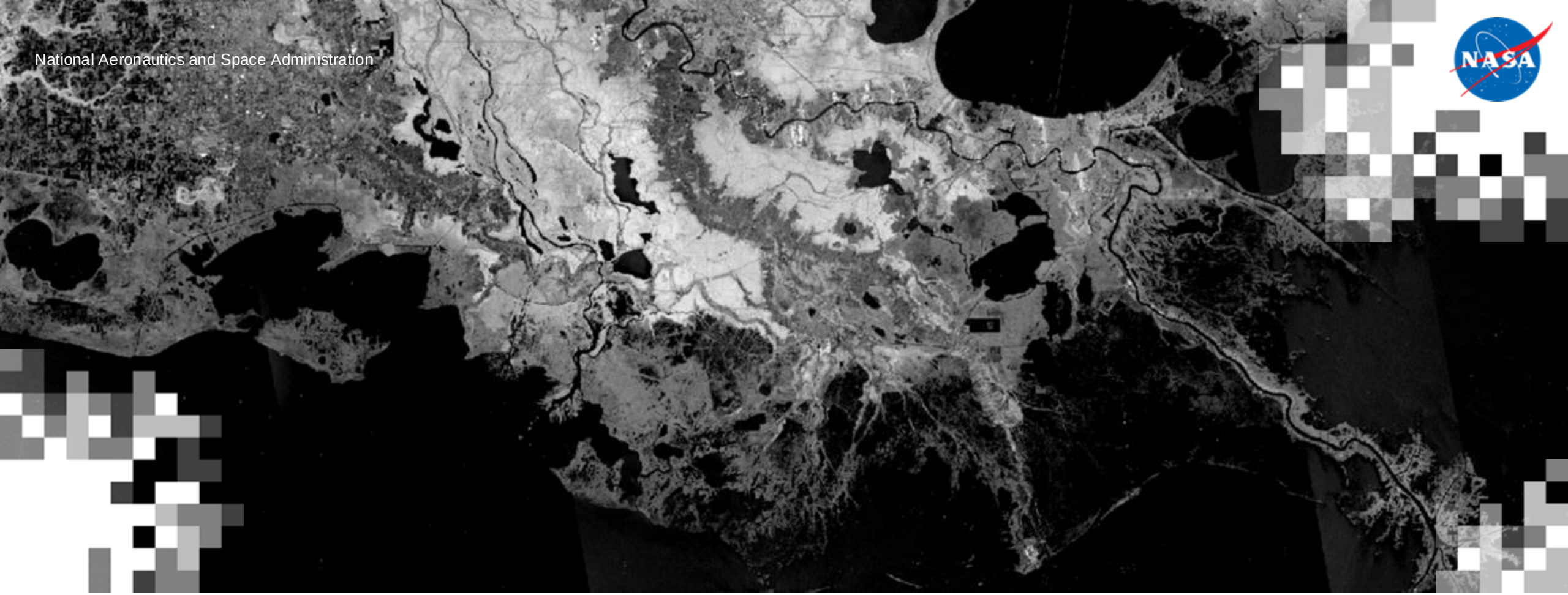


An Introduction to SAR and Its Applications

Part 3: An Overview of SAR Data Sources and Tools

Dr. Franz J. Meyer (University of Alaska Fairbanks, Alaska Satellite Facility),
Heidi Kristenson (Alaska Satellite Facility)

November 20, 2024

Training Outline

Part 1

Introduction to Synthetic Aperture Radar (SAR)

November 6, 2024

11:30 am - 01:30 pm EST (UTC-5:00)

Part 2

Introduction to Interferometric SAR (InSAR)

November 13, 2024

11:30 am - 01:30 pm EST (UTC-5:00)

Part 3

An Overview of SAR Data Sources and Tools

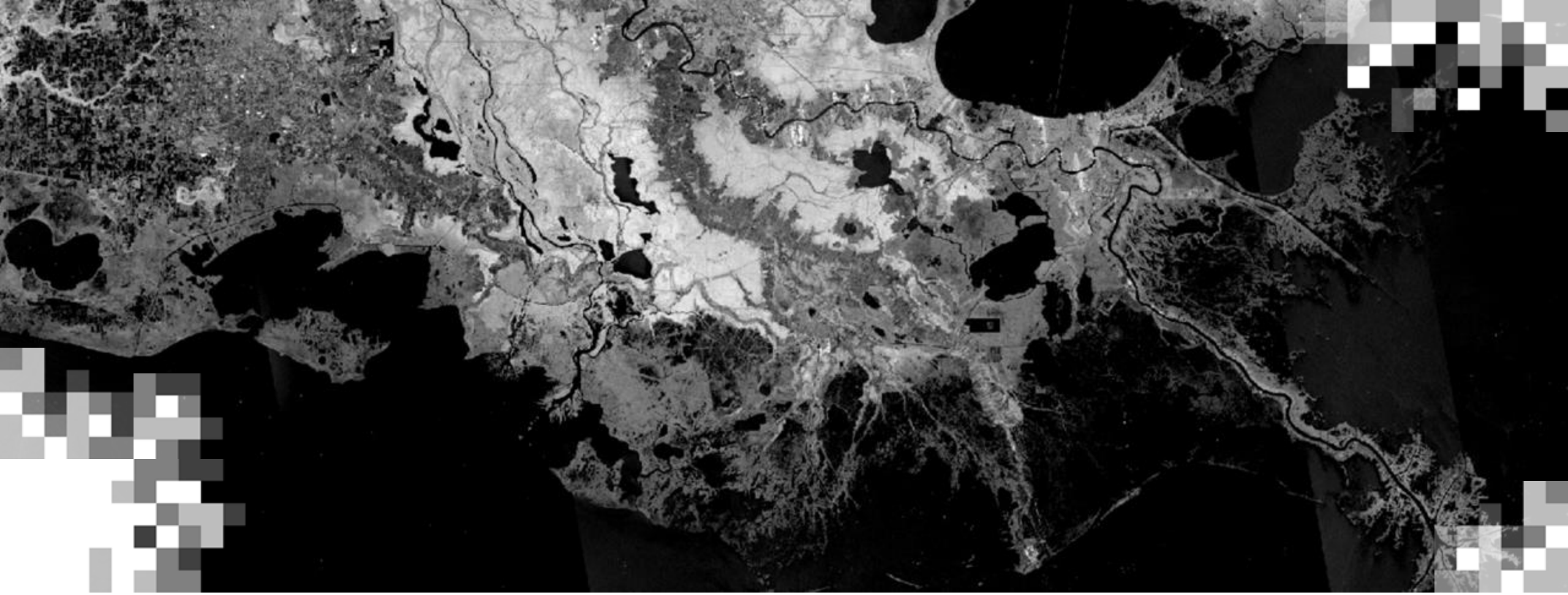
November 20, 2024

11:30 am - 01:30 pm EST (UTC-5:00)

Homework

Opens November 20 – Due December 4 – Posted on Training Webpage

A certificate of completion will be awarded to those who attend all live sessions and complete the homework assignment(s) before the given due date.



An Introduction to SAR and Its Applications

Part 3: An Overview of SAR Data Sources and Tools

Review of Prior Knowledge

- Synthetic Aperture Radar (SAR) uses an active microwave sensor to image the Earth's surface.
  - Different sensor configurations, including wavelength and polarization, provide different information about surface characteristics.
  - Surface parameters that influence the radar signal are related to moisture and structure.
- SAR datasets include both amplitude and phase components.
  - Amplitude is used to generate imagery that displays the intensity of radar backscatter.
  - Phase indicates the distance between the sensor and the surface and is the basis of interferometric SAR (InSAR), which can be used to identify and quantify surface deformation.
- SAR imagery has distortions caused by the side-looking geometry of SAR acquisitions.
  - Radiometric Terrain Correction adjusts for both geometric and radiometric distortions, allowing SAR imagery to align with other geospatial datasets.

How to Ask Questions

- Please write your questions in the 'Q&A' window, which you can find in the bottom right under the three '…'. We will address them at the end of this session.
- Feel free to enter your questions during the presentation. We will try to answer all of the questions during the Q&A session at the end of this webinar.
- The remaining questions will be answered in the Q&A document, which will be posted to the training website in approximately one week.

Session 3 Objectives

By the end of Session 3, participants will:

- Understand the role of the Alaska Satellite Facility (ASF) within NASA's Earthdata organization
- Be aware of the range of SAR data ASF serves, particularly analysis-ready products
- Know how to search for SAR data available from ASF
- Know how to access analysis-ready SAR datasets from ASF, including archived products and customized products generated on demand

Part 3 – Trainers

Dr. Franz J. Meyer

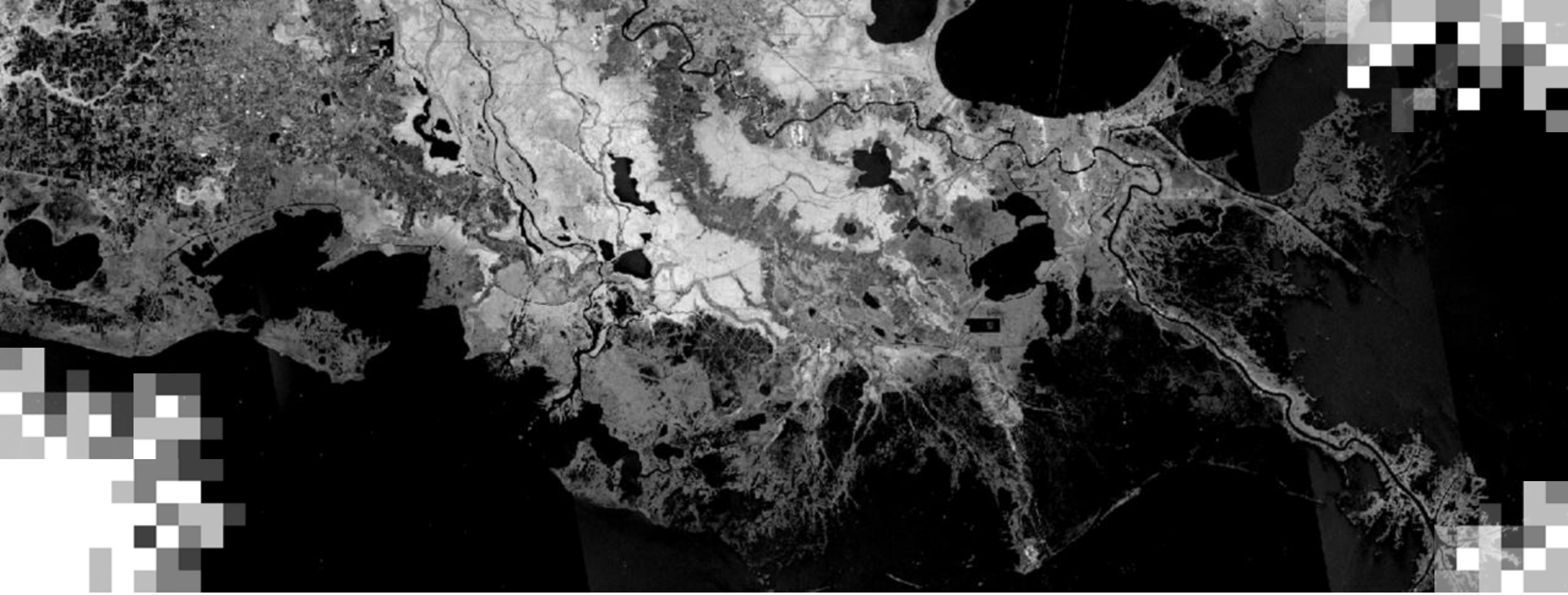
Professor of Remote Sensing, UAF

Chief Scientist, ASF

Heidi Kristenson

Senior GIS Specialist

ASF



Part 3:

Introduction to the Alaska Satellite Facility (ASF)

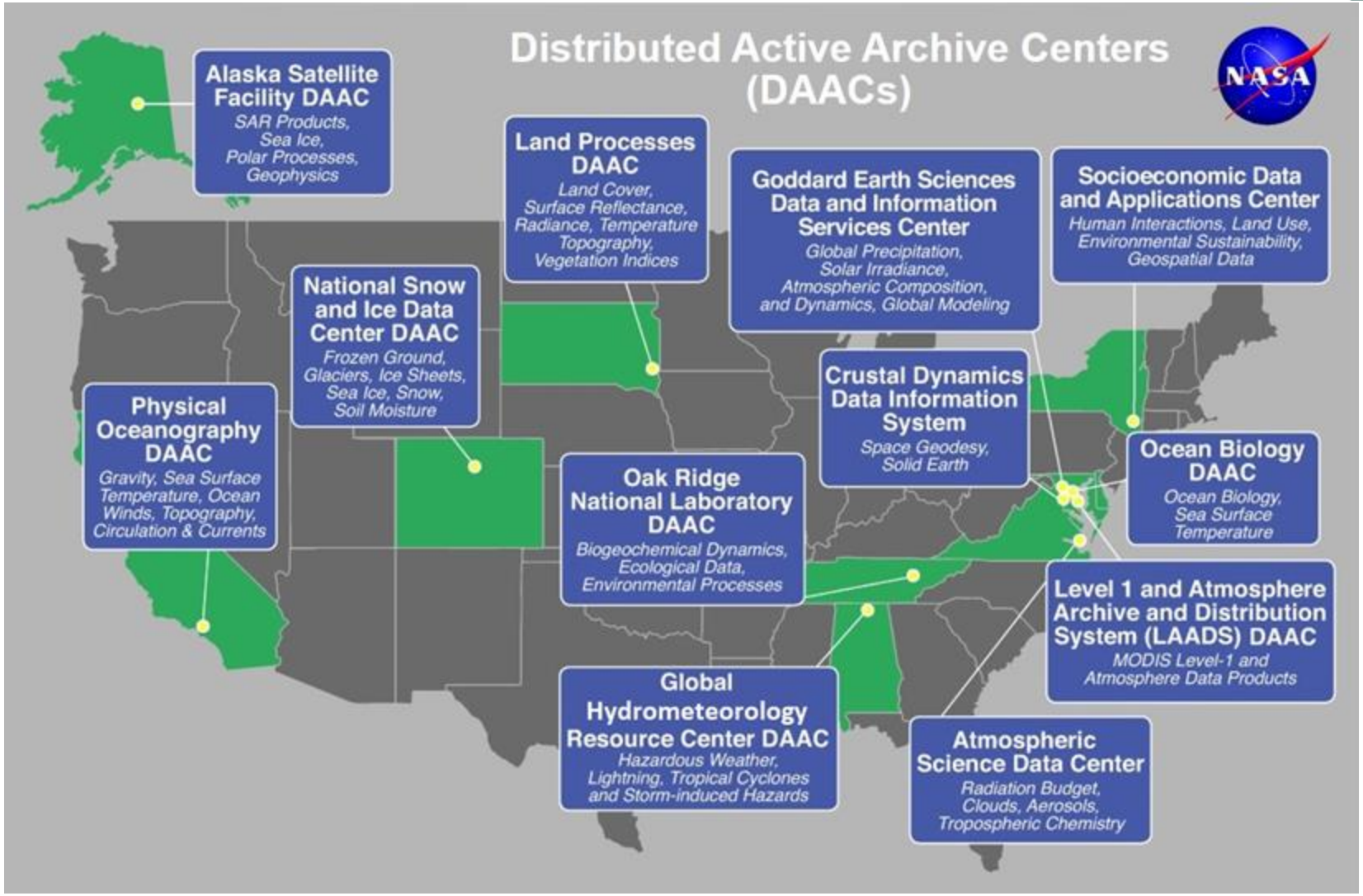
The Alaska Satellite Facility (ASF) is One of 12 NASA DAACs

DAACs are custodians of NASA mission data and ensure that data will be easily accessible to users.

Reliable, robust services to the science and applications communities

User Engagement:

- Chief Scientist
- User Working Group
- User Support

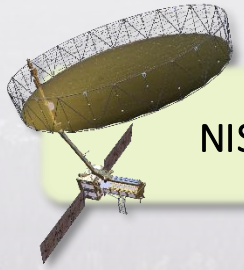


The NASA Alaska Satellite Facility (ASF) DAAC

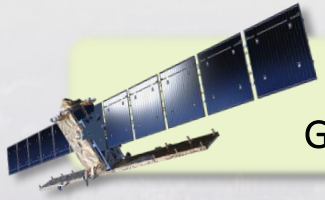
- **ASF is NASA Distributed Active Archive Center (DAAC) for Synthetic Aperture Radar Data**
  - Established in 1991 as the prime U.S. downlink and processing center for SAR data
  - Operates 3 antennas for command uplink and data downlink of NASA and non-NASA remote sensing satellite systems
- **Currently, ASF is housing about 23PB of SAR data in its archives, most of which in the Amazon Web Service Cloud → All data is available for immediate download.**

SCAN ME

41 Years of SAR Data (Since '78)
https://search.asf.alaska.edu



NISAR DAAC (All L0 – L2 data)



Host of
Global Sentinel-1 Archive

Visit ASF @ www.asf.alaska.edu

ASF provides access to modern SAR sensors that provide regularly sampled, free-and-open SAR data on a global scale.

Sentinel-1

esa

Frequency:
C-band
Launch Date:
2015 & 16

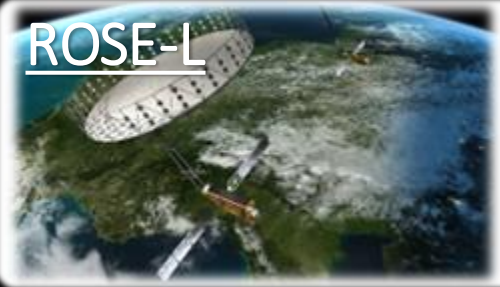
NISAR

NISAR
NASA - ISRO SAR Mission

NASA

Frequency:
L-band
Launch Date:
Spring 2025

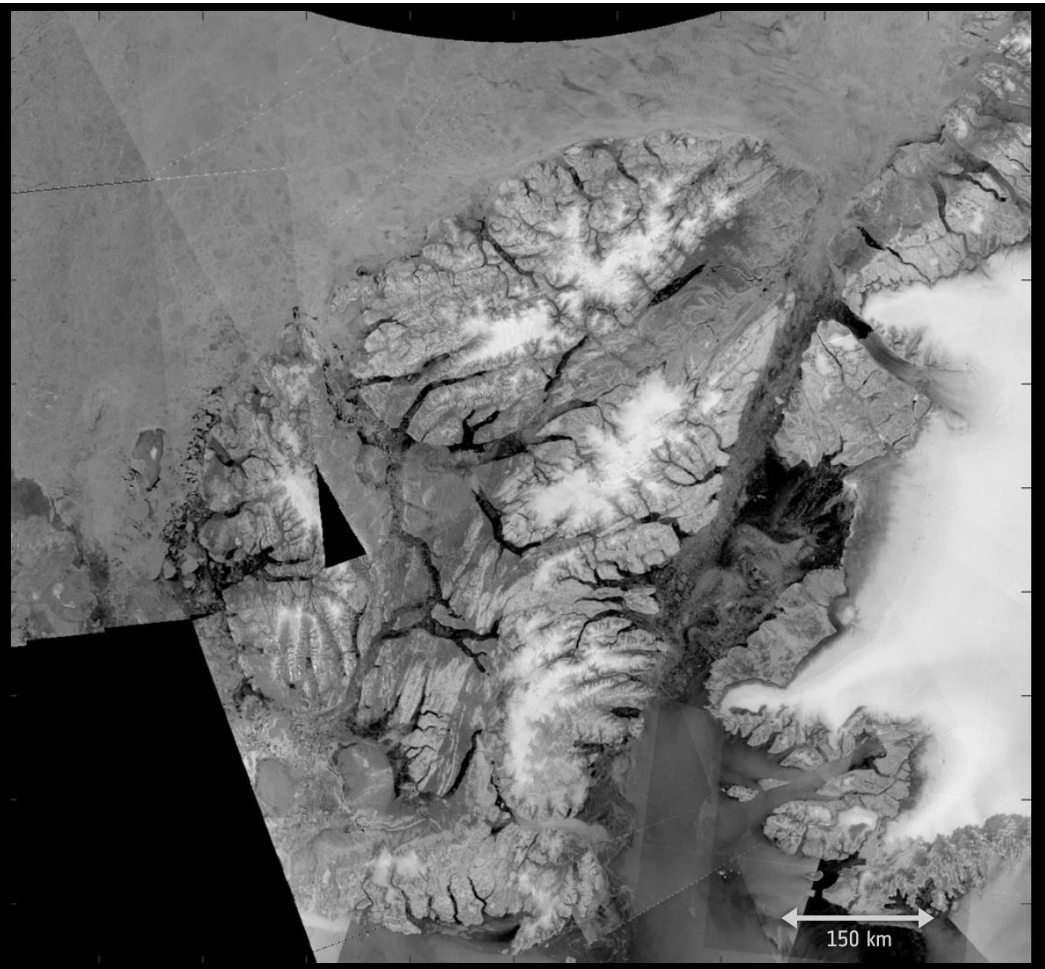
ROSE-L



esa

Frequency:
L-band
Launch Date:
TBD

October 2016
November
December
January 2017
February
March
April
May



Arctic Sea Ice Export through Nares Strait

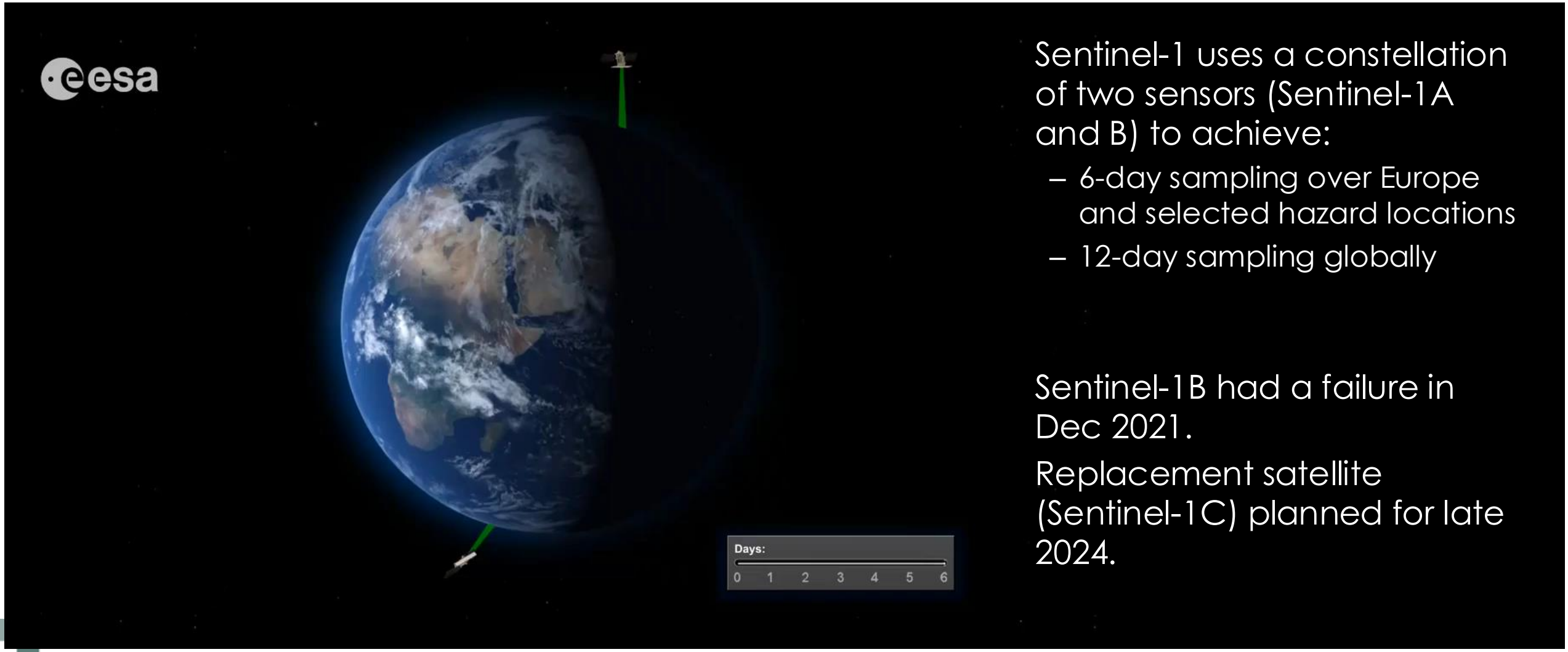
Copyright contains modified Copernicus Sentinel data (2016–17), processed by David Small

ASF hosts data from the Sentinel-1 Constellation.

- **Sentinel-1 (2014–Today): First SAR Satellite System with Operational Mission**
  - Regular, reliable observation according to operational requirements
  - Imaging all landmasses, coastal zones, and shipping routes every six days
  - Specifically designed for InSAR

FREE AND OPEN DATA!

Sentinel-1 Constellation – Acquisition Concept



Sentinel-1 uses a constellation of two sensors (Sentinel-1A and B) to achieve:

- 6-day sampling over Europe and selected hazard locations
- 12-day sampling globally

Sentinel-1B had a failure in Dec 2021.

Replacement satellite (Sentinel-1C) planned for late 2024.

ASF Will Provide Access to Upcoming NASA-ISRO SAR (NISAR) Mission

Launch In Early 2025

First spaceborne L- and S-band SAR

Full global coverage in 12 days

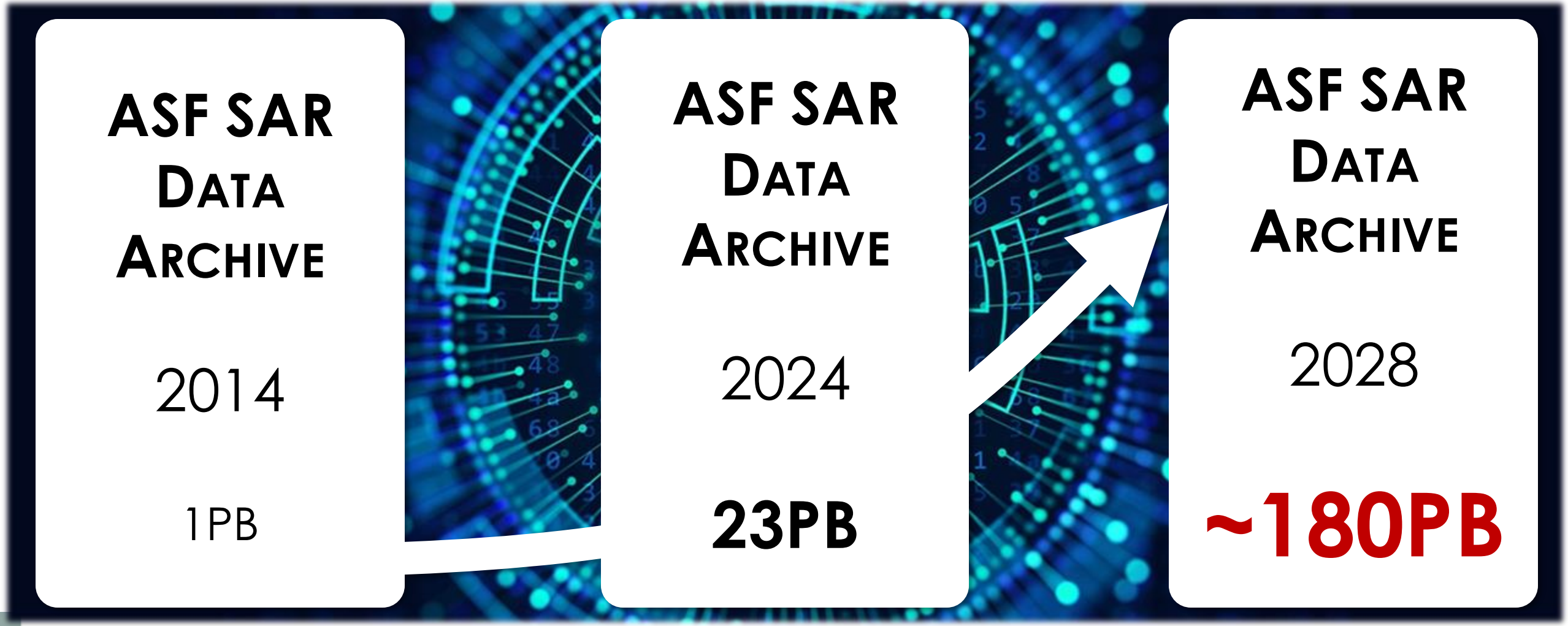
150 petabytes of Earth observation data/year

All Data Free and Open!

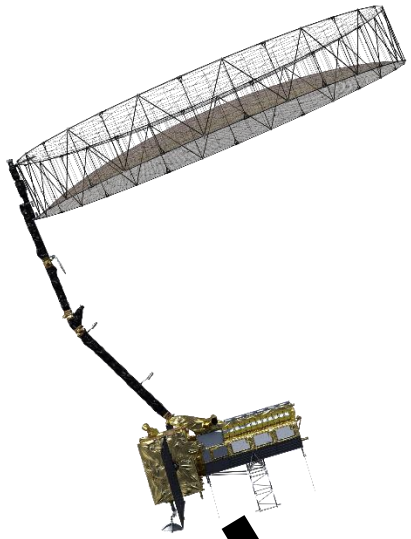
ASF & NISAR

NISAR Data Center
NISAR Ground Station
NISAR Science Team Member

ASF hosts its rapidly growing free-and-open SAR archive in the cloud.



ASF has developed efficient mechanisms for users to access and work with its growing SAR data archive.



Discovery

Access

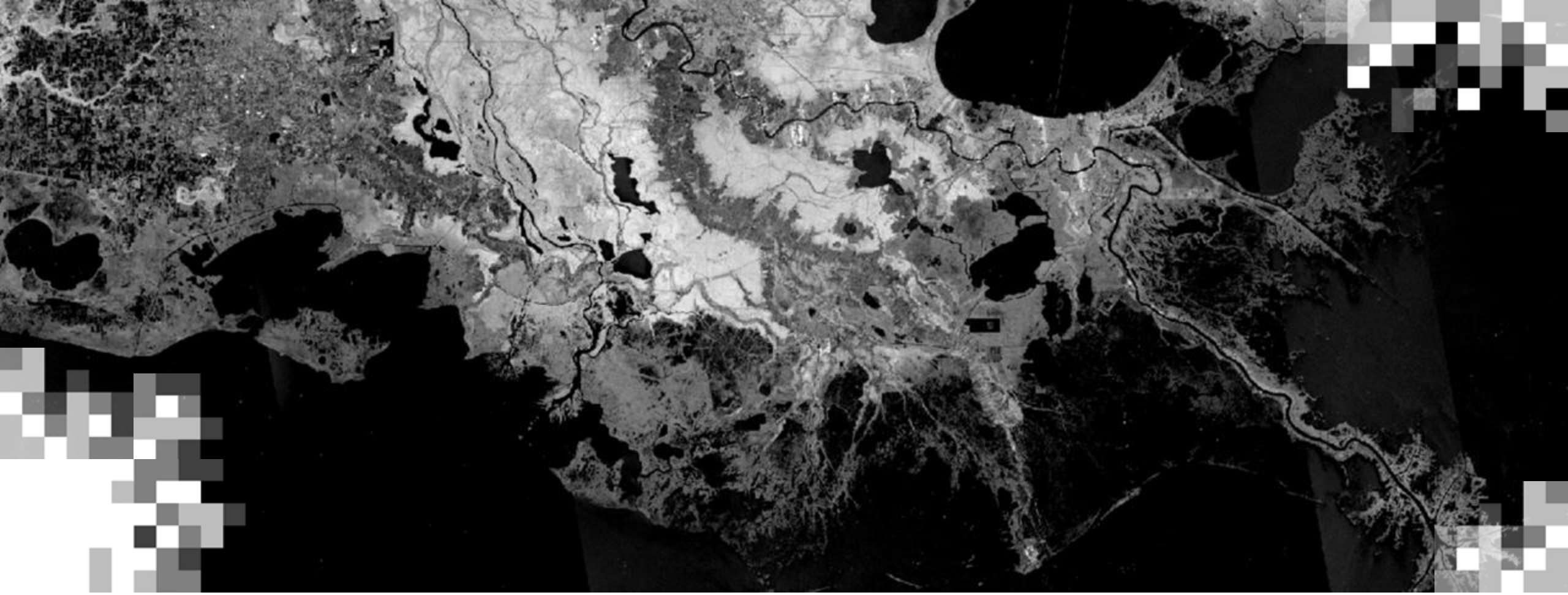
Services

ASF's Cloud-Based Archive

AWS

Next: Heidi Kristenson

- ASF Data Access
- ASF Custom Processing Services



Part 3:

Datasets Available from ASF

SAR Data Available from ASF

- Partner Agencies:
  - NASA, ESA, JAXA, CSA
- Different Platforms:
  - Satellite-Borne
  - Airborne
  - Mounted on Space Shuttle
- Range of Sensor Configurations:
  - Band (Wavelength)
    - Mostly C and L
    - Some P and X
  - Polarizations
  - Beam/Acquisition Modes
- Repeat Intervals Vary

- Access Options:
  - Search and Download Options:
    - Map-Based Web Interfaces
    - Programmatic Methods
  - All data can be downloaded.
  - Some datasets can also be accessed directly from cloud storage.

SAR Data from ASF: Missions

- Continuous Coverage
  - First spaceborne SAR mission
    - Seasat: 1978
  - Currently Active Missions:
    - Sentinel-1: 2014-Present
    - ALOS-2: 2014-Present (coming soon)
  - Many different missions since the 1990s
    - ERS-1: 1991-1997, ERS-2: 1995-2011
    - JERS: 1992-1998
    - RADARSAT-1: 1995-2008
    - ALOS PALSAR: 2006-2011
    - SMAP: 2015
- Discrete Missions:
    - SIR-C: 1994 (on Space Shuttle Endeavour)
    - AIRSAR: 1988-2004
    - UAVSAR: 2008-Present

Learn more about the SAR missions supported by ASF

Coming Soon: NISAR!

Due to Launch Early 2025

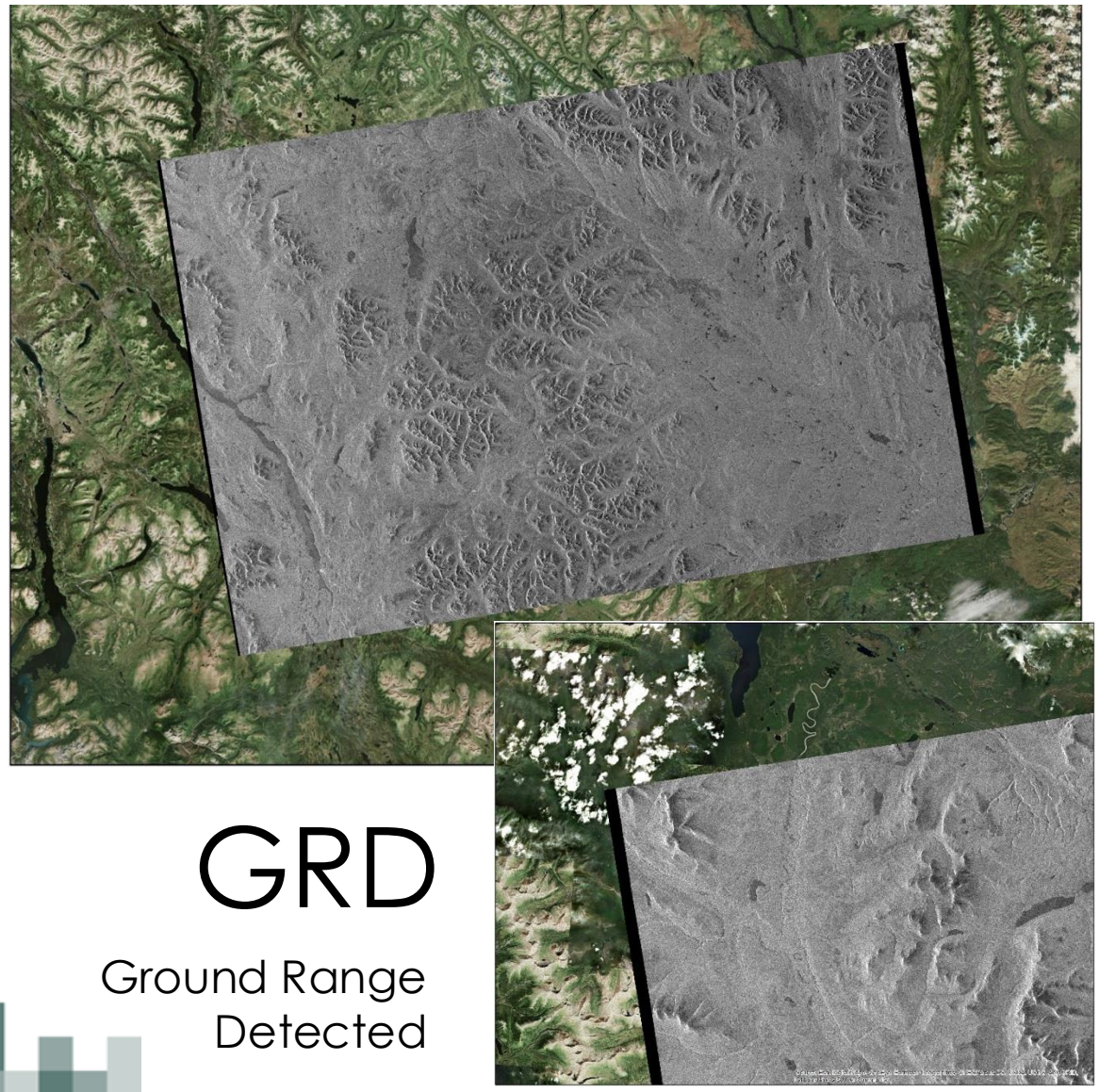
Learn More About the Mission

Sentinel-1

- European Space Agency (ESA) and European Commission (EC)
  - Copernicus Initiative
- Global Coverage with C-band SAR
  - 2-satellite constellation
  - Sentinel-1A launched 2014, 1B launched 2016
    - Sentinel-1B mission ended December 2021
    - 1A is nearing its end
    - 1C due to launch December 2024
    - 1D launch to be determined
  - Each with 12-day return cycle, orbiting 180° apart (when 2 satellites are in orbit)
    - Some areas have coverage every 6 days (Europe, EU areas of interest)
    - Polar regions can have even more frequent coverage due to polar orbit
- New data available to download within 3 days of acquisition (usually < 24 hours)
- Free and easy to download raw data and Level-1 products (GRD, SLC)

Sentinel-1 Mission Website

Sentinel-1 Level-1 Products



GRD

Ground Range Detected

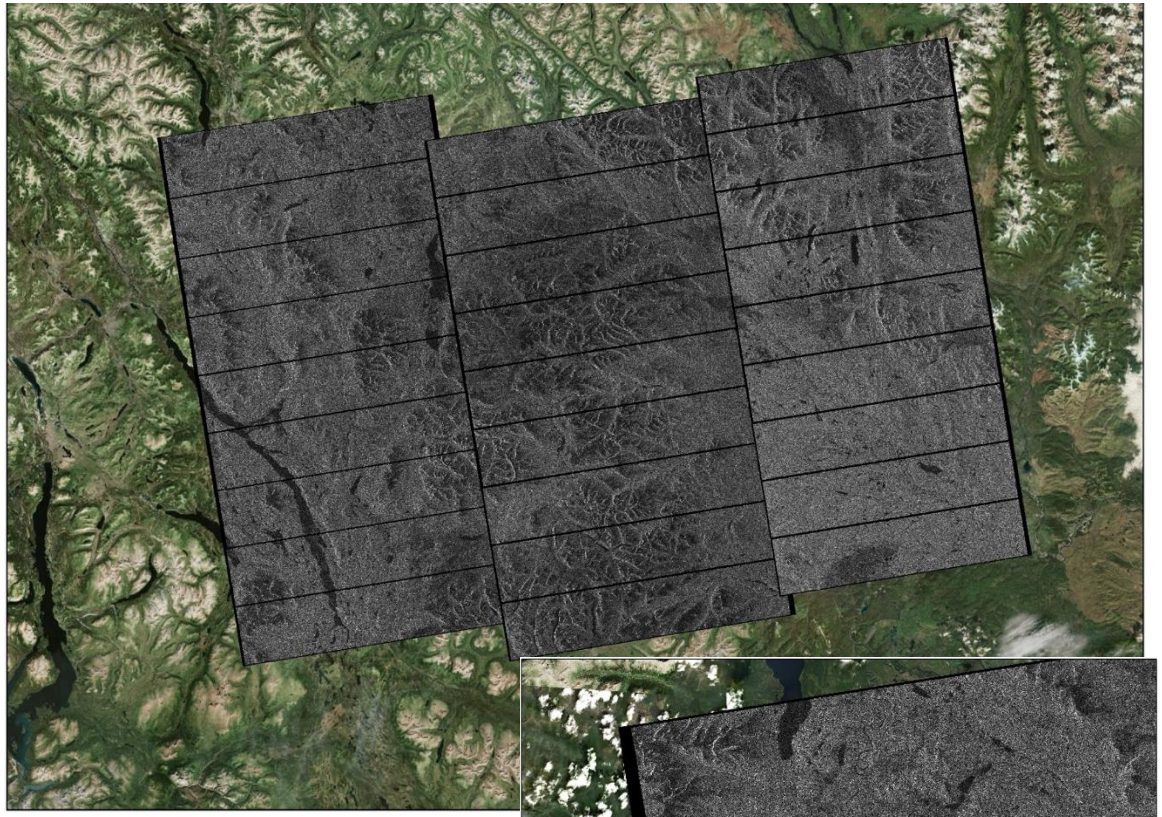
SLC

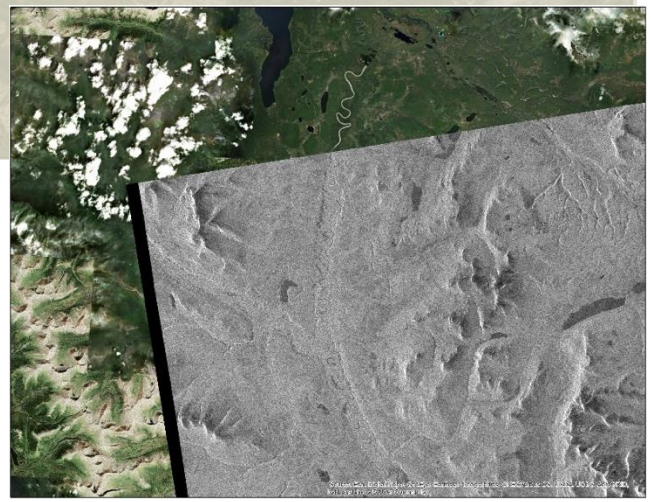
Single Look Complex

Sentinel-1 GRD

Suitable for Amplitude Applications

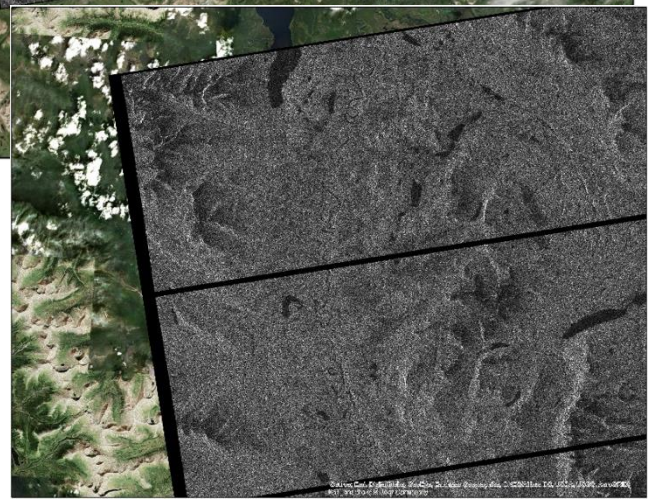
- Suitable source image for RTC correction
- Easy to use in GIS environment
  - ✓ Pixels are in ground-detected geometry
  - ✓ Georeferenced, easy to reproject
  - ✓ Square pixels
- Single image file for each polarization
  - ✓ Overlapping pixels are combined
- Smaller file size





GRD

Ground Range Detected



SLC

Single Look Complex

Sentinel-1 SLC

Suitable for Amplitude Applications

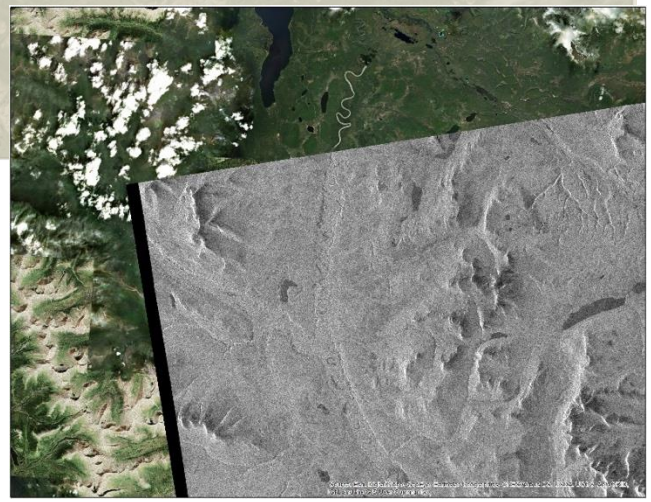
- Suitable source image for RTC correction
- Easy to use in GIS environment
  - ✓ Pixels are in ground-detected geometry
  - ✓ Georeferenced, easy to reproject
  - ✓ Square pixels
- Single image file for each polarization
  - ✓ Overlapping pixels are combined
- Smaller file size

Necessary for Interferometry

- Remains in slant-range geometry
- Phase data is retained
  - ✓ Required for generating interferograms
  - ✓ Suitable for other workflows requiring phase
- Separate image file for each subswath
- Full extent of each burst, including overlap
  - ✓ Black line grid indicates burst boundaries

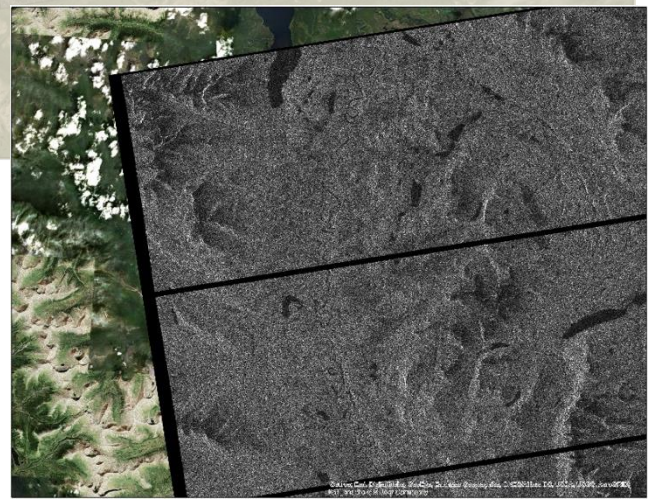
GRD

Ground Range Detected

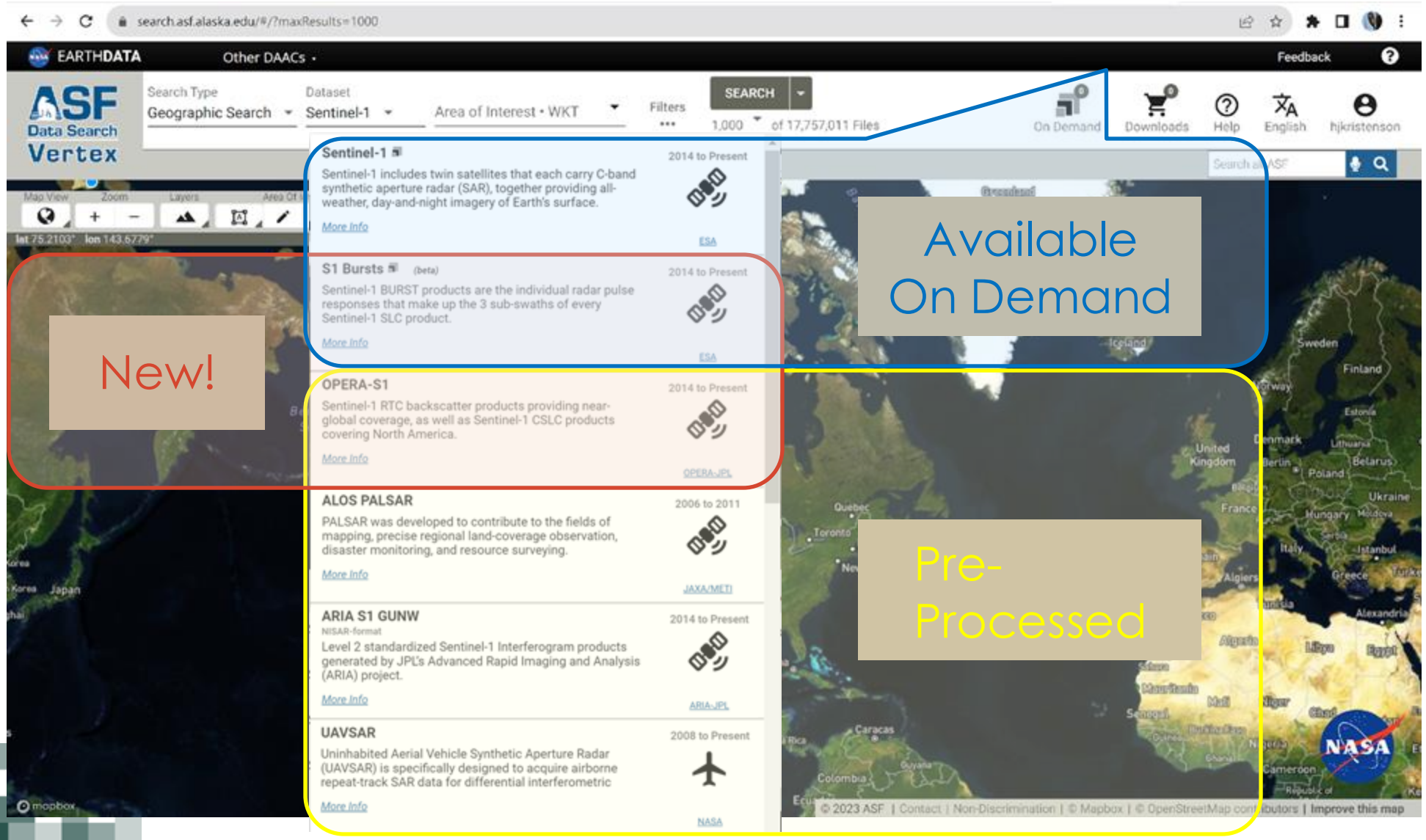


SLC

Single Look Complex



Analysis-Ready Products from ASF

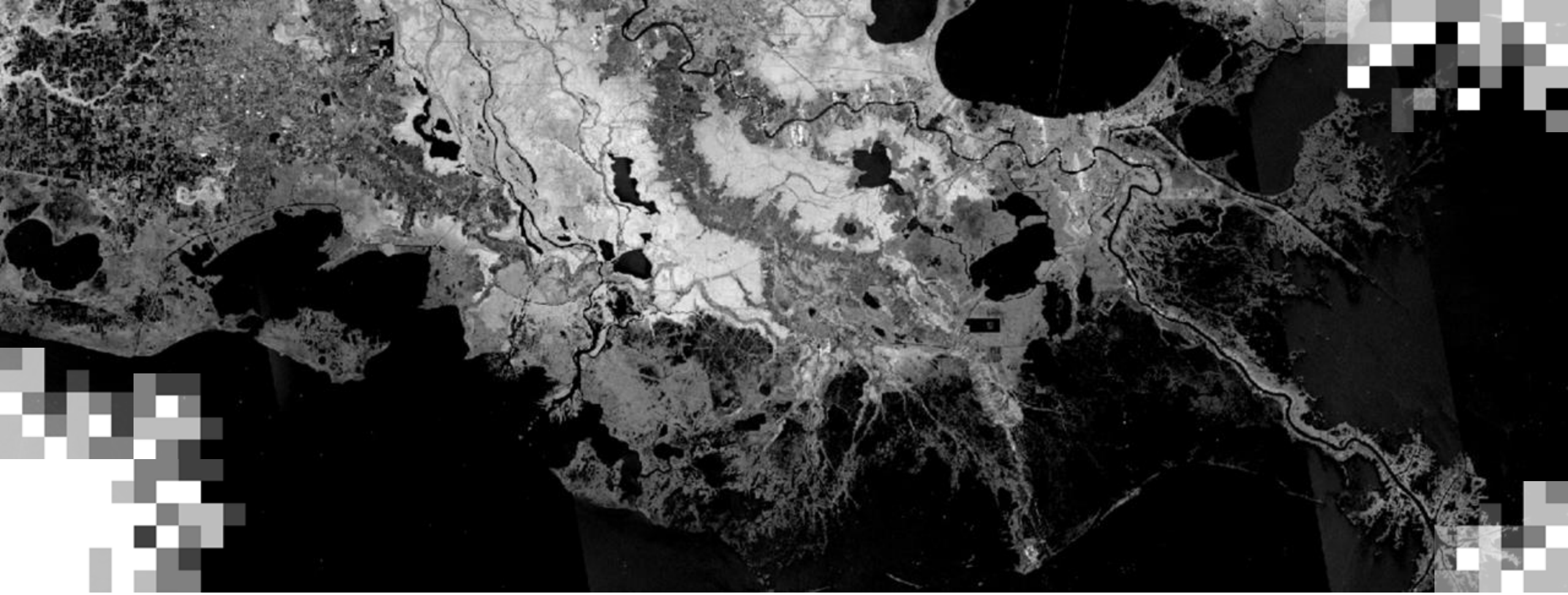


- **Sentinel-1**
  - On Demand RTC
  - On Demand InSAR
- **Sentinel-1 Bursts**
  - On Demand InSAR
- **OPERA S1 RTC**
  - Since Oct. 4, 2023
  - Near-Global
  - Forward Processing
- **ALOS PALSAR**
  - 2006-2011
  - Subset of Data has Pre-Processed RTC
- **ARIA S1 GUNW**
  - InSAR Products
  - Limited Locations
  - On Demand Soon
- **UAVSAR**
  - Airborne Sensor
  - Limited Space/Time

NISAR

- Due to launch 2025 – Earliest possible window is February
- Joint venture between NASA and Indian Space Research Organisation (ISRO)
- L-Band:
  - Greater penetration through canopy and soil than C-band
- Also has an S-band sensor (12 cm wavelength) – limited spatial coverage
- 12-day average repeat cycle
  - Complement to Sentinel-1 C-Band
- **Analysis-ready products will be produced as part of the mission, and readily available for use/download.**
  - Sample Data Products available from JPL
  - Guidance for working with these sample products available from ASF

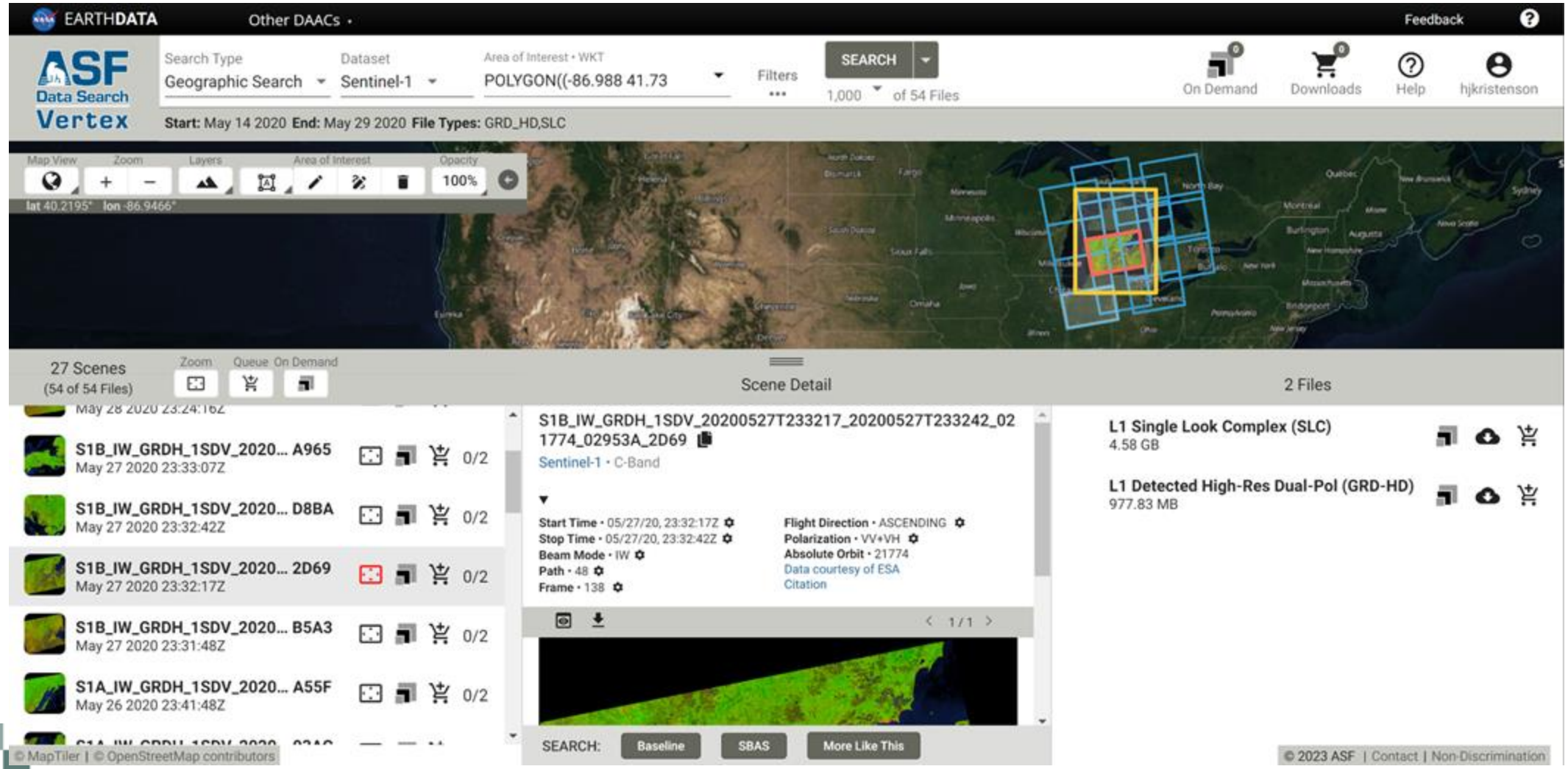
NISAR Mission Website



Part 3:

Search & Discovery of SAR Data

ASF Data Search: Specialized for SAR

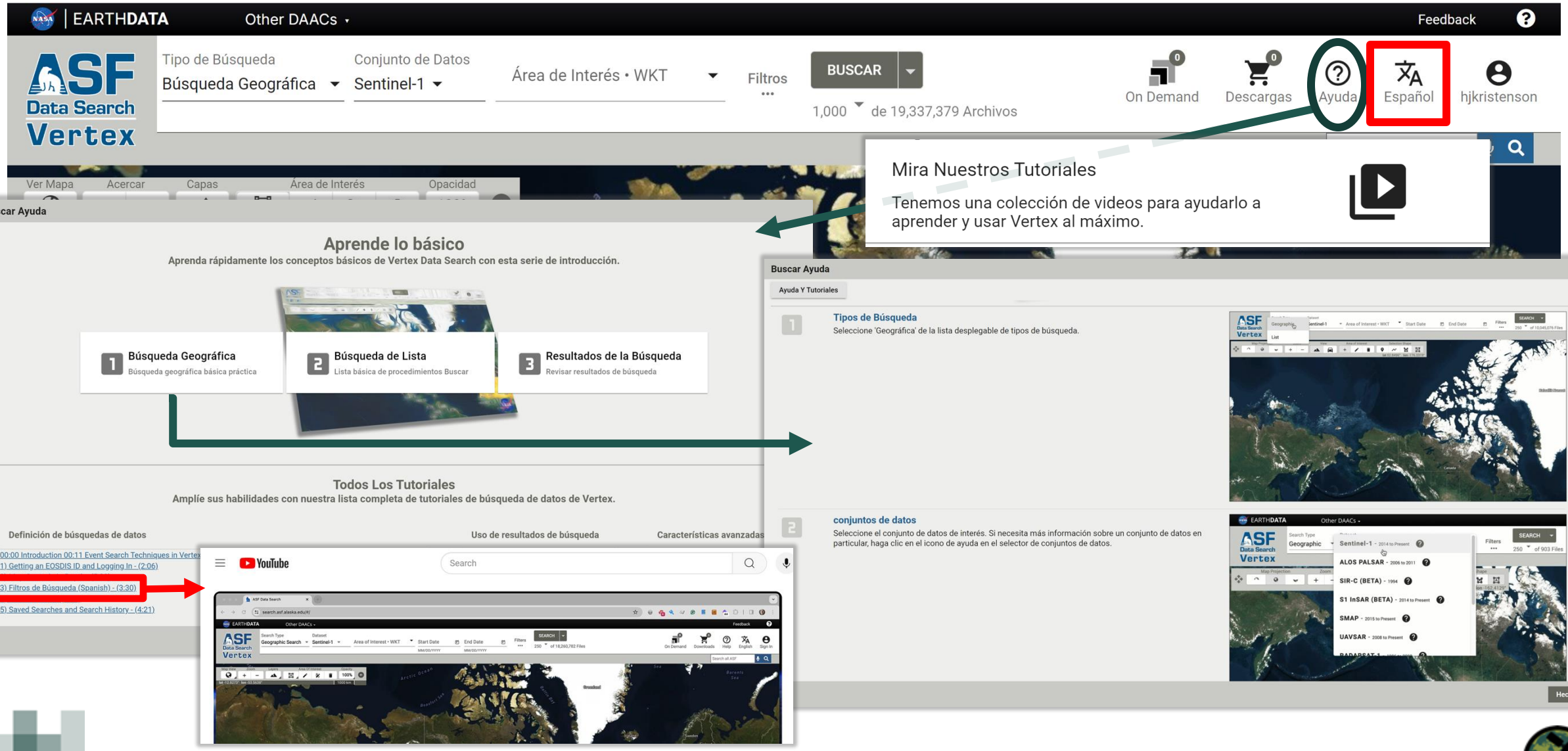


Explore and access/ download ASF's data holdings

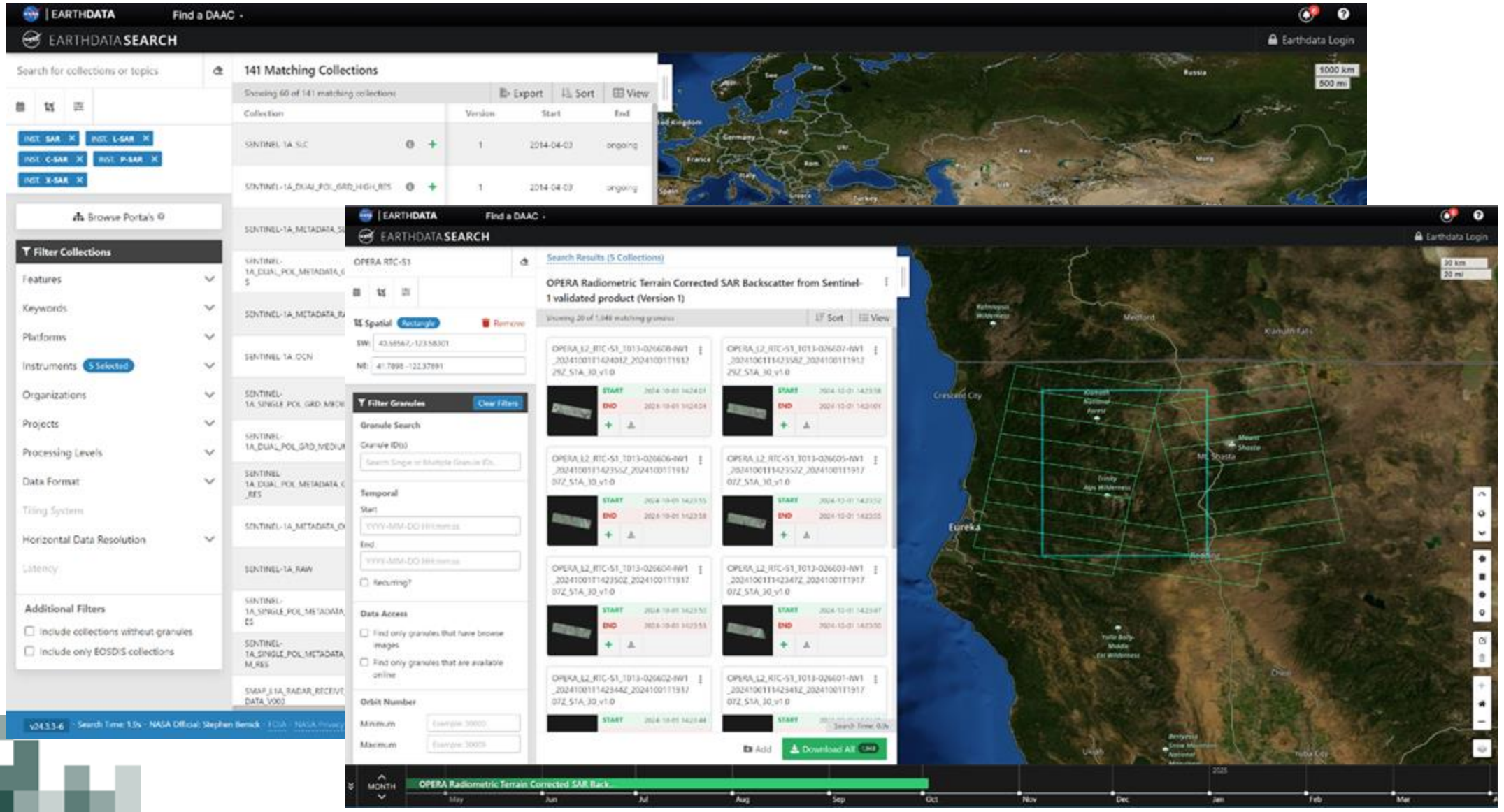
Programmatic Access

- asf_search Python Package
- ASF Search API

Spanish Language Support in Vertex



Earthdata Search: Find All EOSDIS Data (Including SAR)



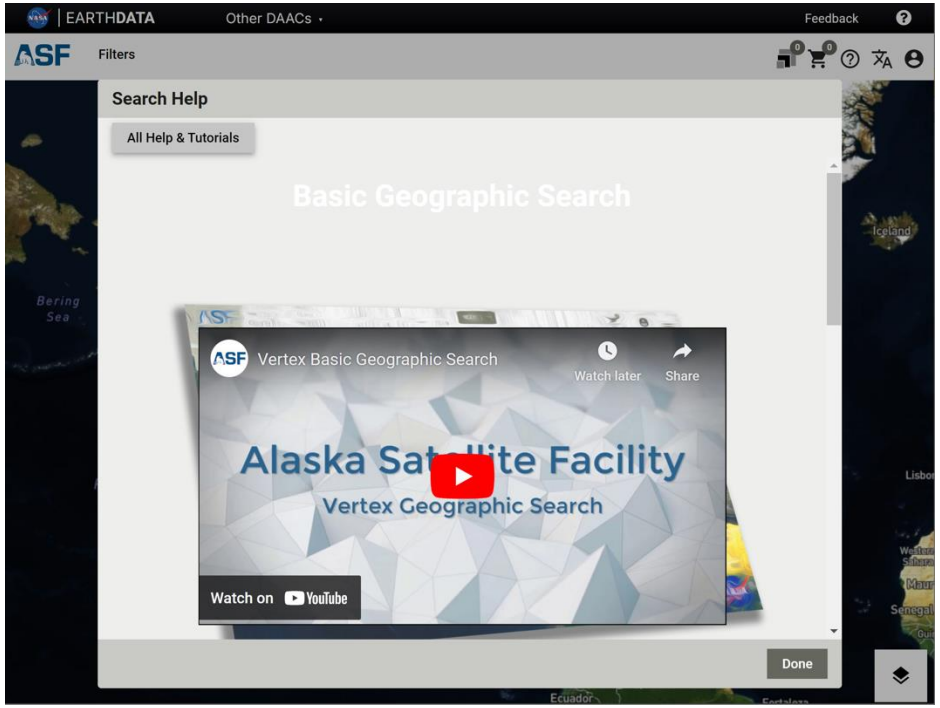
Provides access to holdings from all the DAACs in EOSDIS

Programmatic Access

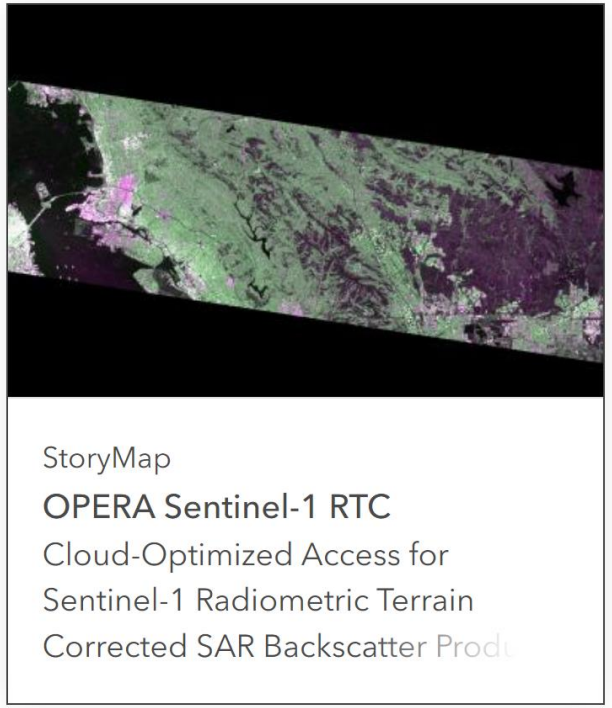
- [earthaccess Python Package]

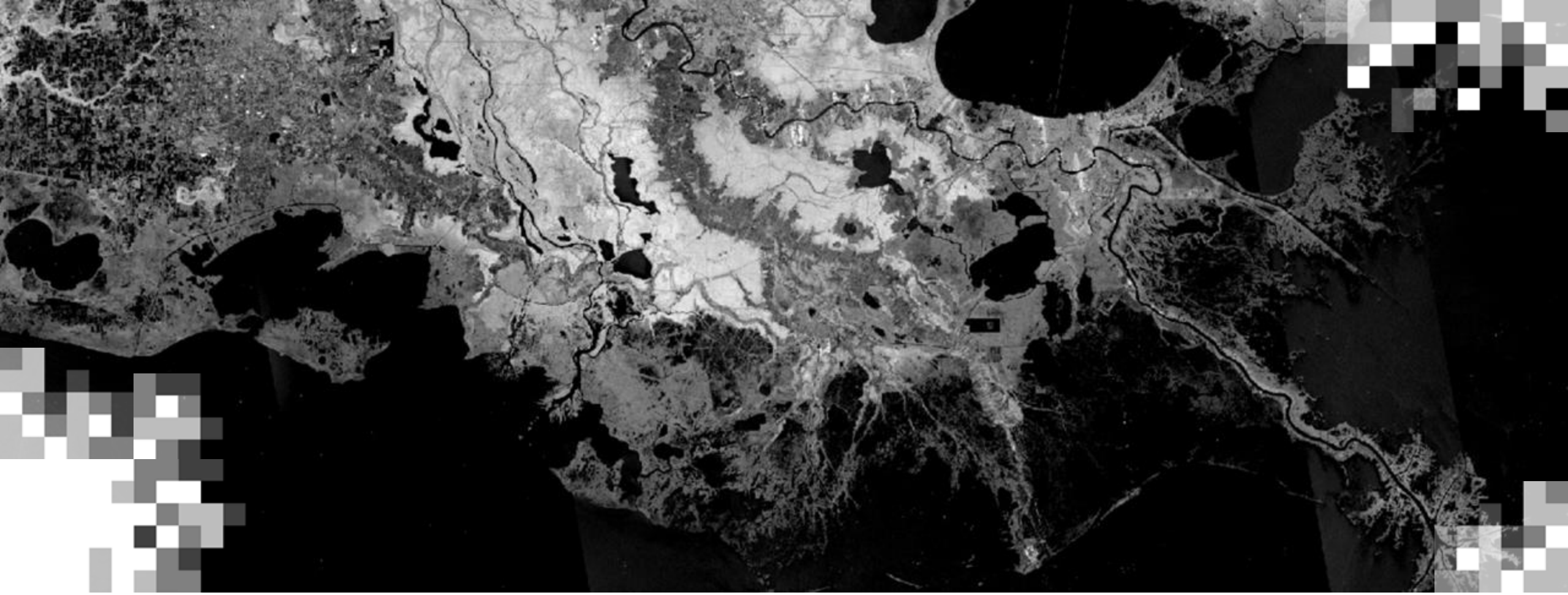
DEMO!

[Vertex Video Tutorials]



[OPERA RTC-S1 Tutorial]





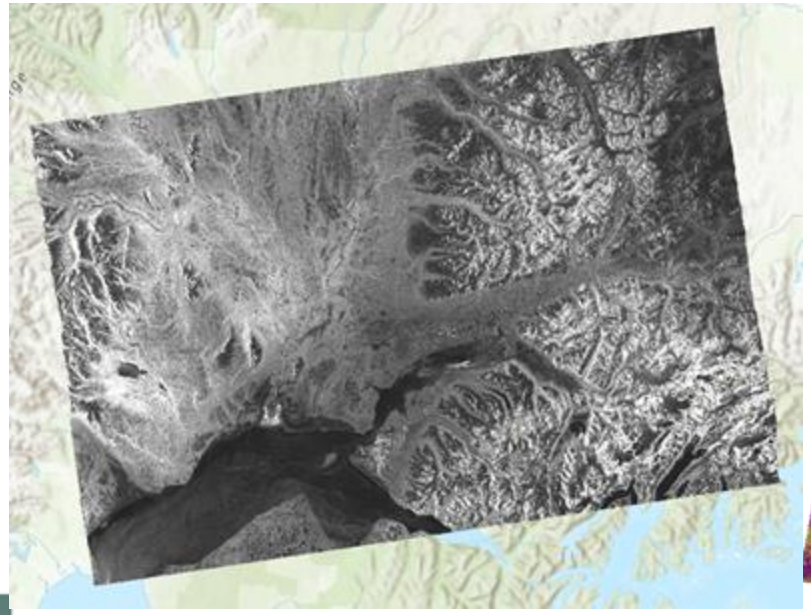
Part 3:

Ordering and Downloading On-Demand Products from ASF

On Demand Products for Sentinel-1

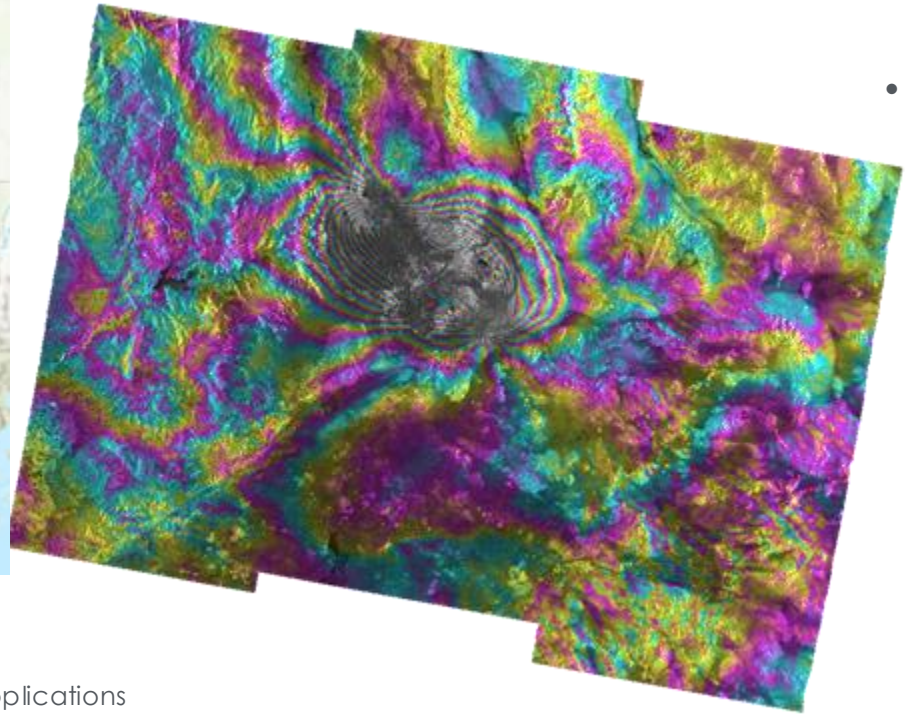
RTC

- Radiometric Terrain Correction
- Amplitude data in all available polarizations and RGB Decomposition
- Processed using GAMMA software
- Easy to use in GIS workflows



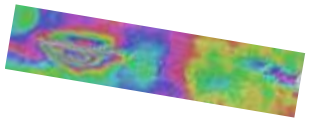
InSAR

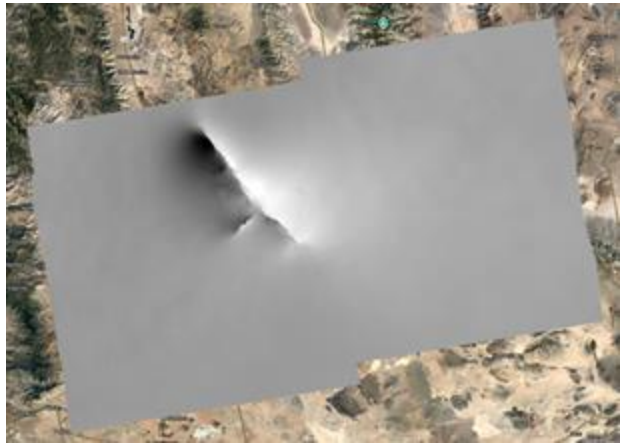
- SAR Interferometry (phase differencing)
- Uses full Sentinel-1 SLC scenes
- Wrapped and unwrapped phase, coherence, displacement maps
- Processed using GAMMA software



Burst InSAR

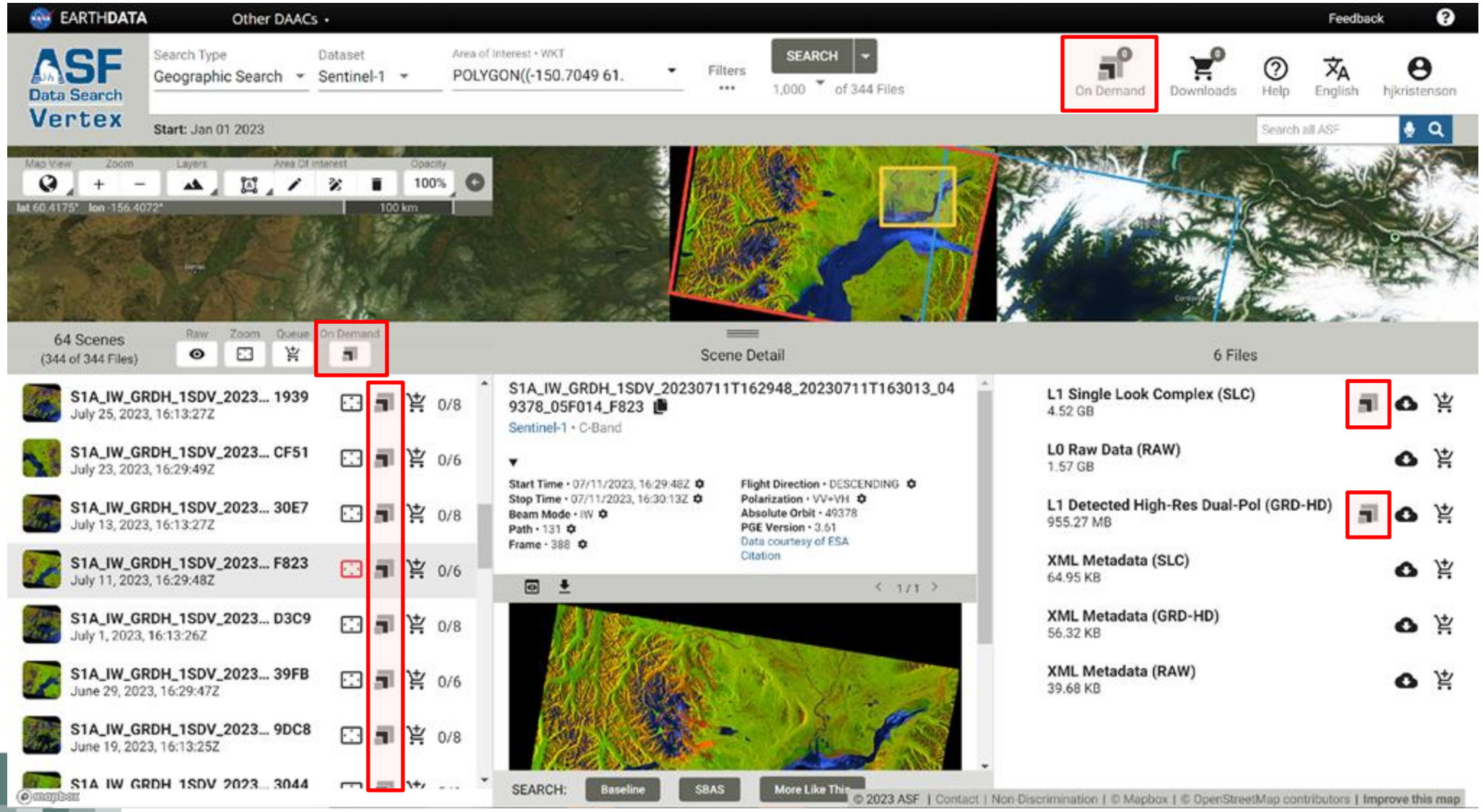
- SAR Interferometry (phase differencing)
- Processes single SLC bursts
- Wrapped and unwrapped phase, coherence, connected components
- Processed using ISCE2 software (open source)
- Multi-burst processing (merged bursts) coming soon!

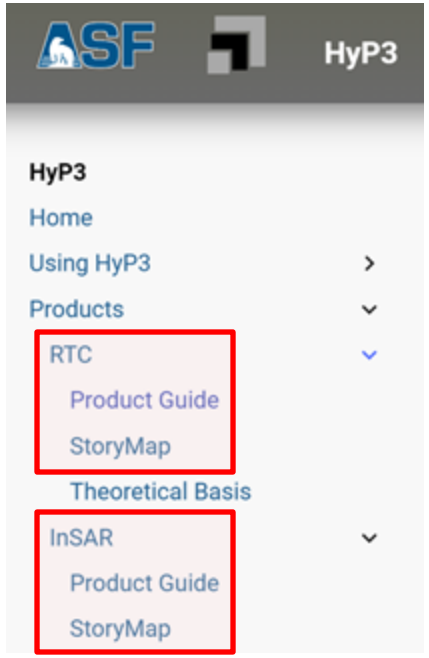




On-Demand Processing with HyP3

HyP3
ASF's Hybrid Pluggable Processing Pipeline





DEMO!

RTC On Demand Tutorial

StoryMap

RTC On Demand!

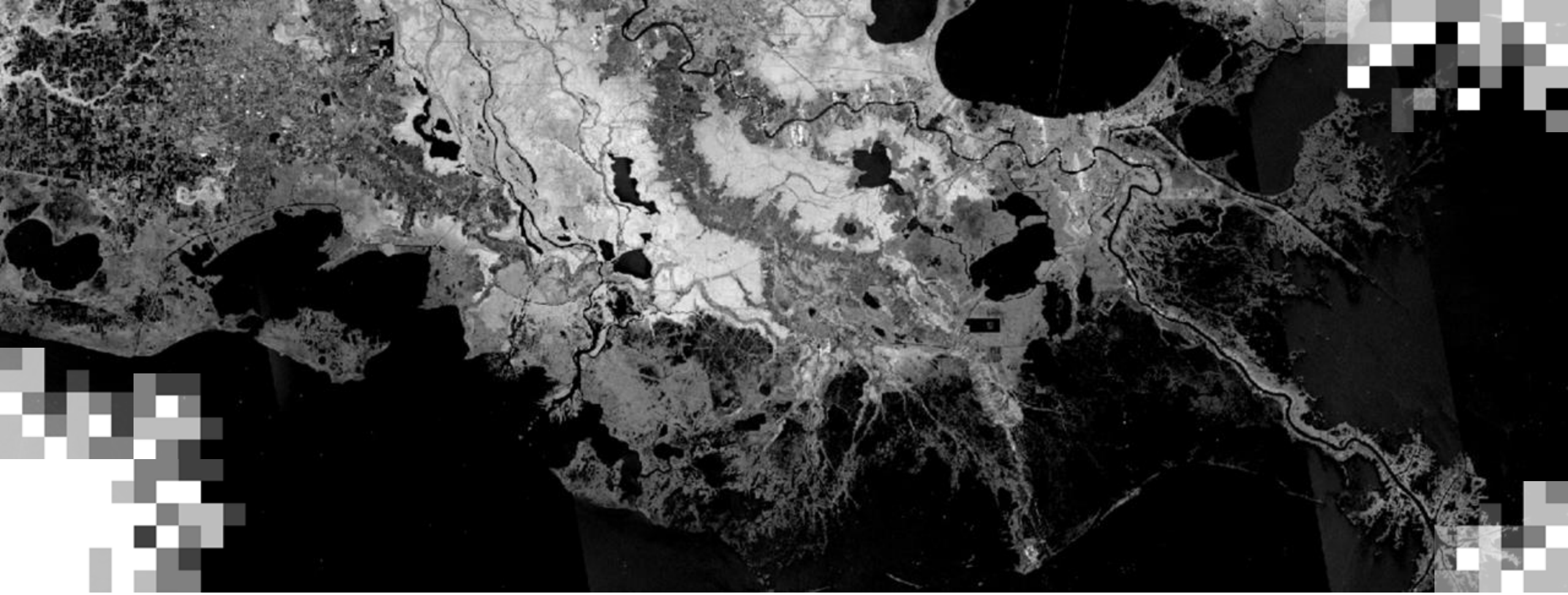
Working with Radiometrically Terrain Corrected Sentinel-1 SAR datasets from the Alaska Satellite Facility

InSAR On Demand Tutorial

StoryMap

InSAR On Demand!

Ordering Sentinel-1 InSAR datasets from the Alaska Satellite Facility



Part 3:
Summary

Summary

- The Alaska Satellite Facility (ASF) is one of the 12 Distributed Active Archive Centers (DAACs) that comprise NASA's Earth Observing System Data Information System (EOSDIS).
  - ASF specializes in Synthetic Aperture Radar (SAR) data.
- ASF's holdings are free and easy to access.
  - Search and download using interactive map-based web interfaces.
    - Vertex for ASF's holdings, optimized for SAR searches: https://search.asf.alaska.edu
    - Earthdata Search for all of NASA's EO holdings: https://search.earthdata.nasa.gov/search
  - Search and download programmatically:
    - asf_search Python package or Search API, optimized for SAR searches
    - earthaccess Python package for all of NASA's Earth Observation holdings
- A range of analysis-ready SAR products are available from ASF.
  - Sentinel-1 Products:
    - OPERA RTC-S1 and ARIA GUNW InSAR available for download
    - On-demand RTC and InSAR processing also available for entire Sentinel-1 archive
  - UAVSAR products and ALOS PALSAR RTC available for limited areas

Resources – Part 3

ASF Data Search – Vertex
https://search.asf.alaska.edu/

Earthdata Search
https://search.earthdata.nasa.gov/search

ASF ArcGIS Online Homepage (StoryMap Tutorials)
https://asf-daac.maps.arcgis.com/home/index.html

On Demand (HyP3) Documentation
https://hyp3-docs.asf.alaska.edu

Vertex Documentation
https://docs.asf.alaska.edu/vertex/manual/

ASF Website
https://www.asf.alaska.edu/

Contact ASF
https://www.asf.alaska.edu/contact/

EdX SAR Certificate
(3 courses, can be taken individually)

NASA EOSDIS Webinar: Introduction to SAR

NASA EOSDIS Webinar: SAR Applications in GIS

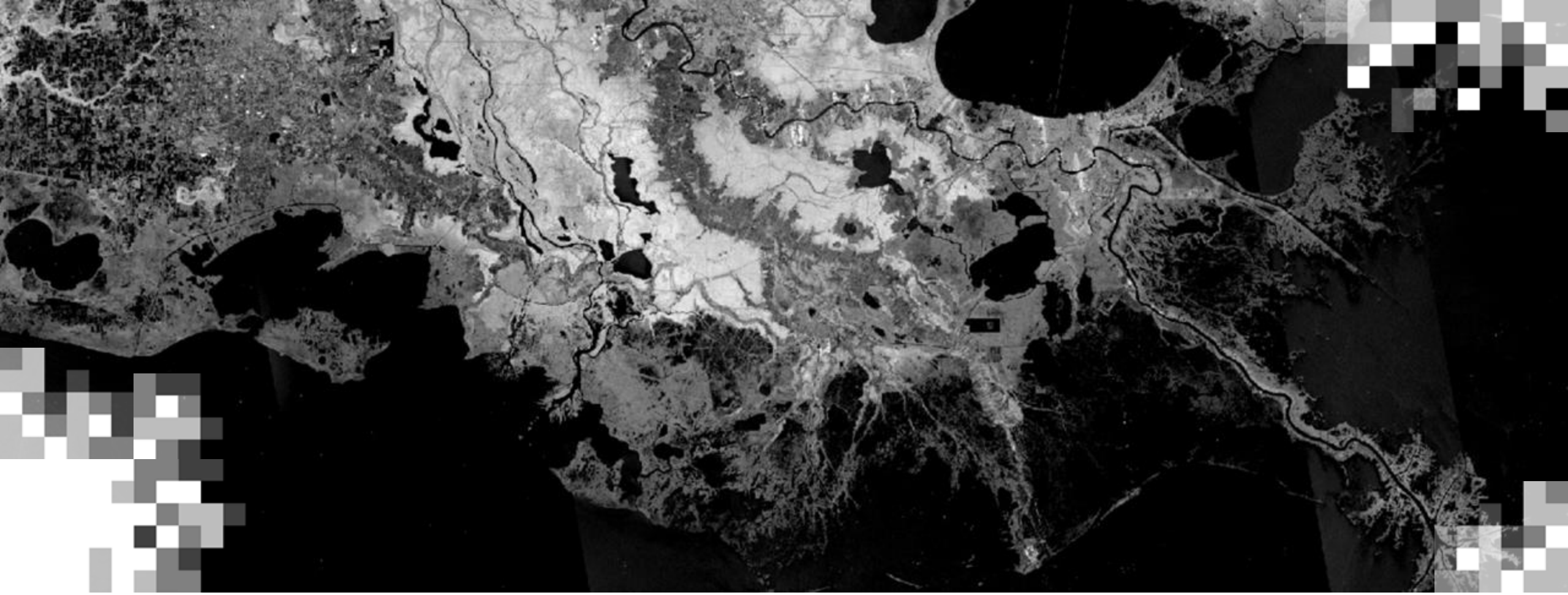
NASA EOSDIS Webinar: On-Demand Sentinel-1 RTC

NASA EOSDIS Webinar: On-Demand Sentinel-1 InSAR

SAR Handbook

ArcGIS Toolbox

Earthdata Login



An Introduction to SAR and Its Applications

Summary

Training Summary

- In SAR the azimuth (along track) resolution is different from the range (across track) resolution.
- The three radar parameters are wavelength, polarization and incidence angle.
- The longer the wavelength the greater the penetration depth.
- The length of the wave will determine the interaction with the surface objects.
- Polarization provides information related to the structural characteristics of the objects on the surface.
- Incidence angle will influence the signal penetration into the target.
- The two surface parameters that influence the radar signal are structure and moisture.
- The main backscatter mechanisms are specular scattering, rough surface scattering, volume scattering and double bounce.
- Radar images have geometric distortions in areas of complex topography.
- Speckle is the graininess inherent in SAR images. It can be reduced through multi-looking or with a spatial or temporal filter.
- Radar can be used for different ecosystem studies such as mapping landcover, crops, wetland inundation, and soil moisture.

Training Summary

- SAR interferometry (InSAR) measures the distance from the satellite to the ground with high precision by using the phase of the reflected radar signals.
- Coherence of InSAR phase is sensitive to the surface or surface cover stability at the radar wavelength scale.
- Phase cycles in a repeat-pass interferogram show change in distance to ground by half the radar wavelength, 2.8 cm for Sentinel-1 and 12 cm for NISAR.
- New pre-processed InSAR products enable user analysis of interferograms with few additional steps.
- InSAR measurements of surface motion are useful for a variety of geological processes, some hydrological processes, dynamics of glaciers, and other effects that displace surface or large structures.

Homework and Certificates

- **Homework:**
  - One homework assignment
  - Opens on 11/20/2024
  - Access from the training webpage
  - Answers must be submitted via Google Forms
  - **Due by 12/04/2024**

- **Certificate of Completion:**
  - Attend all three live webinars (attendance is recorded automatically)
  - Complete the homework assignment by the deadline
  - You will receive a certificate via email approximately two months after completion of the course.

Contact Information

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Thank You!