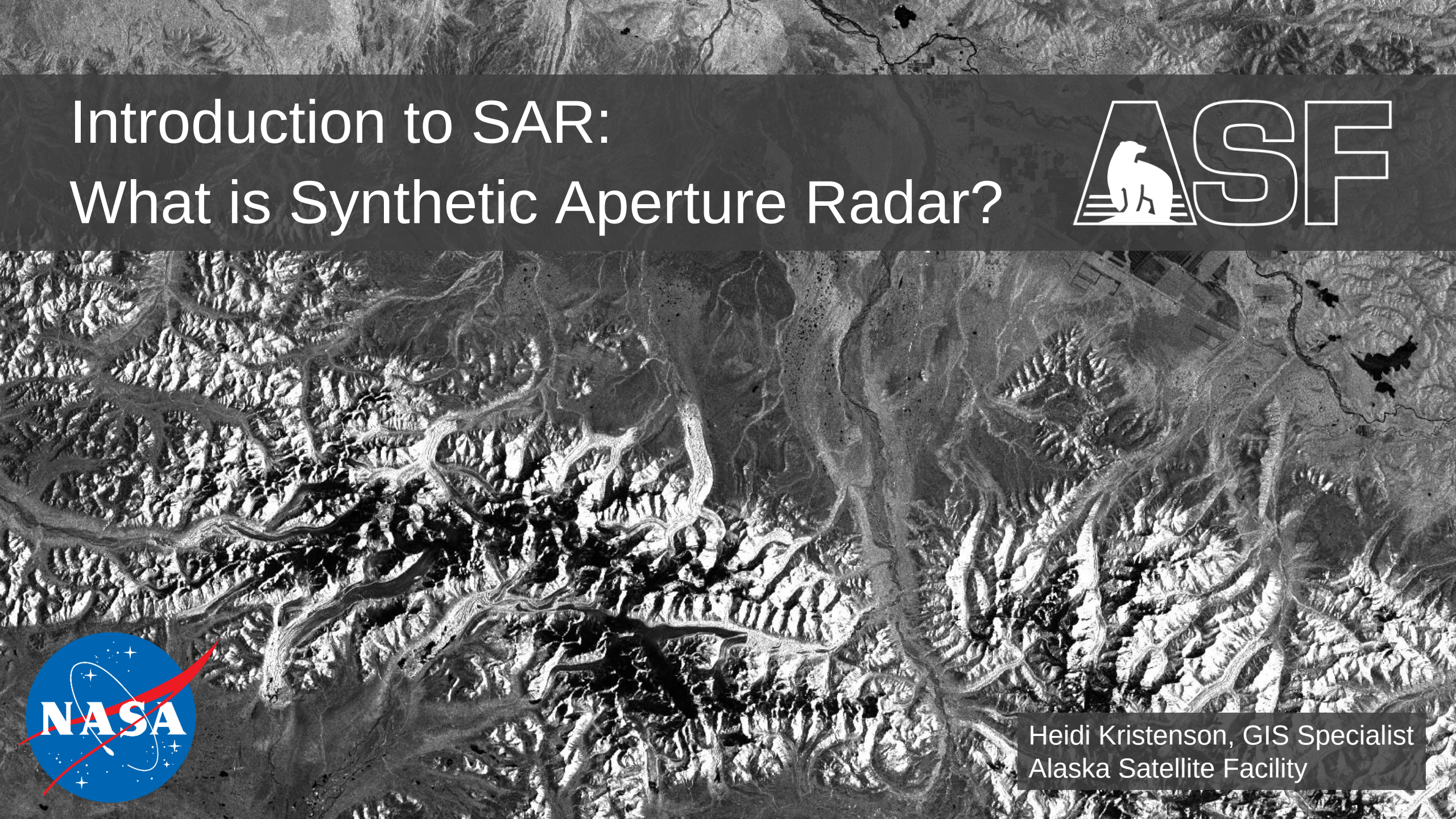
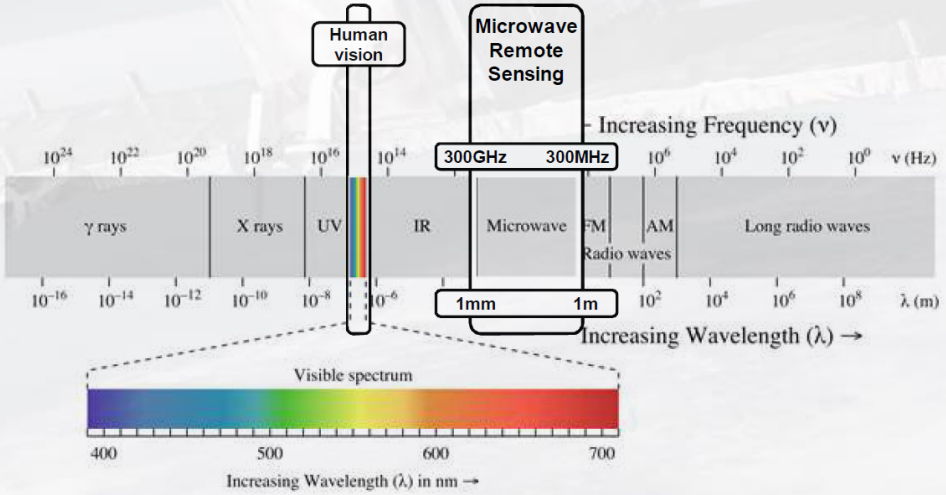
Introduction to SAR:
What is Synthetic Aperture Radar?



Heidi Kristenson, GIS Specialist
Alaska Satellite Facility

Synthetic Aperture Radar (SAR) Data Acquisition

- Microwave range
  - Longer wavelength than infrared, shorter than radio waves
- Active vs. Passive System
- Side-looking Geometry



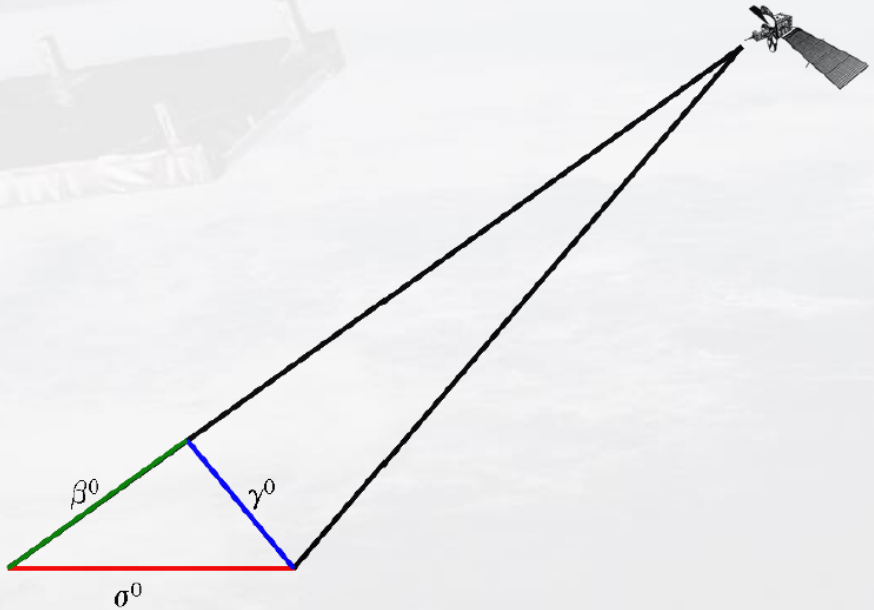
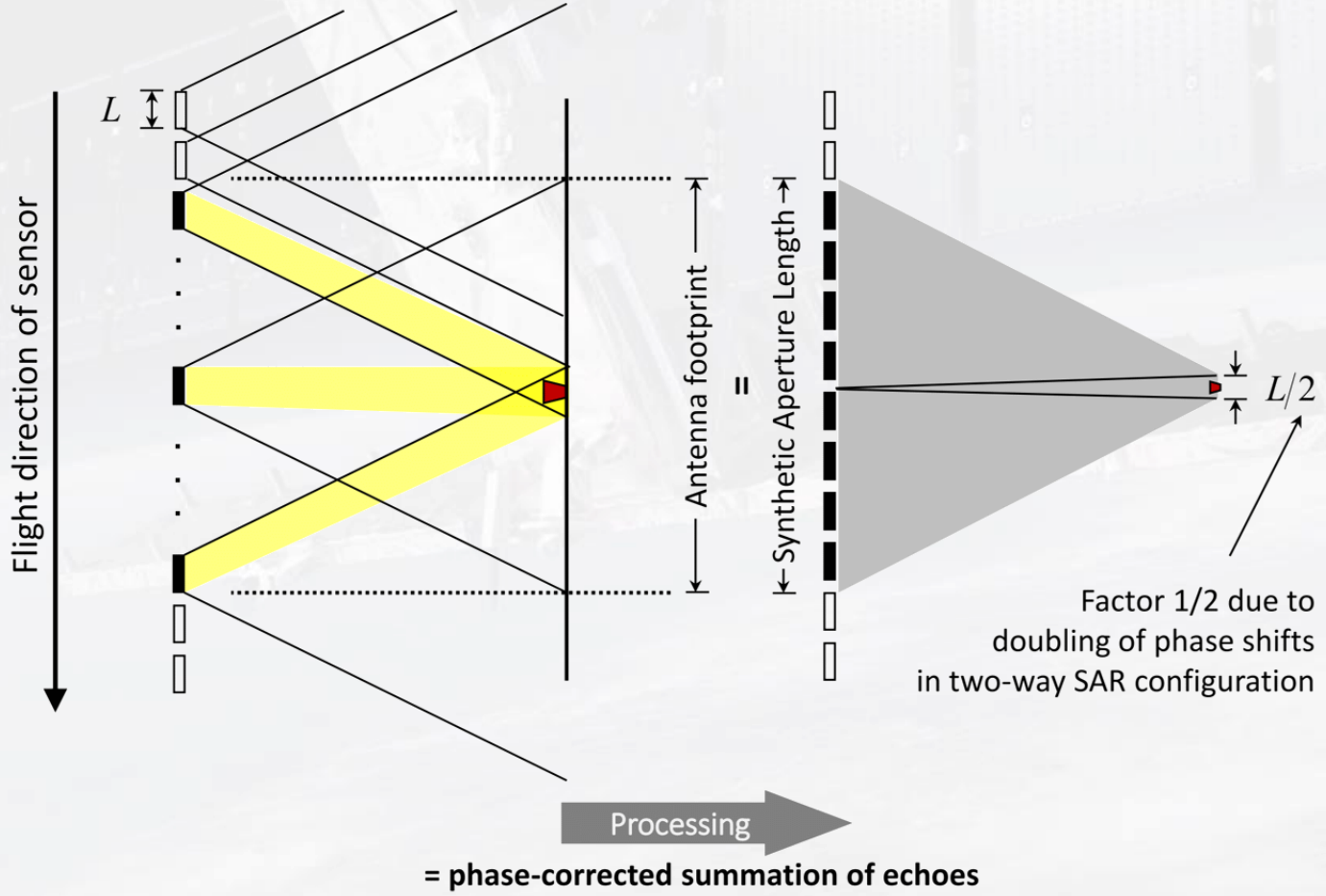
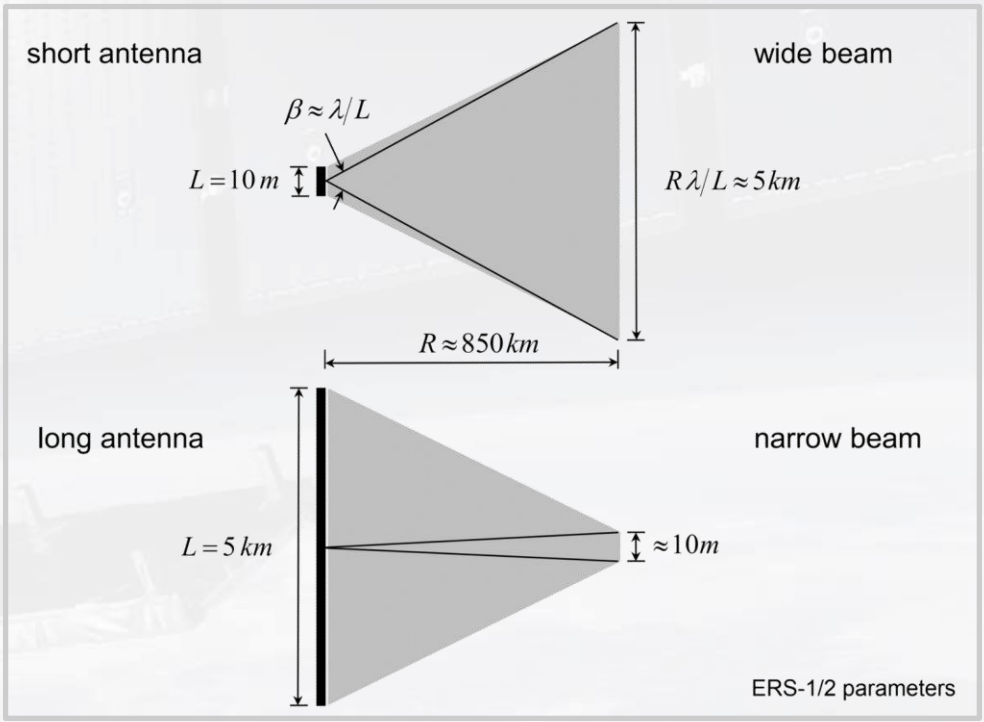


Image: Sentinel-1 Poster, ESA

What is Synthetic about SAR?

- To get reasonable resolution, the antenna would need to be longer than would be physically possible in orbit





- SAR uses the movement of the sensor and data post-processing to synthesize the resolution of a much larger antenna

Diagrams: Franz Meyer Image: Sentinel-1 Poster, ESA

Why Use SAR?

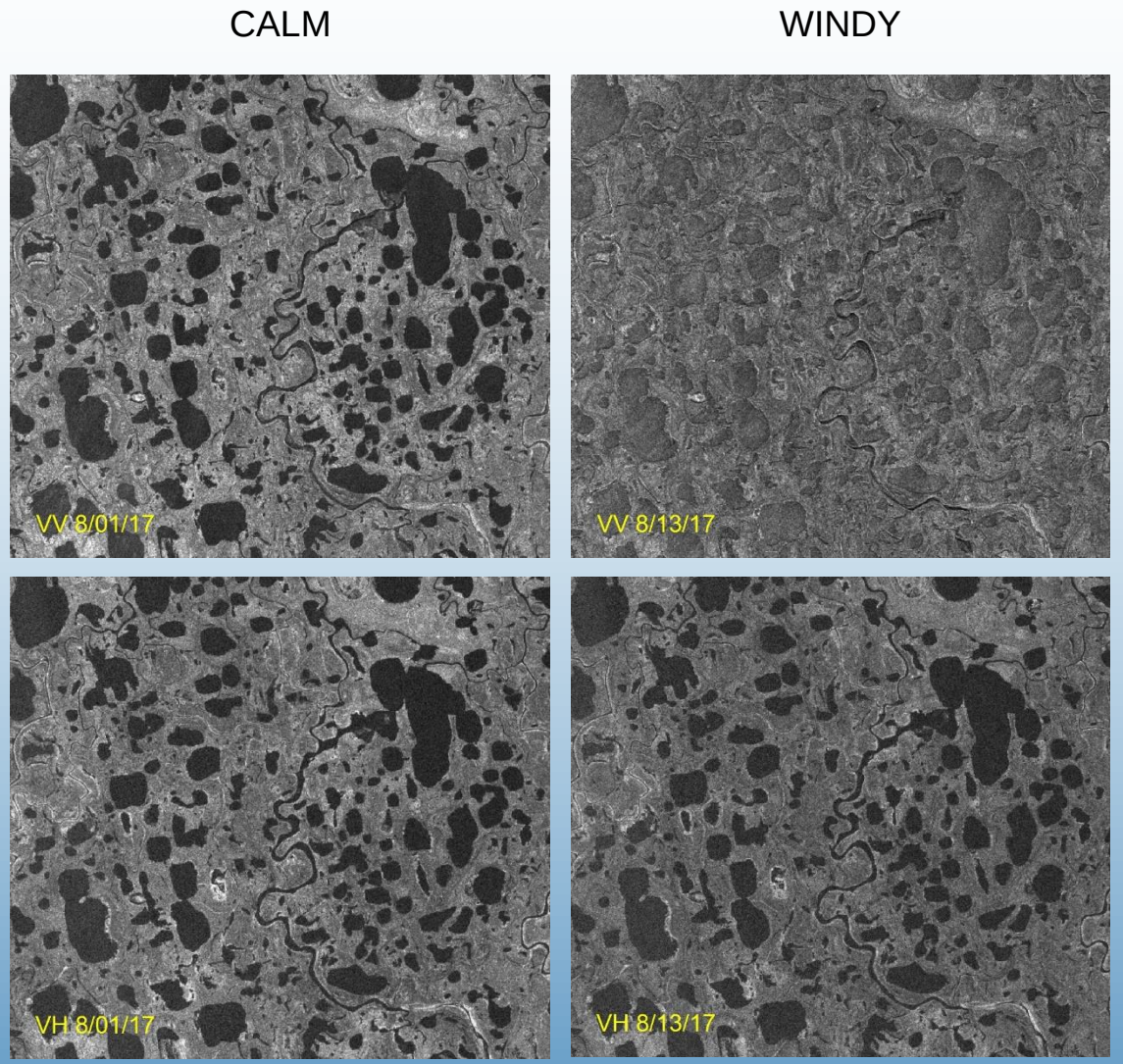
- Can penetrate cloud cover
  - Able to collect imagery in bad weather and in areas prone to frequent cloud-cover
- Not sensitive to light availability
  - Can collect data 24 hours a day
- Global coverage
- Frequent and regular imaging
  - Newer constellations have very frequent return rates and stable orbits
- Different polarizations → detection of different target properties
- Sensitive to very small changes in elevation on the Earth's surface

Image: Sentinel-1 heading for orbit, ESA/ATG medialab

AMPLITUDE

Amount of signal returned to the sensor (Radar Backscatter)

- Polarization
  - VV polarization: surface roughness
  - VH polarization: vegetation
- Dielectric Constant
  - Targets with higher dielectric properties reflect more signal



Images: ASF DAAC 2019 using GAMMA software. Contains modified Copernicus Sentinel data 2017, processed by ESA.

AMPLITUDE

Amount of signal returned to the sensor (Radar Backscatter)

- Polarization
  - VV polarization: surface roughness
  - VH polarization: vegetation
- Dielectric Constant
  - Targets with higher dielectric properties reflect more signal
- Wavelength
  - Signal wavelength determines penetration ability

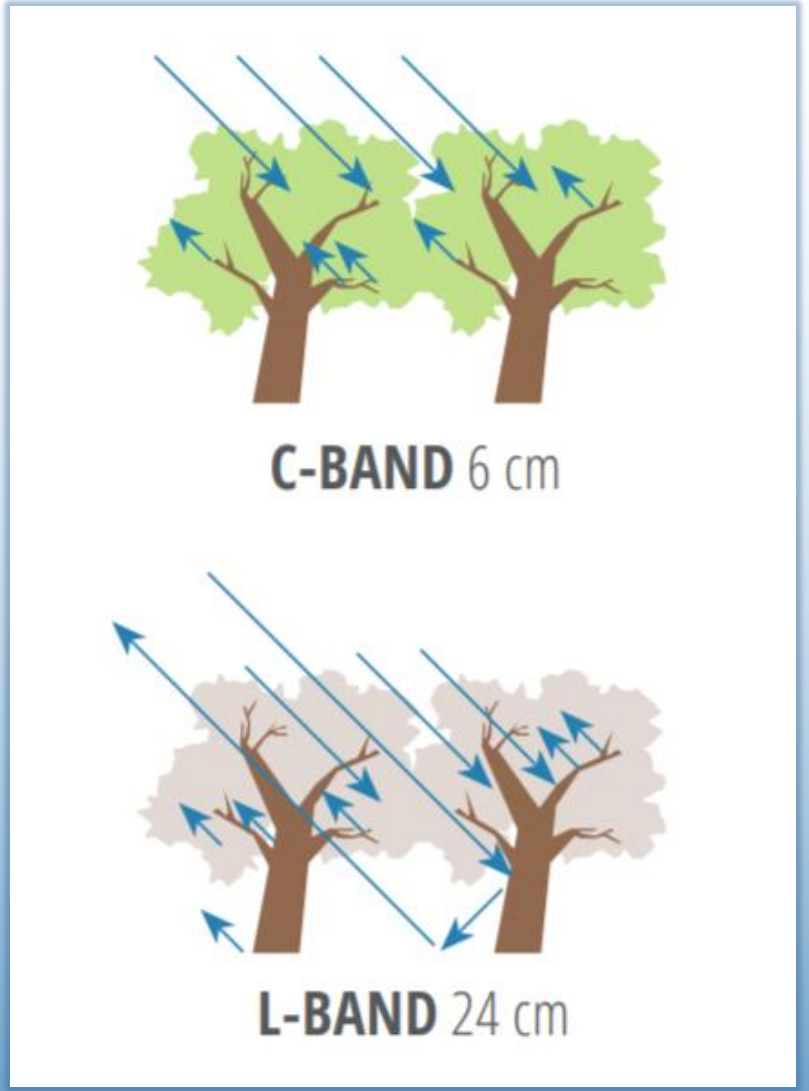
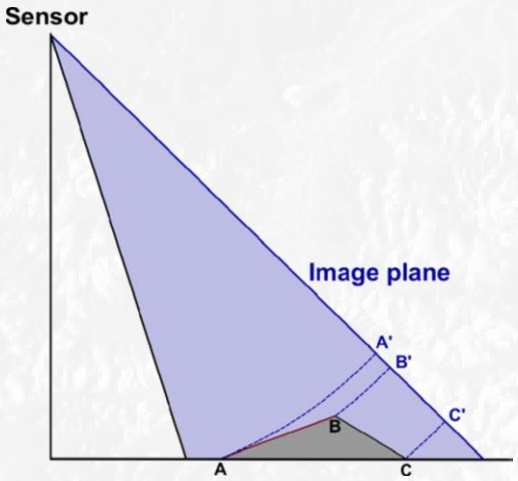


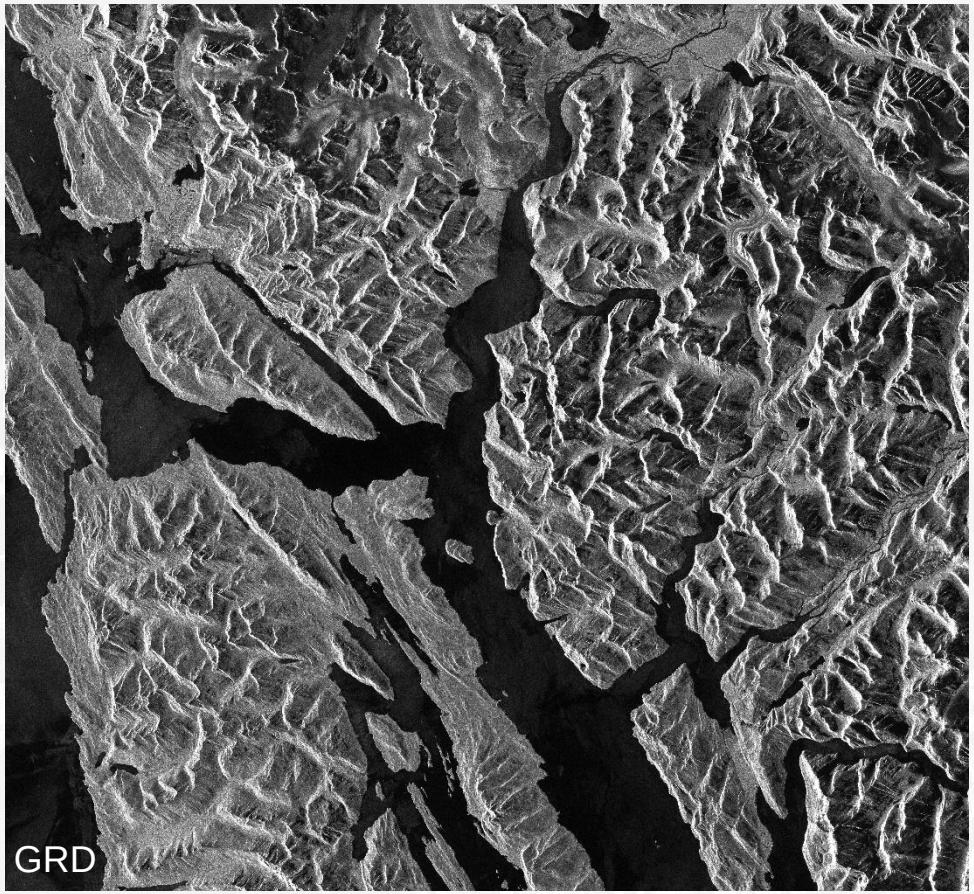
Figure from *The SAR Handbook* DOI: 10.25966/nr2c-s697

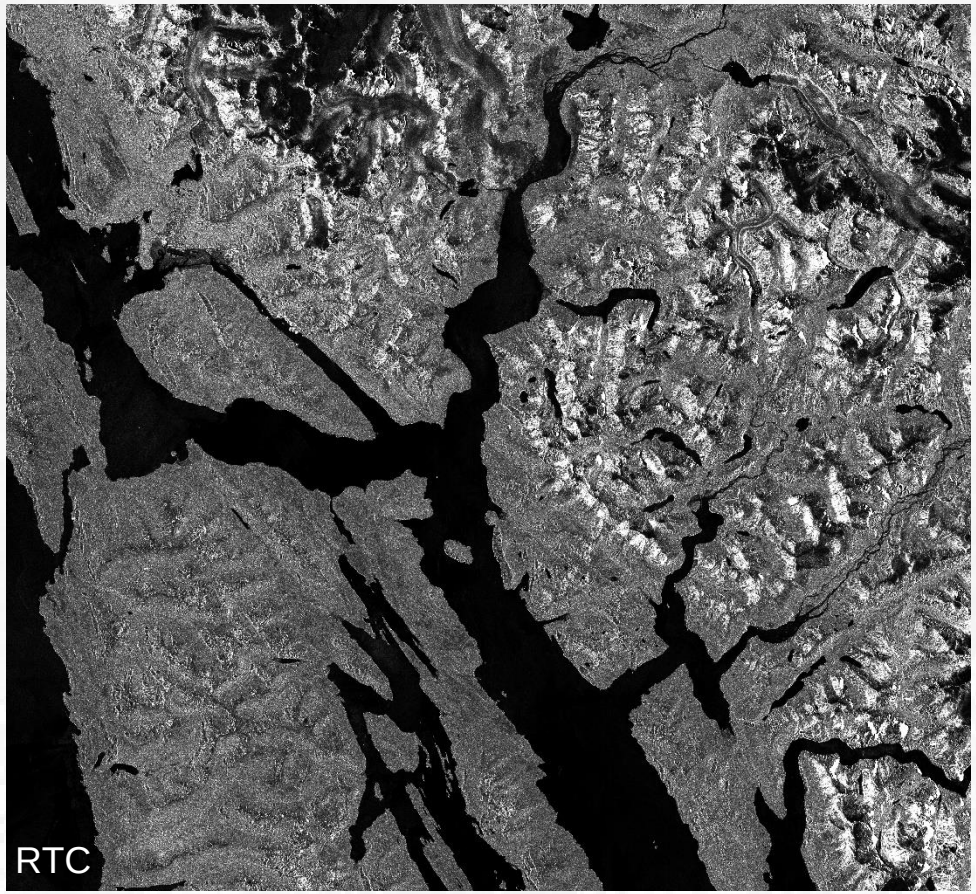
Radiometric Terrain Correction



- Matches features in SAR image to actual landscape features
- Adjusts radiometric returns to represent the appropriate surface area

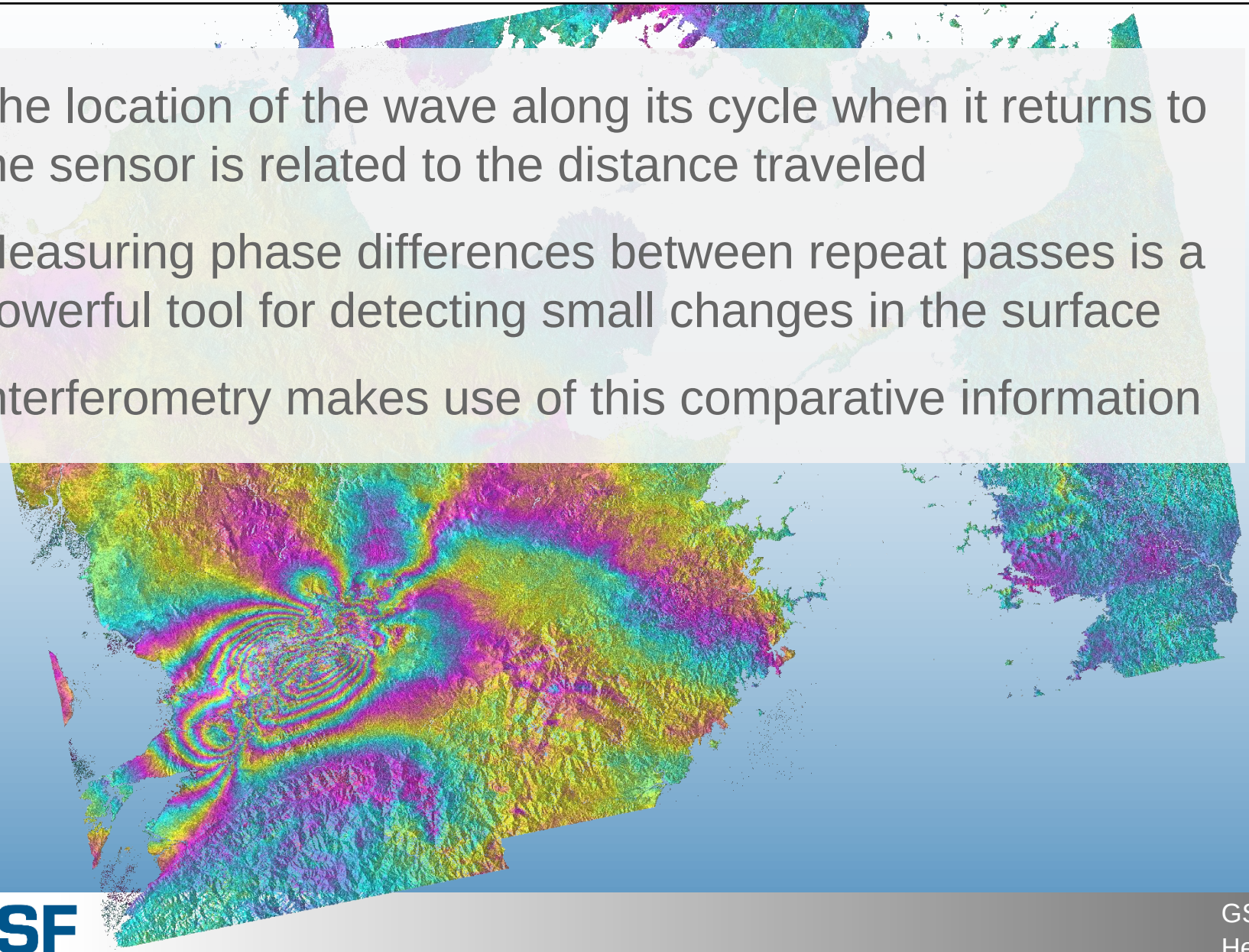
The signal backscattered from the mountaintop (B) is received shortly after the signal from the bottom, even though the bottom (A) is much closer to the sensor on the ground, making the mountains look like they're leaning left, with bright tops.

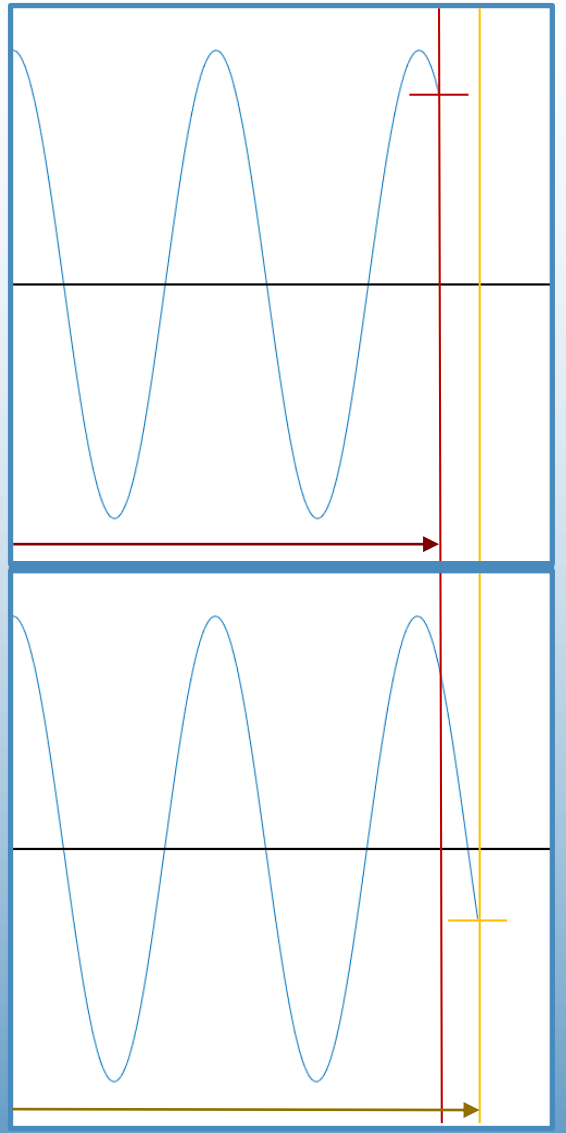




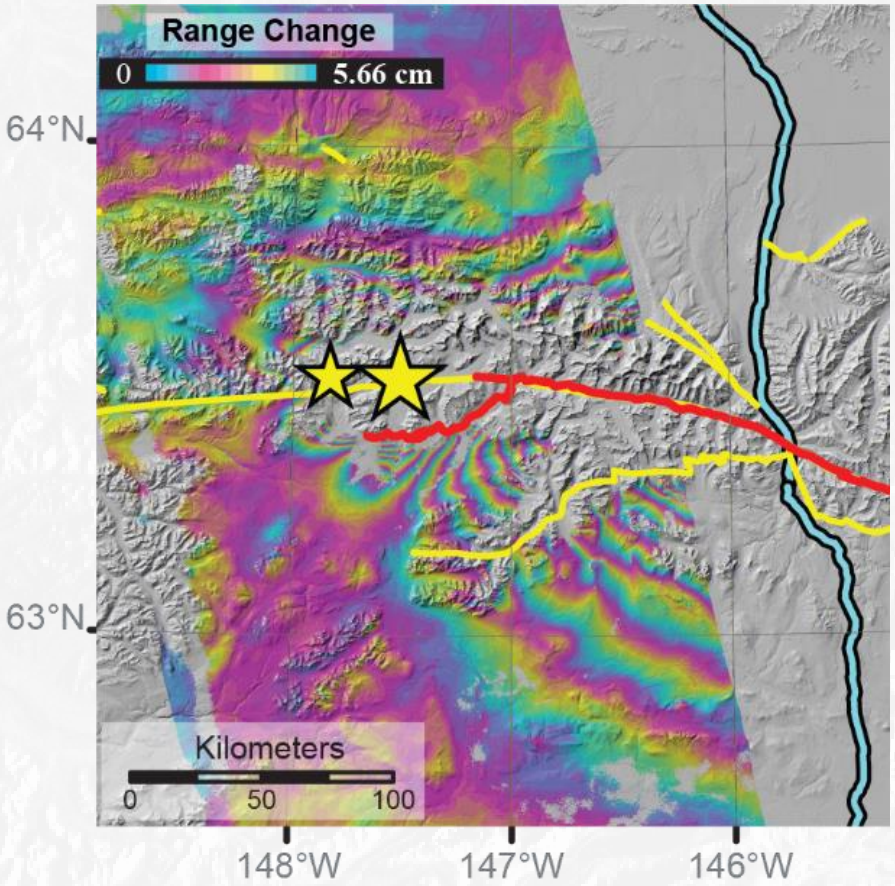
PHASE

- The location of the wave along its cycle when it returns to the sensor is related to the distance traveled
- Measuring phase differences between repeat passes is a powerful tool for detecting small changes in the surface
- Interferometry makes use of this comparative information





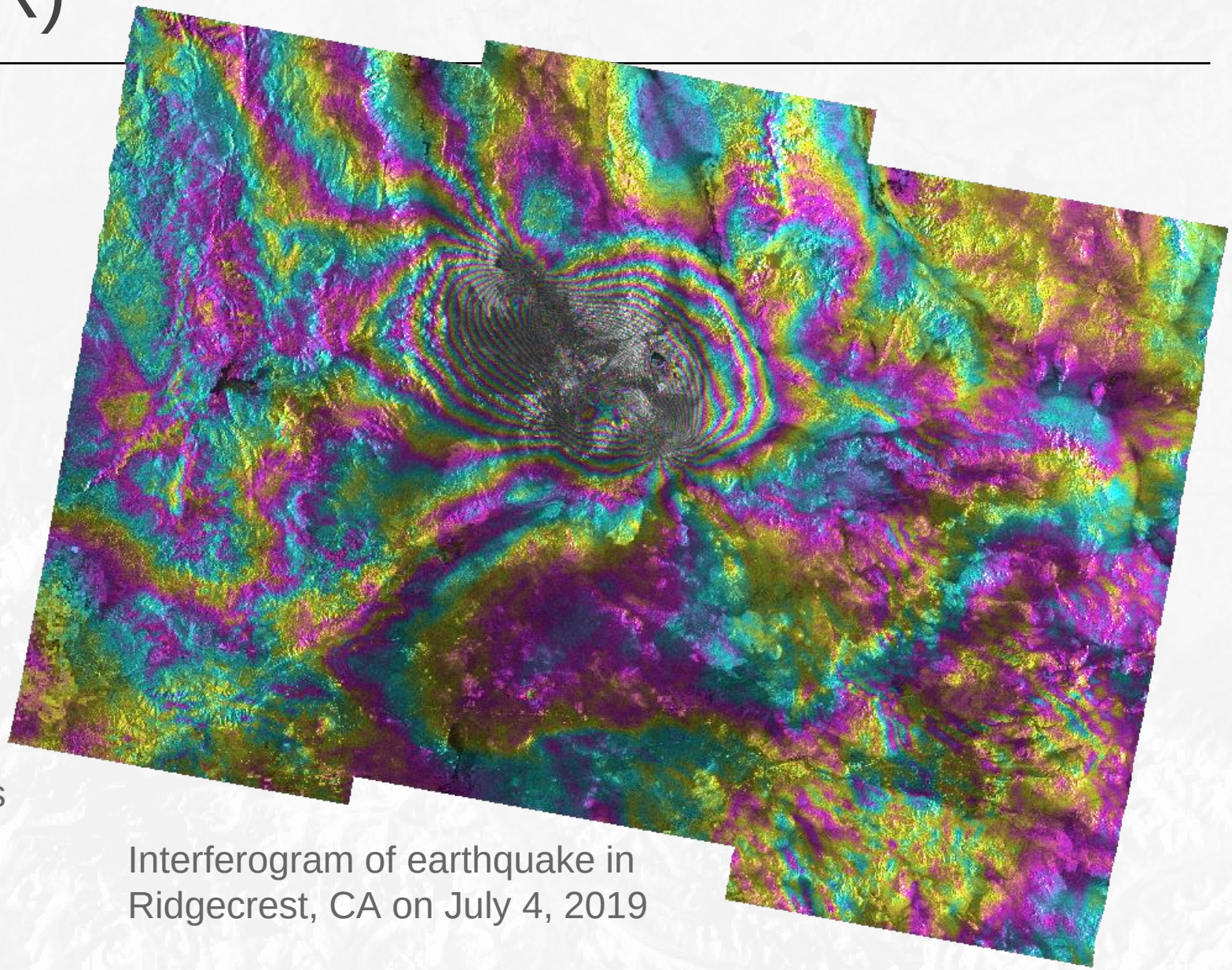
Interferometry (InSAR)



Interferogram for the analysis of effects of earthquakes along the Denali fault

Large star: 7.9 main shock epicenter, November 2002

Small star: 6.7 foreshock epicenter, October 2002



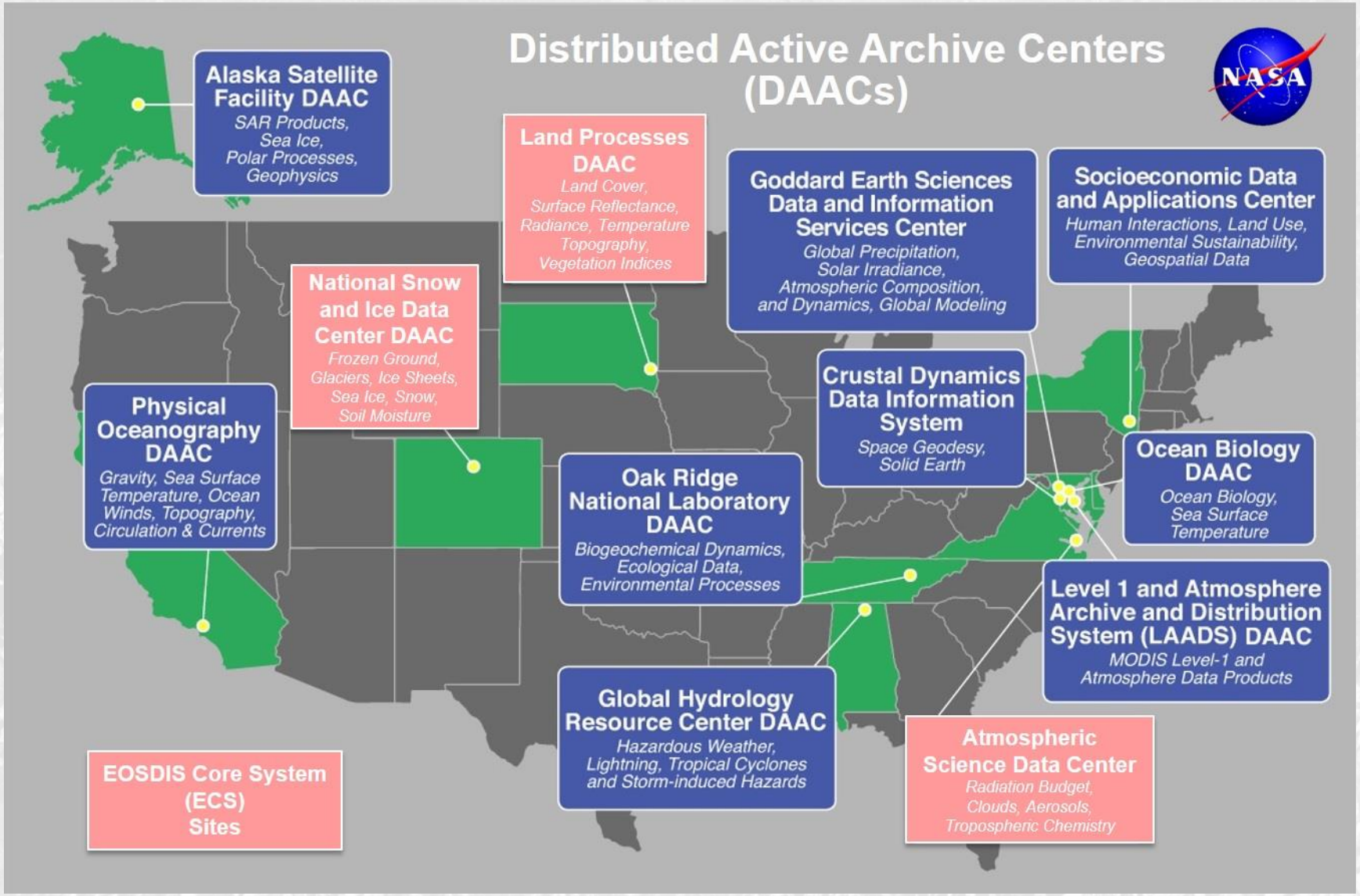
Interferogram of earthquake in Ridgecrest, CA on July 4, 2019

SAR Datasets Available from ASF

Heidi Kristenson, GIS Specialist
Alaska Satellite Facility

About ASF DAAC

- 1 of 12 DAACs providing data and support services for EOSDIS (Earth Observing System Data and Information System)
- Maintains NASA archive of SAR data
  - Data from NASA, ESA, JAXA, CSA
- Serving datasets that are easy to access and free to use



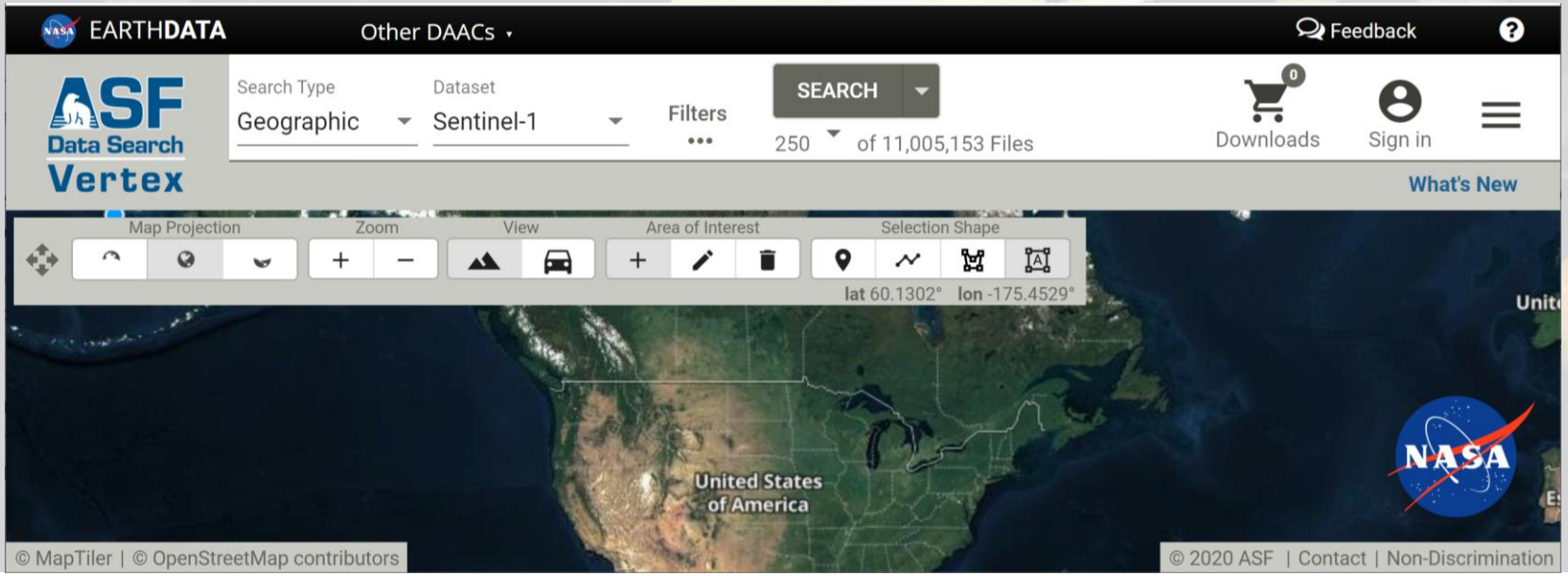
Data Access: ASF Data Search - Vertex

Requirements for Downloading Data:

- Earthdata Login credentials (EOSDIS User Registration)
- Accept the ASF End User License Agreement (EULA) on Vertex

https://urs.earthdata.nasa.gov/users/new

https://search.asf.alaska.edu/

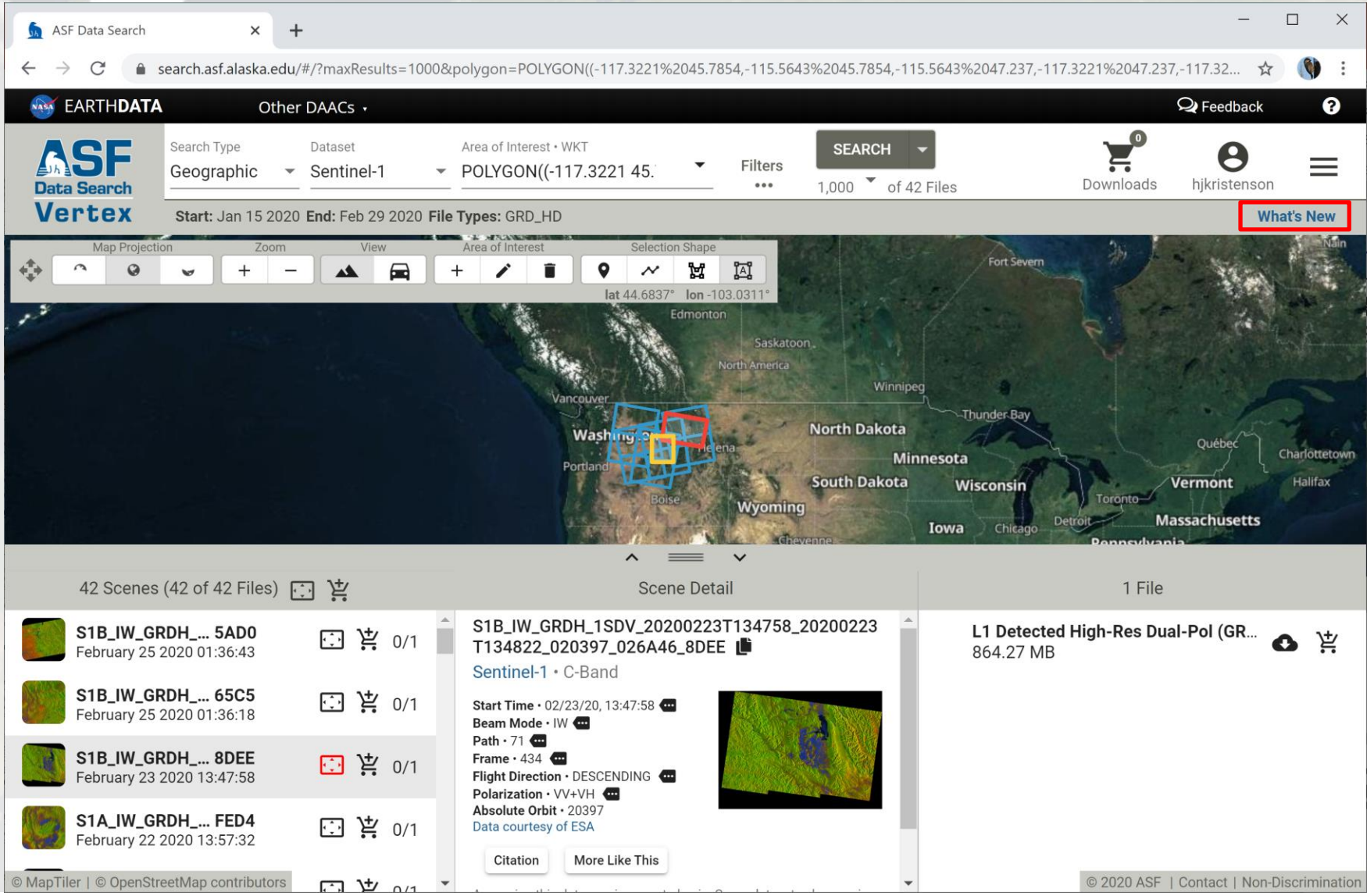


ASF Data Search - Vertex

https://search.asf.alaska.edu

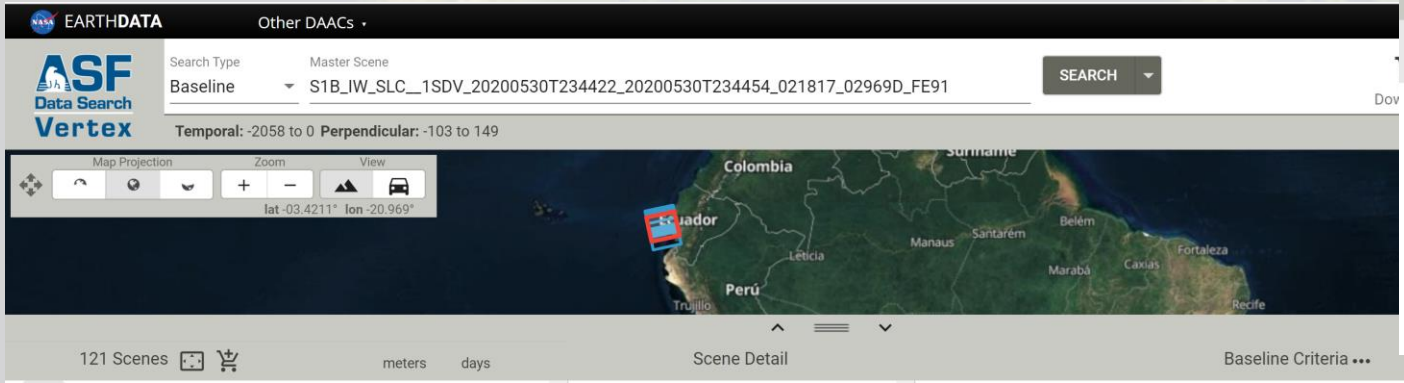
Recent Updates

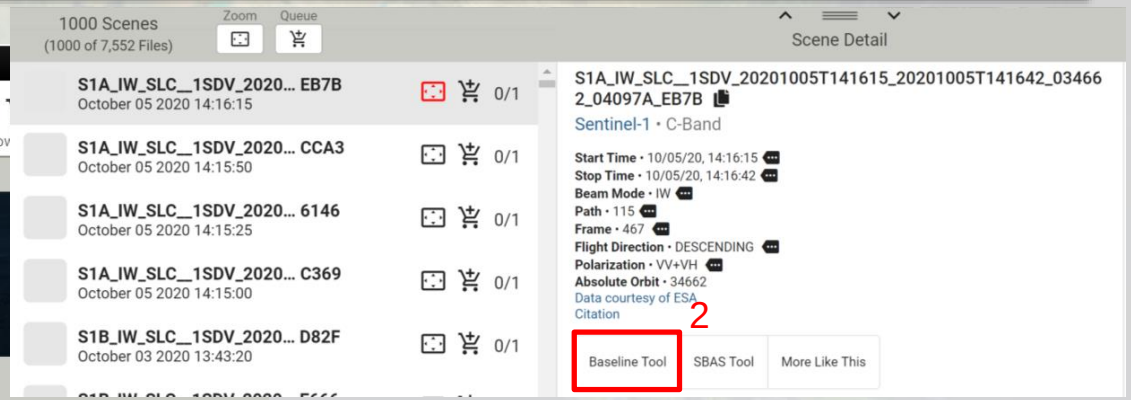
- ✓ Baseline & SBAS Integration/Updates
- ✓ View Components of Zip Archives and Download Individually
- ✓ More AOI support
  Shapefile, KML, JSON, WKT
- ✓ Saved Searches
- ✓ Share Searches

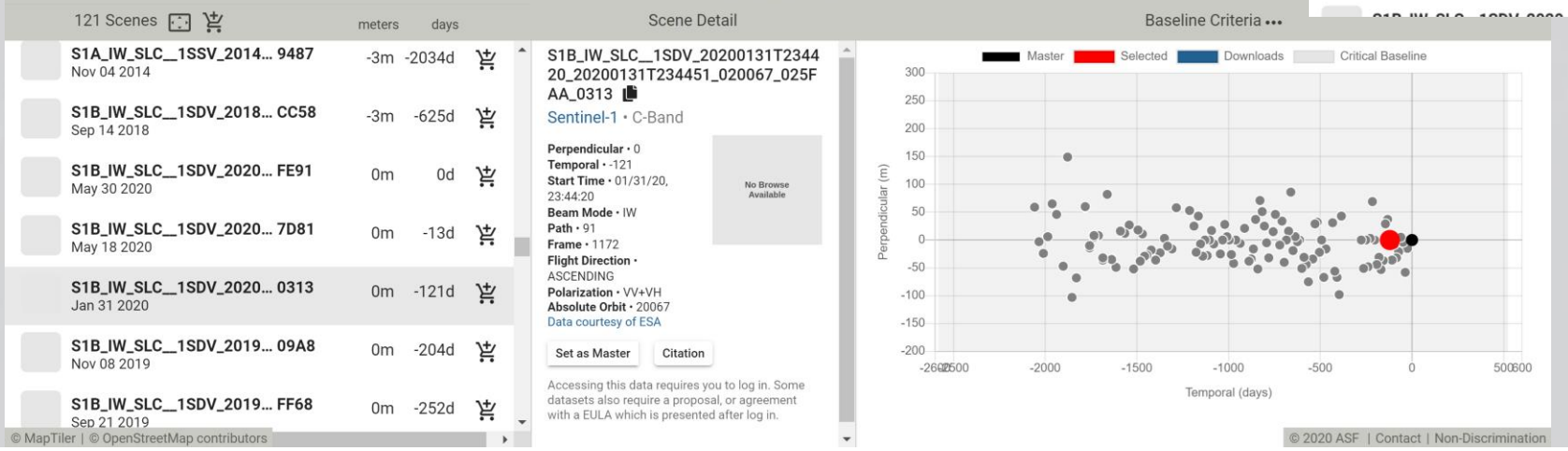


Baseline Tool – Updated & Integrated

- Helps identify granules suitable for interferometry
- Now integrated directly into Vertex, with additional features/functionality





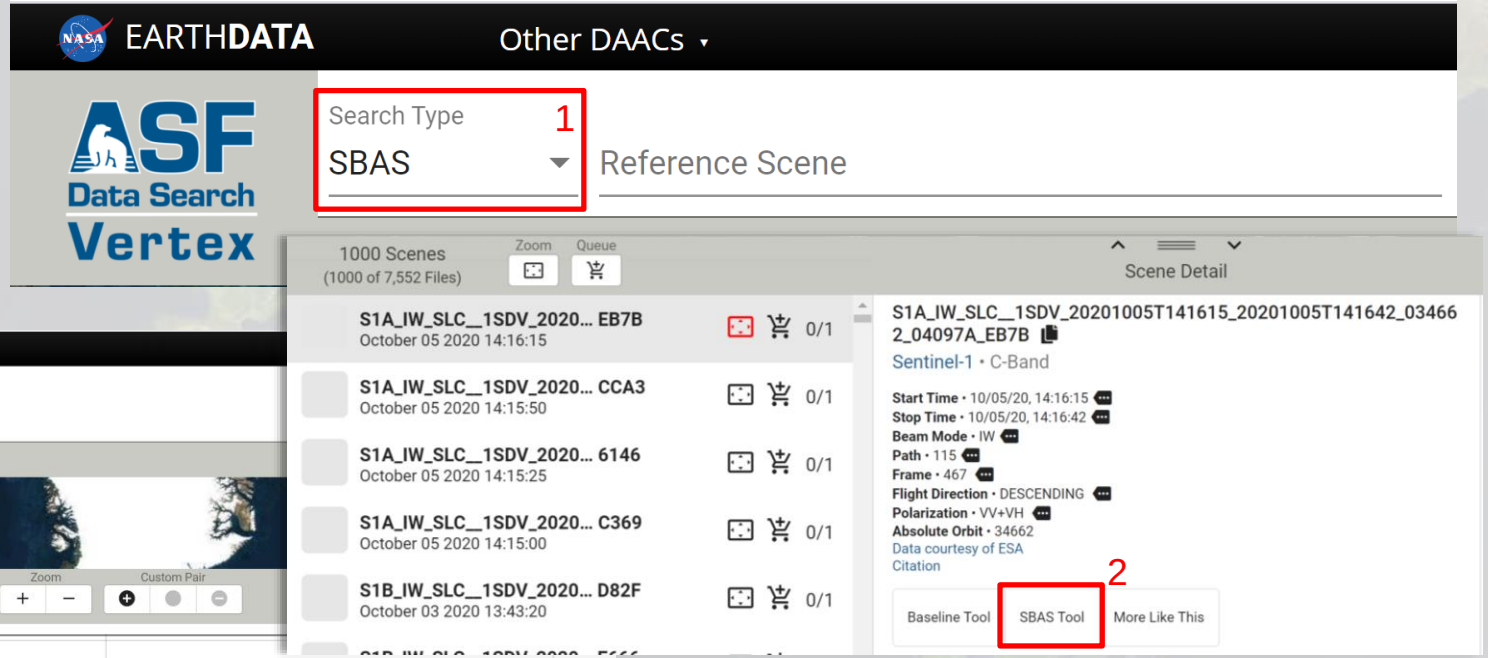


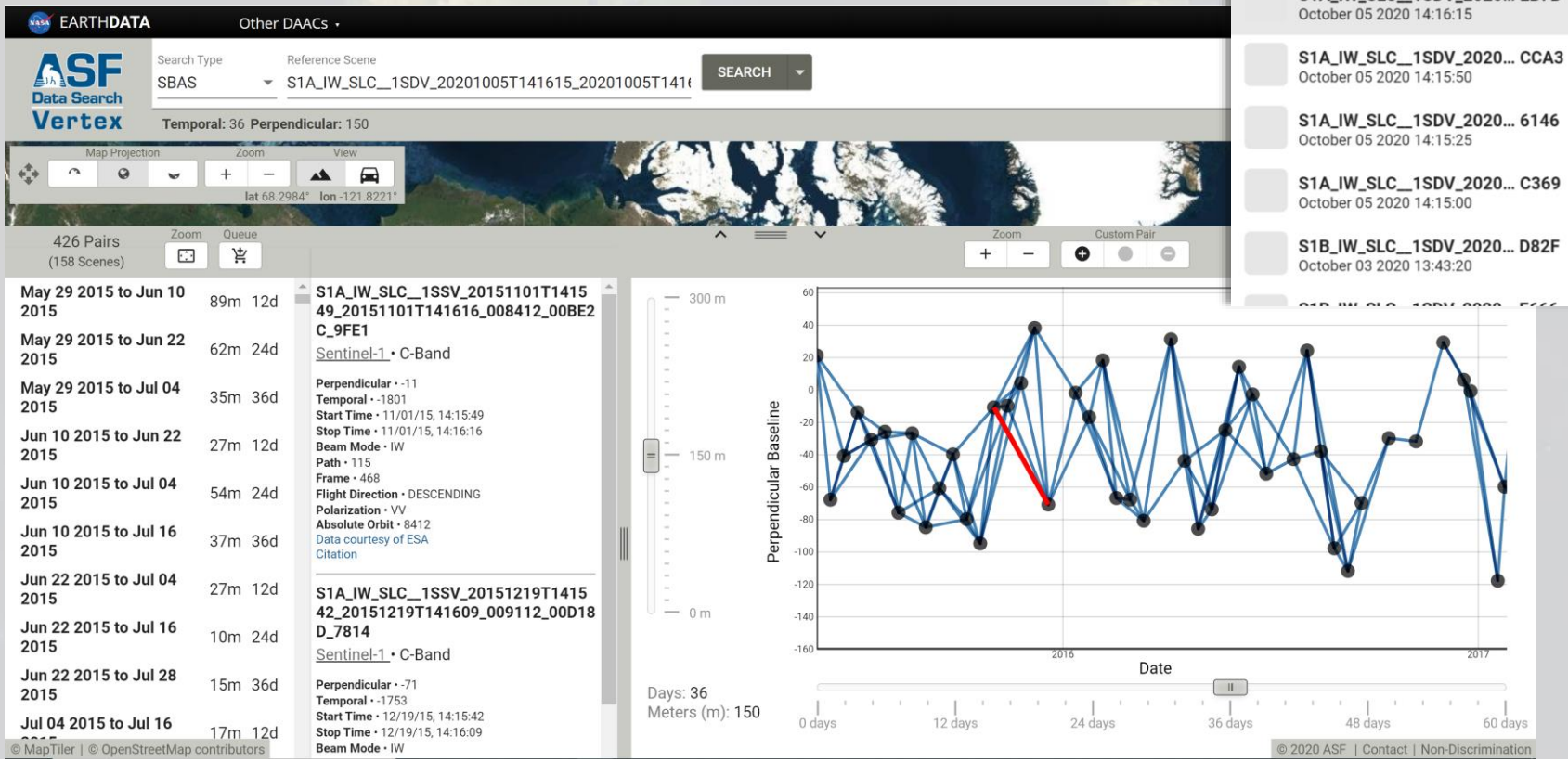
Access Options (shown above)

1. Select Baseline for the Search Type and manually enter the filename of the reference scene
2. Search for a scene in Vertex and click the Baseline Tool button in the search results to launch Baseline with that scene set as the reference

SBAS – Short Baseline Pair Identification

- Identifies suitable granule pairs for InSAR time-series analysis
- Now integrated directly into Vertex, with additional features/functionality





Access Options (shown above)

1. Select SBAS for the Search Type and manually enter the filename of the reference scene
2. Search for a scene in Vertex and click the SBAS Tool button in the search results to launch SBAS with that scene set as the reference

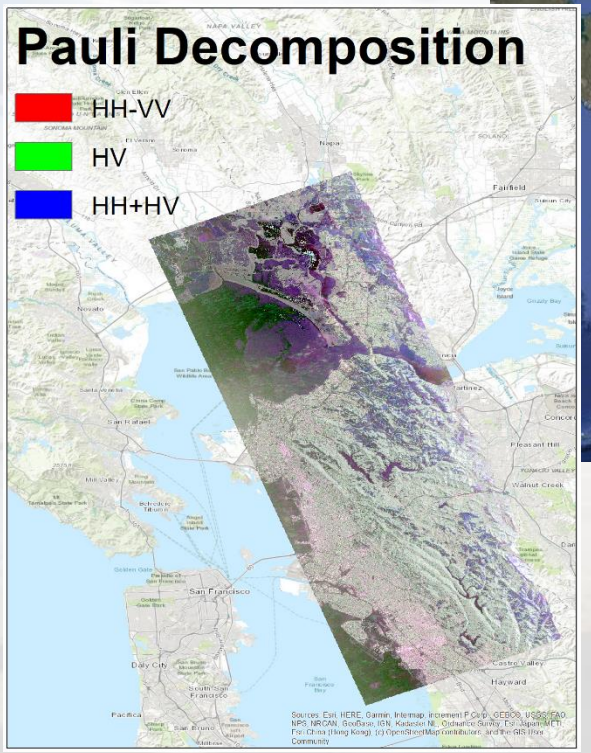
Datasets – Historic

- Seasat – NASA – (L-band)
  - First spaceborne SAR mission, 1978
  - GeoTIFFs available
- AIRSAR – NASA – (C/L/P-band)
  - Airplane, periodically 1990-2004
  - Limited extent, irregular coverage, variety of sensors and frequencies
  - JPGs available (not georeferenced)
- ERS – ESA (European Space Agency) – (C-band)
  - ERS-1 1991-1997, ERS-2 1995-2011, repeat every 35 days
  - We hold a subset of the ERS data, focused on Alaska, Western Canada, Chukotka and Antarctica
  - CEOS data format (no spatial reference)
- JERS – JAXA (Japan Aerospace Exploration Agency) – (L-band)
  - 1992-1998, ***most data is restricted; requires a research agreement***
- RADARSAT-1 – CSA (Canadian Space Agency) – (C-band)
  - 1995-2008, ***most data is restricted; requires a research agreement***
  - CEOS data format (no spatial reference)
- ALOS PALSAR – JAXA – (L-band)
  - 2006-2011
  - Several products available – including RTC in GeoTIFF format
  - Now unrestricted!

Image: Seasat 1, NASA/JPL-Caltech

NASA Datasets – Ongoing Acquisition

- UAVSAR – JPL (Jet Propulsion Laboratory)
  - Quad-pol L-band, 2008-present
  - Airborne, targeted locations, irregular timing
  - Flights can be requested for your area of interest
  - Pre-processed backscatter and interferometric products
    - PolSAR and Repeat-Pass Interferometry
  - Data is free and openly available



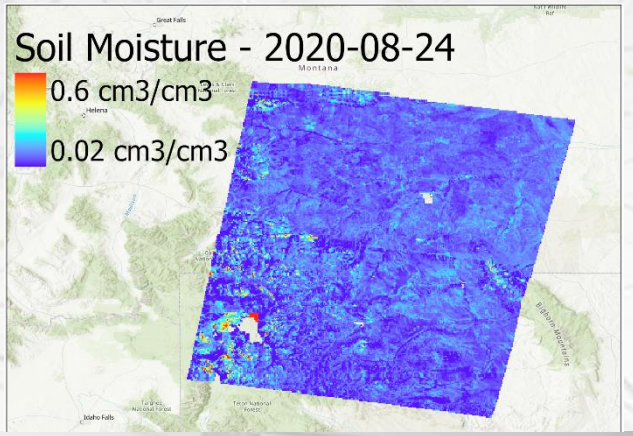
UAVSAR coverage in Alaska

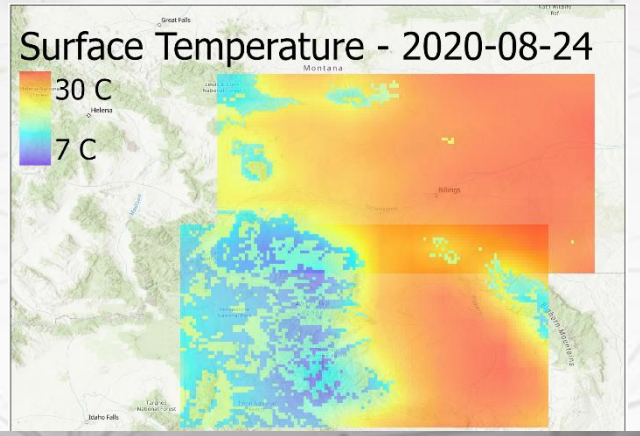
NOTE: UAVSAR data will be used for the GeoGateway tutorial later in this course.

Image: UAVSAR Aircraft, NASA/JPL-Caltech

NASA Datasets – Ongoing Acquisition

- SMAP (Soil Moisture Active Passive) – NASA
  - L-band, 2015-present (currently only passive sensor operational)
    - ASF serves the SAR data acquired when active sensor was operational
  - Measures soil moisture and freeze-thaw state in top 5 cm of soil globally every three days (multi-kilometer resolution)
    - High resolution capabilities lost with loss of active sensor
    - Recent efforts to integrate Sentinel-1 data have generated higher-resolution products
  - Variety of soil moisture products available: https://smap.jpl.nasa.gov





1-km products generated using Sentinel-1 SAR (Soil Moisture and Surface Temperature)

Image: SMAP Antenna, NASA/JPL-Caltech

Sentinel-1

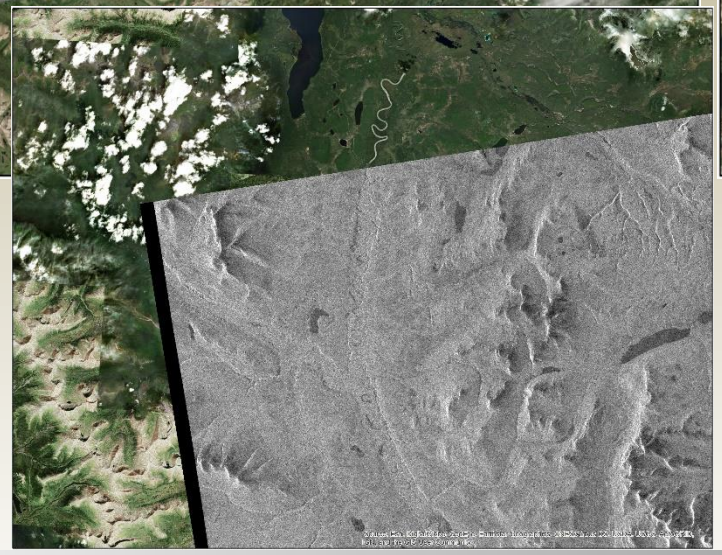
European Space Agency

https://sentinel.esa.int/web/sentinel/missions/sentinel-1

- Global coverage with C-band SAR
- 2 satellites
  - Sentinel-1A launched 2014, 1B launched 2016
  - Each with 12-day return cycle, orbiting 180° apart
  - Most places on the earth are currently imaged at least every 6 days
    - Polar regions generally have even more frequent coverage due to polar orbit
- New data available to download within 3 days of acquisition
  - Most often available within 24 hours of acquisition
- Free and easy to download in several formats (RAW, SLC, GRD, OCN)

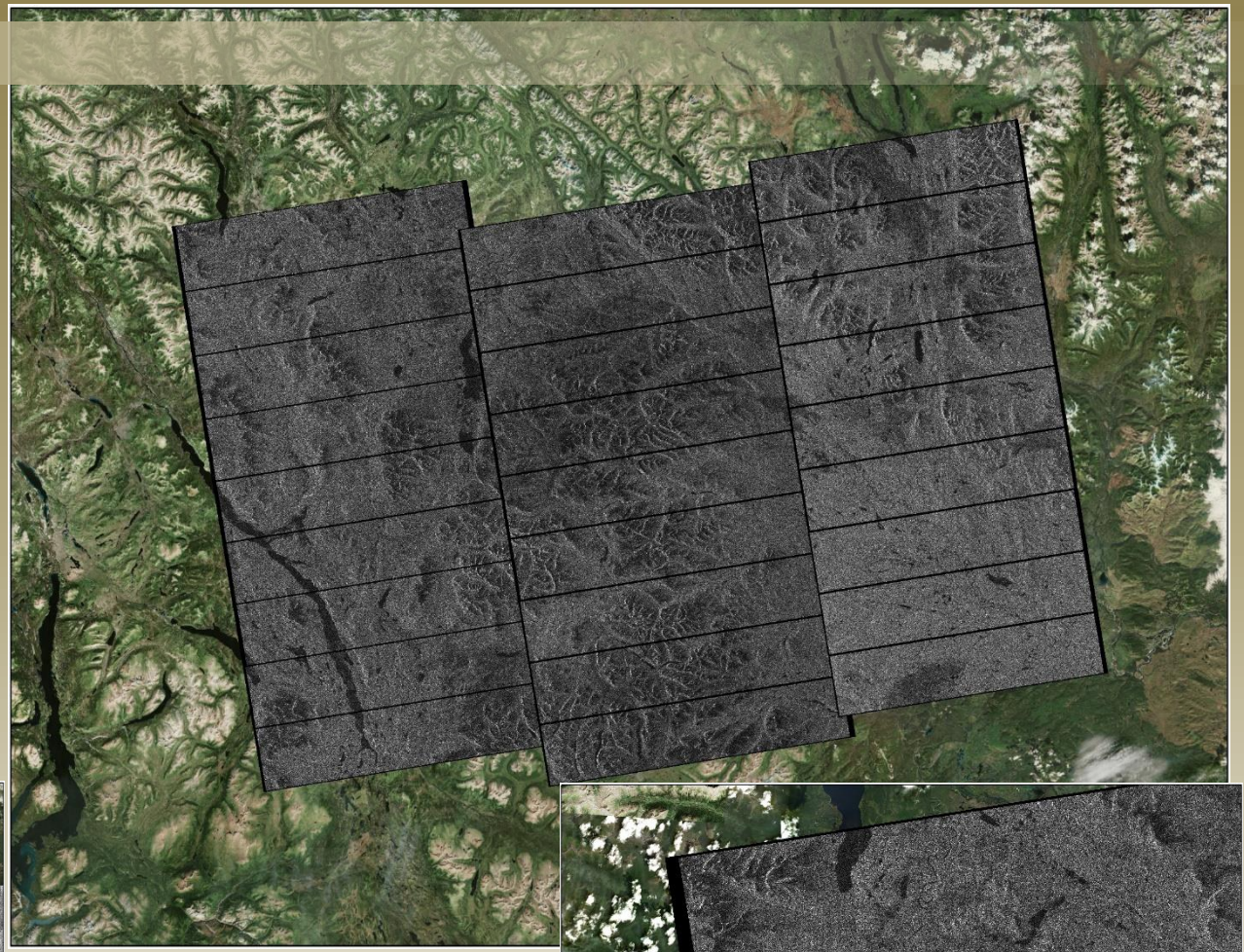
Image: Sentinel-1 Poster, ESA

LEVEL-1 SAR PRODUCTS: SENTINEL-1



GRD

Ground Range
Detected

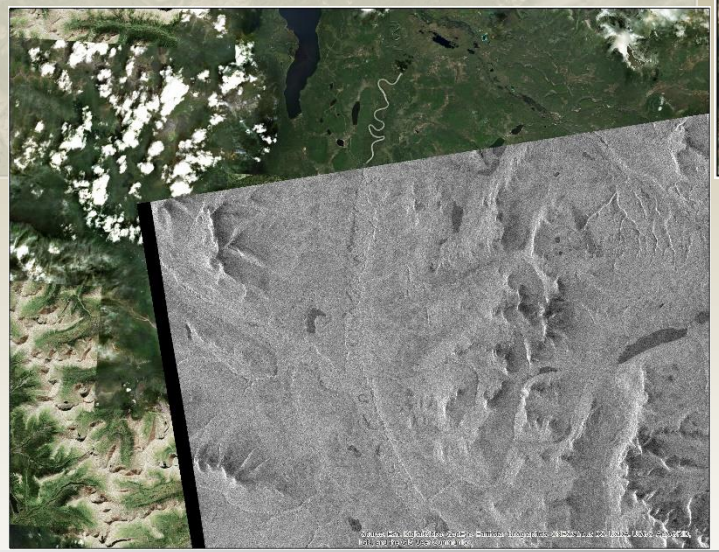


SLC

Single Look
Complex

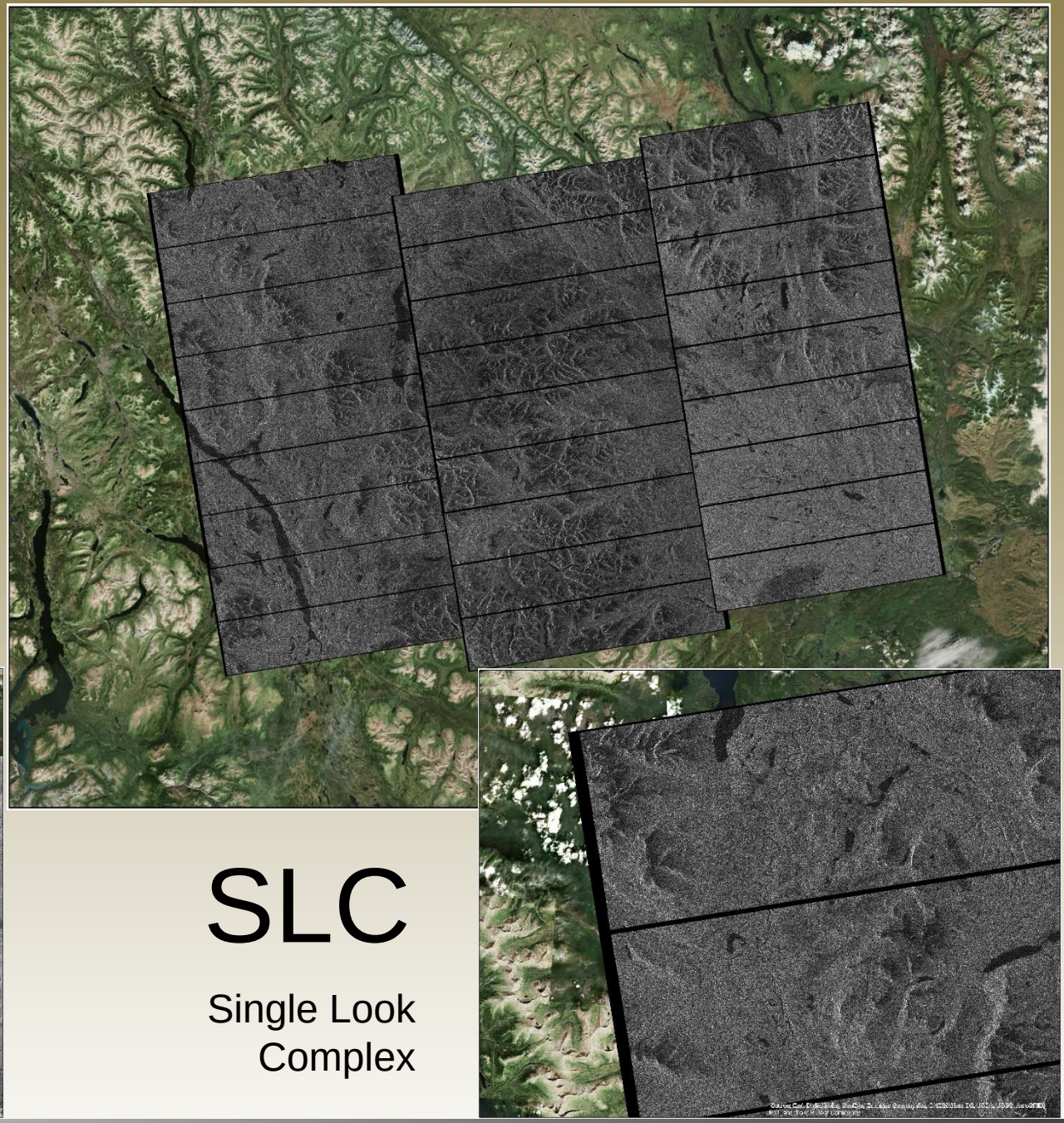
Best for Amplitude applications

- No effort required to view data in a GIS
- Easy to project to desired coordinate system
- Pixels are in ground-detected geometry
- One consolidated image for each polarization
- Square pixels
- Smaller file size



GRD

Ground Range Detected



SLC

Single Look Complex

Best for Amplitude applications

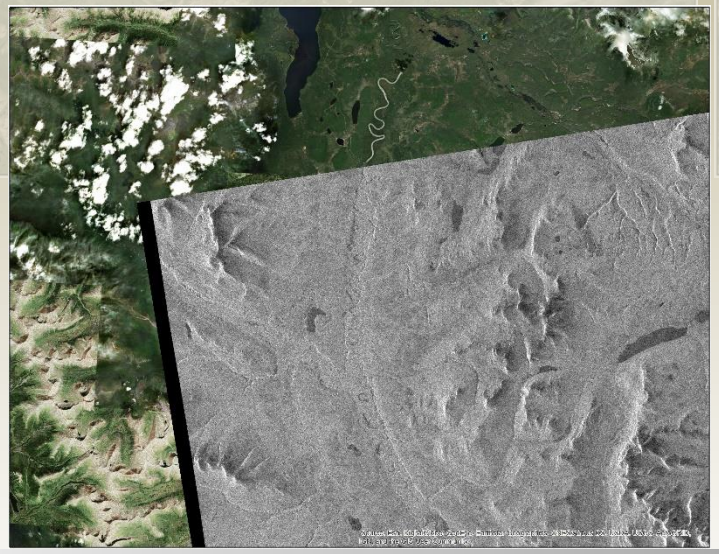
- No effort required to view data in a GIS
- Easy to project to desired coordinate system
- Pixels are in ground-detected geometry
- One consolidated image for each polarization
- Square pixels
- Smaller file size

Necessary for Interferometry

- Remains in slant-range geometry
- Phase data is retained
  - ✓ Suitable for detecting changes in surface elevation
  - ✓ Required for generating interferograms
- Several images for each SLC
- Retains each subswath (including overlap) and series of bursts, with a black line grid

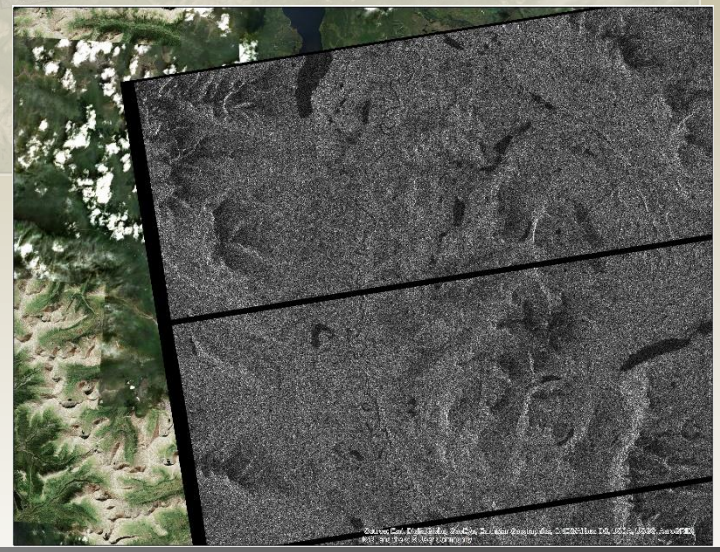
GRD

Ground Range Detected



SLC

Single Look Complex



Planning for the Future

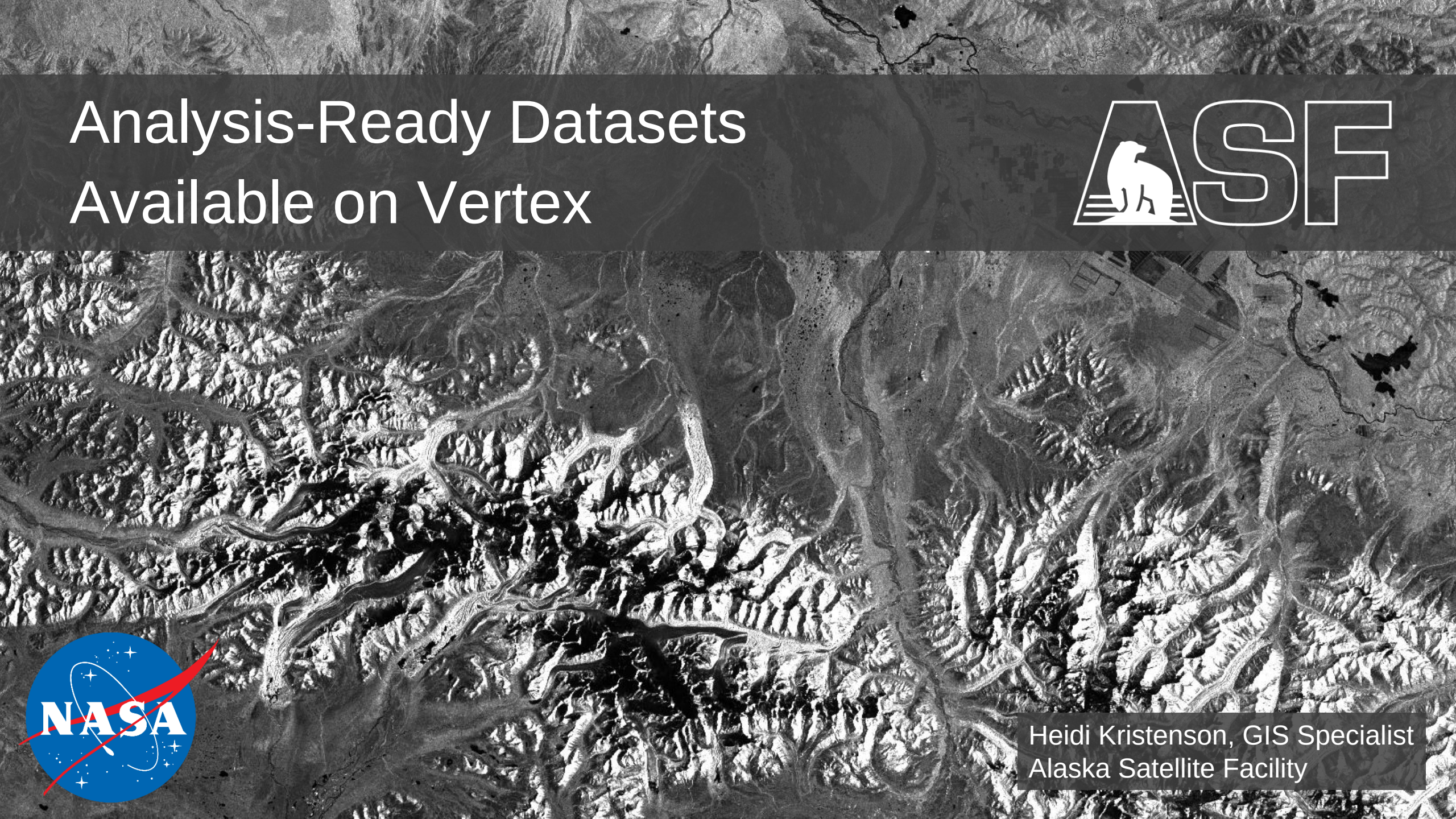
NISAR

https://nisar.jpl.nasa.gov/

- Launching in 2022
- Joint venture between NASA and ISRO (Indian Space Research Organisation)
- L-band (greater penetration through canopy and soil than C-band)
  - Also an S-band sensor (12 cm wavelength)
- 12-day average repeat cycle
- Analysis-ready (Level-2) products (including InSAR)

Image: NISAR rendering, NASA/JPL-Caltech

Analysis-Ready Datasets Available on Vertex



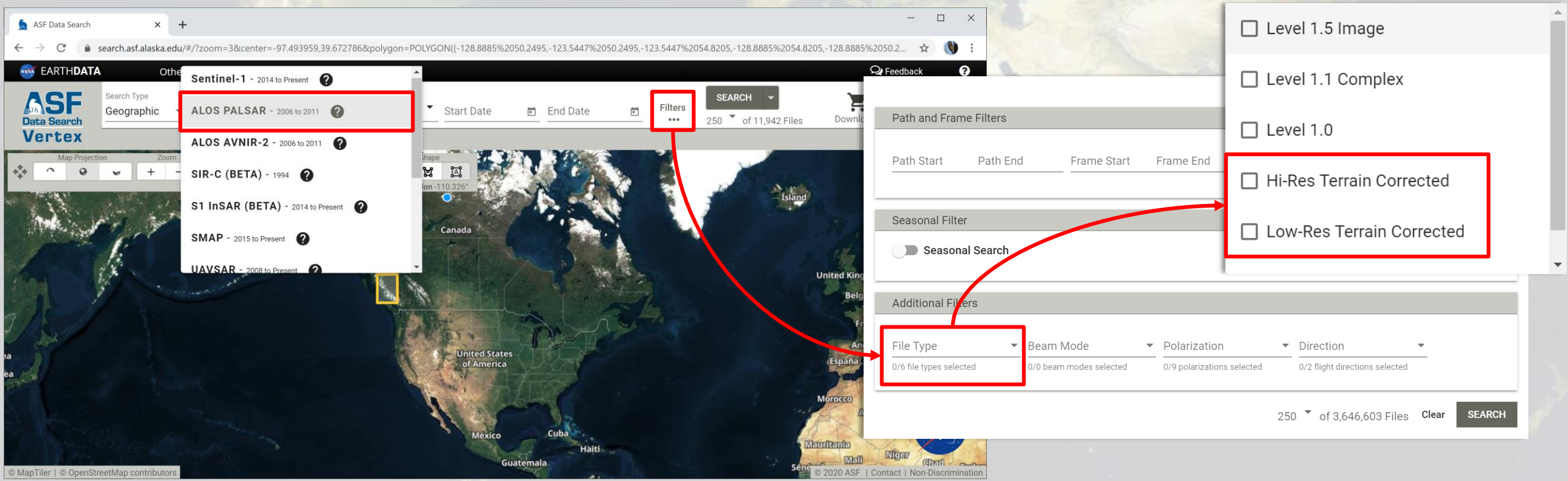
Heidi Kristenson, GIS Specialist
Alaska Satellite Facility

ALOS PALSAR RTC Products

- Download directly from Vertex

  https://search.asf.alaska.edu

  – Already processed, ready for use
  – Available in 12.5-m or 30-m resolution
  – Projected to UTM Coordinates

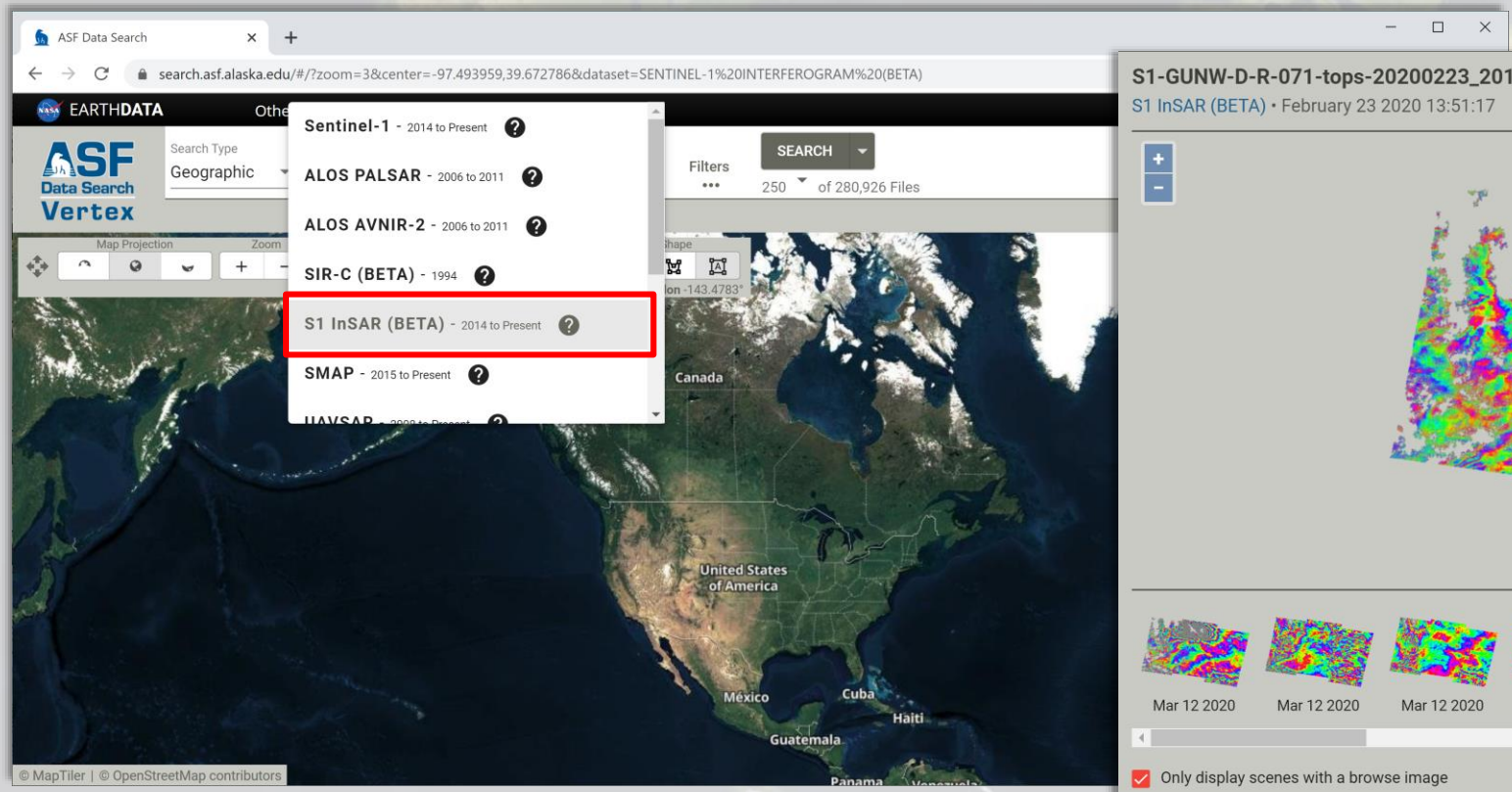


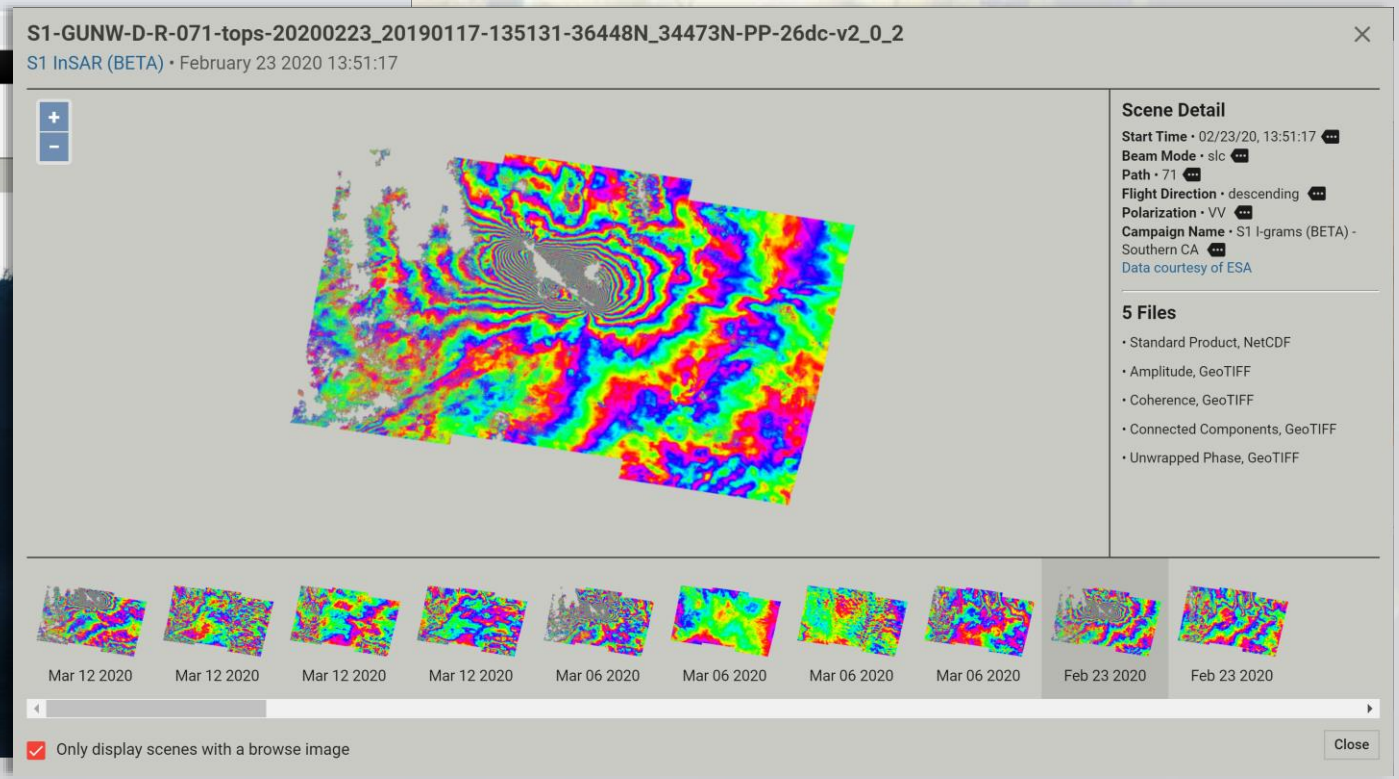
Sentinel-1 Interferograms (Limited spatial coverage)

- Download directly from Vertex

  https://search.asf.alaska.edu

  - Already processed, ready for use
  - Download choices:
    - Full netCDF product
    - Select layers as GeoTIFFs





UAVSAR Georeferenced Products (KMZ format)

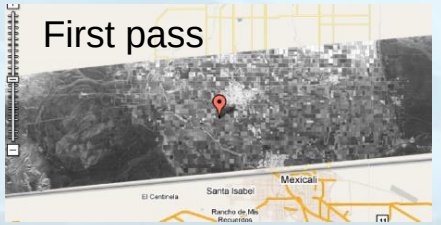
UAVSAR Georeferenced Products
(~6 m Pixel Spacing)

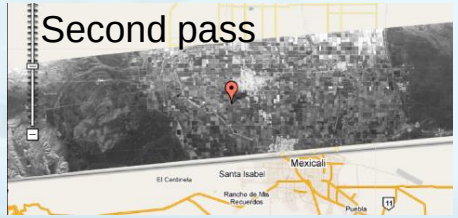
PolSAR

Polarimetry (Single-Pass)
(quad-pol backscatter decomposition)
Red: HH | Green: HV | Blue: VV

Repeat-Pass Interferometry

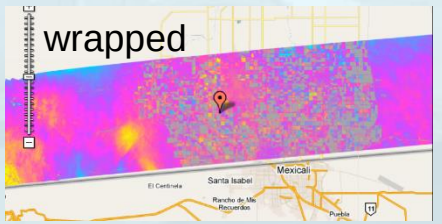
Amplitude
(backscatter for each polarization)

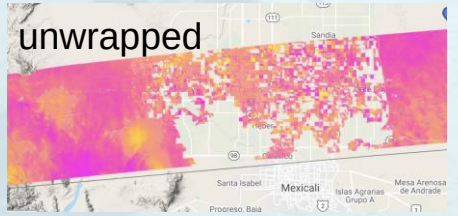




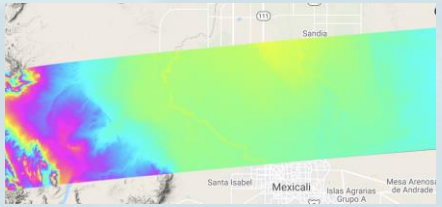
Correlation
(phase coherence between passes)

Interferometry
(landscape change)

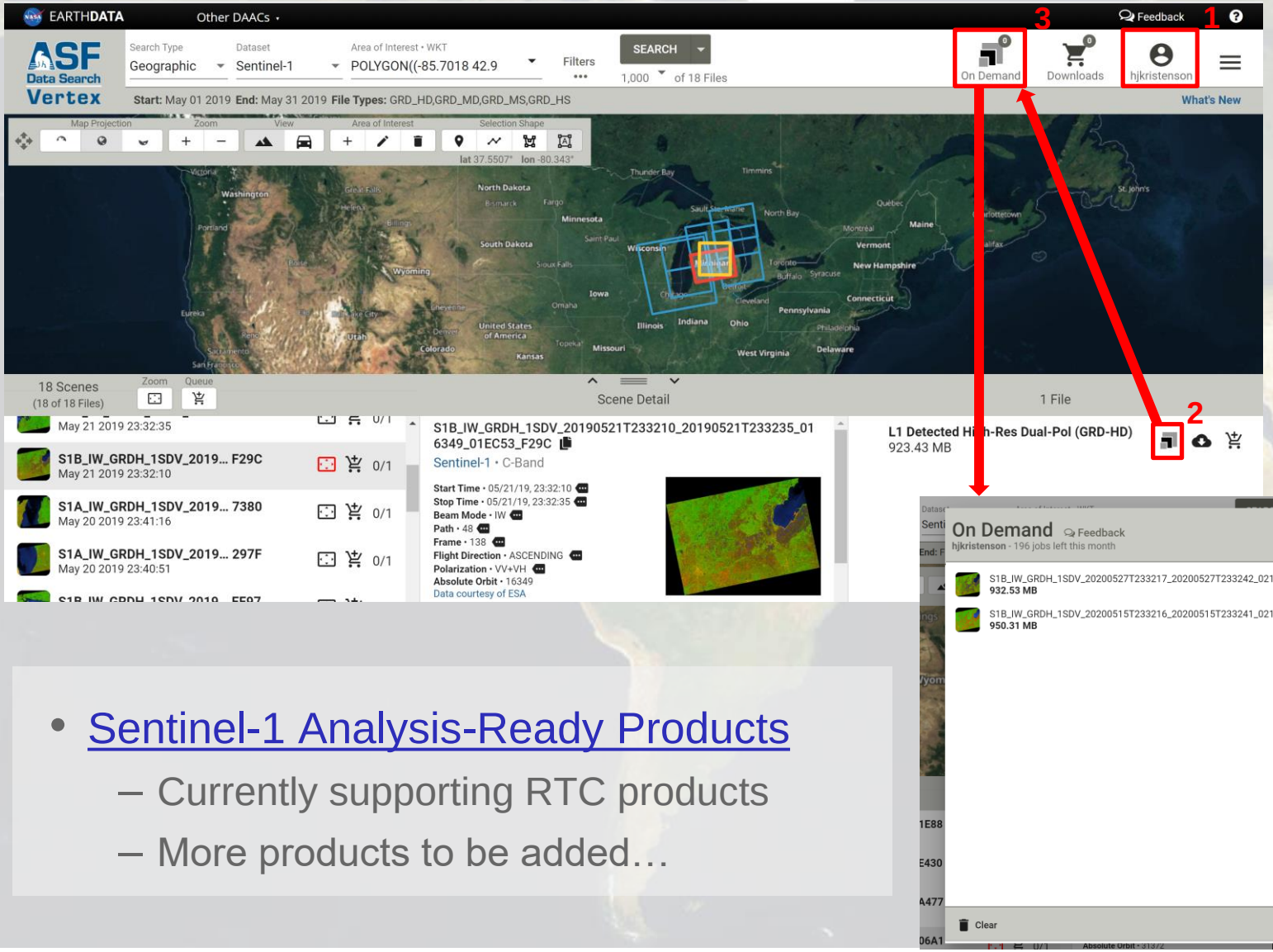


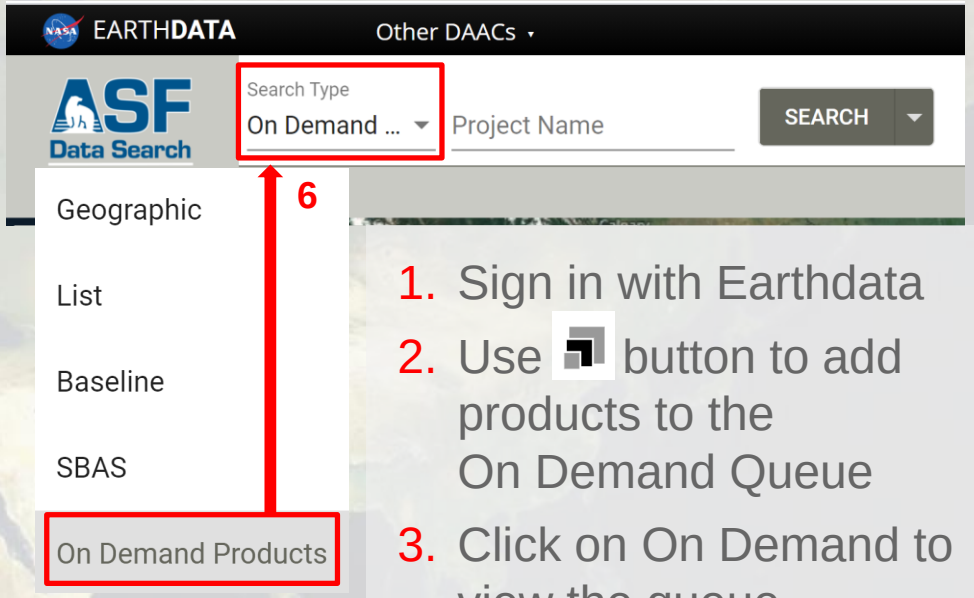


Digital Elevation Map
(reference)



NEW! On-Demand SAR Processing in Vertex



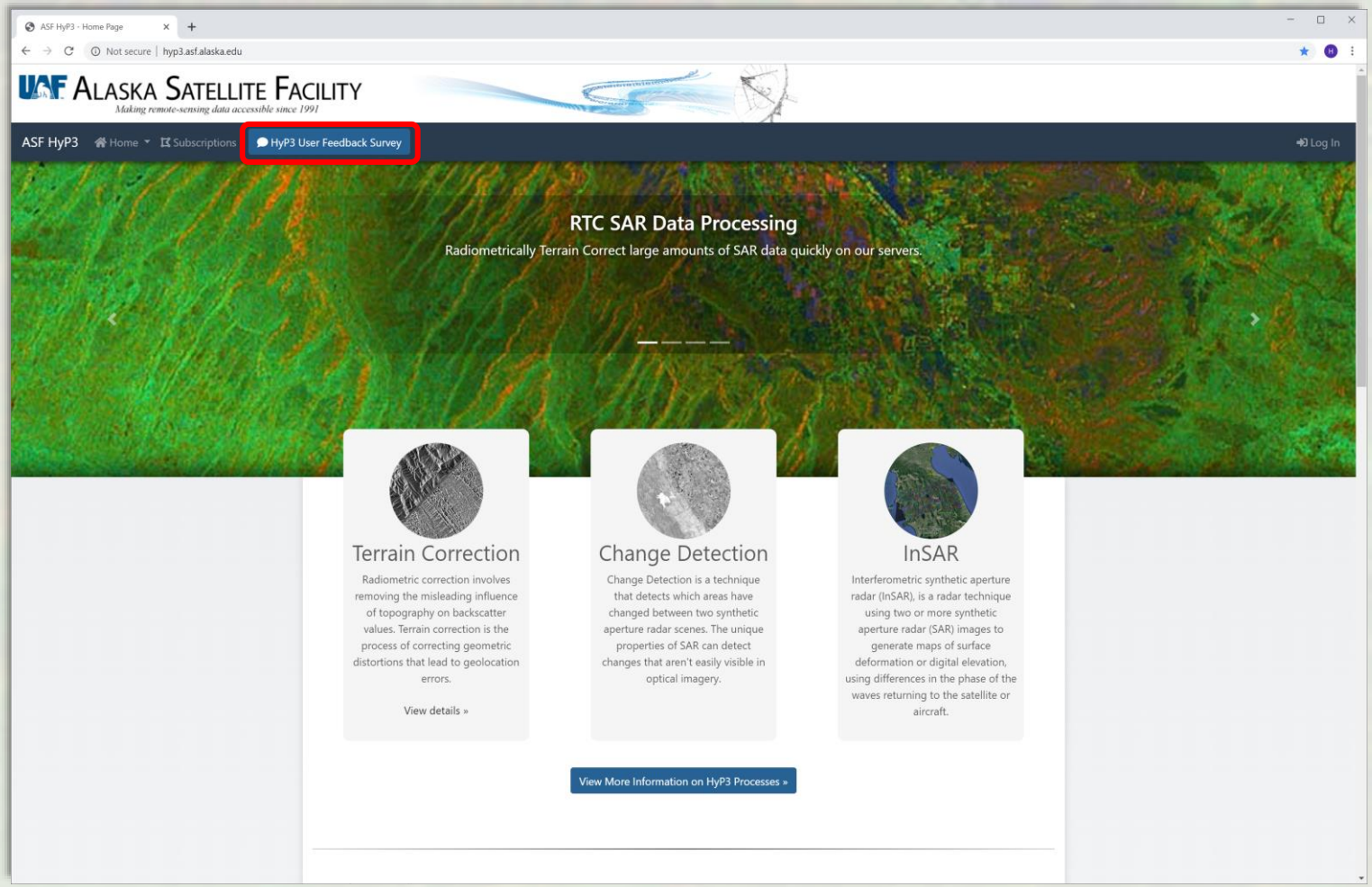


- [Sentinel-1 Analysis-Ready Products]
  - Currently supporting RTC products
  - More products to be added…

1. Sign in with Earthdata
2. Use button to add products to the On Demand Queue
3. Click on On Demand to view the queue
4. Enter a Project Name and adjust processing options (if desired)
5. Click the Submit Queue button
6. Select On Demand Products Search Type to view products

HyP3 v1 – On-demand SAR Processing

- Cloud-based SAR Processing
- Order/Access products using the GUI or API
- Multiple Product Types
  - Plan to integrate more of the product types into HyP3 v2
- Beta: Users can test in exchange for feedback

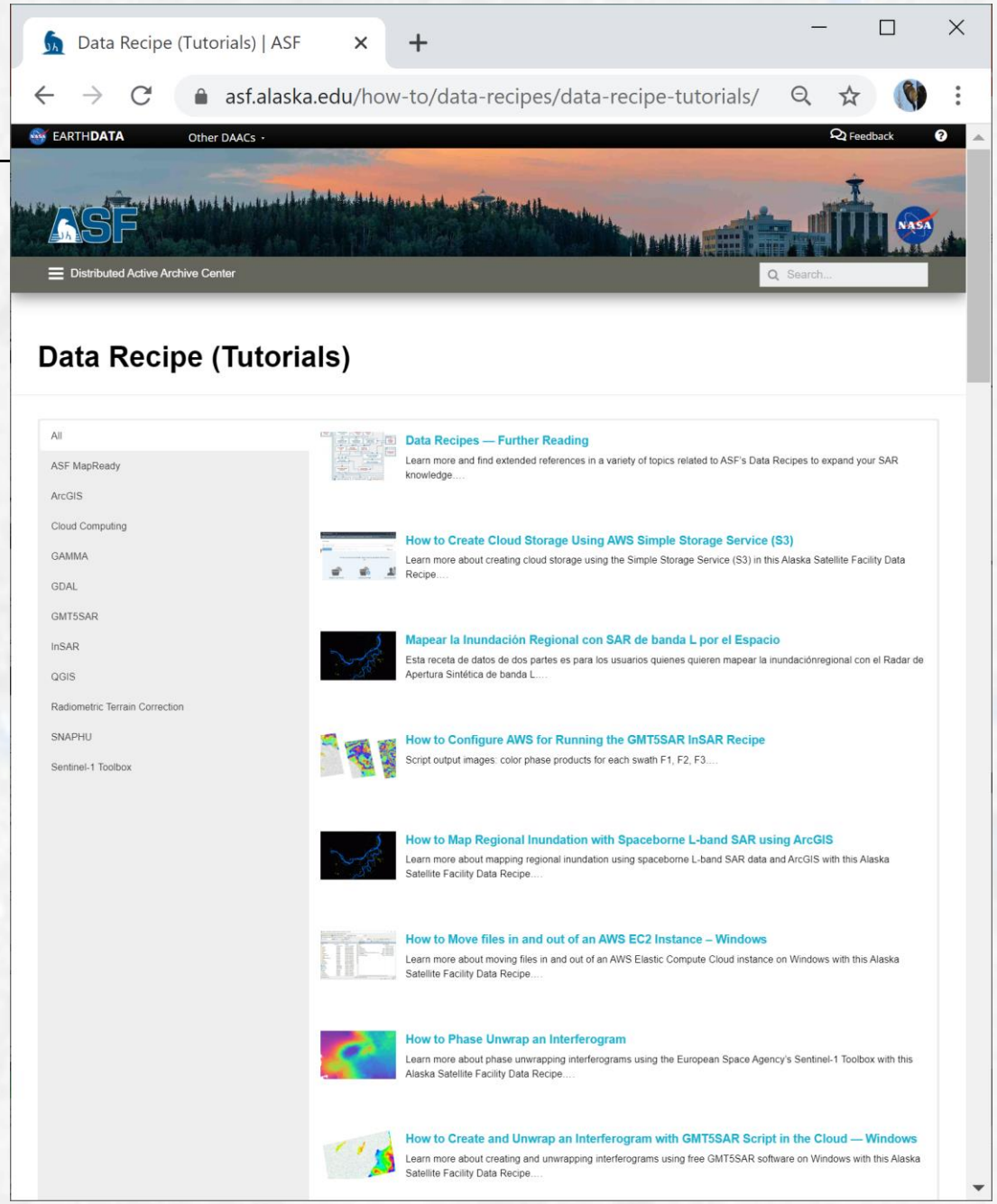


http://hyp3.asf.alaska.edu/

Data Recipes

https://asf.alaska.edu/how-to/data-recipes/data-recipe-tutorials/

- Radiometric Terrain Correction
- InSAR (Interferometry)
- Inundation Mapping
- Environmental Change Detection
- Your requested recipe….



QUESTIONS?

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

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

Heidi Kristenson
hjkristenson@alaska.edu

Image: Hurricane Florence Color Decomposition, ASF DAAC 2018.
Contains modified Copernicus Sentinel data 2018, processed by ESA
Basemap: National Geographic