Questions & Answers Part 2

Please type your questions in the Question Box. We will try our best to get to all your questions. If we don't, feel free to email Laura Dingle-Robertson (laura.dingle-robertson@agr.gc.ca), Armando Marino (armando.marino@stir.ac.uk) or Sean McCartney (sean.mccartney@nasa.gov).

Question 1: Are Single Look Complex (SLC) or Ground Range Detection (GRD) SAR images useful in crop mapping?
Answer 1: The simple answer is that both can be used for crop mapping. Typically, if you are only interested in using SAR intensity, you will only need to use the GRD (Ground Range Detected) data; however, if you require a richer dataset to classify your crop types you can use the Single Look Complex (SLC) data and derive the polarimetric parameters as we've describe here. We have found that in our research, the polarimetric parameters add additional value in separating crop types (accuracies are higher and the improvement in classification is crop type specific). This improvement can be explained by the fact that the difference in SAR response from one crop to another, is not only about the differences in the intensity/magnitude of the SAR backscatter from crop to crop. How the wave scatters (how the energy is depolarized and the angle of scattering) can be very informative. We have found, for example, that the Stokes parameters perform very well in crop classification, as these 4 parameters capture much more about the characteristics of scattering than simply the intensity of backscatter.

Question 2: How can we georeference the output of PolSARPro? I ask because SNAP provides georeference outputs to any preprocessing.
Answer 2: The Python script that we have provided and explained during this presentation georeferences the output of the PolSARPro parameters.

Question 3: Why wasn't SNAP used for deriving polarimetric parameters although the tool is available there?
Answer 3: The polarimetric parameters that can be derived with SNAP require fully polarimetric (e.g. quad pol) data and this is why we used a combination of SNAP and PolSARPro to generate the polarimetric parameters from the dual polarimetric Sentinel-1 data. Additionally PolSARPro provides many more polarimetric

functionalities that SNAP does not have. This is why we wanted to show you this fantastic tool that is available to the community.

Question 4: What is the difference between Single Look Complex (SLC) and Ground Range Detection (GRD)?
Answer 4: SLC stands for Single Look Complex, which is the image in complex number format (keeping the phase information). GRD stands for Ground Range Detected and here the data are in a real number format where we consider the intensity of the complex number. This means that the phase information is lost in the GRD data. Some PolSAR processing (e.g. Cloude-Pottier decomposition) cannot run without the phase information.

Question 5: Can we clip SLC/GRD data to a particular Area of Interest (AOI) and then do all the preprocessing? If so, how?
Answer 5: It is the step S1 Tops Split, which reduces the data to specific bursts within a specific subswath. Interferometric Wide swath data has 3 subswaths with multiple bursts each. You will need to know within which subswath (or subswaths) and which bursts your AOI is located. In addition, there is also a function called Subset in SNAP that can be used for this. However, Subset can sometimes create artifacts or errors and therefore the processing approach shown in the presentation is more robust.

Question 6: When applying an Orbit file I face the Node Id error and no orbit file is downloaded, and for some dates and scenes it can't be downloaded manually from POD. Could you please help, thanks.
Answer 6: We have at times run into this problem too. It can be related to either firewall issues within your organization or to the SNAP edition that you are using (there was a known issue, which has been corrected by the SNAP development team). It could also be related to whether or not the precise orbit file is available. There are threads on ESA's STEP Forum that can provide suggestions as to how to correct this issue.
https://forum.step.esa.int/

Question 7: What is the difference between a speckle filter applied to GRD imagery and the polarimetric speckle filter applied to SLC imagery?
Answer 7: Polarimetric speckle filters in SNAP are designed to preserve the phase. Be sure to select a polarimetric speckle filter for SLC data, otherwise phase statistics will be distorted and any polarimetric parameters derived from the SLC data will not be correct/accurate. In a nutshell, you will lose information if you apply any averaging on

complex images before converting them into a covariance matrix format or Stokes vector format. This is because you need to average/filter the second order statistics of the scattering vector. Additionally, once polarimetric parameters are generated (like entropy), other radar adapted filters can be applied to these data layers without the risk of losing polarimetric information.

Question 8: During Stokes parameter generation, why do we set a 5x5 window size? What is the default for this operation?
Answer 8: This is a sliding window size that takes the average of the matrix value, further reducing noise. This can be set to what is appropriate for your area of interest. In our research, we found that a 5x5 window size is appropriate (based mostly on the size of our agricultural fields). However, we often suggest that you test different window sizes for your area of interest to see how a changing window size changes the output. There is no “one size fits all”.

Question 9: Relating to the Entropy / Alpha (slide 41), is there a list of entropy examples for paddy?
Answer 9: In our experience, Entropy in particular has been very useful for mapping and monitoring crop growth (not only crop type, but growth stage and crop condition). We do not have an exhaustive list of papers to cite with respect to polarimetric research in paddy rice, but a literature search will likely reveal research in the use of E/A. Once you begin to work with fully or partially polarized SAR data (from S1, RCM, SAOCOM, etc.) you will find that these polarimetric parameters have a strong correlation with crop development. One reference to start with is:
Subhadip Dey, Narayanarao Bhogapurapu, Avik Bhattacharya, Dipankar Mandal, Juan M. Lopez-Sanchez, Heather McNairn & Alejandro C. Frery (2021) Rice phenology mapping using novel target characterization parameters from polarimetric SAR data, International Journal of Remote Sensing, 42:14, 5519-5543, DOI: 10.1080/01431161.2021.1921876

Question 10: Is there a relationship between Entropy and any other vegetation index?
Answer 10: Yes, absolutely. Our research has proven, repeatedly, that entropy (degree of randomness) varies depending on crop type, but also crop condition and crop growth stage. The degree of randomness in scattering changes as crops develop (due to an increase in biomass and Leaf Area Index [LAI]). As you can imagine, even though the transmitted wave is fully polarized when it enters the canopy, as vegetation

structure changes as crops grow, the predictability of how a wave scatters (not only in terms of intensity but scattering characteristics) decreases. We have found that Entropy is correlated with LAI and also NDVI. Having said that, using multiple SAR polarimetric parameters will improve the accuracy of tracking crop development (thus think about exploiting more than just Entropy).

Question 11: Last time the SAR NASA training was done with Google Earth Engine (GEE), is it not possible to do processing with GEE?
Answer 11: GEE is a great tool, but unfortunately up to now it does not host SLC images, it only hosts GRD images. Therefore if you want to use the phase information, the only way to do this in GEE is to upload the SLC data yourself. Additionally, some of the functionalities in SNAP are not implemented as functions in GEE, so you will need to do quite some coding to supply them.

Question 12: Can we also use Google Colaboratory as an alternative to Jupyter?
Answer 12: I believe this is a possibility and I have heard of people doing this. The advantage is that it boosts collaboration and you can store products in the Cloud. We don't use it because we prefer to run everything on our servers and keep most of the intermediate data products with us, but I can definitely see the advantages of Google Colab.

Question 13: Can polarimetric parameters like RVI and forest degradation index be computed from the Sentinel-1 data?
Answer 13: As we mentioned last week, these are intensity derived parameters and within SNAP, the tool that generates these require fully polarimetric parameters. This is because RVI requires the intensity of HH as well as VV and VH (rather than just dual pol S1). However, we mentioned that there are ways to generate RVI-like (e.g. RVI4S1) indices using Sentinel-1 data. This link: https://custom-scripts.sentinel-hub.com/custom-scripts/sentinel-1/radar_vegetation_index/ provides access to a script that will generate an RVI from Sentinel-1 data. Another source is: Mandal, D., Bhattacharya, A., Rao, Y.S. (2021). Radar Vegetation Indices for Crop Growth Monitoring. In: Radar Remote Sensing for Crop Biophysical Parameter Estimation. Springer Remote Sensing/Photogrammetry. Springer, Singapore. https://doi.org/10.1007/978-981-16-4424-5_7

Question 14: Is there any reason to start the processing pipeline in SNAP with "Apply Orbit File" or can we move that process down in the pipeline, e.g. after "Terrain Correction"?
Answer 14: Typically we follow this particular order of operations in SNAP to maintain the phase information and generate the C2 matrix for export to PolSARPro. You can try to change the order of operations as long as the phase information is preserved (e.g. not geocoding SLC data before transforming it into a covariance matrix format). We have found through testing that this particular order works and generates the appropriate C2 matrix required to be used in PolSARPro.

Question 15: Is there any information about how to interpret the values generated with PolSAR pro regarding crop characteristics? (I mean stokes parameters, degree of linear polarization, entropy, etc.)
Answer 15: This is a very important point and often, users exploit these parameters without fully understanding the connection between these parameters and the biophysical characteristics of the target (crop canopy). There is some information in the literature that describes the relation between the parameters and crop characteristics. Some papers have discussed the physics behind parameters like entropy, alpha, anisotropy, pedestal height, span, and degree of polarization. These papers discuss why these parameters change when crops develop, and in general, these SAR parameters are responding to changes in the balance between the amount of polarized and unpolarized scattering within the canopy. In addition, how the wave scatters in terms of the difference between the H and V components, will change the degree of ellipticity of the response. As such, not only does the amount of depolarization increase as crops develop, but the ellipticity also changes. We have linked some of these parameters (like Stokes parameters) to crop phenology, LAI and biomass (as the structure of the crop changes during its growth). Remember as well, that many polarimetric parameters are highly correlated. Some references include:

Löw, J., Ullmann, T. and Conrad, C. 2021. "The Impact of Phenological Developments on Interferometric and Polarimetric Crop Signatures Derived from Sentinel-1: Examples from the DEMMIN Study Site (Germany)." Remote Sensing, 13 (15). doi: 10.3390/rs13152951.

Mercier, A., Betbeder, J., Baudry, J., Le Roux, V., Spicher, F., Lacoux, J., Roger, D. and Hubert-Moy, L. 2020. "Evaluation of Sentinel-1 & 2 Time Series For Predicting Wheat

And Rapeseed Phenological Stages." ISPRS Journal of Photogrammetry and Remote Sensing, 163:231-56. doi: 10.1016/j.isprsjprs.2020.03.009.

Wiseman, G., McNairn, H., Homaayouni, S., and Shang, J. 2014. "RADARSAT-2 Polarimetric SAR Response to Crop Biomass for Agricultural Production Monitoring." IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 7:4461-4471. doi:10.1109/JSTARS.2014.2322311

Chirakkal, D. Haldar, and A. Misra, "Evaluation of Hybrid Polarimetric Decomposition Techniques for Winter Crop Discrimination," Progress In Electromagnetics Research, vol. 55, pp. 73–84, January, 2017.

Question 16: What is the BEST (i.e., optimal for pricing) virtual machine in cloud service for resolving these tasks?
Answer 16: I do not have enough experience about processing data in the cloud except for GEE (which is free), so I am not the best person to comment on this. But I believe there is not an all-purpose optimal option. It depends on what you need to do in terms of speed of processing, tools offered, cost of storage, etc. On the web, you can find lots of comparisons about cloud services and you will need to find out what suits your application the best.

Question 17: Could it be possible to consider providing a virtual operating system (Windows/Linux), which is ready-to-use with the all necessary setups (e.g. Python, SNAP, libraries like spectra, etc.) for the training, and can be downloaded and used in virtual machines–for example Oracle virtual machine? It will save a lot of time and we can just focus on image processing and the training.
Answer 17: SECOND PART: Indeed you are right, installing libraries is often difficult. For the practical on SAOCOM and RCM you will not need to install any libraries (other than the Anaconda installer), but if you want to bring this to another level, you will indeed need to install external libraries (GDAL and Rasterio for example) and also their updates. It takes some time at the start, but I find that tools like Anaconda are very useful.

Question 18: Instead of Python, can we get all the described tasks done in MATLAB? Can we run MATLAB scripts in SNAP?
Answer 18: Indeed you can use MATLAB to run SNAP functions. You can do absolutely everything shown in the second part of the practical using MATLAB. I have never tried

to run the gpt of SNAP using MATLAB, but I am aware this is possible. If MATLAB is your favorite programming language you can definitely use it.

Question 19: Can we use the Python script for Sentinel-1 C2 matrix for time series analysis? Was the geocoding operation only performed on the stack?
Answer 19: SECOND PART: yes we can process the time series of S1 using Python, in a very similar way that we did with RCM and SAOCOM data. The main difference is that S1 is dual-pol and not quad-pol. This means you need to remove/comment some lines of code where we use the third missing image. The geocoding was performed on the covariance matrices by SNAP, and the geocoded images were stacked (in SNAP) using Co-registration to a master. Python can be used to call and run these SNAP functions using the Graph Processing Tool gpt.

Question 20: After doing this processing can I set these data as benchmark datasets for machine learning and is that going to be valid? I ask because the wavelength will not be the same depending on the different sensors I may have to collect data from multiple satellites?
Answer 20: You are absolutely correct. Different crop canopies have different amounts of biomass. Not only does biomass vary from crop to crop, but biomass also changes as crops grow. Research has demonstrated repeatedly that integrating different SAR frequencies will be extremely helpful in delivering accurate crop maps, and to monitor crop condition throughout the season. We want the radar waveform to penetrate into the crop canopy to scatter within the canopy, but we do not want the wave to scatter too far such that some scattering comes from the soil. This is why a multi-frequency approach will deliver the best results.

Question 21: Can we apply the same procedure for mangrove studies?
Answer 21: Absolutely, there are many research studies which have used polarimetric SAR to map and monitor wetlands, including coastal wetlands.

Question 22: How can we display the Entropy/Anisotropy/Alpha info in the H/a diagram (scatterplot) to see the distribution of scatterers (python code)?
Answer 22: The easiest way to plot “H” against “alpha” is to use the pyplot function {scatter}. The first two arguments are the x and y coordinates of your plot. So you have something like:

```
plt.figure()
```

```
plt.title('My title')
plt.scatter(H, alpha)
```

However if you have lots of points you may have problems discerning the shape of the distribution. An alternative is generating a 2D histogram.

```
plt.hist2d(H, alpha)

plot.show()
```

You can explore all the {hist2d} parameters to make the figure more visually appealing.

Question 23: Can we use simple GDAL command lines to create and associate hdr and img output files (stuck files)?
Answer 23: If I understand this correctly the question is about using GDAL to read the header files of the images in the stack, and to save images in ENVI format. The answer is yes, you can do it, you can use GDAL instead of Spectral. I use Spectral here because I found that this is easier to install if it is your very first library you are installing. I have experience with students having some issues installing GDAL, but nobody I know had big issues with Spectral. My suggestion to you, if you want to do this more operationally, is to absolutely get GDAL installed.

Question 24: You have talked about multi-looking and boxcar filtering, can you explain the differences between these processing steps?
Answer 24: Polarimetric speckle filters, like Boxcar filtering, are applied to SLC data after they are converted in the covariance matrix format. The covariance matrix format preserves the phase information since it contains the second order statistics of the scattering vector. This means that the phase statistics are not distorted and that any polarimetric parameters that are subsequently generated are correct. Multi-looking also reduces noise, just as the boxcar, but it reduces the number of pixels at the end. What it does is basically decimating (i.e. subsampling) the data by picking 1 pixel for each window size. Multi-looking is also applied to data in the covariance matrix format and NOT in the native SLC (complex data) format. However, be careful because if you apply multi-looking before you create the covariance matrix, the phase will not be preserved. In summary, a multi-looked component of the covariance matrix is equal to a boxcar filtered component of the covariance matrix after subsampling.

Question 25: I would like to know about the availability of SAOCOM imagery. What is the procedure to get those?
Answer 25: Very interesting point. I am aware that CONAE is discussing the possibility of offering some of their fantastic datasets for free to the scientific community. The best, if you want to know more, is to contact CONAE about this, but I believe some SAOCOM data will be available in the future. Stay tuned :)

Question 26: In the case of dual-Pol data, does entropy and alpha have the same meaning as the Full-Pol case?
Answer 26: The E and alpha values you get using dual and quad-pol processing are NOT the same in theory, because the interpretation of alpha requires the use of the Pauli basis which is not accessible with dual pol data. However, whether H and alpha are calculated from T3 or C2 matrices, these are highly correlated and are responding to/sensitive to the same biophysical crop parameters. E and alpha (from dual-pol SLC or FP) tell us the same thing about the randomness of the scattering from point to point in the field, and what type of scattering dominates. Research at AAFC has investigated the E and alpha from both data sets, and have found excellent results (crop classification and tracking crop growth) using both sources of data. For more information, please refer to:
Cloude, S. 2007. "The Dual Polarization Entropy/Alpha Decomposition: A PALSAR Case Study," Proceedings of the 3rd International Workshop on Science and Applications of SAR Polarimetry and Polarimetric Interferometry, edited by H.; Ouwehand Lacoste, L. Noordwijk, Netherlands, 644:1-6.