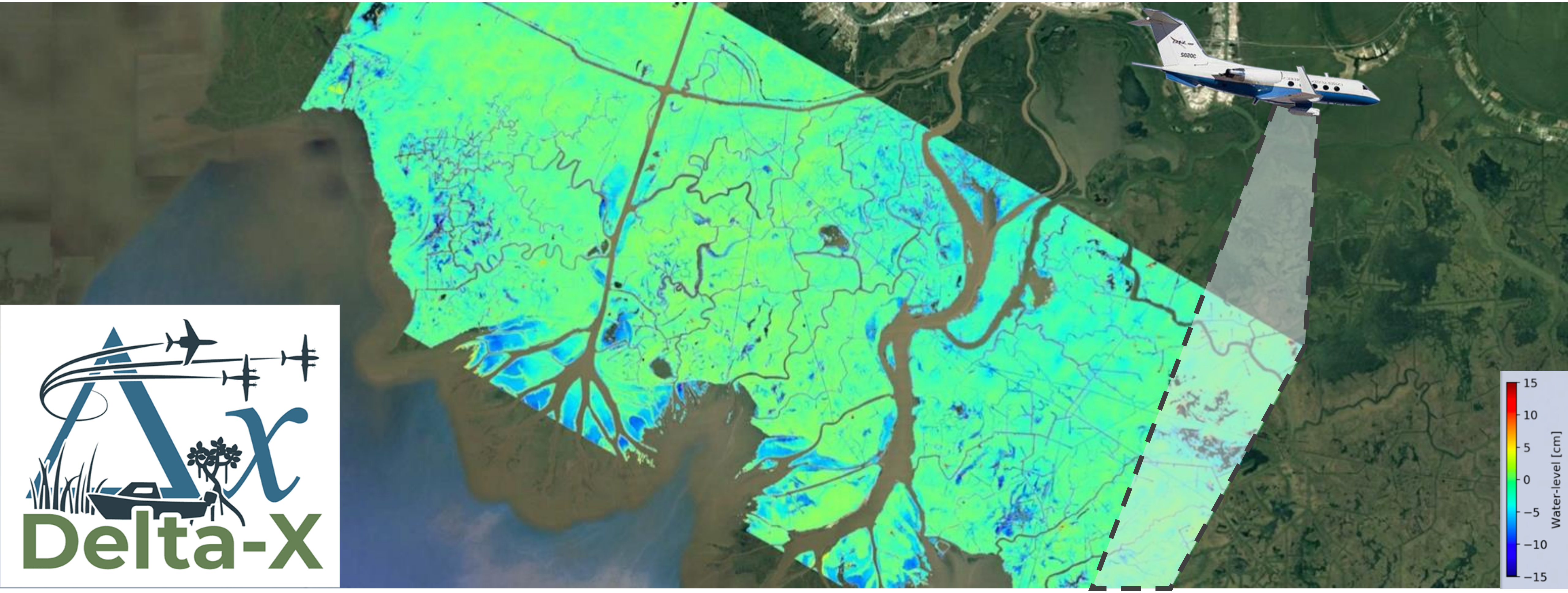


Delta-X Open Data Workshop (JPL June 5, 2023)

UAVSAR InSAR-derived water level change

Authors: Talib Oliver-Cabrera, Cathleen E. Jones, Marc Simard & Bhuvan K. Varugu

Jet Propulsion Laboratory
California Institute of Technology

UAVSAR Data Delivery Summary

- UAVSAR acquisitions
  - Spring campaign:
    - 137 nominal lines
    - Acquired between March 27 – April 18, 2021
  - Fall campaign
    - 83 nominal lines
    - Acquired between September 3 – 13, 2021
  - 6 stacks for each campaign

- UAVSAR Delta-X deliverables

Level	UAVSAR Deliverable Products	Volume (GB)	File in dataset
1	UAVSAR single-look complex (SLC) STACK product, quad-polarized	6000	1460
	UAVSAR coregistered interferometric products in radar coordinates (interferogram, coherence, unwrapped phase, ancillary)	210	1924
2	UAVSAR georeferenced interferometric products (interferogram, coherence, unwrapped phase, ancillary)	486	1924
3	UAVSAR water level change vs. time, georeferenced	69	293
	UAVSAR channels >10 m wide, georeferenced	0.022	2

L1 Single Look Complex (SLC) quad-polarized

The L1 dataset contains SLC stack products for all the acquired Delta-X flight lines during the spring campaign (03/27/2021 to 04/18/2021) and fall (09/03/2021 to 09/13/2021) campaigns.

These L1 UAVSAR products are delivered with all polarizations (quad-pol = HH, HV, VH, and VV)

Spring campaign

UAVSAR flight line	Date	Number of acquisitions
atchaf_06309	2021/03/27	8
	2021/04/01	7
	2021/04/02	9
atchaf_19809	2021/03/27	9
	2021/04/01	9
	2021/04/02	9
wterre_16300	2021/04/05	8
	2021/04/06	7
	2021/04/07	7
wterre_34202	2021/04/05	8
	2021/04/06	6
	2021/04/07	8
eterre_08705	2021/04/12	8
	2021/04/16	6
	2021/04/18	7
eterre_27309	2021/04/12	7
	2021/04/16	7
	2021/04/18	7

Total SAR acquisitions = 137

Fall campaign

UAVSAR flight line	Date	Number of acquisitions
atchaf_06309	2021/09/05	9
	2021/09/13	2
atchaf_19809	2021/09/05	9
	2021/09/13	4
wterre_16300	2021/09/03	6
	2021/09/12	7
wterre_34202	2021/09/03	7
	2021/09/12	8
eterre_08705	2021/09/04	8
	2021/09/07	8
eterre_27309	2021/09/04	8
	2021/09/07	7

Total SAR acquisitions = 83

A single image product from the UAVSAR SLC stack product atchaf_19809_02 collected on March 27, 2021, over the Atchafalaya Basin, Louisiana. The image shows the amplitude of the HH-polarization SLC data in radar coordinates.

https://daac.ornl.gov/cgi-bin/dsviewer.pl?ds_id=1984

L1 Single Look Complex (SLC) quad-polarized

Delta-X application workshop tutorial
github.com/ornldaac/deltax_workshop_2022/blob/main/tutorials/deltax_applications_workshop/deltax_l1_slc.ipynb

Exploring SLC L1 products

In this notebook we take a look at the Single Look Complex (SLC) RADAR images acquired by UAVSAR for the Delta-X campaign.

```
To access the data please visit ORNL DAAC https://daac.ornl.gov/
```

L1 SLC Data Characteristics

Link to dataset

https://daac.ornl.gov/DELTAX/guides/DeltaX_L1_UAVSAR_SLC_Stack.html

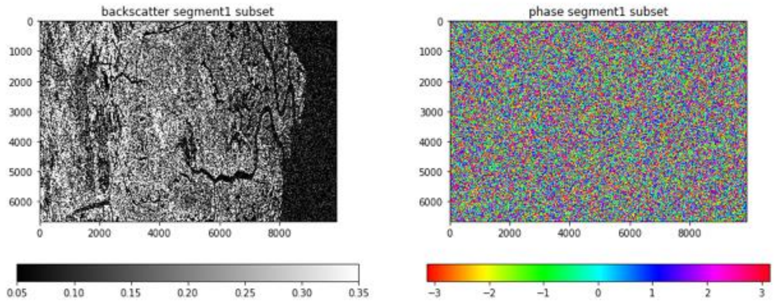
Data File Information

This dataset contains UAVSAR Level 1 (L1) Single Look Complex (SLC) stack products for Delta-X flight lines. This L1 dataset is intended for users who are familiar with data from synthetic aperture radar, especially products from UAVSAR (https://uavsar.jpl.nasa.gov/). Contact UAVSAR for detailed information on how to interpret the files (https://uavsar.jpl.nasa.gov/cgi-bin/contact.pl).

These L1 data contain slant range single look complex (SLC), latitude/longitude/height, look vector, doppler, and metadata files. The data are provided in SLC stack format (.slc) *with associated annotation* (.ann), latitude-longitude-height (*.llh), look vector (*.lkv), and Doppler centroid-slant range (*.dop) files. The single look complex (SLC) stacks are in the HH, HV, VH, and VV polarizations. The same area was sampled at approximately 30-minute intervals. The SLCs are not corrected for residual baseline (BU).

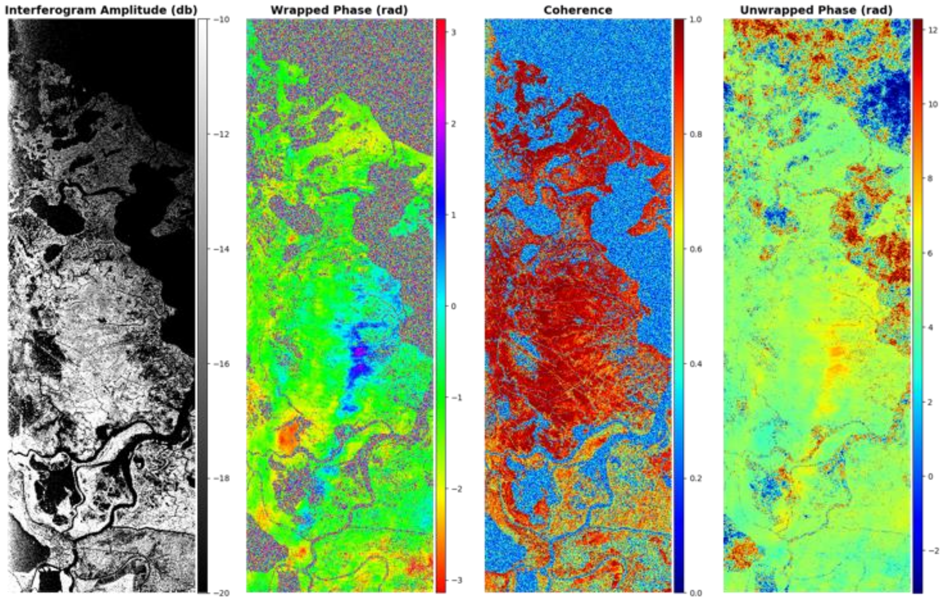
- Spatial Coverage: Atchafalaya River and Terrebonne Basins in southern Louisiana
- Spatial Resolution: 0.8m (along- flight-line) by 1.7 m (slant range, along line-of-sight (LOS))
- Temporal Coverage: 2021-03-27 to 2021-04-18 and 2021-09-05 to 2021-09-13
- Temporal Resolution: estimates at 30-minute intervals
- File naming convention:

```
## Plot a subset
# fig = plt.figure(figsize=(14, 12))
# # display backscatter of the slc
# ax = fig.add_subplot(2,2,1)
# cax = ax.imshow(backscatter_seg1[60000:,0:], vmin=0.05, vmax=0.35, c
# ax.set_title("backscatter segment1 subset")
# cbar = fig.colorbar(cax, orientation='horizontal')
# #display phase of the slc
# ax = fig.add_subplot(2,2,2)
# cax = ax.imshow(phase_seg_1[60000:,0:], cmap='hsv')
# ax.set_title("phase segment1 subset")
# cbar = fig.colorbar(cax, orientation='horizontal')
# # display backscatter of the slc
# ax = fig.add_subplot(2,2,3)
# cax = ax.imshow(backscatter_seg2[50000:,0:], vmin=0.05, vmax=0.35, cmap='gray')
# ax.set_title("backscatter segment2 subset")
# cbar = fig.colorbar(cax, orientation='horizontal')
# #display phase of the slc
# ax = fig.add_subplot(2,2,4)
# cax = ax.imshow(phase_seg_2[50000:,0:], cmap='hsv')
# ax.set_title("phase segment2 subset")
# cbar = fig.colorbar(cax, orientation='horizontal')

# plt.show()
# plt.close("all")
```

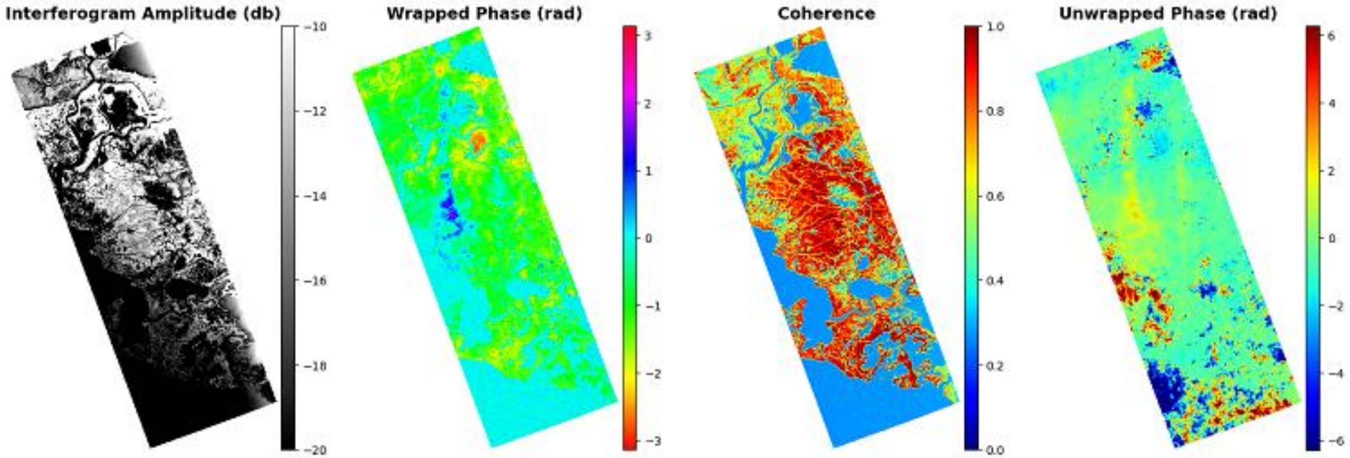


L1b and L2 Interferometric products

The wrapped InSAR interferograms and interferometric coherence products were generated for nearest-neighbor (NN), NN+1, and NN+2 pairs for VV-polarization data acquired within a single flight (one day).



- Interferometric amplitude.
- Wrapped interferometric phase.
- Interferometric coherence.
- Unwrapped interferometric phase products.



https://daac.ornl.gov/cgi-bin/dsviewer.pl?ds_id=1979
https://daac.ornl.gov/cgi-bin/dsviewer.pl?ds_id=2057

L1b and L2 Interferometric products

Spring campaign

UAVSAR flight line	Date	Number of acquisitions	Number of interferograms
atchaf_06309	2021/03/27	8	18
	2021/04/01	7	15
	2021/04/02	9	21
atchaf_19809	2021/03/27	9	21
	2021/04/01	9	21
	2021/04/02	9	21
wterre_16300	2021/04/05	8	18
	2021/04/06	7	15
	2021/04/07	7	15
wterre_34202	2021/04/05	8	18
	2021/04/06	6	12
	2021/04/07	8	18
eterre_08705	2021/04/12	8	18
	2021/04/16	6	12
	2021/04/18	7	15
eterre_27309	2021/04/12	7	15
	2021/04/16	7	15
	2021/04/18	7	15

Total interferograms = 303

Fall campaign

UAVSAR flight line	Date	Number of acquisitions	Number of interferograms
atchaf_06309	2021/09/05	9	21
	2021/09/13	2	1
atchaf_19809	2021/09/05	9	21
	2021/09/13	4	6
wterre_16300	2021/09/03	6	12
	2021/09/12	7	15
wterre_34202	2021/09/03	7	15
	2021/09/12	8	18
eterre_08705	2021/09/04	8	18
	2021/09/07	8	18
eterre_27309	2021/09/04	8	18
	2021/09/07	7	15

Total interferograms = 178

https://daac.ornl.gov/cgi-bin/dsviewer.pl?ds_id=1979
https://daac.ornl.gov/cgi-bin/dsviewer.pl?ds_id=2057

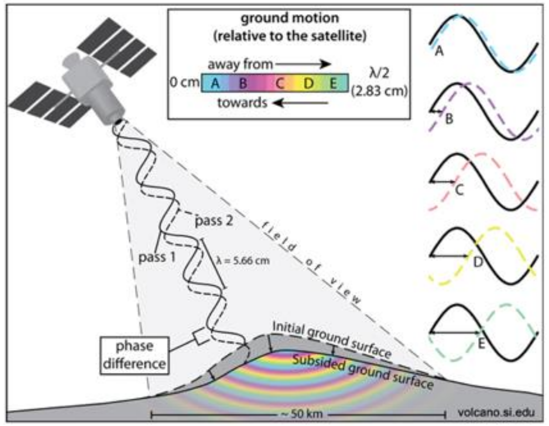
L1b and L2 Interferometric products

Delta-X application workshop tutorial

github.com/ornldaac/deltax_workshop_2022/blob/main/tutorials/deltax_applications_workshop/deltax_l1b_l2_interferograms.ipynb

Radar interferometry (InSAR)

Synthetic Aperture Radar (SAR) is a type of radar, generally mounted on a space or airborne platform. This system uses the platform flying path to simulate a very large antenna and produce high-resolution images. Interferometric synthetic aperture radar (InSAR) is a remote sensing technique that uses the difference of phase return between to SAR acquisitions taken over a same location in different time periods. Since SAR sensors are often mounted in satellite platforms, the InSAR technique is commonly used to observe changes in the Earth's surface (Bürgmann et al., 20000; Hansen et al., 2001; Rosen et al., 2000).



(Illustration explaining InSAR; source volcano.si.ed

Delta-X UAVSAR InSAR L1B data overview

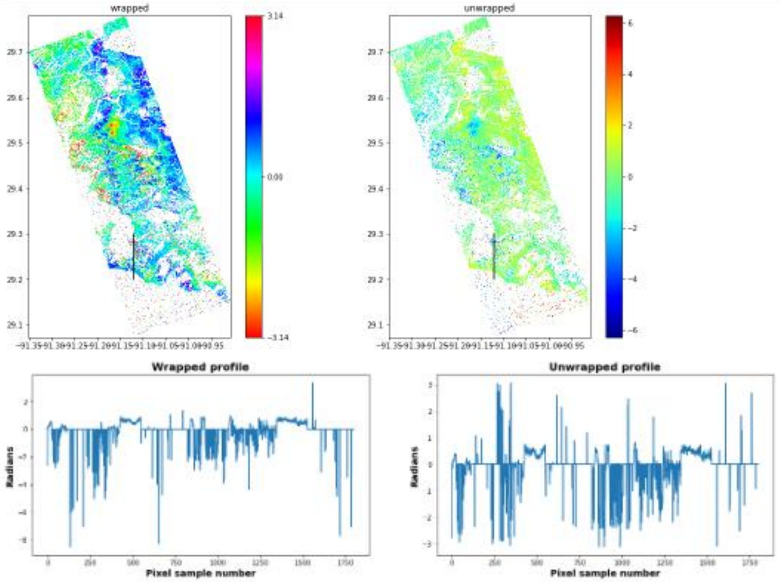
This dataset contains UAVSAR Level 1B (L1B) interferometric products for Delta-X flight lines acquired during the spring and fall deployments 2021-03-27 to 2021-04-18 and 09/03/2021 to 09/13/2021. The study area includes the Atchafalaya Basin, in Southern Louisiana, USA, within the Mississippi River Delta (MRD) floodplain.

(UAVSAR data coverage)

A set of nearest-neighbor (NN), NN+1, and NN+2 co-registered VV-polarization interferograms were generated from the quad-polarization SLC stack level-1 (L1) product using a combination of the InSAR Scientific Computing Environment (ISCE)(Rosen et al., 2012), the statistical-cost, network-flow algorithm for phase unwrapping (SNAPHU)(Chen et al., 2001), and previously developed python code. The data are provided in non-georeferenced ENVI file format and include:

In [24]:

```
# Define profile for wrapped and unwrapped phase
# Vertical profiles
geo_pf_w_int = geo_w_int_msk[8637:10437, 4172]
geo_pf_unw_int = geo_unw_int_msk[8637:10437, 4172]

fig = plt.figure(figsize=(16, 8))
ax = fig.add_subplot(1,2,1)
cax=ax.imshow(np.ma.masked_where(geo_w_int_msk==0, geo_w_int_msk), extent=geo_corners,
              interpolation='nearest', cmap='hsv')
ax.plot([-91.12, -91.12],[29.3, 29.2],'-k')
ax.set_title("wrapped")
cbar = fig.colorbar(cax, ticks=[-3.14, 0, 3.14],orientation='vertical')
ax = fig.add_subplot(1,2,2)
cax=ax.imshow(np.ma.masked_where(geo_unw_int_msk==0, geo_unw_int_msk), extent=geo_corners,
              interpolation='nearest', vmin=-6.28, vmax=6.28, cmap='jet')
ax.plot([-91.12, -91.12],[29.3, 29.2],'-k')
ax.set_title("unwrapped")
cbar = fig.colorbar(cax,orientation='vertical')
plt.show()

fig = plt.figure(figsize=(20,5))
ax = fig.add_subplot(1,2,1)
cax=ax.plot(geo_pf_unw_int)
ax.set_title("Wrapped profile", fontweight='bold', fontsize=16)
plt.xlabel("Pixel sample number", fontweight='bold', fontsize=14)
plt.ylabel("Radians", fontweight='bold', fontsize=14)
ax = fig.add_subplot(1,2,2)
cax=ax.plot(geo_pf_w_int)
ax.set_title("Unwrapped profile", fontweight='bold', fontsize=16)
plt.xlabel("Pixel sample number", fontweight='bold', fontsize=14)
plt.ylabel("Radians", fontweight='bold', fontsize=14)
plt.show()
plt.close("all")

geo_pf_w_int = None; geo_pf_unw_int = None
```



L3 InSAR derived water level change

Spring campaign

UAVSAR flight line	Date	Number of acquisitions	Number of interferograms
atchaf_06309	2021/03/27	8	18
	2021/04/01	7	15
	2021/04/02	9	21
atchaf_19809	2021/03/27	9	21
	2021/04/01	9	21
	2021/04/02	9	21
wterre_16300	2021/04/05	8	18
	2021/04/06	7	15
	2021/04/07	7	15
wterre_34202	2021/04/05	8	18
	2021/04/06	6	12
	2021/04/07	8	18
eterre_08705	2021/04/12	8	18
	2021/04/16	6	12
	2021/04/18	7	15
eterre_27309	2021/04/12	7	15
	2021/04/16	7	15
	2021/04/18	7	15

Total water level change time series = 18

Fall campaign

UAVSAR flight line	Date	Number of acquisitions	Number of interferograms
atchaf_06309	2021/09/05	9	21
	2021/09/13	2	1
atchaf_19809	2021/09/05	9	21
	2021/09/13	4	6
wterre_16300	2021/09/03	6	12
	2021/09/12	7	15
wterre_34202	2021/09/03	7	15
	2021/09/12	8	18
eterre_08705	2021/09/04	8	18
	2021/09/07	8	18
eterre_27309	2021/09/04	8	18
	2021/09/07	7	15

Total water level change time series = 11

https://daac.ornl.gov/cgi-bin/dsviewer.pl?ds_id=2058

L3 InSAR derived water level change

Delta-X application workshop tutorial

github.com/ornldaac/deltax_workshop_2022/blob/main/tutorials/deltax_applications_workshop/deltax_l3_wlc_time_steps.ipynb

L3 Data Characteristics

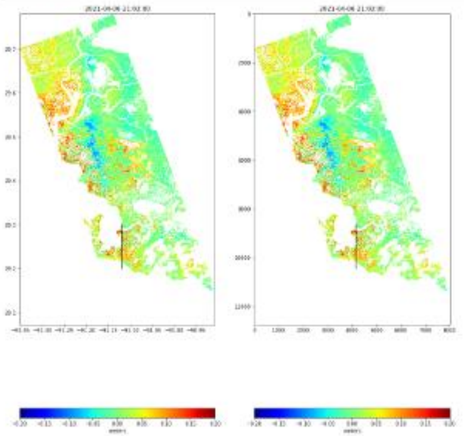
Data aplication and derivation

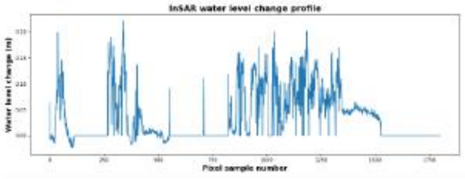
The UAVSAR interferometric products serve as maps of surface change throughout the wetland regions. This data is used to produce water level change time series measurements that are used to evaluate and compare hydrodynamic model performance.

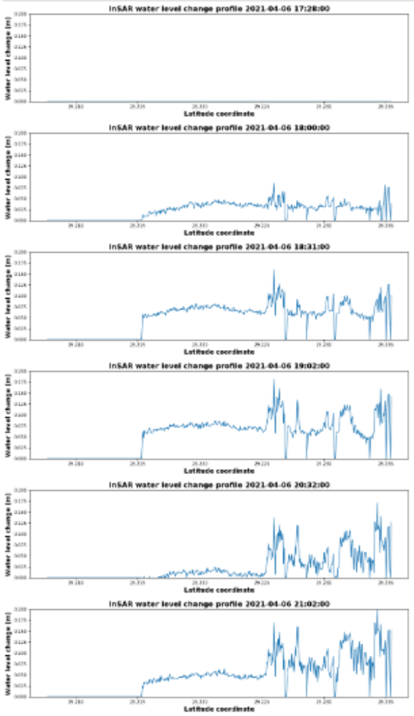
Data information

- Spatial Coverage: Atchafalaya River and Terrebonne Basins in southern Louisiana
- Spatial Resolution: 0.000063 degrees (approximately 6m)
- Temporal Coverage: 2021-03-27 to 2021-04-18 and 2021-09-05 to 2021-09-13
- Temporal Resolution: estimates at 30-minute intervals
- InSAR deriver water level change units: meters
- File naming convention:
  - Water level change naming convention: ssssss_IIIII_YYLLDDHHMM_yylldhhmm_vv_waterlevelchange
  - Temporal coherence naming convention: ssssss_IIIII_YYLLDD_vv_temporalcoherence.grd.dat

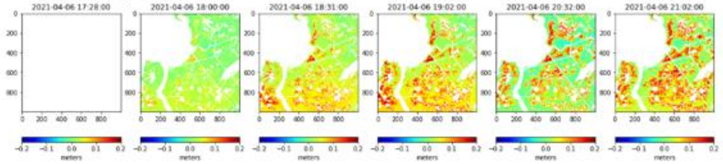
Field	Content
ssssss	6-character alphanumeric site name assigned to the UAVSAR flight line
IIIII	5-character flight line ID assigned to the UAVSAR flight line. The first 3 characters are the aircraft heading i characters are an alphanumeric counter chosen to ensure uniqueness of the ID.
YYLLDDHHMM	UTC time of the start of Acq. #1, encoded as:
	YY = the last two digits of the year
	LL = month (1-12)
	DD = day of month
	HH = hour (0-24)
	MM = minute





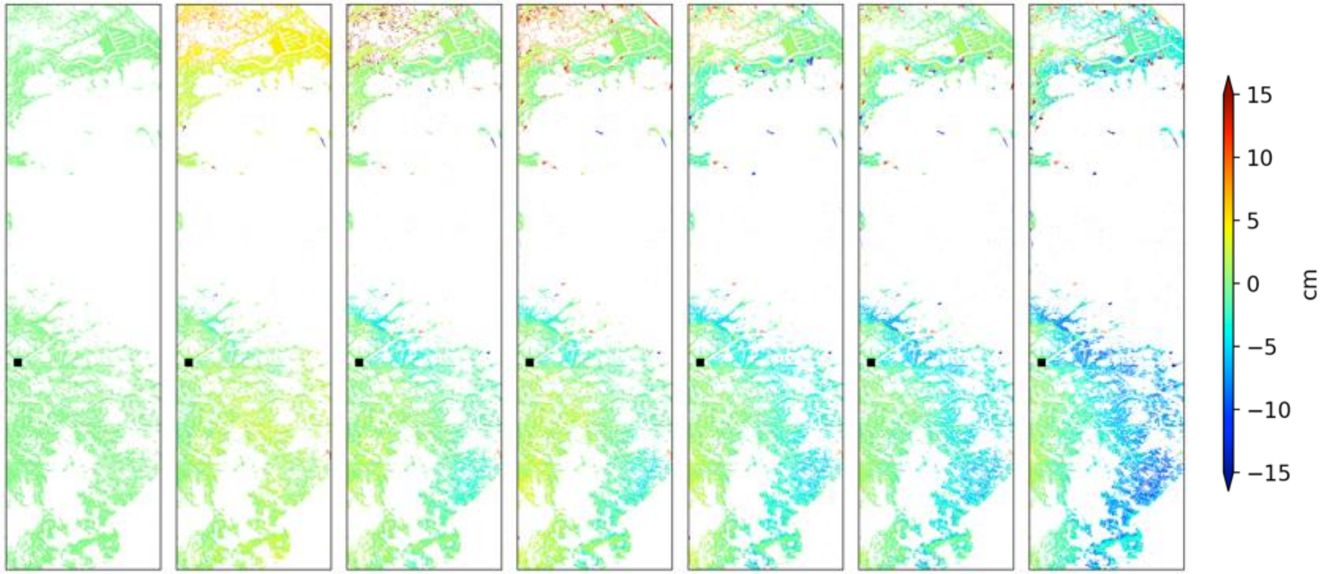


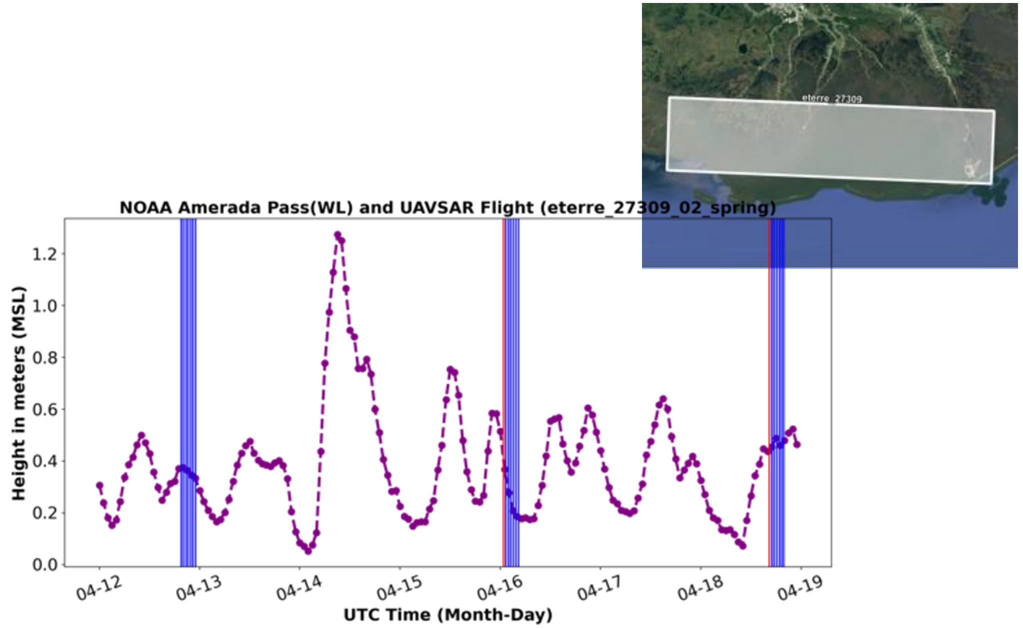

```
In [38]:
## Generate a sample for each InSAR time step.

# insar sample size
insar_ss = 500

# Center coordinates lon, lat
sample_coord_x, sample_coord_y = get_pixel_coord(-91.12, 29.25)
print('Raster pixel coords x, y = ', sample_coord_x, sample_coord_y)

# create figure
fig = plt.figure(figsize=(20, 5))

# Loop over the time steps
for date in dt_list:
    i = dt_list.index(date)
    ## Extract sample
    insar_sample = insar_ts[i, sample_coord_y - insar_ss: sample_coord_y + insar_ss,
                            sample_coord_x - insar_ss:sample_coord_x + insar_ss]
    # Plot the InSAR sample
    ax = fig.add_subplot(1,6,i+1)
    cax = ax.imshow( np.ma.masked_where(insar_sample[ :, :] == 0, insar_sample[ :, :]),
                    vmin = -0.2, vmax = 0.2, cmap = 'jet', interpolation='nearest')
    ax.set_title(dt_list[i])
    cbar = fig.colorbar(cax, orientation='horizontal')
    cbar.set_label('meters', rotation=0)

plt.show()
plt.close("all")
insar_sample = None; sample_coord_x = None; sample_coord_y = None

Raster pixel coords x, y =  4172 9537
```

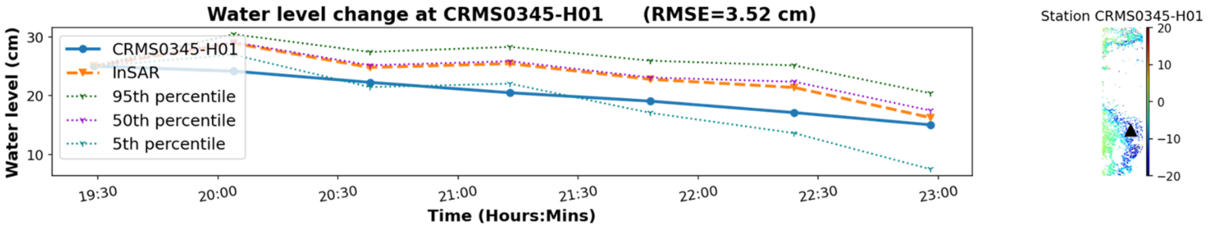


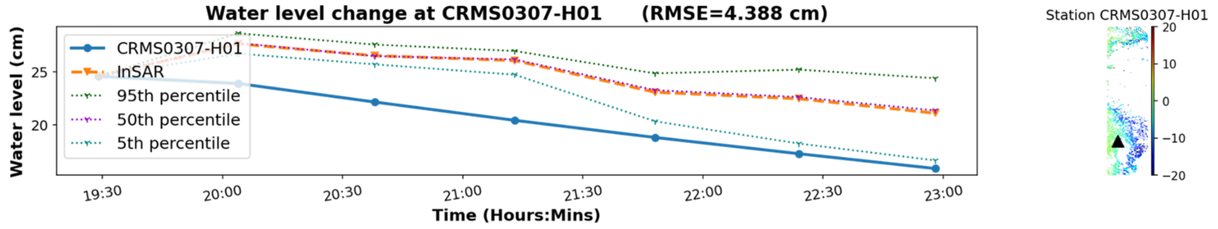
L3 InSAR derived water level change

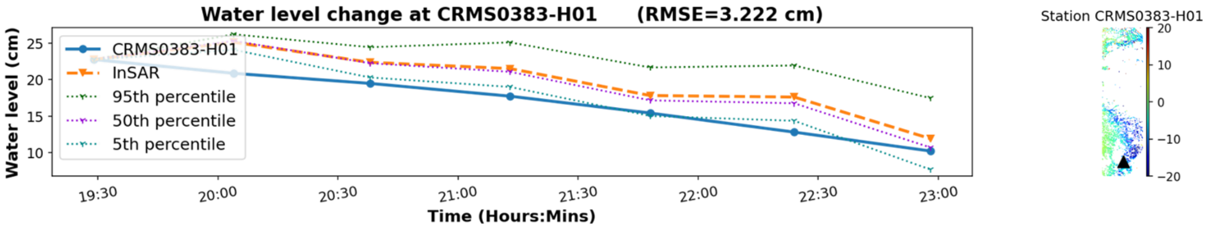
Eterre_27309_210412 time series in radar coordinates

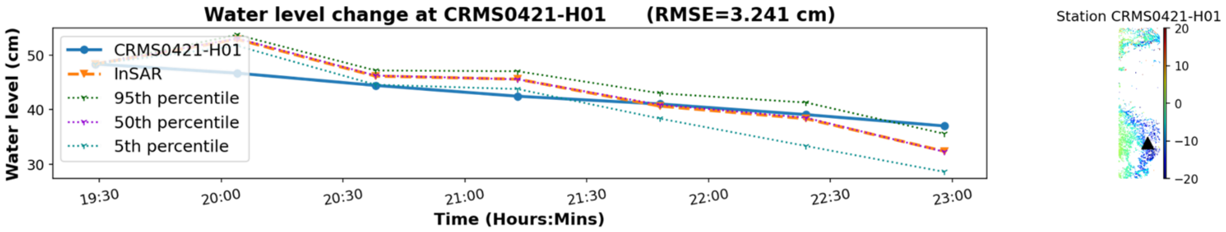






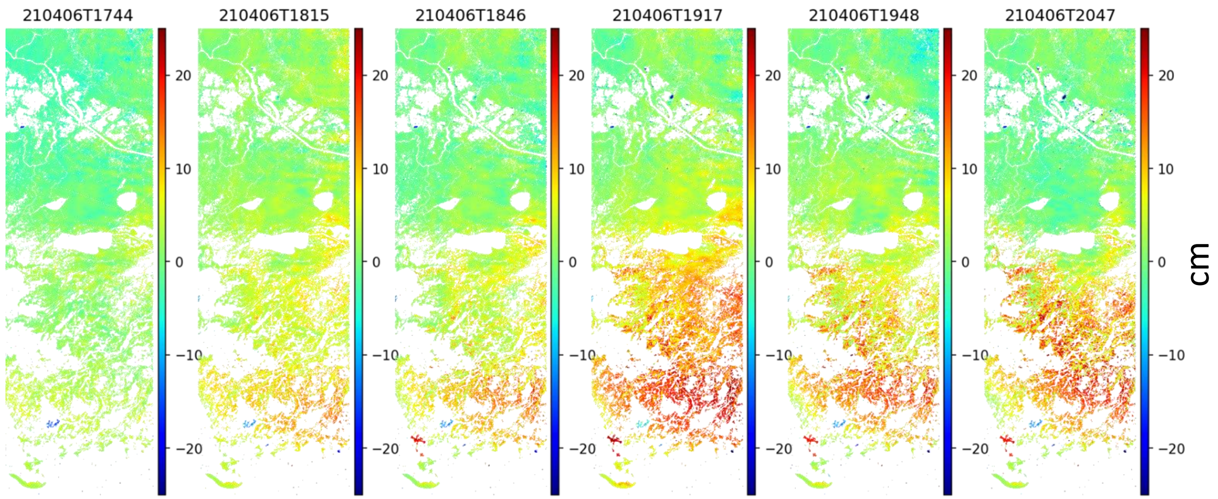


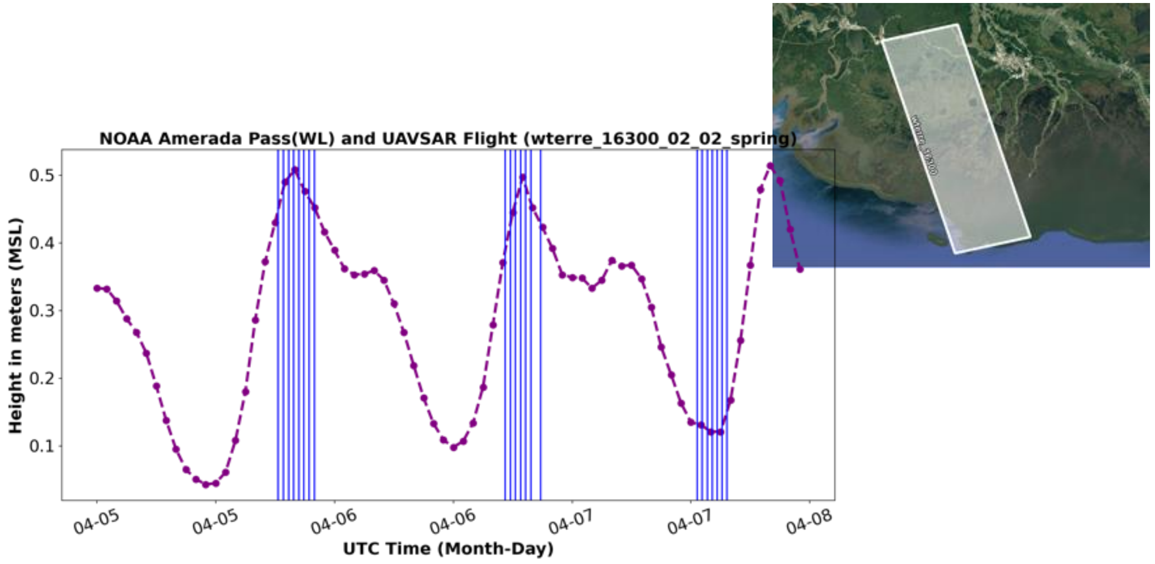


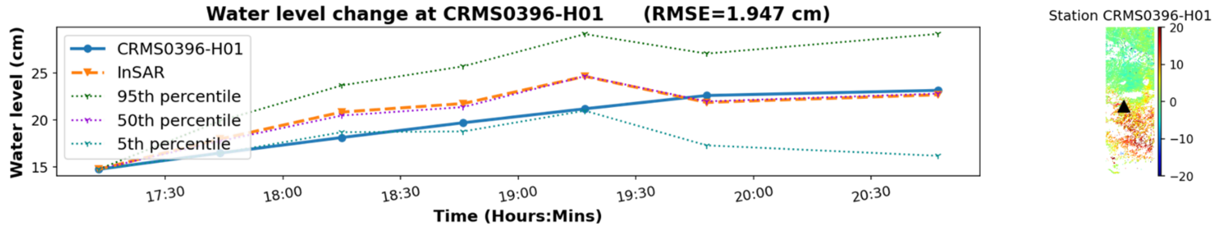


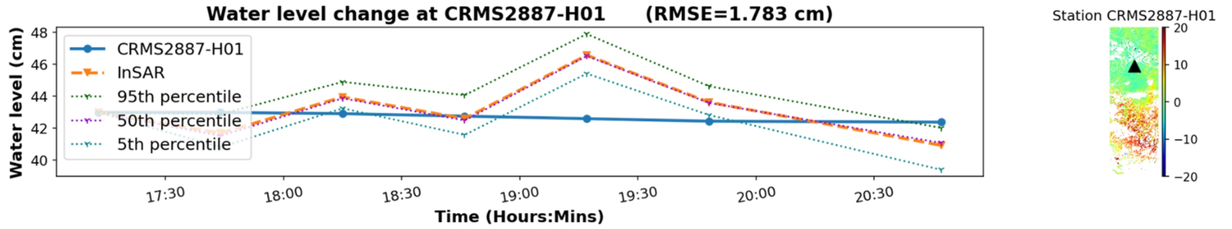
L3 InSAR derived water level change

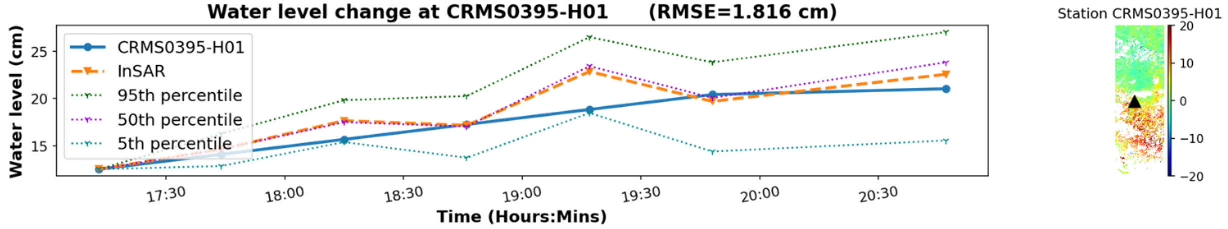
Wterre_16300_20210406 time series in radar coordinates

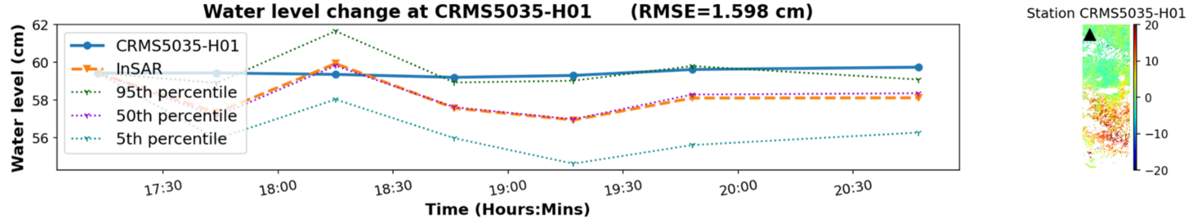












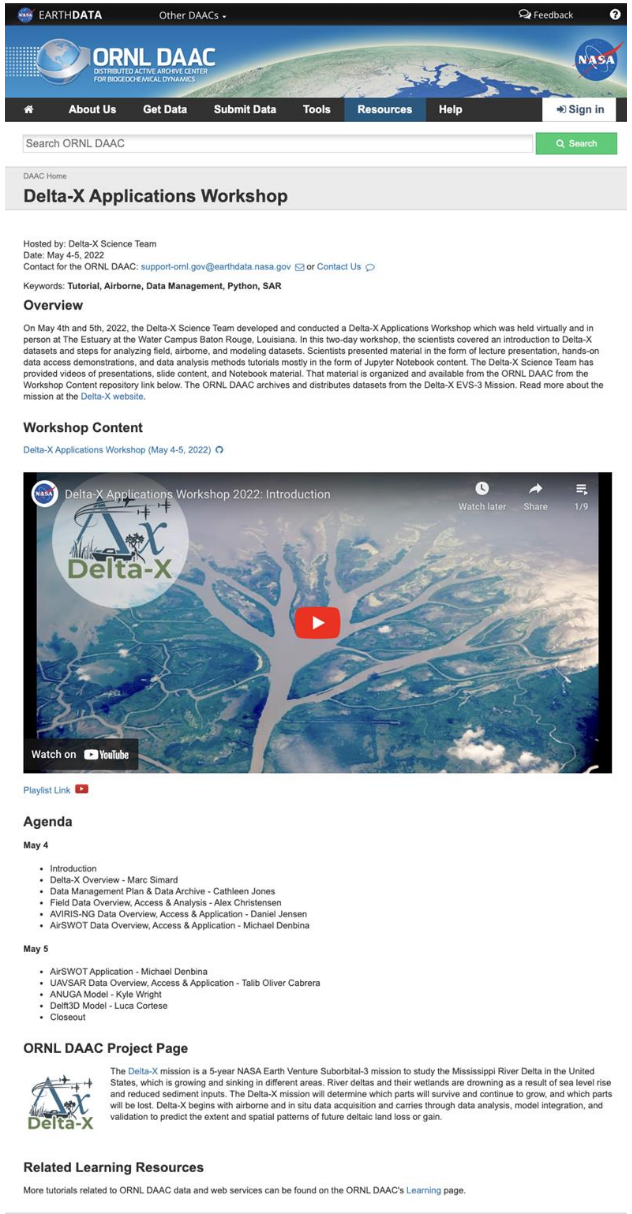
Delta-X applications workshop

Delta-X application workshop tutorial:
daac.ornl.gov/resources/tutorials/2022_deltax_workshop/

- L1 Single Look Complex (SLC):
  github.com/ornldaac/deltax_workshop_2022/blob/main/tutorials/deltax_applications_workshop/deltax_l1_slc.ipynb

- L1b and L2 Interferometric products:
  github.com/ornldaac/deltax_workshop_2022/blob/main/tutorials/deltax_applications_workshop/deltax_l1b_l2_interferograms.ipynb

- L3 InSAR derived water level change:
  github.com/ornldaac/deltax_workshop_2022/blob/main/tutorials/deltax_applications_workshop/deltax_l3_wlc_time_steps.ipynb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Delta-X Applications Workshop

Hosted by: Delta-X Science Team
Date: May 4-5, 2022
Contact for the ORNL DAAC: support-ornl.gov@earthdata.nasa.gov or Contact Us

Keywords: **Tutorial, Airborne, Data Management, Python, SAR**

Overview

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Workshop Content

Delta-X Applications Workshop (May 4-5, 2022)

Delta-X Applications Workshop 2022: Introduction
Watch later Share 1/9
Delta-X
Watch on YouTube

Playlist Link

Agenda

May 4

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ORNL DAAC Project Page

Delta-X

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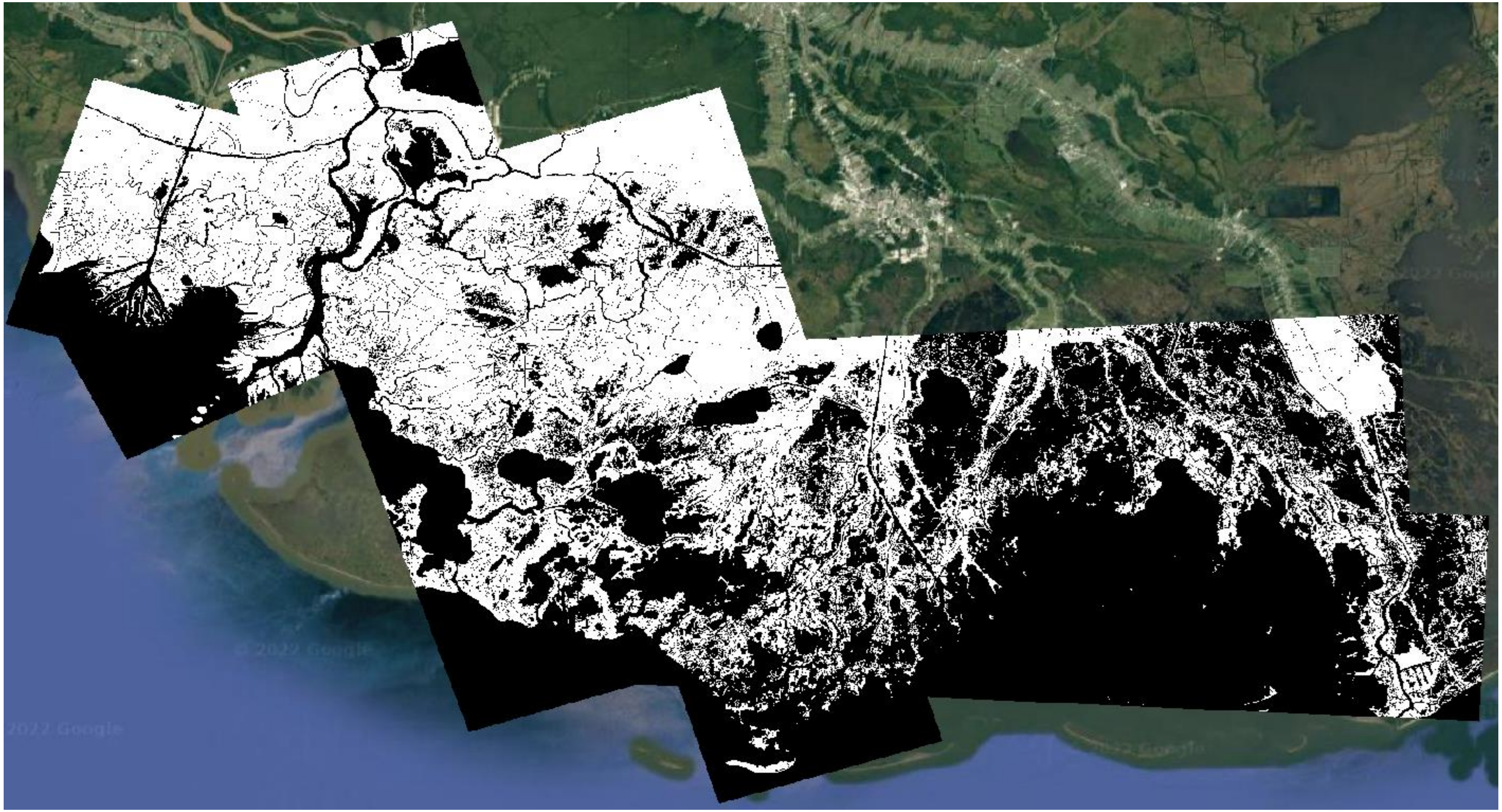
Delta-X: UAVSAR L3 Gridded Open Water Channels



Dr. Cathleen Jones
Dr. Bhuvan Varugu

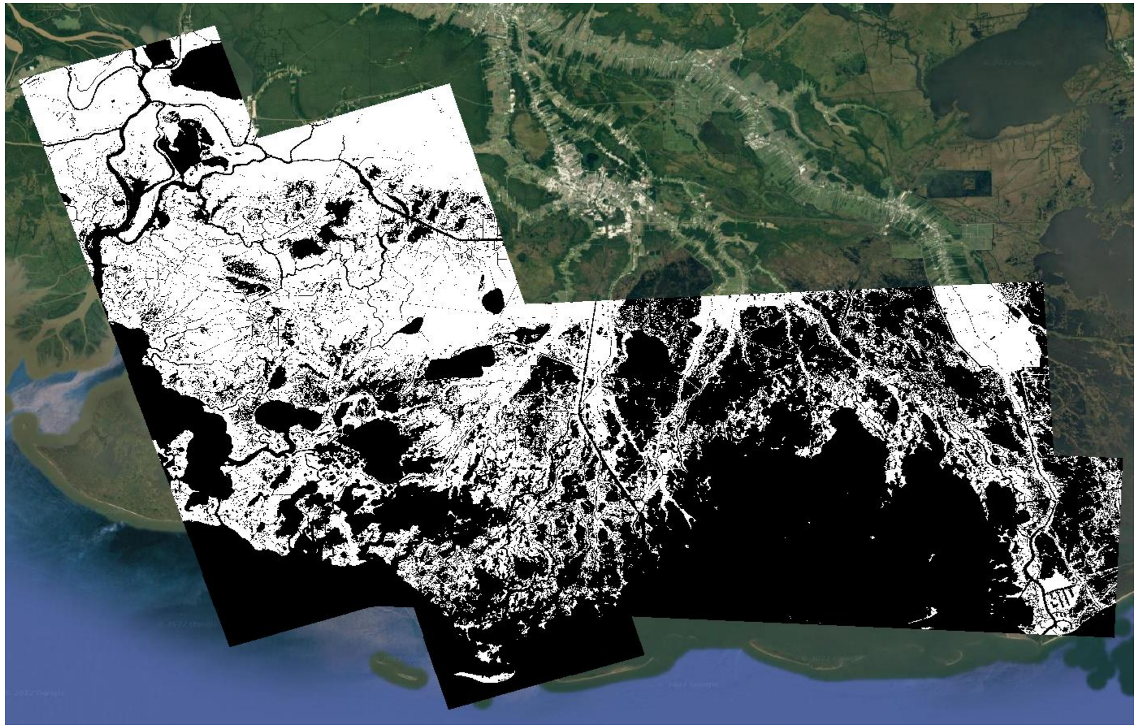
daac.ornl.gov/DELTAX/guides/DeltaX_UAVSAR_L3_ChannelMap.html

Delta-X: UAVSAR L3 Gridded Open Water Channels

- UAVSAR coherence and amplitude are sensitive to the ground surface characteristics.
- We use the amplitude and coherence over multiple interferograms (L-1B) to identify pixels as water and land
- Two separate geocoded masks are available for the Atchafalaya and Terrebonne tracks
- Masks are useful to identify open water paths in hydrodynamic models.

Atchafalaya

Terrebonne



Delta-X: UAVSAR L3 Gridded Open Water Channels

- **Data from both spring and fall were used** because the spring campaign had many inundated areas that obscured the channel network and because in both spring and fall some of the lines had low coherence over parts of the scene, probably from heavy cloud cover.

- To get the best channel extent without a lot of seasonally flooded areas included in the map, **in general the higher tide Fall campaign data was used** to make the map, although in some cases channels in parts of the scene were taken from data acquired in other flights for the reasons mentioned above.

UAVSAR flight line	Date	Number of acquisitions
atchaf_06309	2021-09-05	9
	2021-09-13	2
atchaf_19809	2021-09-05	9
	2021-09-13	4
eterre_08705	2021-09-07	8
eterre_27309	2021-09-07	7
wterre_16300	2021-04-07	7
	2021-09-12	7
wterre_34202	2021-04-07	8
	2021-09-12	8

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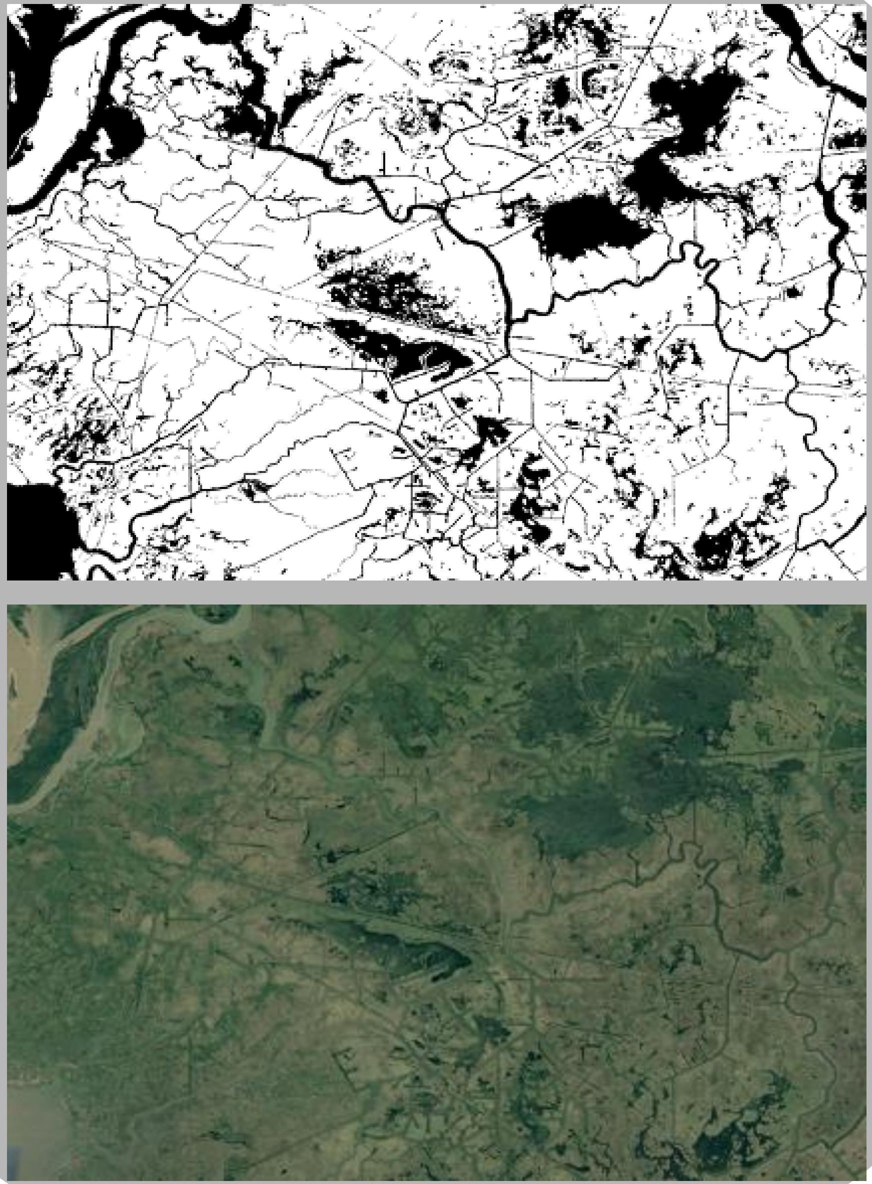

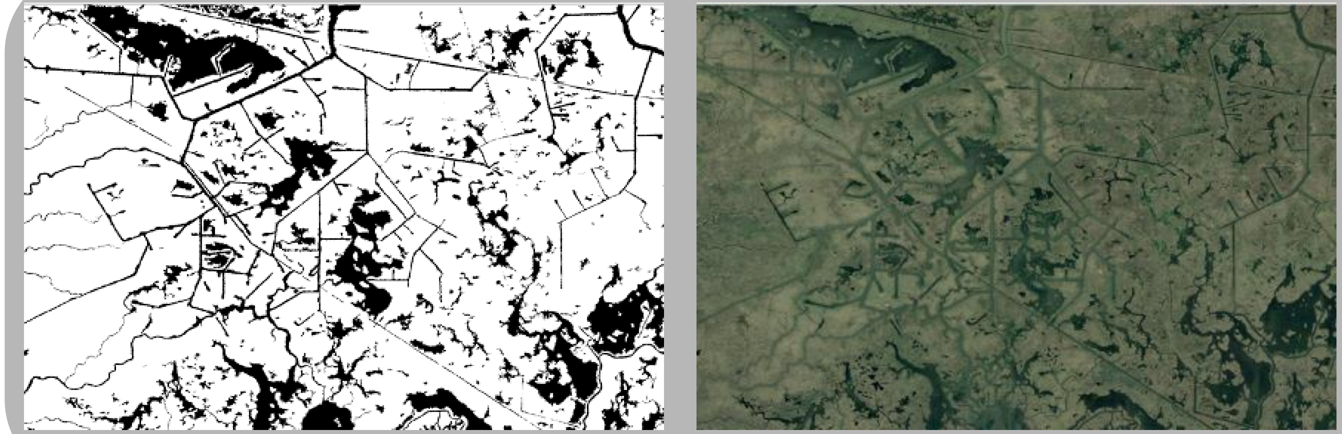

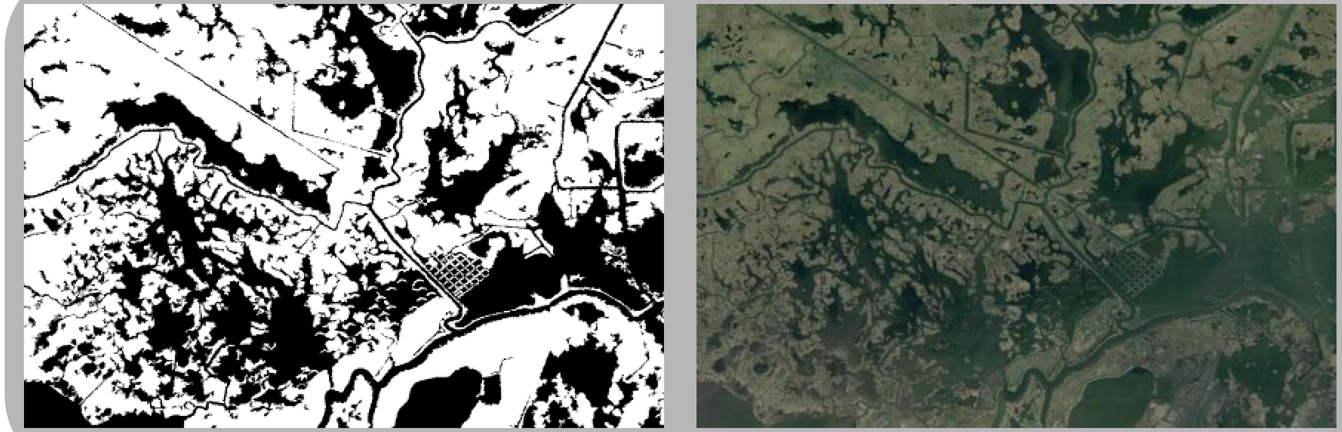

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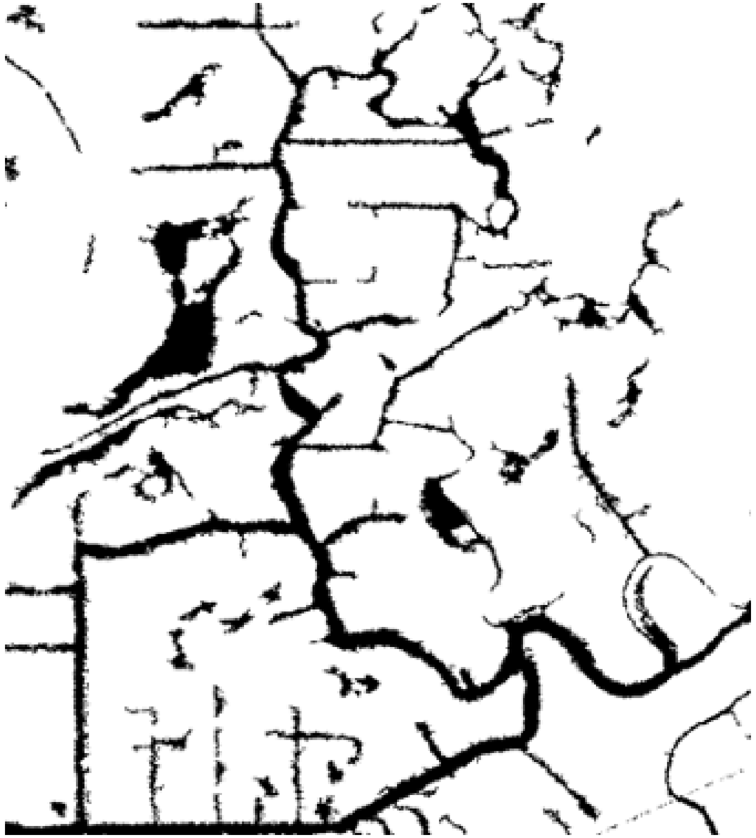
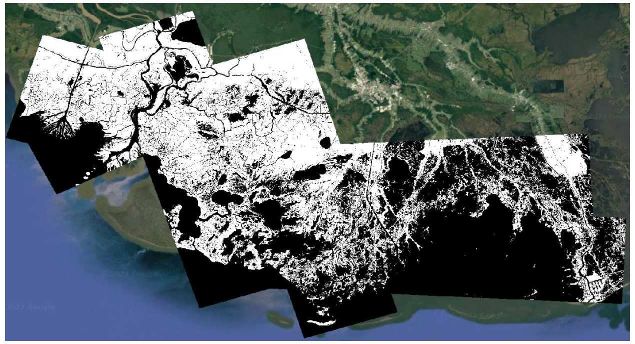
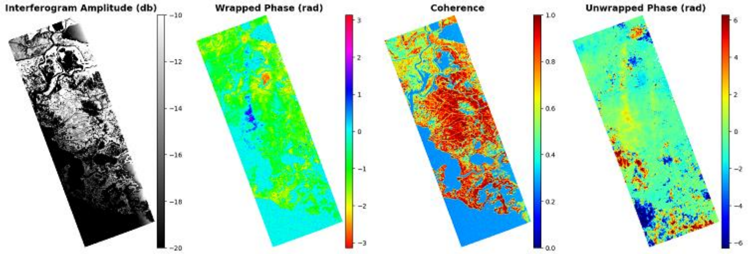


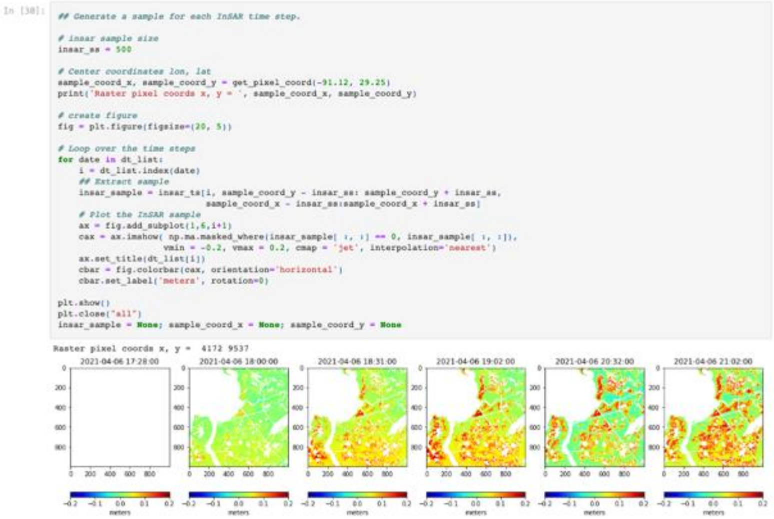
Available at: daac.ornl.gov/DELTAX/guides/DeltaX_UAVSAR_L3_ChannelMap.html

Delta-X: UAVSAR products and resources available at OARNL DAAC

- L1 Single Look Complex (SLC) quad-polarized
github.com/ornldaac/deltax_workshop_2022/blob/main/tutorials/deltax_applications_workshop/deltax_l1_slc.ipynb
- L1b and L2 Interferometric products
github.com/ornldaac/deltax_workshop_2022/blob/main/tutorials/deltax_applications_workshop/deltax_l1b_l2_interferograms.ipynb
- L3 InSAR derived water level change
github.com/ornldaac/deltax_workshop_2022/blob/main/tutorials/deltax_applications_workshop/deltax_l3_wlc_time_steps.ipynb
- Delta-X: UAVSAR L3 Gridded Open Water Channels
daac.ornl.gov/DELTAX/guides/DeltaX_UAVSAR_L3_ChannelMap.html
- Delta-X application workshop tutorial:
daac.ornl.gov/resources/tutorials/2022_deltax_workshop/



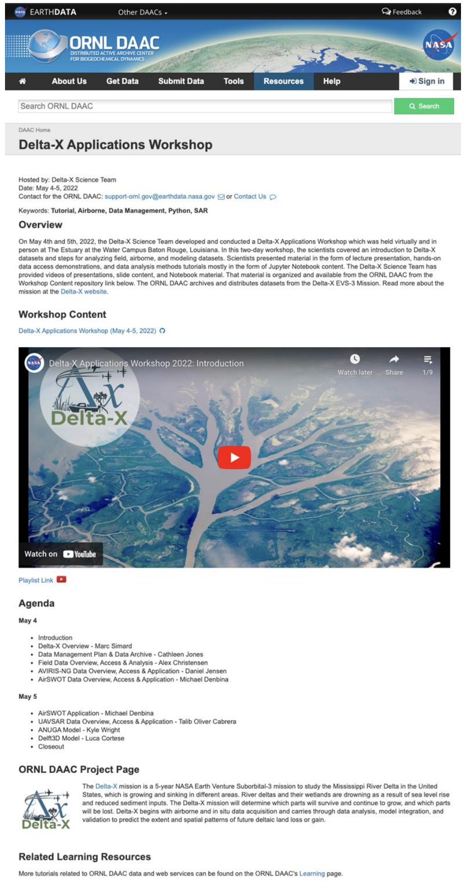




In [30]:

```
## Generate a sample for each InSAR time step.

# insar sample size
insar_ss = 500

# Center coordinates lon, lat
sample_coord_x, sample_coord_y = get_pixel_coord(-91.12, 29.25)
print('Raster pixel coords x, y = ', sample_coord_x, sample_coord_y)

# create figure
fig = plt.figure(figsize=(20, 5))

# Loop over the time steps
for date in dt_list:
    i = dt_list.index(date)
    ## Extract sample
    insar_sample = insar_ts[i, sample_coord_y - insar_ss: sample_coord_y + insar_ss,
                            sample_coord_x - insar_ss:sample_coord_x + insar_ss]
    # Plot the InSAR sample
    ax = fig.add_subplot(1,6,i+1)
    cax = ax.imshow( np.ma.masked_where(insar_sample[ :, :] == 0, insar_sample[ :, :]),
                    vmin = -0.2, vmax = 0.2, cmap = 'jet', interpolation='nearest')
    ax.set_title(dt_list[i])
    cbar = fig.colorbar(cax, orientation='horizontal')
    cbar.set_label('meters', rotation=0)

plt.show()
plt.close("all")
insar_sample = None; sample_coord_x = None; sample_coord_y = None
```

```
Raster pixel coords x, y =  4172 9537
```

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Delta-X Applications Workshop

Hosted by: Delta-X Science Team
Date: May 4-5, 2022
Contact for the ORNL DAAC: support-ornl.gov@earthdata.nasa.gov or Contact Us

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