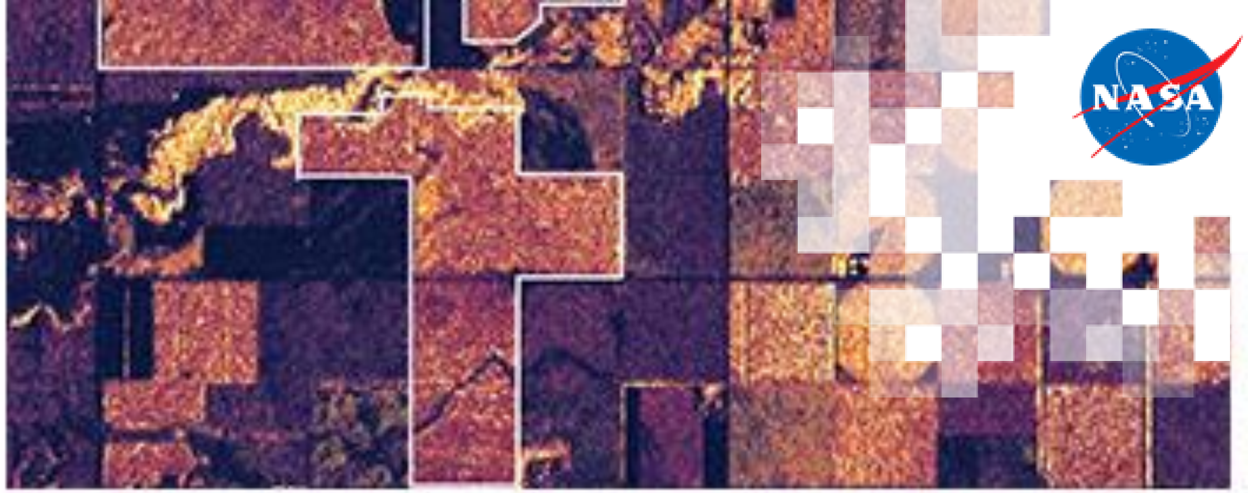
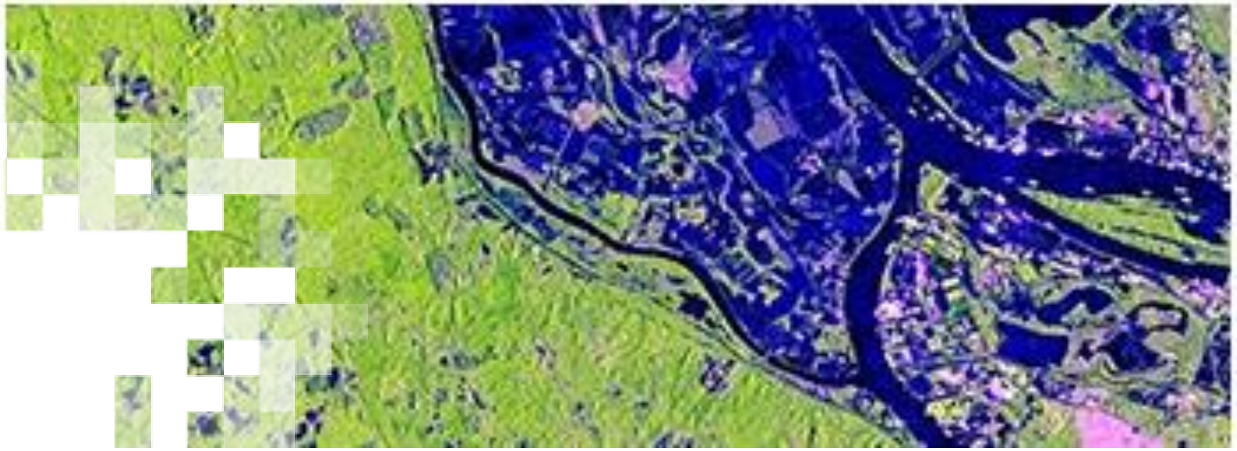
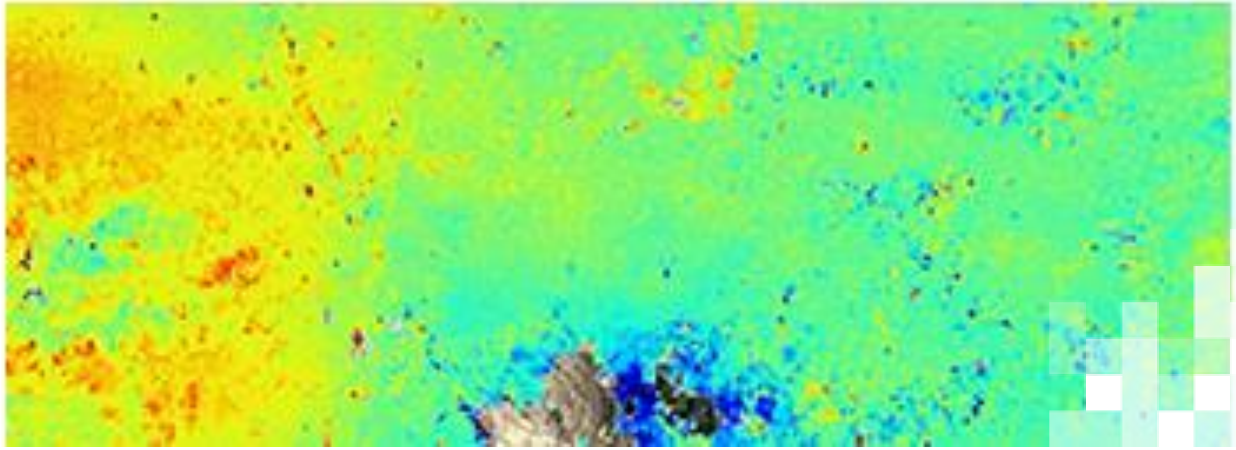
National Aeronautics and Space Administration







Harnessing NISAR: Next-Generation Radar Observations for Earth Applications

Session 3: Monitoring Earthquakes, Volcanoes, and Landslides with NISAR's InSAR Capability

Eric J. Fielding (Jet Propulsion Laboratory, California Institute of Technology)

July 16, 2026

Training Outline

Session 1	Session 2	Session 3
An Introduction to NISAR	NISAR Data Access and Tools	**Monitoring Earthquakes, Volcanoes, and Landslides with NISAR's InSAR Capability**
July 9, 2026	July 2, 2026	**July 16, 2026**
11:30 a.m. - 1:30 p.m. EDT	11:30 a.m. - 1:30 p.m. EDT	**11:30 a.m. - 1:30 p.m. EDT**
(1530-1730 UTC)	(1530-1730 UTC)	**(1530-1730 UTC)**

Homework

Opens July 16, 2026– Due Aug. 6, 2026 – Posted on Training Webpage

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

How to Ask Questions

- To ensure we see your question, please locate the three dots (...) to the bottom right of your training window.
- You will see a Slido/Q&A option. You may also see a standalone Slido tab or app.
- Please write your questions there and we will answer them during the Q&A session.
- We will try to respond all of the questions during the Q&A session after the webinar. The remaining questions will be answered in the Q&A document, which will be posted to the training website about a week after the training.

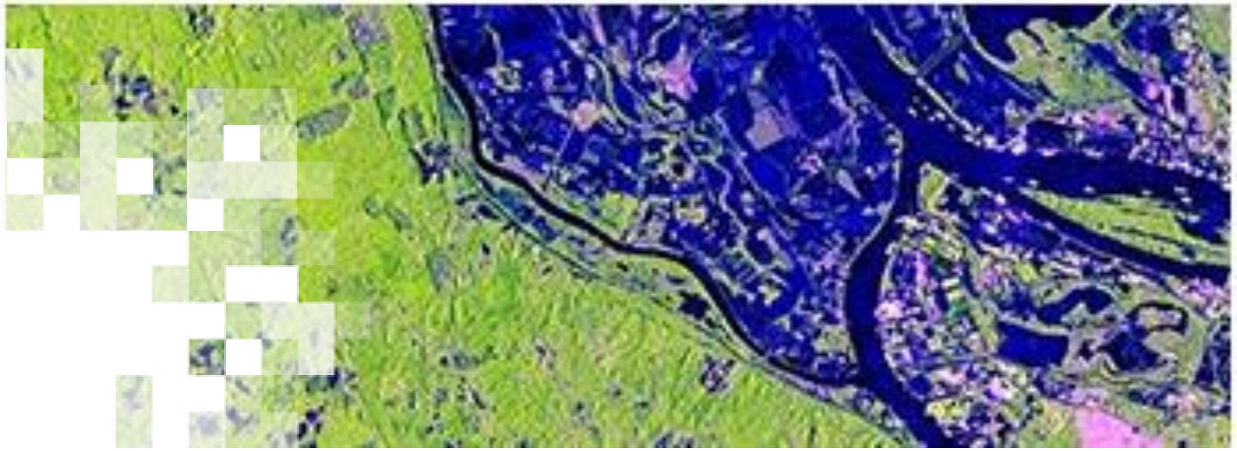
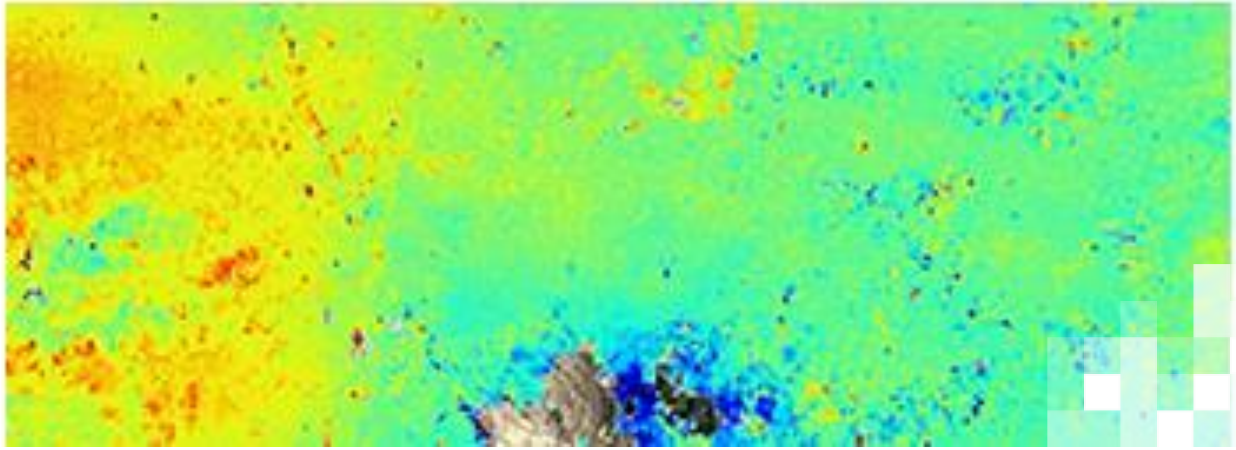
Session 3 – Guest Instructor

Dr. Eric Fielding

Senior Research Scientist

JPL, Caltech



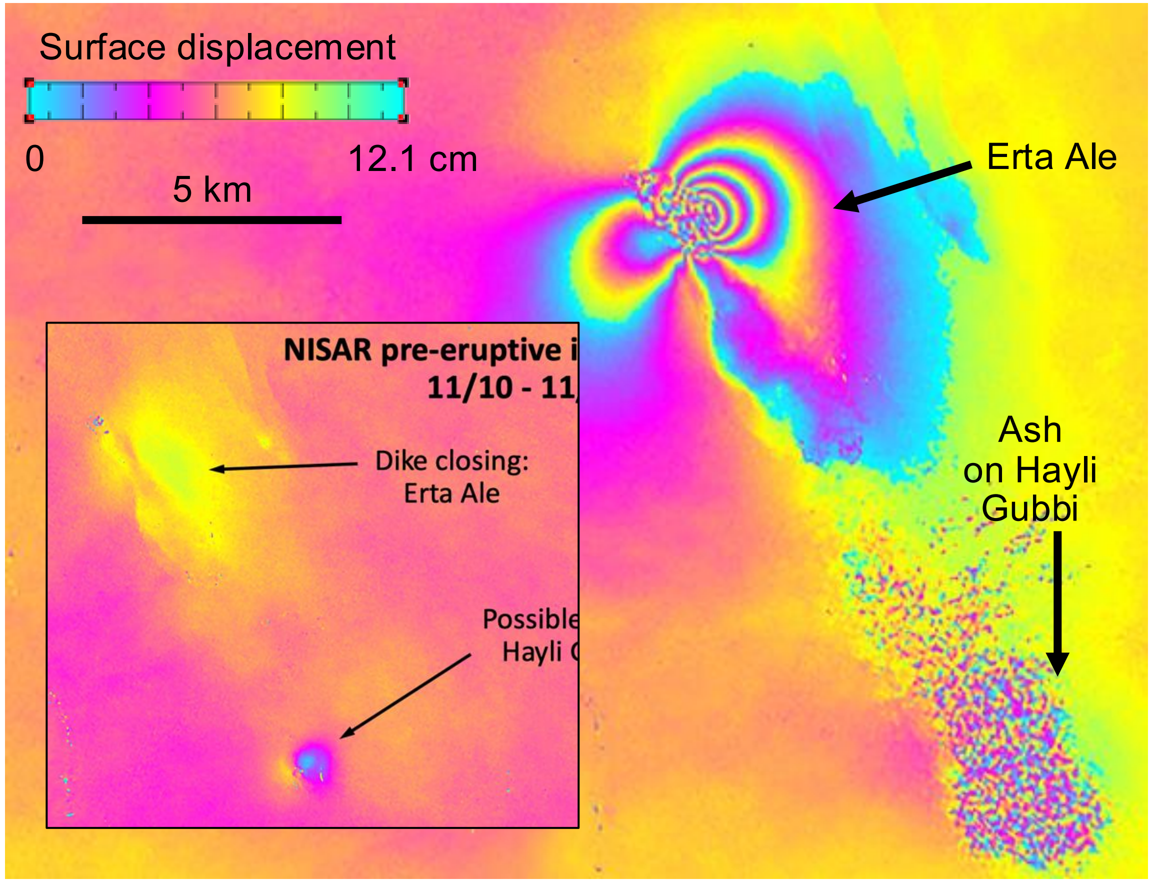



Monitoring Earthquakes, Volcanoes, and Landslides with NISAR's InSAR Capability

Overview

NISAR InSAR

- Interferometric SAR (InSAR) measures surface displacements
- Session 3 will focus on natural geological hazards
- Earthquakes, volcanoes, and landslides
- Example:
  November 2025 volcanic eruption of Hayli Gubbi in Ethiopia



InSAR images courtesy Matt Pritchard, Cornell

Prerequisites

- Fundamentals of Remote Sensing
- SAR Processing and Data Analysis 2017
- Introduction to SAR Interferometry 2017
- Session 1: An Introduction to NISAR
- Session 2: NISAR Data Access and Tools

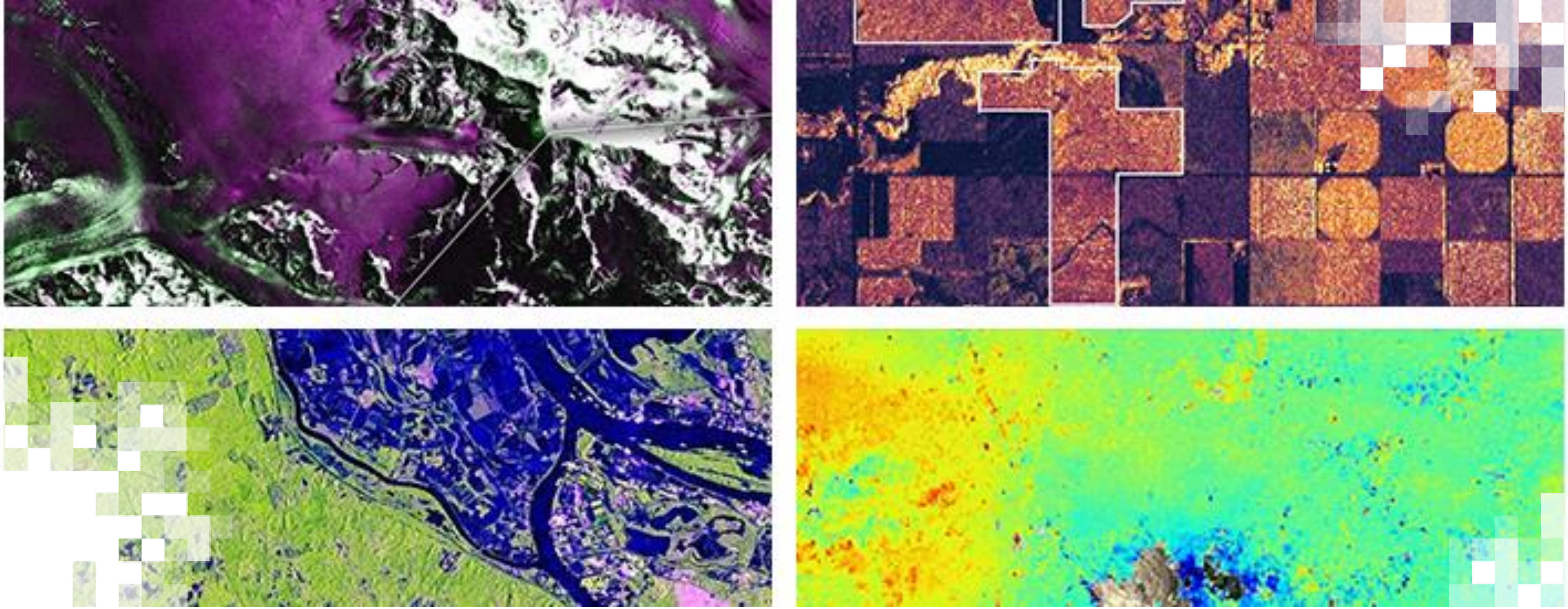
Session 3 Objectives

By the end of this training, participants will be able to:

- Identify NISAR InSAR data products and their characteristics
- Recognize uses and limitations of NISAR InSAR data
- Explain the use of NISAR InSAR to study large displacements of volcanoes and earthquakes
- Apply InSAR to study gradual displacements of landslides

Review of Prior Knowledge

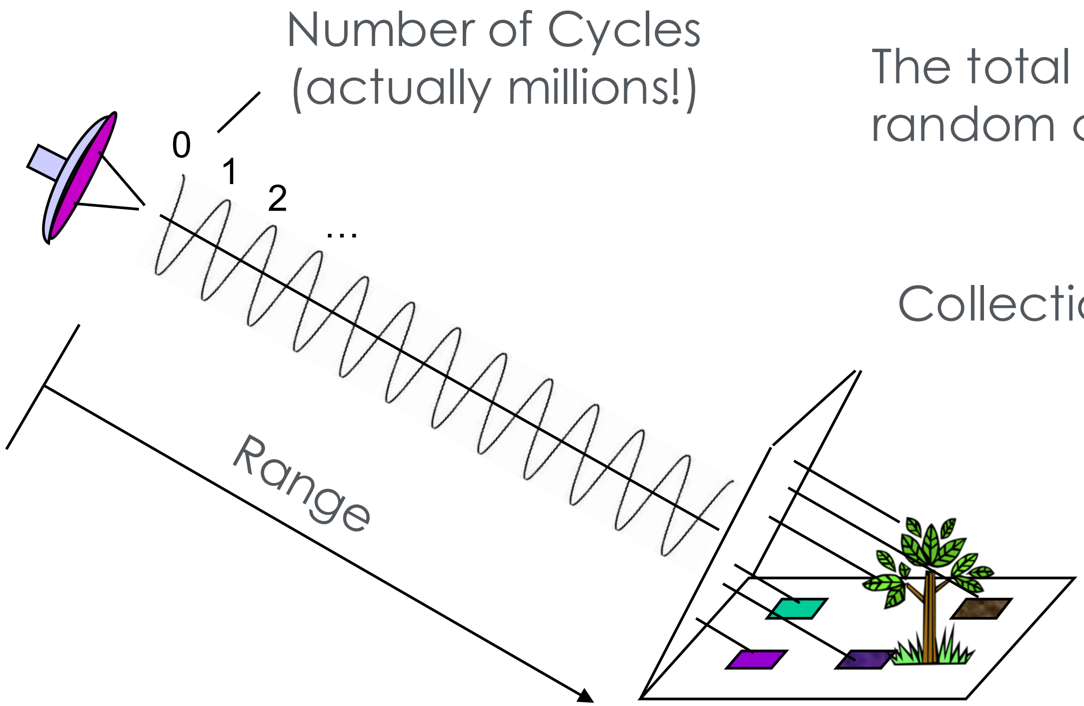
- Quick review of synthetic aperture radar interferometry theory
- See the 2017 ARSET training "Introduction to SAR Interferometry" for more details
- InSAR interferometry is all about the phase of the SAR signal



Session 3: Monitoring Earthquakes, Volcanoes, and Landslides with NISAR's InSAR Capability

SAR Phase – A Measure of the Range and Surface Complexity

The phase of the radar signal is the number of *cycles of oscillation* that the wave executes between the radar and the surface and back again



The total phase is a two-way range measured in wave cycles + random components from the surface

Collection of random path lengths jumbles the phase of the echo

Only *interferometry* can sort it out!

Slide Courtesy of Paul Rosen (JPL)

A Simplistic View of SAR Phases

Phase of Image 1 $$\phi_1 = \frac{4\pi}{\lambda} \cdot \rho_1 + other\ constants + n_1$$

Phase of Image 2 $$\phi_2 = \frac{4\pi}{\lambda} \cdot \rho_2 + other\ constants + n_2$$

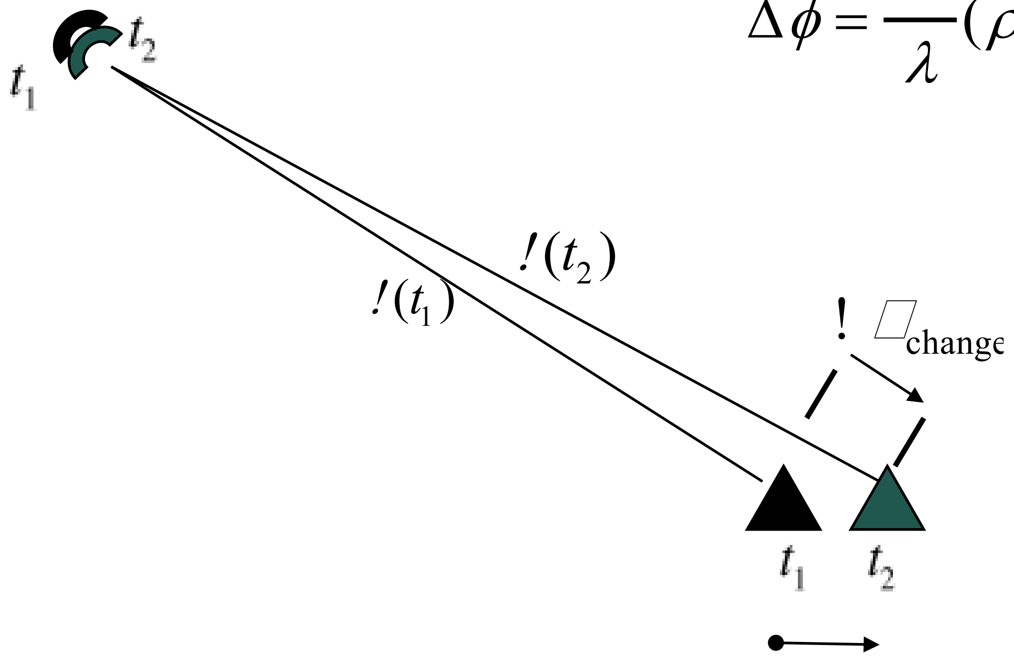
1. The "other constants" cannot be directly determined
2. "Other constants" depends on scatterer distribution in the resolution cell, which is unknown and varies from cell to cell
3. The only way of observing the range change is through interferometry (cancellation of "other constants")

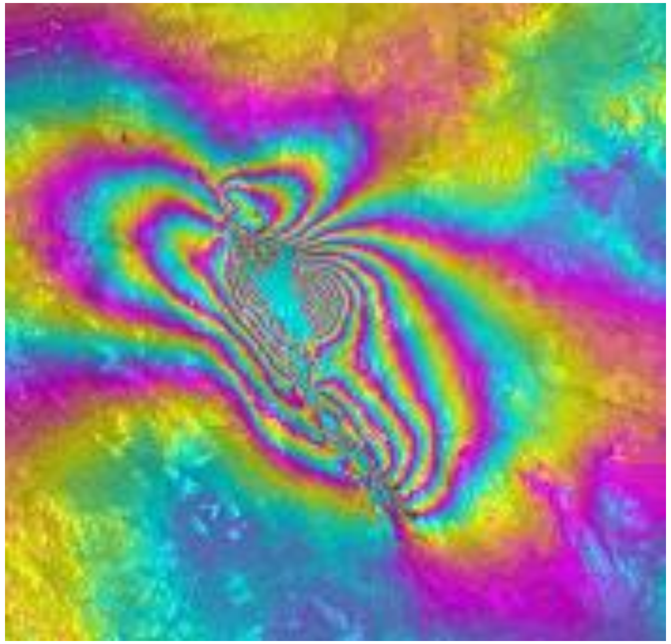
Slide modified from Paul Rosen (JPL)

Differential Interferometry

When two observations are made from the same location in space but at different times, the interferometric phase is directly proportional to any change in the range of a surface feature.

$$\Delta\phi = \frac{4\pi}{\lambda}(\rho(t_1) - \rho(t_2)) = \frac{4\pi}{\lambda}\Delta\rho_{\text{change}}$$

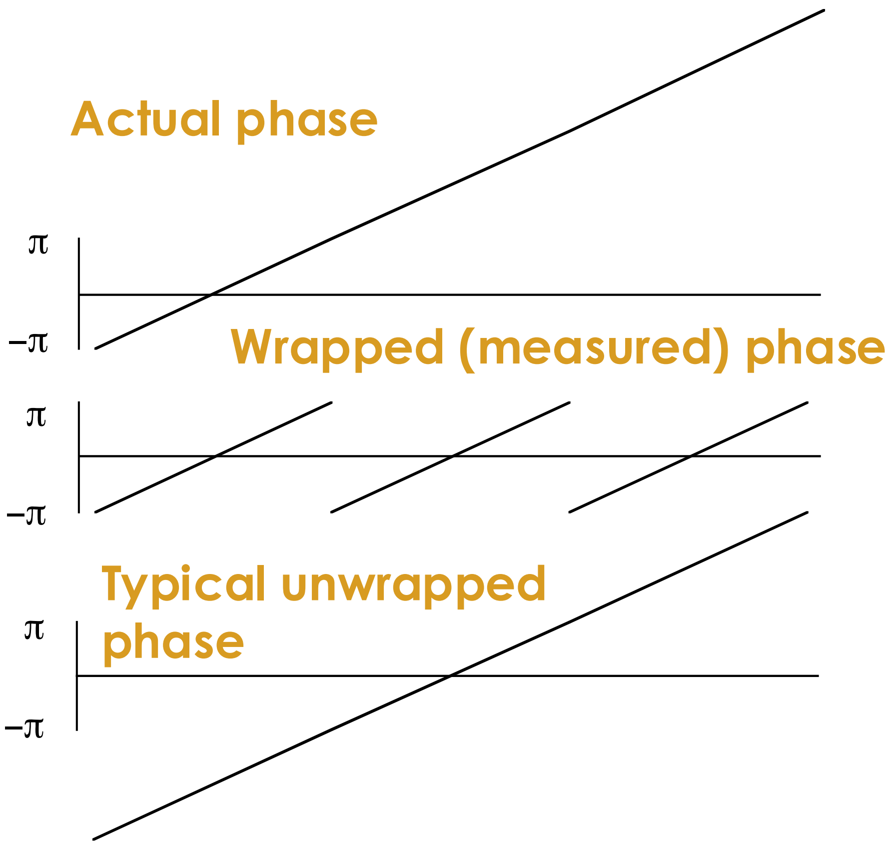




Slide modified from Paul Rosen (JPL)

Phase Unwrapping

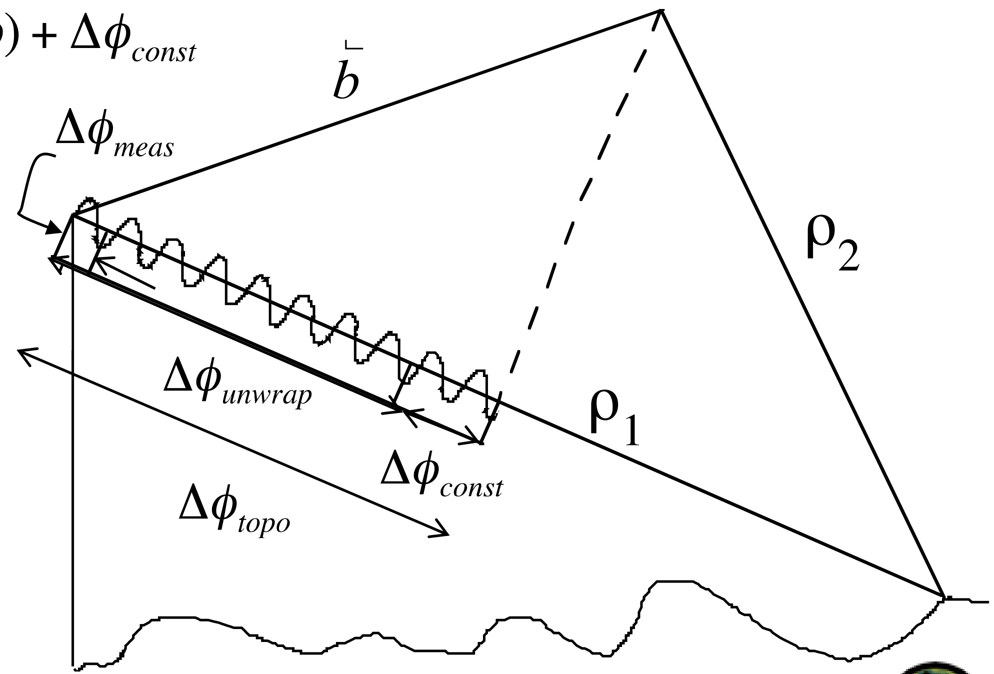
From the measured, wrapped phase, unwrap the phase from some arbitrary starting location, then determine the proper 2pi phase "ambiguity"



$$\Delta\phi_{topo} = \frac{2\pi p}{\lambda}\left(\rho_1 - \rho_2\right) = \frac{2\pi p}{\lambda}\vec{b} \bullet \vec{l}$$

$$\Delta\phi_{meas} = \mathrm{mod}\left(\Delta\phi_{topo}, 2\pi\right)$$

$$\Delta\phi_{unwrap}(s,\rho) = \Delta\phi_{topo}(s,\rho) + \Delta\phi_{const}$$

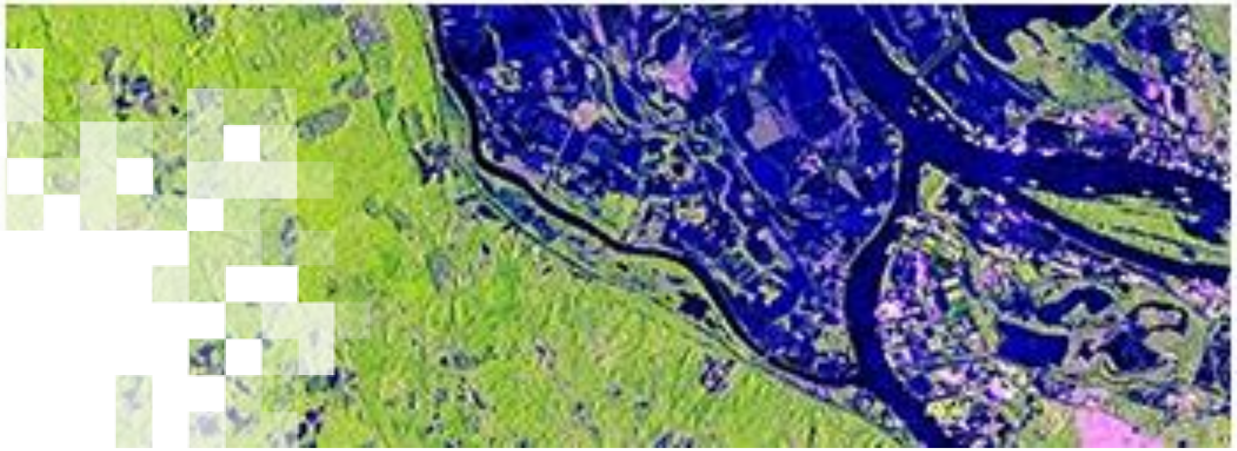


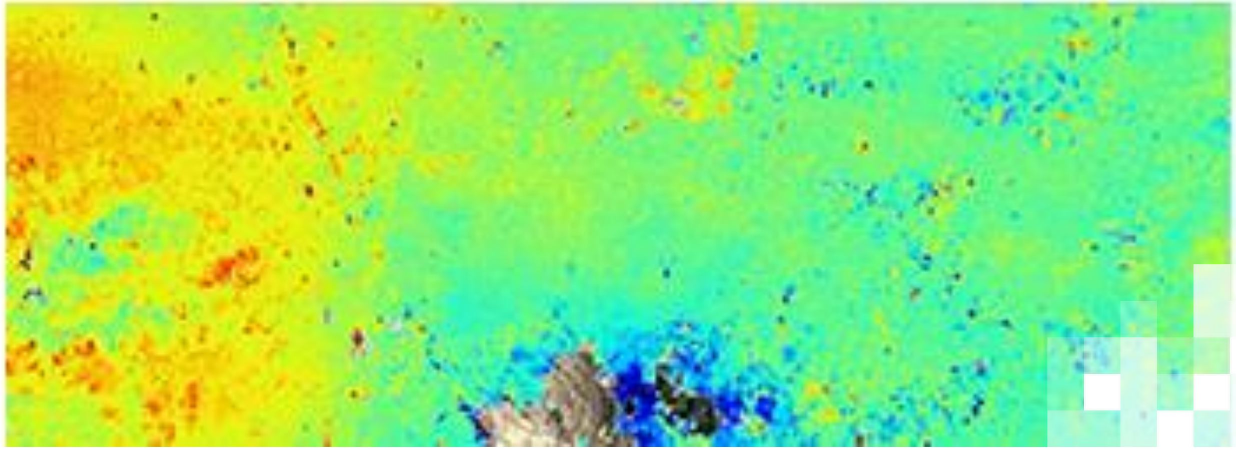
Slide modified from Paul Rosen (JPL)

Correlation or Coherence Theory

- "Correlation" and "Coherence" are often used synonymously, coherence is used more often in the last decade
- InSAR signals decorrelate (become incoherent) due to
  - Thermal and Processor Noise
  - Differential Geometric and Volumetric Scattering
  - Rotation of Viewing Geometry
  - Random Motions Over Time
- Decorrelation or loss of coherence relates to the local phase standard deviation of the interferogram phase
  - Affects height and displacement accuracy
  - Affects ability to unwrap phase

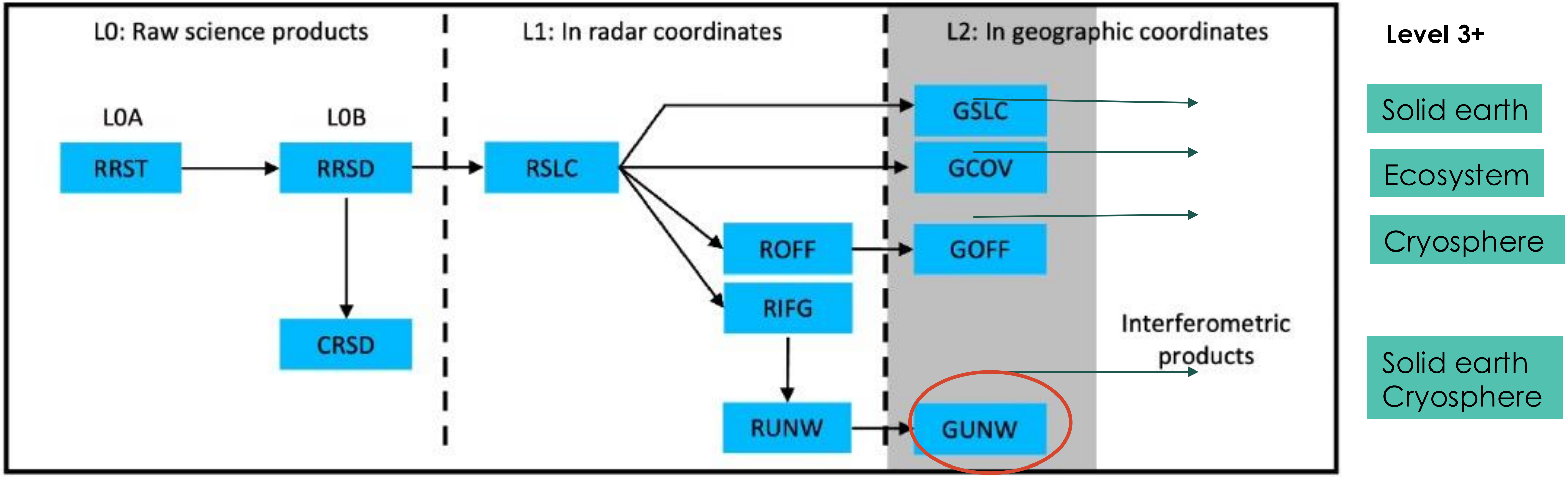
Slide modified from Paul Rosen (JPL)





Section 1: NISAR InSAR Data Products and their Characteristics

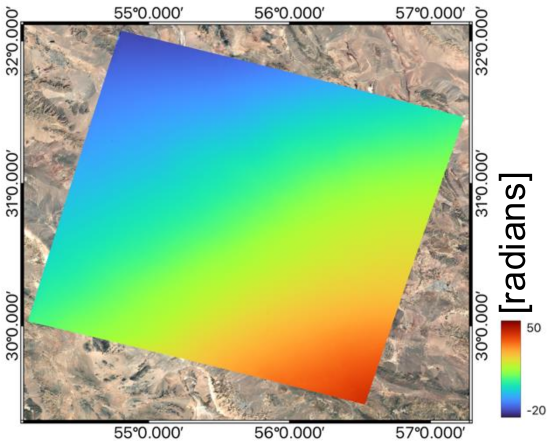
NISAR L-SAR Level-1 and Level-2 science product flow



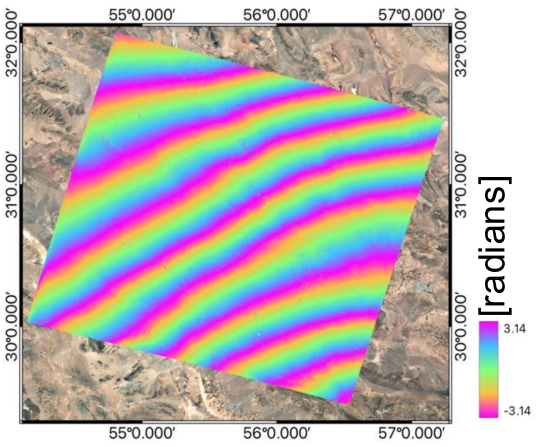
Slide Courtesy of Heresh Fattahi (JPL)

NISAR L2 GUNW (Geocoded Unwrapped Interferogram)

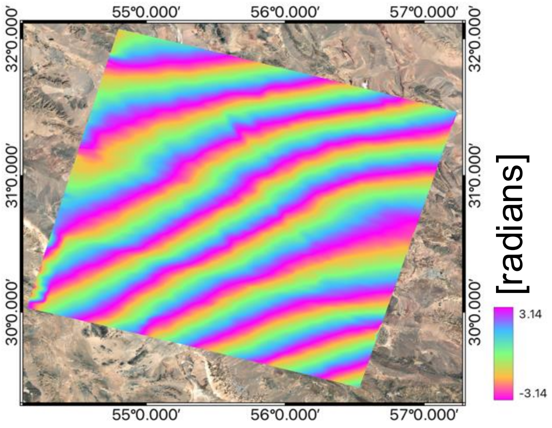
Unwrapped Phase (80 m)



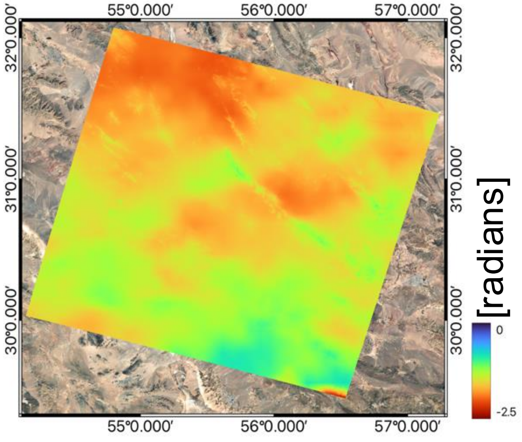
Wrapped Phase (20 m)



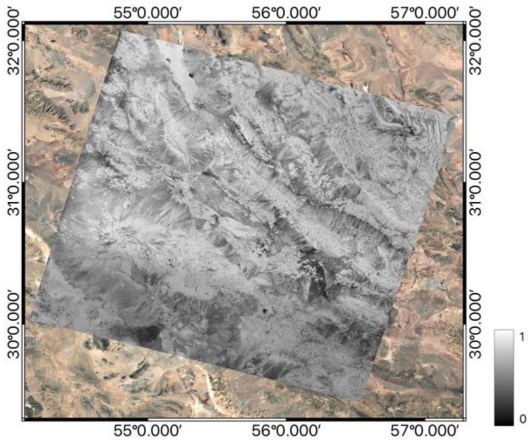
Ionospheric Phase (Rewrapped)



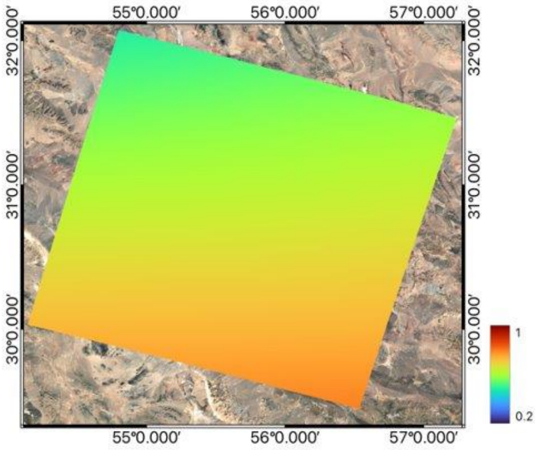
Tropospheric Phase (3D Cube)



Coherence (80 m)



Solid earth tide (3D cube)



- **GUNW** (Geocoded Unwrapped and Wrapped phase) is produced globally over solid earth and cryosphere regions
- 80 x 80 m for unwrapped phase and its coherence layer
- 80 x 80 m for ionospheric
- Water and sub-swath masks at 80 m
- 20 x 20 m Wrapped phase and its coherence
- Tropospheric delay and Solid Earth Tide as 3D cubes
- Range Doppler Wrapped and Unwrapped products (RIFG and RUNW) are produced over Cryosphere regions

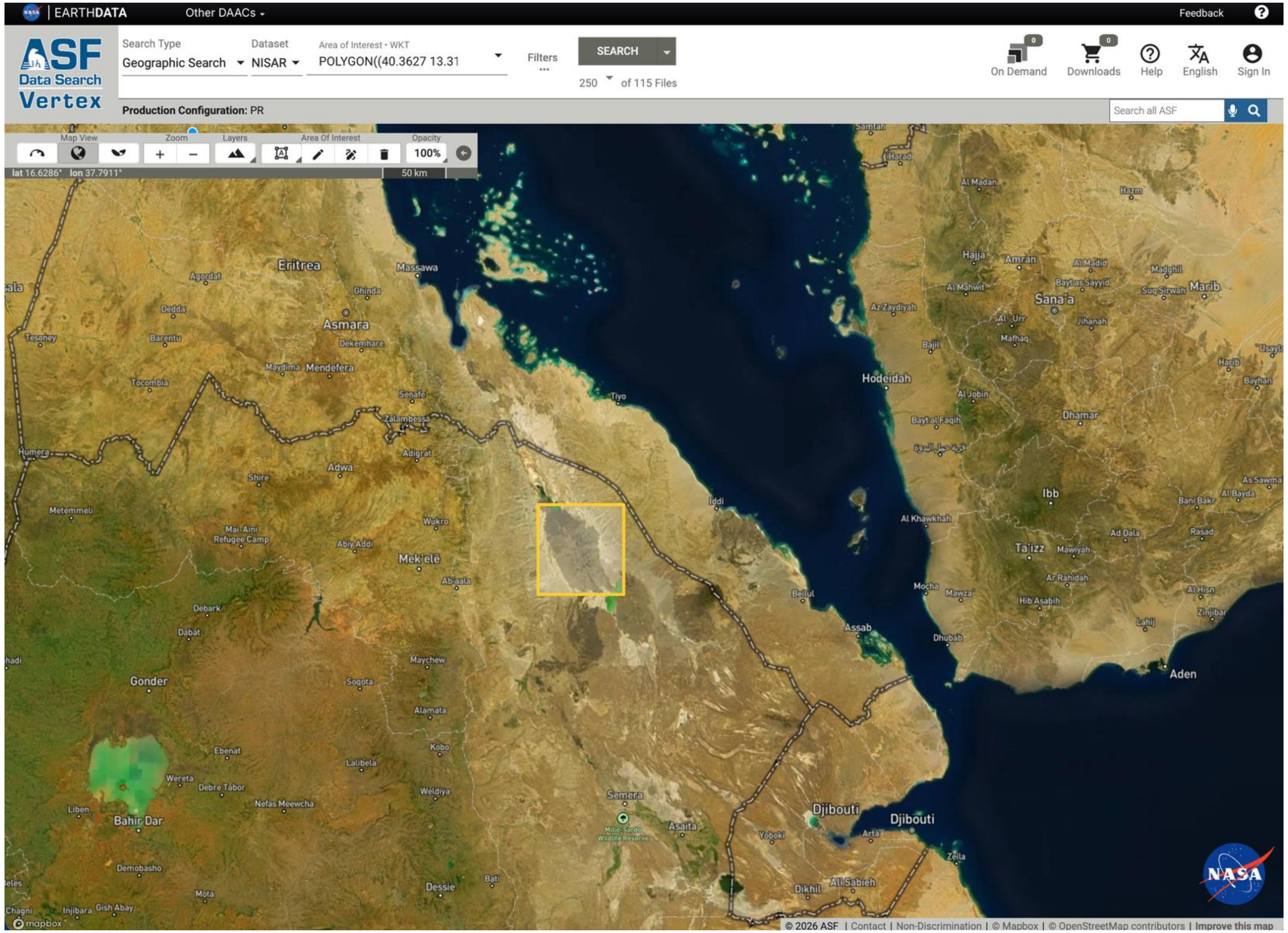
Slide Courtesy of Heresh Fattahi (JPL)

NISAR Data Access (Review from Session 2)

- NISAR data are stored in the NASA EarthData system, hosted in Amazon Web Services (AWS)
- EarthData can be searched directly from their search for any NASA dataset: https://search.earthdata.nasa.gov/
- Alaska Satellite Facility (ASF) has search specifically for SAR data, including NISAR: https://search.asf.alaska.edu/
- Downloads from ASF and Earthdata are the same data, only a different interface
- ASF guide to NISAR data download, usage, tutorials, etc.: https://nisar-docs.asf.alaska.edu/
- As of June 2026, only a limited set of uncalibrated data have been released.
- Planned release of calibrated data is in July. Check this page for release updates: https://nisar-docs.asf.alaska.edu/availability-overview/#data-release-timeline

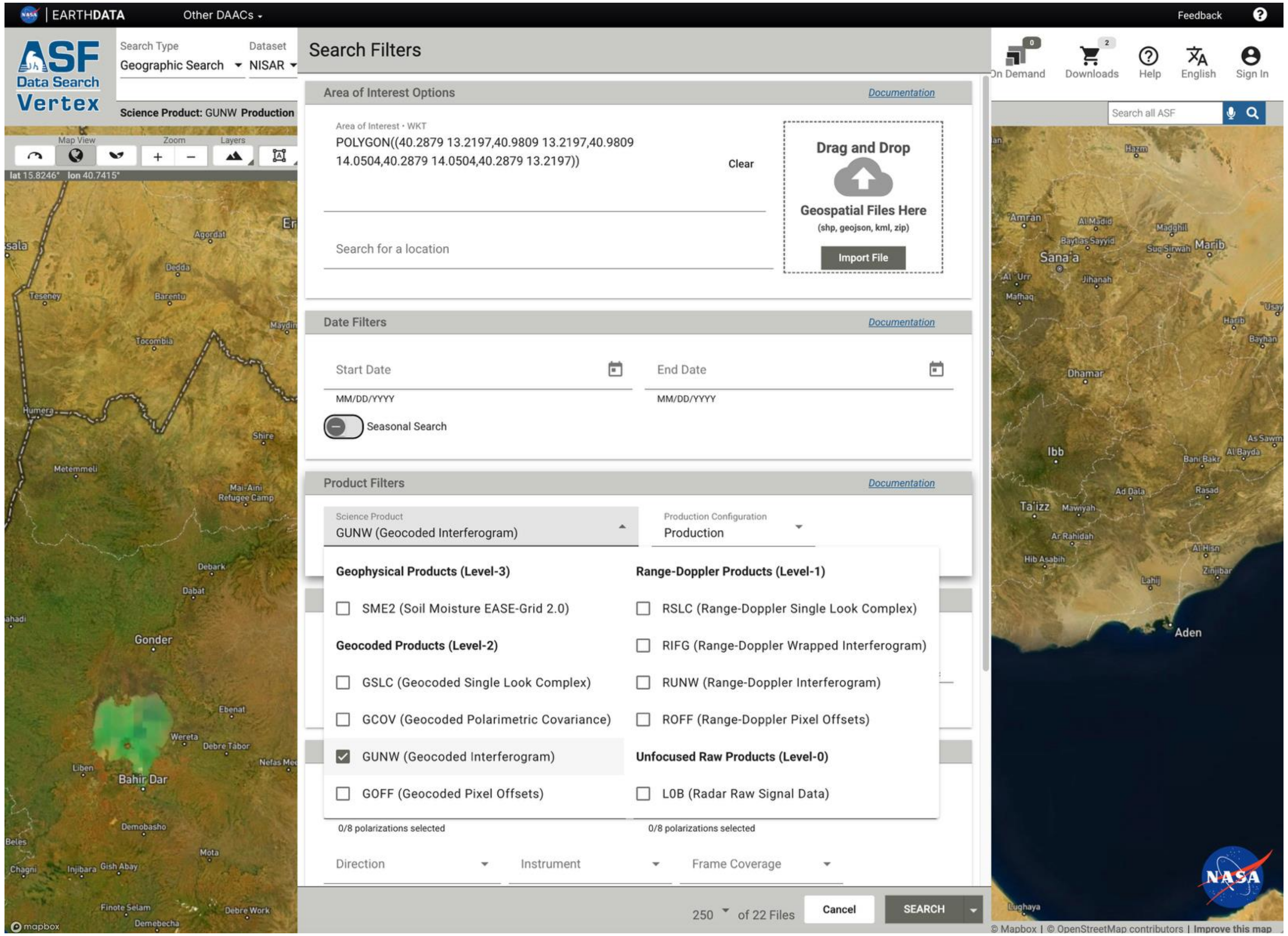
NISAR GUNW Search at ASF

- The Alaska Satellite Facility (ASF) search starts with NISAR as default dataset
- Draw a box around your area of interest
- This area is the Erta Ale volcano and an adjacent volcano Hayli Gubbi in Ethiopia
- Hayli Gubbi erupted suddenly on 23 November 2025
- Magma drained out of Erta Ale feeding the eruption



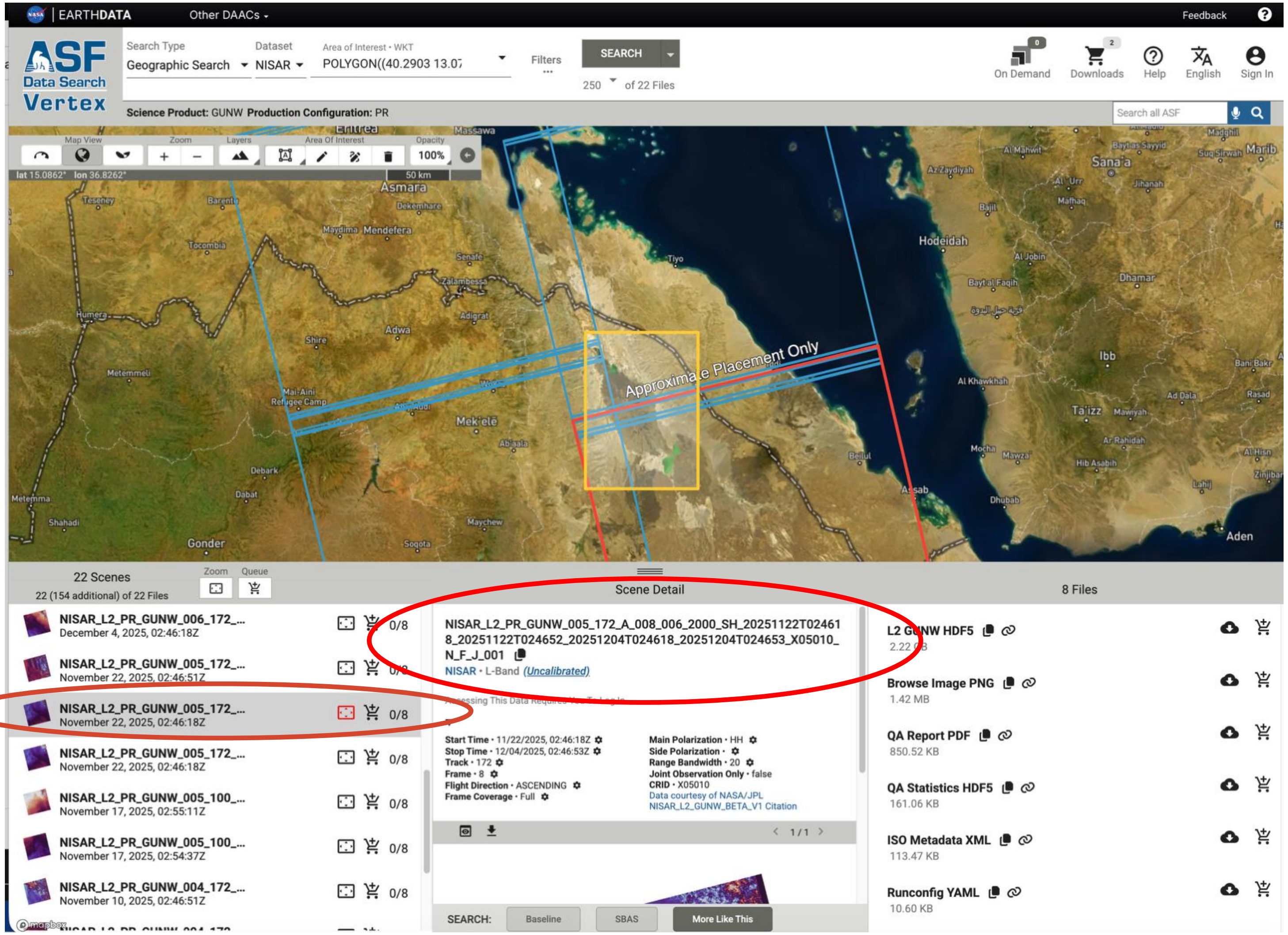
NISAR GUNW Search Filters at ASF

- We can choose the filters button to select more options
- Science products brings up a list of NISAR product types
- We only want GUNW products, so check that box
- Other filters can be used to select a range of dates



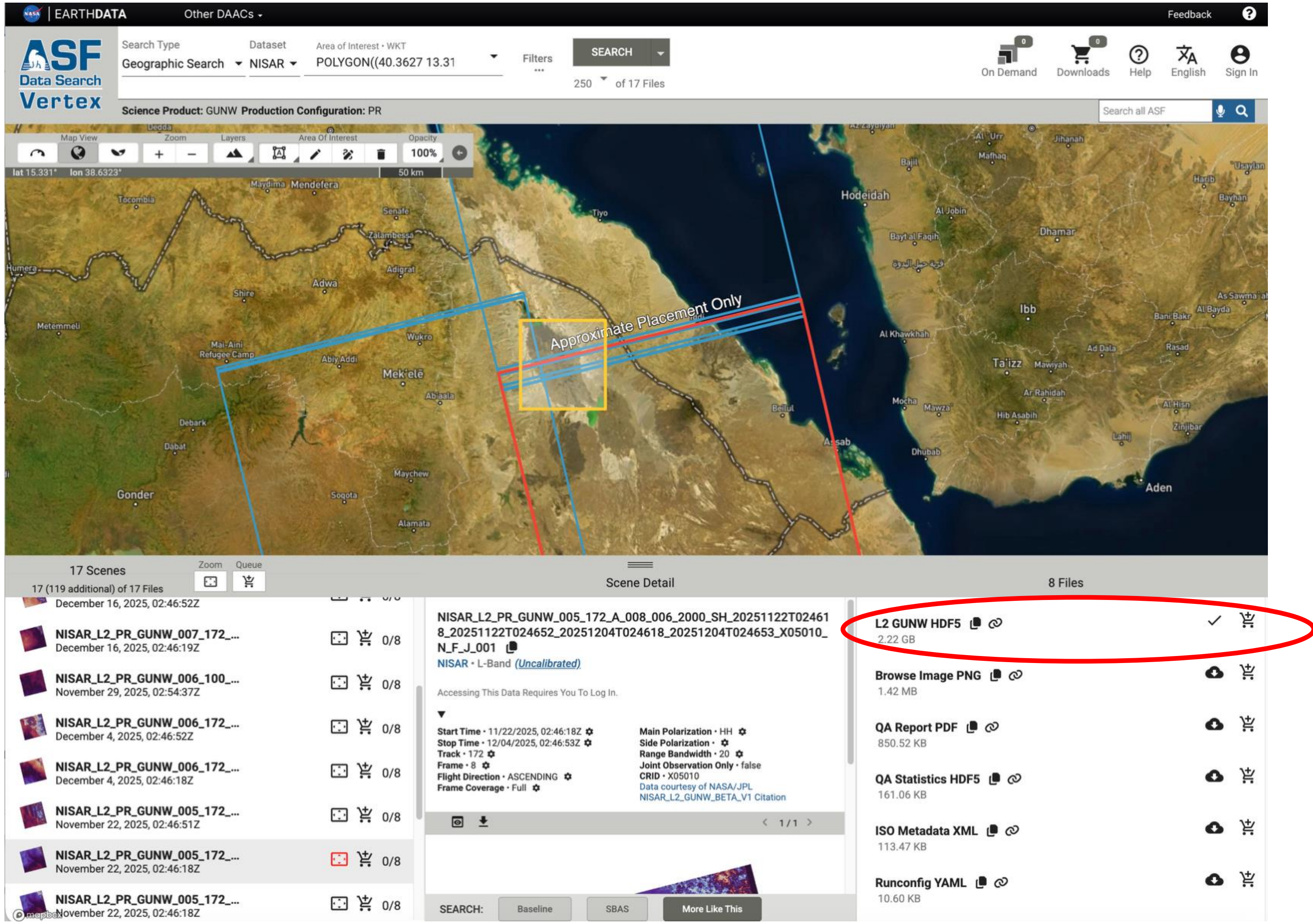
NISAR GUNW Search Results at ASF

- NISAR GUNW products are interferograms between two dates
- GUNW are listed by the first date of the two
- Choose the pair starting from November 22, 2025
- This has a second date of December 4, 2025 and includes the eruption



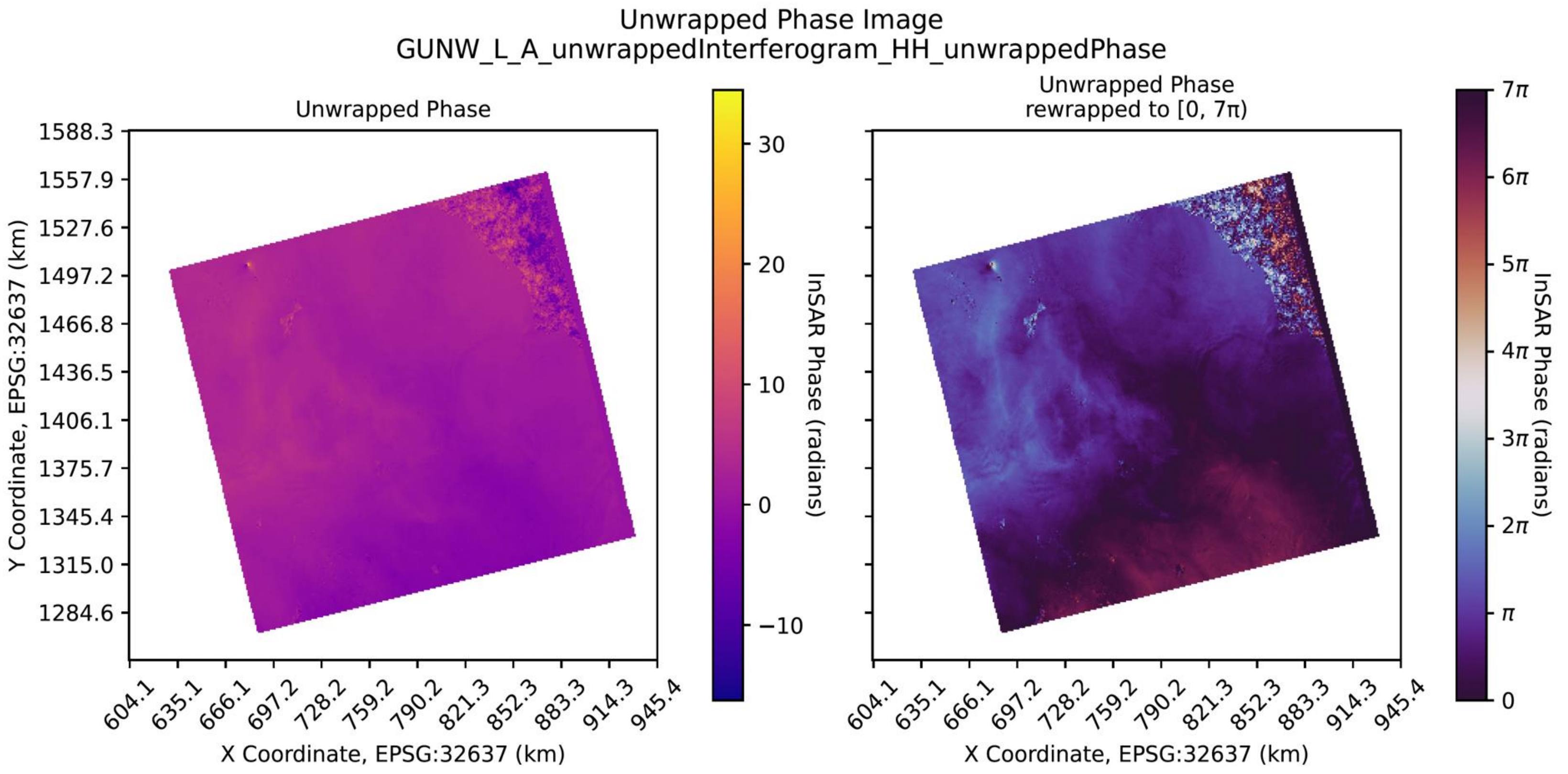
NISAR GUNW Download at ASF

- NISAR GUNW product files are listed in the lower right panel
- Press the download button on the files that you want
- You may need to login to your Earthdata account
- GUNW HDF5 is the main data file
- A useful summary of the GUNW contents: “QA Report PDF”
- ”Browse Image PNG” and “Footprint KML” can be displayed in Google Earth



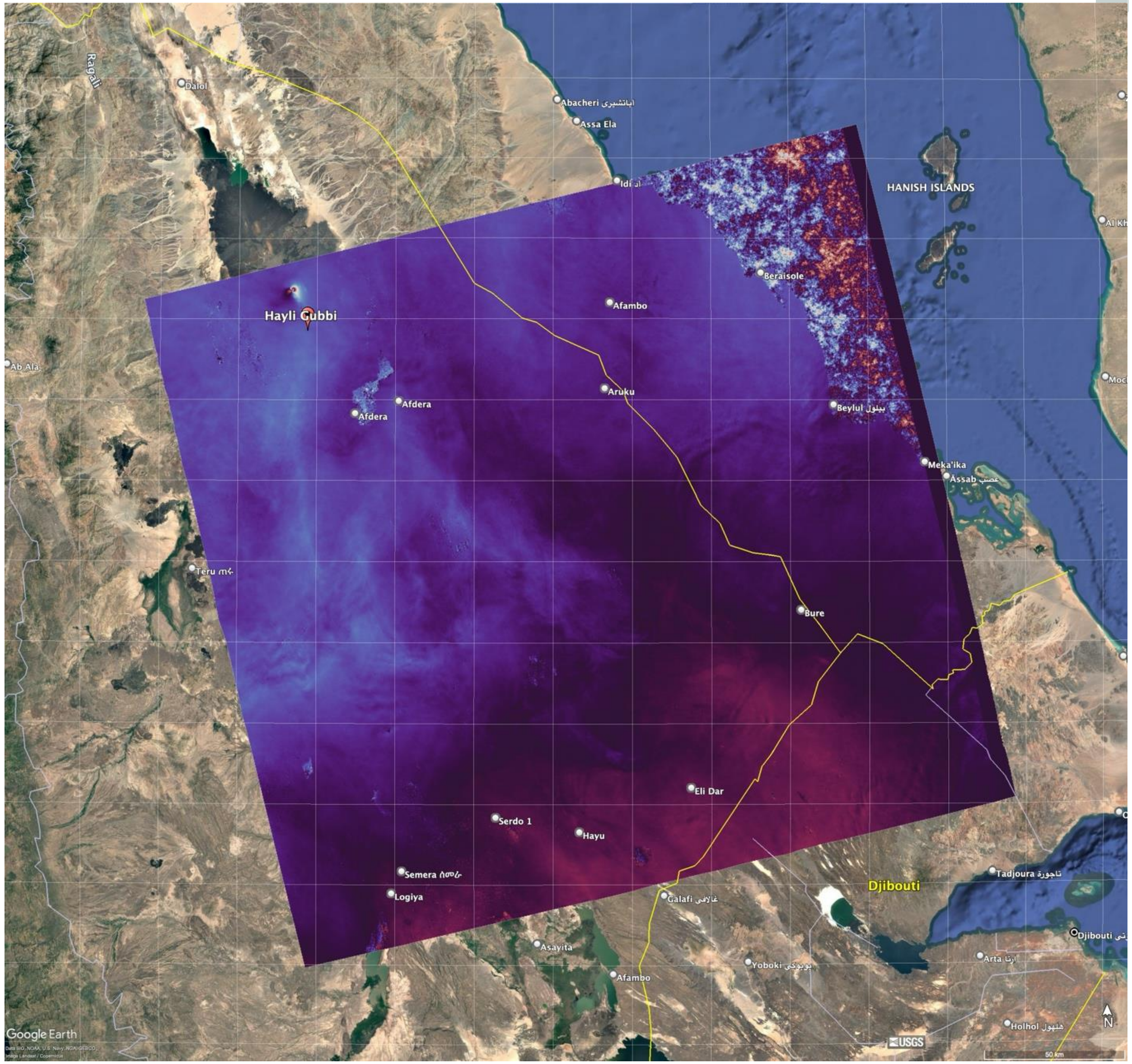
GUNW QA Report

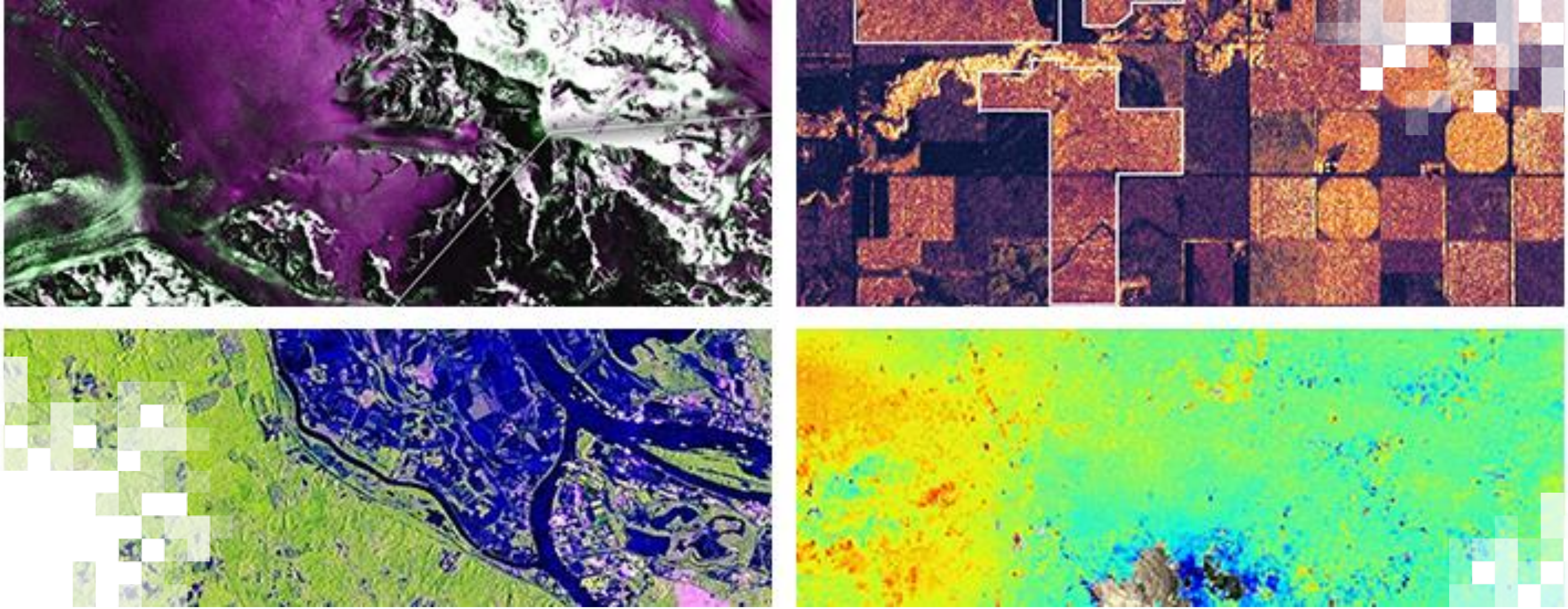
- NISAR data QA(quality assurance) reports are available for all L1-L3 products
- The first page has basic metadata
- The following pages have maps and graphs
- The unwrapped phase is shown with full range and rewrapped (7*pi in the early release)
- You can see previews of all the GUNW layers



GUNW Browse

- NISAR data have browse PNG images
- A KML file allows display of the browse image in Google Earth or Google maps
- Convenient way to verify coverage of a NISAR frame before downloading the full file
- GUNW browse is the unwrapped phase with 7*pi rewrap for old products
- Final products will use 2*pi rewrap

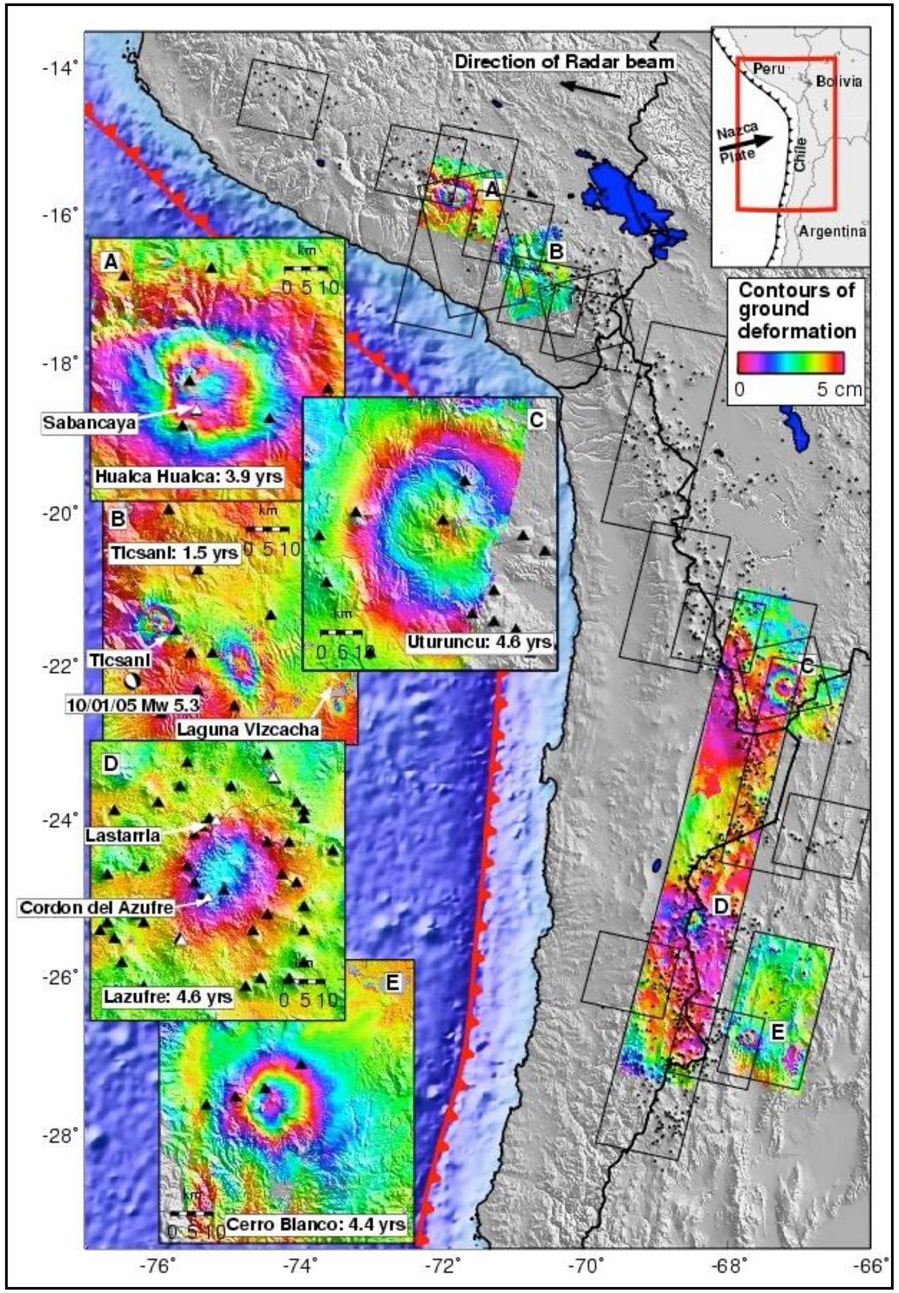




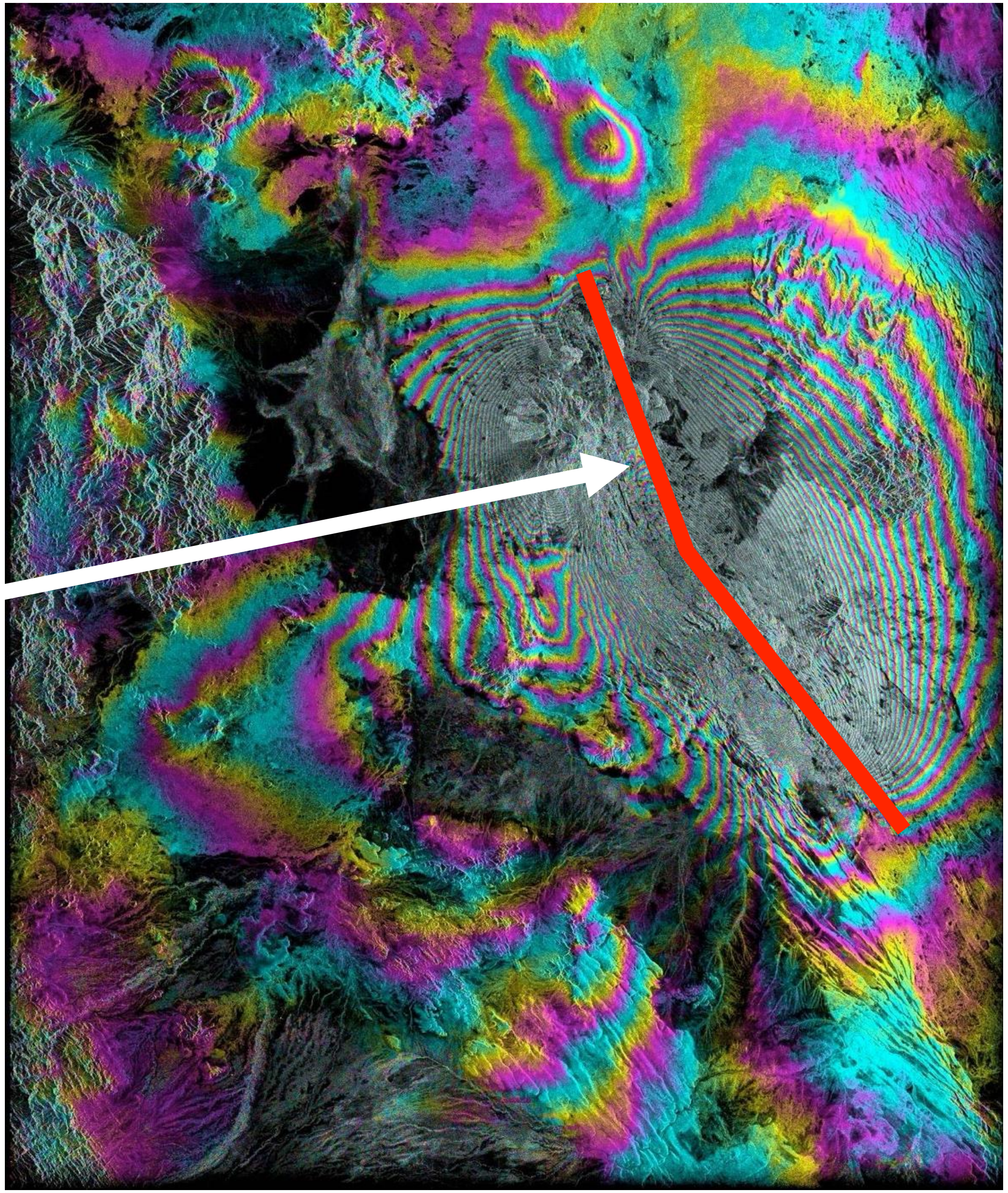
Section 2: Uses and Limitations of NISAR InSAR Data

Volcanoes of the Central Andes

- Map of deformation in and around volcanoes
- European ERS-1 and ERS-2 satellites (C-band)
- Some related to recent eruptions
- Others were not known to be active now
- M. Pritchard (now at Cornell)



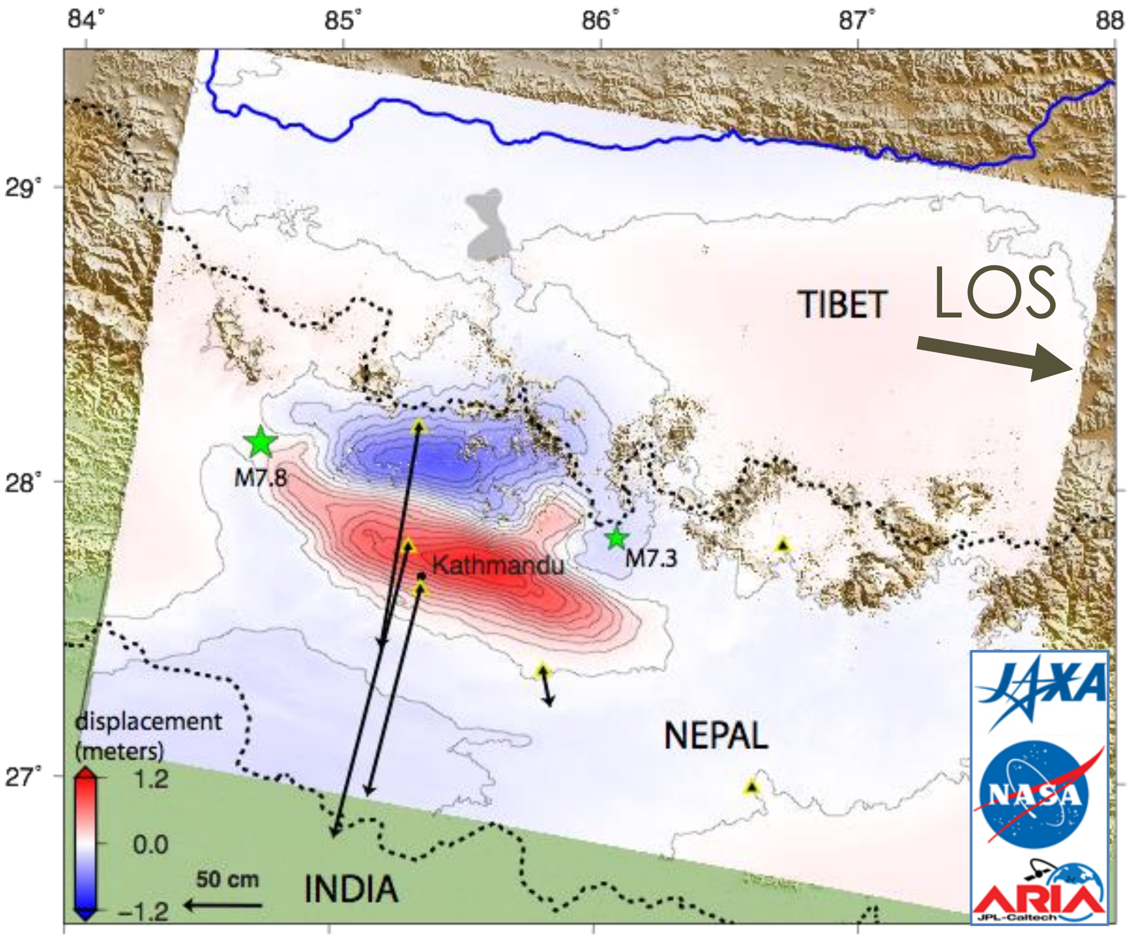
Asal Rift Dike Injection



6 May – 28 Oct 2005;
from Tim Wright,
University of Leeds

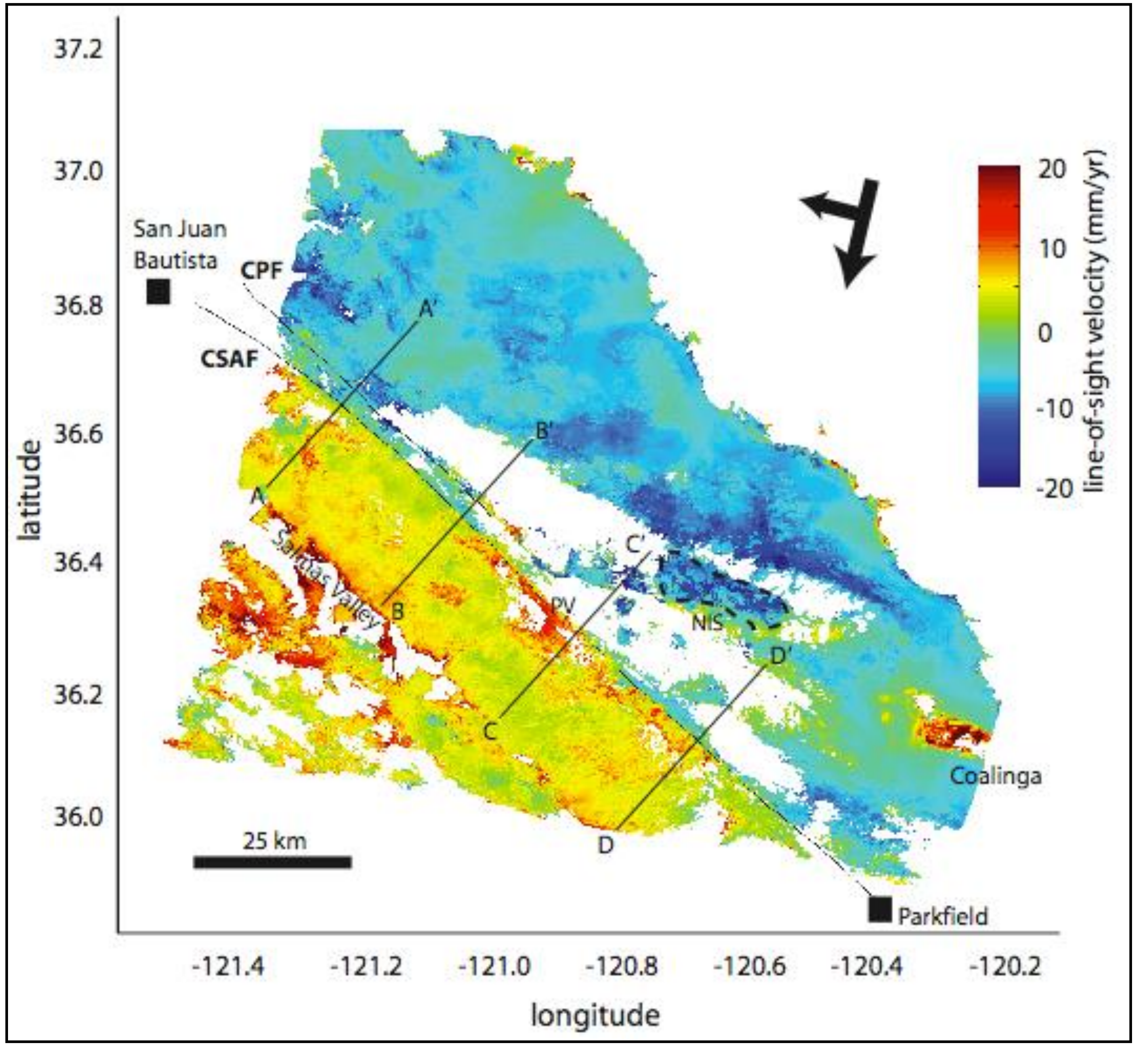
2015 M7.8 Gorkha Earthquake in Nepal

- ALOS-2 ScanSAR interferogram
- Descending line-of-sight (LOS) perpendicular to horizontal
- InSAR phase only sees vertical component
- High Himalayas dropped down as much as 1.2 m
- Yue, H., et al. (2016), Depth varying rupture properties during the 2015 Mw 7.8 Gorkha (Nepal) earthquake, *Tectonophysics*, doi:10.1016/j.tecto.2016.07.005.



GPS data from Galetzka, J., et al. (2015), Slip pulse and resonance of the Kathmandu basin during the 2015 Gorkha earthquake, Nepal, *Science*, *349*(6252), 1091-1095

Creep on the San Andreas Fault

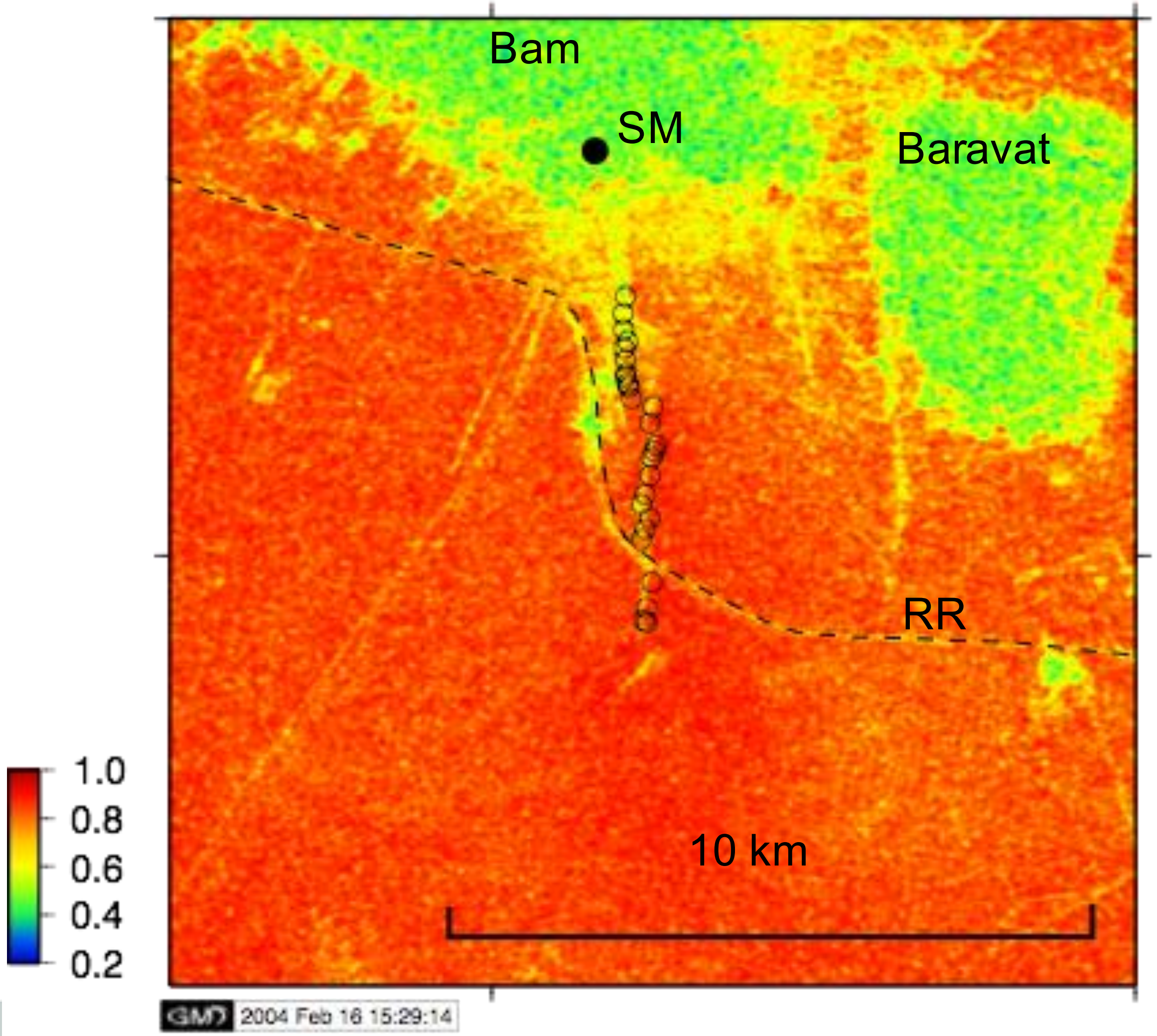


Stack of 12 ERS interferograms spanning May 1992-Jan 2001

Figure from Isabelle Ryder, UC Berkeley

Decorrelation Shows Surface Ruptures

2003 M6.5 Bam Earthquake in Iran



35 days: 2003/12/3 –2004/1/7

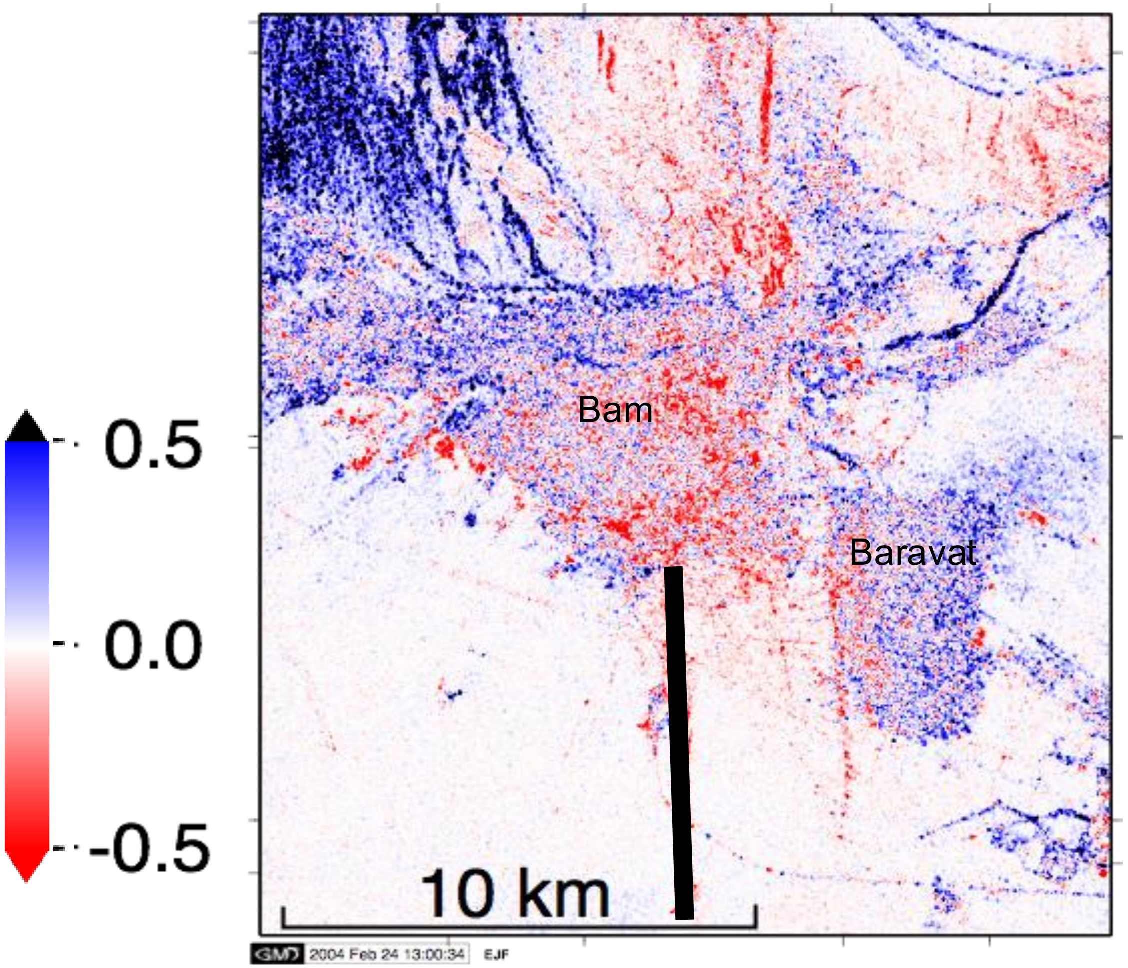
Satellite: Envisat

Track: Descending

Perpendicular Baseline: 580 m

Fielding, E. J., M. Talebian, P. A. Rosen, H. Nazari, J. A. Jackson, M. Ghorashi, and R. Walker (2005), Surface ruptures and building damage of the 2003 Bam, Iran, earthquake mapped by satellite synthetic aperture radar interferometric correlation, *J. Geophys. Res.*, *110*(B3), B03302, doi:10.1029/2004JB003299.

Correlation Change

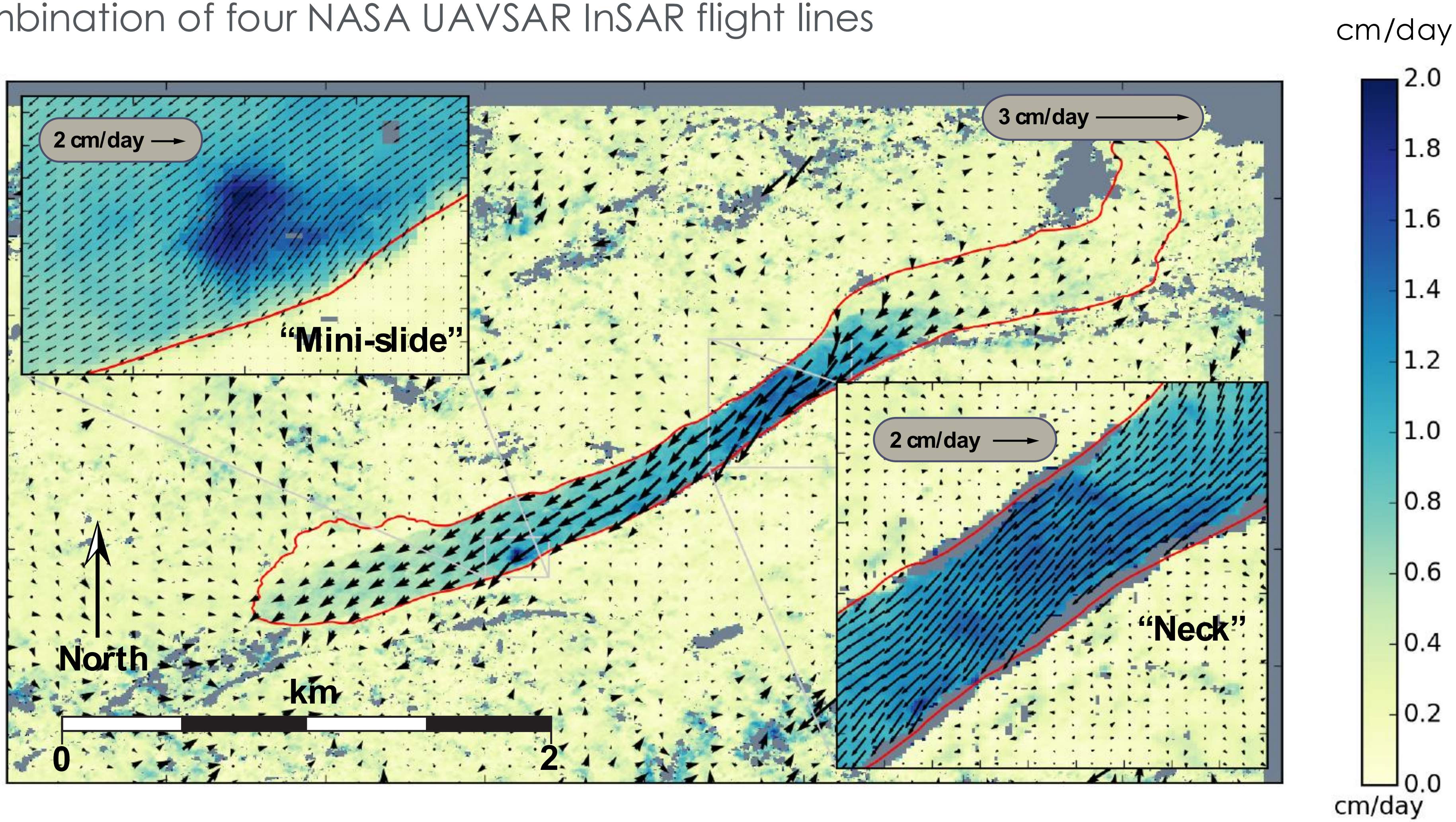


Co-seismic correlation minus pre-seismic correlation

Red = Co-seismic decorrelation

Landslide Motion

Combination of four NASA UAVSAR InSAR flight lines



Delbridge, B. G., R. Bürgmann, E. Fielding, S. Hensley, and W. H. Schulz (2016), Three-dimensional surface deformation derived from airborne interferometric UAVSAR: Application to the Slumgullion Landslide, J. Geophys. Res. Solid Earth, 121(5), 3951--3977, doi:10.1002/2015JB012559.

InSAR Errors

- InSAR errors add (or subtract) from the surface displacement we want to measure

$$\phi_{\{obs\}} = \phi_{\{LOS\}} + \phi_{\{tropo\}} + \phi_{\{iono\}} + \phi_{\{DEM\}} + \phi_{\{noise\}}$$

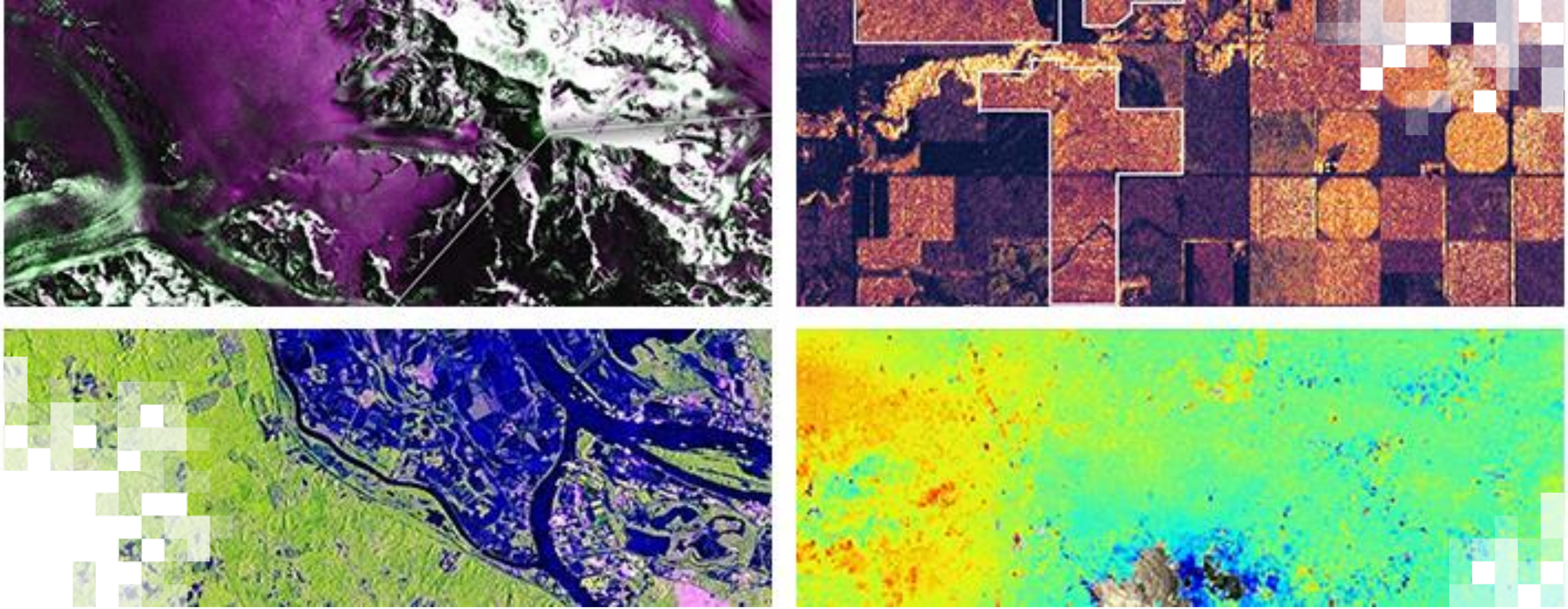
- Where:
  - $\phi_{\{obs\}}$ is the observed interferogram phase
  - $\phi_{\{LOS\}}$ is the line-of-sight surface displacement

InSAR Coherence Components

- Coherence or correlation effects multiply, unlike phase effects that add.
- Low coherence or decorrelation for any reason causes loss of information in that area.

$$\gamma = \gamma_v \gamma_g \gamma_t \gamma_c$$

Where:
γ_v is volumetric (trees)
γ_g is geometric (steep slopes)
γ_t is temporal (gradual changes)
γ_c is sudden changes

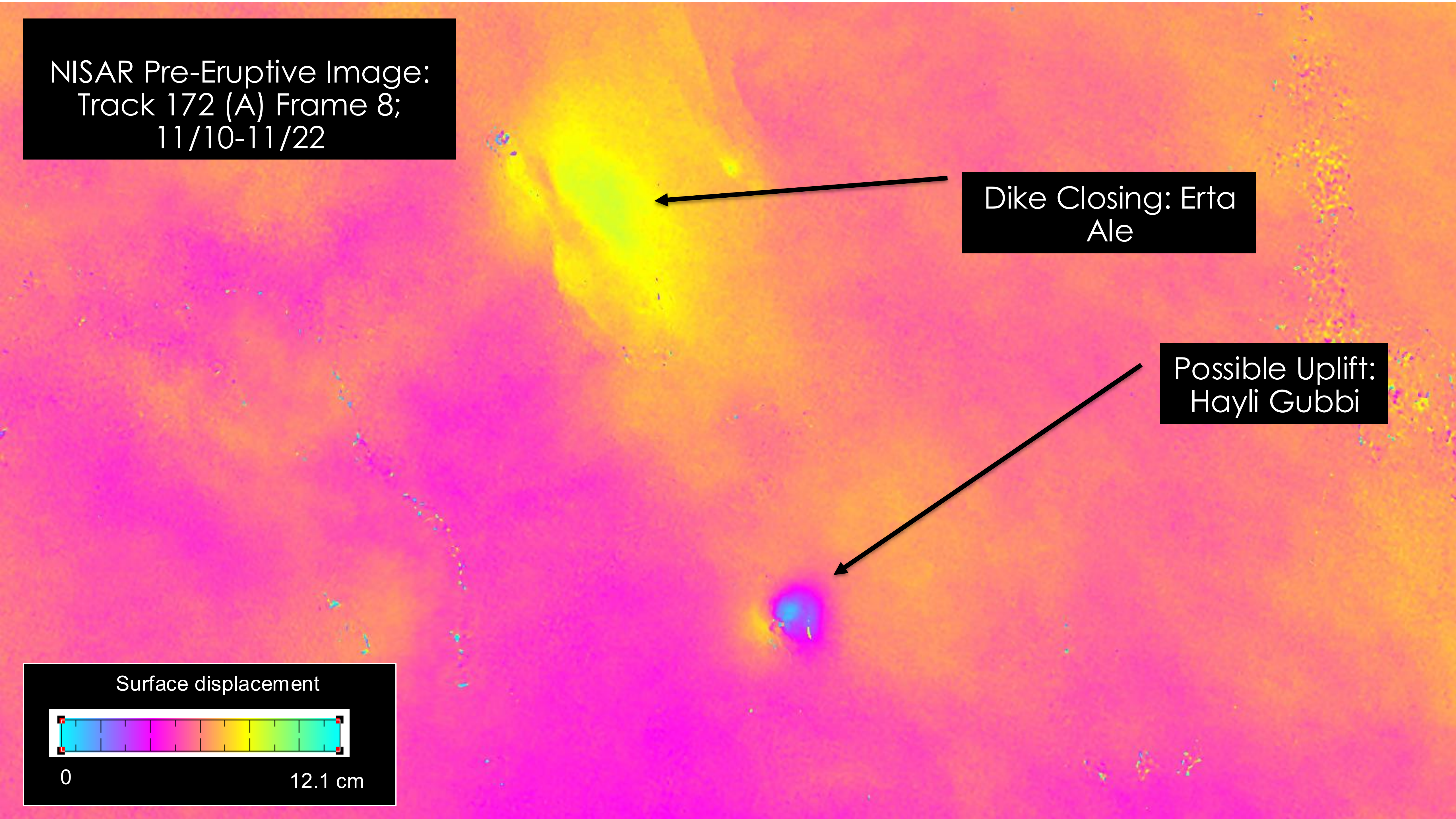


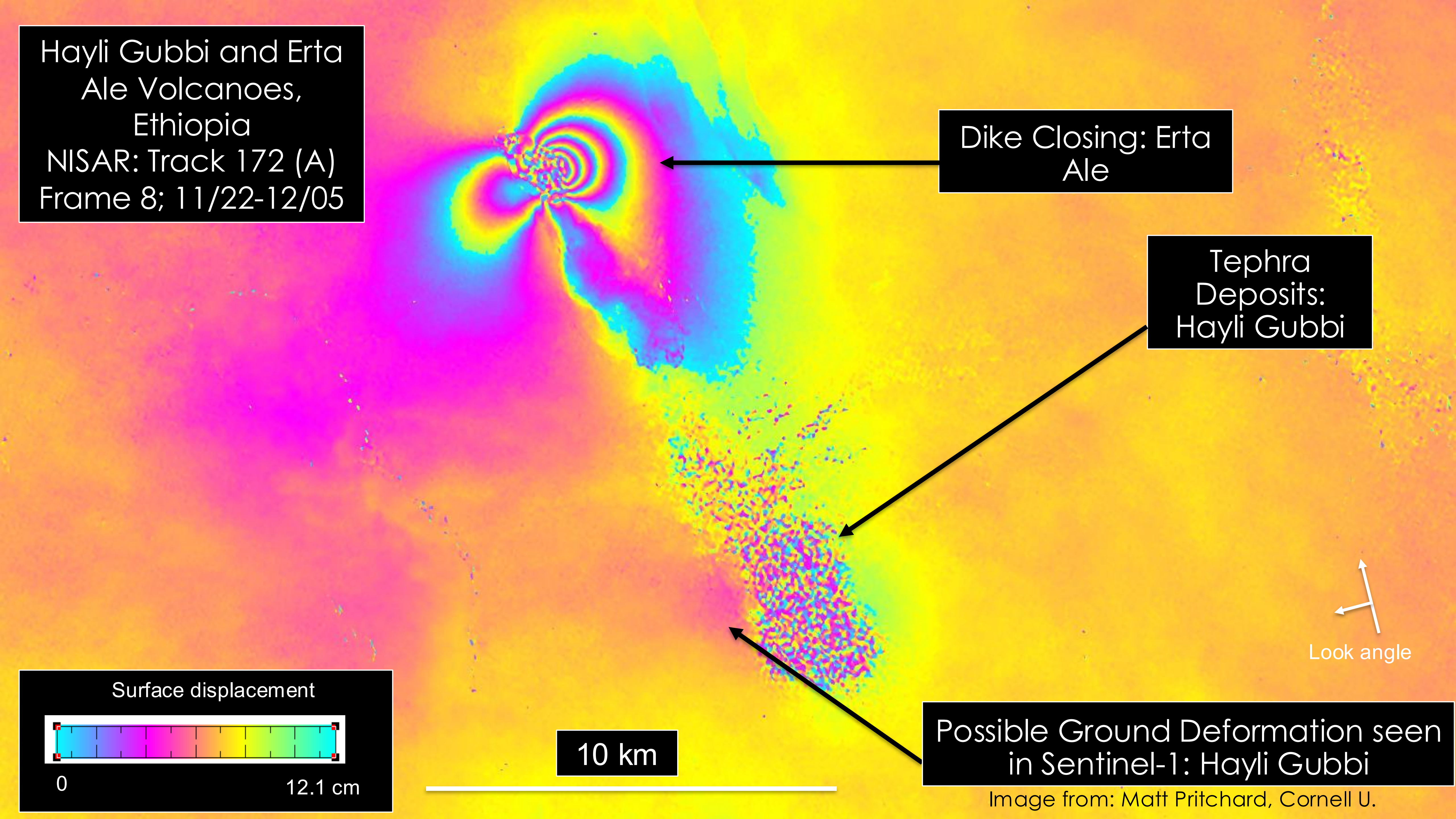
Section 3: Case Study Using NISAR InSAR Data for Volcanoes and Landslides

Hayli Gubbi and Erta Ale Volcanoes in Ethiopia

- No earthquakes with significant InSAR signals were part of the NISAR L-band preliminary release
- We focus on a volcanic eruption instead
- Area is the Erta Ale volcano and an adjacent volcano called Hayli Gubbi in Ethiopia
- They are part of the East African Rift system
- Hayli Gubbi erupted suddenly on 23 November 2025
- Magma drained out of Erta Ale feeding the eruption at Hayli Gubbi

- First, we look at some wrapped interferograms mapped by Matt Pritchard, Cornell
- These maps are for a small subset of the full NISAR frame


NISAR Pre-Eruptive Image:
Track 172 (A) Frame 8;
11/10-11/22
Dike Closing: Erta Ale
Possible Uplift: Hayli Gubbi
Surface displacement
0
12.1 cm


Hayli Gubbi and Erta Ale Volcanoes, Ethiopia
NISAR: Track 172 (A)
Frame 8; 11/22-12/05
Dike Closing: Erta Ale
Tephra Deposits: Hayli Gubbi
Look angle
Surface displacement
0
12.1 cm
10 km
Possible Ground Deformation seen in Sentinel-1: Hayli Gubbi
Image from: Matt Pritchard, Cornell U.

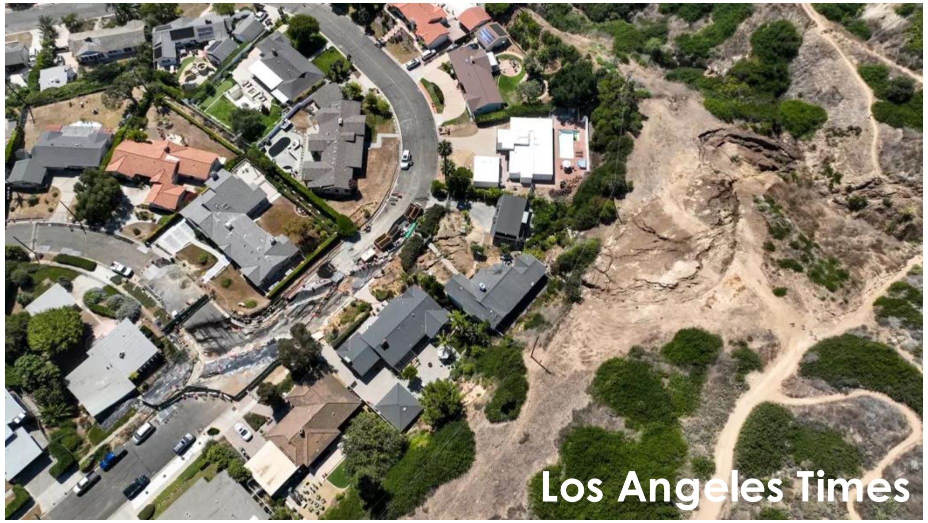
GUNW Full Scene Analysis

- NISAR data are stored in HDF5 (.h5) format
- HDF5 files are also a version of NetCDF
- ArcGIS can read NISAR HDF5 directly
- Present version of GDAL needs to be told that the file should be opened with the NETCDF driver
- QGIS uses GDAL to open the files
- Two options:
  - Rename ".h5" file as ".nc"
  - Add "NETCDF:" to the front of the file name in QGIS input or other GDAL call
- QGIS cannot display wrapped interferogram layers directly

Landslides

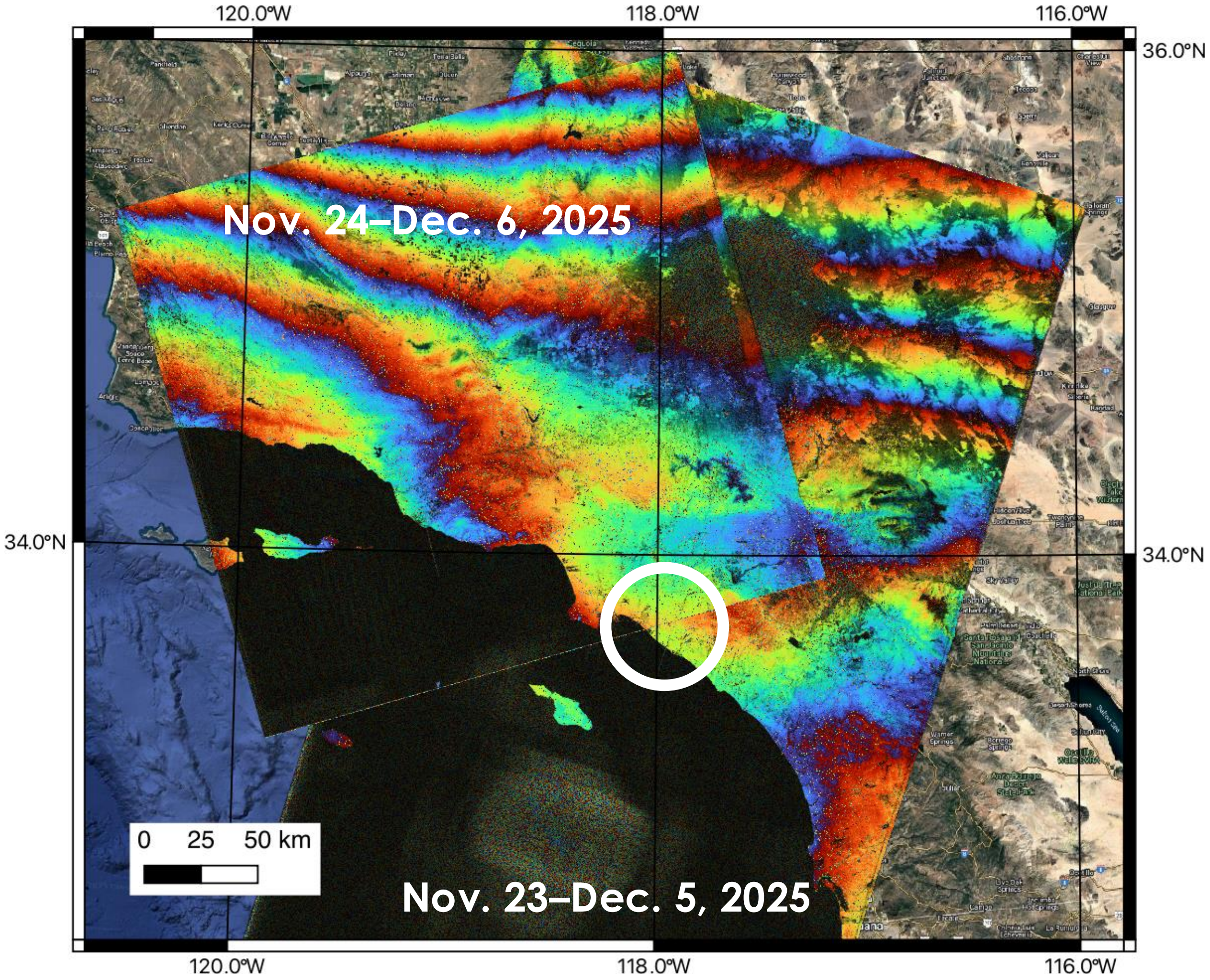
- Slow-moving landslides are a major natural hazard and are an important process eroding mountainous landscapes
- The hazardous impact and erosive potential of landslides depends on their properties including the velocity, geometry, and frequency of occurrence
- NISAR will provide frequent coverage with high-resolution L-band InSAR to map landslides worldwide
- We illustrate preliminary NISAR results over the Palos Verdes landslide complex in California that has damaged many homes

Rancho Palos Verdes' Seaview Neighborhood



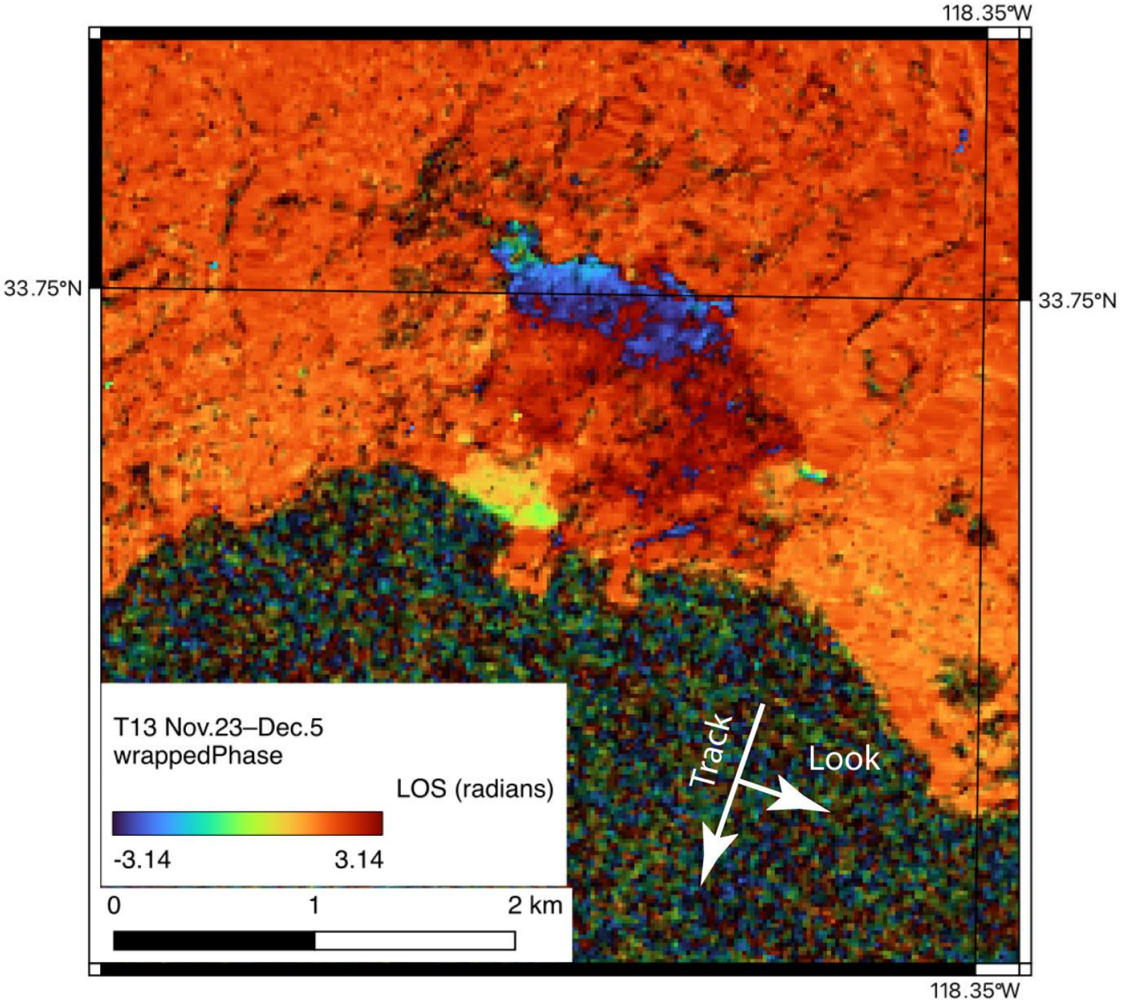
Example: Slow-Moving Landslides – Palos Verdes

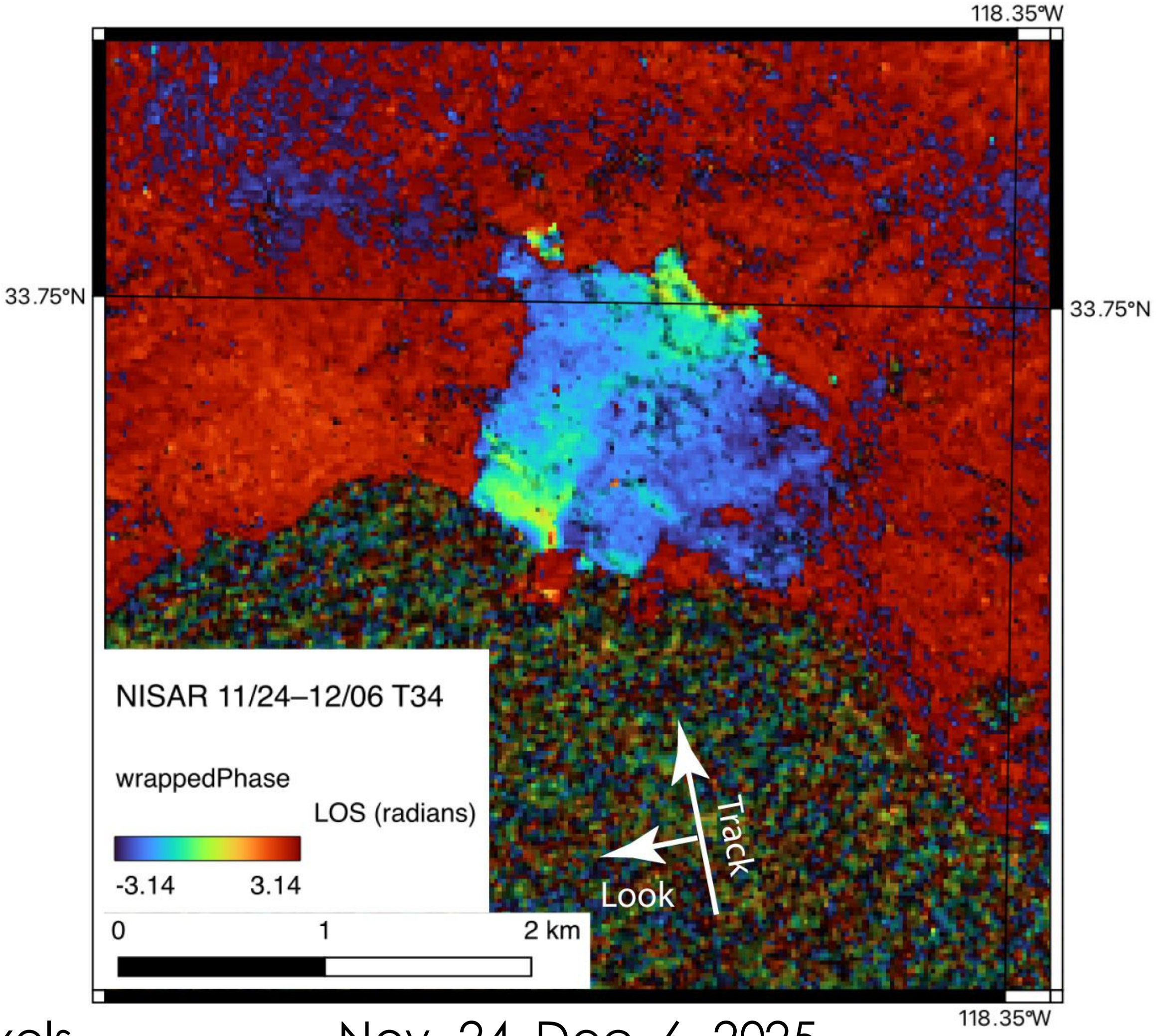
- Palos Verdes Peninsula is southwest of downtown Los Angeles, California
- The central south coast of Palos Verdes has a large ancient landslide complex
- Several parts of the landslide complex have been moving for about 60 years, including Abalone Cove, Portuguese Bend (PBL), and Flying Triangle landslides
- Heavy rainfall in 2023 and 2024 caused acceleration of these landslides and areas that were previously stable



NISAR Results – Wrapped Interferogram

NISAR L-band Wrapped Phase and Coherence





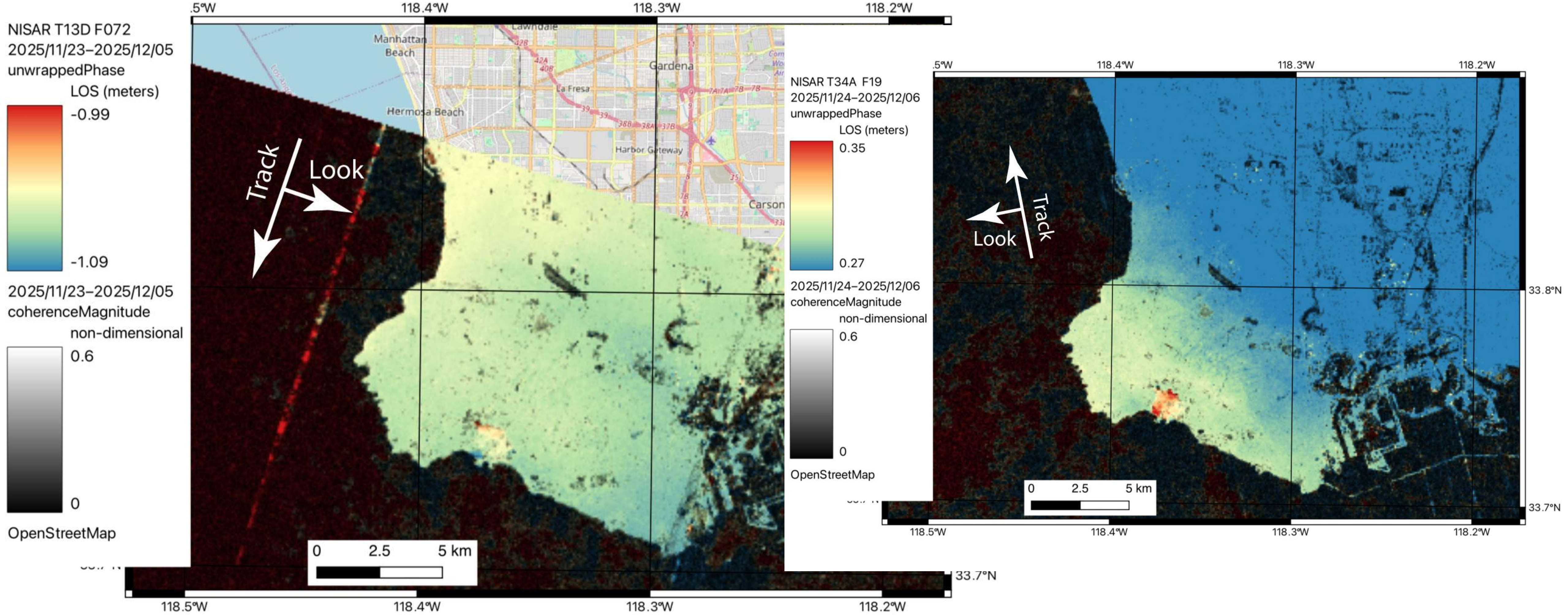
Nov. 23–Dec. 5, 2025

20 m Pixels

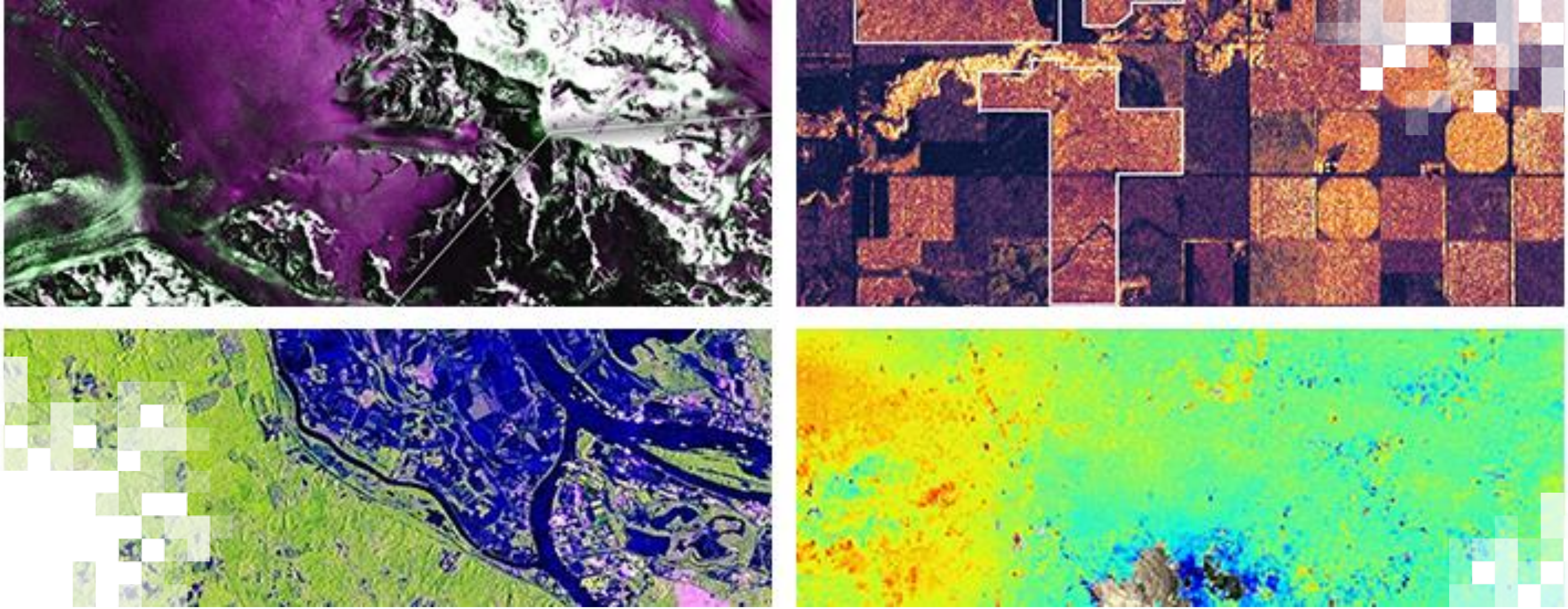
Nov. 24–Dec. 6, 2025

NISAR Results

NISAR L-band GUNW Unwrapped Phase Converted to Meters with Coherence



Nov. 23–Dec. 5, 2025 80 m Pixels Nov. 24–Dec. 6, 2025



Summary

Summary – Session 3

- SAR interferometry (InSAR) measures the distance from the satellite to the ground with high precision by using the phase of the reflected radar signal.
- The coherence of the InSAR phase is a measure of surface cover stability at the radar wavelength scale.
- Phase cycles in a repeat-pass interferogram show change in distance to the ground by half the radar wavelength, which is 12 cm for NISAR.
- New pre-processed InSAR products from NISAR enable user analysis of interferograms with few additional steps.
- NISAR InSAR measurements of surface motion are useful for a variety of geological processes, some hydrological processes, dynamics of glaciers, and other effects that displace the surface or large structures.
- The NISAR GUNW interferometric product is geocoded and is best suited for users new to InSAR.

Summary – Session 2

- NISAR data are freely and openly available.
- L-band data can be accessed through the Alaska Satellite Facility (ASF), while S-band data, along with coincident L-band observations, are available through ISRO's Bhoonidhi platform.
- L-band provides near-global coverage every 12 days, whereas S-band observations are acquired primarily over India and selected science and calibration/validation sites outside India.
- NISAR data are distributed in HDF5 format.
- Level 2 products are geocoded, allowing them to be readily overlaid with other geospatial datasets.
- Open-source Jupyter Notebooks contain algorithms for the mission's different science disciplines, which are publicly available.
- The only global Level 3 product generated by NISAR is soil moisture, which has a spatial resolution of 200 m.
- The GCOV product is the geocoded geometrically terrain corrected backscatter data (gamma naught) and is the most suited for those new to radar and wanting to do ecosystem type studies (deforestation, biomass, agriculture, flooding, etc.)
- The GUNW product is the geocoded wrapped and unwrapped interferogram and is the best suited for those new to InSAR and wanting to do surface deformation/movement type studies.
- NISAR data can either be downloaded for local analysis or accessed and processed in the cloud, depending on your workflow.

Summary – Session 1

- NISAR is designed to monitor continuous Earth surface changes (centimeter-to-meter scale) globally, day and night, and through almost all weather/cloud conditions. Key focus processes include tectonic deformation, ice sheet motion, ecosystem change, and agricultural monitoring.
- NISAR has an L-band (24 cm wavelength) and an S-band (9.4 cm wavelength) radar. The satellite has an exact 12-day repeat cycle, an imaging swath greater than 240 km using the SweepSAR technique, and spatial resolutions varying between 3 and 30 meters depending on the radar mode.
- Polarization acquisitions vary depending on acquisition mode.
- Core science disciplines cover the Cryosphere (glacier/ice sheet/sea ice), Ecosystems (agriculture, biomass, wetlands, forest degradation) and Solid Earth (earthquakes, volcanoes, and landslides).
- NISAR can address different applications and support disaster and hazard management.
- Data processing levels span from Level 0 (raw data) to Level 3 (geocoded derived products), with soil moisture being the only L3 global product being generated.
- L1 and L2 products contain information about amplitude, phase, interferometric products, coherence, and pixel offsets.
- L1 data are in radar coordinates (range-doppler) and L2 products are geocoded and analysis ready.
- *In July 2026 the* fully calibrated forward processed data will be released with a data availability latency of 36–72 hours.

Homework and Certificates

- **Homework:**
  - One homework assignment
  - Opens on Jul. 16, 2026
  - Access from the training webpage
  - Answers must be submitted via Google Forms
  - **Due by Aug. 6, 2026**

- **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.

Acknowledgements – Guest Instructors

Dr. Franz J. Meyer

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ASF

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For questions, comments, or to share how you have applied our trainings to your work or studies, email nasa.arset@gmail.com.

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Share Your Thoughts!

Within a day or two, we will send you an invitation to complete a short online survey.* **Your feedback helps us improve the ARSET program.**

- Participation is optional, and all responses are confidential.
- **Survey data are crucial to helping us understand how to better meet your needs. We want to help you use Earth observation data more effectively.**
- We read every survey comment – so please share your thoughts!

*The survey will come from noreply@alchemer.com. This is not spam.

Thank You!