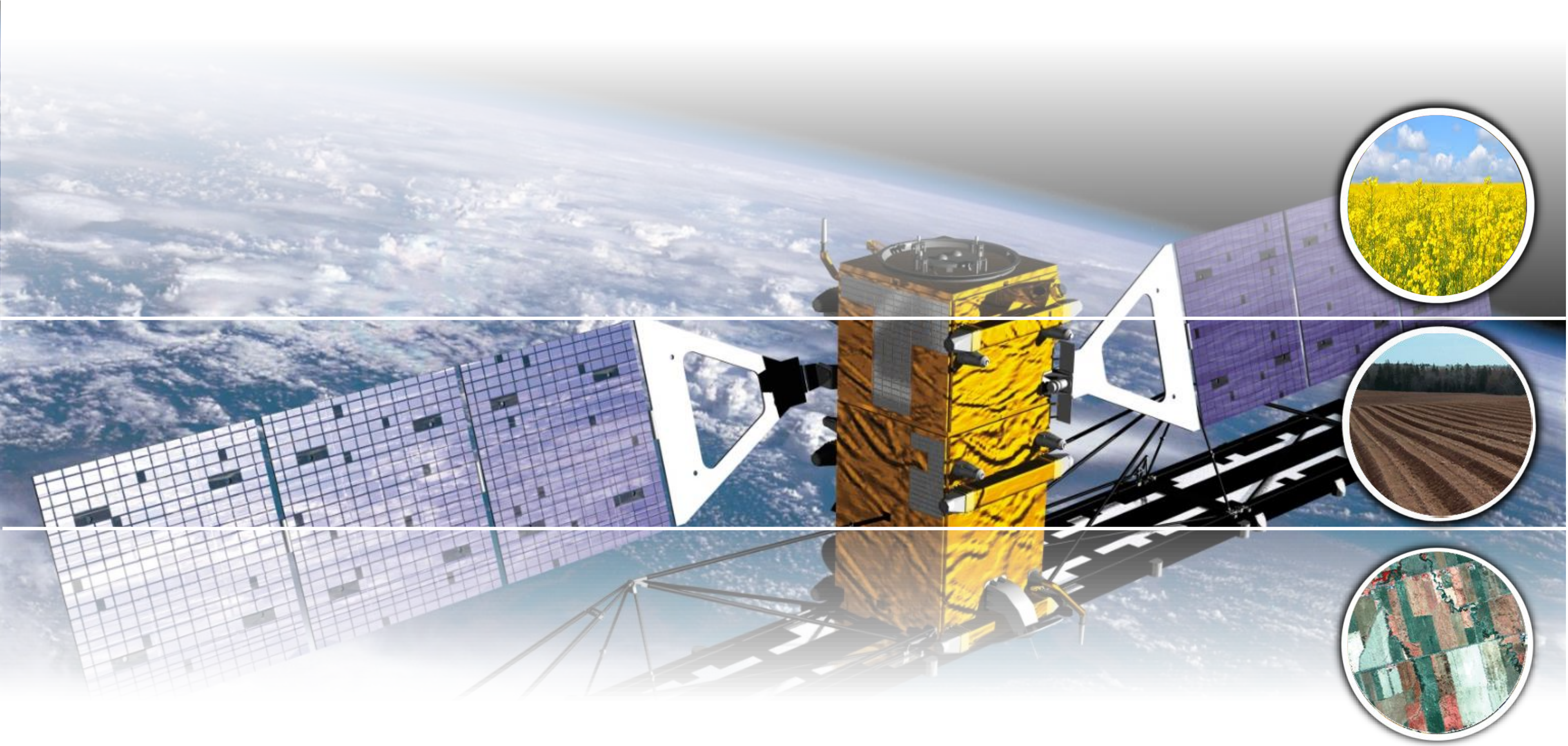


Lab 3 B:
SAR Processing – RADARSAT-2

Carleton University
Canada's Capital University

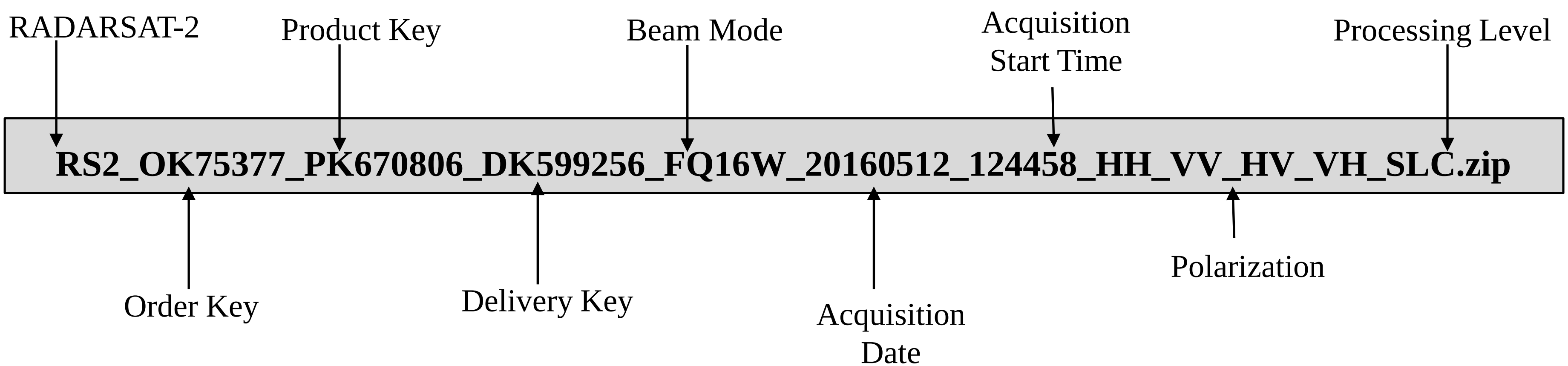
Natural Resources Canada | Ressources naturelles Canada

CSA ASC

Agriculture and Agri-Food Canada | Agriculture et Agroalimentaire Canada

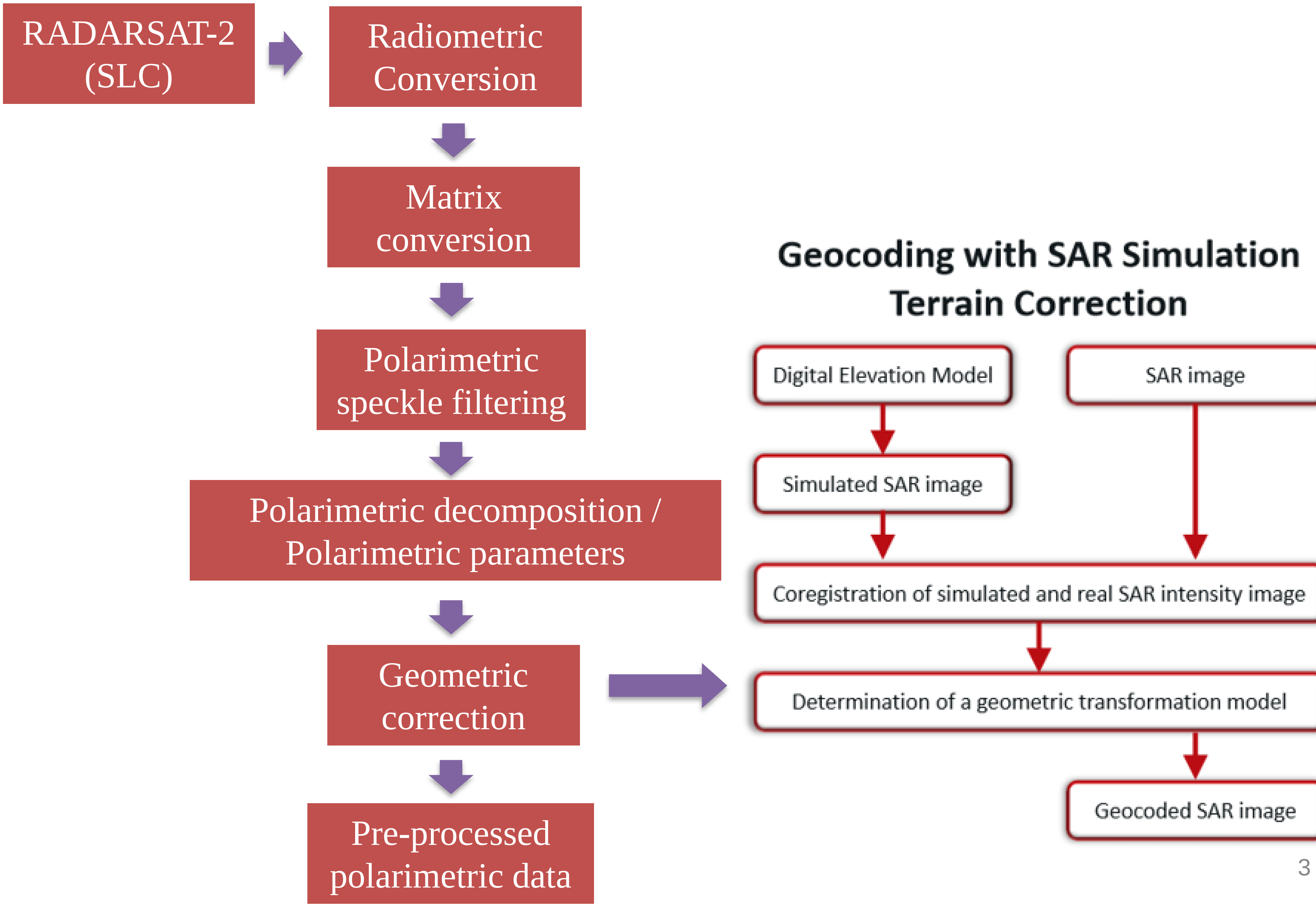
RADARSAT-2 Polarimetric Processing

The sample data: RADARSAT-2 fully polarimetric SLC image acquired in Wide Fine Quad-Pol mode over a an agricultural test site in southern Manitoba.



- In SLC product each image pixel is represented by a complex (real *I* and imaginary *Q*) magnitude value.
- This data format is intended for polarimetric processing analysis that require the full bandwidth and phase information.

The Order of Pre-processing

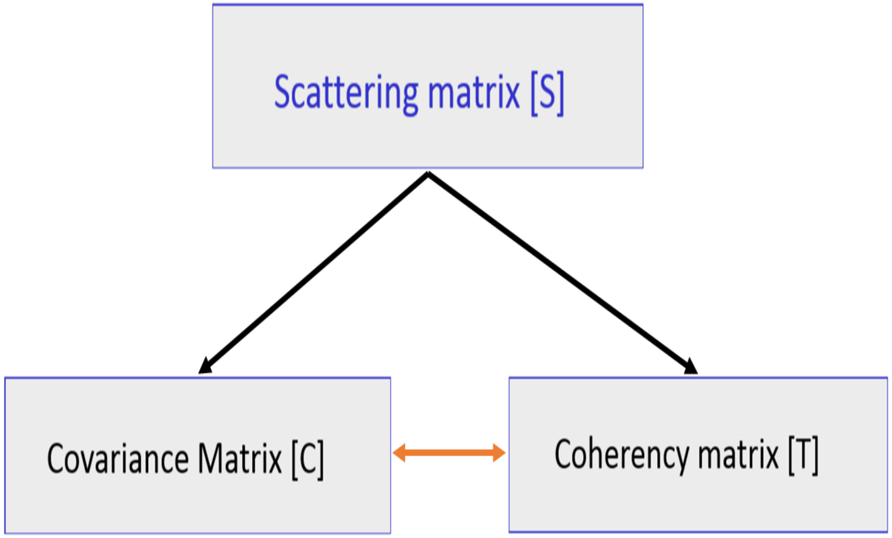


RADARSAT-2 Radiometric Conversion

- SAR digital numbers information stored within SAR image SLC product need to be covert to radar backscatter intensity and complex channels .
- The conversion is mission-specific and for polarimetric processing the data must be complex.
- Look Up Tables (LUTs) provided with the RADARASAT-2 SLC products are used to convert DN to complex real and imaginary bands.
- SNAP will automatically determine what kind of input product you have and what conversion needs to be applied based on the product’s metadata.

Polarimetic Matrix Conversion

- All polarimetric tools require either covariance or coherency matrices as input.
- Coherency and covariance matrices are generated from the scattering matrix.
- For each polarization, RADARSAT-2 quad-pol SLC data is provided in a complex format.
- For monostatic backscattering case, the transmitter and the receiver are collocated. The reciprocity constrains the covariance and coherency matrices to 9 elements each.



Polarimetric Speckle Filtering

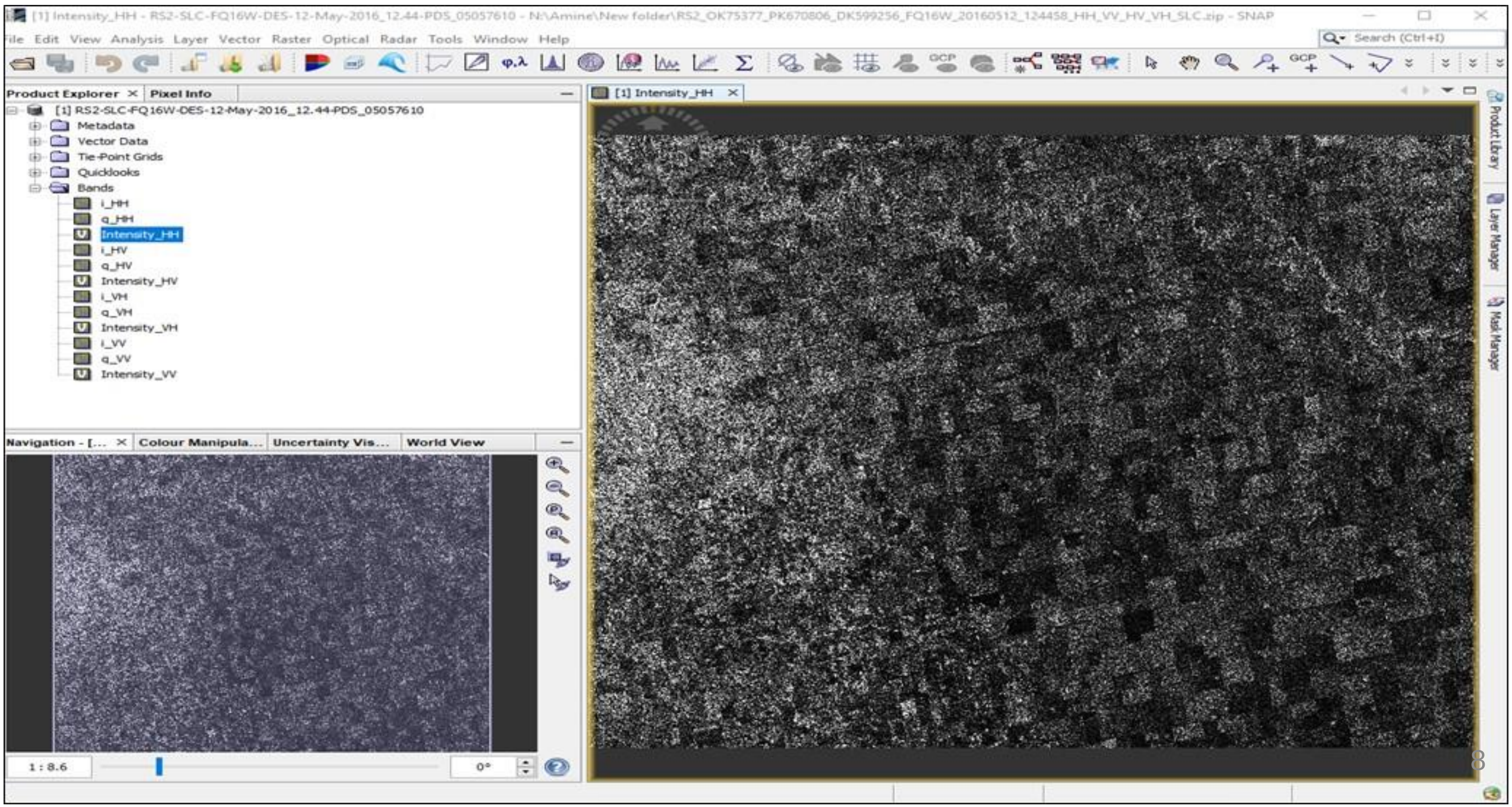
- For polarimetric SAR data, the speckle filtering is based on incoherent averaging and requires handling covariance or coherency matrices.
- These polarimetric filters reduce the speckle inherent to SAR images while preserving phase and intensity information.
    - **Boxcar:** used to increase the effective number of looks (ENL) in fully polarimetric data by local averaging. This filter presents the best performance over homogeneous areas. However sharp edges are generally blurred and point targets are over filtered.
    - **Refined Lee:** developed based on the multiplicative noise model and operates with an non-square sliding window. Spatial information is preserved by using an edge detector to identify a homogeneous local neighborhood over which to estimate the filter parameters. This filter is adapted to edge and point targets filtering.
    - **Improved Lee Sigma:** Assumes Gaussian noise distribution and filters in the sliding window with average of pixels within a range based on the distribution of the selected sample (speckle probability density function). This allows better handling of non-edge pixels in performing filtering statistics.

Break for Hands-On Exercise:

Open, display, convert and filter a RADARSAT-2 image with SNAP

Open RADARSAT-2 Image in SNAP

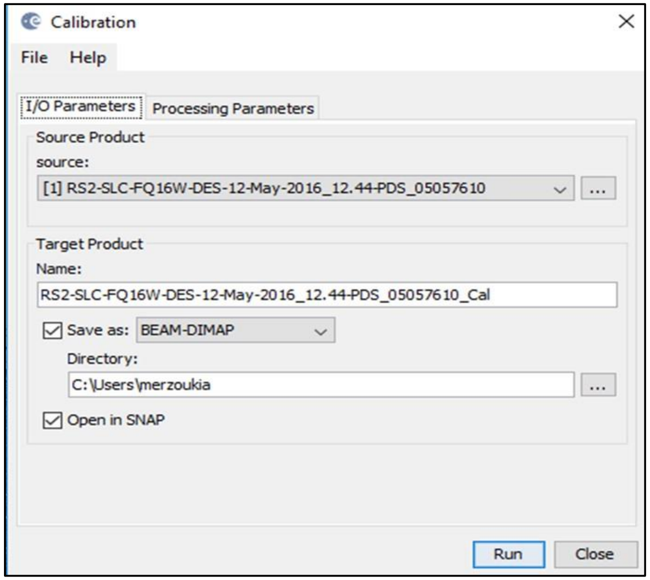
- Initiate the SNAP tool.
- In the SNAP interface, go to File menu >> open product.
- Select the folder that contains RADARSAT-2 data, and double click on the “.zip” file.
- The Product Explorer window of the SNAP contains like-pol and cross-pol bands in intensity and complex formats.

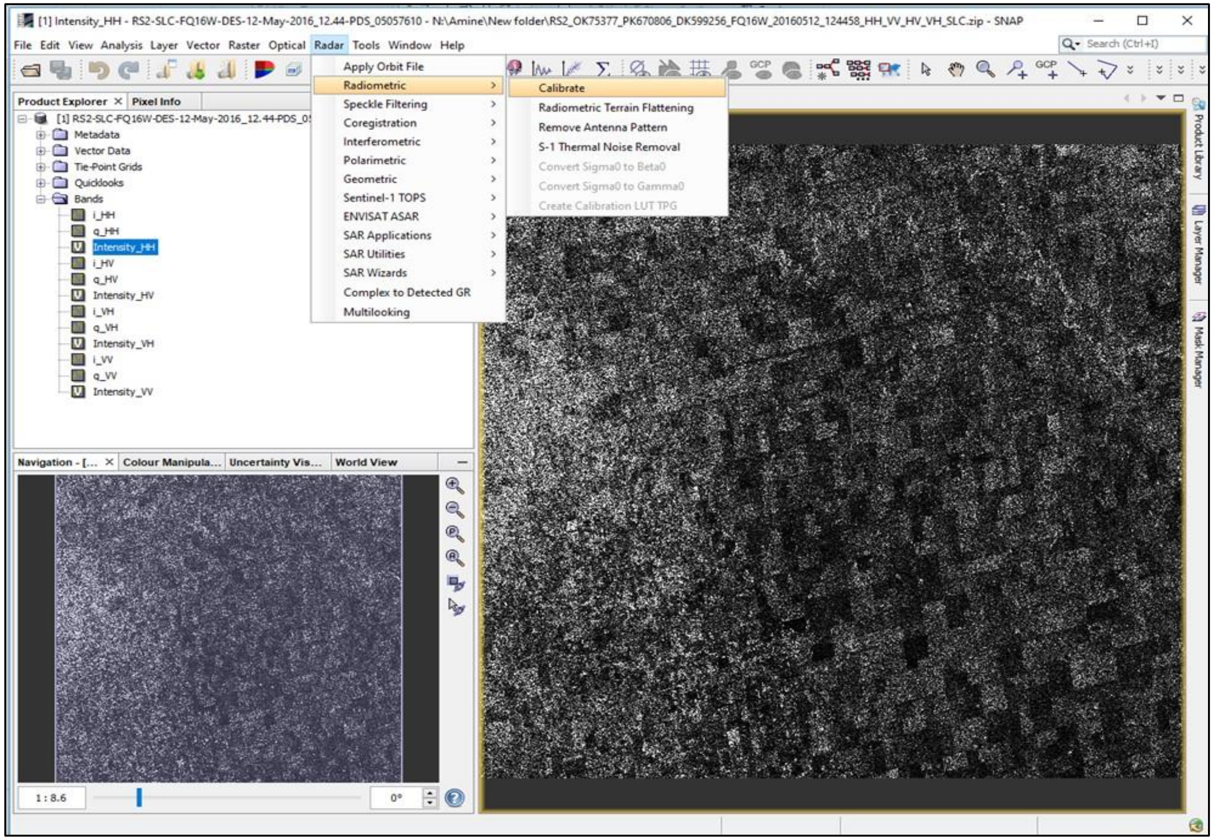


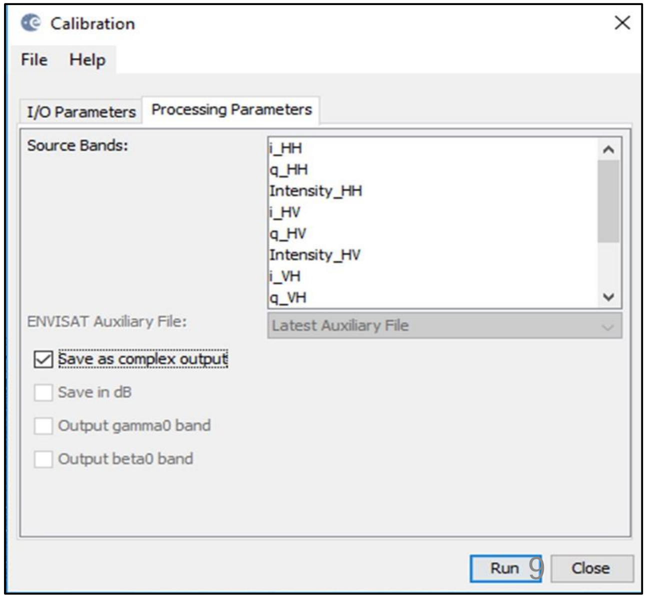
Radiometric Conversion in SNAP

Go to Radar Menu >> Radiometric >> Calibrate – Calibration:

- I/O Parameters tab: source → Raw RADARSAT-2 image + Target product
- Processing Parameters tab: source bands → all bands; Save as complex output
- Click Run and Close window when completed



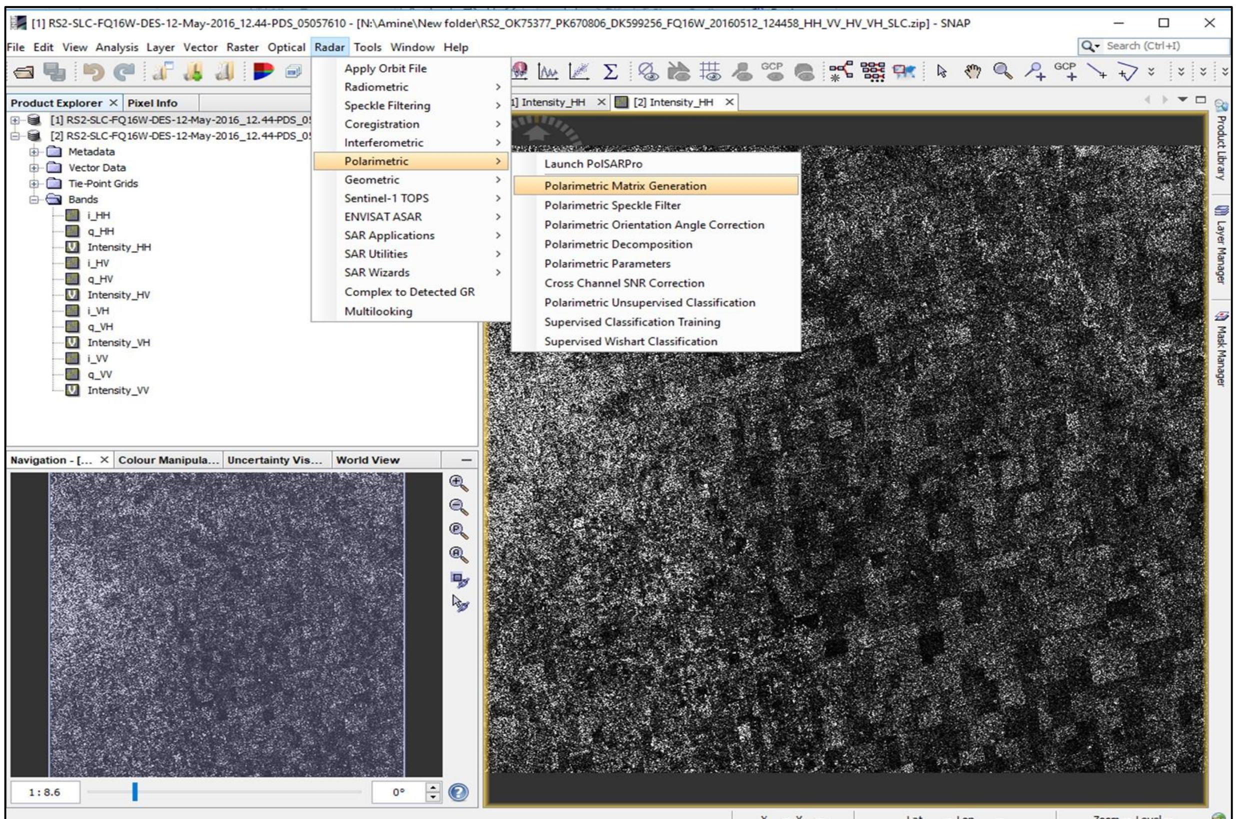


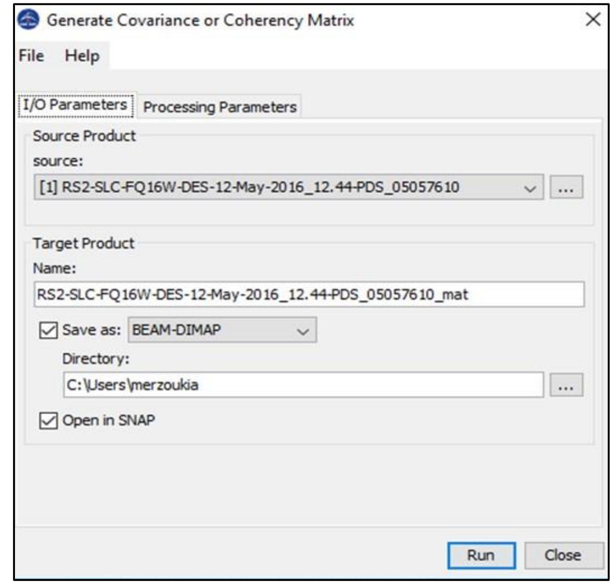


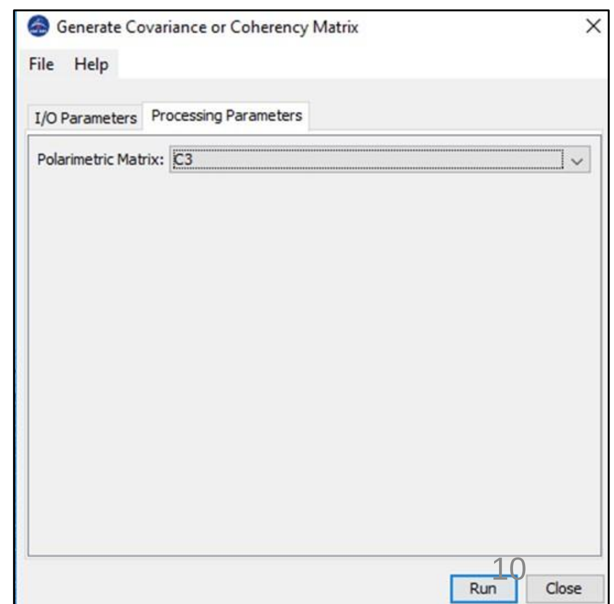
Polarimetic Matrix conversion in SNAP

Go to Radar Menu >> Polarimetric >> Polarimetric Matrix Conversion – Generate Covariance or Coherency Matrix:

- I/O Parameters tab: source → Radiometricaly converted image + Target product
- Processing Parameters tab: specify the matrix type (C3, C4, T3 or T4)
- Click Run and Close window when completed



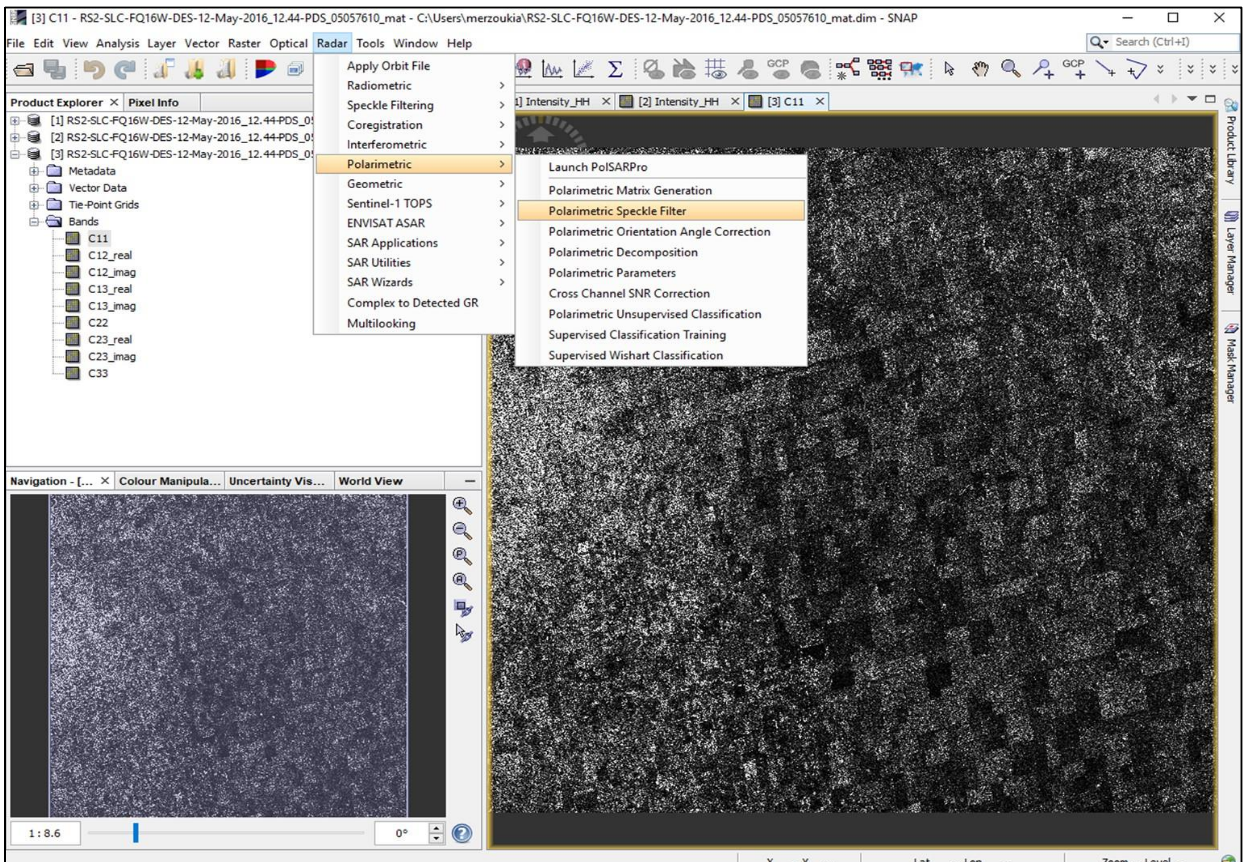


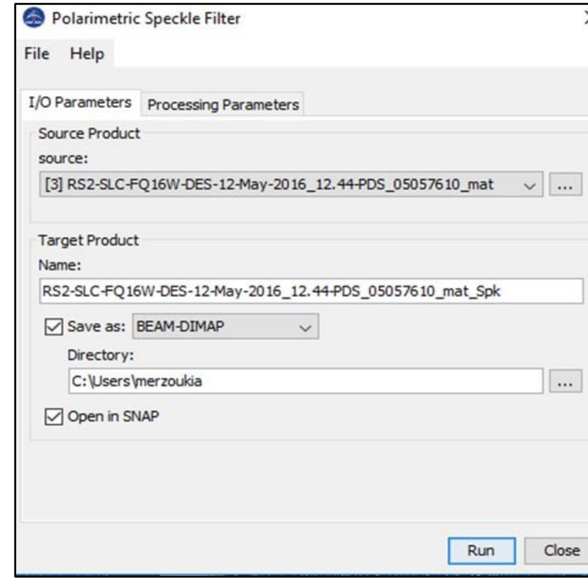


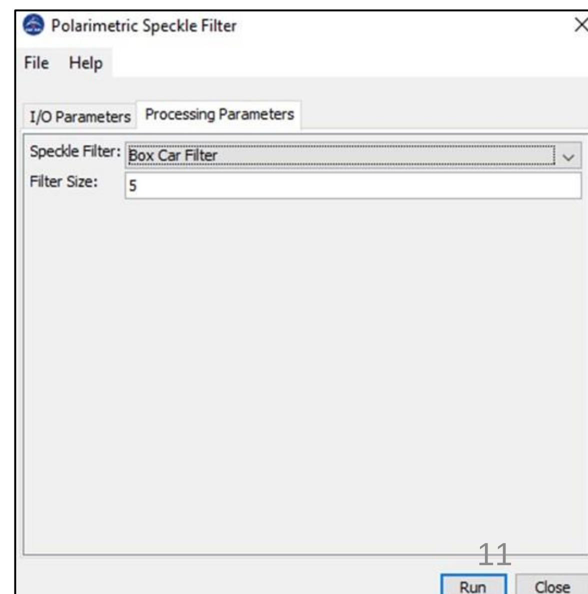
Polarimetic Speckle Filtering in SNAP

Go to Radar Menu >> Polarimetric >> Polarimetric Speckle Filter:

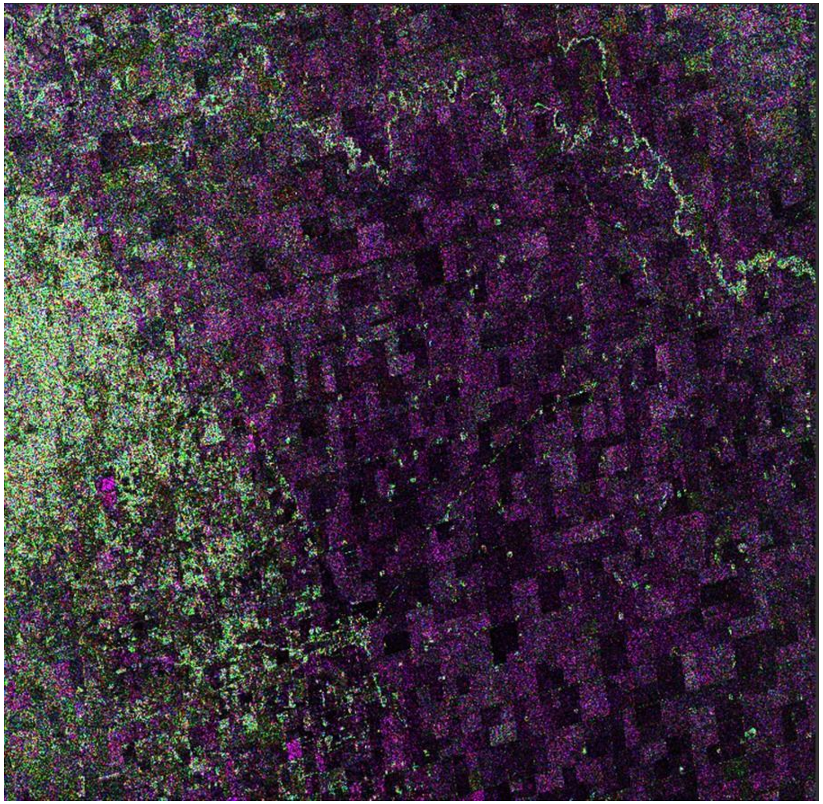
- I/O Parameters tab: source → C3 or T3 image + Target product
- Processing Parameters tab: Speckle Filter → BoxCar; Filter Size → 5
- Click Run and Close window when completed



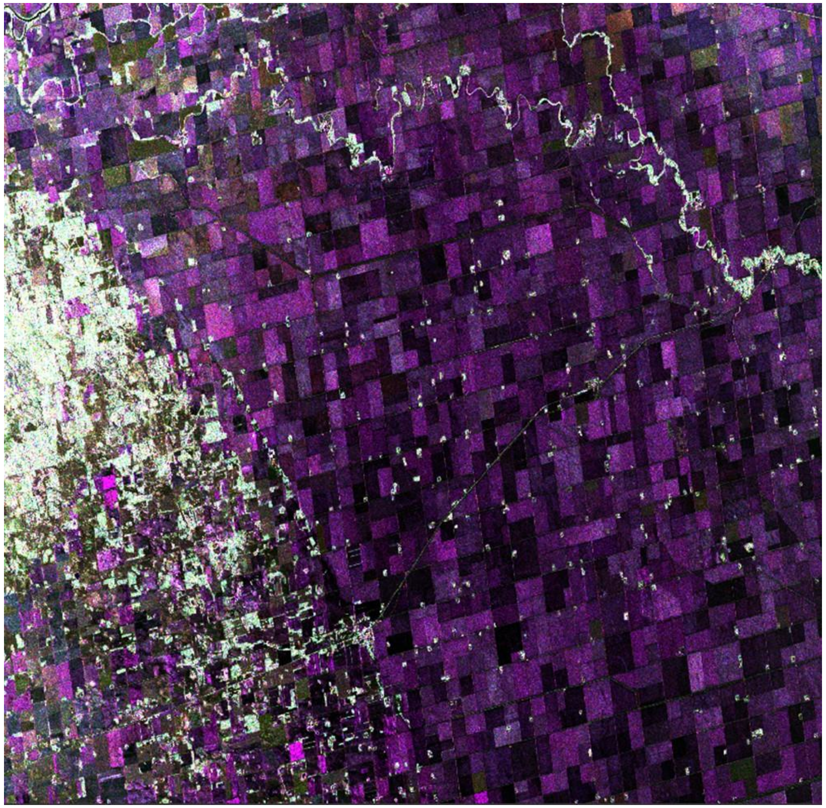




Polarimetic Speckle Filtering in SNAP



Unfiltered image



Boxcar 5x5 filter applied

RADARSAT-2 FQ16W sample image filtering example

Back to Lecture:

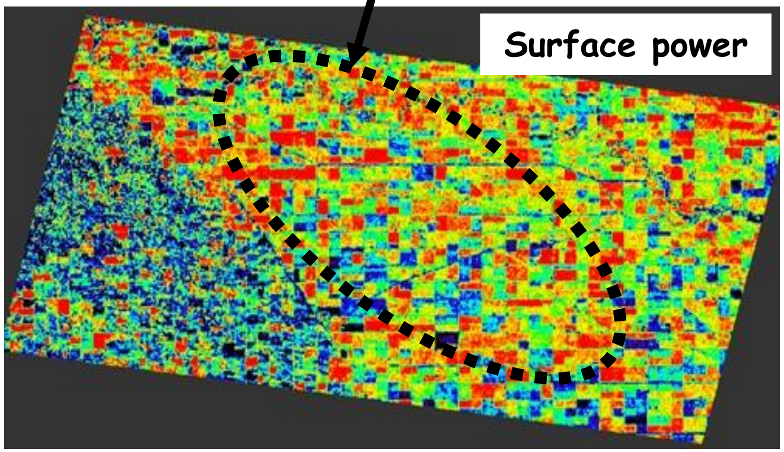
SAR Polarimetric Processing

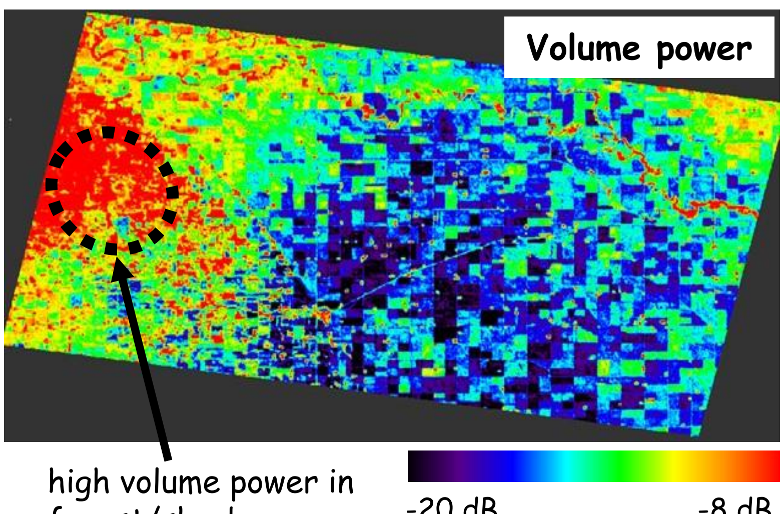
Polarimetric Parameters: Freeman-Durden Decomposition

- Freeman-Durden decomposition models the covariance matrix as the contribution of three scattering mechanisms defined by three parameters:

P_v: Volume scattering power
P_d: Double-bounce scattering power
P_s: Surface/single bounce scattering power

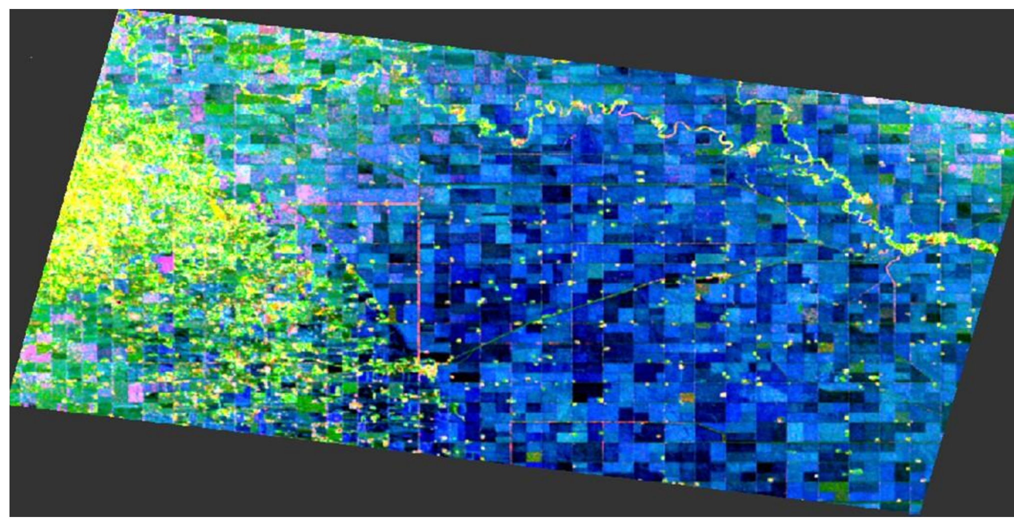
High surface power in bare agricultural fields





high volume power in forest/shrub area

- Image acquired in early season with low vegetation (May 12, 2016).



RGB image of Freeman –Durden decomposition parameters (Double bounce power, Volume power, Surface/Single bounce power)

Polarimetric Parameters: Yamaguchi Decomposition

- The Yamaguchi decomposition is proposed to decompose the covariance matrix to deal with the non-reflection symmetric scattering case.

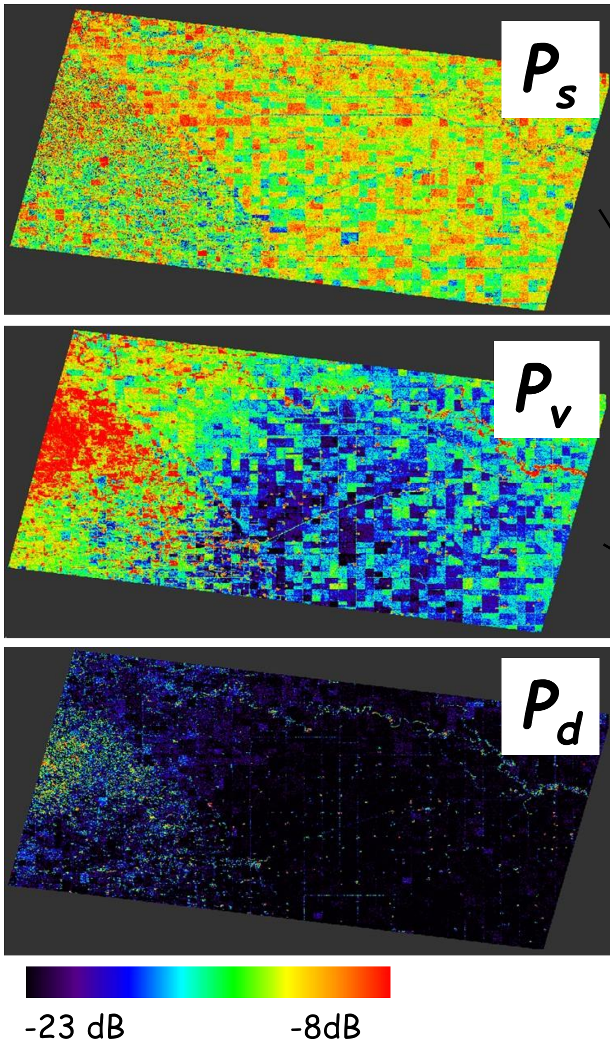
- This decomposition is an improved version of Freeman-Durden’s three-component decomposition for dealing with the reflection symmetry condition that the co-pol and the cross-pol correlations are close to zero.

- The power associated with the volume scattering in Freeman-Durden has contributions not only from the cross-pol component but also from double bounce and surface scattering.

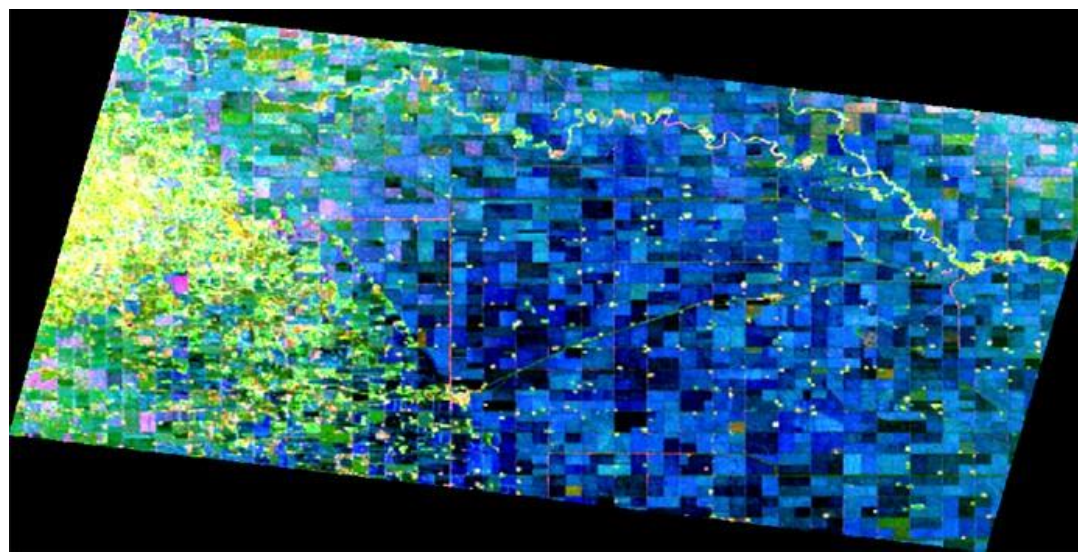
- Therefore volume scattering is often overestimated, decreasing the reliability of this parameter for interpreting vegetation condition.

Polarimetric Parameters: Yamaguchi Decomposition

- Compared to FDD, Yamaguchi decomposition introduces a 4th component scattering mechanism (Helix scattering) to model areas where the reflection symmetry assumption does not hold.
- Helix scattering power term appears only in complicated shape targets or man-made structures.



- ➢ RGB composites are used for qualitative interpretation of the physical scattering mechanisms.
- ➢ These 3 components are highly correlated to Freeman-Durden products.



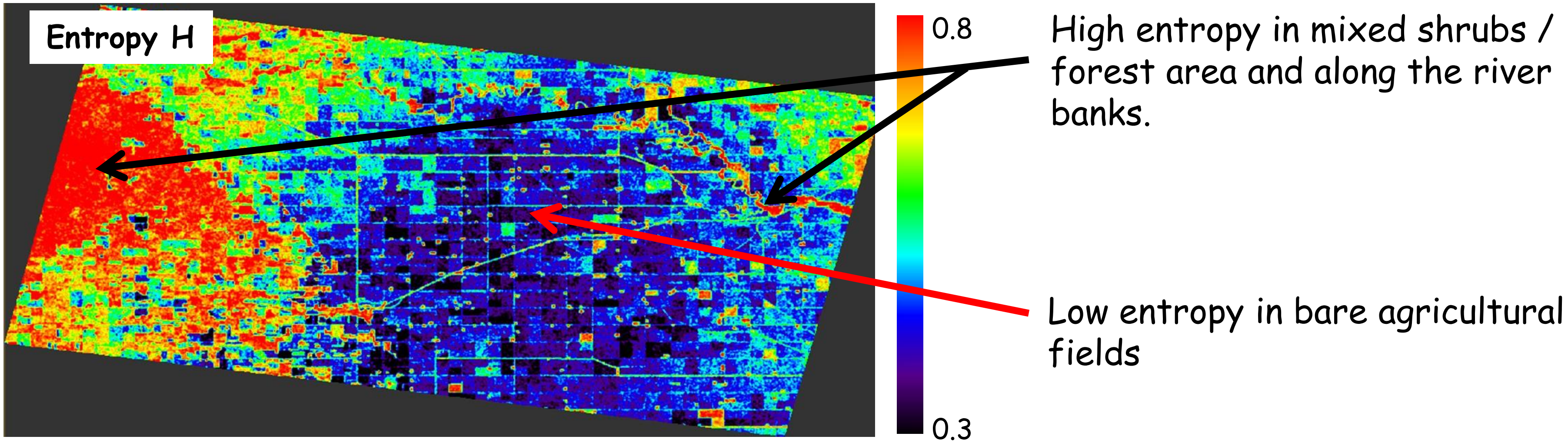
RGB image of Yamaguchi parameters (P_s P_v P_d)

Polarimetric Parameters: Cloude-Pottier Decomposition

- Cloude-Pottier decomposition models the coherency matrix to extract different scattering mechanism through a set of parameters.
- The entropy (*H*), the alpha angle (α), and the anisotropy (*A)* are computed from the eigenvalues and eigenvectors of the diagonalized coherency matrix.

H Characterize the randomness and the amount of mixing between different scattering mechanisms.

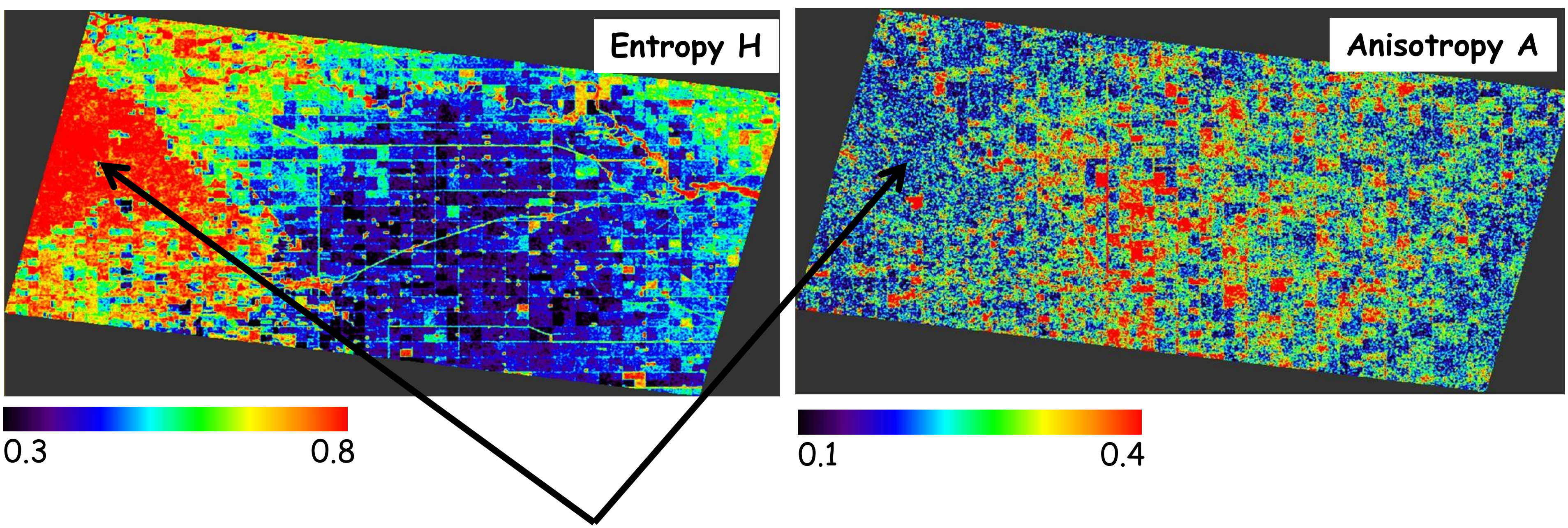
- If $H = 1$: incoherent target characterized by totally unpolarised radar return.
- If $H = 0$: coherent target characterized by totally polarised radar return.



Polarimetric Parameters: Cloude-Pottier Decomposition

A the anisotropy is a measure of the importance of the 2nd and the 3rd scattering mechanisms. This parameter is complementary to the entropy ***H***.

- If *H*= *A* = *0*: single dominant scattering mechanism.
- If *H* = *1* and *A* = *0*: incoherent target characterized by 3 equal scattering mechanisms.
- If *H* > *0.7* and *A* = *0*: random scattering with no dominant scattering mechanism.
- If *H* > *0.7* and *A* > *0*: 2 dominant scattering mechanisms with the same importance.



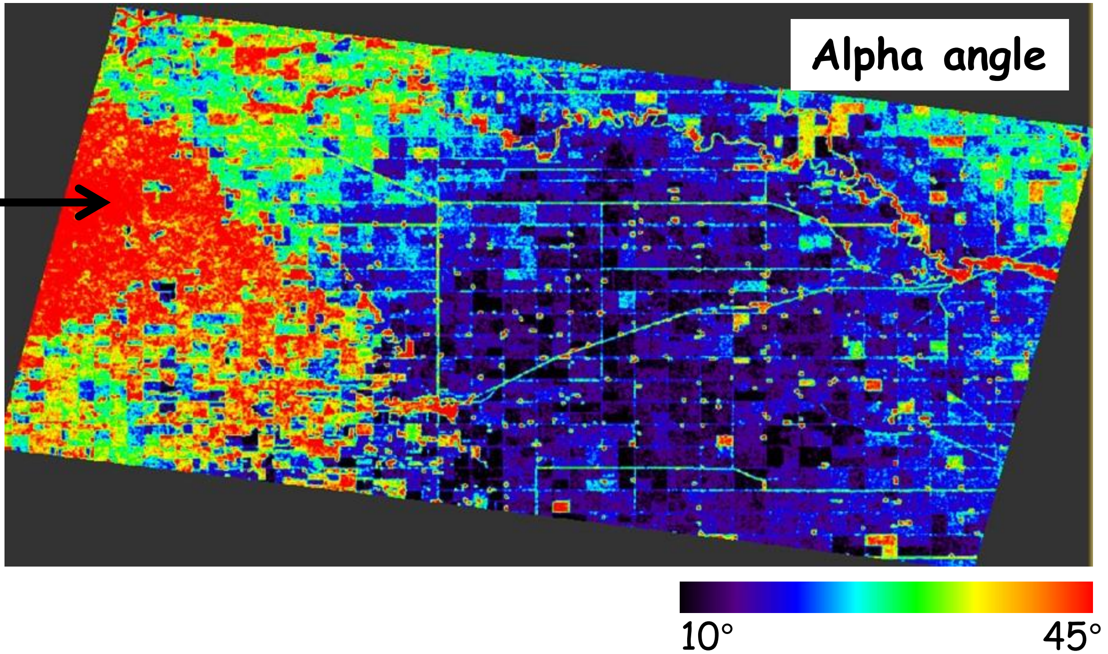
H > 0.7 and *A > 0* in mixed shrubs/forest area and along the river banks → 2 dominant scattering mechanisms.

Polarimetric Parameters: Cloude-Pottier Decomposition

***α*:** the alpha angle characterizes the scattering mechanism for a given eigenvector. Its values range between 0° and 90°.

- $\alpha = 0°$: indicates surface/single bounce scattering.
- $\alpha = 45°$: indicates volume scattering.
- $\alpha = 90°$: indicates double bounce scattering.

H > 0.7, A > 0, 35°< α <45° in mixed shrubs/forest area → 2 dominant scattering mechanisms: Surface/single bounce + volume scatterings.



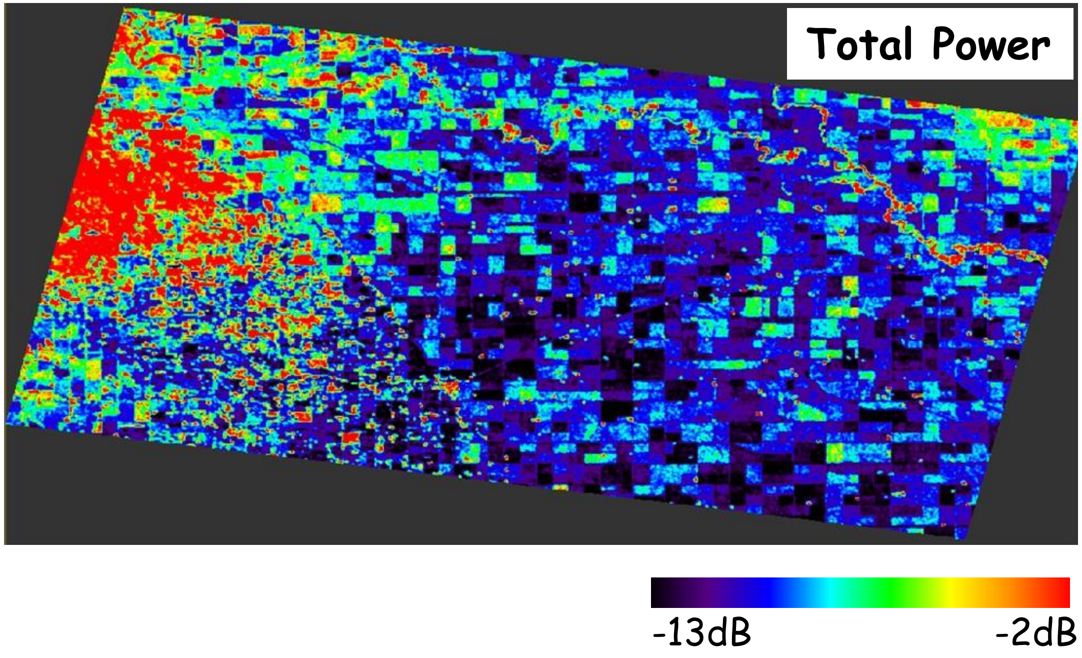
Polarimetric Discriminators

Total Power - Span

- A quantity giving the total power received by the four channels of a polarimetric radar system.
- In terms of the scattering matrix, the total power equal to the sum of all the matrix elements.

- Low Span in bare agricultural fields due to the quasi-specular reflection of the SAR waves.

- High Span in mixed forest and shrubs area due to the high radar return linked to volume scattering



Polarimetric Discriminators

Co-pol Correlation Coefficient

- A complex parameter representing the correlation between the HH and VV channels:

$$\gamma = \frac{\langle S_{hh} S_{vv}^{*} \rangle}{\sqrt{|S_{hh}|^2 |S_{vv}|^2}}$$

- If $|\gamma|=1$: the received signals from the two channels are linearly related.
- If $|\gamma|< 1$: the received waves in H and V polarizations are partially polarized.
- γ is correlated to HH, VV and RL intensities.

Polarimetric Discriminators

Co-pol Phase Difference

- It is the phase angle of the co-pol correlation coefficient between the HH and VV channels.
- Very helpful in classifying a pixel, as it is characteristic of the number of bounces that the incident wave experiences during reflection.
    - A single/odd bounce scatterer will have a co-pol phase difference of 180°.
    - A double/even bounce scatterer will have a co-pol phase difference of 0°.

Note: There is also a "cross-pol phase difference“ which is usually very random, as there is generally little correlation between the channels. If a scene-dependent pattern is observed in the cross-pol phase difference, it is likely due to channel cross-talk that has not been corrected in the processing.

Polarimetric Discriminators

Degree of Polarization

The ratio of the power in the polarized part of an electromagnetic wave to the total power in the electromagnetic wave. It is given by Stokes parameters:

$$D_{pol} = \frac{\sqrt{S_1^2 + S_2^2 + S_3^2}}{S_0}$$

Degree of polarization is correlated to:

- HV and RR intensities
- Pedestal height
- Freeman- Durden and Yamaguchi volume scattering power (P_v)
- Cloude-Pottier entropy (H)

Polarimetric Discriminators

Coefficient of Variation

Also known as the fractional polarization is a normalized ratio between the maximum and minimum power in a polarization signature.

$$CV = \frac{P_{max} - P_{min}}{P_{max}}$$

- If $CV = 1$: the received signal is fully polarized.
- If $CV = 0$: the received signal is unpolarized (e.g. all noise).

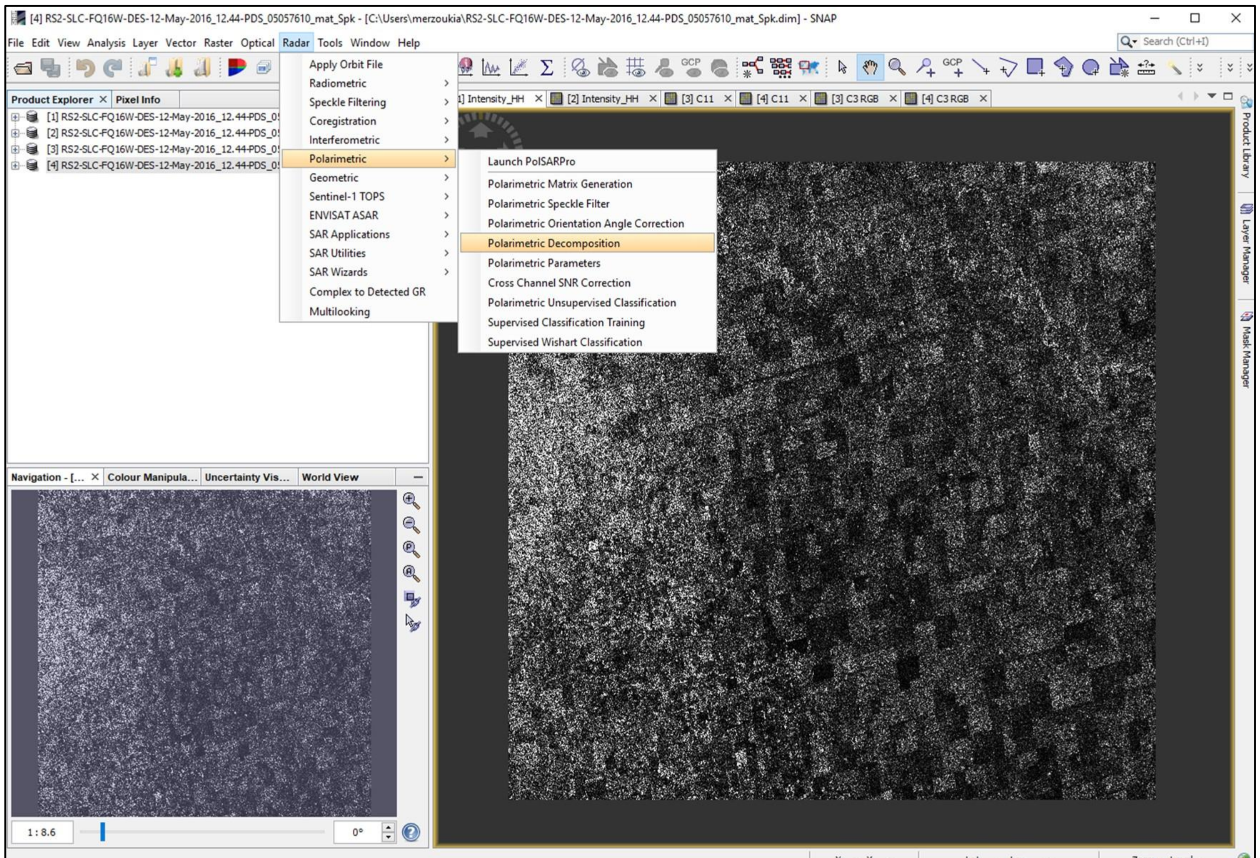
Break for Hands-On Exercise:

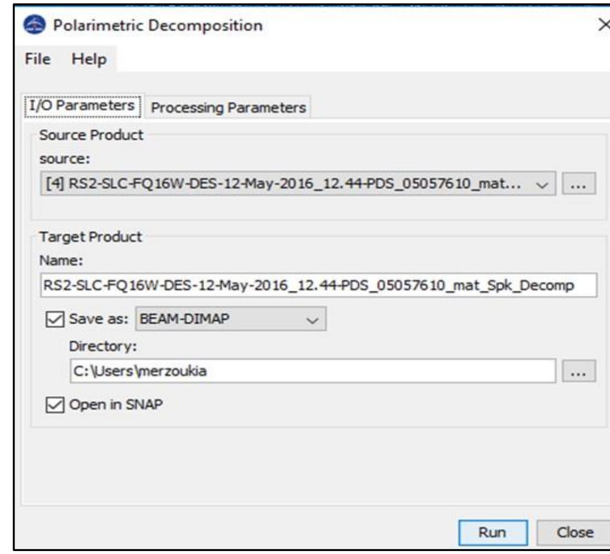
Polarimetric decomposition processing and geometric correction with SNAP

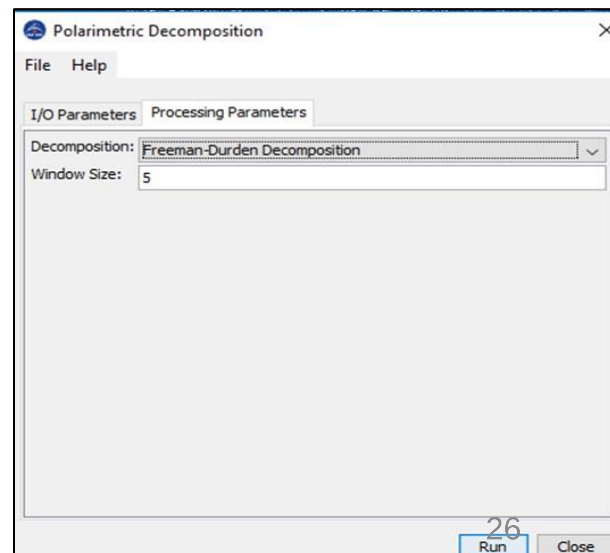
Polarimetic Decomposition in SNAP

Go to Radar Menu >> Polarimetric >> Polarimetric Decomposition:

- I/O Parameters tab: source → Speckle filtered image + Target product
- Processing Parameters tab: Decomposition→ Freeman-Durden; Window Size → 5
- Click Run and Close window when completed



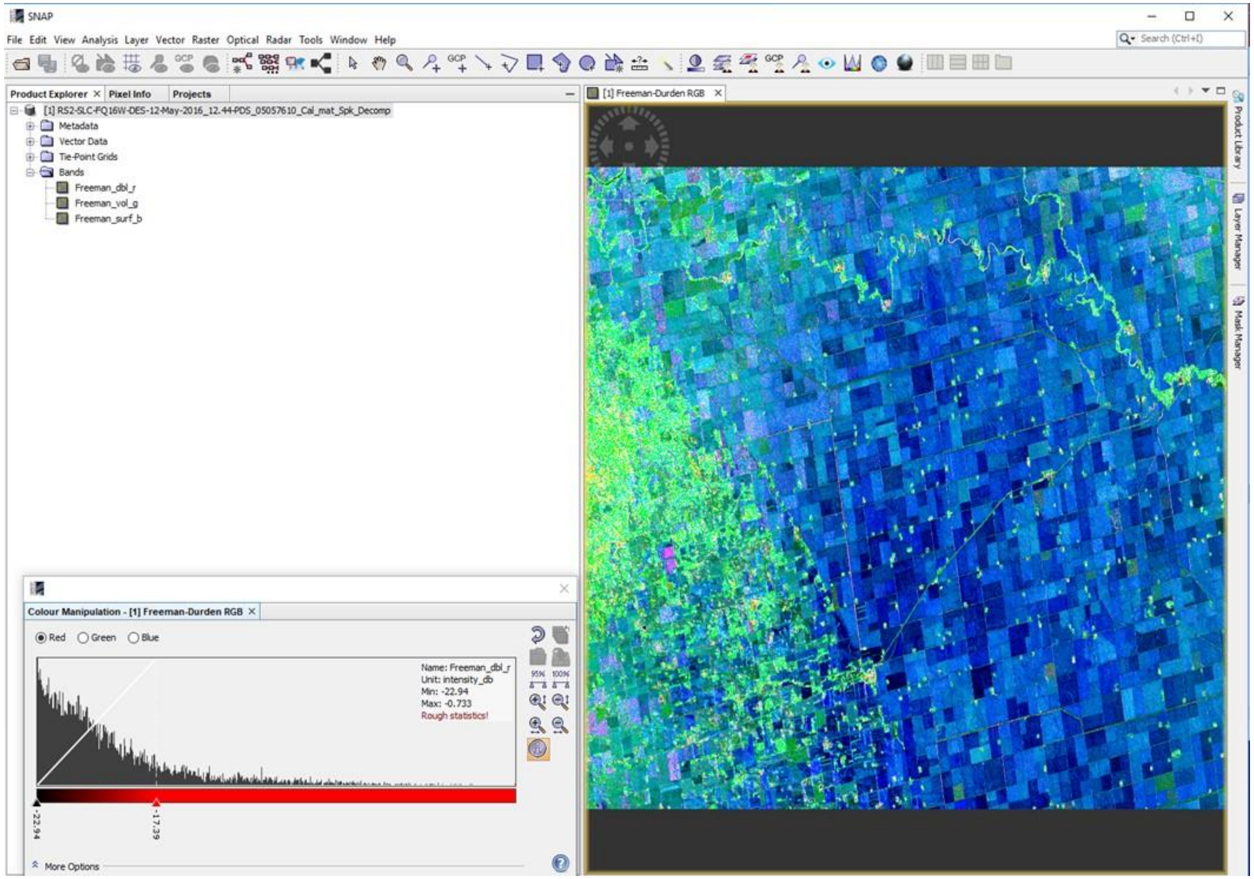


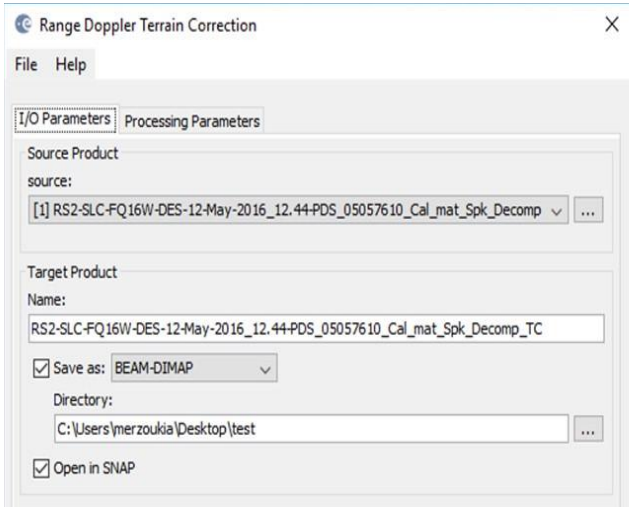


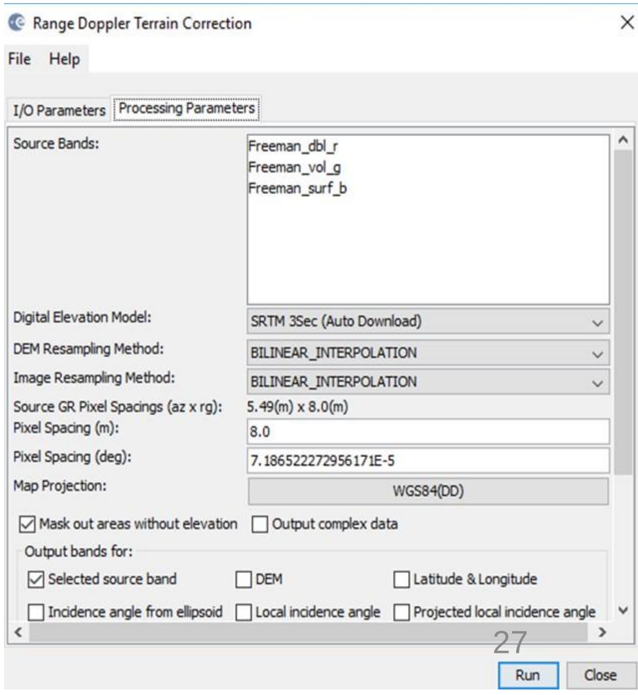
Geometric Correction in SNAP

Go to Radar Menu >> Geometric >> Terrain Correction >> Range-Doppler Terrain Correction:

- I/O Parameters tab: source → Freeman Durden image + Target product
- Processing Parameters tab: DEM→ SRTM 3Sec; Pixel Spacing → Default
- Click Run and Close window when completed

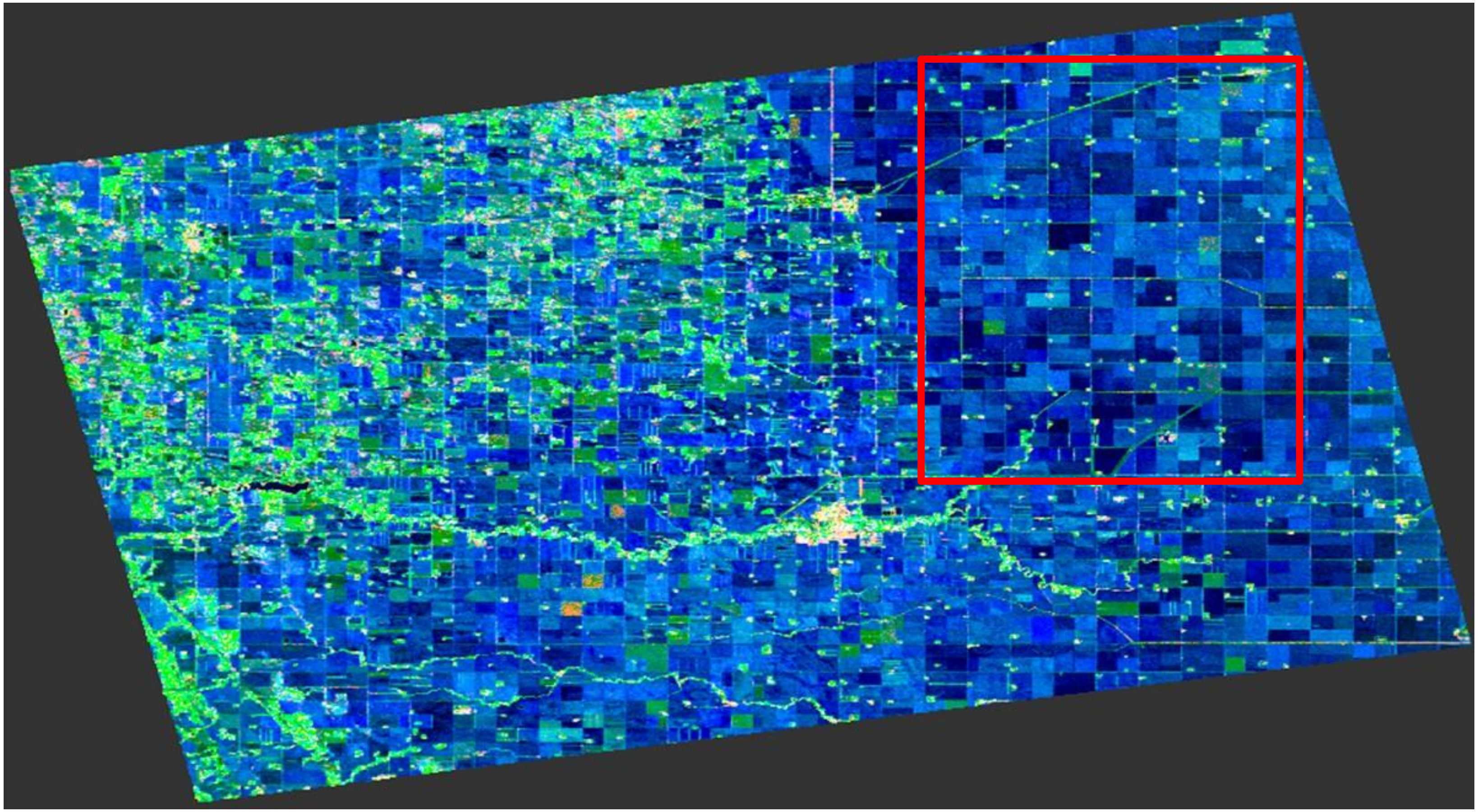






Polarimetic Decomposition in SNAP

Freeman-Durden Decomposition Parameters



RGB of three polarimetric variables derived from the RADARSAT-2 FQ15W image (16 May 2016) using Freeman –Durden decomposition. Terrain correction was applied using Range Doppler method in SNAP. (**R=Double Bounce power**, **G=Volume power**, **B=Surface/Single bounce power**)

Polarimetic Decomposition in SNAP

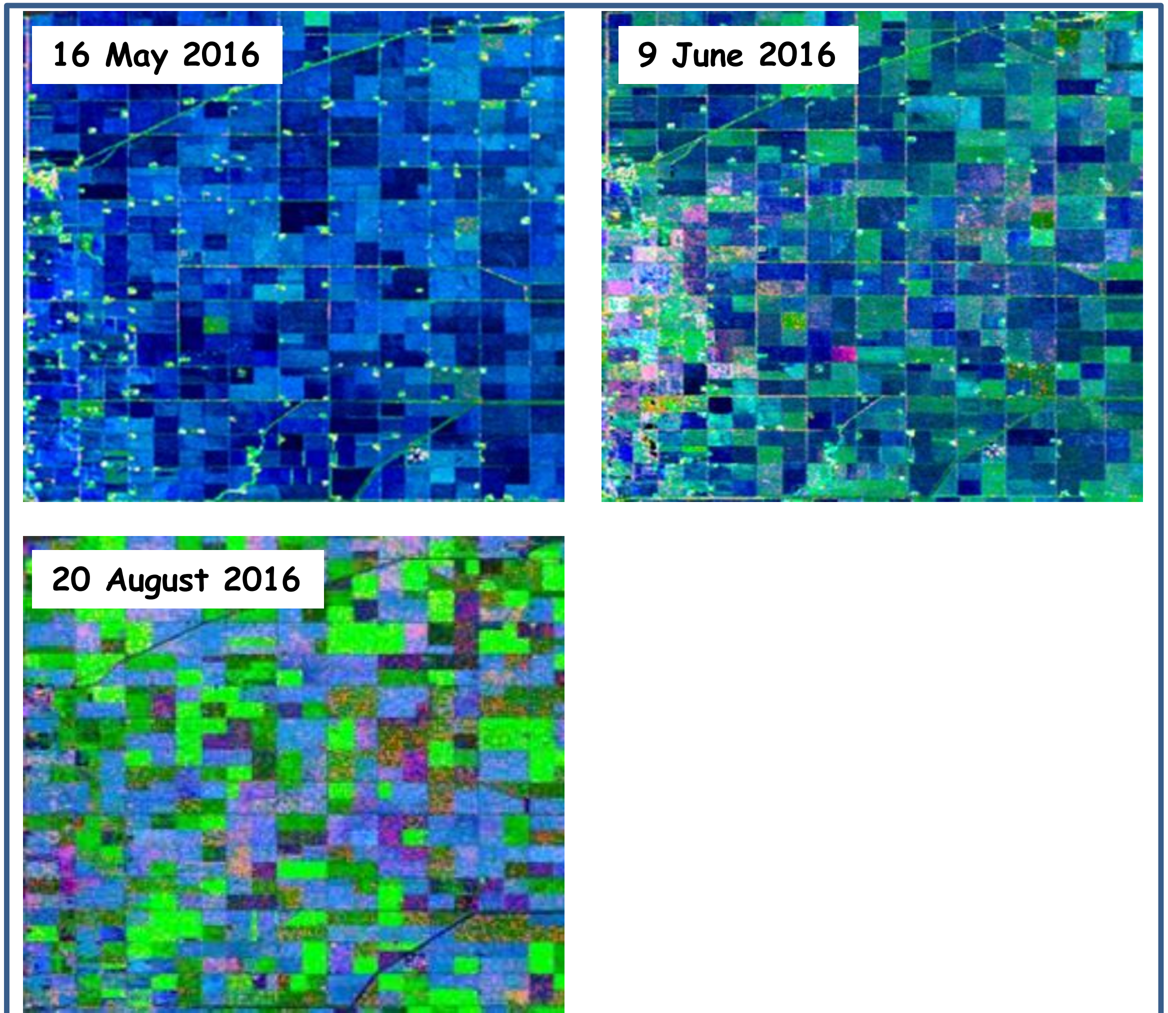
Freeman-Durden Decomposition Parameters

1. Apply Freeman-Durden decomposition to 3 pre-processed images over the growing season:
    - RS2-SLC-FQ15W-ASC-16-May-2016_00.20-PDS_05057680_Cal_Spk
    - RS2-SLC-FQ15W-ASC-09-Jun-2016_00.20-PDS_05109170_Cal_Spk
    - RS2-SLC-FQ15W-ASC-20-Aug-2016_00.20-PDS_05229220_Cal_Spk

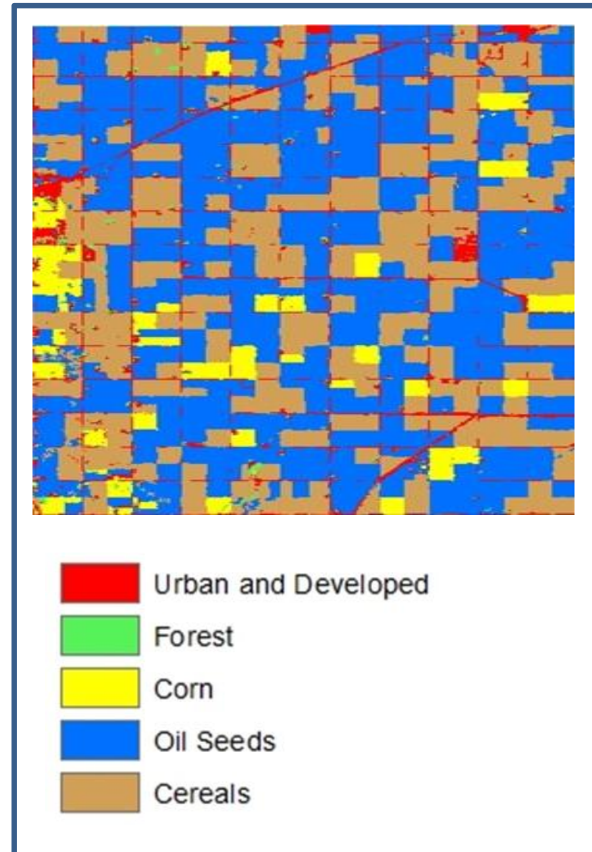
2. Apply terrain correction using Range Doppler method in SNAP to Freeman-Durden decomposition products:
    - RS2-SLC-FQ15W-ASC-16-May-2016_00.20-PDS_05057680_Cal_Spk_FDD
    - RS2-SLC-FQ15W-ASC-09-Jun-2016_00.20-PDS_05109170_Cal_Spk_FDD
    - RS2-SLC-FQ15W-ASC-20-Aug-2016_00.20-PDS_05229220_Cal_Spk_FDD

Polarimetic Decomposition in SNAP

Freeman-Durden Decomposition Parameters



RGB of 3 polarimetric variables derived from the RADARSAT-2 FQ15W images (R=Double Bounce power, G=Volume power, B=Surface/Single bounce power)

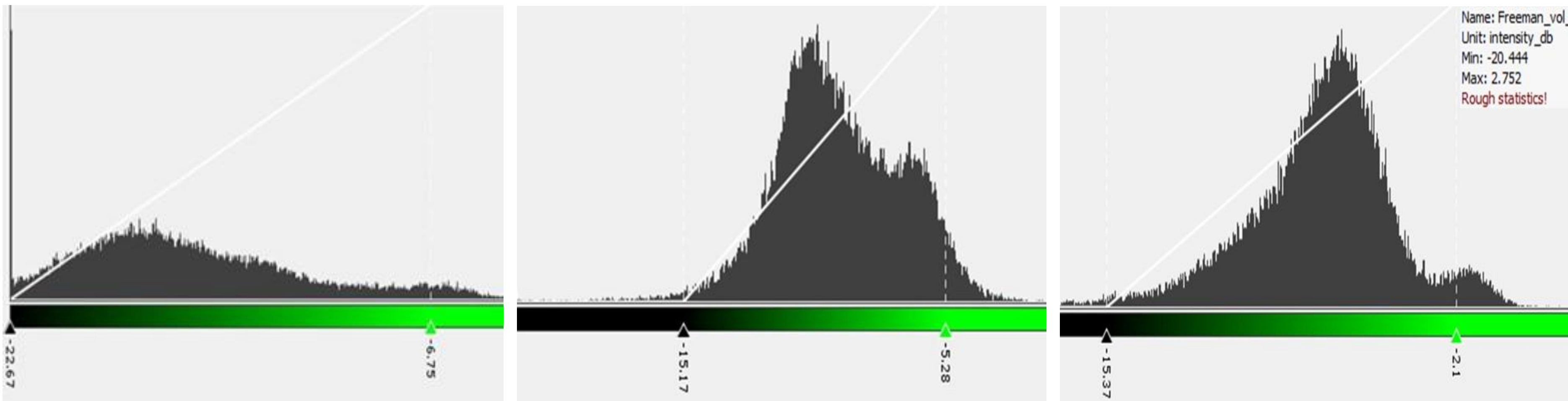


2016 crop inventory map

Polarimetic Decomposition in SNAP

Freeman-Durden Decomposition Parameters

- Generate and compare volume scattering histograms from each Freeman Durden decomposition product:



16 May 2016 **9 June 2016** **20 August 2016**

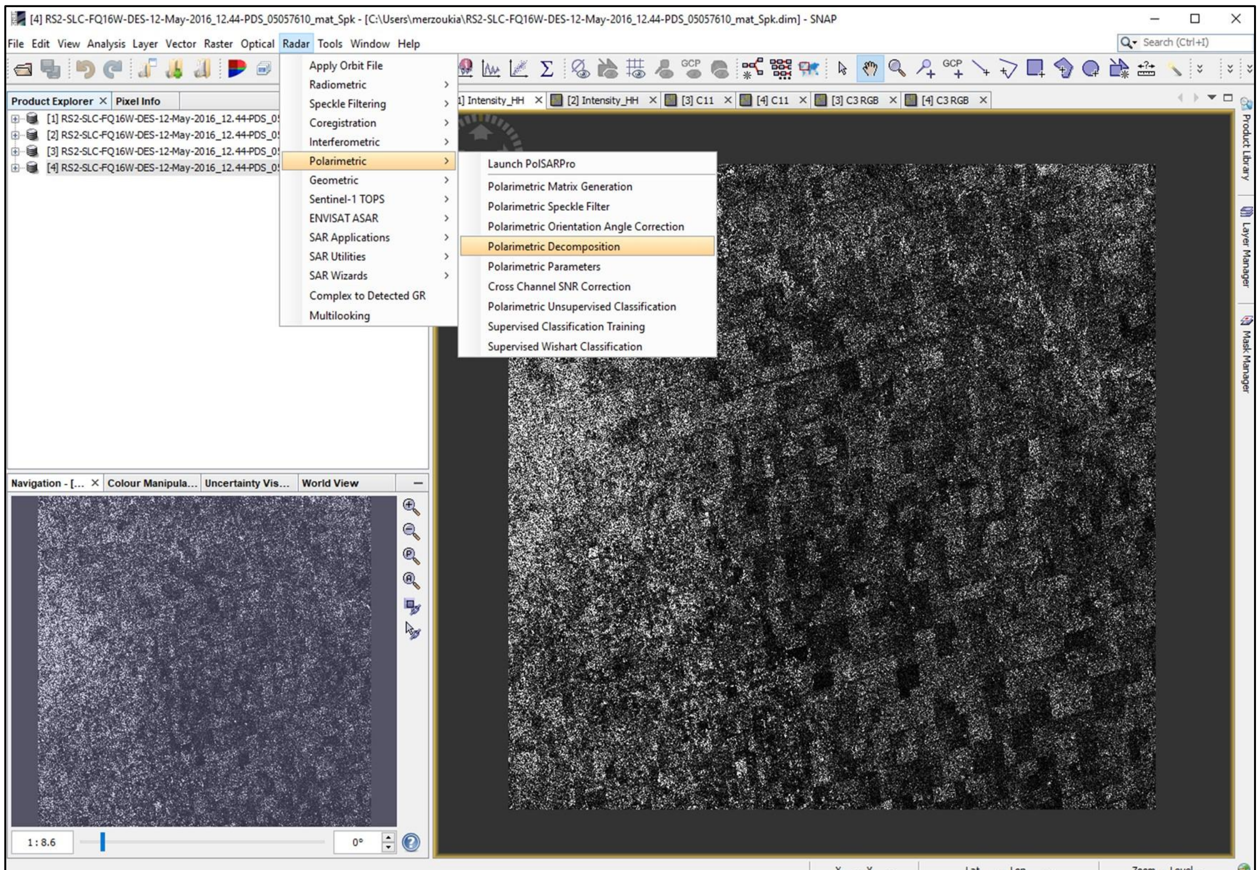
Crop Growth

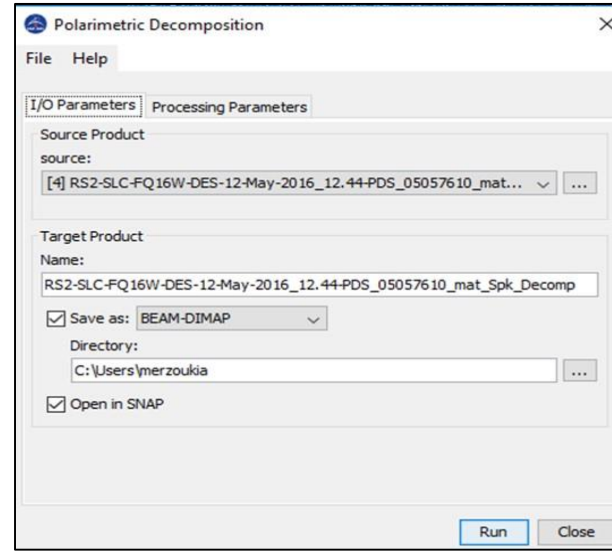
- The volume scattering power increases over time due to the crop growth.

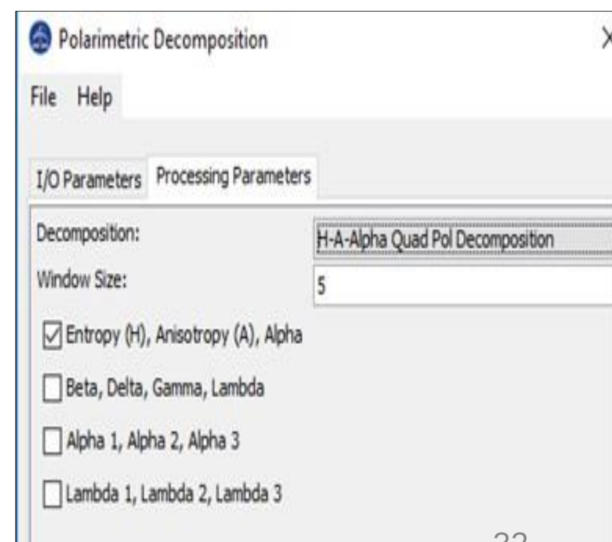
Polarimetic Decomposition in SNAP

Go to Radar Menu >> Polarimetric >> Polarimetric Decomposition:

- I/O Parameters tab: source → Speckle filtered image + Target product
- Processing Parameters tab: Decomposition→ H-A-Alpha Quad Pol Decomposition; Window Size → 5
- Click Run and Close window when completed







Polarimetic Decomposition in SNAP

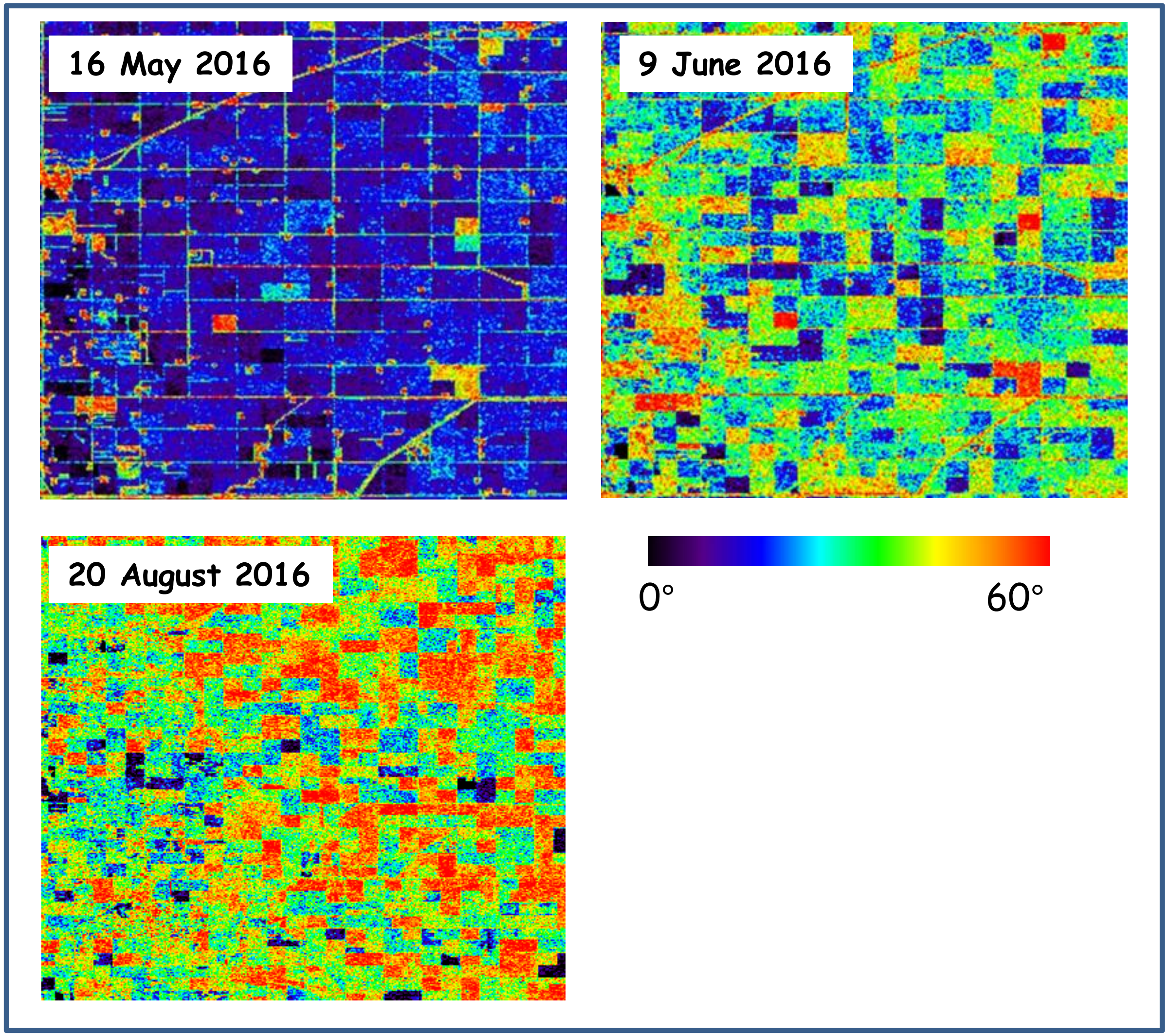
Cloude Pottier Decomposition Parameters

1. Apply H-A-Alpha decomposition to 3 pre-processed images over the growing season:
    - RS2-SLC-FQ15W-ASC-16-May-2016_00.20-PDS_05057680_Cal_Spk
    - RS2-SLC-FQ15W-ASC-09-Jun-2016_00.20-PDS_05109170_Cal_Spk
    - RS2-SLC-FQ15W-ASC-20-Aug-2016_00.20-PDS_05229220_Cal_Spk

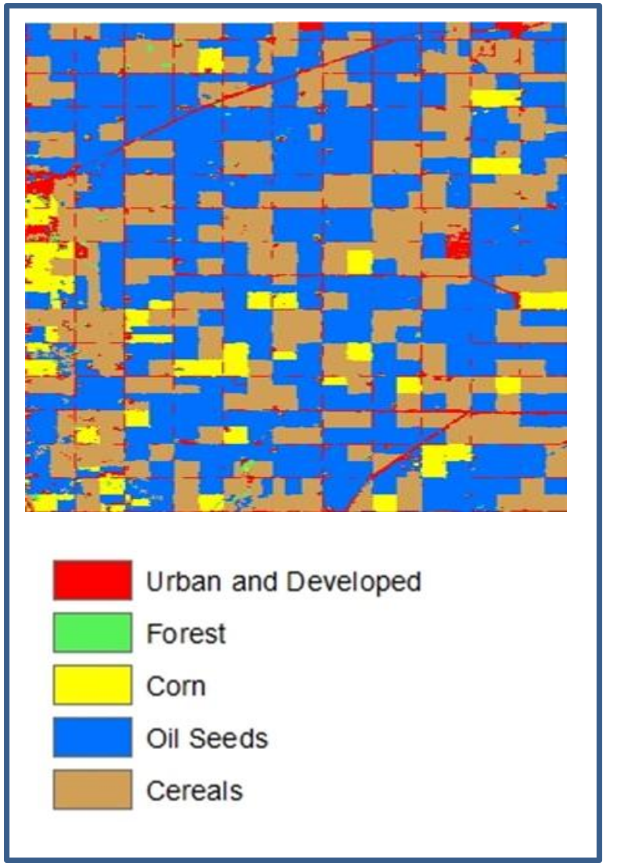
2. Apply terrain correction using Range Doppler method in SNAP to Cloude Pottier decomposition products:
    - RS2-SLC-FQ15W-ASC-16-May-2016_00.20-PDS_05057680_Cal_Spk_CPD
    - RS2-SLC-FQ15W-ASC-09-Jun-2016_00.20-PDS_05109170_Cal_Spk_CPD
    - RS2-SLC-FQ15W-ASC-20-Aug-2016_00.20-PDS_05229220_Cal_Spk_CPD

Polarimetic Decomposition in SNAP

Cloude Pottier Decomposition Parameters



Alpha parameter derived from RADARSAT-2 FQ15W images

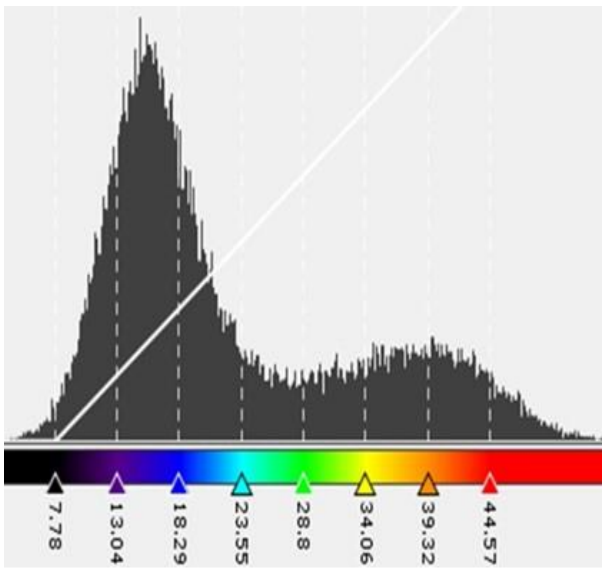


2016 crop inventory map

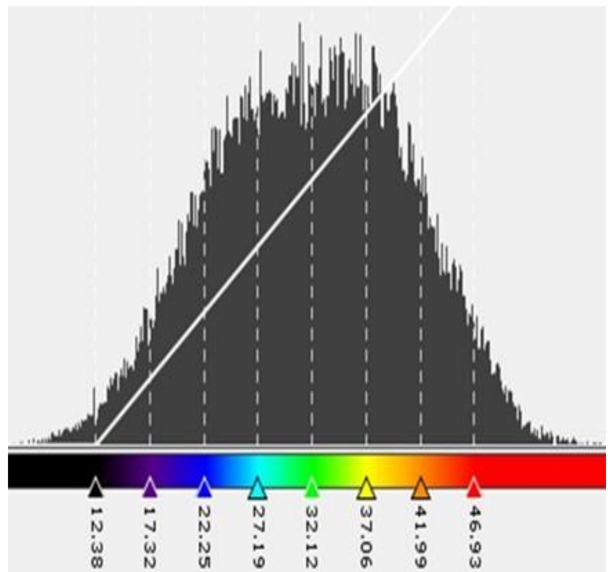
Polarimetic Decomposition in SNAP

Cloude Pottier Decomposition Parameters

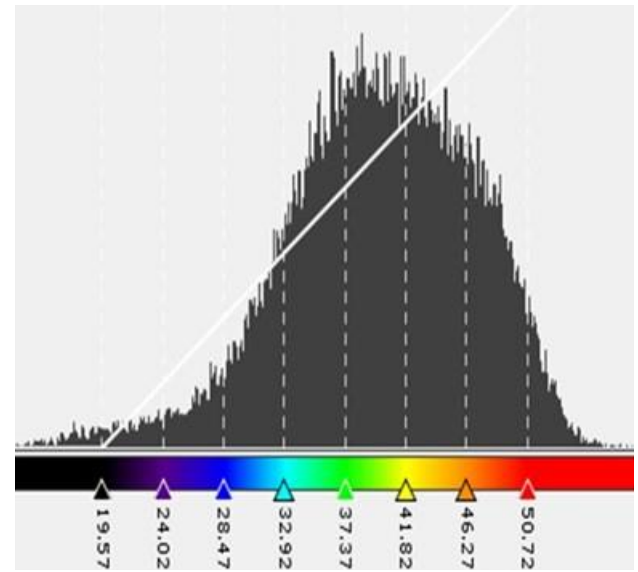
- Generate and compare alpha angle histograms from each Cloude Pottier decomposition product:



16 May 2016



9 June 2016



20 August 2016

Crop Growth

- Very low α indicates surface/single bounce scattering early in the growing season.
- $\alpha \sim 45°$ indicates the importance of volume scattering in August acquisition.