Questions & Answers Part 2

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 Eric Fielding (eric.j.fielding@jpl.nasa.gov) or Erika Podest (erika.podest@jpl.nasa.gov).

Question 1: Flooding, especially in riverine systems, is not a "flat" surface. Is there a way to estimate the elevation of a water surface, say in a canal or river valley, as it flows downstream?
Answer 1: Yes, the NASA Surface Water and Ocean Topography (SWOT) mission, planned for launch in December 2022, will use single-pass SAR interferometry with two radar antennas to measure the elevation of water surfaces in rivers and lakes.
https://swot.jpl.nasa.gov

Question 2: How can we measure the penetration of different microwave wavelengths in ice or snow? Please guide us with some insights for snow depth measurements using InSAR.
Answer 2: This is not my area of expertise, but NASA has sponsored SnowEx (Snow Experiment) studies for a number of years to learn about the depth of penetration for snow with different radar wavelengths, including measurements of snow depth and characteristics in the field at the time of satellite and airborne radar acquisitions.
https://snow.nasa.gov/campaigns/snowex

Question 3: How do I select the best InSAR pairs for generation of interferograms? How do I select the perpendicular baseline and temporal baseline, and what should be the best perpendicular baseline?
Answer 3: For measuring displacements, the shortest baselines are best and the usable baseline length is proportional to the radar wavelength. The Copernicus Sentinel-1A and -1B satellites (C-band; 6 cm) are kept in orbits with short baselines (less than about 100 meters perpendicular baselines) so all pairs are usable for InSAR. The JAXA ALOS-2 satellite (L-band; 24 cm) is similarly kept in an orbit with short baselines (less than about 300 meters, similar considering the longer wavelength) and also has all pairs usable for InSAR.
The temporal baseline that can be used will depend on both the land surface cover conditions and the radar wavelength. In desert areas with no vegetation and no loose sand, very long time intervals can be used (many years) even with short radar

wavelengths. In areas of tropical forests, with C-band data even 6-day intervals may be low coherence and longer intervals of 24 days are often completely incoherent. L-band data in tropical forests can be coherent over time intervals of about 6 months in many cases.

Question 4: If "precipitation largely controls landslides..."; is it possible to simultaneously collect SAR-based soil moisture data, while collecting interferometry data?
Answer 4: Yes, we are working on estimating soil moisture from the SAR data from the NASA airborne SAR called UAVSAR over landslides. We published a paper on this last year: Liao, T.-H., S.-b. Kim, A. L. Handwerger, E. Fielding, M. Cosh, and W. H. Schulz (2021). High-Resolution Soil Moisture Maps Over Landslide Regions in Northern California Grassland Derived from SAR Backscattering Coefficients, Ieee J-Stars **14,** no. 4547-4560, doi:10.1109/jstars.2021.3069010.

Question 5: Was land use change considered as well for the landslides?
Answer 5: Yes, land use changes can affect landslide motion. In some cases, irrigation of land above landslides has led to increases of landslide motion. Cutting down trees or wildfires burning vegetation covering landslides often leads to increased risk of landslides and debris flows.

Question 6: How do you deal with the atmospheric and topographic correction within the interferogram? Does the time series allow us to predict beforehand whether a landslide is going to occur? Could we use ground-based InSAR and geotechnical monitoring systems in order to anticipate and mitigate the risk in these areas?
Answer 6: Landslides have relatively small areas, so the atmospheric corrections are not necessary because the atmosphere varies over larger distances. We need a topographic dataset or Digital Elevation Model (DEM) to estimate and remove the topographic phase from interferograms and to do the geocoding. Time-series analysis of slowly moving landslides can be used to monitor the motion over time and might detect an acceleration of motion that could lead to a catastrophic collapse of the landslide. Ground-based InSAR and other geotechnical systems are effective ways of monitoring landslides that are at risk of accelerated motion.

Question 7: I cannot install software from github for windows. Is there some tutorial?
Answer 7: Try using Anaconda, which is probably the easiest method for Windows.

Question 8: About the 247 active landslides in CA: do you generate the polygons for landslide margins in addition to the geographic locations?
Answer 8: Yes, we mapped the outlines of the landslides in California. See Handwerger, A. L., E. J. Fielding, S. S. Sangha, and D. P. S. Bekaert (2022). Landslide Sensitivity and Response to Precipitation Changes in Wet and Dry Climates, Geophysical Research Letters **49,** no. 13, doi:10.1029/2022gl099499.

Question 9: What is the process of acquiring the displacement?
Answer 9: The InSAR time series analysis estimates the line-of-sight displacements of the pixels relative to the reference point and the reference date through an inversion of the interferogram displacements. The interferogram displacements are measured directly from the geocoded, unwrapped phase.

Question 10: Did you experiment using multiple reference points within the analysis vs a single point to create a standard average for the spatial correlation/coherence? If so, how much did the coherence/correlation change when modeling the shift in landslides?
Answer 10: The MintPy software is designed to use a single reference point. It is possible to rerun the time-series inversion with different reference points but we did not do that here. In most cases, the coherence does not change much with different reference points, but the errors due to atmospheric variations tend to increase with increasing distance from the reference point and with increasing elevation difference from the reference point.

Question 11: If I wanted to prepare a similar dataset for another area not inside those white rectangles where this dataset has been pre-processed, is there an open source library that converts the raw data to the data structures process-able by Mintpy?
Answer 11: Yes, you can do the full installation of the ISCE2 (InSAR Scientific Computing Environment version 2) software from github and do your own processing of the time series. There is also the option at ASF to do on-demand processing. They use a software called Gamma and make products that can be loaded into MintPy. It is possible to process interferograms with SNAP and load them into MintPy if they are coregistered.

Question 12: Is it possible to use different satellites to produce interferograms?
Answer 12: You have to use satellites that are completely compatible. Sentinel-1A and 1B are identical, so in that case you can. They have to be the same type of satellite from the same orbit. The European Space Agency (ESA) ERS-1 and ERS-2 satellites

had the same orbit and radar system so they can also be used together, but the ESA Envisat satellite had a slightly different radar so it cannot be used with the ERS-1 and ERS-2 data despite having the same orbit.

Question 13: What are the major limitations of InSAR derived from Sentinel-1 over mountainous regions like the Himalayas? Is NISAR going to address some of these limitations?
Answer 13: The slopes are steep and vegetated in the Himalayas, with snow cover at the highest elevations. Both steep slopes and vegetation or snow cause low coherence, which makes it difficult to unwrap the phase. We have looked at Sentinel-1 interferometry in the Himalayas and it's not very effective due to the C-band radar wavelength. NISAR will have the L-band radar wavelength with 12-day orbit repeat, so the coherence and phase unwrapping should be much better with NISAR.

Question 14: Can the InSAR technology be applied in the monitoring of open-pit mines for vertical change monitoring?
Answer 14: When the surface is mined or disrupted it will become incoherent for repeat-pass InSAR. In some cases it is possible to get single pass interferometry (Tandem-X, TerraSAR-X) to measure topographic changes.

Question 15: Can I ask ARIA to process any data to GUNW products for a region of interest?
Answer 15: At this time we don't have a method for requesting ARIA processing. This is something we're looking at in the future.

Question 16: What bands or pairs of interoferograms are suitable for delineating lithological/rocks cover?
How reliable will their penetration be from the surface to the rocks?
Answer 16: Radar has been used to delineate different types of rocks. Radar responds to the surface roughness rather than the lithology. Smooth volcanic flows would have low backscatter and rough flows would have high backscatter. Radar is not as useful for distinguishing rock lithologies as optical data, so you would likely want to combine it with optical data. Radar can be used to map bedrock boundaries with adjacent alluvium as alluvial surfaces are often much smoother. Radar at the wavelengths we use for SAR (Ka, X, C, L, and P-bands; wavelengths up to 70 cm) does not penetrate solid rocks more than a few cm.

Question 17: Are there specific dependencies needed to be installed before installing Mintpy on my Jupyter Notebook?
Answer 17: Yes, the MintPy installation procedure has a “requirements.txt” text file with all the dependencies.

Question 18: I plan to conduct research in the UK. Is there a source of airborne SAR data C, S, L, P-band that can I find for my study area? (free or paid)./ Q2: is there a spaceborne P-band dataset that I can find for my study area?
Answer 18: I’m not aware of airborne SAR data for the UK. NASA had two P-band SAR systems, the AirSAR system that operated in the 1980’s and early 1990’s and the AirMOSS system that started flying around 2015. The AirMOSS system was later renamed UAVSAR P-band. You can search for the UAVSAR P-band data on the UAVSAR search tool (https://uavsar.jpl.nasa.gov/cgi-bin/data.pl) when you select the P-band option. I only see data over sites in North America.

There is not a spaceborne P-band radar at this time, but ESA is planning to launch one called Biomass in a few years. It will likely have coarse resolution though, because of the international radio frequency allocation issues.

Question 19: Do you have some international request to provide such monitoring?
Answer 19: There are a number of companies in several countries that provide monitoring (value added companies) anywhere in the world. Italy, Switzerland, and Norway all have very active landslide monitoring programs.

Question 20: How much did earthquakes affect the SAR imagery coherence? Also, did you notice increased shifts in landslides following an earthquake event?
Answer 20: Yes, earthquakes are one of the big causes of landslide motion. Earthquakes also can cause loss of coherence due to fault motion, large surface ruptures, liquefaction, and damage to buildings.

Question 21: When looking at lake drainage events on ice-sheets using Sentinel-1, the fringes generated are quite small. Does this mean that the confidence in surface change due to drainage is low?
Answer 21: The confidence in the surface change is proportional to the coherence. If the number of fringes is small, but coherence is high, confidence can be high. With C-band you can measure displacements down to a few millimeters with high coherence.

Question 22: What will the frequency and resolution of the new SWOT imagery be?

Answer 22: The SWOT radar is using a very short radar wavelength called Ka-band. Since it's single-pass it will have high coherence. See https://swot.jpl.nasa.gov/ and https://podaac.jpl.nasa.gov/SWOT for more information. "SWOT will observe rivers wider than 100 m and lakes with a surface area of 15 acres or more (i.e., an outline of 250 m x 250 m or 820 ft x 820 ft)."

Question 23: Hi, How can I use the radar images for cadastral applications? Do you suggest a specific application to focus on my thesis?

Answer 23: For cadastral applications, you might want to use the radiometrically terrain-corrected (RTC) SAR products that are available from the ASF On-demand system where you can request the RTC processing of Sentinel-1 SAR images. The NISAR mission will provide RTC products globally.

Question 24: Outside the CONUS, what is your preferred DEM/DSM/DTM for landslide analysis?

Answer 24: The new Copernicus DEM called GLO-30 has roughly 30-meter spacing for the land globally. It has high quality and is freely available from Copernicus servers.