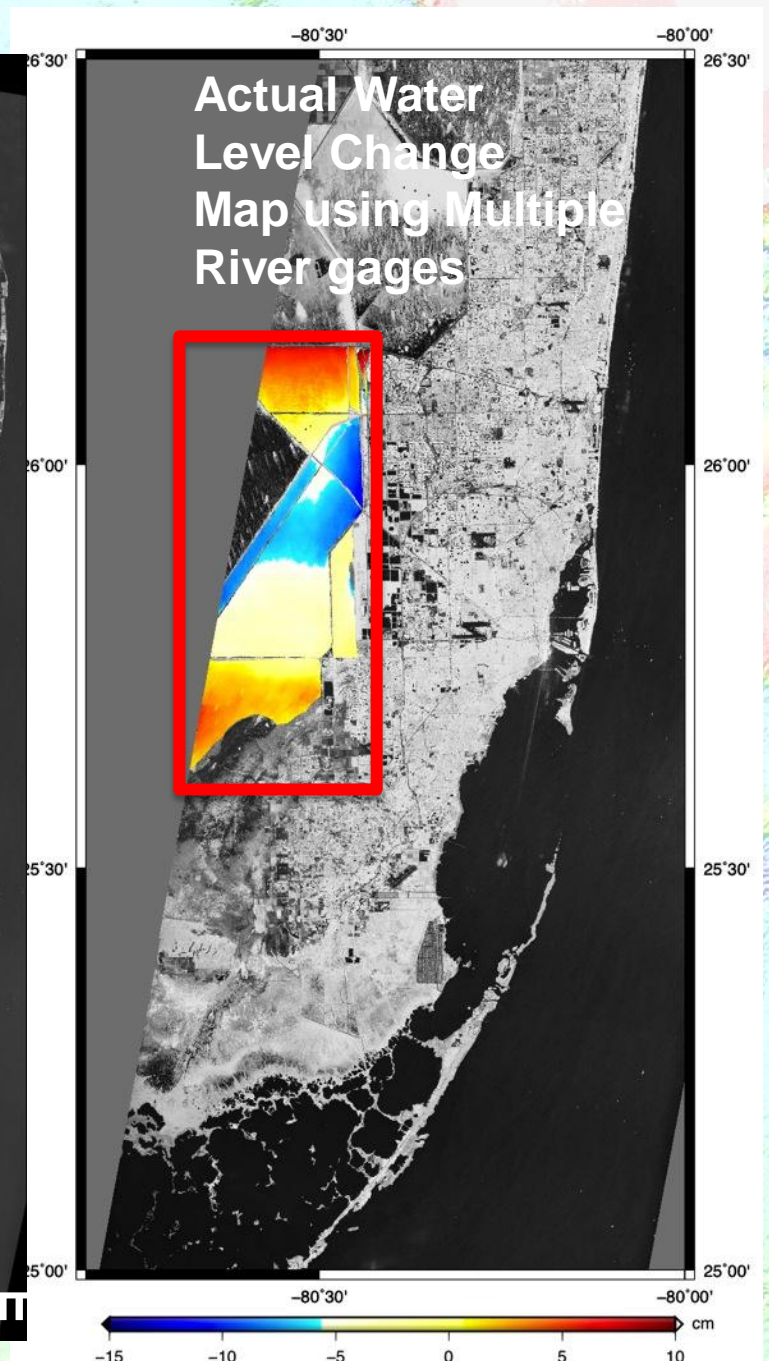
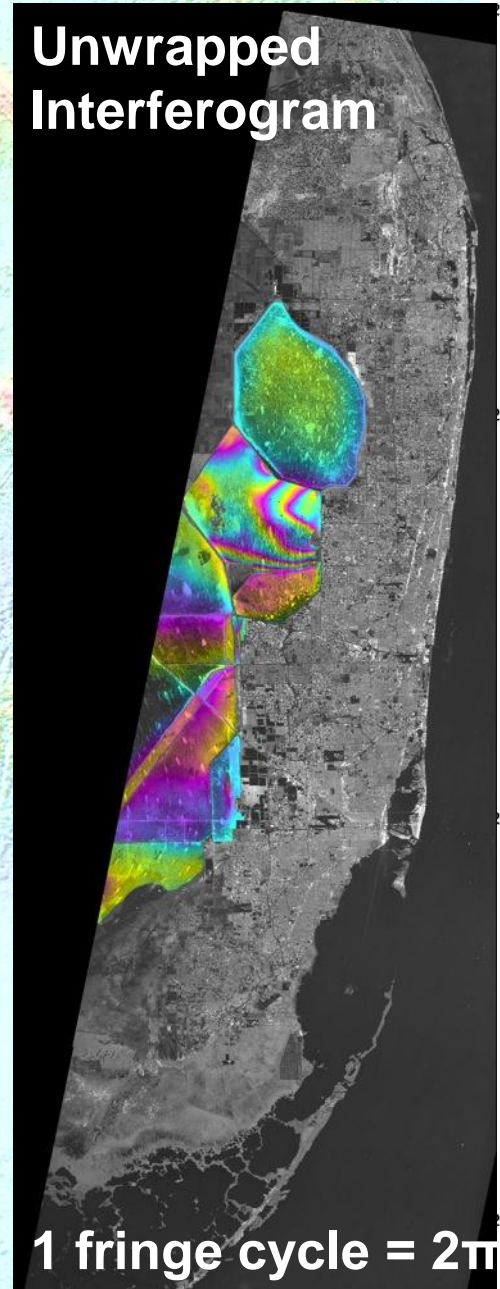
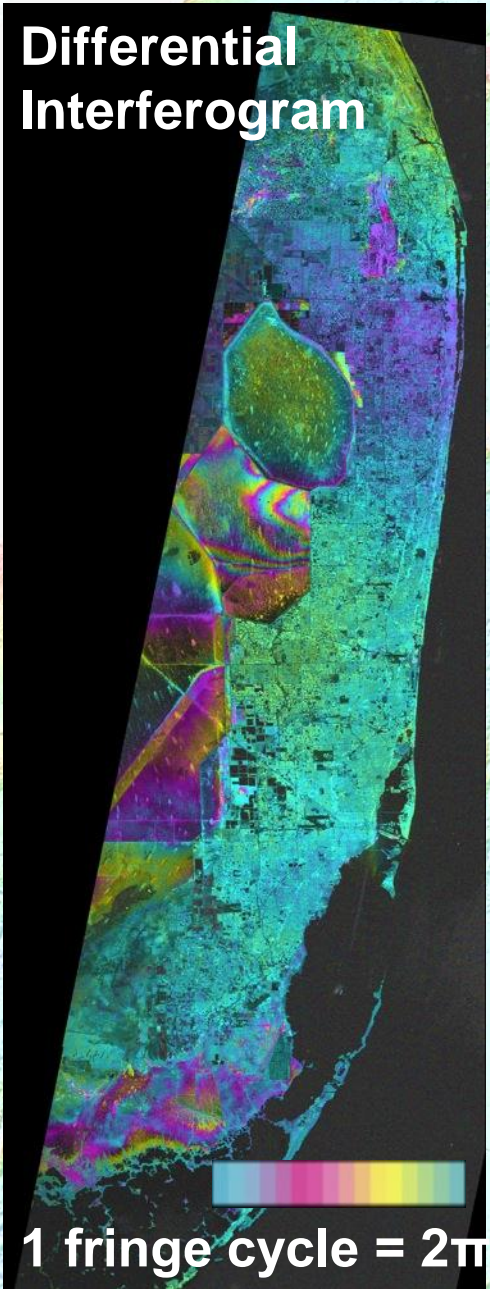
1 fringe cycle =  $2\pi$



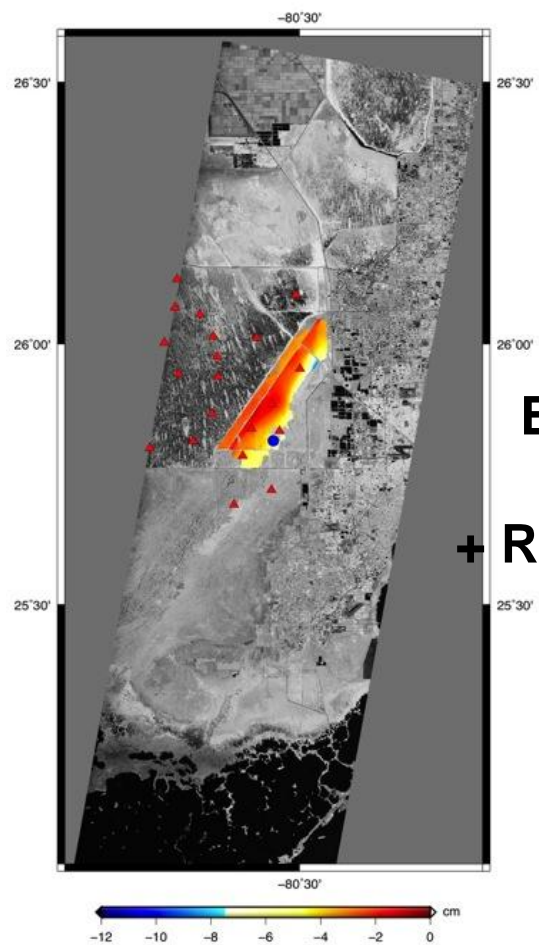
### 3. P464: 2009.11.07 ~ 2010.02.07



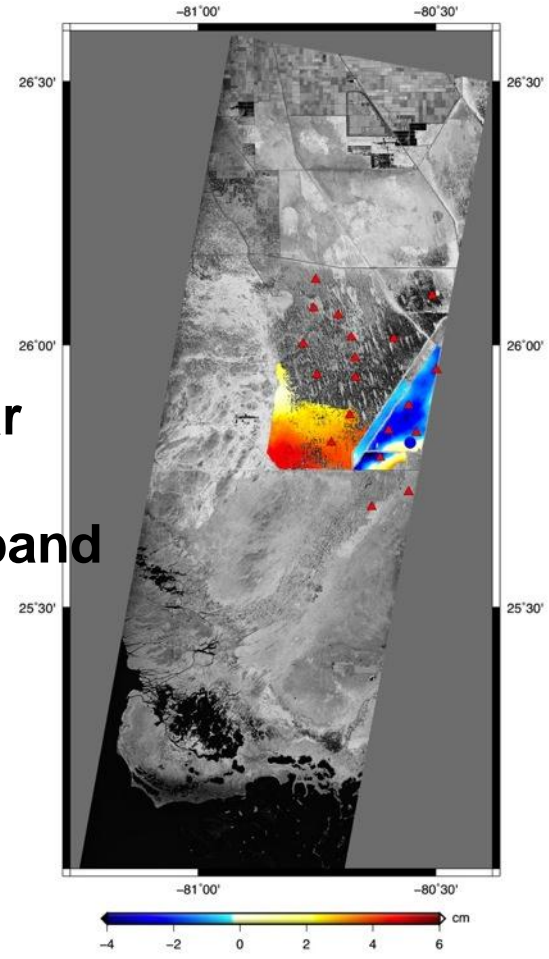
# 4. P464: 2010.02.07 ~ 2010.03.25



# Combination of ENVISAT altimetry and C-band InSAR product



**ENVISAT radar altimetry + Radarsat-1 C-band**



**Blue circle: ENVISAT radar altimetry**

**2007. 12. 26 ~ 2008. 01. 19**

**Accuracy (evaluated at gages): 0.99 cm**

**2007. 12. 22 ~ 2008. 01. 15**

**Accuracy (evaluated at gages): 1.54 cm**

# CONCLUSIONS

- **Satellite altimeter (Envisat) can successfully measure water height changes as well as monitor inundated region over the Everglades wetlands.**
- **SAR (ALOS; ScanSAR, Finebeam) can successfully classify inundated area.**
- **InSAR (ALOS; ScanSAR-ScanSAR, Finebeam-Finebeam) can detect high-resolution (100 m or 40 m) 2-D water height change map using gauge or altimeter measurements as a reference.**