Part 2 Questions & Answers Session

Please type your questions in the Question Box. We will try our best to get to all your questions. If we don't, feel free to email intructors Eric Fielding (eric.j.fielding@jpl.nasa.gov) or Erika Podest (erika.podest@jpl.nasa.gov).

Question 1: Hello, can we import and analyze InSAR data in GEE?
Answer 1: You can save your InSAR analysis products as GeoTIFF images and import them in GEE (or other GIS), but GEE cannot be used to calculate InSAR because it cannot handle the complex radar phase data.

Question 2: Can we do interferometry using any SAR mode (SCAN, STRIP, SPOT)?
Answer 2: It is possible to do interferometry with SAR modes that are acquired with interferometric compatibility. Stripmap is always compatible when acquired on the same satellite track. ScanSAR (and Sentinel-1 TOPS mode) data has to be acquired with precisely synchronized bursts, and similarly, the Spotlight mode has to be acquired with exactly the same imaging parameters for InSAR. It is possible but not always done.

Question 3: Is it possible to mix the modes?
Answer 3: In some cases, it is possible to do InSAR analysis with stripmap and ScanSAR from satellites, including ALOS-2. The ISCE2 application "alos2App.py" supports this mixed-mode InSAR.

Question 4: Between Cross-Track Interferometry and Along-Track Interferometry, which is better and for what type of situation?
Answer 4: Cross-track interferometry measures topography. Along-track interferometry measures ocean wave motion. So they measure different things.

Question 5: Can you please brief about colorization of SAR imagery?
Answer 5: One way we portray the wrapped is with a rainbow color scheme. With amplitude images, Slide 44 from Session 1 shows image color combinations.

Question 6: How is Copernicus DEM different from SRTM data? Is the DEM generated actually a DSM and SRTM is DEM?

Answer 6: Both Copernicus DEM and SRTM DEM are Digital Surface Models. The Copernicus DEM is derived from the TanDEM-X satellites, using X-band (3 cm) radar, and the SRTM DEM is from the C-band radar (6 cm) wavelength, so they are reflecting from different parts of forested areas. Neither one is imaging the ground through forests.

Question 7: Can InSAR be used to measure the surface roughness of water, such as in detecting variations in water surface texture or wave height?
Answer 7: InSAR phase cannot measure surface roughness of water, radar systems can measure water waves by the radar backscatter amplitude. This is a common technique used in a number of satellites.

Question 8: Can we map topographic change by use of free data (temporal analysis)? Which data should we use?
Answer 8: The SRTM data acquired in February 2000 and the Copernicus DEM measured in 2015-2017 are both free and can be used to measure topographic change between those two times. Some countries have other free topographic data and change acquired at different times. Some countries have free topographic data.

Question 9: Have NASA or other space/Earth sensing groups ever proposed attaching radar antennae to commercial flights to collect high-resolution data regularly from the surface?
Answer 9: Synthetic aperture radar from airplanes requires special design of the airplane. It cannot be done from any airplane.

Question 10: What is the minimum size deformation detectable using Sentinel-1 satellites?
Answer 10: The spatial size of InSAR that Sentinel-1 can measure is about 20 by 20 meters if the coherence is high. The displacement magnitude that can be detected in a single interferogram is around 5 mm, but measurements of 1 mm are possible if you can add interferograms over a long time interval. However, the atmospheric noise can be 1-5 cm and sometimes higher, however, so the accuracy will be lower if the atmosphere is active.

Question 11: Does ICEYE radar work on the same SAR interferometry principle? How would an ICEYE image be converted to a DEM for input into a GIS, for example?
Answer 11: Most ICEYE data is not acquired with InSAR compatible geometry to make a DEM. They are starting to acquire more data with orbits that are close enough together for InSAR.

Question 12: Is InSAR data from Sentinel-1 only available? Please specify how to access the data.
Answer 12: The availability of Sentinel-1 data will be covered in more detail in Part 3 of this series. It is available from the Copernicus Dataspace and the NASA Alaska Satellite Facility (ASF).

Question 13: If we are able to monitor crops with SAR, then when we try to build the topography with InSAR, doesn't that mean we may end up getting signals from the plants instead of the ground surface? Is it possible to separate the signal from the plants with InSAR?
Answer 13: InSAR measurements are affected by crops. If the crops have dense leaves, they can cause loss of coherence for the short-wavelength InSAR with Sentinel-1 and other C-band satellites or X-band satellites. The L-band radar of NISAR will largely go through the crop vegetation and enable InSAR measurements of the ground surface below.

Question 14: Can you share some resources to preprocess SAR images using SNAP and also with Python only?
Answer 14: The ESA STEP Forum (https://forum.step.esa.int/) has a lot of information about using SNAP.

Question 15: How accurate is detection of change in terms of meters/cm, in case I want to detect height change of a building or want to do volumetric calculation in my area?
Answer 15: If a building is under construction, then it will be changing the radar reflections and become incoherent for InSAR. Only single-pass cross-track InSAR topographic maps could be used to measure building height changes.

Question 16: What do you mean by displacement sensitivity?
Answer 16: This is how sensitive we are to displacement on the ground. We can see ½ cm of displacement using C-Band.

Question 17: Please discuss the difference between DInSAR and PSInSAR.
Answer 17: This is an advanced topic, but the basic difference is that DInSAR or distributed scatterer InSAR has averaged a number of SAR pixels to measure phase and displacement over an area of 5-20 or more pixels. The persistent scatterer InSAR method finds pixels that have stable phase and amplitude and measures the displacements of those limited numbers of pixels.

Question 18: How do different phase unwrapping algorithms perform in areas with steep topography or discontinuities, and what are the trade-offs between computational efficiency and accuracy?
Answer 18: That is an advanced topic but here are some references:
-Goldstein, R. M., & Werner, C. L. (1998). "Radar interferogram phase recovery and its application to interferometric synthetic aperture radar (InSAR) data"
-Lu, Z., & Parasnis, D. S. (2002). "A review of phase unwrapping algorithms"
-Jiang, L., & Xu, X. (2011). "Phase unwrapping in interferometric synthetic aperture radar: a review"
-Huang, Y., & Zhang, L. (2014). "Phase unwrapping for InSAR applications: a review of algorithms and challenges"

Question 19: What are the limitations of the 2π phase ambiguity resolution when dealing with temporal decorrelation in multi-temporal InSAR applications?
Answer 19: This is an important limitation of phase unwrapping or phase ambiguity resolution. It cannot be accurately calculated if the coherence is too low or the area is decorrelated.

Question 20: Could you discuss the challenges of phase unwrapping in areas with low coherence, and what novel approaches are being developed to address this issue?
Answer 20: Similar to the answer to #19. A method is to average more pixels to try to extract the phase over a larger area. If there is no information in the phase, then it will be impossible.

Question 21: How can we process InSAR images for time series land displacement? Please share how to process.
Answer 21: We have covered this in previous trainings: Please see these trainings:
1. ARSET SAR for Detecting and Monitoring Floods, Sea Ice, and Subsidence from Groundwater Extraction (Session 2)
2. ARSET Disaster Assessment Using Synthetic Aperture Radar (Session 2)

Question 22: Besides ice motion, is it possible to measure ice thickness and roughness?
Answer 22: You can detect ice due to differences in its roughness with open water. Please refer to the following ARSET training on sea ice detection with SAR (Session 1)
- ARSET SAR for Detecting and Monitoring Floods, Sea Ice, and Subsidence from Groundwater Extraction (Session 1)

Question 23: What is the major difference between SAR and InSAR applications?
Answer 23: InSAR is for measuring displacement that affects the radar phase. Other apps use the SAR amplitude of the radar return and variations with different polarizations to learn about soil moisture, vegetation structure, crop growth, and other applications.

Question 24: What is the common spatial framework that these systems are coordinated against? That is, to know 'where' the observation platform is and how it is oriented in relation to the sensed object, what coordinated framework is used? I think you mentioned that the satellites themselves will have advanced systems to measure the difference between the antenna, but the position of the platform in relation to the DEM? Specific geodetic models or something?
Answer 24: The recent SAR satellites use GNSS receivers on the spacecraft to determine the platform position. The satellite orbit is estimated from the GNSS data and in a terrestrial reference frame as a standard part of the operations.

Question 25: How can we be sure if our analysis is true or accurate? How do we make sure the analysis is not affected by noise? Or should some kind of ground survey also be done to validate the analysis?
Answer 25: This is an advanced topic that we can’t cover in detail for this introduction to InSAR, but it is important. Comparisons to ground displacement measurements, typically with GNSS or GPS ground stations, is an excellent way of validating InSAR analysis results. Another way to separate noise from the atmospheric effects from

ground displacement signals is to make multiple InSAR measurements with data from different dates and do time-series analysis. We covered this in previous ARSET InSAR training.

Question 26: Can InSAR be used to monitor ground acceleration in case of seismic activity?
Answer 26: No, InSAR is only a static measurement of the total displacement, not acceleration or velocity during an earthquake. It shows the permanent displacement after the earthquake is finished.

Question 27: How do the colors in interferometry translate to physical distance of displacement? Is it possible to measure the actual displacement from the colors?
Answer 27: In this demonstration, we showed what are called “wrapped interferograms”, with the rainbow patterns that are like contours of the ground displacement signal. We can count the contours to get an estimate of the total displacement. Each time, a color repeats, that is the equivalent of ½ the radar wavelength for displacement. For Sentinel-1, the radar wavelength is 5.6 cm, so each color repeat (which InSAR specialists call a fringe) is 2.8 centimeters. In other cases, the InSAR data is shown as an “unwrapped interferogram” where the colors can be directly mapped to the total displacement.

Question 28: I'd like to inquire about the precision of horizontal and vertical deformation measurements in relation to volcanic eruption predictions. Specifically, is there a definitive deformation threshold that reliably indicates an imminent eruption within, say, two days?
Answer 28: There is no definitive deformation threshold that can be applied to every volcano. InSAR should be combined with other data such as seismicity to have information on imminent eruptions.

Question 29: Can SAR data be used to pick up any patterns to predict earthquakes? In Japan they are expecting a mega quake in the Nankai Trough in the near future. Can SAR data help to take countermeasures in such a scenario?
Answer 29: We have not found any patterns of surface displacement measured with InSAR or GNSS/GPS data that can predict the exact time of a future earthquake. We use InSAR and GNSS data to measure the gradual build-up of stress in the Earth that will likely result in an earthquake and map the areas of higher risk, but we can’t predict the exact time it will occur.

Question 30: How do you determine displacement size 1.2 with reference to the Nepal earthquake?
Answer 30: We used InSAR analysis to measure the surface displacements. First we unwrapped the InSAR phase to make an unwrapped interferogram and then we chose a reference point some distance from the earthquake to measure the 1.2 meters of ground displacement caused by the 2015 magnitude 7.8 Gorkha, Nepal earthquake. The best data was from the Japan Aerospace Exploration Agency (JAXA) ALOS-2 SAR satellite.

Question 31: Can we use SAR interferometry for vegetation structure determination? Can interferometry concepts be used to identify different growth stages of crops?
Answer 31: Yes, SAR interferometry can be used to provide information about vegetation structure. The loss of InSAR coherence or decorrelation in vegetated areas is related to the height and density of plants, especially for the shorter radar wavelengths. A major difficulty with using InSAR to measure vegetation, including crop growth, is that the InSAR is always calculated from a pair of SAR acquisitions and it will reflect the vegetation on the two dates and changes between the two dates. Ecosystem structure scientists usually use the SAR amplitude and polarization to estimate crop growth because those measurements are for each date not for pairs of dates.

With airborne InSAR systems, such as the NASA UAVSAR system, they have done experiments where they acquire two images with a short time separation (maybe half an hour) and a longer spatial separation to use the amount of InSAR coherence loss to estimate the height of the forest. This is an InSAR effect called volumetric decorrelation.

Question 32: Is it possible to detect changes between two dates? And, if yes, with what resolution?
Answer 32: Yes, InSAR is able to detect changes on the ground between two dates at scales near the radar wavelength and larger scales. We do this by examining the InSAR coherence and phase change between the two dates. If the changes are surface displacement that is consistent over an area of several radar pixels, then we use the InSAR phase to measure the change in surface location. If the changes are chaotic or inconsistent over the radar pixels, then we use the InSAR coherence to detect where

the changes have occurred. We typically use an area of about 25 or 64 pixels to estimate the InSAR coherence from the InSAR spatial correlation, so the spatial resolution is equivalent to the correlation window used. For Sentinel-1 InSAR, the spatial resolution of coherence measurements is usually about 50 meters.

Question 33: How reliable can the calculation and analysis of multi-temporal slow subsidence, expressed in millimeters, be when using coherence values > 0.4 from two pairs of Sentinel-1 InSAR satellite images with a three-month interval?
Answer 33: The measurement of slow subsidence is almost always affected by atmospheric noise. Two pairs of Sentinel-1 InSAR over a three-month interval is not likely to be enough to estimate the level of atmospheric noise that is due to tropospheric water vapor variations. It depends on the location, because some areas, especially closer to the equator and at lower elevations, have much more variation in water vapor. To measure slow subsidence, we typically use dozens or hundreds of interferograms over an area to better separate the signal from the atmospheric noise. With Sentinel-1 images acquired every 12 days, it can take three years of data to get the slow surface displacement errors down to about 2 millimeters per year.

Question 34: Can SAR imagery be used to measure the depth of surface water on roads following heavy rainfall?
Answer 34: Flood mapping is a growing area of SAR analysis. The OPERA Dynamic Surface Water Extent estimated from Sentinel-1 (DSWx-S1) measures the extent of surface water, which could be combined with a detailed digital elevation model (DEM) to estimate the depth of the water. The Sentinel-1A satellite only acquires images once or twice over an area every 12 days, so it is not likely to capture short-term flooding. Another NASA satellite that uses SAR, the Surface Water and Ocean Topography (SWOT) mission, can measure the depth of water because it has two antennas to measure the surface elevation changes with single-pass InSAR, but it also has somewhat infrequent coverage of each area and it is primarily designed to measure water levels in lakes and rivers in addition to the oceans, so I don’t know if it will measure flooding of roads.

Question 35: This is an extremely helpful session for my research. I am working on examining land subsidence due to water extraction in city planning. Can we understand how to create such studies from InSAR data?

Answer 35: The ARSET InSAR tutorial from 2023 was about measuring land subsidence due to groundwater extraction, so that is one place to learn more. There are many papers published on this topic.

Question 36: How are we calculating the displacement? Is it by subtracting the pre image from the post image? And how do we understand the direction of movement (horizontal)?

Answer 36: Yes, InSAR is essentially subtracting the phase of the before image from the after image. The direction of the surface displacement measured by InSAR is along the vector between the ground and the satellite (or airplane). This direction is often called the radar line-of-sight (LOS) direction. For most InSAR satellites, the vector direction is near 35 degrees from the vertical and close to either East or West, depending on whether the satellite is going north or south. InSAR analysis systems will normally provide the radar line-of-sight direction in addition to the phase measurement.

Question 37: How can we know land deformation values for the part of the interferogram which has low coherence?

Answer 37: If the coherence level is very low, then repeat-pass InSAR cannot measure the surface deformation of that area. With smaller areas of low coherence, people usually interpolate the values from adjacent areas.

Question 38: Is it possible to measure change in water volume of a water body using interferometric change of water surface elevation (and surface water extent from other data sources)? What about in heavily vegetated wetlands (forested or emergent)?

Answer 38: See the answer to Question 34. The SWOT satellite uses single-pass InSAR to measure water volume changes for water bodies, but it uses a very short radar wavelength (Ka-band or about 1.5 cm) so it cannot measure water elevation beneath vegetation. Long-wavelength SAR, such as the L-band of NISAR and other satellites can be used to estimate the water extent in vegetated wetlands from the SAR amplitude, but not InSAR.

Question 39: Can interferograms be used to predict location or likelihood of post-event aftershocks?

Answer 39: Earthquake scientists use interferograms and other data to determine the location of the fault that ruptured in an earthquake and the extent and amount of slip on the fault. The fault slip distribution can then be used with mechanical models of the

Earth to calculate the changes in stress of the rocks in surrounding areas and areas of increased stress are more likely to have aftershocks.

Question 40: Can you explain better the practical effect of coherence? When it is low, interferometry will not be possible, right? Since coherence is low with higher volume scattering, which happens in vegetation, how can we monitor forest height changes then?
Answer 40: Short-wavelength InSAR is not likely to be helpful for monitoring forest height changes. Longer wavelengths such as the L-band on NISAR and the P-band on the ESA BIOMASS mission will be more effective for measuring forest height changes in areas of dense forest, but ecosystem scientists primarily use the SAR amplitude and not InSAR.

Question 41: Is UAVSAR available across the entire world? What is its resolution?
Answer 41: No, the NASA UAVSAR is only acquired over limited areas, mostly inside the USA. Airborne radar depends on the airplane flying range and funding constraints and also requires getting permission from the countries to be imaged. The standard UAVSAR multi-look SAR and InSAR products have 5- to 7-meter resolution, but the single-look complex resolution is about 1 meter.

Question 42: Is NISAR an active or passive sensor?
Answer 42: NISAR is an active SAR sensor.

Question 43: If NISAR is launching in early 2025, when will it be operational? Or in other words, when can people start using its data?
Answer 43: The NISAR plan is to complete preliminary calibration of the system in the first three months after launch, begin science data acquisitions, and start releasing preliminary data to the public.

Question 44: I see that NISAR shows some gaps in the upper part of North Africa. Does this mean that it works over some parts of Africa, specifically in the Northern regions?
Answer 44: NISAR will acquire data over the Sahara in North Africa, but some of the coverage will use lower resolution modes that will be more effective in the sand-covered areas that have very low radar reflection at L-band. Loose sand will be incoherent for InSAR, so InSAR measurements are not likely to work in sand-covered areas.

Question 45: Which SAR data is best for ground deformation analyses.
Answer 45: The best InSAR data depends on what size (area and amount) of deformation you want to measure and what is the land cover of the study area. No SAR system is best for every analysis.

Question 46: What is the advantage of combining short and long wavelengths in the NISAR satellite? Would it complicate the data processing?
Answer 46: The NISAR satellite will acquire L-band (24 cm) and S-band (12 cm) SAR data. The two wavelengths will have different interactions with vegetation, snow, and other surface materials. The L-band data will be processed and available from NASA and the S-band data will be processed and available from ISRO, but the data formats are designed to be the same to make further analysis easier.

Question 47: How effective is the detection of water leakage from a dam or ground pipelines using Sentinel-1 satellite images?
Answer 47: The C-band Sentinel-1 satellites are somewhat effective for measuring soil moisture variations, but the L-band from NISAR will be more effective because L-band penetrates about four times deeper into the soil.

Question 48: Can we use InSAR to distinguish between evergreen and deciduous trees? If so, what radar band should be used?
Answer 48: Ecosystem scientists generally use the SAR amplitude variations over the seasons to distinguish between evergreen and deciduous trees instead of InSAR. See answer to Question 31.

Question 49: What are the ground truths for InSAR data validation in general? Would love to hear a quick overview of radiometric calibration. Polarimetric and cross-system calibration too, if time permits.
Answer 49: Radiometric calibration is not required for InSAR analysis. See Part 1 of this training. InSAR ground truth or validation is usually done with GNSS or GPS ground station measurements.

Question 50: Is SAR data correlated with crop diseases and pests?
Answer 50: This is out of my area of expertise. Part 1 of this training has more information on SAR applications for agriculture.

Question 51: I saw research using InSAR to monitor soil moisture, but I couldn't figure out how they separate the moisture from the soil and the moisture from the plants. Could you give me some hints?
Answer 51: InSAR and SAR amplitude are both affected by volumetric scattering in the vegetation and soil. Soil moisture measurements typically use models of the vegetation moisture derived from SAR or InSAR images acquired over a longer time interval to separate that from the soil moisture.

Question 52: How and where can AI be used in interferogram processing? I need to know various applications.
Answer 52: Machine Learning and Artificial Intelligence are starting to be applied in InSAR analysis. They are applied to a set of interferograms and show promise for detecting InSAR signals of surface deformation due to volcanoes, earthquakes, and landslides, but the field is very new so new applications will likely be added.

Question 53: How do you interpret a fringe and how do you tell a layman what they are seeing in a fringe map?
Answer 53: The fringes of a wrapped interferogram are contours of InSAR phase that is mostly surface motion, very similar to a topographic contour map. Instead of contours showing the elevation of topography, the contours are on the amount of surface motion but can also include other effects such as atmospheric variations.

Question 54: How does one decide on which datasets are correct to use for what study?
Answer 54: For most studies, it can be helpful to look at all available SAR data for the study area and compare the information provided by each dataset.

Question 55: In parts of the world where the Opera Project cannot provide co-registered products, which dataset (on the Earthdata site) is more suitable to create an interferogram?
Answer 55: NASA ASF Vertex and NASA EarthData provide the Sentinel-1 SAFE SLC files from Copernicus and also now distribute burst-wise SLCs (not geocoded or coregistered). The ASF provides an on-demand Sentinel-1 InSAR processing service where you can request interferogram processing for any area where the Sentinel-1 data is available.

Question 56: Can I create a DEM from Sentinel data over a small region?

Answer 56: The InSAR from Sentinel-1 has short spatial baselines and is repeat-pass InSAR, so it is not likely to be possible to create accurate DEM's due to atmospheric variations between the two dates.

Question 57: Can there be use cases of InSAR in agriculture? If yes, can you give some examples?
Answer 57: See the answer to Question 31.

Question 58: What Sentinel-1 processing level can be used to calculate interferogram outside the US?
Answer 58: See the answer to Question 55.

Question 59: What are the most important hints used by SAR experts to choose suitable SAR products for land deformation? Should the two selected products be in the same mode (descending or ascending)? What is the recommended perpendicular baseline length, etc.?
Answer 59: Looking at InSAR products with two different look directions can be a big help for separating vertical from horizontal surface displacements. For deformation analysis, the shortest baselines are always better, and there is an upper limit for baselines where the InSAR will be difficult. The recommended perpendicular baseline limit for will depend on the radar wavelength and resolution, so it is not possible to give a single number.

Question 60: How can we count the interferogram fringes automatically? To get the height change map in cm?
Answer 60: There are many InSAR analysis programs that can automatically unwrap the wrapped interferograms, which is essentially counting the fringes. The ARIA S1-GUNW products at NASA ASF are already unwrapped, and NISAR will also provide unwrapped GUNW (Geocoded UNWrapped) interferograms.