



## Part 1 Questions & Answers

Please type your questions in the Question Box. We will try our best to answer all your questions. If we don't, feel free to email Erika Podest ([erika.podest@jpl.nasa.gov](mailto:erika.podest@jpl.nasa.gov)) or Sean McCartney ([sean.mccartney@nasa.gov](mailto:sean.mccartney@nasa.gov)).

**Question 1: There's a problem downloading this file:**

**S2B\_MSIL2A\_20200622T100559\_N0214\_R022\_T32TQQ\_20200622T134211**

**All other files are perfectly fine. Any ideas?**

Answer 1: The file has been corrupted and a ticket has been submitted to Copernicus Open Access Hub to resolve the issue. In the meantime, users can download the data from USGS Earth Explorer.

**Question 2: How can we decide which polarization has to be used for a specific application? What characteristic of the target decides that?**

Answer 2: We have learned a lot from research over many years, whether agriculture or forestry. The structure of the target will give us some great clues as to the best polarizations. For example, we know that vegetation creates a great deal of volume scattering from all the leaves, branches, etc. This is because vegetation has a complex structure. Polarizations like HV or VH are sensitive to this volume scattering. We also know that V polarized waves will “couple” with vertically oriented vegetation. That means greater interaction of the transmitted wave with the vegetation. Because of this, we know from research and operations that VH (or HV) + VV are the best 2 polarizations for vegetation mapping. Thus, always try to picture how the transmitted wave is oriented and how it might interact with your target of interest. Digging into the literature will help you understand the best polarization for your particular target.

**Question 3: Which polarization among VV and VH is best for mapping inundated rice fields and why?**

Answer 3: HH is the preferred polarization because it has a higher likelihood of penetrating through the canopy, resulting in a strong double bounce response. VV is the second best polarization, with noticeably less double bounce because there is greater interaction of the signal with vertical structure (which is predominant in forests) and less of it makes it through the canopy. Cross-pol usually misses most of the inundated vegetation because it is primarily interacting with the vegetation structure



and there is much less likelihood that the signal will penetrate all the way through to cause a strong double-bounce effect. However, this is the case for forests (with L-band) and not for areas with low vegetation.

Here are some references:

- SAR-based detection of flooded vegetation – a review of characteristics and approaches: <https://apirs.plants.ifas.ufl.edu/site/assets/files/380897/380897.pdf>
- Flood mapping under vegetation using single SAR acquisitions: <https://users.monash.edu.au/~jpwalker/papers/rse20-1.pdf>

**Question 4: Is there a resource that provides information on crop type and the type of band or does it change during the crop phenology?**

Answer 4: Polarization is easier to understand and, regardless of the crop type, HV or VH is most sensitive to crop type. This is true of most phenological stages. Keep in mind, however, that VV can also contribute information on crop type. Deciding on the best frequency/wavelength is more complicated. We want the wave to penetrate enough into the canopy to create scattering. But if the wavelength is too large relative to the canopy, the wave will penetrate too deep and interact with the soil. Overall, we favour shorter wavelengths for lower canopies and longer wavelengths for large biomass crops like corn. Of course the agricultural landscape is a mix of large and small biomass crops, and biomass changes as the crops grow. As such, integrating data from different frequencies is very helpful in mapping these varied canopies.

**Question 5: When would you use ground range instead of slant range?**

Answer 5: It is convenient to use ground range whenever we want to stack datasets together and particularly if we want to integrate these data with other geospatial data. This is because in slant to ground range conversion we tie the data to the Earth geoid. The geometry of the target (think of agricultural fields) is correctly represented in these ground range products. If you take a look at airborne SAR imagery or satellite imagery with large swaths, the compression of the target is very noticeable.

**Question 6: Dear trainer, I didn't understand the incident angle concept on slide 19 as related to rough and smooth surfaces. Could you please clarify.**

Answer 6: For all fields (smooth or rough), as incidence angle increases, backscatter increases. Part of this is due to the simple fact that the power generated by an antenna that hits the target decreases with range (distance), and there is also a spreading loss of energy that increases with distance. Recall that the angle increases with range (or



distance from the antenna). This explains the general decrease in backscatter with angle. However, as we discussed, roughness creates greater scattering in all directions, including back to the antenna. As such, this impact of decreasing scatter with angle, varies depending on the roughness of the target.

**Question 7: Could you please mention which open-source software can be used to convert slant range to ground range?**

Answer 7: You will learn about SNAP during this ARSET series. This process is available in SNAP (look under Radar menu - under Geometric - see Slant Range to Ground Range).

**Question 8: What are the differences between the different modes in Sentinel-1 (e.g., wave mode, strip map mode, extra wide swath mode, and interferometric wide swath mode)?**

Answer 8: ESA has a great website that discusses the characteristics of these different modes and how they are created:

<https://sentinel.esa.int/web/sentinel/user-guides/sentinel-1-sar/acquisition-modes>

For our work in agriculture, we use the IW (interferometric wide mode) as it provides the swath, resolution and dual polarizations (VV and VH) that are useful for crop mapping.

**Question 9: What is the difference between power and intensity?**

Answer 9: In SAR, the terms are sometimes used interchangeably. Intensity is the power transmitted per unit area.

**Question 10: In the case of multi-temporal analysis and change detection - for forests it would work for detecting disturbances over a short period to avoid significant incident angles. If we want to monitor disturbances taking place over many years, might we get a different incident angle due to the growth of the forest?**

Answer 10: It is always best to minimize any change in microwave response that might be due to the SAR itself (thus, if angle changes over time, some of the measured change will be due to the difference in incident angle and not the change in the forest cover). That is the simplest approach. However, there are some physical and semi-empirical models in agriculture (the Water Cloud Model is one we work with) where the incident angle is a parameter in the model. In this case, the WCM can be used to estimate measures of vegetation (like biomass). We can use data from different incident angles in models like the WCM, as they also model the incident angle.



**Question 11: Why is the Doppler shift only important for side-looking radars?**

Answer 11: All SAR instruments are side-looking instruments. The Doppler shift is a phenomenon that is present all around us (when waves are transmitted and the source of the wave is moving). But in SAR, this effect is used to record a history of this shift in order to create a longer look at the target - creating a synthetic and longer aperture.

**Question 12: Slide 32 the write-up and the contents on the image are not matching. When approaching the target do we have a negative or positive shift?**

Answer 12: Good catch and apologies. Sometimes we have to be careful of our point of reference. Here I always think of the observer. The frequency is an upward shift (with respect to the observer) as the source of the pulse approaches (more pulses per unit time hit the observer). The example of the bug on the previous slide should clarify this.

**Question 13: How exactly is the synthetic aperture reconstructed from the radar signals? What is the mathematics behind this process?**

Answer 13: Please refer to Part 1 of this webinar series along with previous ARSET trainings on SAR:

<https://appliedsciences.nasa.gov/join-mission/training/english/arset-introduction-synthetic-aperture-radar>

The book “Microwave Remote Sensing, Active and Passive” is considered the remote sensing bible. It has three volumes and it is written by Fawwaz T. Ulaby, Richard K. Moore, and Adrian K. Fung.

Also, here is a great introductory tutorial: [Esa SAR Tutorial.pdf](#)

**Question 14: Can you please explain Beta Nought and Gamma Nought again? Thanks.**

Answer 14: Beta nought is the reflectivity (intensity) per unit area (think of, for example, intensity per 1x1 m area) in the slant range. We can transform beta to gamma nought if we wish to represent this reflectivity in the plane perpendicular to the slant range. We wanted to introduce all three - beta, gamma, and sigma - since in the literature you will see all three. Most often, researchers transform the SAR products into sigma nought, since typically we are interested in how much energy is scattered per unit area from a ground target (like an agricultural field).

**Question 15: How can we integrate both coherence and intensity to map flooded vegetation using a Random Forest classifier?**



Answer 15: The interesting advantage of RF is that you can integrate any type of data. You will see this in the training next week, where the ARSET trainers will talk about integrating different data layers into an RF classifier.

**Question 16: Is the speckle-related noise very high in soil moisture-related data? How can you reduce noise in such cases?**

Answer 16: Speckle is a fundamental characteristic of all SAR data. So yes, you will encounter noise when using SAR for soil moisture retrieval. To reduce this noise, you can request a multi-look product (if that is provided) or you can apply a SAR adaptive filter to spatially average the image. You will learn how to do that next week in the ARSET training.

**Question 17: What does multi-look mean in physical terms? How does the multi-look process compromise the resolution?**

Answer 17: Please refer to Part 3 of this webinar series for more information.

**Question 18: Is there another Python 3.x library to process Sentinel-1 data other than SNAP?**

Answer 18: Our AAFC team does not use this. I will defer this question to the RUS and/or ESA ARSET presenters in Parts 2-5 of this series.

**Question 19: Is there a significant impact in images formed by different polarizations: HH, HV, VH, VV?**

Answer 19: Yes, absolutely. Think about the orientation of a transmitted polarization and the structure of the target. H or V transmitted waves will interact quite differently; and the type of scattering that happens when the transmit wave hits the target depends on the polarization and the target structure. As such, the intensity and angular scattering characteristics are quite different among these polarization combinations.

**Question 20: How can we take care of the geometric distortions when studying mountainous regions? How do we generate appropriate masks?**

Answer 20: These are challenging regions. Using a DEM during orthorectification can help to generate a geo-referenced product, but the intensity is distorted due to the layover and foreshortening impacts. One strategy is to select different orbits (ascending and descending), which will provide a different look relative to the topography. This would help, for example, where we have radar shadows, since we would have both a descending and ascending view. Creating a mask of the shadows is your best bet.



**Question 21: Can you explain the difference between single and dual polarizations?**

Answer 21: Single is simply data where we have one transmit and one receive polarization, for example H transmit and H receive (HH). Dual polarization SARs will transmit one or two polarizations and receive one or two polarizations (HH and HV, for example).

**Question 22: How can we retrieve plant biophysical variables from Sentinel-1?**

Answer 22: There are several ways to do this. Some researchers have used empirical methods, but there has also been a great deal of work done using the semi-empirical Water Cloud Model to retrieve LAI/biomass. You will also need to have information on soil moisture to use this model. Researchers are also having great success using machine learning methods.

**Question 23: Waves with higher frequencies have higher energy ( $E = h \cdot c / \lambda$ ). So, these should be able to penetrate deeper compared to shorter frequencies. But on slide number 42, it is said that longer-wavelength waves penetrate deeper. Can you please explain?**

Answer 23: In volume scattering, the energy of a transmitted wave is redistributed into different directions, resulting in a loss of the transmitted wave. Losses are due to absorption and scattering and the total loss is the sum of these two losses. This total loss per unit length is known as extinction coefficient.

Absorption: Penetration depth is a function of wavelength times the square root of the dielectric constant over  $2 \cdot \pi \cdot$  dielectric loss factor. This indicates that the longer the wavelength the larger the penetration depth. The dielectric loss factor on the bottom indicates that as absorption increases, the penetration depth of the wave travelling through the medium decreases.

Scattering: This is a function of the size of the wave relative to the scatterer.

For example, C-band (wavelength ~5cm) will penetrate less into a dense vegetation canopy than L-band (wavelength ~24cm), because it will scatter primarily from the components of the vegetation that are in the middle to the top of the canopy (e.g., leaves, twigs, or branches that are similar in size to the wavelength). L-band will scatter with the larger components of the vegetation (e.g., the branches or trunk), and hence will penetrate deeper into the canopy.

In the case of a wet soil, there will be greater attenuation of the signal and hence less penetration at shorter wavelengths than at longer wavelengths.



**Question 24: How deep can the radar penetrate in soil?**

Answer 24: This depends on the SAR wavelength and incidence angle, as well as how much water is in the soil or target. Thus, there is no precise answer. However, when we think about C- or L-band, the penetration for most agricultural soils is a few centimeters. There have been studies showing that L-band can penetrate up to 2 meters deep in some very dry desert soils.

**Question 25: In the example (slide 43) of multiple frequencies, how were the bands and polarizations chosen?**

Answer 25: We know that VH or HV and VV are the best polarizations for agricultural crop mapping.

**Question 26: What should be the angle and bandwidth for grass biomass assessment and soil moisture estimation?**

Answer 26: Soil moisture is an easier answer. From a lot of research over the years, we know that L-band is a better frequency for soil moisture estimation. For biomass, this will require a bit more investigation. It will depend on the biomass of your grasslands. Typically, we favour smaller wavelengths (X or C) for low biomass crops, and larger wavelengths (L) for larger biomass crops.

**Question 27: Is there a need to apply band ratio-ing in SAR data?**

Answer 27: Sometimes this can be helpful. We have looked at some SAR band ratios and how they relate to crop condition and biomass. It would be worthwhile for you to investigate the use of band ratios.

**Question 28: I am currently working on crop modeling (wheat). I want to develop an LAI map over a particular region? How do I isolate the wheat LAI signals from the low-vegetation LAI data?**

Answer 28: One strategy would be to create a crop map (you will learn how to do that next week in the ARSET training). This would allow you to mask non-wheat fields.

**Question 29: In the image Integration of data from RADARSAT-2, ALOS, and TerraSAR-X, there is a difference in polarizations. Is it okay to combine VH polarization with VV polarization with different sensors?**

Answer 29: This depends on what the goal of your project is. For crop mapping, combining different frequencies and polarizations is actually very helpful. If I was



applying a model to estimate biomass, for example, then I would want to stay with one frequency.

**Question 30: Why is cross polarization best for agricultural crop classification?**

Answer 30: When a wave (like H transmit) enters a canopy, there is a great deal of multiple scattering. As you can imagine, the leaves, stalks, and stems cause the transmitted wave to scatter within the canopy. These multiple scattering events cause a re-polarization of waves (from H to V, for example). The HV image is detecting how much of the H transmit energy is being re-polarized to V due to these multiple scattering events.

**Question 31: For the crop maps developed on slide 43 in Manitoba, how accurate are these maps using only radar with different wavelengths? I had always thought that such maps need to be developed with data physically gathered from these different crop fields. To what extent do you ground-truth these radar-generated crop maps?**

Answer 31: You will learn a great deal about how AAFC generates these crop maps during the ARSET training next week. Our operational system uses optical plus SAR. We collect field observation data across the country to train our classification models. The AAFC team will explain how we do that in the next training session. Our target accuracy is 85%, and we typically exceed this classification accuracy (it will depend on the available image for that year and location, and amount of training data).

**Question 32: For monitoring rice phenology, which polarization among VV and VH is preferred and why?**

Answer 32: In our research, we have found that VH is better at estimating crop phenology.

**Question 33: For mapping rice fields, which incidence angle is preferred: small or large?**

Answer 33: For any classification, the most important dimension is time. What I mean is that acquiring many images over the growing season is important to a successful classification. The AAFC method uses radar imagery acquired at many different incidence angles because we want as many images over the growing season as possible. If we limit the number of images by limiting ourselves to one angle, we will have fewer images over the season to classify. Although incident angle is an important





SAR parameter to understand, we can integrate images acquired at different angles for classification purposes.

**Question 34: In the case of vine crops, soil moisture measurements really get affected by noise. How does one reduce noise and improve measurements in soil moisture? Can it be a combination of optical and radar signals?**

Answer 34: Noise in radar imagery can be reduced in one of three ways: apply multi-looking or multi-look the image yourself; spatial average using an adaptive radar filter; or average over time using a temporal filter (these will be covered in the ARSET training next week). There are a number of models/methods to retrieve soil moisture. When crops or vegetation are present, you can consider a semi-empirical model like the Water Cloud Model or a change detection approach.

**Question 35: How much does the physical state of water (liquid vs. solid) typically influence the penetration depth for different wavelengths?**

Answer 35: When water molecules are in a frozen state, they are unable to rotate. As such, incident energy cannot be stored in this rotation (regardless of the SAR frequency). As such a soil that is frozen will look dry to the radar, regardless of water content, and the depth of penetration will increase.

**Question 36: Regarding Rule #1, how can we check whether it was raining or not during the acquisition time?**

Answer 36: Yes, this is a great strategy. The metadata with the SAR image will have the exact time of image acquisition. Check local weather data to see if at the time of acquisition rain occurred.

**Question 37: I am not clear about the water interaction with the radar pulse. Will the dielectric content result in a change in the phase? I was wondering if when the water rotates and stores the energy does this delay result in the phase delay? Or is this storage time very short?**

Answer 37: The storage time is very short. Relaxation of the molecule occurs as each pulse passes.

**Question 38: I would like to know if mapping and monitoring of crops could be carried out at the Scheme level using SAR?**

Answer 38: I am not sure what scheme level means. If you clarify, I can then answer your question. Thanks.



**Question 39: Which method is more effective and faster - conventional remote sensing methods in crop classification or crop classification using machine learning?**

Answer 39: ML methods are very data-driven. Research is active in this area, but typically, if training data are robust and the volume of training data is large, we see good results with ML (often higher accuracies). However, without good training data, ML methods will not perform well. Research is ongoing as to how well ML architectures can be transferred or used over time (different seasons) and space (different locations). ML methods are data-hungry and are likely to require more computing resources.

**Question 40: Are HV and VH the best polarizations just for Canada? Or can they be used for different countries?**

Answer 40: This should apply to most vegetation, not just crops in Canada. However, you will need to investigate in more depth for your site and crop mixes. AAFC is active in sharing and collaborating with partners to test our method over other sites.

**Question 41: Do these satellites cover all areas on the surface of the planet?**

Answer 41: Yes. However, most SARs are programmed and thus users must ask the SAR data provider to program the satellite over their site. An exception is Sentinel-1, where ESA is acquiring systematic collections. This makes Sentinel-1 a very useful source of data.

**Question 42: 1. To what extent can one use SAR to map/identify crop types on small fields averaging 3 acres? These are often the plot sizes of the majority of African farmers. 2. Would it be possible to model plots with mixed crops? 3. What would be the best approach to use if one wants to use SAR to model food security/insecurity in a specific region. What is the most promising approach?**

Answer 42: The spatial resolutions of SARs are improving. Many satellites are able to acquire SAR data in very high resolutions (<5m). However, this can come at the expense of swath coverage (typically high resolution modes have smaller swaths) and polarization (typically high resolution modes are collected in only one polarization). However, satellites like the Radarsat Constellation Mission (RCM) can acquire data using compact polarimetry (using circular transmit polarization). We have been collecting these CP data for some sites in Canada at resolutions of 3-5 m. All the research going on around developing radar vegetation indices would be very helpful, just as optical NDVI is for monitoring crop production.



**Question 43: Are most radar datasets free?**

Answer 43: Some are and some are not. Sentinel-1 data are free and open. Radarsat Constellation Mission (RCM) data can be accessed if users are vetted by the government of Canada. However, many public SAR data providers are adopting open data policies for future missions. Keep an eye out for future missions, as many will provide open data (such as NISAR).

The Alaska Satellite Facility has a number of different historic SAR datasets that are openly available.

**Question 44: How are accuracies measured in terms of sensitivity in SAR data? How is quality flagged?**

Answer 44: I think this is a calibration question. SAR data providers typically have extensive programs to calibrate SARs. In terms of intensity, these agencies use point targets (like corner reflectors) to measure what intensity the radar measures and compare that to what the intensity should be from these corner reflectors. Distributed targets like the Amazon are used to measure the radar antenna pattern and to determine the stability of the SAR imaging over time. Space agencies are also very active in monitoring and correcting for artifacts that might appear in the SAR products. Most SAR data providers provide calibration targets and performance metrics so that users know how well the SAR is calibrated in an absolute sense and from image to image (typically documented as an error in dB). Note that each image mode must be calibrated separately.

**Question 45: Is it possible to use SAR data in mapping disease and pest infestation in agricultural crops?**

Answer 45: I am not aware of research that would measure the disease directly. But if the disease/infestation impacts the structure of the crop, it makes sense that the radar might see that. A great research project!

**Question 46: Can SARcal-NDVI be used like NDVI to generate LAI using empirical equations?**

Answer 46: We have not carried that forward, but it makes sense that it would work. We are still researching the SARcal-NDVI, but your suggestion would be a good idea to try.



**Question 47: Hello, from Ethiopia. How could we use this technique for fragmented and diversified crop fields?**

Answer 47: These fields are more complicated, no doubt. But the physics of the radar interaction is the same. However, for these types of landscapes you will need to think about the resolution of the radar product. In Canada, we rely a lot on data collected at 10-30m resolutions, which is fine for our field sizes. In your situation, you will need to access SAR at higher resolutions, which many satellites offer.

**Question 48: Can we use the SNAP tool for larger-scale applications?**

Answer 48: In theory, yes. But you will likely want to build scripts to do so. This will be covered in the next ARSET webinars.

**Question 49: Will the Radarsat Constellation Mission data be free to global users?**

Answer 49: Users can access RCM data. However, they must first be vetted by the Government of Canada. Once vetted, they can access most SAR images collected by RCM.

**Question 50: While tracking the tillage events, how do you eliminate the effect of soil moisture?**

Answer 50: If our method monitors tillage by measuring changes in intensity over time and relates this to a tillage event, then soil moisture cannot change between acquisition 1 and acquisition 2. We would need knowledge of soil moisture to confirm that only roughness changes and not moisture. This is a limitation of a change detection approach. The physical IEM model models soil moisture (dielectric) and roughness (rms and l), but our experience using C-band SAR is that the IEM does not estimate roughness very well. This is one reason that the AAFC team is now looking at CCD or InSAR to detect tillage. This is an active area of research and results look good so far, but we are still wondering what the impact might be of changing soil moisture on this method as well.

**Question 51: Can we use the DInSAR method to monitor as well as track tillage events?**

Answer 51: This is an active area of research for our team. In short, yes. We believe this method will work. As farmers till their fields, the height of the soil changes and the distance between the soil and the SAR antenna changes as well.



**Question 52: Regarding the Radar-Based Vegetation Index (NDVI), for which crops does it work?**

Answer 52: To date, we have validated this for canola. But our team is also developing this method for corn, soybeans, and wheat. The application to other crops would be interesting.

**Question 53: What is the effect of incidence angle on crop identification? Could you explain?**

Answer 53: The effect of angle, in our experience in Canada, has not been a driving factor in our crop classification methods. Theoretically, we want the signal to penetrate the canopy, but not far enough as to create scattering from the soil. But in practice, the AAFC method integrates SAR data with many different angles. The cropping mixes are complex and different across the entire country. Thus, selecting one best angle is not easy for operations. You will see in the ARSET training of the AAFC Crop Mapping Roadmap that we integrate SAR data with different angles and the accuracies (SAR + optical data) are over 85%.

**Question 54: It appears that many crop differentiation examples are demonstrated through monoculture targets/fields. Can radar be used to classify/differentiate polyculture targets (i.e., will these crop mixtures have identifiable and discernible characteristics as well)?**

Answer 54: You are correct that in Canada, our fields are overwhelmingly monoculture. This would take some adaptation to use SAR and these methods to more complex cropping systems. Improved spatial resolution is one obvious way to adapt. We should also always think about the best data for the job at hand, and/or to integrate different sensors. In your case, it may be that very high resolution optical is the best option.

**Question 55: While tracking the tillage events, how do you eliminate the effect of soil moisture?**

Answer 55: Please see the answer to Question 51.

**Question 56: How do you correct for the effects of layover and foreshortening?**

Answer 56: Please see the answer to Question 20.

**Question 57: What is the most important approach/method to validate between the analyzed results and ground accuracy of crop types?**



Answer 57: You will see how AAFC approaches this in the ARSET training next week. In summary, some of our ground data is set aside for independent validation. We generate well known accuracy statistics (overall accuracy, users, producers [by crop type], and Kappa). Something that is missing is a measure of uncertainty. Our operations do not measure that, but it is also an important metric that you can consider calculating.

**Question 58: On slide 53 you mentioned "Never use SAR if it was raining at the time of the acquisition". But is there a way to correct for precipitation, e.g., if you want to use SAR to monitor an ongoing flooding event?**

Answer 58: The rain droplets create a great deal of scattering and “wash out” the image intensities. Very light rain, or “sprinkles”, may have less of an effect on scattering and you can certainly study whether under these conditions, the radar data is still usable (especially if you are only concerned with mapping flooded and non-flooded landscapes). But in general, images acquired during rain events cannot be corrected.

**Question 59: Are there any easy to use, free repositories for obtaining SAR data?**

Answer 59: ESA provides great access to Sentinel-1 data. In the other ARSET sessions you will learn how to access these data. Also, the Alaska Satellite Facility has a number of historic SAR datasets that are openly available.

**Question 60: Regarding tillage detection using Sentinel-1, do you apply a precise orbit file in processing? Since it is available 20 days after the image acquisition, it may be late for near-real time monitoring applications.**

Answer 60: Our current research is focused on the use of coherent change detection and tillage, where we are most focused on the change in coherence over time. However, if you are looking solely at the intensity data (and change in intensity over time), then the delay in the availability of the precise orbit information would impact real time monitoring. However, the impact of this delay will vary depending on the intended use of the tillage information. Often we are using this to track the uptake of best management practices, or to know the tillage/soil status just prior to the winter freeze-up. In this case, we do not need tillage information in near real time. But, of course, this requirement in product delivery times will change with user needs.

**Question 61: What is the physical parameter measured by radar in soil moisture assessments? Is it a relationship between the signal and the soil conductivity?**

Answer 61: Scattering is primarily related to soil permittivity.



**Question 62: You mentioned that water stores energy and releases it as the wave causes the molecules to rotate to align with the polarization. When the energy is released, does it travel back toward the source? Does it result in a lower or higher backscatter?**

Answer 62: Whether the energy scatters back to the SAR or forward scatters (or a combination of both) is dictated by the soil roughness. For rough soils, for example, the energy that is stored and then released will scatter in many different directions with some of that released energy scattering back to the SAR. If the soil is smooth, most of that stored energy will forward scatter away from the SAR antenna.

**Question 63: Is the slant range to ground range conversion performed by the sensor equipment? Or is it part of a post-processing step after the acquisition?**

Answer 63: This can be achieved in both ways. Many SAR data providers will provide an option to request slant or ground range products. But if you order slant range data and wish to convert to ground range, you can use software like SNAP to do so.

**Question 64: As per your opinion, can SAR data be used to monitor plant health conditions to minimize forest fires? Because radar waves can penetrate clouds, fog, etc.**

Answer 64: Yes. This can be done by estimating LAI or biomass directly from the SAR data. This is an area of active research and there are quite a few papers by many different researchers. We (and others) are also developing vegetation indices to estimate and track vegetation health and productivity.

Microwave data can also be used to estimate vegetation water content, however, this is an active area of research.

<https://nph.onlinelibrary.wiley.com/doi/10.1111/nph.15808>

<https://www.sciencedirect.com/science/article/pii/S003442572030167X?via%3Dihub>

**Question 65: What about the spatial resolution? Is it different from the optical satellite?**

Answer 65: Most SAR satellites offer a choice of many different modes. Typically these modes acquire SAR imagery in different spatial resolutions and swath sizes.

Resolutions can range from 1m up to 100m, depending on the mode selected.

**Question 66: We want to assess the crop water requirements for our project area, but we are always hindered by cloud cover during the monsoon and are unable to**



**use optical remote sensing data. I think SAR images will be greatly useful, but there is a lot of complexity involved. Do you think it's possible to estimate the crop water requirements using SAR images for a large contiguous area like 100,000 ha at intervals during a crop duration like 90 to 120 days?**

Answer 66: This could be tackled a number of different ways. There are methods (semi-empirical models like the Water Cloud Model or machine learning methods) that can estimate vegetation status (biomass, LAI, or even Vegetation Water Content). You would then need to link this to the requirements for the crop (if you now know the biomass, LAI, VWC relates to crop needs). We are also working on a SAR vegetation index (as are other researchers) which gives an indication of crop status, similar to NDVI.

**Question 67: Why does water vapor in the atmosphere not affect the microwaves, whereas water in the plant tissue does?**

Answer 67: This is partially about scale. The small water vapor particles in the atmosphere are much smaller than the size of the radar microwaves. As such, these water vapor molecules do not cause scattering. Large rain droplets will scatter the SAR microwaves, and we see this scattering in the radar imagery. Once the microwaves interact with the canopy, the water molecules in the vegetation rotate and store energy.

**Question 68: Are there any crops or structures that do not produce a significant signal that can be identified in SAR? Anything to be aware of or correct for when using the Sentinel-1 data in GEE?**

Answer 68: Some crops (or growth stages) may create more attenuation than scattering. This is because the elements (leaves and stems) are much smaller than the size of the incident waves. We also see attenuation of the SAR signal in wheat crops during booting. To be honest, we are not sure why this attenuation occurs. Nevertheless, it is the differential scattering (or attenuation) of the microwave among different crop types and growth stages that helps us map and monitor crops. Please listen in to the next ARSET training to ask questions on processing of Sentinel-1 data.

**Question 69: If I have the same crop but with different moisture content, does that mean I will get different results?**

Answer 69: Yes. You might see that. For example, when crops senesce at the end of season, the backscatter changes.





**Question 70: Is it generally difficult to obtain information when the ground is frozen? Or is it just something about SAR?**

Answer 70: This is unique to SAR. Freezing of the soil will not impact optical reflectance, for example.

**Question 71: What do you use between V and H in the event that the field being mapped is mixed with trees (e.g., in agroforestry)? What effects do changes in crop systems bring about in terms of change in use of V or H?**

Answer 71: HV or VH would also be a good choice for forest applications.

**Question 72: How can we access RADARSAT-2 temporal satellite data for the SMAPVEX16-Manitoba field project?**

Answer 72: These data are not publicly available, but please contact me to discuss.

**Question 73: Can you use thresholds to determine crop type and growth stage? Please share what threshold you used for corn and rice in Canada.**

Answer 73: We have not been using that approach. For crop type, we are using classification methods (DT, RF, etc.). For phenology, we are investigating machine learning methods.

**Question 74: Is it possible to download the RADAR imagery from R instead of Python?**

Answer 74: The SAR imagery is not downloaded this way. Maybe the question is about ingesting the data and can be asked during the next ARSET webinars.

**Question 75: Do satellites use different antennas to transmit and receive the EM signal (specially for those which have cross polarization)?**

Answer 75: It depends on the design. Some designs allow for transmitting and receiving in different polarizations with just one antenna. Other designs have two different antennas.

The design of the antenna and central electronics will be different if one wants to transmit H or V, or circular for that matter. If the SAR is transmitting H and receiving V, the antenna and electronics must be designed to do so.

**Question 76: It was mentioned in the lecture that penetration increases with an increase in wavelength, but I think it is the opposite. The shorter the wavelength,**



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**the higher the frequency, and hence the greater the penetrating effect. Please clarify.**

Answer 76: Refer to response #26.