



Questions & Answers Part 1

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 Sarah Banks (sarah.banks@ec.gc.ca), Laura Dingle-Robertson (laura.dingle-robertson@agr.gc.ca), or Sean McCartney (sean.mccartney@nasa.gov).

Question 1: What is the difference in the data for signals received in H and V, for a same signal sent in V?

Answer 1: A strong return in VV would indicate that your targets or elements within the resolution cell are also mostly vertically oriented (e.g., a field of wheat). A strong return in VH is indicative of multiple/volume scattering, so is typically observed in areas where targets also exhibit varying or random orientation (e.g., forested areas).

Question 2: Can a SAR sensor typically send out multiple polarizations? Or do they typically only have one or two? How can you tell in the data what polarization it is?

Answer 2: Most sensors today have the capacity to acquire multiple polarizations and even quad pol data. Radarsat-2, for example, can acquire any combination of HH, HV, VH, and VV (single, dual, or quad pol). Sentinel-1 can also acquire quad pol data, though most of the time operates in a coherent dual pol mode (e.g., VV and VH). You can always refer to the metadata to identify what polarization it is. Also, you can request a specific polarization to be acquired, and with time you can visually tell the difference, sometimes depending on the values you get from a specific land cover.

Question 3: How do I calculate RVI from Sentinel-1 data for areas where HH polarization data are not available?

Answer 3: The Radar Vegetation Index (RVI) is a vegetation index that was created from fully polarimetric data (HH, VV and VH/HV). Therefore it is not possible to generate RVI using Sentinel-1 dual polarimetric data. However, you can generate the cross-pol ratios of VV/VH or HH/HV and see if there are relationships with crop type or condition that are similar to the relationships with RVI. In the next session in this series, we will describe deriving pseudo-polarimetric parameters from dual pol SLC Sentinel-1 data including generating parameters like the Stokes vectors, degree of linear polarization, etc.



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Question 4: Can you provide more information about the indices, e.g. if they will be suitable? You mentioned understanding physics, but can you provide more context information or where to look to see if it makes sense?

Answer 4: Consider how you expect the wave to scatter within your target of interest. Let's consider vegetation. As Sarah stated, these types of targets have randomly oriented components (leaves, stalks, etc.) and this will create a re-polarization and depolarization of the incident wave. The cross-polarization intensities (HV or VH) are indicative of this type of scattering. Given this, consider ratios or indices that use HV or VH. The Radar Vegetation Index (RVI) is a good example of that. However, if we limit ourselves to ratios that do not exploit HV or VH (think about HH/VV, for example), we will miss important information about the vegetation target. A lot of research has been published that has demonstrated the sensitivity of HV or VH to crop biomass, LAI, etc. And this all links back to how the wave scatters within the vegetation. As such, consider SAR systems and SAR imaging modes which capture the cross-polarization intensities (HV or VH), and select indices and other methods that exploit the cross polarization. There are also other SAR parameters, which can be derived from fully or dual polarimetric data that, like HV or VH, are sensitive to volume scattering. These include, for example, the degree of polarization and the volume scattering component of SAR decompositions (like Freeman-Durden). A couple of papers to start with:

Steele-Dunne, S.C., McNairn, H., Monsivais-Huertero, A., Judge, J., Liu, P-W., and Papathanassiou, K. (2017). Radar remote sensing of agricultural canopies: a review. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, 10: 2249-2273.

Homayouni, S., McNairn, H., Hosseini, M., Jiao, X, and Powers, J. (2019). Quad and compact multitemporal C-band PolSAR observations for crop characterization and monitoring, *International Journal of Applied Earth Observations and Geoinformation*, 74: 78-87.

Question 5: Can we choose a DEM of higher resolution instead of SRTM?

Answer 5: Yes. You should consider the DEM that is appropriate for your area and provides the highest resolution. You can use a DEM that is outside of the list of SNAP options to best suit your needs.



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Question 6: I would like to know which criteria should be considered to choose the most adequate speckle filter. In the example the gamma filter was chosen. Why this one?

Answer 6: It is important to choose a radar filter that respects the statistics of radar scattering, but also reduces noise. There are other “radar adaptive” filters that can be selected. Gamma is one that is widely used, but not the only appropriate radar filter. Gamma does tend to preserve linear features such as field edges. Second, the size of the filter kernel should be adapted to the size of the unit/target (in this case the field size). It is advantageous to use as large a filter kernel size as possible to reduce noise. Refer back to the ARSET training from October 2021, where we covered SAR basics and applications to crop monitoring.

Laura Dingle Robertson, Andrew Davidson, Heather McNairn, Mehdi Hosseini, Scott Mitchell, Diego De Abelleira, Santiago Verón & Michael H. Cosh (2020) Synthetic Aperture Radar (SAR) image processing for operational space-based agriculture mapping, *International Journal of Remote Sensing*, 41:18, 7112-7144

DOI: [10.1080/01431161.2020.1754494](https://doi.org/10.1080/01431161.2020.1754494)

Question 7: Can we apply polarimetric parameters (ratios, RVI etc.) after preprocessing of the data (like speckle filtering, terrain and radiometric correction, subsetting)? Or is it to be applied before these steps as told here? What could be the differences between the two results?

Answer 7: We generally follow these steps to process the data and generate the polarimetric parameters. We have completed research in the past on the order of operations for our crop classification preprocessing and have found that in many cases it doesn't make a difference for intensity or backscatter, other than the time to process the imagery. This can be important for operational endeavors.

<https://doi.org/10.1080/01431161.2020.1754494>

Laura Dingle Robertson, Andrew Davidson, Heather McNairn, Mehdi Hosseini, Scott Mitchell, Diego De Abelleira, Santiago Verón & Michael H. Cosh (2020) Synthetic Aperture Radar (SAR) image processing for operational space-based agriculture mapping, *International Journal of Remote Sensing*, 41:18, 7112-7144

DOI: [10.1080/01431161.2020.1754494](https://doi.org/10.1080/01431161.2020.1754494)



Question 8: How do you calculate the plant height from Single Look Complex (SLC) data?

Answer 8: Recall that we can use phase to represent time or distance from the wave leaving the SAR antenna to when it reaches the target (and returns). SLC data contain intensity and phase information. Using phase (with techniques like InSAR) can be tricky for targets like vegetation. With repeat pass InSAR (where we measure changes in phase from one image acquisition to the next image acquisition), temporal decorrelation can occur. Decorrelation is a result of, for example, the position of the scatterer (leaves for example) changing over time. These changes could be due to crops filling out, or due to effects like the wind changing where leaves are in space. For some crops with very large leaves (like bananas), which may be less affected by phenomena like wind, temporal decorrelation may be less of an issue. In these cases, a change in phase (distance that the wave travels) from image to image might be indicative of the plant height changing. Recall as well that with SLC data we can generate a lot of polarimetric parameters (not just HV or VH intensity, but also volume scattering, entropy, etc). Another way to potentially estimate crop height is to use these SAR parameters in semi-empirical models like the Water Cloud Model (WCM). WCM has been used to estimate crop parameters like biomass and LAI, and it could be assessed for crop height. The critical issue is that field measurements of plant height are needed to calibrate the WCM. Here are some papers on the WCM:

Hosseini, M., McNairn, H., Mitchell, S., Dingle Robertson, L., Davidson, D., Ahmadian, N., Bhattacharya, A., Borg, E., Conrad, C., Dabrowska-Zielinska, K., de Abelleira, D., Gurdak, R., Kumar, V., Kussul, N., Mandal, D., Rao, Y.S., Saliendra, N., Shelestov, A., Spengler, D., Veron, S.R., Homayouni, S., and Becker-Reshef, I. (2021). A comparison between support vector machine and water cloud model for estimating crop leaf area index, *Remote Sensing*, 13, 1348, doi:10.3390/rs13071348.

Mandal, D., Kumar, V., Lopez-Sanchez, J., Bhattacharya, A., McNairn, H., and Rao, S.(2020). Crop biophysical parameter retrieval from Sentinel-1 SAR data with a multi-target inversion of Water Cloud Model, *International Journal of Remote Sensing*, 41:5503-5524, doi: 10.1080/01431161.2020.1734261.

Hosseini, M., McNairn, H., Mitchell, S., Dingle-Roberston, L., Davidson, A., and Homayouni, S. (2019). Synthetic aperture radar and optical satellite data for estimating the biomass of corn, *International Journal of Applied Earth Observations and Geoinformation*, available online, doi.org/10.1016/j.jag.2019.101933



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Hosseini, M., and McNairn, H. (2017). Using multi-polarization C- and L-band radar to estimate biomass and soil moisture for wheat fields. *International Journal of Applied Earth Observation and Geoinformation*, 58:50-64

Question 9: What are the best "vegetation" indices (for crops) we can estimate from Sentinel-1?

Answer 9: Our AAFC research team has developed a SAR vegetation index calibrated to NDVI. We started the method (in paper below) using fully polarimetric RADARSAT-2 data. We have now adapted this to use Sentinel-1 data. The Sentinel-1 publication is under review, but results have been very good. The SAR index is able to track crop development over the season, and is correlated with crop biomass. In the case of Sentinel-1, we are using several polarimetric parameters derived from Sentinel-1 SLC data to estimate crop condition.

Jiao, X., McNairn, H., and Dingle Robertson, L. (2021). Monitoring crop growth using a canopy structure dynamic model and time series of Synthetic Aperture Radar (SAR) data, *International Journal of Remote Sensing*, 42:6437-6464, doi: 10.1080/01431161.2021.1938739.

Question 10: Please tell me how to download microwave remote sensing images for the above analysis?

Answer 10: For the RCM data, the data used in this research are available from the ARSET site. However if you want access to the RCM catalog you can do this by going to the Earth Observation Data Management Site (EODMS) website (see below) and register for an account. Next you can apply for vetted user access. There is a link on the EODMS site. <https://www.eodms-sgdot.nrcan-rncan.gc.ca/>

[https://wiki.gccollab.ca/Earth_Observation_Data_Management_System_\(EODMS\)#RADARSAT_CONSTELLATION_MISSION_.28RCM.29](https://wiki.gccollab.ca/Earth_Observation_Data_Management_System_(EODMS)#RADARSAT_CONSTELLATION_MISSION_.28RCM.29)

<https://appliedsciences.nasa.gov/join-mission/training/english/arset-mapping-crops-and-their-biophysical-characteristics>

Question 11: How do I make corrections in the tiles to make it homogenous while doing a mosaic?

Answer 11: This might be a good question for our ESA colleagues. Refer to the coming presentations in Part 3 & 4 of the webinar series.



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Question 12: What might be some good resources/lists to study SAR based indices?

Answer 12: As part of our work as the @SistersofSAR on twitter, Laura, Heather, and I, plus Dr. Gopika Suresh, maintain a list of SAR training resources, which can be found here: <https://sistersofsar.wixsite.com/sistersofsar/sar-resources>. You will find information on SAR based indices plus much more. Today there are many resources online. Here is a good review paper to start with as well:

Steele-Dunne, S.C., McNairn, H., Monsivais-Huertero, A., Judge, J., Liu, P-W., and Papathanassiou, K. (2017). Radar remote sensing of agricultural canopies: a review. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 10: 2249-2273.

Question 13: Does RVI correlate with NDVI? Where does it fail?

Answer 13: In our research, the strength of the correlation between RVI and NDVI has varied. For some crops, the correlations are pretty strong, and for others they are not as well correlated. Remember that RVI also uses HH and VV, and HH is not often a useful polarization for crops (HH is better for forage crops, but not other crops like corn, soybeans, wheat, etc.). Our team at AAFC is developing a radar VI that uses mostly polarimetric parameters sensitive to volume scattering (like HV/VH, entropy, volume scattering, etc.)

Question 14: Is there any non-negligible impact of wind and other weather conditions over intensity and polarization returns? And if so, how can we eliminate them?

Answer 14: This will depend on your target. Hard targets probably won't be affected by wind and weather conditions, but vegetation can be. Wind can change the orientation of vegetation, which in turn will affect backscatter. If your canopy is wet, this can also affect your data, but it can be difficult to remove these affects. We conducted a study many years ago and demonstrated that early morning dew on a crop canopy can also impact backscatter (see paper below). As well, in temperate regions, the freezing of soil will change the dielectric and thus impact SAR backscatter. It is important to pay attention to environmental conditions (rain, dew, freeze/thaw). The best strategy is to select satellite orbits (descending or ascending passes) when you believe for your study region, these environmental impacts will be less likely to occur.



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Wood, D., McNairn, H., Brown, R.J., and Dixon, R. (2002). The effect of dew on the use of RADARSAT-1 for crop monitoring: choosing between ascending and descending orbits. *Remote Sensing of Environment*, 80:241-247.

Question 15: The RVI formula uses sigma nought data but the calibration in the example outputs complex numbers. Is calibration to sigma enough not required?

Answer 15: Sigma nought is the radar reflectivity per unit area in ground range, so it reflects how the data are calibrated, which is different from how we express phase and intensity (using complex numbers).

Question 16: Can those parameters be calculated with RADARSAT-2?

Answer 16: Yes. Because RADARSAT-2 is fully polarimetric data, these parameters can also be calculated using RADARSAT-2 data.

Question 17: How can cross-pol power and volume scattering power be analyzed over agricultural fields?

Answer 17: HV/VH intensity and the amount of volume scattering (from polarimetric decompositions) are typically highly correlated. Both are useful for crop monitoring. These can be used to help classify crops because we know that different crops will create different amounts of volume scattering. Think about the structure of the target...different crops have different structures and this creates different amounts of volume scattering. Thus both HV/VH and volume scattering will be different from one crop to another. In addition, we know that the structure of a crop will change as it grows. As such, HV/VH intensity or volume scattering will also be correlated with changes in crop biomass and other indicators of crop development (like LAI). There are several methods that can use cross-pol or volume scattering to monitor crop growth. These SAR parameters can be used in semi-empirical models (like the Water Cloud Model), or in machine learning (ML) algorithms. Both have produced good results. A few references to these methods are listed under Questions 4, 8 and 9. An addition reference below, uses ML to estimate crop phenology:

McNairn, H., Jiao, X., Pacheco, A., Sinha, A., Tan, W., and Li, Y. (2018). Estimating canola phenology using synthetic aperture radar, *Remote Sensing of Environment*, 219: 196-205.



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Question 18: When you talk about phase data, are you referring to the phase difference between the emitted wavelength and the received one? I just want to confirm if I got it right or not. Thank you.

Answer 18: It would be the phase difference between, for example, HH and VV. Imagine we transmit H and V at the same time. The phase difference would be the time delay between them when we receive them separately at the sensor.

Question 19: As far as I know, a 35-45 degrees incidence angle is mostly suitable for crop monitoring with the SAR dataset. A bit more explanation on that will be helpful. Thanks.

Answer 19: I don't think it's as straightforward as a particular incidence angle range. We also have to consider the SAR frequency and the size of the crop canopy. Our ultimate goal is to have a wave (based on frequency and incident angle) that penetrates deep enough into the canopy to create the opportunity for the wave to scatter amongst the leaves and stalks, but not so deep that it interacts with the soil. As you can imagine this required depth of penetration will vary whether we use X or L band radars, if we are imaging sugarcane or alfalfa, and when in the growing season we are gathering our data (is the crop still small or at peak biomass). Having said that, typically, very steep angles tend to have greater soil contributions regardless of canopy or SAR frequency, and these steep angles would be less desirable.

Question 20: Is Polarization only Horizontal and Vertical? Can it be at an angle?

Answer 20: Technically, waves can be transmitted and received at any angle (and thus polarization). In fact ambient waves are found in many different polarizations. However, SAR antennas are typically designed to transmit and receive in the linear horizontal and linear vertical only. Those are the most common transmit and receive polarizations. Compact polarimetric sensors are one exception. Sensors like the RADARSAT Constellation Mission (RCM) can transmit circularly polarized waves, and receive H+V (coherently).

Question 21: Can SAR data be used in deriving an optical image vegetation index?

Answer 21: The AAFC team has developed a SAR vegetation index calibrated to NDVI. The first rendition of the index was based on RADARSAT-2 data (see reference, below). A new adaptation to the SAR VI uses Sentinel-1 data (paper is in review). Xianfeng Jiao, Heather McNairn & Laura Dingle Robertson (2021) Monitoring crop growth using a canopy structure dynamic model and time series of synthetic aperture radar (SAR) data, International Journal of Remote Sensing, 42:17, 6433-6460



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Question 22: The sensor ALOS has ceased to operate since 2011. How do we currently obtain polarimetric datasets?

Answer 22: ALOS 2 and PALSAR 2 L-band polarimetric data are available through JAXA, and SAOCOM data are available from ESA (I believe) for L-band data. NISAR will acquire dual linear polarization data globally, and will acquire fully polarimetric data over some select regions of the world.

<https://alos-pasco.com/en/>

<https://earth.esa.int/eogateway/missions/saocom>

<https://nisar.jpl.nasa.gov/>

Also, there is some fully polarimetric ALOS PALSAR (2006-2011) data over certain regions. These can be downloaded through the Alaska Satellite Facility:

<https://asf.alaska.edu>

Question 23: To what extent can RVI be compared with NDVI? Is data fusion possible?

Answer 23: See question 13. With respect to RVI, research published by our team at AAFC has indicated that RVI is correlated with vegetation condition for some crops, but not all. As such our team has created a SAR VI that is calibrated to NDVI. We have coupled the SAR VI with a crop model, such that vegetation condition can be determined, daily.

Jiao, X., McNairn, H., and Dingle Robertson, L. (2021). Monitoring crop growth using a canopy structure dynamic model and time series of Synthetic Aperture Radar (SAR) data, *International Journal of Remote Sensing*, 42:6437-6464, doi: 10.1080/01431161.2021.1938739.

Question 24: May we assume that different crops generate different signal responses based on SAR, which we may further use to recognize different crops?

Answer 24: Completely, we have done a lot of research in terms of the SAR response of different crop types. Consider the differences in structure among different crop types, and how crop structure changes throughout the growing season. As a wave enters a crop canopy, how the wave scatters (intensity and scattering characteristics) changes depending on the structure of the canopy. We can exploit the variations in



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SAR response due to canopy structure to map different crop types or monitor how crops develop throughout the season.

Question 25: What are the critical factors to combine ascending and descending modes? What is an effective way to do so?

Answer 25: ASC and DSC orbits have a couple of impacts – time of day (ask if your target is changing diurnally) and look direction between the SAR antenna and target. If your target has an orientation (think about crops grown in rows, or direction of soil tillage), there can be an impact between ASC and DSC. For crop classification, we have combined ASC and DSC to improve repeat coverage. But for biophysical modeling, one should pay much closer attention to these differences. Diurnal changes can impact your target (dew in the morning, freeze thaw of soil); orientation of row features (planting, tilling) with respect to SAR look direction, will impact response.

Question 26: What is the effect of water vapor in the air on the polarization of the EM waves?

Answer 26: The water vapor in the air is not generally something that we are concerned about from the radar perspective, because the size of the water vapor molecules is small relative to the SAR wave. This is not true of water droplets, which are larger and can scatter radar waves. The ionosphere will slightly impact the polarization of longer waves (like L-band) but this impact is often addressed during SAR calibration.

Question 27: Can SNAP be used to monitor carbon sequestration?

Answer 27: There is a significant amount of research on estimating aboveground biomass using SAR, especially using longer wavelengths L and P band SAR, which can penetrate into the canopy providing information on its structure. Though these data are not widely available (some archive data through JAXA), new missions like BIOMASS and NISAR will be free and open. One approach is to build an empirical model using field data. You can process the data to do this in SNAP, or you can measure height from SAR and use that as an input to an allometric equation, and to do that you can use something called InSAR, which can also be done in SNAP. If we are thinking about soil carbon sequestration, this cannot be directly estimated with SAR. However, it may be possible to determine land management practices that impact soil carbon (cover crops, tillage and residue). The AAFC team is assessing the use of SAR to, for example, determine if farmers are tilling fields. Tillage will impact soil health and the rate of decomposition of post-harvest residue.



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Question 28: How do we choose between gamma and sigma transformations?

Answer 28: Typically in agriculture applications we utilize a sigma nought conversion because it's understandable in relation to the ground as it's a measure in relation to a unit area on the ground. Gamma nought is typically used for calibration as the range cell is equally distant to the satellite so both the near and far range are equally bright. There may be instances when it may be useful to use a gamma nought transformation.

Question 29: Does SNAP only work with full granules/tiles as the initial input? Is there any way to take advantage of COG partial reads to read & process only a subset of an S1 granule?

Answer 29: Next week we will describe how to minimize the amount of a S1 image that we will be using for deriving the pseudo polarimetric SAR parameters. This will include reducing the data to specific sub swaths and individual bursts. S1 images are very large and take quite a bit of time to process.

Question 30: Can these processes (pre-processing) be implemented in Google Earth Engine?

Answer 30: Depending on what you want to do. Ground range detected data are available in GEE. This may be all you need for your application, but currently, you will need to go outside of GEE to have access to full-phase information which is stored in single look complex data.

Question 31: Is the biomass index (and other indices) accurate, if data comes from a sensor with a short wavelength (e.g., Sentinel-1 with 5cm)?

Answer 31: The only index in SNAP that we have examined for agriculture has been the RVI. With RVI we are evaluating its use, using C-band SAR. As a general comment, always consider the size of the wave with the canopy (total biomass). Because different canopies have different amounts of biomass (crop to crop) and biomass changes over the season (beginning, middle, end), a multi-frequency approach is very helpful.

Question 32: How can we deal with the biomass saturation issues, particularly with Sentinel-1 data?

Answer 32: There is no simple answer to this. It really relates back to physics (size of wave and its ability to penetrate). Wait for NiSAR, and this will be a great opportunity to integrate the L and C band. We often think about longer wavelengths being better but that is not necessarily true. Longer L-band waves for example, can penetrate too far



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into a smaller canopy and too much of the signal scattering comes from the soil. For agriculture, combining different frequencies will be very useful.

Question 33: There are some negative pixels in the ASTER GDEM. How do you remove them?

Answer 33: You could edit the DEM if you are able to store it locally, then point to that edited DEM when using SNAP. It might be worthwhile to check whether these negative values have been removed. I am not sure what version SNAP is grabbing.

Question 34: In the southeast Asian region, paddy and jute are the most cultivated crops. On both, the field properties change from time to time, and with that, the dielectric properties change too. So how does that impact RVI?

Answer 34: RVI is measuring total scattering (this will be due to the structure and biomass of the crop, but also the water in the target). It will be difficult to separate out the contribution of water to total backscatter. Instead, consider semi-empirical models, such as the Water Cloud Model (WCM). In WCM we can model both the dielectric/water contributions as well as other contributions such as biomass. Some references are provided under Question 8.

Question 35: Is the RCM data commercial or is it also open access?

Answer 35: RCM Satellites are owned by the Government of Canada and there is open access to the data through the process that I described above. That being said the data collection is programmed mostly over Canada; however, there are imagery being acquired over other areas of the world. Follow the procedure to get vetted user access and you can check that catalog to see what is available.

Question 36: In the Philippines, croplands are very small (the majority of the farmers have less than 1 hectare), do you think polarization or any software manipulation can help determine different indices and crop classification with such very small area against the hardware resolution limitation of the SAR satellites?

Answer 36: Often we find with these very small crop areas we need higher spatial resolution imagery; however other options that we think will help with crop classifications in such areas are these polarimetric parameters; or multifrequency SAR along with classifiers that can take into account these very complex cropping systems. These would include deep learning methodologies such as neural networks (AI). We have been looking at areas in the world that have very complex cropping systems with



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small fields and we are finding better classification results using polarimetric parameters and multi-frequency data.

Question 37: For compact-pol SAR data, is there any available vegetation index in SNAP?

Answer 37: Not yet, but this would be completely doable. Compact polarimetric (CP) can be decomposed to provide metrics like entropy and volume scattering. We have developed SAR VI that uses these exact same polarimetric parameters. As such, there is no reason to believe CP would not perform equally well. There is one study (below) where we have looked at the volume to surface ratio using simulated CP:

Homayouni, S., McNairn, H., Hosseini, M., Jiao, X, and Powers, J. (2019). Quad and compact multitemporal C-band PolSAR observations for crop characterization and monitoring, *International Journal of Applied Earth Observations and Geoinformation*, 74: 78-87.

Question 38: How do you use Sentinel-1 for soil moisture estimation and correlate it to the ground observations?

Answer 38: There is an excellent approach that has been developed by a group in Italy. This is a change detection approach. The changes in backscatter from Sentinel-1 over time are linked with soil moisture. This has been validated at several sites around the world. It has worked very well for two test sites in Canada, as an example.

Balenzano, A., Mattia, F., Satalino, G., Lovergine, F.P., Palmisano, D., Peng, J., Marzahn, P., Wegmüller, U., Cartus, O., Dabrowska-Zielińska, K., Musial, J.P., Davidson, M.W.J., Pauwels, V.R.N., Cosh, M.H., McNairn, H., Johnson, J.T., Walker, J.P., Yueh, S.H., Entekhabi, D., Kerr, Y.H., and Jackson, T.J. (2021). Sentinel-1 soil moisture at 1km resolution: a validation study, *Remote Sensing of Environment*, 263 DOI: doi.org/10.1016/j.rse.2021.112554.

Question 39: I have noticed in some literature that Gamma0 is the preferred choice when preparing analysis-ready SAR data for vegetation analysis purposes. Can you share your opinion?

Answer 39: See question 28. There is some literature that does support the use of Gamma nought, but typically what we see in agriculture applications is the use of Sigma nought.



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Question 40: Is down- or up-scaling (resampling) possible for SAR data? Are there special controls or care that must be taken?

Answer 40: The same consideration should be given if you were down or up scaling optical data. For example, resampling from fine to coarse resolution, does not produce new information. For continuous data, nearest neighbor resampling should be avoided. You should process your data before applying resampling to preserve phase information, and resampling multiple times should be avoided.

Question 41: Can we calculate the radar vegetation index with a simple polarization? If not, can we consider the radar vegetation index as an intrinsic parameter to polarimetry?

Answer 41: The RVI as presented here is calculated using simple intensity. It is not a polarimetric parameter per se where phase must be considered. Thus, I wouldn't necessarily call it intrinsic to SAR polarimetry.

Question 42: Can we use machine learning algorithms (traditional and deep neural networks) to classify crop types or predict crop characteristics (e.g., LAI, biomass) without deriving indices? Can we let the algorithm handle finding important features so that we do not need to calculate indices?

Answer 42: Absolutely! Though it depends on what method you are using that will determine the algorithm's capacity to "find" important features. Random forest, for example, will not calculate additional features from what you provide. In that case it might be advantageous to calculate these indices. They may be more important than the intensity values alone.

Question 43: How do we check the polarimetric calibration (both intensity and phase) of dual, compact, and quad PolSAR data over an agricultural test site?

Answer 43: Most often, the degree of calibration will be posted by the SAR data provider, either in publications, on their websites, or in metadata. If you cannot find this then I would suggest reaching out to the data provider. This information will include absolute calibration (against calibration targets like corner reflectors for intensity and polarimetric active radar calibrators for polarimetric data [intensity and phase]) and relative calibration (stability of system over time, often comparing backscatter from "flat" targets like the rainforest measured repeatedly over time). For a user to assess calibration, it is a bit tricky and less precise, unless you know that there is a point calibration target in your image. If you have temporally coincident data from different sensors (perhaps RADARSAT and Sentinel-1), you can compare the responses of both.



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If you have a “flat” target over time (like the rainforest) where you do not expect scattering to change over time, then you can extract backscatter profiles for multiple images to determine if the backscatter is deviating over time (and indicative of a relative error). Finally, sometimes, responses seem “odd” and outside of what would be expected. An easy example is that cross-pol responses (for distributed targets) should be less than co-pol responses. As well, sometimes image artifacts are visible in an image and if that is the case, you can reach out to the data provider to see if there is a protocol to reprocess or mitigate these artifacts. In conclusion, most SAR’s are backed up by a team of calibration experts. No SAR system is without system errors (absolute and drifting over time). What is important is that the degree of system error is understood by the user so that they are not attempting to measure a target response that is within these error budgets.