# POLARIMETRY EXERCISE IN POLSARPRO: CLASSIFICATION AND SHIP DETECTION WITH QUAD POL AND DUAL POL DATA (ALOS PALSAR, RADARSAT-2 AND TERRASAR-X)

This exercise uses data from different bands and sensors, both quad pol and dual pol, to do classification and detect ships using polarimetric techniques.

List of datasets:

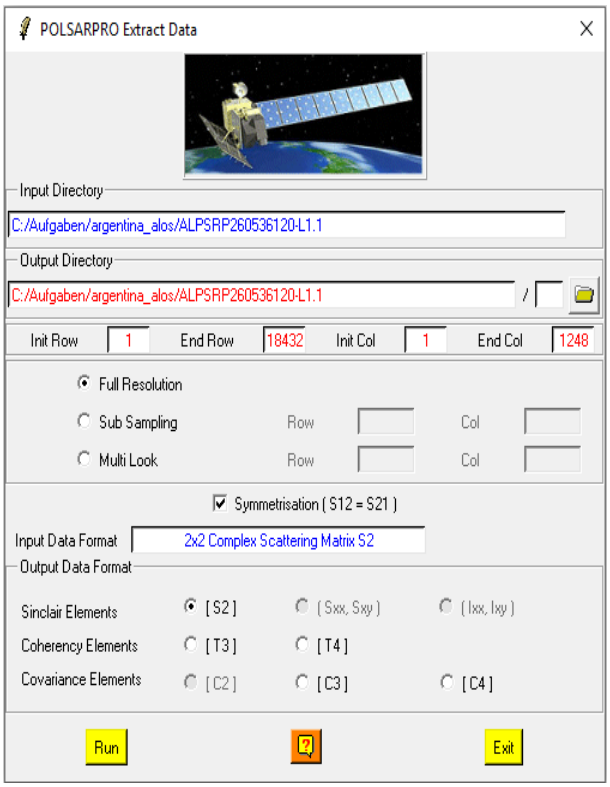
| Sensor | | Acquisition date | Image ID | Area |
|---|---|---|---|---|
| TerraSAR-X (X-Band) | Stripmap Polarisation: HH+ VV | 2014-01-28<br>2014-03-02<br>2014-03-13<br>2014-04-15<br>2014-09-05 | 1483504<br>1483506<br>1483508<br>1483512<br>1623765 | Buenos Aires |
| Radarsat-2 (C-Band) | Polarisation: HH+VV+HV+VH | 2018-08-31<br>2017-09-22<br>2017-09-22 | 662586<br>588510<br>588510 | Buenos Aires<br>Puerto Madryn<br>Puerto Madryn |
| ALOS PALSAR (L-Band) | Polarisation: HH+VV+HV+VH | 2010-12-15<br>2011-04-06 | ALPSRP260536120-L1.1<br>ALPSRP276866490-L1.1 | Strait of Magellan<br>Buenos Aires |

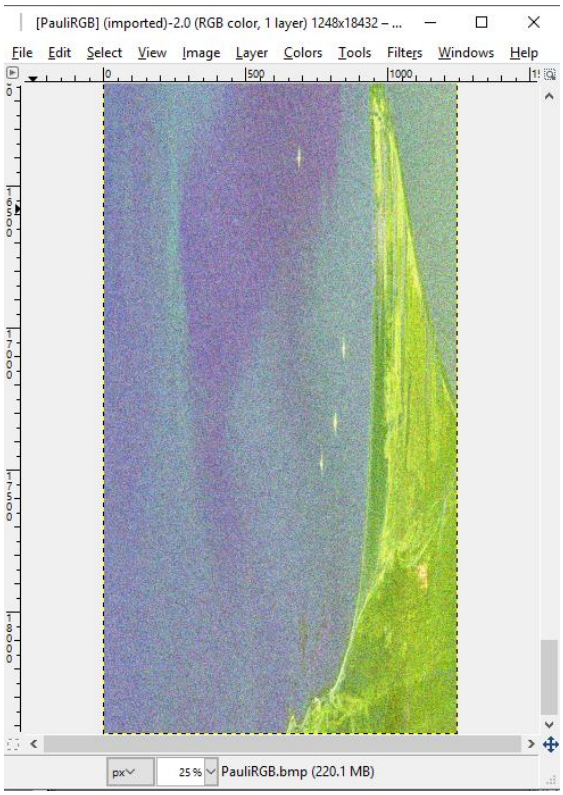
The instructions below are applicable to the three sensors below, besides small adaptations in step 1, where the specific path depends on the sensor used. Note however that, even if with dual pol datasets (such as TerraSAR-X) it is possible to do Cloude-Pottier decomposition and ship detection (the processing is identical), it is not possible to do change basis, Yamaguchi decomposition or any compact pol analysis.

1. Importing Data
   1.1. Go to *Environment / Single Data Set* and select the folder that contains your unzipped original dataset, This is where we will save the outputs of this image. In case a pop-up window appears warning you that no data files were found, close it by clicking 'Yes'.
   *1.2.* Go to *Import / Spaceborne Sensors / Alos-1 – Palsar / Quad-Pol/ CEOS Format* and select the Alos-1 file which starts with 'LED'. Now click on the 'Check Files' button and then on the 'Read Header' button. Confirm your choice with 'Ok'.

2. Visualizing Pauli RGB
   After importing the data, the Pauli RGB is automatically stored in the output folder. This will create an RGB image of the scene in Pauli representation in the current data directory. If you have linked an image viewer like GIMP to PolSARpro, the image will display automatically.
   *2.1. Import / Extract PolSAR images.* Here you can select different visualizations (Full Resolution, Sub Sampling, Multi Look) Select 'Full Resolution'.
   *2.2.* Leave the default parameters. Click Run. Create a link with GIMP if asked, and wait until the RGB image is displayed.

   Observe the sea appears blue (surface scattering), land is a mix of colours with plenty of green (volume scattering) and ships are sometimes red (horizontal dihedral scattering). Notice the zoom option at the bottom of the window.




3. Preliminary multilook

A common pre-processing step for many SAR applications is multilooking. This process is used to reduce speckle and to create pixels on the ground with a more square shape.

3.1. Go again to Import / Extract PolSAR images

3.2. Select 'Multi Look' and enter 3 and 1 into the Row and Col fields respectively. This choice is determined by the fact that pixel spacing is 9m and 3m.

3.3. Verify that the output data format is '[T3]', then run the process. This will create a folder called "T3".

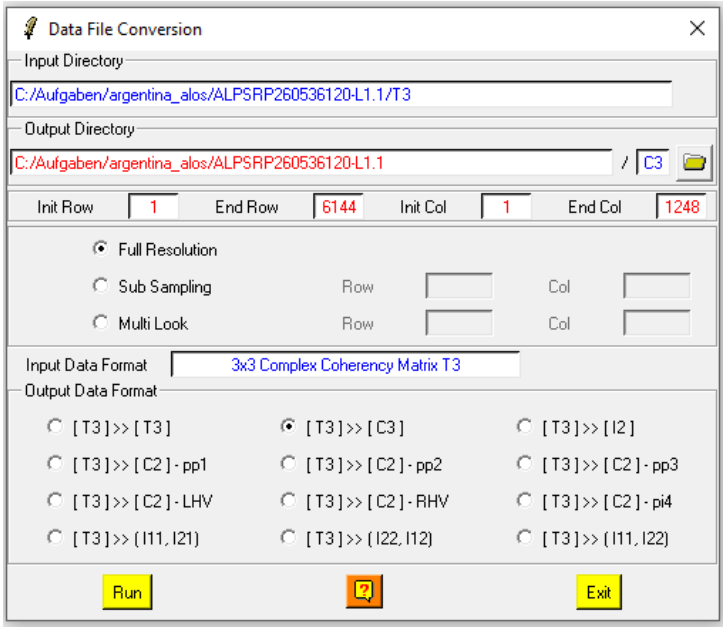
4. Convert coherency matrix (T3) to covariance matrix (C3)

There are different ways to represent radar images. We can use PolSARpro to convert data from one representation into another. Here we will convert the image from a complex coherency matrix representation (T3) to a complex covariance matrix representation (C3). This might be useful to, for example, evaluate the correlation between HH and VV.

4.1. Go to *Convert*

4.2. Select 'Full Resolution' and '[T3]>>[C3]' as output data format.

Once the covariance matrix has been created, a new folder named 'C3' will appear in your working directory. All your data representations are saved in separate folders which allow you to switch between them easily. To do so, use the 'Polarimetric Data Format' option in the upper left corner of the user interface.




## 5. Polarimetric decompositions

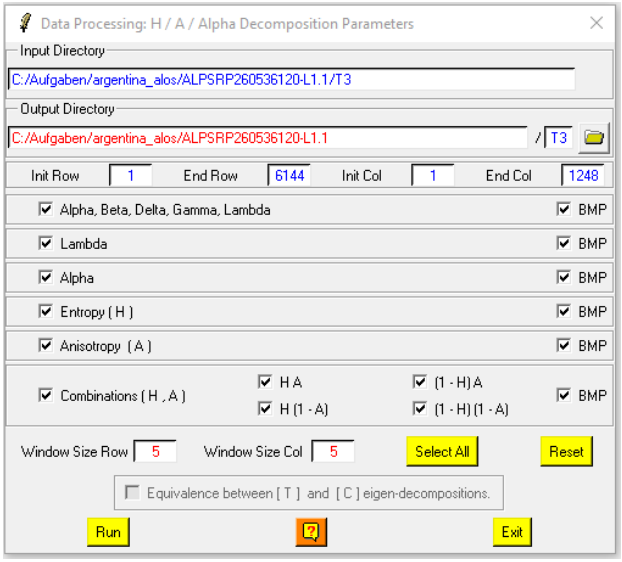
Decompositions help interpret the scene and extract information. In this step you will compute the Cloud-Pottier decomposition, and make .bmp images of each of the parameters. In practice you will only use a limited amount of parameters, but it is educational to have a look at all of them

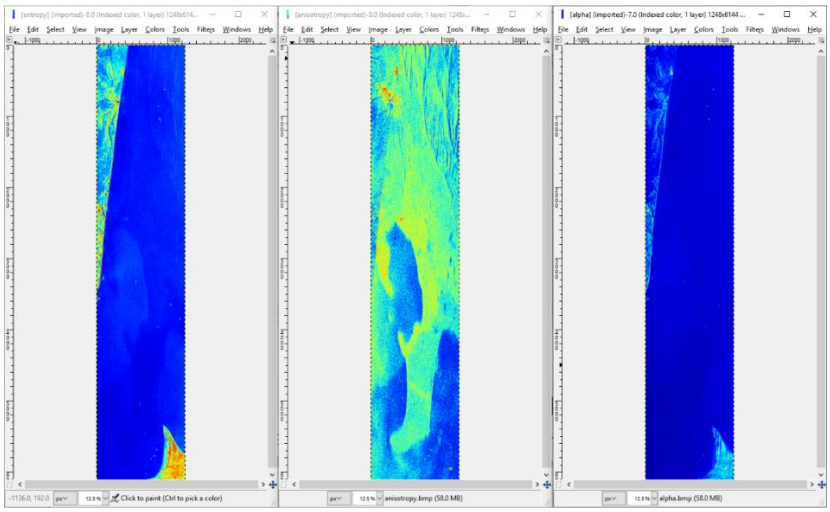
### 5.1. Cloude-Pottier Decomposition (H, A, Alpha Decomposition)

5.1.1. Switch to T3 representation using the 'Polarimetric Data Format' button.
5.1.2. Process / H, A, Alpha Decomposition / Decomposition Parameters
5.1.3. Click on 'Select All' to create images for all possible decompositions.
5.1.4. Set Window Size Row and Col to 5 each.
5.1.5. Run

Note: Some averaging is needed because the 3x1 boxcar applied earlier is not enough to estimate properly the decomposition parameters. In this example you have 15 x 5 pixels, which is a decent number of pixels. You can experiment with smaller or larger windows.

Note that, you can apply the Cloude-Pottier to any matrix format (i.e. space basis), even dual pol (e.g. C2). With other basis, the decomposition still return a result, but the interpretation of some parameters (e.g. alpha) is different. So you need to take care about the matrix is selected to apply the decompositon (upper left corner).





5.2. Yamaguchi 4 Component Decomposition

This is an example of a model based decomposition. Here we want to decompose (i.e. project) the data over a pre-defined scattering model. Some averaging is again needed. Also, to prevent oriented dihedrals from being confused as volume, it is useful to apply de-orientation of the data. The three parameters are useful to separate targets, even in situations where the model does not fit too well (the model was originally developed for forests).

5.2.1. Go to Process / Polarimetric Decompositions / YAM4
5.2.2. Select 'Four Component Decomposition with Rotation Transformation'
5.2.3. Tick the options 'With / Without Extended Volume Scattering Model', 'TgtG … ' and 'BMP Target Generators'
5.2.4. Finally, set the window size to 5 in each direction.
5.2.5. Run

## 6. Hybrid polarimetry

SAOCOM will acquire compact natively, therefore you will not need to perform the step in this section when working with SAOCOM. But if you start from quad-pol, you need to emulate hybrid data with the following procedure. We are converting the 3D covariance matrix into a 2D hybrid covariance matrix. We select the hybrid which uses Left circular for transmitter and Horizontal and Vertical linear for receivers.

6.1. Switch to C3 representation using the 'Polarimetric Data Format' button (top left corner).
6.2. Go to *Convert a*nd select [C3]>>[C2] – LHV
6.3. This will create an output folder called C2

## 7. Raney decomposition

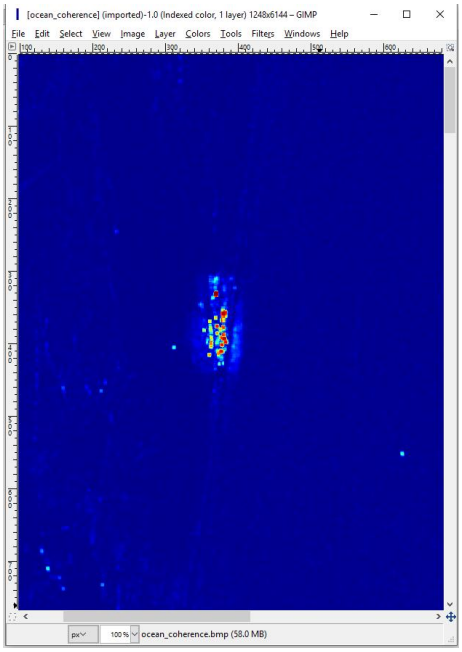
We can still do lots of dual pol decompositions. In particular Raney decomposition was developed specially for this type of compact data. If we observe the difference between surface scattering and volume scattering we can still appreciate that it does not work bad over the sea. It is not as good as with quad pol, but we improve with respect to single pol. Also Raney is only one decomposition, there are others you can apply.

7.1. Process / Polarimetric Decompositions / 2KR : Raney Decomposition
7.2. Check the options 'TgtG …' and 'BMP Target Generators (TgtG)' and leave the rest as default.
7.3. Run

## 8. Ship Detection

In this final section you can explore the new algorithms implemented in PolSARpro during the ESA POLSARap project. This is a collection of POLSAR applications in different environments. There is also one for ocean which contains a ship detector, the polarimetric notch filter.

8.1. Change the data representation to T3 using the 'Polarimetric Data Format' button.
8.2. Go to *Education / PolSAR-ap Showcases / Ocean*
8.3. Set Window Size-Test to 5 by 5, the threshold value to 0.9 and the reduction ratio to 0.01.

In the resulting image, ships are clearly visible. The map of polarimetric coherence is high when the object is different from the sea. A threshold on this coherence returns a detector.

Repeat the steps in this tutorial for the other full pol datasets (Radarsat-2).