



SENTINEL-1 Toolbox

Polarimetric Tutorial

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Polarimetric Tutorial

The goal of this tutorial is to provide novice and experienced remote sensing users with step-bystep instructions on working with RADARSAT-2 data with the Sentinel-1 Toolbox. The tools have to be developed with the goal of making polarimetric processing easy to use and intuitive.

In this tutorial you will process a Quad Pol RADARSAT-2 product and produce polarimetric classifications of the data.

For an introduction to polarimetric concepts, please see the "<u>Radar Polarimetry</u>" chapter of the "<u>Fundamentals of Remote Sensing</u>" tutorial from the Canadian Centre for Remote Sensing (CCRS).

Sample Data

Sample data for RADARSAT-2 Fine Quad-Pol products supplied by MDA can be found at:

https://mdacorporation.com/geospatial/international/satellites/RADARSAT-2/sample-data

For this tutorial, we will use the Vancouver Fine Quad Frame 1 dataset. Vancouver in British Columbia is the third largest metropolitan area in Canada located on the Pacific coast.



Vancouver Fine Quad Frame 1 Location in World Map

Download the Vancouver_R2_FineQuad15_HH_HV_VH_VV_SLC products.

Supported Products

The toolbox can support Quad Pol SLC products from:

- RADARSAT-2
- TerraSAR-X
- ALOS PALSAR 1 & 2

The toolbox can support Dual Pol SLC products from:

- SENTINEL-1
- ENVISAT ASAR
- RADARSAT-2
- TerraSAR-X

ALOS PALSAR 1 & 2

Opening a Quad Pol Product

In order to process fully polarimetric data, the input products should be Quad Pol (HH, VV, HV, VH) products and should also be Single Look Complex (SLC).

Step 1 - Open a product: Use the ^{COND} **Open Product** button in the top toolbar and browse for the location of the **Vancouver Fine Quad Frame 1 RADARSAT-2** product.

Select the product.xml file and press Open Product.

If your product is contained within a zip file, the Toolbox will also be able to open the product simply by selecting the zip file.

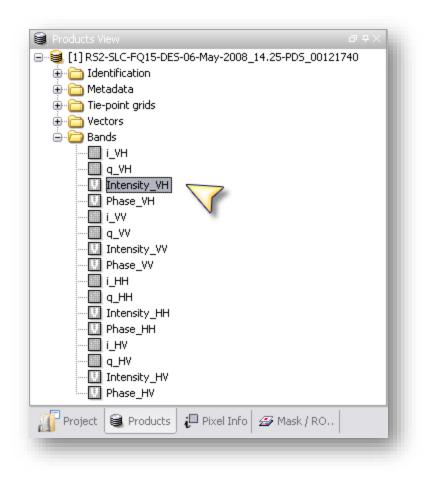
Look in:	Uancouver	_R2_FineQuad15_Frame2_SLC	 ≫
	퉬 schemas		
24	🛃 BrowseIm	age.tif	
Recent Items	DFAIT_RS	2 Single User License.pdf	
	🛃 imagery_l	H.tif	
_	🛃 imagery_ł	IV.tif	
	🛃 imagery_\	/H.tif	
Desktop	🛃 imagery_\	(V.tif	
,	📋 lutBeta.xn	h	
	📄 lutGamm	a.xml	
	IutSigma.	ml	
My Documents	product.x	ml	
	readme.tx	t	
Computer			
compater			
	File name:	product.xml	Open Product
Network	Files of type:	All Files	 Cancel

Opening a Product

Step 2 - View the product: In the **Products View** you will see the opened product. Within the product bands you will see four polarizations:

- VH
- VV
- HH
- HV

For each polarization, there will be the complex data i and q bands and two virtual bands for intensity and phase.



Products View

Step 3 - View a band: To view the VH band, double-click on the **Intensity_VH** band. Zoom in using the mouse wheel and pan by clicking and dragging the left mouse button.



Intensity_VH Band

Pan and zoom to the Vancouver airport area.

Creating a Subset

To reduce the amount of processing needed, you may create a subset around the particular area in which you are interested.

Step 4 - Create a subset from the view: Once you have zoomed and panned to your area of interest, right click on the image view and select Spatial Subset from View in the Context menu.

Geometry from WKT
WKT from Geometry
Export Transect Pixels
Export Mask Pixels
Export View as Google Earth KMZ
Export View as Image
Export Colour Palette as File
Export Colour Legend as Image
Spatial Subset from View
Copy Pixel-Info to Clipboard

Context Menu

The subset dialog will automatically select the area you were viewing.

🖆 Specify Product Subset 🛛 🔀					
Spatial Subset Band Subset Tie-Point Grid Subset Metadata Subset					
	Pixel Coordinates Geo Coord	dinates			
	Scene start X:	53 🚔			
	Scene start Y:	4041 🚔			
	Scene end X:	2361 🚔			
	Scene end Y:	5695 🚔			
	Scene step X:	1 💌			
Contraction of the local sectors of the local secto	Scene step Y:	1 🛬			
	Subset scene width:	2309.0			
	Subset scene height:	1655.0			
	Source scene width:	3332			
	Source scene height:	7009			
	a	Estimated, raw storage size: 29.1M			
		OK Cancel Help			

Specifying Product Subset

By default, all bands will be included in the subset. You will need all the bands to do the polarimetric processing. Press **OK** to create the subset.

Calibrating the Data

To properly work with the SAR data, the data should first be calibrated.

Calibration radiometrically corrects a SAR image so that the pixel values truly represent the radar backscatter of the reflecting surface.

The corrections that get applied during calibration are mission-specific, therefore the software will automatically determine what kind of input product you have and what corrections need to be applied based on the product's metadata. Calibration is essential for quantitative use of SAR data.

Step 5 - Calibrate the product: From the Radar menu, go to the Radiometric menu and select Calibrate.

Apply Orbit File	_	
Radiometric	•	Calibrate
Speckle Filtering	•	Radiometric Terrain Flattening
Coregistration	•	Remove Antenna Pattern
Interferometric	•	S-1 Thermal Noise Removal
Polarimetric	•	Convert Sigma0 to Beta0
Geometric	•	Convert Sigma0 to Gamma0

Radiometric Menu

The source product should be your newly created subset. The target product will be the new file you will create. Also select the directory in which the target product will be saved to.

Polarimetric Tutorial

Calibration X	Calibration X
File Help	File Help
I/O Parameters Processing Parameters	I/O Parameters Processing Parameters
Source Product source: [2] subset_0_of_RS2-SLC-FQ2-DES-15-Apr-2008_14.38-PDS_0511 v Target Product Name: subset_0_of_RS2-SLC-FQ2-DES-15-Apr-2008_14.38-PDS_05116980_Cal Save as: BEAM-DIMAP v Directory: C:\\$1TBX Tutorials V Open in SNAP	Source Bands: I_HH I_HH Intensity_HH Intensity_HH I_HV I_HV I_HV Intensity_HV I_VH I_VH V ENVISAT Auxiliary File: I_atest Auxiliary File Save in dB Create gamma0 virtual band Create beta0 virtual band
Run Close	Run Close

Calibration Dialog

If you don't select any source bands, then the calibration operator will automatically select all real and imaginary (i, q) bands.

NOTE

For polarimetric processing the data must be complex. By default, the calibration operator will produce real sigma0 bands. To produce complex output, check mark the **Save in complex** parameter.

What Polarimetric Tools are Available?

In order to properly exploit the information within polarimetric data, you will need processing tools that convert that data into more useable forms for analysis.

The Toolbox includes polarimetric tools for:

- Polarimetric Matrix Generation
- Polarimetric Speckle Filtering
- Polarimetric Decompositions
- Polarimetric Classification

Polarimetric Matrix Generation

All the polarimetric tools work with either Coherency or Covariance matrices as input. Starting from a Quad Pol SLC product, you may use the **Matrix Generation** operator to convert the product into one of the following matrices:

- Covariance matrix C2
- Covariance matrix C3
- Covariance matrix C4
- Coherency matrix T3
- Coherency matrix T4

The Coherency matrix T3 is sometimes preferred because its elements have a physical interpretation (odd-bounce, even-bounce, diffuse, etc.).

Use the **Matrix Generation** operator when you would like to explicitly select which matrix to use. For simplicity, a Quad Pol SLC product can be used directly by any polarimetric operator. In such a case, the input Quad Pol will automatically be converted to a T3 matrix.

Step 6 - Generate a T3 matrix: Select Polarimetric Matrix Generation from the Polarimetric menu.

Radar Tools Windo	w Help	>
Apply Orbit File		—
Radiometric	>	
Speckle Filtering	>	
Coregistration	>	
Interferometric	>	
Polarimetric	>	Compact Polarimetry
Geometric	>	Polarimetric Classification
Sentinel-1 TOPS	>	Polarimetric Matrix Generation
ENVISAT ASAR	>	Polarimetric Speckle Filter
SAR Applications	>	Polarimetric Orientation Angle Correction
SAR Utilities	>	Polarimetric Decomposition
		Polarimetric Parameters
		Cross Channel SNR Correction

Polarimetric Menu

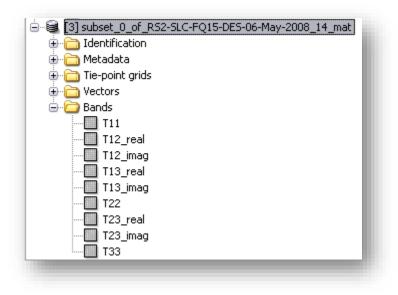
The source product should be your newly created calibrated subset. The target product will be the new file you will create. Also select the directory in which the target product will be saved to.

Generate Covariance or Coherency Matrix X	Generate Covariance or Coherency Matrix X
File Help	File Help
File Help I/O Parameters Processing Parameters Source Product source: [3] subset_0_of_RS2-SLC-FQ2-DES-15-Apr-2008_14.38-PDS_0511 Target Product Name: subset_0_of_RS2-SLC-FQ2-DES-15-Apr-2008_14.38-PDS_05116980_Cal_mat Subset_0_of_RS2-SLC-FQ2-DES-15-Apr-2008_14.38-PDS_05116980_Cal_mat Subset_0_of_RS2-SLC-FQ2-DES-15-Apr-2008_14.38-PDS_05116980_Cal_mat Subset_0_of_RS2-SLC-FQ2-DES-15-Apr-2008_14.38-PDS_05116980_Cal_mat Subset_0_of_RS2-SLC-FQ2-DES-15-Apr-2008_14.38-PDS_05116980_Cal_mat Subset_0_of_RS2-SLC-FQ2-DES-15-Apr-2008_14.38-PDS_05116980_Cal_mat Subset_0_of_RS2-SLC-FQ2-DES-15-Apr-2008_14.38-PDS_05116980_Cal_mat Subset_0_of_RS2-SLC-FQ2-DES-15-Apr-2008_14.38-PDS_05116980_Cal_mat Subset_0_of_RS2-SLC-FQ2-DES-15-Apr-2008_14.38-PDS_05116980_Cal_mat Other subset_0_0_F	File Help I/O Parameters Processing Parameters Polarimetric Matrix: T3 C2 C3 C4 T3 T4
Run Close	Run Close

Generate Covariance or Coherency Matrix Dialog

In the **Processing Parameters** tab, select a **T3** matrix to convert the Quad Pol product into a Coherency matrix T3. Press **Run** to begin processing.

When the processing completes, a new product will be added to the **Products View**. You will notice the new bands produced correspond to the elements of the **T3** matrix.



Products View Showing New Bands Produced

Polarimetric Speckle Filtering

To clean up some of the speckle inherent in SAR images, you can apply a speckle filter. When working with a single polarized detected or SLC image, you may use the conventional Speckle Filters found in the **SAR Processing** menu. However, for full polarimetric data, there are polarimetric speckle filters available that take advantage of all bands and preserve the complex information.

For polarimetric speckle filtering, the following filters are available:

- Boxcar
- Improved Lee Sigma
- Refined Lee
- Intensity Driven Adaptive Neighbourhood (IDAN)

Step 7 - Apply a Speckle Filter: Select Polarimetric Speckle Filter from the Polarimetric menu.

Apply Orbit File Radiometric Speckle Filtering Coregistration Interferometric)))	
Polarimetric	•	Launch PolSARPro
Geometric		Compact Polarimetry
Sentinel-1 TOPS		Polarimetric Matrix Generation
ASAR WSS	- F 🔁	Polarimetric Speckle Filter
Feature Extraction		Polarimetric Orientation Angle Correction
Biomass		Polarimetric Decomposition
Soil Moisture	•	
SAR Utilities	•	Polarimetric Unsupervised Classification
		Supervised Classification Training
Complex to Detected GR		Supervised Wishart Classification
Multilooking		Supervised Wishart classification

Select Polarimetric Speckle Filter

In the **Processing Parameters** tab, select the **Refined Lee** speckle filter. Press the **Help** button to call up the online help for further information.

length Polarimetric Speckle Filter X	Separation Polarimetric Speckle Filter
File Help	File Help
I/O Parameters Source Processing Parameters Source: [3] subset_0_of_RS2-SLC-FQ2-DES-15-Apr-2008_14.38+PDS_0511 v	I/O Parameters Processing Parameters Speckle Filter: Refined Lee Filter Number of Looks: 1 Window Size: 7x7
Target Product Name: Subset_0_of_RS2-SLC-FQ2-DES-15-Apr-2008_14.38-PDS_05116980_Cal_Spk Save as: BEAM-DIMAP Directory: C:\S1TBX Tutorials Open in SNAP	
Run Close	Run Close

Polarimetric Speckle Filter Dialog

Press Run to begin processing.

When the processing completes, your new speckle filtered product should have the same bands as your T3 product, however the data will have been filtered.

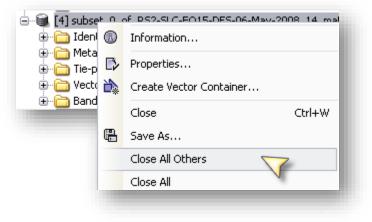
Open the **T11** band in both the **T3** product and in **new speckle filtered T3** product to compare before and after images. The resulting image will have less speckle but also appear more blurred.



Before

After

To clean up your **Products View**, you may now right-click on the **speckle filtered T3** product and from the popup menu select **Close All Others** to close all other products and leave only the **speckle filtered T3** opened.



Closing All Other Products in Products View

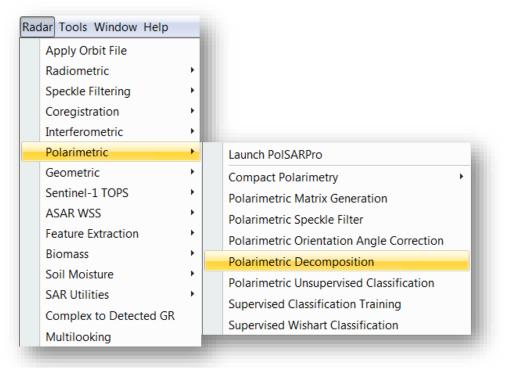
Polarimetric Decompositions

Polarimetric decompositions allow the separation of different scattering contributions and can be used to extract information about the scattering process.

The following polarimetric decompositions are available:

- Sinclair
- Pauli
- Freeman-Durden
- Yamaguchi
- Van Zyl
- Cloude
- H-a Alpha
- Touzi

Step 8 - Produce a decomposition: Select **Polarimetric Decomposition** from the **Polarimetric** menu.



Select Polarimetric Decomposition

Select the Freeman-Durden decomposition.

Polarimetric Decomposition ×	Polarimetric Decomposition
File Help	File Help
I/O Parameters Processing Parameters	I/O Parameters Processing Parameters
Source Product source: [1] RS2-SLC-FQ2-DES-15-Apr-2008_14.38-PDS_05116980 v	Decomposition: Freeman-Durden Decomposition Window Size: Sindair Decomposition Paul Decomposition
Target Product Name:	Freeman-Durden Decomposition Generalized Freeman-Durden Decomposition Yamaguchi Decomposition yan Zyl Decomposition
RS2-SLC-FQ2-DES-15-Apr-2008_14.38-PDS_05116980_Decomp Save as: BEAM-DIMAP Directory: V	Cloude Decomposition H-A-Alpha Quad Pol Decomposition v
C:\SITBX Tutorials	
Run Close	Run Close

Freeman-Durden Decomposition Dialog

The window size parameter corresponds to the amount of averaging applied to each pixel.

Press Run to begin processing.

When the processing completes, your new Freeman-Durden decomposition product will have three bands corresponding to double bounce, volume scattering and surface scattering.

÷		[3]	RS2-SLC-FQ2-DES-15-Apr-2008_14.38-PDS_05116980_Decomp
	÷		Metadata
	÷		Vector Data
	÷		Tie-Point Grids
	÷		Bands
			Freeman_dbl_r
			Freeman_vol_g
			Freeman_surf_b

Products View Showing Freeman-Durden Bands

Step 9 - View in RGB: You can view all three bands in an RGB colour view by right-clicking on the product name and selecting **Open RGB Image Window** from the popup menu.

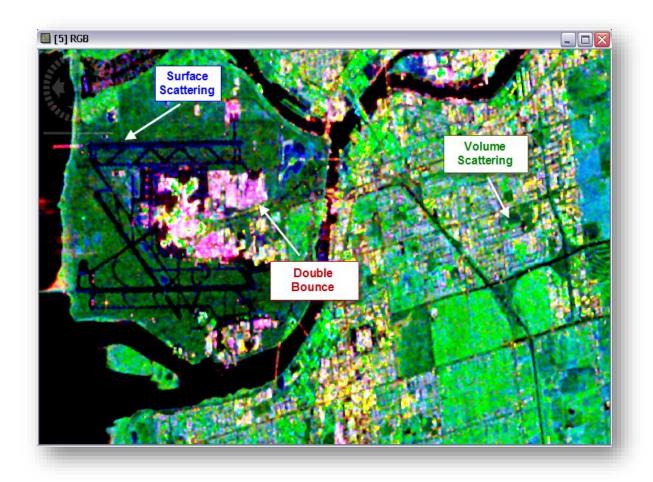
🗄 🗐 🕄 RS2-SLC-FQ2-DE	.15.	Apr-2008 14 38-DDS 05116080 Decomp
🖶 📄 Metadata		Band Maths
🕀 📄 Vector Data		Add Elevation Band
🕀 📄 Tie-Point Grids		Add Land Cover Band
🖻 📾 Bands	~	Group Nodes by Type
Freeman_db	· ·	Gloup Nodes by Type
		Open RGB Image Window
Freeman_su		Open HSV Image Window

Viewing Products in RGB

Within the RGB channel selection dialog, select the Red, Green, Blue components for the respective bands **Freeman_dbl_r**, **Freeman_vol_g**, **Freeman_surf_b**. Press **OK** to create the RGB view.

le Selec	ct RGB-Image Channels						
Profile:							
Red:	Freeman_dbl_r						
Green:	Freeman_vol_g 🔹 🗤						
Blue:	Freeman_surf_b						
Store RGB channels as virtual bands in current product							
	OK Cancel Help						

Selecting RGB Image Channels



RGB Freeman-Durden Image

The resulting RGB image shows surface scattering in **blue** from the airport runways, roads and water bodies. Buildings produce double bounce and are shown in **red**. Vegetation produces volume scattering and is therefore shown in **green**.

Step 10 - Export the RGB as an image: You may now wish to export the colour image to an image file format such as JPEG or PNG to use in a report or presentation.

The processed data will usually be saved as Float64 data type. Although it is possible to save JPG, PNG and GeoTIFF files as Float64, the typical image viewing software may expect data to be in UINT8 or UINT16.

To convert the data type, select **Convert Data Type** from the Raster menu, under Data Conversion

Raster Optical Radar Tools Window Help

Band Maths		
Filtered Band		
Convert Band		
Propagate Uncertainty		
Geo-Coding Displacement Bands		
Subset		
DEM Tools	>	
Geometric Operations	>	
Masks	>	
Data Conversion	>	Convert Datatype
Image Analysis	>	Converts bands to/from dB
Classification	>	Amplitude to/from Intensity
Segmentation	>	Linear to/from dB
Export	>	Complex i and q to Intensity
		Complex i and q to Phase
		Band Select
		Set No-Data Value

Select Convert Data Type

In the Convert Data Type dialog, choose to output UINT8 using linear scaling clipping to 95% of the histogram.

🛃 Convert Datatype		×
File Help		
I/O Parameters Proce	essing Parameters	
Source Bands:	Freeman_dbl_r Freeman_vol_g Freeman_surf_b	
Target Data Type:	uint8	\sim
Scaling:	Linear (between 95% clipped histogram)	\sim
Target no data value:		0.0
	Run	Close

Select uint8 with Linear Scaling

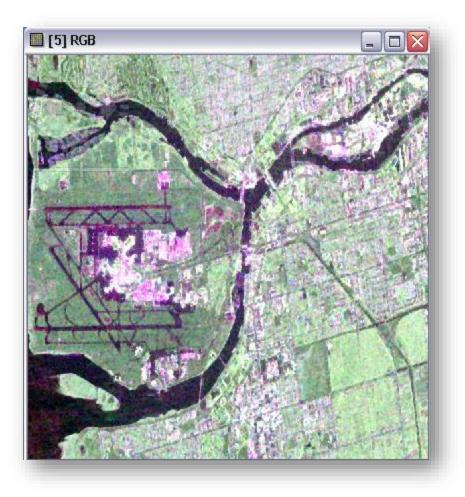
Now you may export the converted product to a common image file format.

From the **File** menu, go to the **Export** submenu, Other submenu, and select **View as Image**. In the **Save** dialog, enter the name, location and type of image to export.

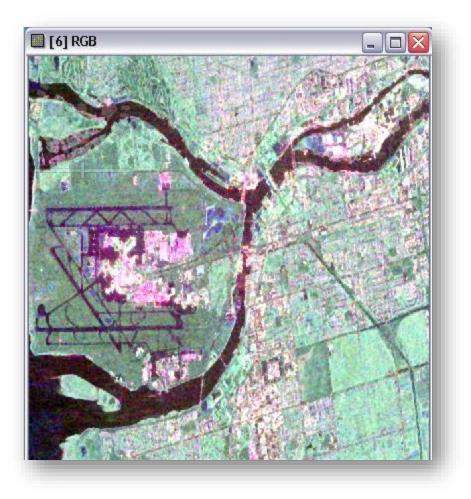
File	Edit View Analysis Layer	Vecto	r		
	Open Product				
	Reopen Product >				
8	Product Library				
	Close Product				
	Close All Products				
	Close Other Products				
	Save Product				
	Save Product As				
	Session >				
	Projects >				
	Import >				
	Export >		Other	>	Colour Legend as Image
	Exit		SAR Formats	>	Colour Palette as File
		_	GDAL		Geo-Coding as ENVI GCP File
			JPEG-2000		Geometry as Shape file
			CSV		Mask Pixels
			GeoTIFF / BigTIFF		Product Metadata
			BEAM-DIMAP		Transect Pixels
			ENVI		View as Image
			GeoTIFF		View as Google Earth KMZ

Exporting an RGB Image to bmp, jpg, png

Step 11 - Produce all other Decompositions: Using the speckle filtered T3 as input, repeat the decomposition processing for all other decompositions and compare the results.



Sinclair Decomposition



Pauli Decomposition



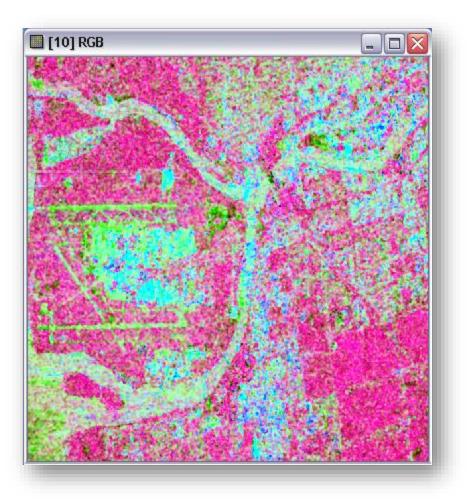
Yamaguchi Decomposition



Van Zyl Decomposition



Cloude Decomposition



H-a-Alpha Decomposition

To clean up your **Products View**, you may now right-click on the **speckle filtered T3** product and from the pop-up menu select **Close All Others** to close all other products and leave only the **speckle filtered T3** opened.

⊡…⊜ [4] subset	0.0		May-2008 14 mai		
	0	Information			
⊕… 🛅 Meta ⊕… 🛅 Tie-p	D>	Properties			
🕀 🧰 Vecto	ð,	Create Vector Container			
🕀 🛅 Band		Close	Ctrl+W		
	8	Save As			
		Close All Others	$\overline{}$		
		Close All	V		

Cleaning up Products View

Unsupervised Polarimetric Classification

Using the **speckle filtered T3** product as input, you will now process the unsupervised polarimetric classification to group similar pixels into classes.

Unsupervised classification does not rely on user specified classes to be matched. Instead, it automatically determines what classes exist in the data and how best each pixel can be grouped.

Step 12 - Apply unsupervised classification: Using the **T3 speckle filtered** product as input, select **Polarimetric Unsupervised Classification** from the **Polarimetric Classification** submenu.

Apply Orbit File				
Radiometric	>			
Speckle Filtering	>			
Coregistration	>			
Interferometric	>			
Polarimetric	>	Compact Polarimetry	>	
Geometric	>	Polarimetric Classification	>	Polarimetric Classification Wizard
Sentinel-1 TOPS	>	Polarimetric Matrix Generation		Polarimetric Unsupervised Classification
ENVISAT ASAR	>	Polarimetric Speckle Filter		Supervised Wishart Classification Training
SAR Applications	>	Polarimetric Orientation Angle Correction		Supervised Wishart Classification
SAR Utilities	>	Polarimetric Decomposition	Ē	
		Polarimetric Parameters		
		Cross Channel SNR Correction		

Select Polarimetric Unsupervised Classification

In the Processing Parameters tab, select the Wishart Classification.

Press the **Help** button to call up the online help for further information.

Polarimetric Classification	Se Polarimetric Classification
File Help I/O Parameters Processing Parameters Source Product source: [3] RS2-SLC-FQ2-DES-15-Apr-2008_14.38-PDS_05116980_Decomp	File Help I/O Parameters Processing Parameters Classification: H Alpha Wishart Window Size: Cloude-Pottier Max Iterations: Cloude-Pottier Dual Pol
Target Product Name: RS2-SLC-FQ2-DES-15-Apr-2008_14.38-PDS_05116980_Decomp_Class Save as: BEAM-DIMAP Directory: C:\S1TBX Tutorials	H Alpha Wishart H Alpha Wishart Dual Pol Freeman-Durden Wishart General Wishart
C Open in SNAP	Run Close

Unsupervised Classification Dialog

Press Run to begin processing.

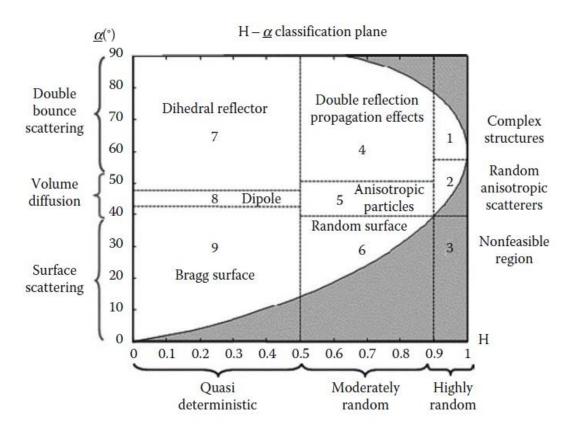
When the processing completes, your new classification results product will have a single band with several regions each belonging to one of nine classes.



Unsupervised Wishart Classification

Both the Cloude-Pottier and the Wishart classifiers are based on the use of the Entropy (H) / Alpha (α) plane. The Wishart classifier will continue to compute the centres of the nine clusters, and then reclassify the pixels based on their Wishart distances to cluster centres.

The classes can be interpreted according to the H- α classification plane.



H-α Classification Plane

You may change the default colours for each class within the colour manipulation tool window. Use the pull-down control on the colour to select a new colour. Use the export and import buttons on the right-hand side to save and load colour look-up tables.

Q Colour Mar	nipulation - [2] Unsupervised	_Wishart_Class	₽₽×	👤 Colour M	anipulation - [2] Unsupervise	ed_Wishart_Class	0 4 X	
Label	Colour	Value	Apply	Label	Colour	Value	Apply	
class_1	232, 237, 174	0	2 💣	class_1	232, 237, 174	0		
class_2	98, 46, 179	1	2 🖷	class_2	98, 46, 179	✓ 1	a 🖉	
class_3	186, 166, 187	2	🕹 🕹	class_3	Nees		🖞 🔒	
class_4	8 , 56, 151	3		class_4	None	3		
class_5	10, 235, 165	4		class_5		4		
class_6	42, 147, 63	5		class_6		5		
class_7	124, 7, 240	6		class_7	Black	6		
class_8	108, 26, 160	7		class_8		7		
class_9	220, 254, 108	8		class_9		8		
					More Colors			
<		>		<		>		
* More Opti	ons		?	* More Options				
🖿 Naviga 👤 Colour 🎏 Layer 🗊 Layer 🔕 World 📔 Naviga 👤 Colour 😂 Layer 🗐 Layer 🚳 World								

Colour Manipulation Tool Window

esa



For more tutorials visit the Sentinel Toolboxes website

http://step.esa.int/main/doc/tutorials/

science toolbox exploitation platform

Send comments to the SNAP Forum

http://forum.step.esa.int/