Part 1 Questions & Answers Session

Please type your questions in the Question Box. We will try to answer all your questions. If we don't, feel free to email instructor Erika Podest (erika.podest@jpl.nasa.gov).

Question 1: Can we use the EM wave to carry the particle from surface to the satellite for measurements or analysis of the soils?
Answer 1: Radar is able to measure the moisture in the soils. Unfortunately, teleportation of soil particles is not yet possible.

Question 2: When you say it can penetrate vegetation/soil, can you say something about depth of penetration? What parameters affect penetration?
Answer 2: Depth of signal penetration will depend on the wavelength and water in the medium. The longer the wavelength the greater the penetration through the medium (vegetation, snow soil). The amount of water in the medium will reduce penetration of the signal. For example, the greater the moisture in the soil the less the penetration.

Question 3: You have mentioned that the effect of topography is one of the major drawbacks of Radar. I am thinking of mapping wetland classes in the Hindu Kush Himalayan (HKH) region using Sentinel-1 imagery. So, due to the topographic effect in the HKH, do you think it's better for me not to use Sentinel-1? Or maybe I can reduce/minimize the topographic effect with some image pre/processing procedures?
Answer 3: It is indeed a challenge (but not impossible) to do analysis with radar data in areas of complex topography. You will need Radiometrically and Terrain Corrected (RTC) images of the same pass (do not combine ascending or descending – just use one) to do time series analysis in areas having complex topography.

Question 4: Does the radar rotate in the cross-track direction to build a line of the image?
Answer 4: Some radars rotate, such as SMAP, but most do not.

Question 5: Please explain if there is difference between resolution of an optical and resolution of a SAR image. How do they differ?

Answer 5: Optical data has spatial resolutions that are square (e.g., 10x10 meters). Radar data has spatial resolutions in the slant range that are not square (e.g., 5x8). The image needs to be projected onto the ground range to a square pixel (e.g., 8x8).

Question 6: Can you share literature in the course webpage where this information is taken from?
Answer 6: There is a list of tutorials and references in the appendix of the session 1 presentation.

Question 7: Could you tell us comprehensively how the Doppler effect is applied in SAR?
Answer 7: Doppler shift refers to the change in frequency or wavelength of a wave due to the relative motion between the source (the radar) and the object on the surface. As the radar platform moves along its flight path, it sends radar pulses, and each pulse is reflected back to the antenna from the Earth's surface. Because the radar is moving along a trajectory, the relative velocity between the radar and the ground surface causes a shift in the frequency of the returned signal. The frequency of the received signal will be slightly different from the transmitted frequency, depending on the relative velocity of the radar with respect to an object on the surface. When the radar is approaching an object on the surface, the frequency of the returned signal increases (positive Doppler shift). When the radar moves away from that point, the frequency decreases (negative Doppler shift). The amount of this frequency shift is directly related to the radar's speed and the angle at which the radar beam hits the ground. The signal from the different objects along the radar's trajectory is then processed to form a synthetic aperture. Here is a great video explaining this concept: https://www.youtube.com/watch?v=g-YICKbcC-A.

Question 8: If I want to study the technicalities and mathematics involved in SAR data in greater depth, are there any resources that the panelists can recommend?
Answer 8: There are several different resources in the Appendix of this presentation – most are introductory level but some are for intermediate and advanced levels. “Microwave Radar and Radiometric Remote Sensing” by Ulaby and Long is a great book.

Question 9: How can SAR systems be designed to optimize either slant range or ground range resolution for specific applications?

Answer 9: By adjusting parameters such as bandwidth, pulse duration, frequency band, platform altitude, antenna length, and look angle—SAR systems can be optimized for either slant range or ground range resolution depending on the requirements of the specific application.

Question 10: How do we identify which is backscatter?
Answer 10: Please clarify.

Question 11: I am interested in mangrove mapping using SAR imagery with the help of cloud computing. Can you guide me on how I can map mangrove and non-mangrove areas?
Answer 11: Session 3 of the following ARSET training is focused on the use of SAR for monitoring mangroves:
https://appliedsciences.nasa.gov/get-involved/training/english/arset-forest-mapping-and-monitoring-sar-data.
Also, the SERVIR SAR Handbook has a chapter on mangrove mapping:
https://servirglobal.net/resources/sar-handbook.

Question 12: The double-bounce signal looks like specular reflection + volume scattering. Why does it have higher intensity than the signal from volume scattering directly?
Answer 12: **Double-bounce scattering** occurs when radar waves interact with two surfaces at right angles; typically a smooth horizontal surface (e.g., water, road) and a vertical surface (e.g., building, tree trunk). **Volume scattering** occurs when the radar signal interacts with a medium (like vegetation, soil) and is scattered in multiple directions due to irregularities in the medium.
Volume scattering spreads the radar signal in various directions, and only a fraction of that energy returns to the sensor. In contrast, double-bounce scattering involves direct reflections, which tend to focus energy back toward the sensor, making the return signal much stronger.

Question 13: Is SAR imagery multispectral or hyperspectral based on wavelength?

Answer 13: SAR is not referred to as multi or hyperspectral, as in optical. SAR is referred to as multi-frequency. All of the current operational and openly available SAR data are single-frequency. NISAR will have multi-frequency SAR (L- and S-bands).

Question 14: Based on atmospheric effects (low), I'm assuming that SAR is not frequently used in atmospheric composition studies. But, I am wondering in what cases SAR data may be valuable for atmospheric studies. In your opinion, what SAR data may be of most value for atmospheric and air quality studies? I'm guessing LCLU in cloudy areas, but am uncertain.
Answer 14: SAR itself does not directly measure atmospheric gasses or composition, however, radar is used for studying atmospheric conditions related to precipitation, storms, rainfall intensity, and tracking storms, including tropical cyclones, hurricanes, and typhoons. Usually shorter wavelengths are used for such studies such as Ku, Ka, or even X bands.

Question 15: Do we have free data for L- and P-Bands?
Answer 15: There is freely available spaceborne data for L-band from PALSAR, JERS-1, Seasat, SIR-C, and SMAP – all available through ASF. There is also airborne L-band data from UAVSAR and AIRSAR, which are also available through ASF.
There is no freely available satellite P-band data.

Question 16: In signal penetration into dry soils, can radar detect an IED (Improvised Explosive Device) that has been put under the soil?
Answer 16: I think it would be difficult. It would depend on the size, structural makeup and orientation of the IED, the depth, the soil conditions, as well as the spatial resolution of the radar data.

Question 17: Can anyone tell me about the Early Adopter Program?
Answer 17: The **NISAR Early Adopters Program (EAP)** is a collaborative initiative aimed at involving scientific and application-focused communities in the early stages of data collection from NASA's **NISAR (NASA-ISRO Synthetic Aperture Radar)** mission. The program provides early access to the data generated by NISAR and enables researchers, institutions, and agencies to begin utilizing and analyzing the data before its official release to the broader scientific community.
https://nisar.jpl.nasa.gov/engagement/early-adopters/. Join us!

Question 18: Which satellites offer free L-Band images?

Answer 18: Please refer to the answer to Question 15.

Question 19: You mentioned that in desert environments, the penetration depth can reach up to two meters. Given the water scarcity in our region, I am curious about how pixels representing desert areas with underlying water would appear on SAR images?
Answer 19: It would depend on how deep the water is. If it is not too deep (2-3 m), you may be able to detect it, depending on the wavelength used.

Question 20: It is NOT always true that higher wavelength SAR images are better than their lower wavelength counterparts. Is this true? Can you explain using examples? Because I remember coming across a point that for some applications, C-Band is better than L- or P-Band. Is this correct?
Answer 20: You are absolutely correct. The wavelength will depend on your application. For agriculture studies – you will want C- or X-bands. For forest studies you will want to use L- or P-bands, for example.

Question 21: Is it possible to penetrate concrete to detect water leaks in a pipeline network? Can SAR be used to detect leakages in drainage?
Answer 21: Unlikely, however, if the concrete has moisture that is higher from the concrete surrounding it, then you might be able to detect it.

Question 22: In what instances would it be useful to explore polarization differences or ratios apart from just the bands (e.g., HH-HV or VH/VV, etc.)?
Answer 22: In all sorts of studies related to structural differences of your objects on the surface, such as differentiating agricultural crops, different types of vegetation, etc.

Question 23: Which radar properties (like bands, frequencies) are used for soil moisture estimations? Can SAR be used to monitor Soil Moisture Content throughout all the phenological stages of crop growth over vegetated areas? To retrieve SMC to be precise.
Answer 23: SAR can be used and is being used to retrieve soil moisture in agricultural areas. It works well in areas where the vegetation is not dense – like agricultural areas. L-band generally works well for soil moisture estimation, especially with denser crops such as a mature corn stand. In such cases, C-band will not work so well because it will likely not penetrate all the way through the canopy to detect the moisture in the soil. Also, like-polarizations work better for detecting soil moisture than

cross-polarizations. The reason for this is because there is a greater likelihood for HH or VV to penetrate all the way through the canopy. HV or VH will be more sensitive to the vegetation volume of the crop. Radar is not so straightforward to estimate soil moisture because the return signal contains information from all of the objects on the surface. One therefore needs to tease out, for example, the vegetation component in the signal in order to get to soil moisture.

Question 24: For ground motion we use buildings and stable surfaces because these decorrelate less. However, as you explained these surfaces are sending back less signal. Could you explain a little about what part of the signal is coming back?
Answer 24: This is more related to InSAR and the decorrelation of the phase. Stay tuned for Part 2 on Nov. 13.

Question 25: To what extent can we use SAR to differentiate between open water and ice in the case of less calm seas? Will there be too much backscatter?
Answer 25: It is all about roughness. The ocean surface will be much smoother (assuming no wind) than sea ice and therefore the backscatter from sea ice will be higher.

Question 26: What are the open sources where we can get the global coverage of each SAR band's data?
Answer 26: The last part of this presentation showed sources of open source SAR data, which included GEE, ESA's Copernicus Hub, the Alaska Satellite Facility, and JAXA's portal. Part 3 of this series will discuss all the SAR data and resources from ASF.

Question 27: How do you control polarization? Is it controlled by the antenna design?
Answer 27: It is controlled by the antenna design. The signal is transmitted with a specific polarization and is then received after being filtered to match the desired polarization.

Question 28: Which band is more preferable for flood monitoring, C-Band or L-Band? Also, what polarization is best to work with? VV, HH, or VV+VH? Do the RGB bands always correspond to the waves for HH, HV, and VV, or will it be

varied? Why is VH polarization not measured? Does it share information with the HH, VV, or HV?

Answer 28: The bands most suited to detect flooding in forests are L- or P-bands. Flooding in areas with short vegetation (e.g., agricultural crops) can be detected with C-band. HH will have a higher probability of detecting flooding, followed by VV. You can create an RGB band however you want, however, for better interpretation it is best to place the HV band in the green channel – because it is most sensitive to the presence of vegetation. Cross polarizations (VH, HV) are usually the exact same, however, VV, HH, and HV (or VH) contain very different information – related to the structural characteristics of the objects on the ground.

Question 29: Is there any software (open-source hopefully) you recommend to work with SAR data? Mostly for visualization. I use software to estimate ground deformation, but I am just exploring the amplitude characteristics of SAR.

Answer 29: ESA has software called SNAP. GEE is good for mining through datasets, visualizing data, and doing analysis. For InSAR, ISCE is a good open source software to use.

Question 30: Are there any studies applying SAR for coastal flooding? Could you provide some papers on this topic?

Answer 30: Here are some references:

- Coastal Flood Inundation Monitoring with Satellite C-Band and L-Band SAR
- Monitoring coastal inundation with Synthetic Aperture Radar satellite data
- Deep Convolutional Neural Networks-Based Coastal Inundation Mapping from SAR Imagery: with One Application Case for Bangladesh, a UN-defined Least Developed Country

Question 31: How large should the area be so that we need to be careful about incidence angle differentiation in the image? Also can we correct for it somehow?

Answer 31: Incidence angle variation depends on the acquisition mode. There are ways to normalize for incidence angle, however,I suggest cutting the edges of the images and just focusing on the middle of the image.

Question 32: Can you explain for which scenarios which SAR polarization(s) are ideal? Like in optical RS, we know which spectral bands are to be used to identify

which surface characteristics are based on spectral reflectance curves. In SAR remote sensing, how do we determine which polarization we need for a specific application, for example, identifying flood waters or landslide debris?

Answer 32: HV or VH are ideal for detecting vegetation and its characteristics. They are also good for detecting open water. The reason for the former is because vegetation is a volume scatterer, therefore, the signal will reflect off many different components of the vegetation. The larger the number of bounces or reflections within a volume, the higher the likelihood that your signal will depolarize (change from H to V or V to H), resulting in high backscatter. This is why cross polarizations are great for detecting vegetation. They are also good at detecting open water because the signal will not depolarize (water is a specular reflector – just one bounce – away from the satellite) and the backatter will therefore be very low. If you want to detect flooded vegetation or soil moisture, then HH is the best polarization (followed by VV) given that there is a higher likelihood for the signal to penetrate all the way through the vegetation canopy.
If you want to identify landslide debris, then VV or HH might be the best polarizations – this is something you will want to explore.

Question 33: Are there new good methods to reduce speckle using neural networks?

Answer 33: There are many different speckle filters, including some that use neural networks. I have not tried these and can therefore not comment. However, it is something that you should explore to determine which one works best to address your needs:

- SAR Image Despeckling by Deep Neural Networks: From a Pre-Trained Model to an End-to-End Training Strategy
- SAR Image Despeckling Using a Convolutional Neural Network

Question 34: How can SAR be used in glacier area mapping? Which polarization is best to choose? And how do backscatter values change depending on elevation and season?

Answer 34: Great application! NISAR will be using InSAR to look at glacier movement. Dr. Eric Fielding in Part 2 will touch on this. Backscatter will change depending on the type of vegetation and conditions (e.g., snow) at different elevations. Also, frozen and thawed conditions as a function of elevation will influence backscatter, with frozen surface conditions resulting in lower backscatter than thawed surface conditions.

Also, phenology will change backscatter because structurally the vegetation is different (leaves vs. no leaves).

Question 35: Can you please elaborate about geological applications of SAR and how to process datasets in order to detect the geology/lithology of any particular area?

Answer 35: SAR is particularly useful for mapping and monitoring surface deformations, lithology, landform structures, and subsurface features. InSAR, for example, is widely used for monitoring land deformation caused by tectonic activities like earthquakes, volcanic eruptions, and fault movements. InSAR can detect subtle changes in the Earth's surface, such as:

- Surface displacement along fault lines after an earthquake.
- Subsidence in areas affected by mining or groundwater extraction.
- Volcanic deformation, such as the uplift or sinking of the ground before or after an eruption.

In addition, different types of rocks and soils have distinct surface roughness characteristics, which can influence how radar signals are scattered. These signal responses can be used for lithological classification.

Question 36: What is the capability of GEE for SAR data analysis?

Answer 36: GEE provides access to the complete Sentinel-1 collection, as well as yearly global PALSAR mosaics and some PALSAR ScanSAR data. Both the PALSAR and Sentinel-1 datasets consist of amplitude images that have been radiometrically and geometrically corrected. All that is needed is to apply a speckle filter. These data are ideal for baseline studies, such as land cover mapping, or for conducting time series analysis of land cover and land use change, among other applications.

Question 37: Where does phase information come in handy apart from InSAR applications, for instance, for land cover classification?

Answer 37: In **polarimetric SAR (PolSAR)**, phase information from multiple radar polarizations (HH, HV, VV, VH) is crucial for capturing differences in how various land cover types interact with the radar signal. The phase of the returned signal provides insights into the geometry, structure, and composition of the surface. This is particularly helpful for discriminating land cover types for example. The 2017 Introduction to SAR training from ARSET has a session on polarimetry (Session 3).

Question 38: Is the dual polarization mode like polarization or cross polarization always?
Answer 38: The dual polarization mode is usually VV and VH or HH and HV.

Question 39: Are there SAR-based indices available for assessing vegetation health, hydric stress, and crop yield, similar to those used with optical imagery? Can one use SAR to detect the degradation of agriculture, similar to using NDVI with optical data? We have vegetation indices for optical imagery, is there a similar thing in the case of SAR?
Answer 39: Yes, there are several SAR-based indices and methods that can be used to assess vegetation health, hydric stress, crop yield, and even detect degradation of agriculture. While optical imagery, such as those based on NDVI (Normalized Difference Vegetation Index), is widely used for vegetation monitoring, SAR can provide complementary information, especially during cloudy weather or at night.
The SAR Vegetation Index (SVI) is a simple index based on the difference in radar backscatter values between VV and VH polarizations. It is useful for detecting changes in vegetation density and health.

- SVI = $(\sigma^0\_VV - \sigma^0\_VH) / (\sigma^0\_VV + \sigma^0\_VH)$
- It can be used to monitor vegetation growth, biomass, and stress.

The Radar Vegetation Index (RVI) is used to assess vegetation cover and biomass based on radar backscatter. It uses the ratio of VV and VH polarizations.

- RVI = $\sigma^0\_VV / \sigma^0\_VH$
- It helps assess vegetation density and stress levels, with higher values indicating denser vegetation.

The Modified SAR Vegetation Index (MSVI) is another index used to assess vegetation and is based on the difference in backscatter values from VV and VH polarizations, but it also considers the surface roughness.

- MSVI = $(\sigma^0\_VV - \sigma^0\_VH) / (\sigma^0\_VV + \sigma^0\_VH + \sigma^0\_VV)$
- This index is designed to provide improved results for areas with dense vegetation or forest cover.

Question 40: Does the signal dielectric depend on the type of sensor or is it unique per element? Are the different corrections unique per type of satellite

image? For example, can I correct a Radarsat image using the same techniques and tools used to correct images of Sentinel?
Answer 40: You have to correct for radio and geometric distortions. This is sensor dependent. Also, the data available has already been corrected.

Question 41: Is the ground range correction calculated from a 'smooth Earth' with curvature? Are there more complex corrections that use an elevation model?
Answer 41: Basic slant-to-ground-range conversion assumes that the Earth's surface is smooth and flat. In this simplified model, the Earth's curvature is typically considered by approximating the Earth as a spherical or ellipsoidal surface. This approach assumes that the terrain is uniform and does not account for any elevation changes. This correction works well for relatively flat terrain or when the topographic variations are small. For more complex or rugged terrains where elevation variations (topography) are significant, the smooth Earth model is insufficient. To address this, DEMs are used. Topographic corrections adjust for terrain distortions caused by changes in elevation. When using a DEM, the radar data is corrected to account for the local elevation of each pixel in the scene.

Question 42: I thought the wavelength of SAR bands is long enough to penetrate water and that's why they are not impacted by clouds. Why do wet ground surfaces have higher backscattering? Does SAR somehow not penetrate the water at the ground surface?
Answer 42: SAR wavelength does not penetrate a water surface because a body of water acts as a specular reflector, reflecting the radar signal back to the sensor. The wavelength of SAR signals is typically much longer than the size of water droplets in clouds, which is why SAR can penetrate clouds. However, this ability to penetrate is dependent on the radar wavelength and the water content of the cloud. For instance, shorter wavelengths (like X-band) are more affected by rain and moisture, while longer wavelengths (such as L-band and P-band) are less impacted by smaller particles and water droplets in clouds.

Soils with high soil moisture have higher backscatter at frequencies like C-band and L-band because of the higher dielectric constant of water compared to dry soil. The increased dielectric leads to stronger reflections of the radar signal, which results in greater backscatter. In addition, the radar signal experiences less penetration into the medium due to the higher reflectivity from the wet surface.

A key distinction in SAR remote sensing is how different surfaces interact with the radar signal. A standing body of water (e.g., a lake or ocean) behaves as a specular reflector, meaning that the smooth water surface reflects the signal away from the satellite. This is different from how SAR interacts with surfaces or objects that have different levels of moisture, like soils, vegetation, etc., where the radar signal return will be in part determined by the amount of water in these surfaces/objects.

Question 43: Referring to Slide 58, do the layover and foreshortening appear on all types of bands, like C-Band, P-Band, etc.?
Answer 43: Yes, layover and foreshortening occur in SAR images across all radar bands (e.g., C-band, L-band, P-band, X-band, etc.), but the degree to which these effects appear can depend on several factors, including the radar wavelength and the incidence angle.

Question 44: I'm using InSAR data for structural health monitoring. I used the European Space Agency's Sentinel-1 C-Band. How would the data processing and interpretation be easier and faster?
Answer 44: Please be sure to tune into Part 2 and 3 of this series. We will cover this.

Question 45: How is radiometric correction applied on coastal regions (e.g., the Gangatic Delta) where elevation is very low?
Answer 45: The same radiometric correction is applied uniformly across all regions. However, there are various types of radiometric distortions, including those caused by the antenna pattern and those caused by terrain relief (which often cannot be completely corrected). In areas with significant topography, the radiometric correction aims to remove the misleading influence of terrain on backscatter values. For example, the correction eliminates bright backscatter caused by radar reflections from steep slopes, leaving only the backscatter that reveals surface characteristics such as vegetation and soil moisture.

The correction is applied uniformly across the image using a digital elevation model (DEM), but in flat regions, the difference in pixel values before and after correction is often negligible.

Question 46: Referring to slide 63, Image A and Image B represent the phase and intensity images in pixel form?

Answer 46: In slide 63, Image A is a hypothetical SAR amplitude image without the effect of speckle. Image B is a realistic SAR amplitude image with speckle.

Question 47: For temporal filtering, this would use 2+ images? How are they correlated so you know the pixel being filtered matches in both images?
Answer 47: In order to do temporal filtering you need to have your images coregistered or stacked so that you average the same pixel from different dates across your time series.

Question 48: Is it necessary to always apply radiometric correction (speckle filtering) before using a SAR image?
Answer 48: Yes, it is important to apply both radiometric and terrain corrections to your images, especially in areas with topography. While flat areas may have minimal distortions, it is still good practice to apply these corrections to all of your images to ensure consistency and accuracy across the dataset.

As for speckle, the level of speckle in your original image will determine whether a speckle filter is necessary. If your image has a large amount of speckle, it is advisable to apply a speckle filter. The size of the filter should be chosen based on the spatial resolution you need. Without filtering, your resulting product (such as a land cover classification) will likely be very noisy.

Question 49: Referring to slide 65, which spatial filter is recommended for speckle reduction? Can you also tell by applying the speckle reduction filter if we trade off the information details present in the image? Is this true?
Answer 49: Choosing the best speckle filter depends on the specific application and the desired balance between noise reduction and feature preservation. There are many SAR speckle filters and some of the more common ones are Boxcar (mean), Lee, Frost, Kuan, Gamma, adaptive, wavelet.

For general use, filters like the Lee and Frost filters are widely applied, but for specialized applications (e.g., preserving edges in complex surfaces), methods like anisotropic diffusion or wavelet-based filtering may be more appropriate. I personally prefer to use the Boxcar filter but this is something that you will have to explore.

Question 50: In which instances can you combine ascending and descending? If I want to create a composite image for each season, can I combine these? Do you

need to correct the rain cells in each image before creating a composite image? If yes, how can you apply this correction?
Answer 50: You cannot correct for rain cells, hence these should be discarded. This is why it's crucial to always visualize the images in your stack to identify and remove any that contain weather-related artifacts.

If your area of interest is flat, you can combine ascending and descending passes. However, in areas with topography, you should never combine the two passes, as this could introduce errors due to differences in viewing geometry and terrain effects.

In general, I do not recommend combining ascending and descending passes to create a single composite. Instead, I suggest creating one composite with the ascending passes and another with the descending passes to avoid any potential issues.

Question 51: Is it possible to derive a high-resolution DSM out of SAR images?
Answer 51: Yes, it is possible with inSAR and TomoSAR.

Question 52: Besides interpolation, would it be useful to consider slope and aspect to correct shadows on the SAR image?
Answer 52: It is useful to consider slope and aspect to predict shadow locations, however, in order to fill in the missing values, you need to perform interpolation. I personally prefer to mask out shadow areas rather than fill them with interpolated values.

Question 53: Could we subtract one image from another to see the difference? Would that be helpful? If we do that, should we compare the same polarization (like HH) between images from different years (like 2000 and 2010)? Do we need to make sure things like wavelength and angle are the same in both images?
Answer 53: Yes, image differencing can be very useful to identify areas of change between two images. For subtraction to be meaningful, the two SAR images should have similar geometry, which means they should be acquired with similar look angles, polarizations, and ideally from the same satellite orbit (ascending or descending).
The images need to be temporally close enough to each other for the differences to reflect true changes. Significant temporal differences (e.g., months or years apart) may introduce natural variations in the scene that are unrelated to the phenomena you're trying to study (e.g., seasonal changes, weather effects, or vegetation growth).

Question 54: Can you please list the methods to separate water pixels from others during flood analysis, other than histogram thresholding? Can we go ahead with some machine learning algorithm for the same. If so, what are the key factors to consider?
Answer 54: Flooding in radar images is dominated by two main backscatter mechanisms: specular scattering, which indicates open water, and double-bounce, which indicates inundated vegetation. As a result, the amplitude values will be very low for open water and very high for flooded areas, allowing for the application of upper and lower thresholds to identify these two flooding categories.

You can also apply machine learning techniques, such as supervised classification using Random Forest, to differentiate open water from other classes in the image. The key factor to consider is having sufficient and adequate training areas. Be mindful of confusion sources, as smooth surfaces like roads or tilled fields may be misclassified as open water. In such cases, incorporating additional layers, such as road networks or agricultural maps, can help mask or inform the algorithm to reduce errors.

Question 55: Can you tell us the paper reference that looked at woody and non-woody vegetation with supervised machine learning? Thank you!
Answer 55: This is the reference:
Podest, E. and S. Saatchi, 2002. "Application of Multiscale Texture in Classifying JERS-1 Data over Tropical Vegetation", *International Journal of Remote Sensing*, 23 (7), 1487-1506.

Question 56: Referring to slide 70, is the image a composite image of all the polarizations? As mentioned HH, HV, VV?
Answer 56: The UAVSAR image in slide 70 is indeed a false color composite consisting of HH in the red channel, HV in the green channel, and VV in the blue channel.

Question 57: What freely available platforms provide access to SAR imagery, and could you outline their spatial and temporal resolutions as well as other key characteristics?
Answer 57: Slides 76-79 discuss the different openly available platforms where you can access spaceborne and airborne SAR data. ASF is NASA's data archive center for radar data and has openly available data from many different sensors. Session 3 of this webinar series will discuss the SAR data available through ASF.

Question 58: Can you please talk about thermal noise and banding effects in SAR, especially in Sentinel-1, and how to reduce that?
Answer 58: In SAR images like Sentinel-1, there are various sources of noise that can degrade the quality of the radar images. Two common types of noise are thermal noise and banding effects, which can introduce unwanted artifacts, affecting the radiometric accuracy and analysis of the data.

Thermal noise is a type of noise that arises from the electronic components of the SAR sensor system. It is caused by random fluctuations of electrons in the system's components due to the inherent heat (temperature) of the components. The noise is particularly noticeable in areas with low backscatter and may obscure weak signals. It is primarily noticeable in areas like open ocean, open water bodies or bare soils. It is especially prominent in the cross-polarization channels (VH and HV) of Sentinel-1 data and can be corrected using specialized algorithms provided by ESA's SNAP software. Banding effects refer to the appearance of periodic, linear stripes or bands in SAR images, often caused by issues with the SAR sensor or image processing. These bands are usually aligned with the range direction (across-track direction) of the radar and can appear as bright or dark stripes across the image. Banding typically arises due to errors in radiometric calibration, sensor instability, or variations in the gain of the radar receiver across the swath. It may also occur due to doppler shifts or problems with the data processing algorithms during the image formation step. To correct for banding in Sentinel-1 images you can apply Radiometric Terrain Correction (RTC) using the SNAP software.

Question 59: Can we use SAR data to detect alluvial/sand deposits within a river or water body?
Answer 59: SAR data data can be used to detect alluvial or sand deposits within rivers or water bodies, though its effectiveness depends on several factors, including the resolution of the SAR data, the surface conditions, and the specific backscatter characteristics of the alluvial or sand deposits, which generally have a distinct texture compared to open water body surfaces or vegetated areas. When the radar signal interacts with these deposits, it is scattered in a way that can be distinguishable from other surfaces. Time series SAR data can help track seasonal changes in sandbars or riverbed features that become exposed or submerged depending on the water level, helping to identify sand deposit patterns over time.

The main challenge in detecting alluvial or sand deposits using SAR is when the sand is wet or submerged. Wet sand, especially in river channels can be a specular reflector (similar to water) making it harder to distinguish from surrounding water surfaces. C-band is a more suitable band to detect these features than L-band.

Question 60: Does using multiple polarization methods aid in differentiating oil spills from ocean slicks and other natural look-alikes? Or would VV be sufficient for such a task?

Answer 60: The use of multiple polarizations in SAR can significantly aid in differentiating oil spills from ocean slicks and other natural look-alikes. VV will provide a certain level of backscatter, but it might not be enough to differentiate between oil spills and other surface features.

Dual-polarized SAR data (e.g., VV and VH) or quad-polarized SAR data (e.g., VV, VH, HH, HV) provides more detailed information about how the radar signal interacts with the surface, which can help distinguish oil spills from other natural look-alikes. The following link leads to an ARSET SAR training that had an entire session (Session 3) dedicated to the use of SAR for oil spill detection: https://appliedsciences.nasa.gov/get-involved/training/english/arset-disaster-assessment-using-synthetic-aperture-radar.

Question 61: I have found ground tracks for Sentinel-1 that cover my area, but how do I find if the radar looks left-to-right or vice-versa? Is there a specific term that I am missing?

Answer 61: Sentinel-1 is mounted to be right-looking. A Sentinel-1, "ascending" orbit means the satellite is moving towards the north while traveling from South to North, viewing the Earth's surface from the west side, while "descending" means it is moving towards the south while traveling from north to south, viewing the Earth's surface from the east side. The ascending or descending orbit is found in the metadata. It can also be found in the file name (depending on the source).

Question 62: I'm wondering if SAR can be used to produce a digital terrain model over a dense vegetation area. I've heard that there are specific bands that can penetrate the vegetation, such as L- and P-Bands. Do you think those bands could generate the terrain elevation model?

Answer 62: Yes, SAR can be used to generate a digital terrain model over vegetated areas if you are using L- and P-bands, which penetrate through the vegetation canopy (though P-band has greater penetration than L-band).

Question 63: How can I find NISAR data? Will NISAR be available in GEE? Will NISAR provide world coverage? And what will be the revisit rate?
Answer 63: The NISAR radar data will be stored in the Alaska Satellite Facility (ASF) and will be openly available. Yes, NISAR L-band data will have global coverage while S-band data will be available over India and cal/val sites around the world. NISAR will have a 12 day exact temporal repeat, however, there will be coverage over the same area if you combine ascending and descending passes.

Question 64: I understand not mixing ascending and descending data in a SAR analysis. Can they be analyzed separately and the products they produce combined, a posterior? That is, will the two generally identify the same ground objects?
Answer 64: Mixing ascending and descending data should not be done in areas of complex topography. You can mix them in areas that are flat (make sure they are Radiometrically Terrain Corrected [RTC]), but I personally prefer not to do this. A good approach is definitely to combine the products generated from ascending passes alone and descending passes alone.

Question 65: Is it possible to use SAR for measuring the above ground biomass?
Answer 65: It is possible to estimate above ground biomass. The SERVIR SAR Handbook is an excellent resource that discusses how to do this (Chapters 5 and 7): https://servirglobal.net/resources/sar-handbook.

Question 66: Which data type is supposed to be downloaded while working on SAR data through programming (i.e., Python)?
Answer 66: It depends what you are doing. If you want analysis ready amplitude data then you should download the Radiometrically Terrain Corrected (RTC) SAR data. If you want to work with the phase then you should download the SLC data.

Question 67: Can I detect aerosol particles by using SAR imagery?
Answer 67: SAR imagery is not typically used to directly detect aerosol particles in the atmosphere. SAR is primarily designed to image the Earth's surface and measure surface properties, such as land cover, topography, and vegetation structure, through

the signal backscatter aerosols, being airborne particles or droplets suspended in the atmosphere, do not interact with the radar signal in a way that would allow for direct detection using SAR. For aerosol detection, optical, infrared, and LiDAR sensors, or passive remote sensing methods, are more appropriate. However, indirect effects of aerosols (such as signal attenuation in specific atmospheric conditions) can sometimes be observed in SAR data, though this is not a primary application for SAR.

Question 68: What criteria should be used to determine the number of looks in the range and azimuth directions? How should the optimal count be selected? Should the number of looks be a multiple of the pixel dimensions in the range and azimuth directions?
Answer 68: The number of looks in SAR processing is a critical parameter that affects both speckle noise reduction and image resolution. It refers to the number of independent radar signal samples averaged to form a final pixel in a SAR image. Choosing the optimal number of looks for both the range and azimuth directions involves balancing the need for noise reduction with maintaining sufficient spatial resolution.

The number of looks should be chosen based on the desired spatial resolution and the level of speckle reduction you are aiming for. Generally, fewer looks (1-2) results in higher resolution but more speckle, while more looks (4-8 or higher) results in lower resolution but less speckle.

While it is not strictly required for the number of looks to be a multiple of the pixel dimensions in the range and azimuth directions, this can be a useful guideline. Using a multiple ensures that the resulting pixel dimensions after averaging still align with the original grid structure of the SAR image, which can help with accurate georeferencing and analysis.

Question 69: If I wanted to use both Sentinel-2 imagery at 10-meter resolution and ALOS PALSAR L-Band data at ~23-meter resolution, how can I use and compare pixels?
Answer 69: While you cannot directly compare pixels from Sentinel-2 and ALOS PALSAR due to their different sensor characteristics, you can either resample and normalize the data for comparative analysis or use advanced techniques like machine learning to process the datasets together as complementary sources of information.

Question 70: Can SAR be used with GRACE data to omit the water and moisture content in the soil and create an optimized GRACE model for groundwater level change?

Answer 70: Yes, SAR can be used in combination with GRACE (Gravity Recovery and Climate Experiment) data to help improve models for groundwater level change, especially by distinguishing the contribution of soil moisture and water content to the total mass change observed by GRACE.

By integrating SAR-derived soil moisture data with GRACE observations, you can "filter out" the contribution of soil moisture and surface water, leaving a more accurate estimate of groundwater storage changes.

There are also studies that have looked at surface deformation through InSAR and how it relates to ground water storage measured by GRACE:

- Using Sentinel-1 and GRACE satellite data to monitor the hydrological variations within the Tulare Basin, California
- https://www.researchgate.net/publication/378386986_Surface_Deformation_Analysis_and_Prediction_of_Groundwater_Changes_from_Joint_SAR-GRACE_Satellite_Data

Question 71: Is there a difference between the SAR signals of saturated soil brought by heavy antecedent rainfall events vs. (high) shallow groundwater tables?

Answer 71: There is no distinction in the SAR signal between these two drivers of soil moisture. The SAR sensor is sensitive to the high dielectric properties of soils caused by elevated moisture levels. However, it cannot differentiate whether the moisture is due to a heavy rainfall event or a shallow groundwater table.