

UNIVERSITY of STIRLING



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Agriculture and Agri-Food Canada

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Environment and Climate Change Canada

Environnement et Changement climatique Canada



# Mapping Crops and their Biophysical Characteristics with Polarimetric Synthetic Aperture Radar and Optical Remote Sensing

## Part 2: Polarimetry Practical – SAR Polarimetry with Sentinel-1, RCM, & SAOCOM Imagery for Agriculture

19 April 2022

# Training Outline

April 12, 2022

SAR Polarimetry for  
Agriculture (Theory and  
Practice)

April 19, 2022

**Polarimetry Practical Part 2:  
SAR Polarimetry with  
Sentinel-1, RCM, &  
SAOCOM Imagery for  
Agriculture**

April 26, 2022

Sen4Stat Open-Source  
Toolbox (Theory and  
Practical)

May 1, 2022

Crop-Specific Time Series  
Analysis for Growth Monitoring



# Homework and Certificate

- Homework Assignment:
  - Answers must be submitted via Google Form
  - Due Date: May 17, 2022
- A certificate of completion will be awarded to those who:
  - Attend all live webinars
  - Complete the homework assignment by the deadline (access from website)
  - You will receive a certificate approximately two months after the completion of the course from: [marines.martins@ssaihq.com](mailto:marines.martins@ssaihq.com)

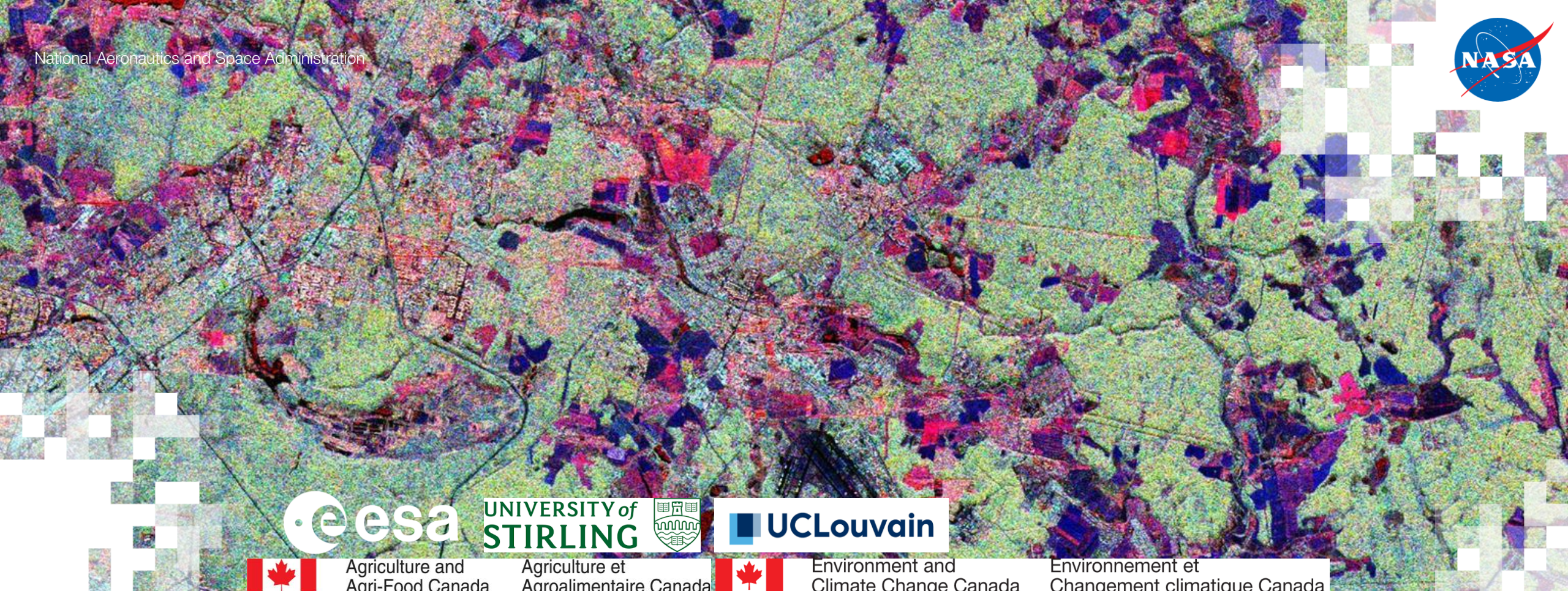


# Training Objectives

By the end of this training attendees will be able to:

- Explain the theory behind SAR Polarimetry, especially as related to crop characteristics
- Generate polarimetric parameters using open-source imagery/software and perform a time series analysis of crop growth
- Identify how Sen4Stat can support National Statistical Offices in the uptake of satellite Earth observations for agricultural statistics
- Perform a time series analysis of crop types using Sentinel-2 derived LAI index





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# Polarimetry Practical: SAR Polarimetry with Sentinel-1

Laura Dingle Robertson, Heather McNairn, Sarah Banks, Xianfeng Jiao

19 April 2022

# Polarimetry with Sentinel-1 Single Look Complex (SLC) Data

- Polarimetry allows for the use of phase and creates “richer” information than just intensity alone.
- Sentinel-1 dual-pol (VV, VH) SLC data can be stored in a 2x2 covariance matrix [C2].
  - uses the full available signal bandwidth, and
  - phase is preserved and each pixel consists of both a real and imaginary component
- Using the 2x2 covariance matrix [C2] we can derive scattering parameters that are similar to fully polarimetric or compact polarimetric parameters.



# 'Pseudo' Polarimetric Parameters

<b>Stokes parameters</b> ( $S_0, S_1, S_2, S_3$ )	A set of values that describe the partial polarization state of an electromagnetic wave	$S_0 =  E_H ^2 +  E_V ^2$ $S_1 =  E_H ^2 -  E_V ^2$ $S_2 = 2 E_H  E_V  \cos \phi_{HV}$ $S_3 = 2 E_H  E_V  \sin \phi_{HV}$
<b>Orientation angle</b> ( $\psi$ )	The orientation of the linear polarization with the strongest backscatter	$\psi = \frac{1}{2} \tan^{-1} \frac{S_2}{S_1}$
<b>Ellipticity angle</b> ( $\chi$ )	The ellipticity of the scattered wave	$\chi = \frac{1}{2} \tan^{-1} \frac{S_3}{\sqrt{S_1^2 + S_2^2}}$
<b>Degree of linear polarization (DoLP)</b>	The degree of linear polarization components in the polarized scattering	$DoLP = \frac{\sqrt{S_1^2 + S_2^2}}{\sqrt{S_1^2 + S_2^2 + S_3^2}}$
<b>Linear polarization ratio (LPR)</b>	The ratio of VH and VV intensities	$LPR = \frac{S_0 - S_1}{S_0 + S_1}$
<b>Span (I)</b>	Total intensity (VH+VV), expressed in power	
<b>Eigenvalues (<math>l_1</math>)</b>	Eigenvalues of the coherency matrix	$l_1 = \frac{1}{2} (S_0 + mS_0)$
<b>Eigenvalues (<math>l_2</math>)</b>	Eigenvalues of the coherency matrix	$l_2 = \frac{1}{2} (S_0 - mS_0)$
<b>Entropy (H)</b>	The degree of randomness of scattering	See Cloude, et al. 2012 <a href="https://www.researchgate.net/publication/260622729_Compact_Decomposition_Theory">https://www.researchgate.net/publication/260622729_Compact_Decomposition_Theory</a>
<b>Alpha (<math>\bar{\alpha}</math>)</b>	The dominant scattering mechanism (in degrees)	See Cloude, et al. 2012 <a href="https://www.researchgate.net/publication/260622729_Compact_Decomposition_Theory">https://www.researchgate.net/publication/260622729_Compact_Decomposition_Theory</a>
<b>Normalized Shannon Entropy (SE)</b>	The sum of total backscatter power and the Barakat degree of polarization, normalized to between 0 and 1	See Réfrégier and Morio 2006 <a href="https://www.researchgate.net/publication/6692148_Shannon_entropy_of_partially_polarized_and_partially_coherent_light_with_Gaussian_fluctuations">https://www.researchgate.net/publication/6692148_Shannon_entropy_of_partially_polarized_and_partially_coherent_light_with_Gaussian_fluctuations</a>



# Stokes Parameters

- Describes the scattering from a partially polarized electromagnetic (EM) field.
- Contains all the polarimetric information to describe scattering from a target.

$$\begin{aligned}S_0 &= |E_H|^2 + |E_V|^2 \\S_1 &= |E_H|^2 - |E_V|^2 \\S_2 &= 2|E_H||E_V| \cos \phi_{HV} \\S_3 &= 2|E_H||E_V| \sin \phi_{HV}\end{aligned}$$

where  $|E|$  is the amplitude of the intensity and  $\phi_{HV}$  is the phase difference between H and V. All four Stokes parameters are real numbers.

- first Stokes vector parameter ( $S_0$ ) indicates the total intensity of the radar backscatter (polarized and unpolarized), which is the sum of the powers of the two orthogonally-polarized received waves.
- other three parameters ( $S_1$ ,  $S_2$ , and  $S_3$ ) describe the properties of the polarized portion of the EM field.





# Degree of Linear Polarization (DoLP)

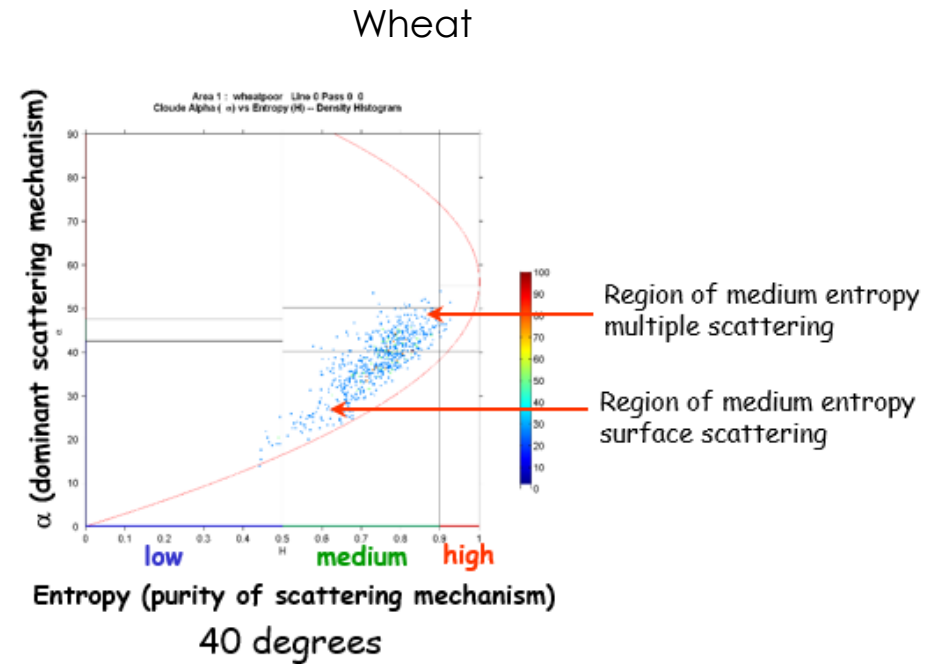
- The wave incident upon the target arrives completely polarized.
- If the target is composed of elements with varying orientations (e.g., leaves, stalks, flowers, etc.) the waves scattered by these individual elements will vary in phase and polarization.
- DoLP measures the percentage of the polarized energy, which is linearly polarized.
- DoLP is low where scattering is dominated by circularly polarized waves and approaches one when scattered waves are linearly polarized (regardless of orientation angle).
- This is based on Stokes and is measured as:

$$DoLP = \frac{\sqrt{S_1^2 + S_2^2}}{\sqrt{S_1^2 + S_2^2 + S_3^2}}$$



# Entropy / Alpha

- Cloude et al. (2012), Cloude(2007) developed a dual-polarized version of the fully polarimetric H/a/alpha decomposition method, which only includes entropy & alpha.
- Extends the idea of alpha as an indicator of the dominant scattering type (e.g., multiple/volume scatterer, single bounce/surface scatterer, and double bounce scatterer), in general:
  - single scatterers will have lower alpha and alpha will increase as biomass increases (indicating a change from dominant surface scattering to multiple and double bounce scattering).
  - keep in mind that how a wave scatters also depends on the incidence angle; both alpha and entropy will change with changing incidence angle.



## Entropy

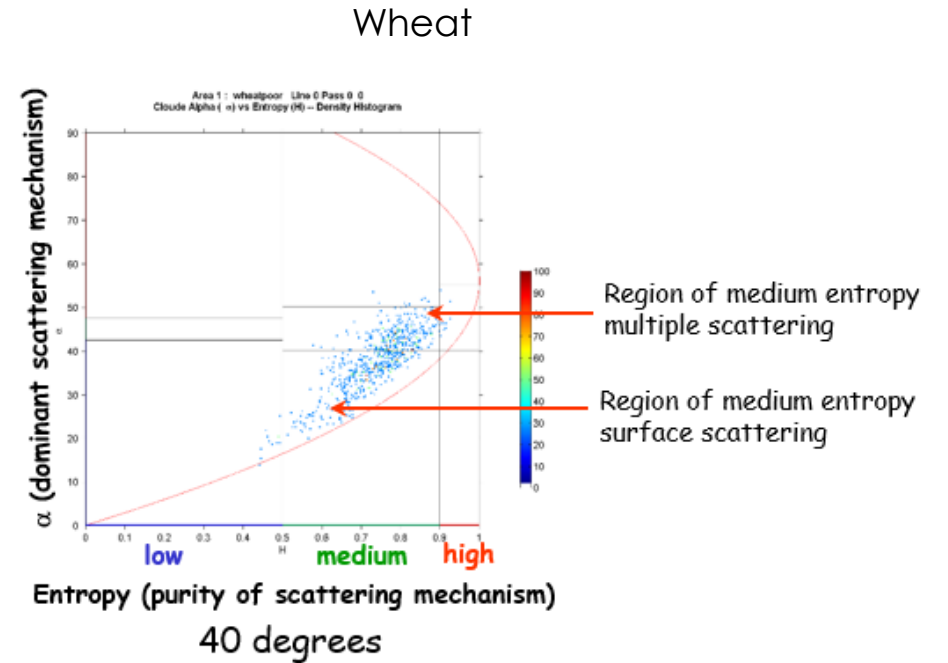
Incidence Angle	Low Biomass	Higher Biomass
25	0.40	0.51
36	0.63	0.69
40	0.74	0.76
45	0.80	0.80

Courtesy: H. McNairn



# Entropy / Alpha

- Extends idea of entropy from fully polarimetric decomposition as a measure of the complexity and/or uniformity of the target.
  - On a bare, smooth field the polarization of the scattered wave will be predictable from location to location; alpha will indicate a dominance of single bounce scattering and entropy will remain low.
  - As vegetation cover increases, the polarization of the scattered wave becomes less predictable, and entropy will increase.



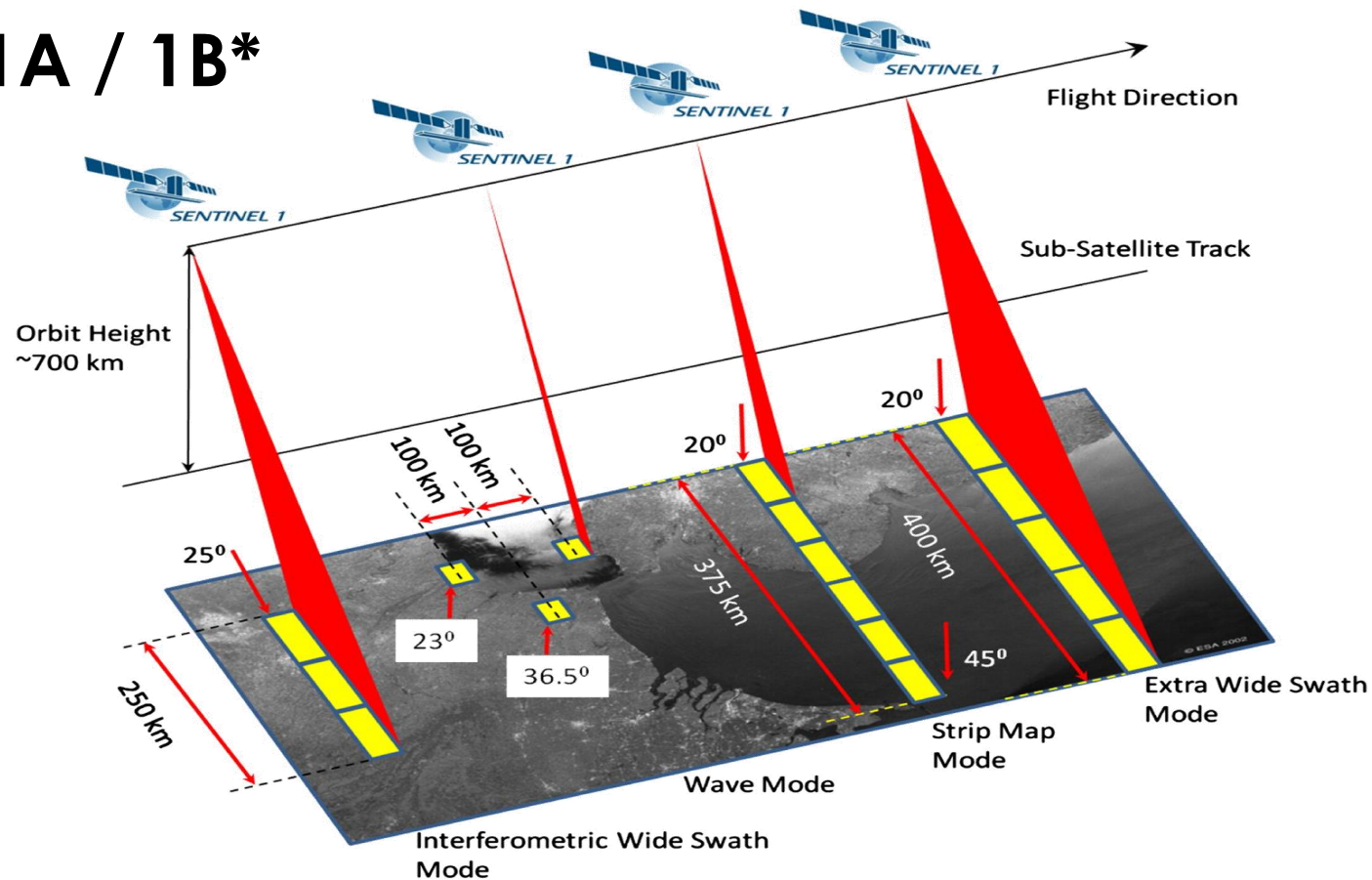
## Entropy

Incidence Angle	Low Biomass	Higher Biomass
25	0.40	0.51
36	0.63	0.69
40	0.74	0.76
45	0.80	0.80

Courtesy: H. McNairn



# Sentinel-1A / 1B\*



## Overview of the Sentinel-1 scanning modes – Revisit time: 6 days

\*Sentinel 1B malfunctioned in December 2021 and has not been acquiring imagery since that date. ESA is working diligently to try and fix the issue. Sentinel 1A continues to collect imagery. See <https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-1/observation-scenario/acquisition-segments> for acquisition plans.

Thales Alenia Space is prime contractor for Sentinel-1C and its twin Sentinel-1 D. Airbus Defence and Space is responsible for both radars. **Expected launch of Sentinel 1C is 2023** (as of April 2022).





# Sentinel-1 Data Access

The screenshot displays the Copernicus Open Access Hub interface. At the top, the ESA and Copernicus logos are visible alongside the text "Copernicus Open Access Hub". Below the header is a search bar with the placeholder text "Insert search criteria...".

The main search panel is titled "Advanced Search" and includes the following filters:

- Sort By:** Sensing Date
- Order By:** (empty dropdown)
- Sensing period:** From 2018/10 to 2018/11
- Ingestion period:** From: to: (empty date pickers)
- Mission:** Sentinel-1 (checked)

Under the "Mission: Sentinel-1" section, there are two columns of filters:

- Satellite Platform:** S1A\_\*
- Polarisation:** (empty dropdown)
- Relative Orbit Number (from 1 to 175):** (empty input field)
- Product Type:** (empty dropdown)
- Sensor Mode:** (empty dropdown)
- Collection:** (empty dropdown)

Below this, the "Mission: Sentinel-2" section is visible but not selected:

- Satellite Platform:** (empty dropdown)
- Relative Orbit Number (from 1 to 143):** (empty input field)
- Product Type:** (empty dropdown)
- Cloud Cover % (e.g [0 TO 9.4]):** (empty input field)

The background of the interface is a map of the Ottawa-Montreal region in Quebec, Canada. A yellow rectangular area highlights a specific region between Ottawa and Montreal, covering areas like Carleton Place, Stittsville, and the Ottawa River valley. The map shows various cities, roads, and water bodies.

<https://scihub.copernicus.eu/dhus/#/home>



# Sentinel-1 Data Access

The screenshot displays the Copernicus Open Access Hub interface. At the top, the ESA and Copernicus logos are visible, along with the text "Copernicus Open Access Hub". Below the search bar, there are navigation icons for user profile, help, and home. The search results panel on the left shows a list of products, with the third product highlighted by a red circle. The map on the right shows a geographic area in Quebec, Canada, with a red polygon indicating the search area. The product list includes the following information:

Product ID	Download URL	Mission	Instrument	Sensing Date
S1A SAR-C S1A_IW_RAW_0SDV_20181103T225242_20181103T225315...	<a href="https://scihub.copernicus.eu/dhus/odata/v1/Products/...">https://scihub.copernicus.eu/dhus/odata/v1/Products/...</a>	Sentinel-1	SAR-C	2018-11-03T225242
S1A SAR-C S1A_IW_GRDH_1SDV_20181103T225221_20181103T225246...	<a href="https://scihub.copernicus.eu/dhus/odata/v1/Products/...">https://scihub.copernicus.eu/dhus/odata/v1/Products/...</a>	Sentinel-1	SAR-C	2018-11-03T225221
S1A SAR-C S1A_IW_SLC_1SDV_20181103T225220_20181103T225247...	<a href="https://scihub.copernicus.eu/dhus/odata/v1/Products/...">https://scihub.copernicus.eu/dhus/odata/v1/Products/...</a>	Sentinel-1	SAR-C	2018-11-03T225220
S1A SAR-C S1A_IW_RAW_0SDV_20181103T225217_20181103T225250...	<a href="https://scihub.copernicus.eu/dhus/odata/v1/Products/...">https://scihub.copernicus.eu/dhus/odata/v1/Products/...</a>	Sentinel-1	SAR-C	2018-11-03T225217



# Alaska Satellite Facility Data Portal

**EARTHDATA** Find a DAAC

## ALASKA SATELLITE FACILITY

Vertex is the Alaska Satellite Facility's data portal for remotely sensed imagery of the Earth.

Vertex | Interactive Tours | Help | ASF Home

Earthdata Login | Download Queue | Contact

Geospatial | Granule | Missions

**Geographic Region**

Option 1: Click on map and move cursor  
Option 2: Enter coordinates:  
Polygon counterclockwise, decimal degrees, (long,lat)  
e.g., -102,37.59,-94,37,-94,39,-102,39,-102,37.59

**Dataset**

Select: All | None

Dataset	Info
<input checked="" type="checkbox"/> Sentinel-1B	2016-now
<input checked="" type="checkbox"/> Sentinel-1A	2014-now
<input type="checkbox"/> SMAP	2015-now
<input type="checkbox"/> UAVSAR	2008-now
<input type="checkbox"/> ALOS PALSAR	2006-2011
<input type="checkbox"/> RADARSAT-1	1999-2008
<input type="checkbox"/> ERS-2	1995-2011
<input type="checkbox"/> JERS-1	1992-1998
<input type="checkbox"/> ERS-1	1991-1997
<input type="checkbox"/> AIRSAR	1990-2004
<input type="checkbox"/> SEASAT	1978-1978

Optional Search Criteria

Search | Reset

World Map | South Polar

Satellite | Map

Please use the map and/or the search parameters on the left to select your search criteria.

Google

Imagery ©2018 NASA, TerraMetrics | Terms of Use

Number of Frames: 1, 2-5, 6-15, 16-20, 21+

Vertex

Copyright © 2018 Alaska Satellite Facility  
Vertex: ASF's Data Portal V3.04-03  
Phone: (907) 474-5041 | [Web](#) | [Contact](#)

UA is an AA/EEO employer and educational institution and prohibits illegal discrimination against any individual. [www.alaska.edu/nondiscrimination](#)

Image Source: <https://vertex.daac.asf.alaska.edu/>

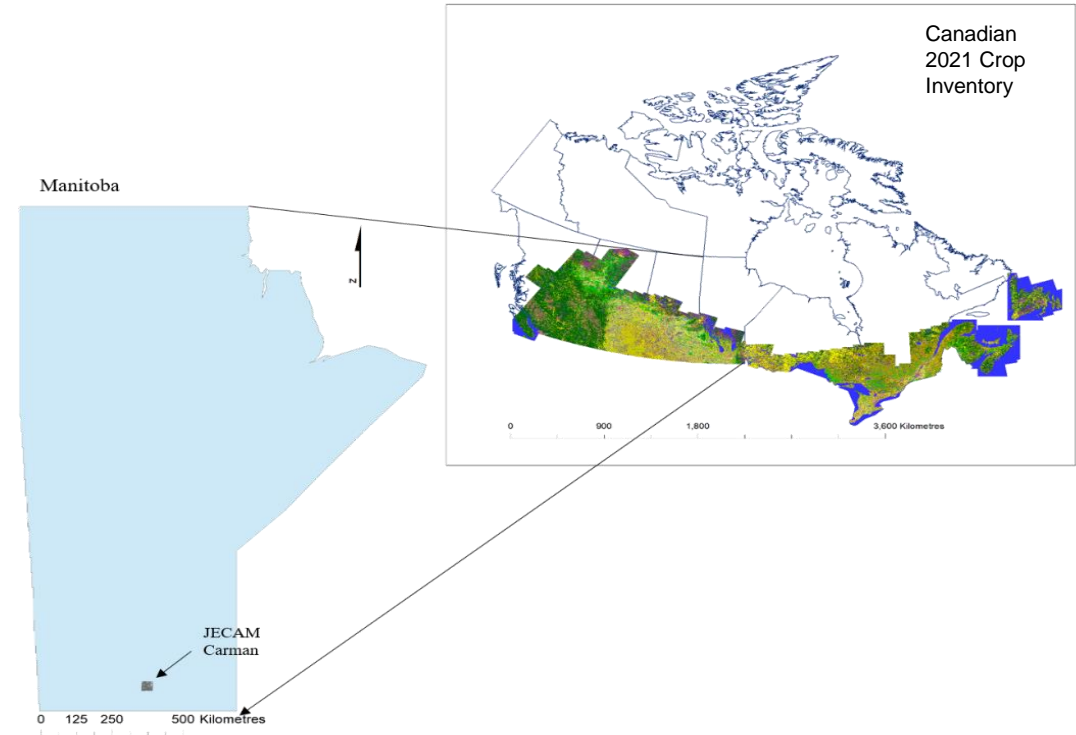
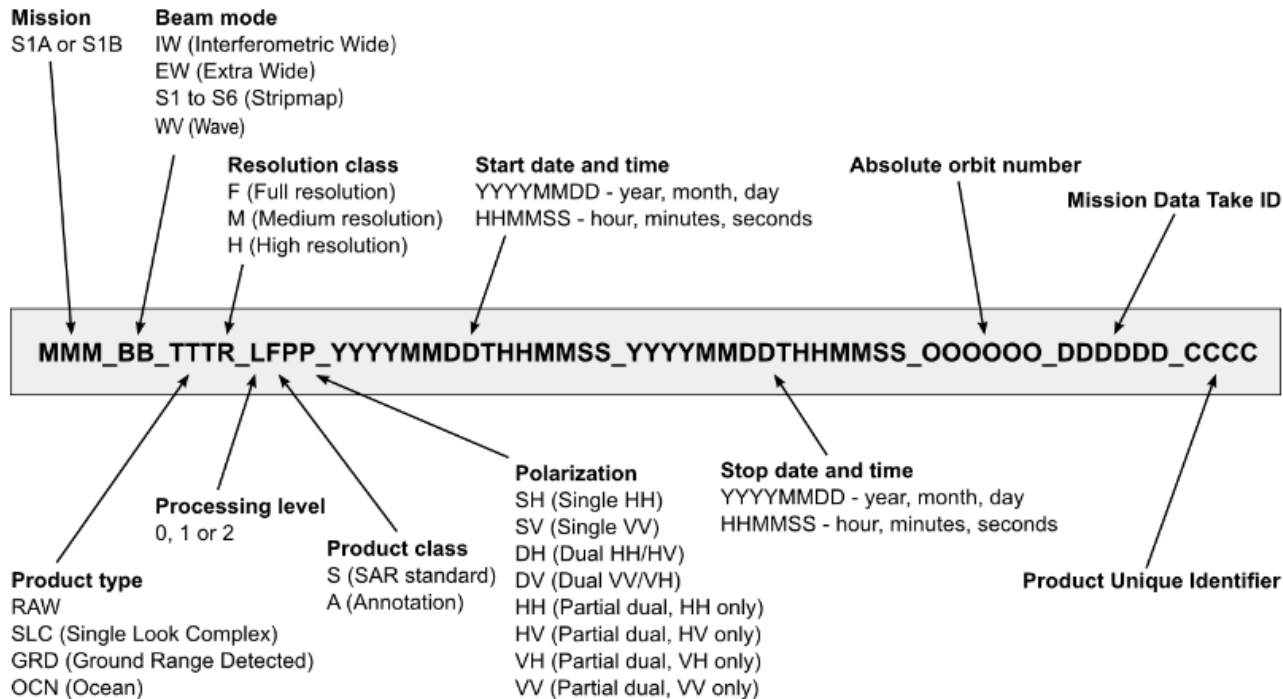




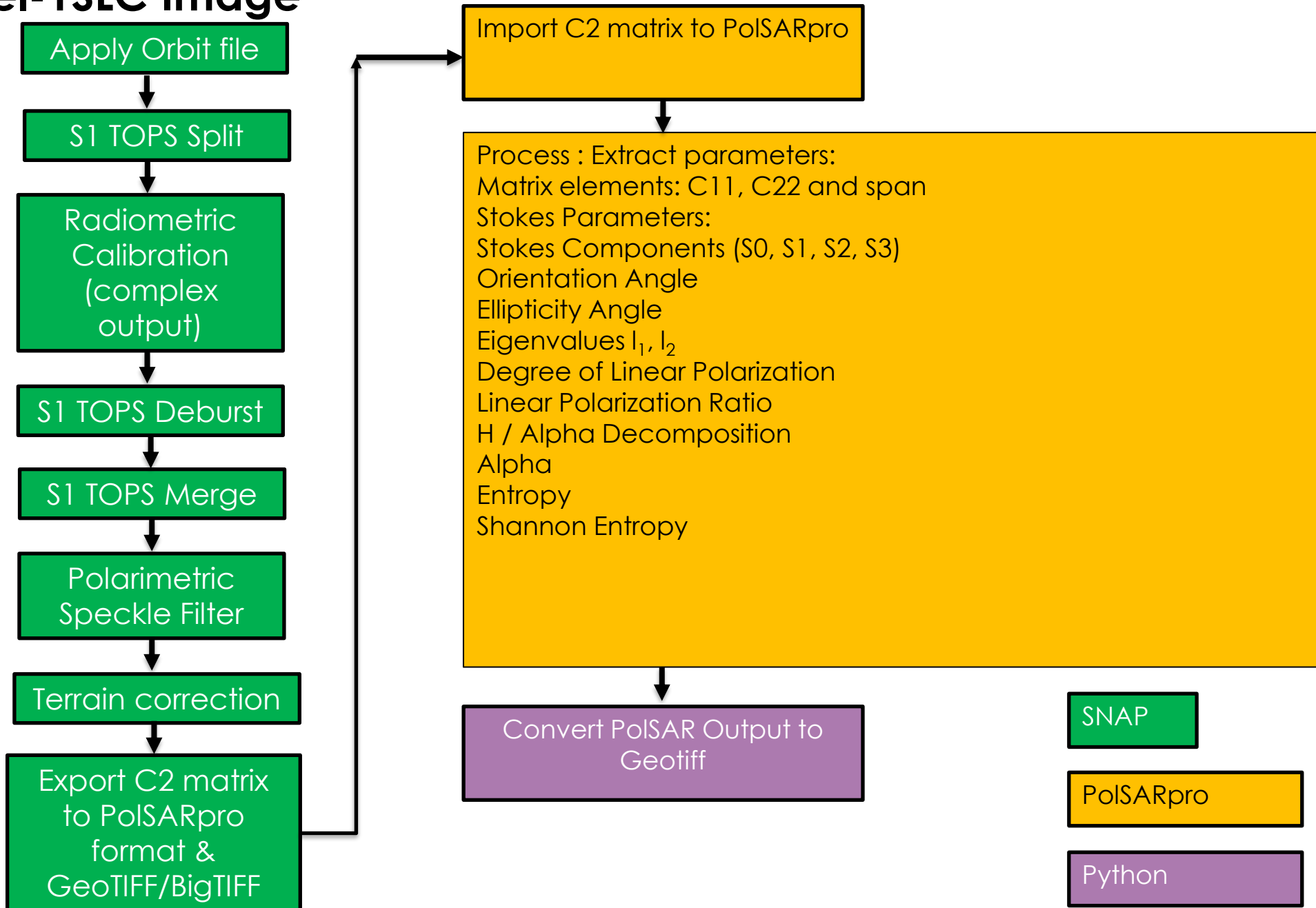
# Area of Interest

- July 9, 2020, image

S1B\_IW\_SLC\_\_1SDV\_20200709T002321\_20200709T002348\_022387\_02A7D6\_65BE



# Sentinel-1 SLC Image



# Generating C2 Matrix with SNAP

- Must use Single Look Complex (SLC) Sentinel-1

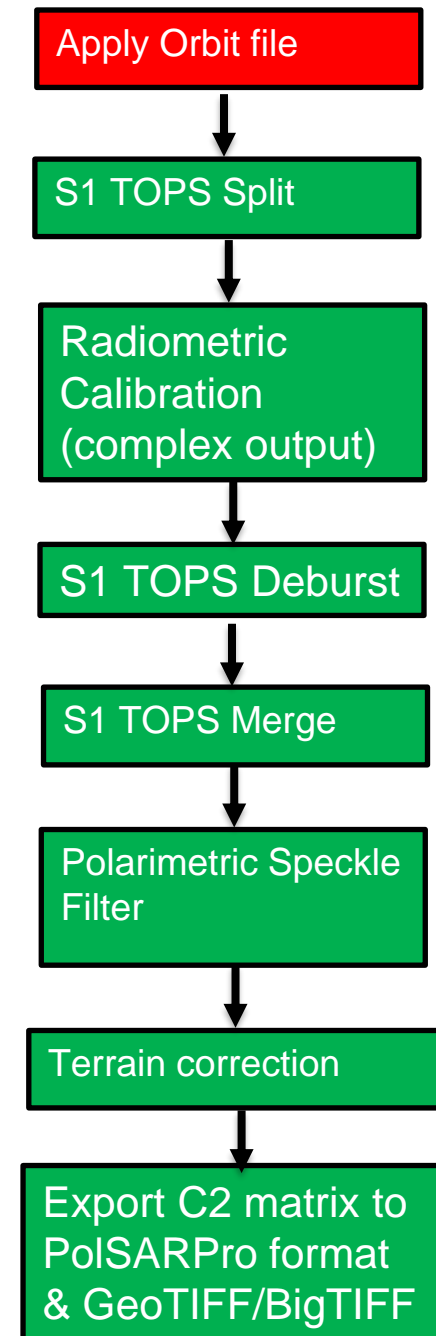
$$C_2 = \begin{bmatrix} C_{11} & C_{12} \\ C_{21} & C_{22} \end{bmatrix} = \begin{bmatrix} \langle |S_{VV}|^2 \rangle & \langle S_{VV} S_{VH}^* \rangle \\ \langle S_{VH} S_{VV}^* \rangle & \langle |S_{VH}|^2 \rangle \end{bmatrix}$$

- First step to create pseudo polarimetric parameters is generating **[C2]** 2x2 Covariance Matrix using ESA's SNAP
- Issues with generating S1 polarimetric parameters include the processing time and memory requirements
- Each interferometric wide swath consists of:
  - Three sub-swaths (IW1, IW2, and IW3) in the range direction.
    - Each sub-swath has 9 bursts in the azimuth direction



# Apply Orbit File

- Satellite positions are recorded by a Global Navigation Satellite System (GNSS).
- To assure a fast delivery of Sentinel-1 products, orbit information generated by an on-board navigation solution is stored within the Sentinel-1 Level-1 products.
- The orbit positions are later refined by the Copernicus Precise Orbit Determination (POD) Service.
- Precise orbit files have less than 5 cm accuracy and are delivered within 20 days after data acquisitions.
- The accuracy of restituted orbit files is less than 10 cm. The files are available 3 hours after data acquisitions.



# Apply Orbit File

Go to Radar Menu → Apply Orbit File

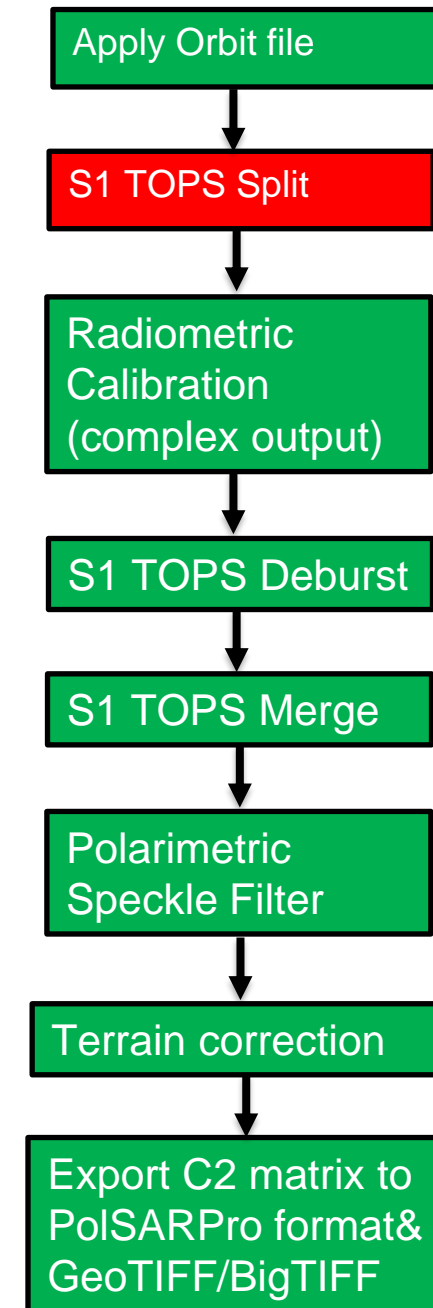
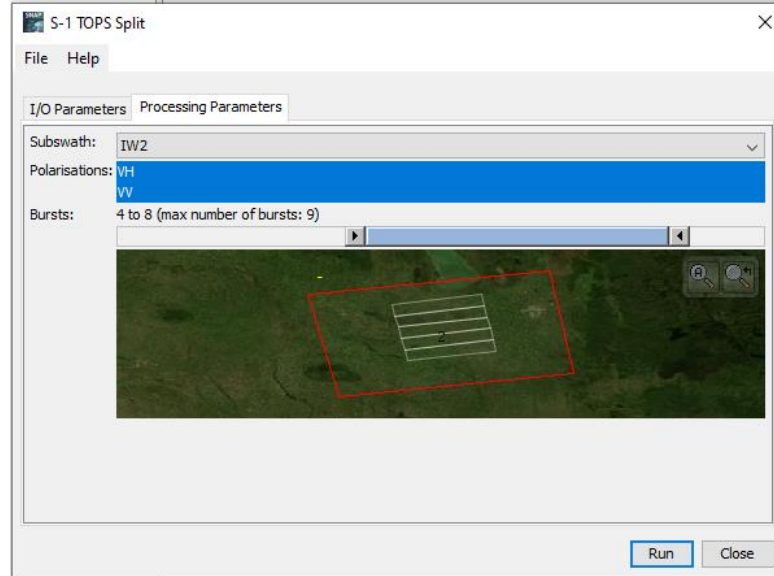
- I/O Parameters tab: source → Sentinel 1 SLC image + Target product
- Processing Parameters tab:
  - Orbit State Vectors: Sentinel Precise (Auto Download).
  - Polynomial Degree: 3
  - Click Run and Close window when completed

The screenshot displays the SNAP (Scientific Data Processing) software interface. The 'Radar' menu is open, showing options such as Radiometric, Speckle Filtering, Coregistration, Interferometric, Polarimetric, Geometric, Sentinel-1 TOPS, ENVISAT ASAR, SAR Applications, Soil Moisture, and SAR Utilities. The 'Apply Orbit File' dialog box is open, showing the 'I/O Parameters' tab. The 'Orbit State Vectors' dropdown is set to 'Sentinel Precise (Auto Download)', and the 'Polynomial Degree' is set to 3. There is an unchecked checkbox for 'Do not fail if new orbit file is not found'. The 'Run' and 'Close' buttons are visible at the bottom right of the dialog. The background shows the SNAP interface with the 'Product Explorer' on the left, displaying a list of bands for a Sentinel-1 SLC image, including Metadata, Vector Data, Tie-Point Grids, Quicklooks, and Bands (i\_IW1\_VH, q\_IW1\_VH, Intensity\_IW1\_VH, i\_IW1\_VV, q\_IW1\_VV, Intensity\_IW1\_VV, i\_IW2\_VH, q\_IW2\_VH, Intensity\_IW2\_VH, i\_IW2\_VV, q\_IW2\_VV, Intensity\_IW2\_VV, i\_IW3\_VH, q\_IW3\_VH, Intensity\_IW3\_VH, i\_IW3\_VV, q\_IW3\_VV, Intensity\_IW3\_VV). The main window shows a satellite image of a coastal area with a red bounding box.



# S1 TOPS Split

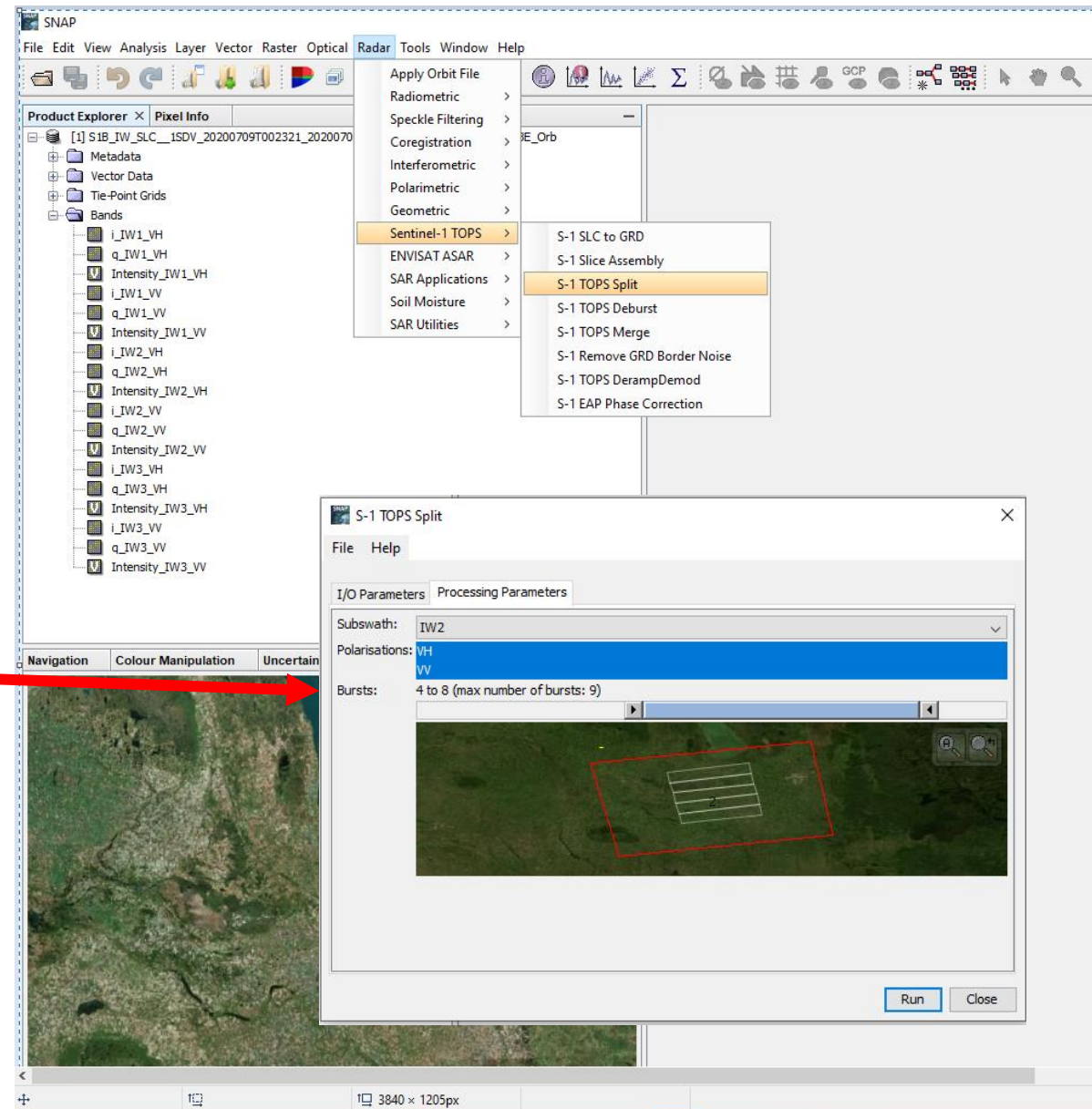
- TOPSAR Split operator splits each sub swath into selected bursts
- Limits the amount of data to process, reducing processing time and memory requirements



# S1 TOPS Split

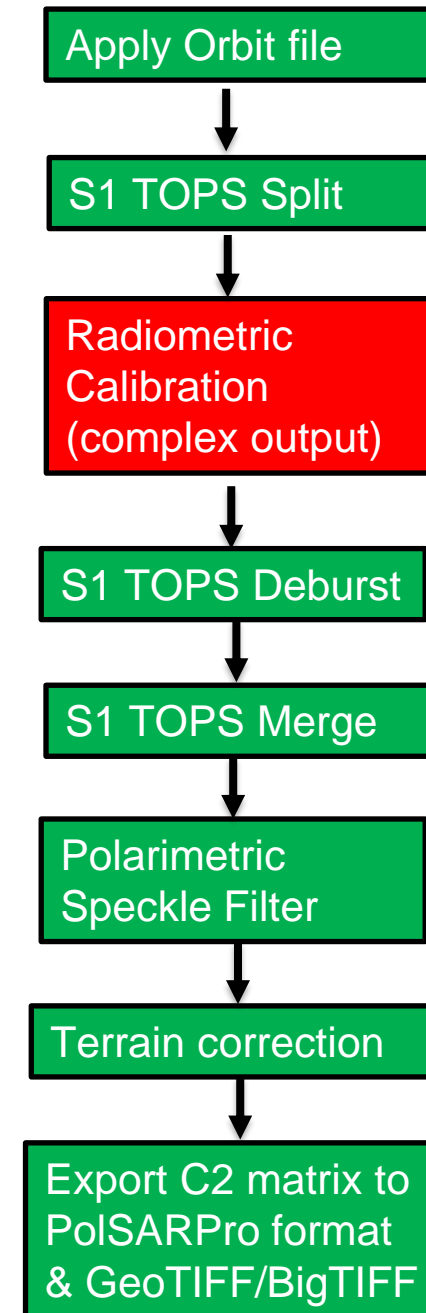
Go to Radar Menu → Sentinel-1 TOPS  
→ S-1 TOPS Split:

- I/O Parameters tab: source → Orbit corrected S1 SLC image + Target product
- Processing Parameters tab:
  - Subswath: choose either IW1, IW2 or IW3
  - Polarisations: Highlight one or both
  - Bursts: Reduce the bursts to those that fall over the top of your area of interest; choose the arrow on either side of the slide bar and move inward
  - Click Run and Close window when completed



# Radiometric Conversion

- SAR SLC products are complex and must be converted to real (intensity) and imaginary (phase) channels.
- The conversion is mission-specific and for polarimetric processing the data must be complex.
- SNAP will automatically determine what kind of input product you have and what conversion needs to be applied based on the product's metadata.

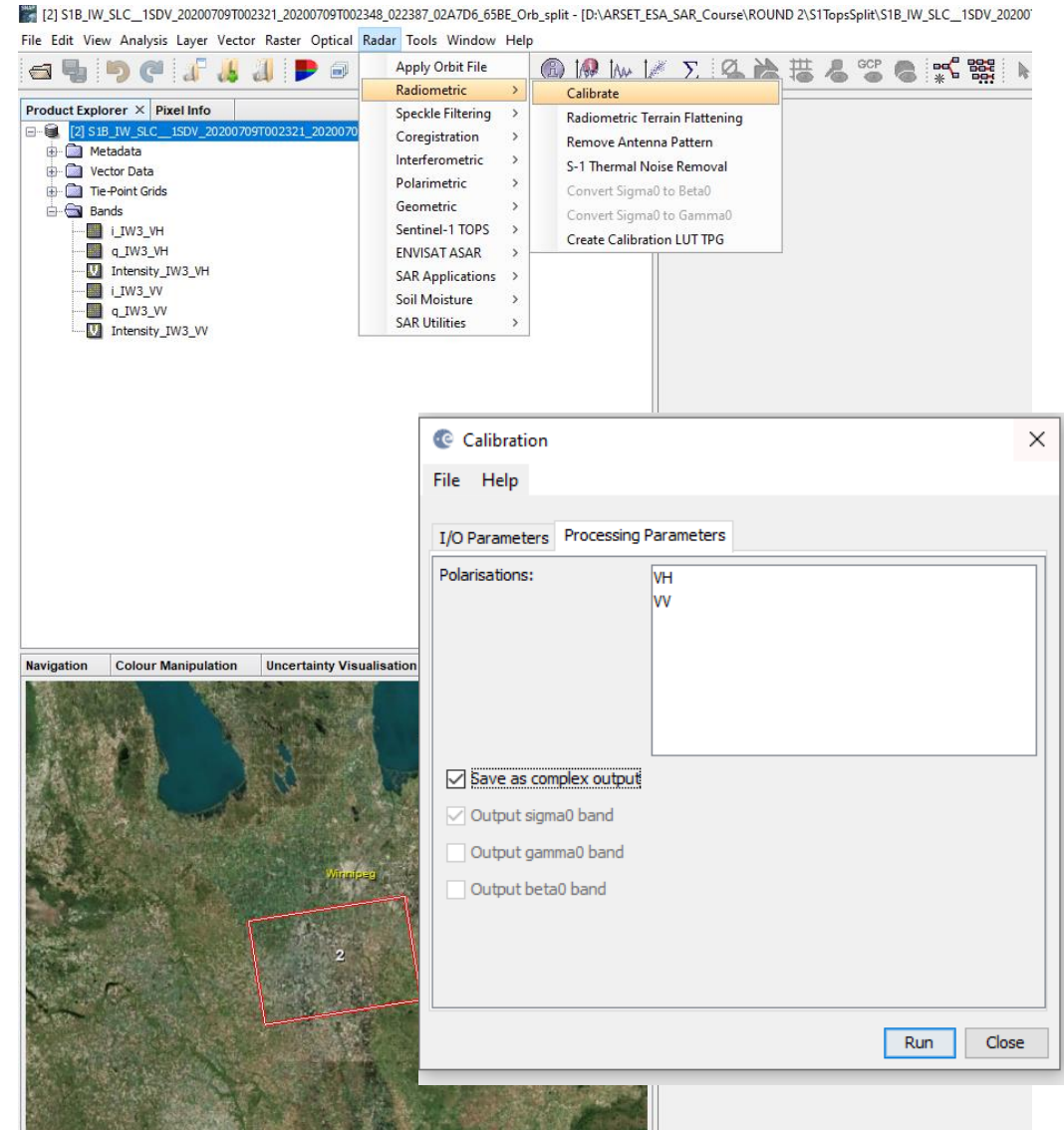




# Radiometric Conversion

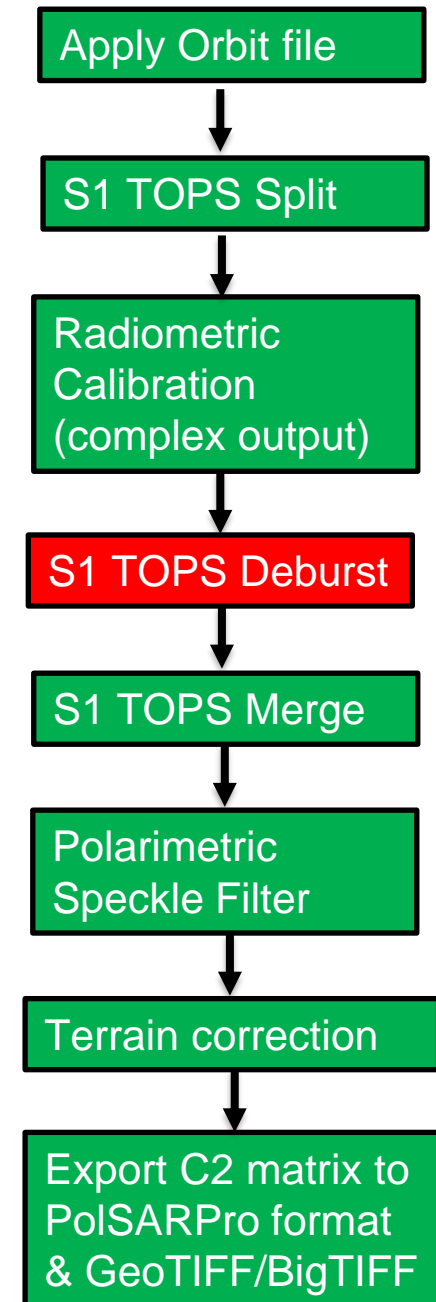
Go to Radar Menu → Radiometric → Calibrate:

- I/O Parameters tab: source → S1 Tops Split & Orbit Corrected Image + Target product
- Select “Save as complex output”
- Processing Parameters tab:
- Click Run and Close window when completed



# S1 TOPS Deburst

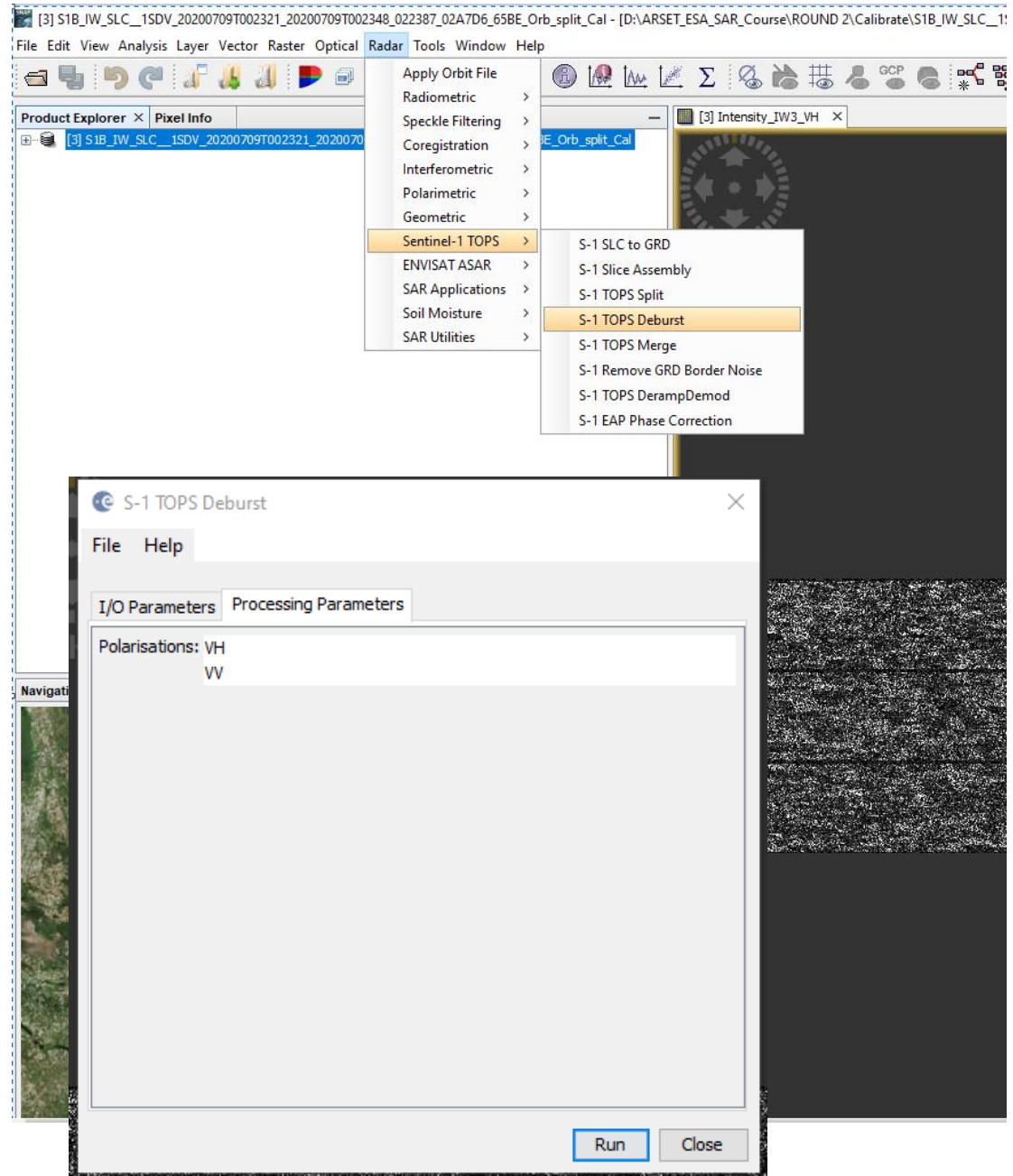
The images for all selected bursts from the previous results in the selected sub-swaths are resampled to a common pixel spacing grid in range and azimuth while preserving the phase information. All bursts are merged.



# S1 TOPS Deburst

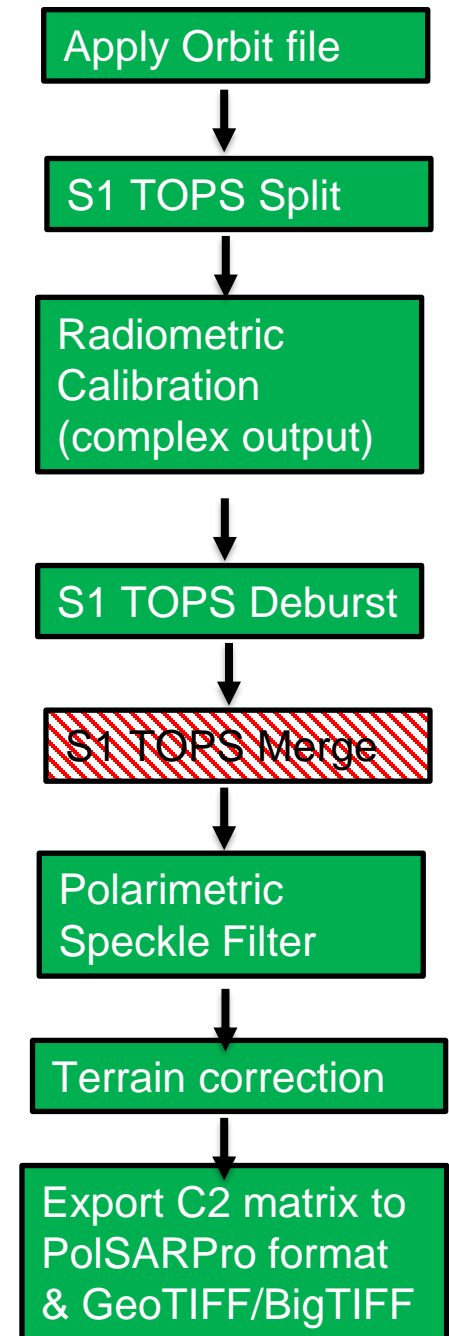
Go to Radar Menu → Sentinel-1 TOPS → S-1 TOPS Deburst:

- I/O Parameters tab: source → Orbit, TOPS Split, Calibrated S1 SLC image + Target product
- Processing Parameters tab:
  - Polarisation: VH, VV
  - Click Run and Close window when completed



# S1 TOPS Merge

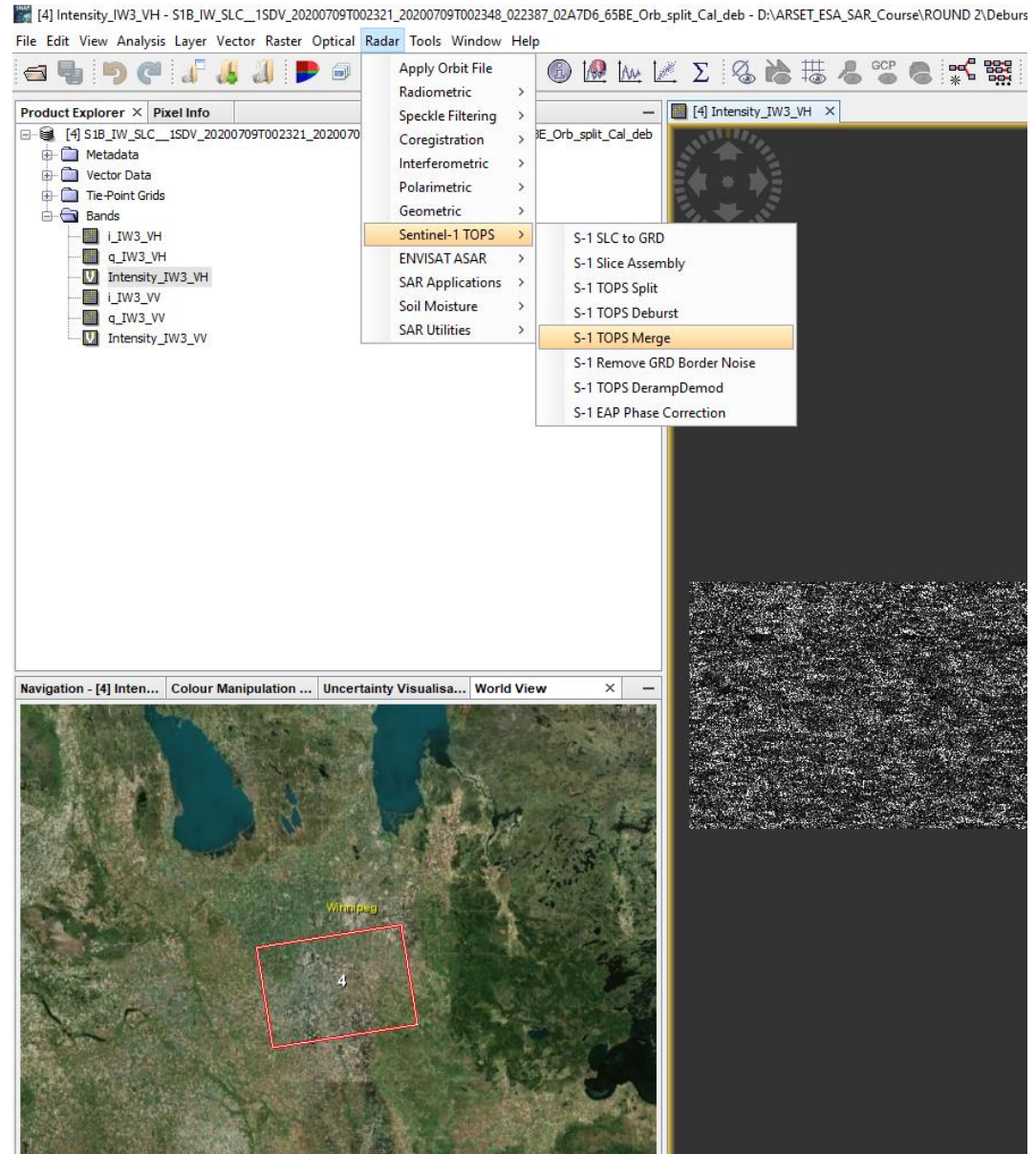
If you have processed multiple sub swaths of one image (e.g., 1 to 3), the S1 TOPS Merge operator merges the merged bursts, as sub-swaths products into one complete product



# S1 TOPS Merge

Go to Radar Menu → Sentinel-1 TOPS → S-1 TOPS Merge:

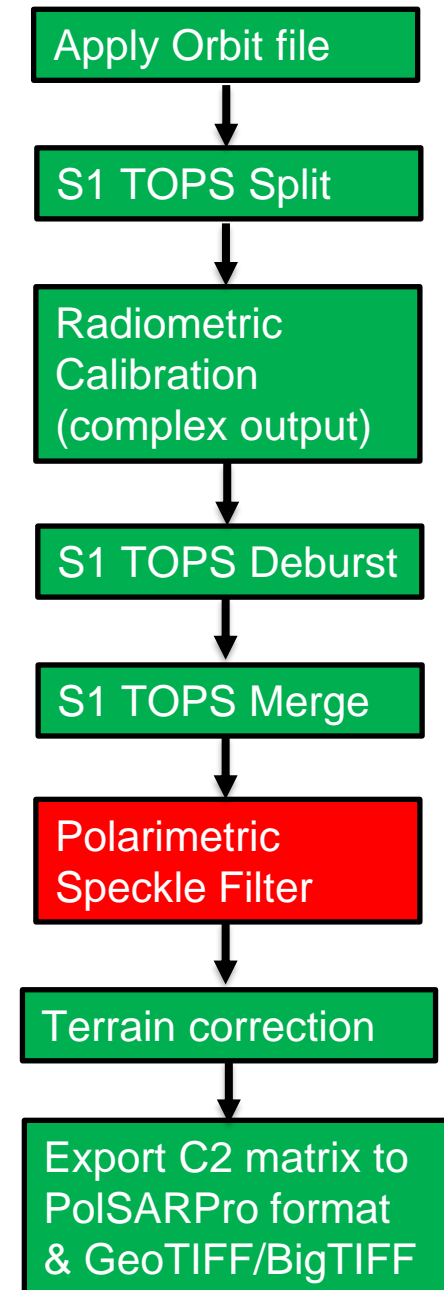
- I/O Parameters tab: source → Orbit, TOPS Split, Calibrated & TOPS Deburst S1 SLC images + Target product
- Processing Parameters tab:
  - Polarisation: VH, VV
  - Click Run and Close window when completed



# Polarimetric Speckle Filter

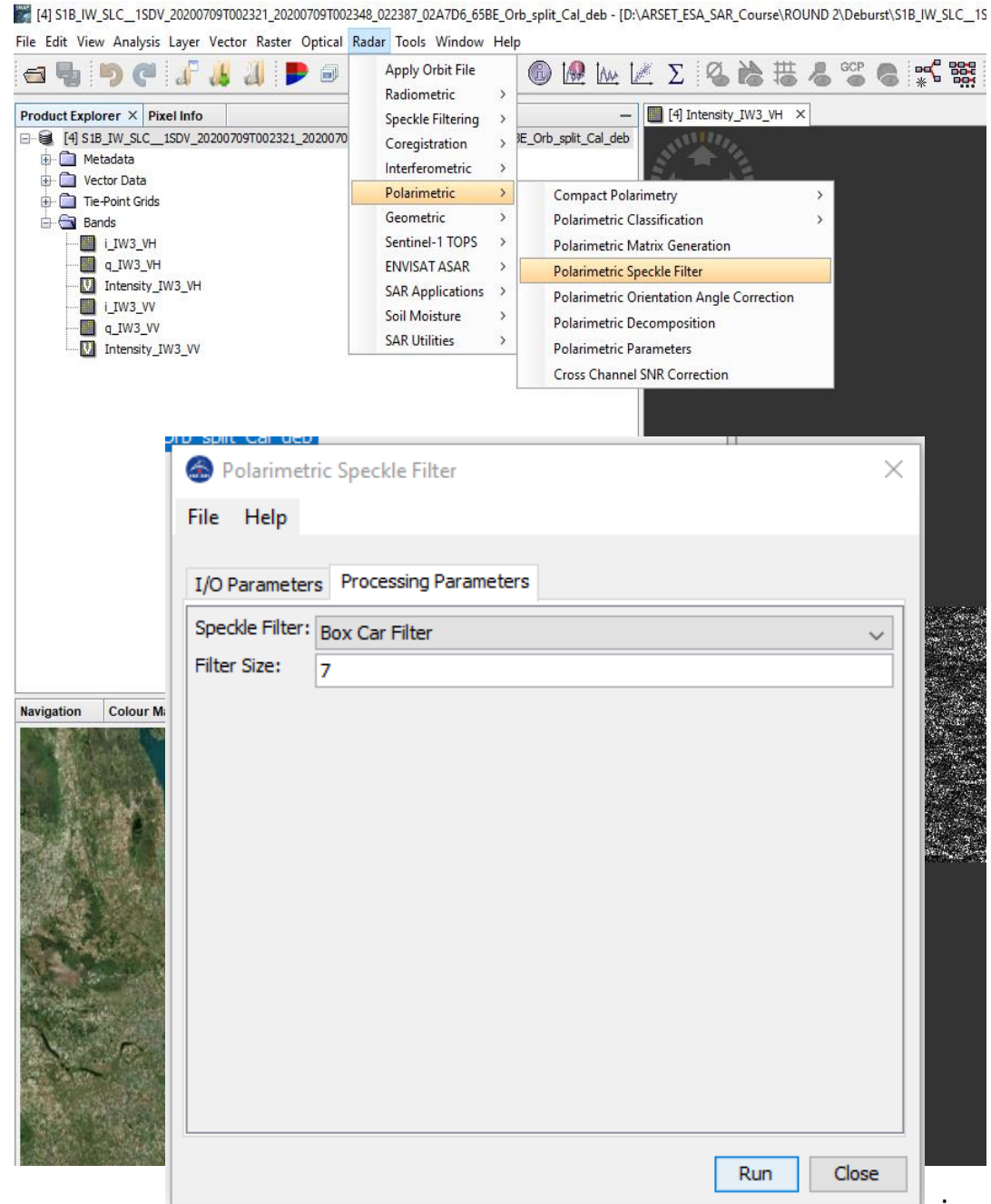
For polarimetric parameters, the filter chosen must ensure that there is a preservation of phase and polarimetric information while suppressing the noise. There are 4 polarimetric speckle filters available in SNAP. The choice of filter type and size should be related to the AOI and what the final data will be used for.

The output of the Polarimetric Speckle Filter is C2 matrix



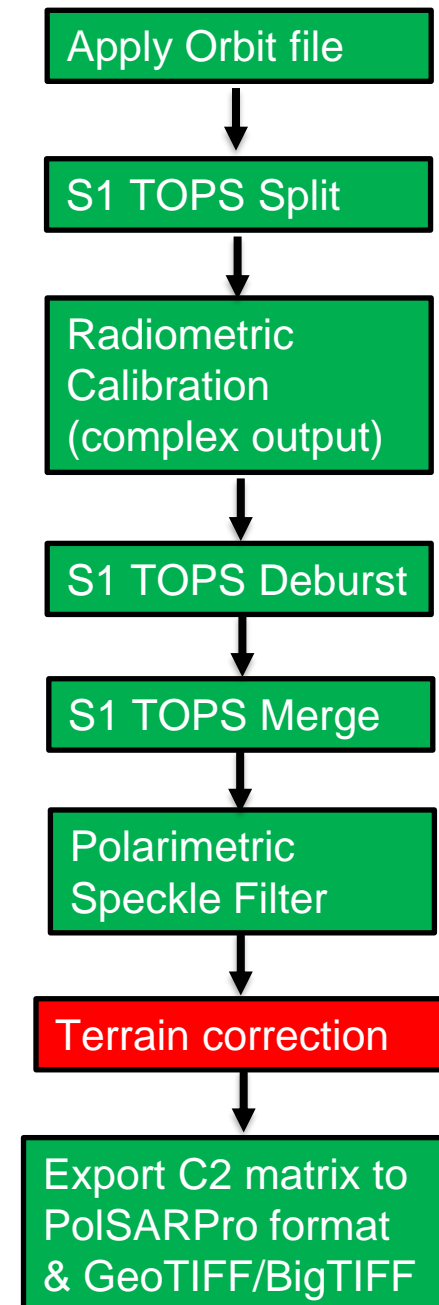
# Polarimetric Speckle Filter

- Go to Radar Menu → Polarimetric  
→ Polarimetric Speckle Filter :
- I/O Parameters tab: source → Orbit, TOPS Split, Calibrated & TOPS Deburst (and Merged if using more than one sub swath) S1 SLC images + Target product
  - Processing Parameters tab:
    - Speckle Filter: Choose one of four speckle filter types
    - Filter Size: Select filter size
    - Click Run and Close window when completed



# C2 Matrix is Generated – Terrain Correction

- Terrain correction, with the use of Digital Elevation Model (DEM) data, corrects topographical distortions like foreshortening, layover, or shadowing.
- The Range-Doppler approach is one way to perform geometric correction. The method needs information about the topography (normally provided by a DEM) as well as orbit satellite information to correct the topographic distortions and derive a precise geolocation for each pixel of the image.





# C2 Matrix is Generated – Terrain Correction

Go to Radar Menu → Radar → Geometric → Terrain Correction → Range Doppler Terrain Correction:

- I/O Parameters tab: source → C2 Matrix + Target product
- Processing Parameters tab:
  - Digital Elevation Model: SRTM 1SEC HGT (or appropriate for your area)
  - Most parameters will be set as per your AOI
  - Click Run and Close window when completed

The image shows the SNAP (Software for Near-Range Applications) interface. The main window displays a satellite image of the Arctic region. The 'Radar' menu is open, and the 'Terrain Correction' sub-menu is selected, showing the 'Range-Doppler Terrain Correction' option. A dialog box titled 'Range Doppler Terrain Correction' is open, showing the 'I/O Parameters' and 'Processing Parameters' tabs. The 'I/O Parameters' tab is active, showing the following settings:

- Source Bands: C11, C12\_real, C12\_imag, C22
- Digital Elevation Model: SRTM 1Sec HGT (Auto Download)
- DEM Resampling Method: BILINEAR\_INTERPOLATION
- Image Resampling Method: BILINEAR\_INTERPOLATION
- Source GR Pixel Spacings (az x rg): 13.9(m) x 3.69(m)
- Pixel Spacing (m): 15
- Pixel Spacing (deg): 1.3474729261792824E-4
- Map Projection: UTM Zone 14 / World Geodetic System 1984
- Mask out areas without elevation  Output complex data
- Output bands for:
  - Selected source band  DEM  Latitude & Longitude
  - Incidence angle from ellipsoid  Local incidence angle  Projected local incidence angle
- Apply radiometric normalization
  - Save Sigma0 band: Use projected local incidence angle from DEM
  - Save Gamma0 band: Use projected local incidence angle from DEM
  - Save Beta0 band
- Auxiliary File (ASAR only): Latest Auxiliary File

Buttons for 'Run' and 'Close' are visible at the bottom right of the dialog box.

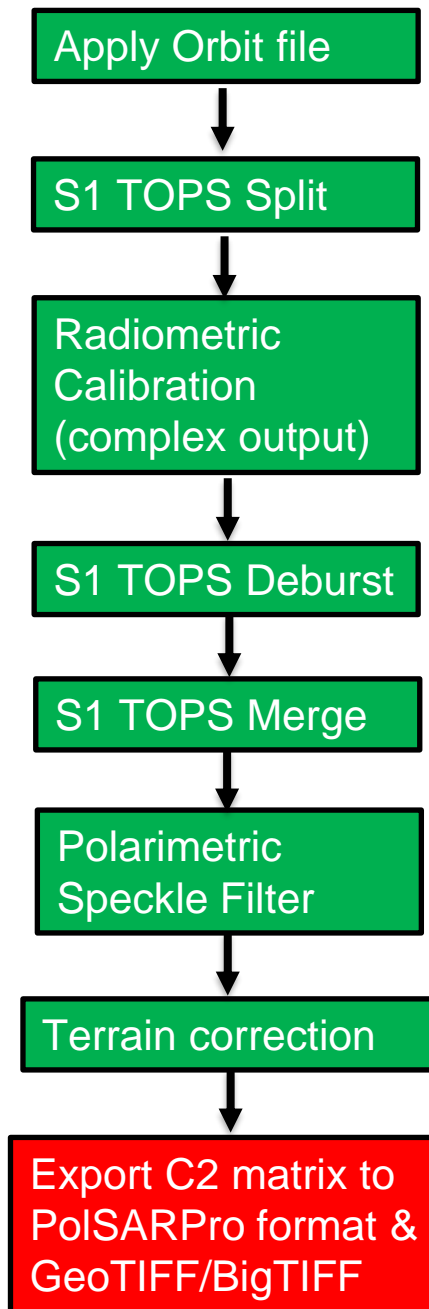


# Export C2 Matrix from SNAP to PolSAR Pro Format & GeoTIFF/BigTIFF

PolSARpro format has all bands of data in .bin and .hdr pairs. A 'config.txt' file and a 'metadata.xml' file are under the output folder.

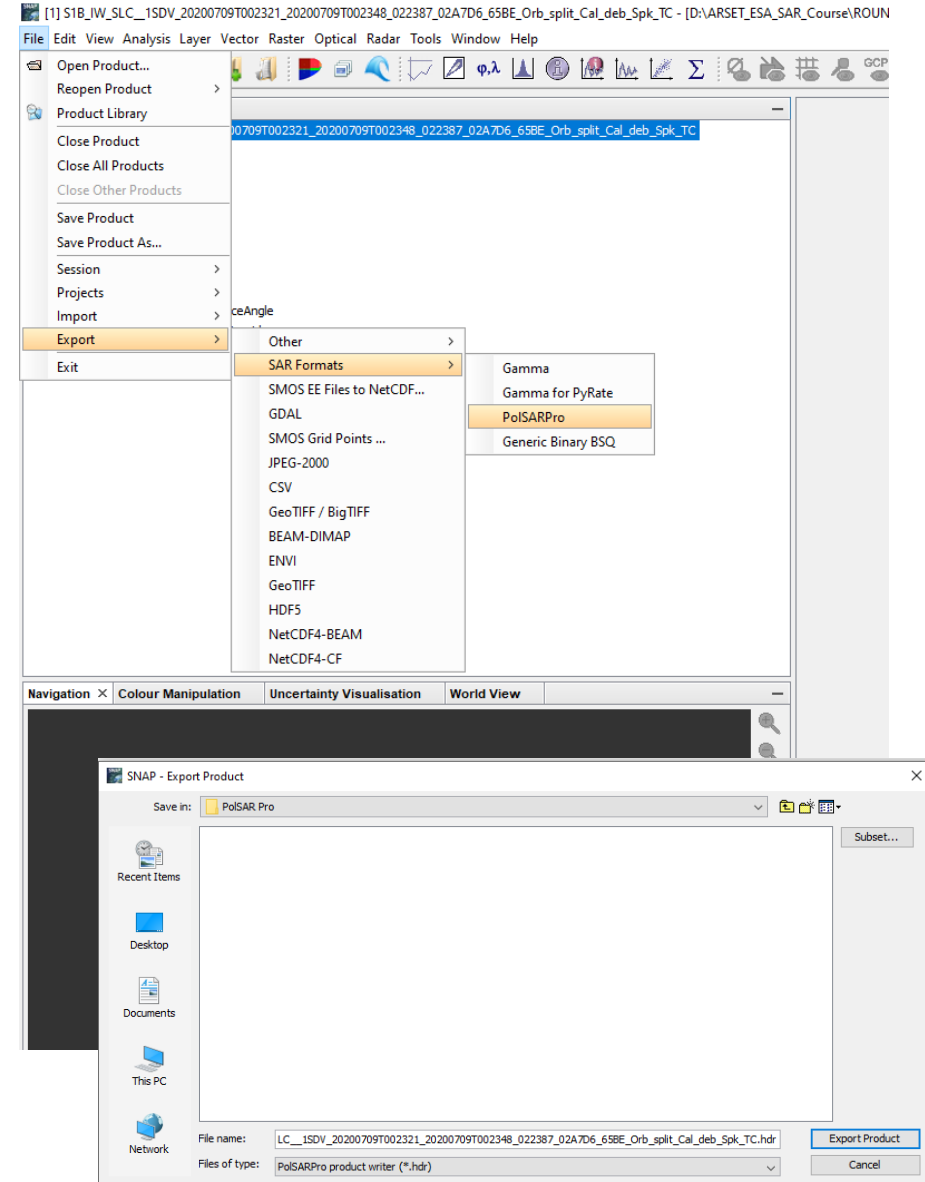
ROUND 2 > PolSARPro > S1B\_IW\_SLC\_1SDV\_20200709T002321\_20200709T002348\_022387\_02A7D6\_65BE\_Orb\_split\_Cal\_deb\_Spk

Name	Date modified	Type	Size
C11.bin	2/18/2022 9:15 AM	BIN File	832,661 KB
C11.bin.hdr	2/18/2022 9:14 AM	HDR File	1 KB
C12_imag.bin	2/18/2022 9:15 AM	BIN File	832,661 KB
C12_imag.bin.hdr	2/18/2022 9:14 AM	HDR File	1 KB
C12_real.bin	2/18/2022 9:15 AM	BIN File	832,661 KB
C12_real.bin.hdr	2/18/2022 9:14 AM	HDR File	1 KB
C22.bin	2/18/2022 9:15 AM	BIN File	832,661 KB
C22.bin.hdr	2/18/2022 9:14 AM	HDR File	1 KB
config.txt	2/18/2022 9:14 AM	Text Document	1 KB
metadata.xml	2/18/2022 9:14 AM	XML Document	66 KB



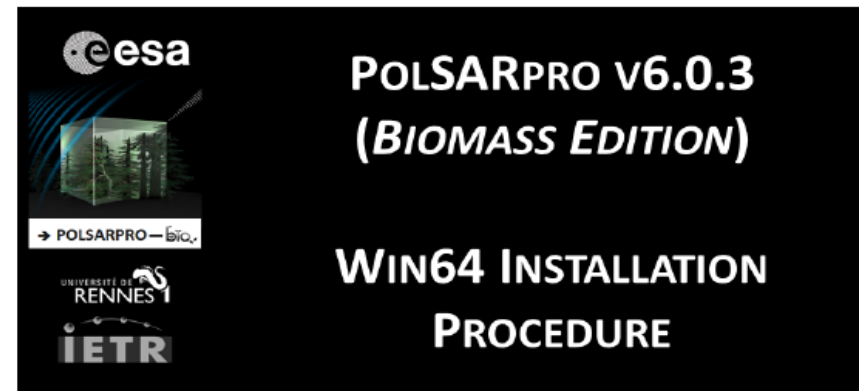
# Export C2 Matrix from SNAP to PolSAR Pro Format & GeoTIFF/BigTIFF

PLUS!! File → Export → GeoTIFF/BigTIFF to be used as “Master Tif” during the Python generation of the Tif’s from the PolSARpro output



# ESA PolSAR Pro v6.0.3

- Long term research software for fully polarimetric data analysis
- Free and open for download
- [PolSARpro v6.0 \(Biomass Edition\) | Institut d'Électronique et des Techniques du numéRique - UMR CNRS 6164 \(univ-rennes1.fr\)](#)



## 1 - PRE - INSTALLATION

**PolSARpro v6.0.3 (Biomass Edition) Software** requires the installation of the following packages (if not already installed on the machine) :



**Tcl (Tool Command Language) - Tk (ToolKit)** enable the execution of powerful GUIs (Graphical User Interface). **Tcl-Tk** binary distribution and installers for Windows platform are available for download from :

<https://www.magicplat.com/tcl-installer/index.html>



**Gimp (GNU Image Manipulation Program)** is a free and open-source graphics editor. The current stable release of **Gimp** for Windows platform is available for download from :

<https://www.gimp.org/downloads/>



**ImageMagick** is a free and open-source software suite for converting / creating / editing image files. The current stable release of **ImageMagick** for Windows platform is available for download from :

<https://www.imagemagick.org/script/download.php#windows>



**SNAP (Sentinel Application Platform)** reunites all Sentinel Toolboxes in order to offer the most complex platform for this mission. The current stable release of **SNAP** for Windows platform is available for download from :

<http://step.esa.int/main/download/>



**Google Earth** is a computer program that renders a 3D representation of Earth based on satellite imagery. The current stable release of **Google Earth** for Windows platform is available for download from :

<https://www.google.com/earth/download/gep/agree.html>





# Calculate SAR Polarimetric Parameters Using PolSARpro: Import Data

- Create a “C2” folder and copy all files exported from SNAP to this folder.
  - The C2 folder name will enable PolSARPro to recognize the dataset
- Modify the config.txt file. Change the ‘PolarType’ to ‘pp2’.
  - This term allows PolSAR Pro to identify that this data is represented as a 2 x 2 matrix

```
config.txt - Notepad
File Edit Format View Help
Nrow
8220
-----
Ncol
25932
-----
PolarCase
monostatic
-----
PolarType
dual
-----
```

Name	Date modified	Type	Size
C11.bin	2/18/2022 9:15 AM	BIN File	832,661 KB
C11.bin.hdr	2/18/2022 9:14 AM	HDR File	1 KB
C12_imag.bin	2/18/2022 9:15 AM	BIN File	832,661 KB
C12_imag.bin.hdr	2/18/2022 9:14 AM	HDR File	1 KB
C12_real.bin	2/18/2022 9:15 AM	BIN File	832,661 KB
C12_real.bin.hdr	2/18/2022 9:14 AM	HDR File	1 KB
C22.bin	2/18/2022 9:15 AM	BIN File	832,661 KB
C22.bin.hdr	2/18/2022 9:14 AM	HDR File	1 KB
config.txt	2/18/2022 9:14 AM	Text Document	1 KB
metadata.xml	2/18/2022 9:14 AM	XML Document	66 KB

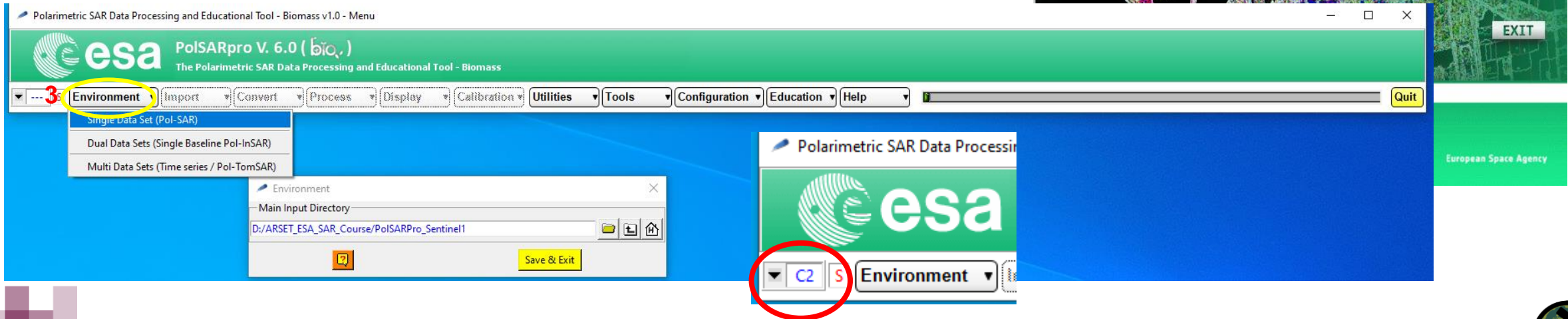
```
*config.txt - Notepad
File Edit Format View Help
Nrow
8220
-----
Ncol
25932
-----
PolarCase
monostatic
-----
PolarType
pp2
-----
```



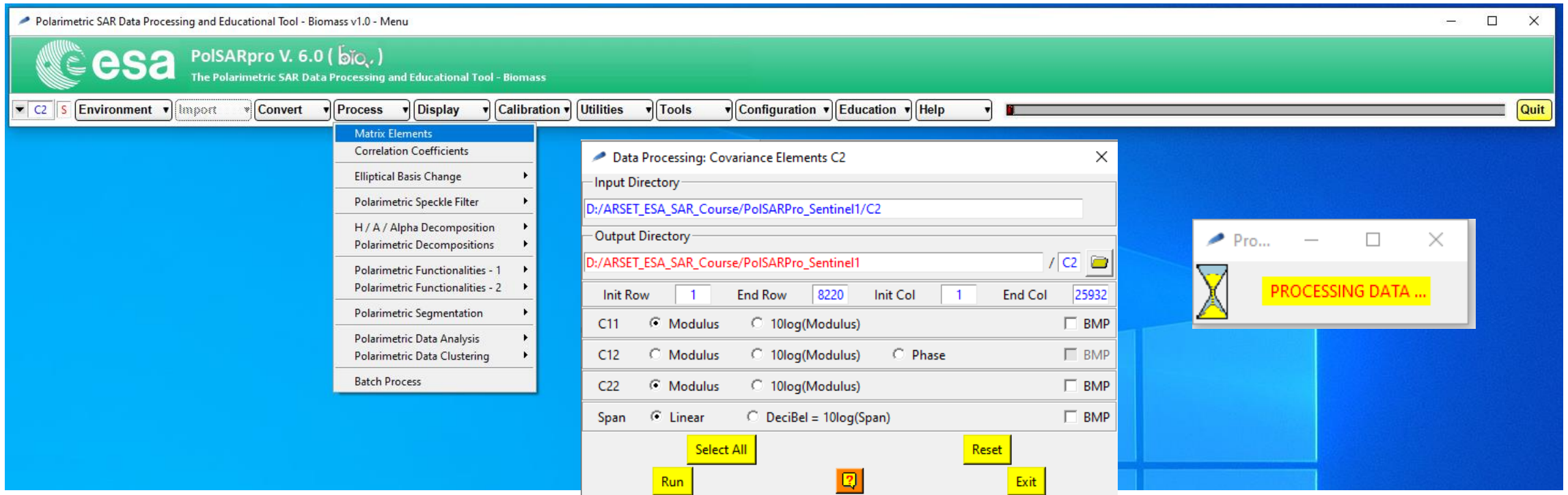
# Setting an Environment in PolSAR Pro

Start your PolSAR Pro edition on your desktop

1. Click on PolSAR Pro Biomass on the initial tool bar and then select “Enter” on the pop up.
2. The main PolSAR Pro Biomass tool bar opens.
3. First set the “Environment”, which is the folder holding your main data set contained in the C2 folder



# Generate the C2 Matrix Elements



Select Process – Matrix Elements and in the popup select C11 Modulus, C22 Modulus, and Span linear. The selected parameters will be generated and stored in the C2 folder. You can create an “output” folder to store items.

- Modulus – is the linear representation of the considered **[C2]** element amplitude.
- Span – A quantity giving the total power (intensity) received.
  - In terms of the scattering matrix, the total power equal to the sum of all the matrix elements.



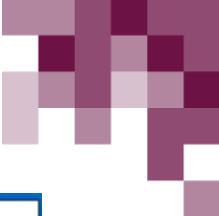
# Stokes Parameter Generation

The screenshot shows the PolSARpro V. 6.0 software interface. The main window has a menu bar with options: Environment, Import, Convert, Process, Display, Calibration, Utilities, Tools, Configuration, Education, and Help. The 'Process' menu is open, showing a list of options including 'Polarimetric Functionalities - 1', 'Polarimetric Functionalities - 2', 'Polarimetric Segmentation', 'Polarimetric Data Analysis', 'Polarimetric Data Clustering', and 'Batch Process'. The 'Polarimetric Functionalities - 1' sub-menu is also open, highlighting 'Stokes Parameters'. A secondary dialog box titled 'Data Processing: Stokes Parameters' is overlaid on the right. It contains fields for 'Input Directory' (D:/ARSET\_ESA\_SAR\_Course/ROUND 2/Files for ARSET/C2) and 'Output Directory' (D:/ARSET\_ESA\_SAR\_Course/ROUND 2/Files for ARSET). Below these are fields for 'Init Row' (1), 'End Row' (7419), 'Init Col' (1), and 'End Col' (7470). The dialog is divided into two columns for 'Jones Vector (s11 / s21)' and 'Jones Vector (s12 / s22)'. Each column has sections for 'Stokes Components' (g0, g1, g2, g3), 'Stokes Angles' (Orientation Angle, Ellipticity Angle, Poincare Planisphere), and 'Wave Descriptors' (Eigenvalues, Probabilities, Entropy, Anisotropy, Contrast, Deg of Lin Polar, Deg of Cir Polar, Lin Polar Ratio, Cir Polar Ratio). Each parameter has a radio button for selection and a checkbox for 'BMP' output. At the bottom of the dialog, there are 'Window Size Row' (5) and 'Window Size Col' (5) fields, along with 'Select All', 'Reset', 'Run', and 'Exit' buttons.

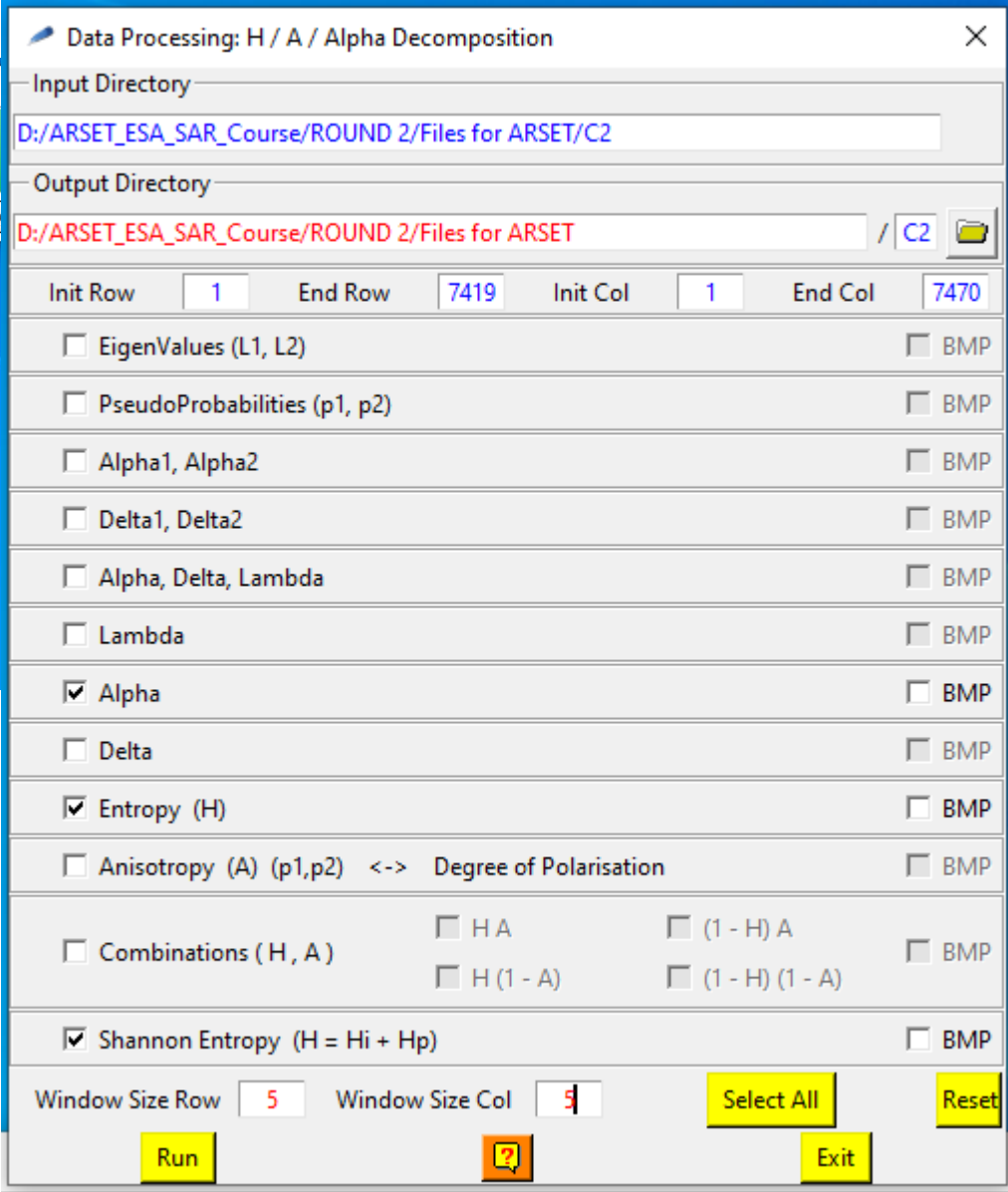
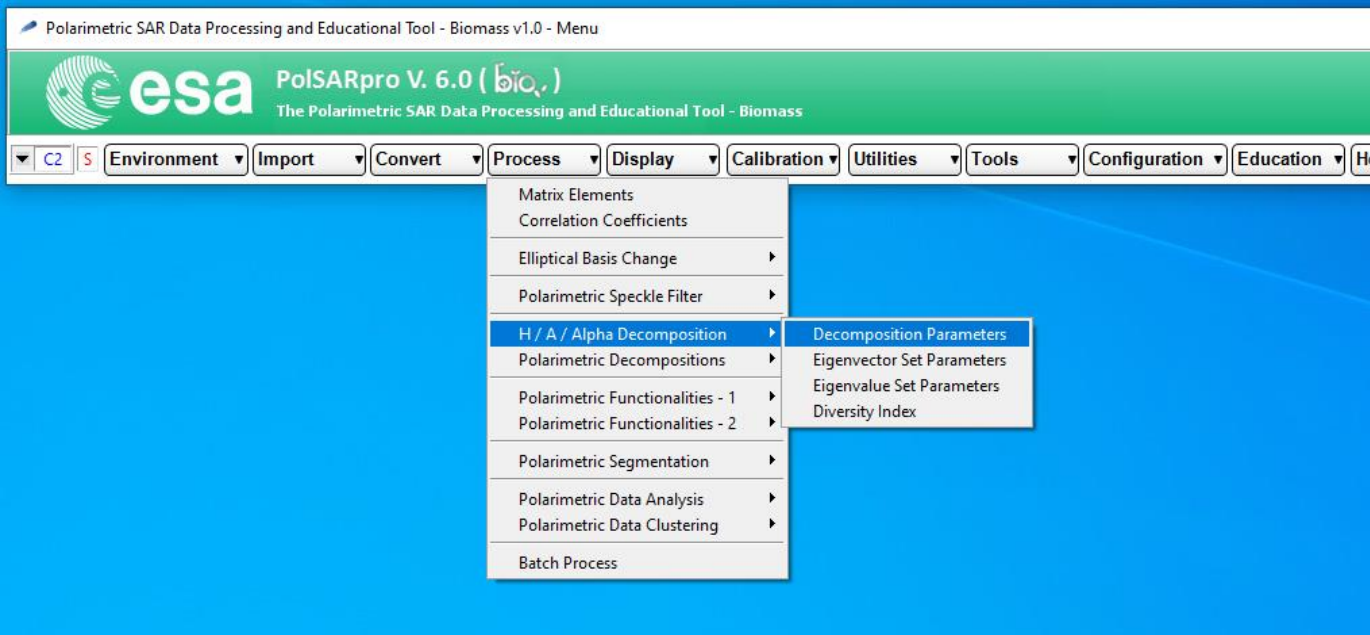
Select Process >> Polarimetric Functionalities-1 → Stokes parameters. Under the Stokes Parameters pop up there are many parameters to choose depending on the application of interest. Select the parameters of interest and set the window size (X by X) of the sliding window used to compute the local estimate of the average matrix. The selected parameters will be generated and stored in the C2 folder.







# Entropy/Alpha Decomposition Parameters Generation



Select Process → H/A/Alpha decomposition → Decomposition Parameters. Select the parameters of interest and set window size. In this case we select, Alpha, Entropy, and Shannon Entropy. The selected parameters will be generated and stored in the C2 folder.





# Converting PolSAR Pro Output to GeoTIFF using Python

**Script:** Convert\_PolSARpro\_Output\_to\_Tif\_20220207.py

**Python:** 3.6 or greater; **must have GDAL**

### Files required:

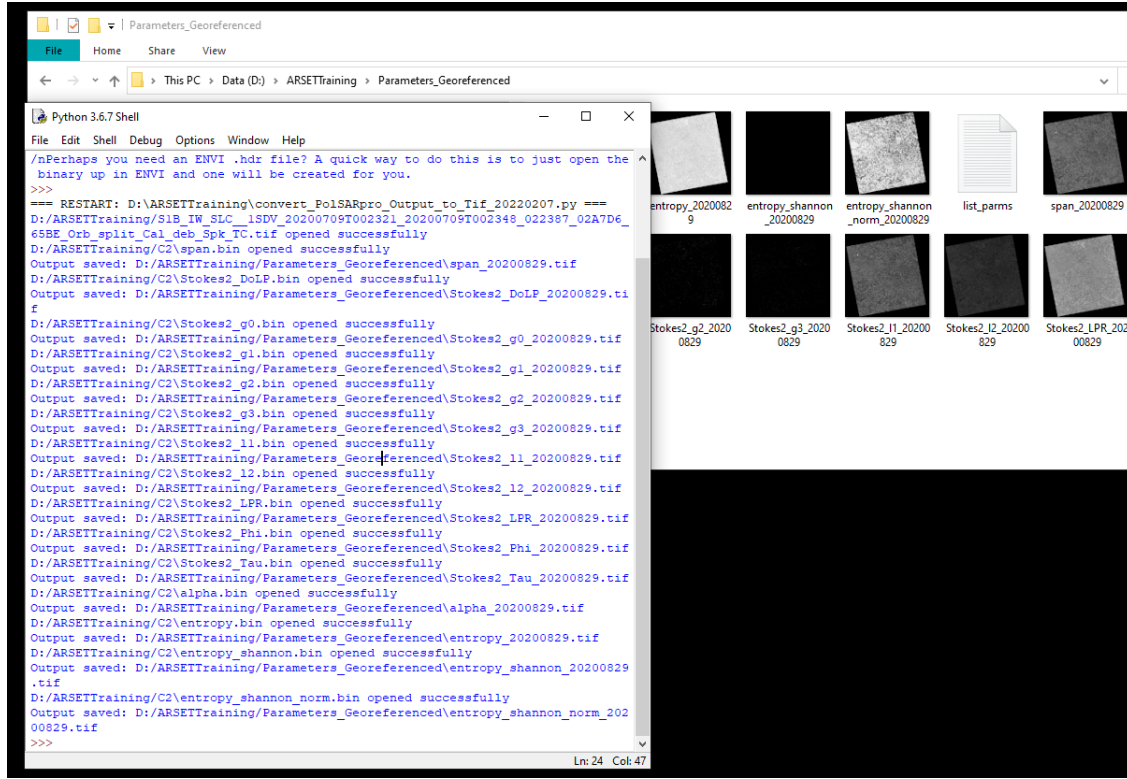
- PolSAR Pro Output (C2 folder)
- MasterTIF: From Exporting the \_TC file to GeoTIFF/BigTIFF from final SNAP step; contains the georeferencing information
- List\_Parms.txt: Contains a list of the parameters in C2 folder to convert to TIF

### Parameters to change are located at the bottom of the script:

Inpath = r'D:/ARSETTraining/C2' – location of C2 folder

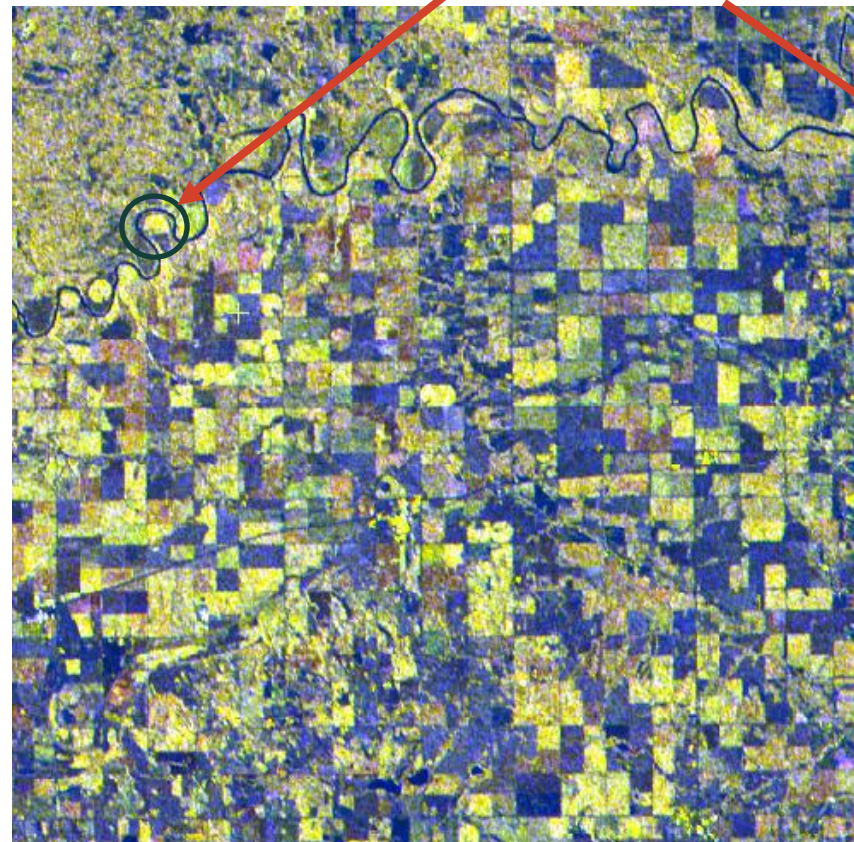
Outpath = r'D:/ARSETTraining/Parameters\_Georeferenced' – location where output should go; "List\_Parms.txt" should be located here

Masterfile =  
 r'D:/ARSETTraining/S1B\_IW\_SLC\_\_1SDV\_20200709T002321\_20200709T002348\_022387\_02A7D6\_65BE\_Orb\_split\_Cal\_deb\_Spk\_TC.tif" – location of Master file for georeferencing

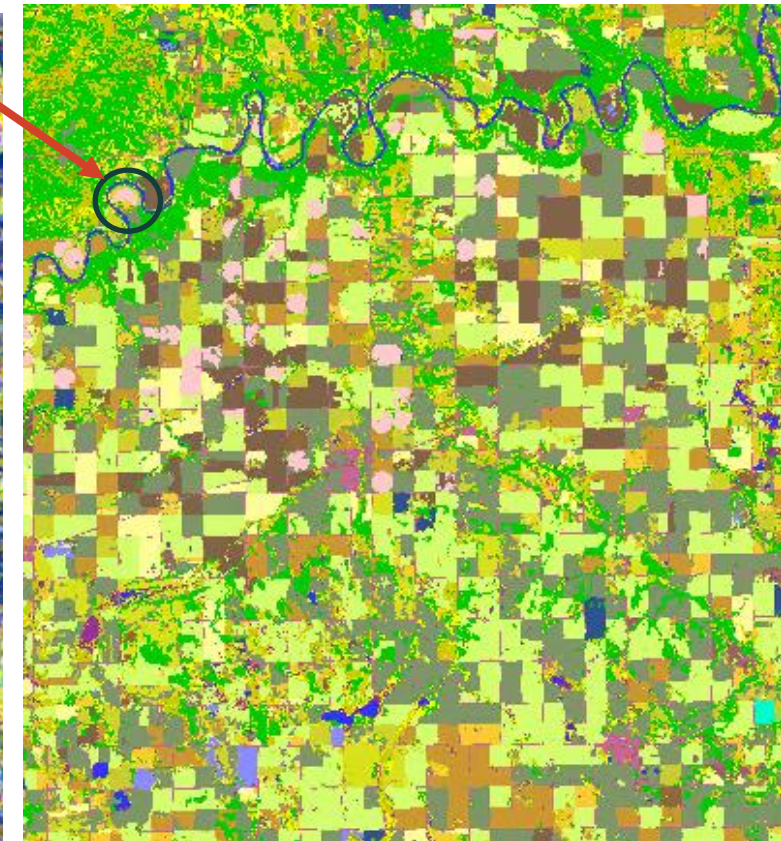


# Stokes Parameters

- First Stokes vector parameter ( $S_{0, \text{RED}}$ ) indicates the total intensity of the radar backscatter (polarized and unpolarized), which is the sum of the powers of the two orthogonally-polarized received waves.
- other three parameters ( $S_{1\text{Green}}$ ,  $S_{2\text{Blue}}$ , and  $S_3$ ) describe the properties of the polarized portion of the EM field.



Potatoes



- $S_0$  July 9<sup>th</sup>, 2020, Sentinel 1 Stokes  
RGB Image  
Carman, Manitoba
- $S_1$
- $S_2$

2020 AAFC Annual Crop  
Inventory Carman, Manitoba



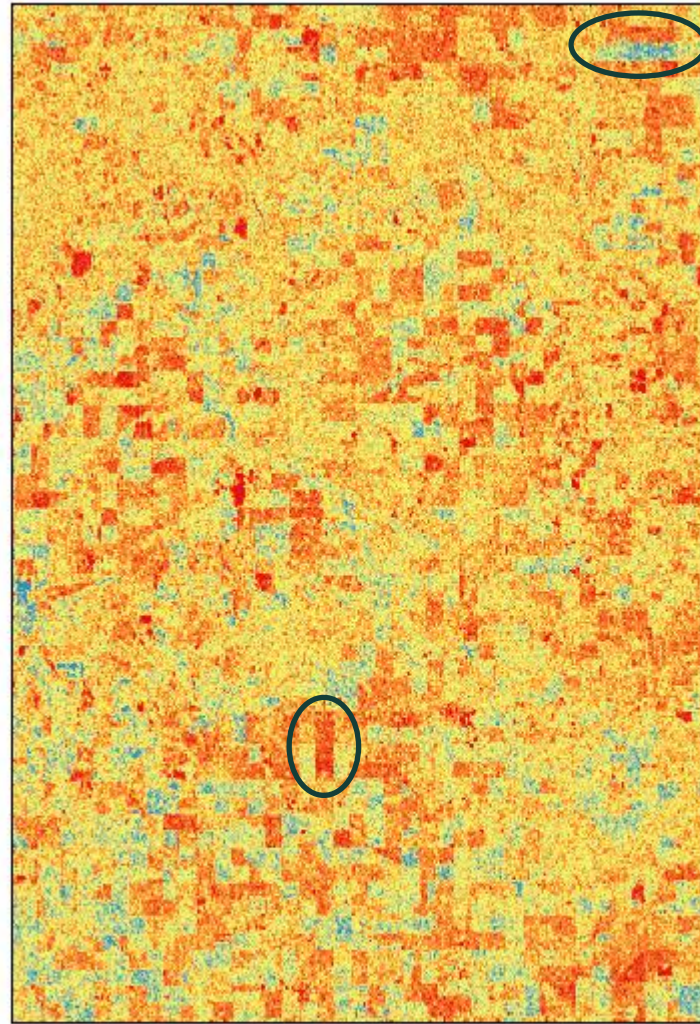
# Degree of Linear Polarization

- High values of degree of linear polarization represent that the waves being scattered are linearly polarized.



Soybean  
~BBCH 60-62  
Early flowering

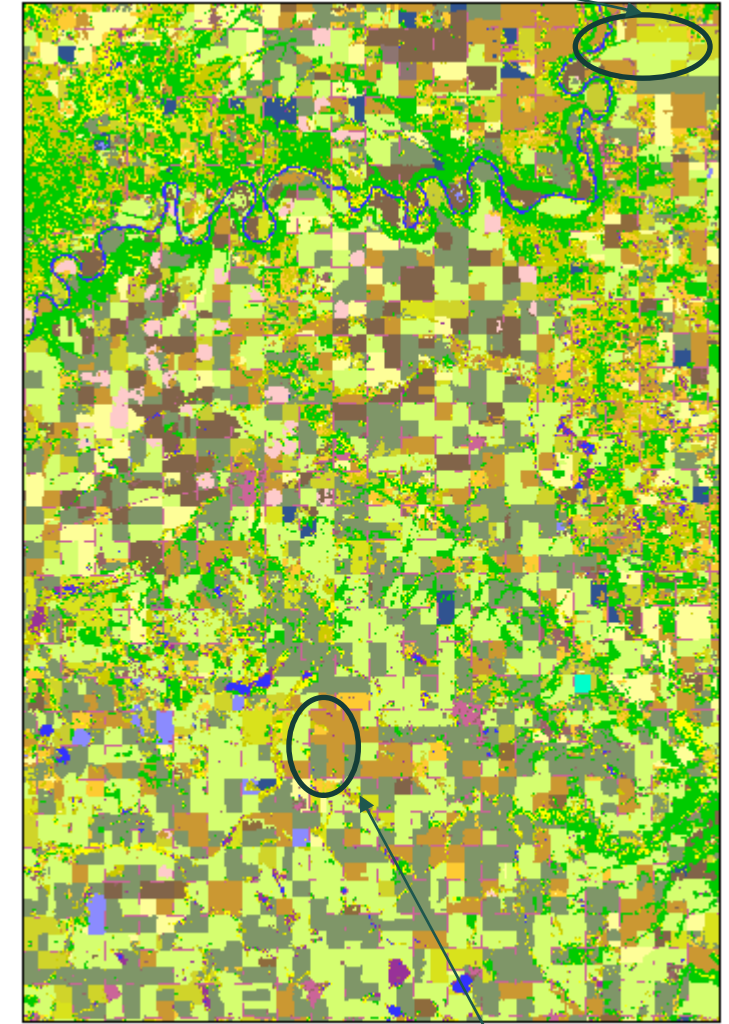
Canola  
~BBCH 65-70  
Late flowering



High : 1  
Low : 0

5.5 2.75 0 5.5 Kilometers

Low DoLP - Canola



High DoLP - Soybeans

July 9<sup>th</sup>, 2020, Sentinel 1 Image  
Carman, Manitoba



# Entropy / Alpha

The incidence angle for this burst/subswath range was approximately 36.1 ° – 41.8°. Alpha ranges from 0 to 65.5° with Entropy values ranging from 0 to 0.99 with most of the values greater than 0.60. These are similar to what has been found for examples in the past using airborne SAR:

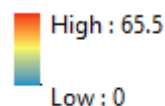
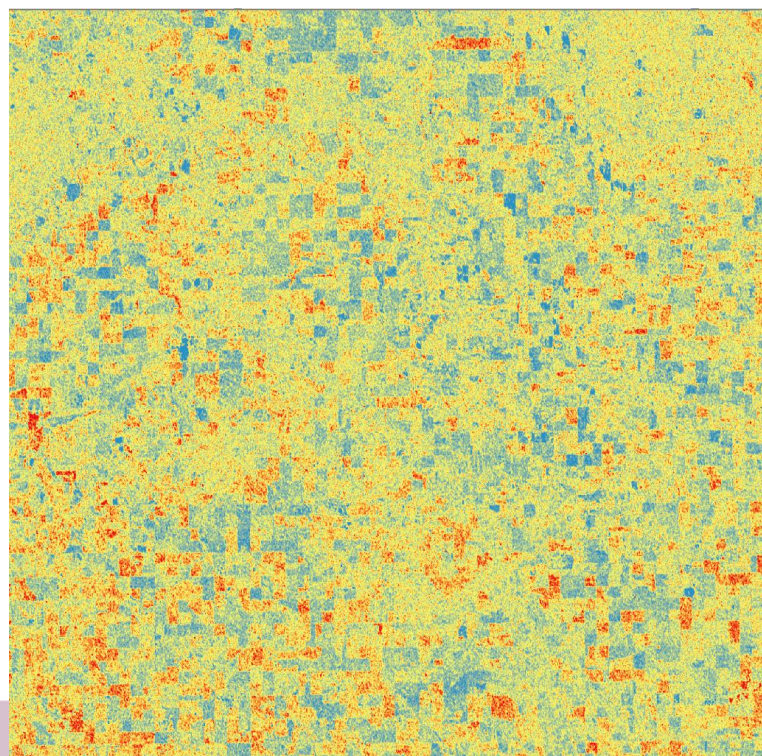
## Wheat Entropy Examples

Incidence Angle	Low Biomass	Higher Biomass
25	0.40	0.51
36	0.63	0.69
40	0.74	0.76
45	0.80	0.80

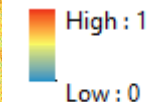
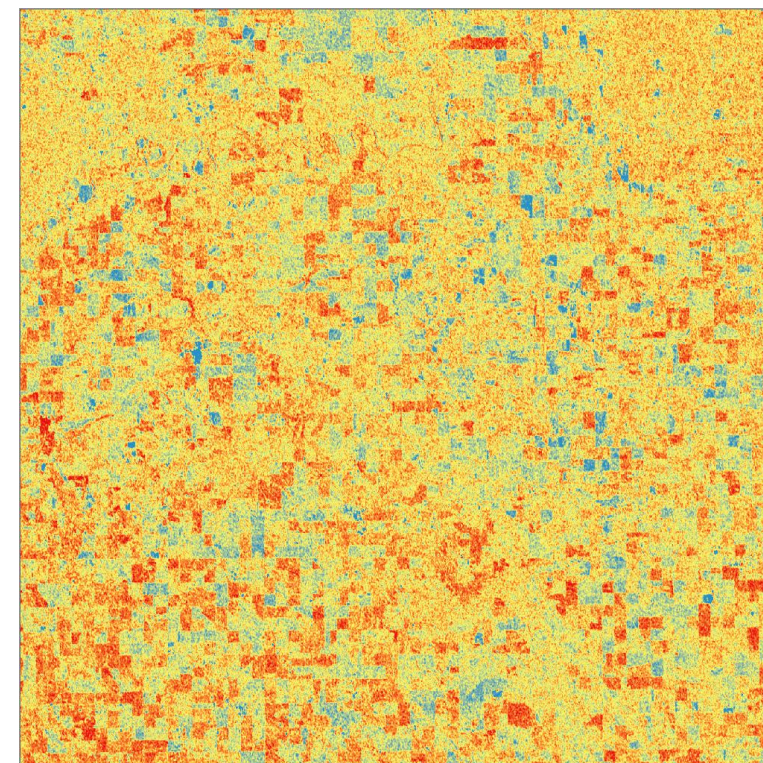
## Canola Entropy Example

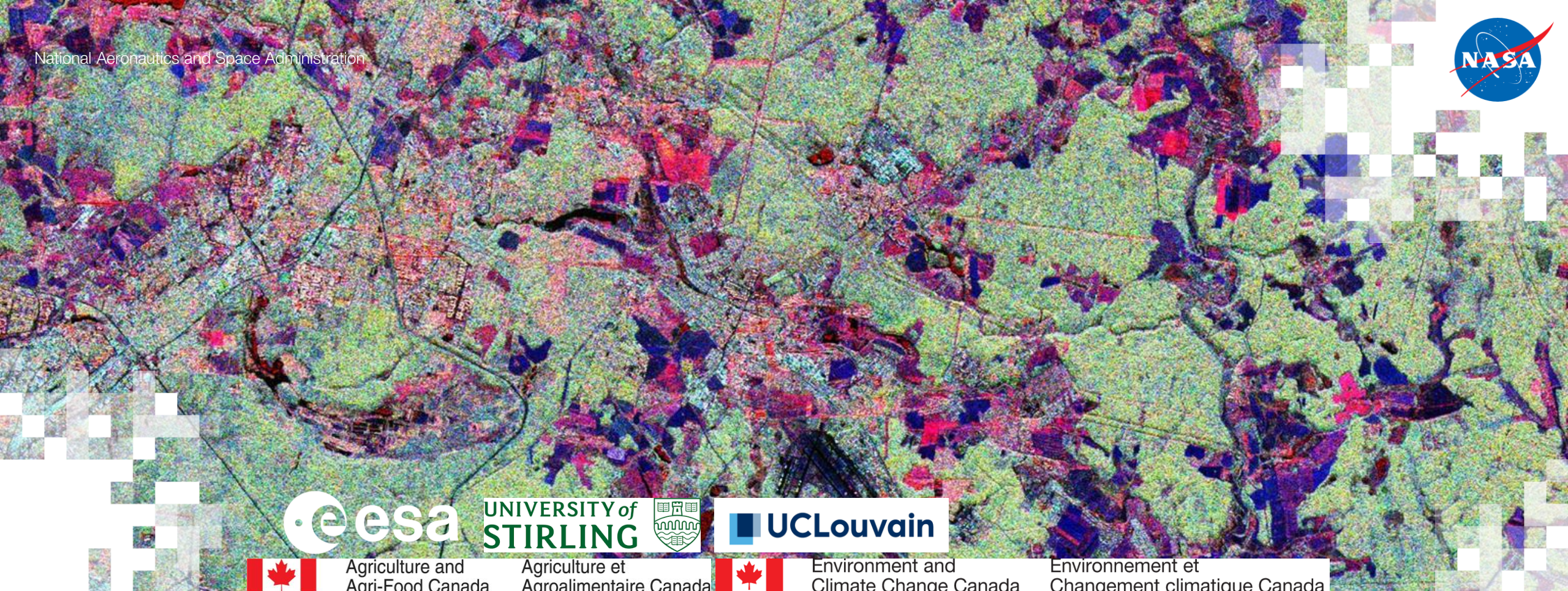
Incidence Angle	Low Biomass	Higher Biomass
25	0.79	0.71
36	0.84	0.75
40	0.88	0.78
45	0.91	0.77

Alpha



Entropy





UNIVERSITY of STIRLING



UCLouvain



Agriculture and Agri-Food Canada

Agriculture et Agroalimentaire Canada



Environment and Climate Change Canada

Environnement et Changement climatique Canada



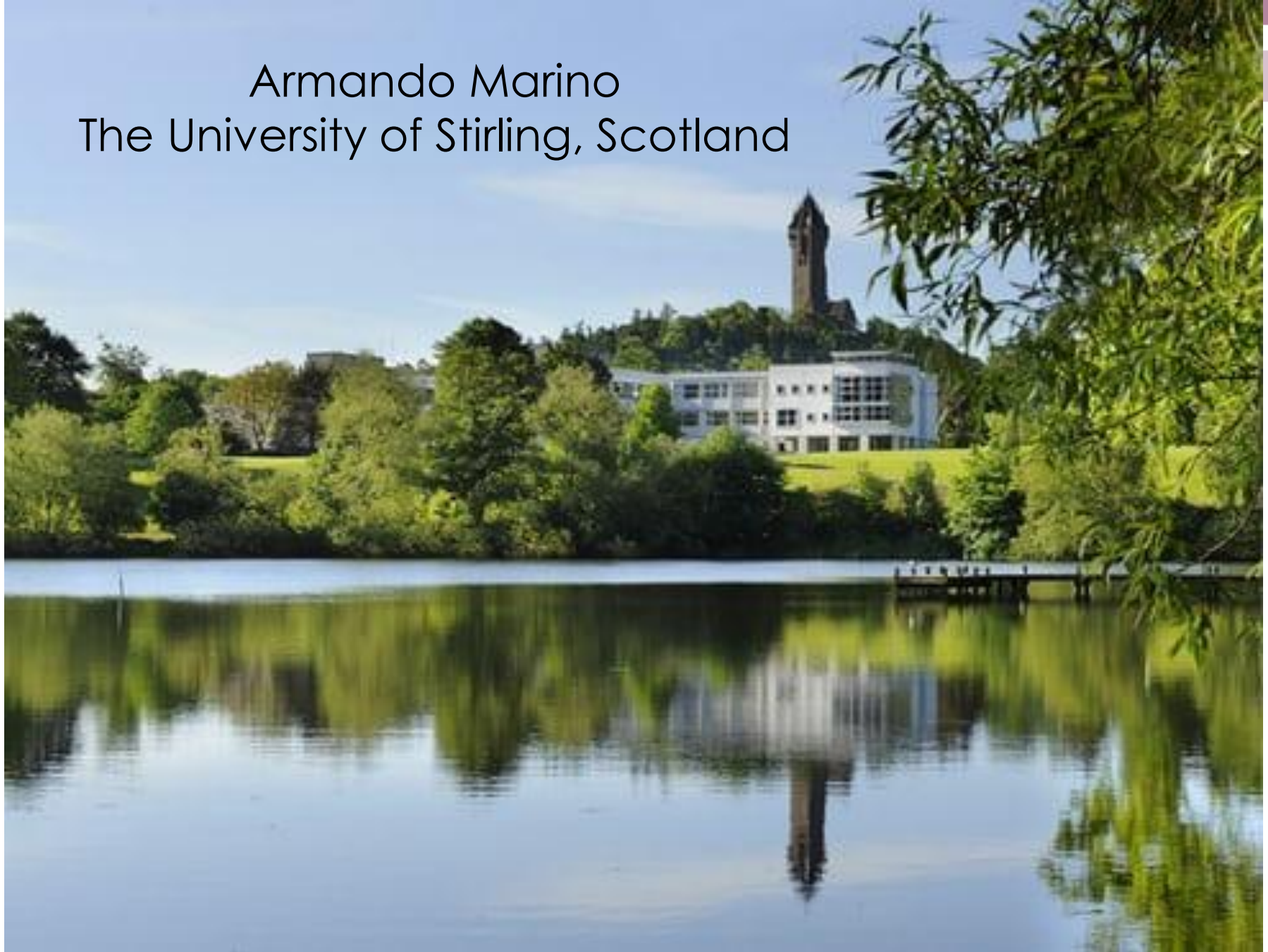
# SAR Polarimetry with Sentinel-1, RCM, & SAOCOM Imagery for Agriculture

Armando Marino, PhD, University of Stirling

19 April 2022

# Introduction

Armando Marino  
The University of Stirling, Scotland



# Learning outcomes:

By the end of this practical you will learn how to:

- ✓ Run python code for processing PolSAR data
- ✓ Open a binary file in Python
- ✓ Visualize the images
- ✓ Perform filtering
- ✓ Manipulate the elements of the Covariance/Coherency matrix
- ✓ Derive the elements of the Cloude-Pottier Decomposition
- ✓ Produce a time series of polarimetric observables





# Python

*“Python is a programming language that lets you work quickly and integrate systems more effectively.”*

<https://www.python.org/>



You can find many tutorials or books on the web, the one I used is the following:

<https://docs.python.org/3/tutorial/>



# Downloading/Installing: Anaconda

My suggestion is to use the *Anaconda installer*, because it comes with most of the common libraries: <https://www.anaconda.com/products/individual?modal=nucleus>

If you do not want to use Anaconda, please make sure you get the 3.x version (3.6+ will be fine), but NOT 2.7, since some functions changed!

The 2.7 version will NOT run with the code I am sharing!

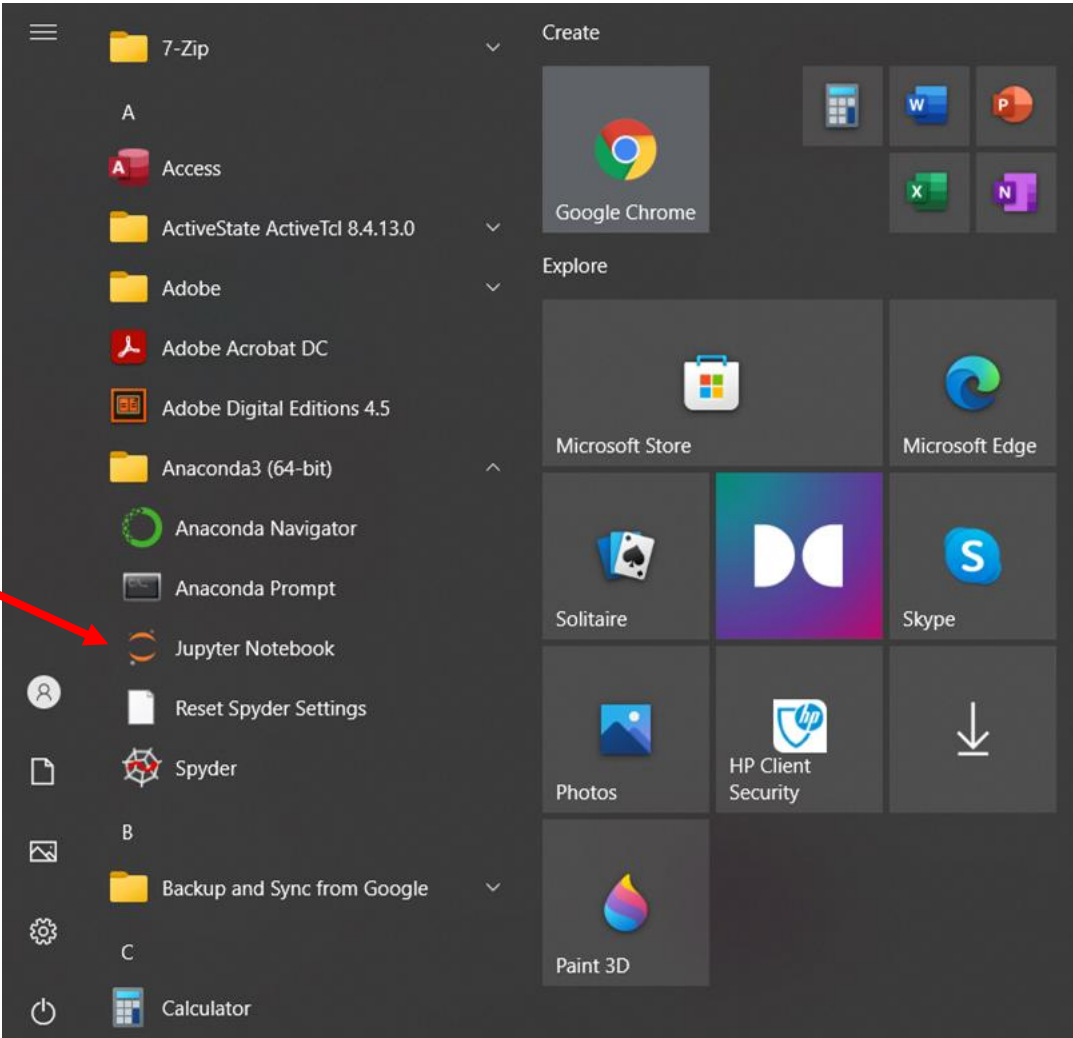
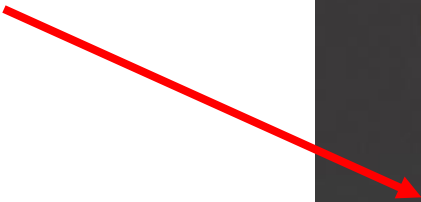
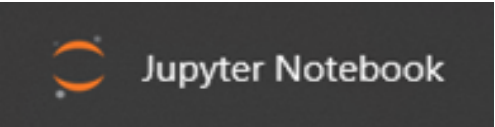
## Anaconda Installers

Windows 	MacOS 	Linux 
Python 3.9 64-Bit Graphical Installer (510 MB) 32-Bit Graphical Installer (404 MB)	Python 3.9 64-Bit Graphical Installer (515 MB) 64-Bit Command Line Installer (508 MB)	Python 3.9 64-Bit (x86) Installer (581 MB) 64-Bit (Power8 and Power9) Installer (255 MB) 64-Bit (AWS Graviton2 / ARM64) Installer (488 M) 64-bit (Linux on IBM Z & LinuxONE) Installer (242 M)



# Jupyter Notebook

Anaconda will install Jupyter Notebook and you should see its icon.



# Jupyter Notebook



Home x +

localhost:8888/tree

jupyter Logout

Files Running Clusters

Select items to perform actions on them.

Upload New ↕ ↻

<input type="checkbox"/>	0 ▾	/	Name ↓	Last Modified
<input type="checkbox"/>		3D Objects		a year ago
<input type="checkbox"/>		ARSET-2022		2 hours ago
<input type="checkbox"/>		Contacts		a year ago
<input type="checkbox"/>		Desktop		8 days ago
<input type="checkbox"/>		Documents		7 months ago
<input type="checkbox"/>		Downloads		2 hours ago
<input type="checkbox"/>		Favorites		a year ago
<input type="checkbox"/>		Google Drive		4 months ago
<input type="checkbox"/>		Links		a year ago
<input type="checkbox"/>		Music		a year ago
<input type="checkbox"/>		Old		5 hours ago
<input type="checkbox"/>		OneDrive		7 months ago
<input type="checkbox"/>		OneDrive - University of Stirling		5 hours ago
<input type="checkbox"/>		Pictures		2 months ago
<input type="checkbox"/>		POLinSAR training 2021		a month ago
<input type="checkbox"/>		RCM1_OK1112357_PK1228080_1_QP22_20200824_002123_HH_VV_HV_VH_SLC_Cal_TC.data		a month ago
<input type="checkbox"/>		Roaming		4 years ago

Jupyter opens in a web browser, and you can upload scripts using the **Upload** button.

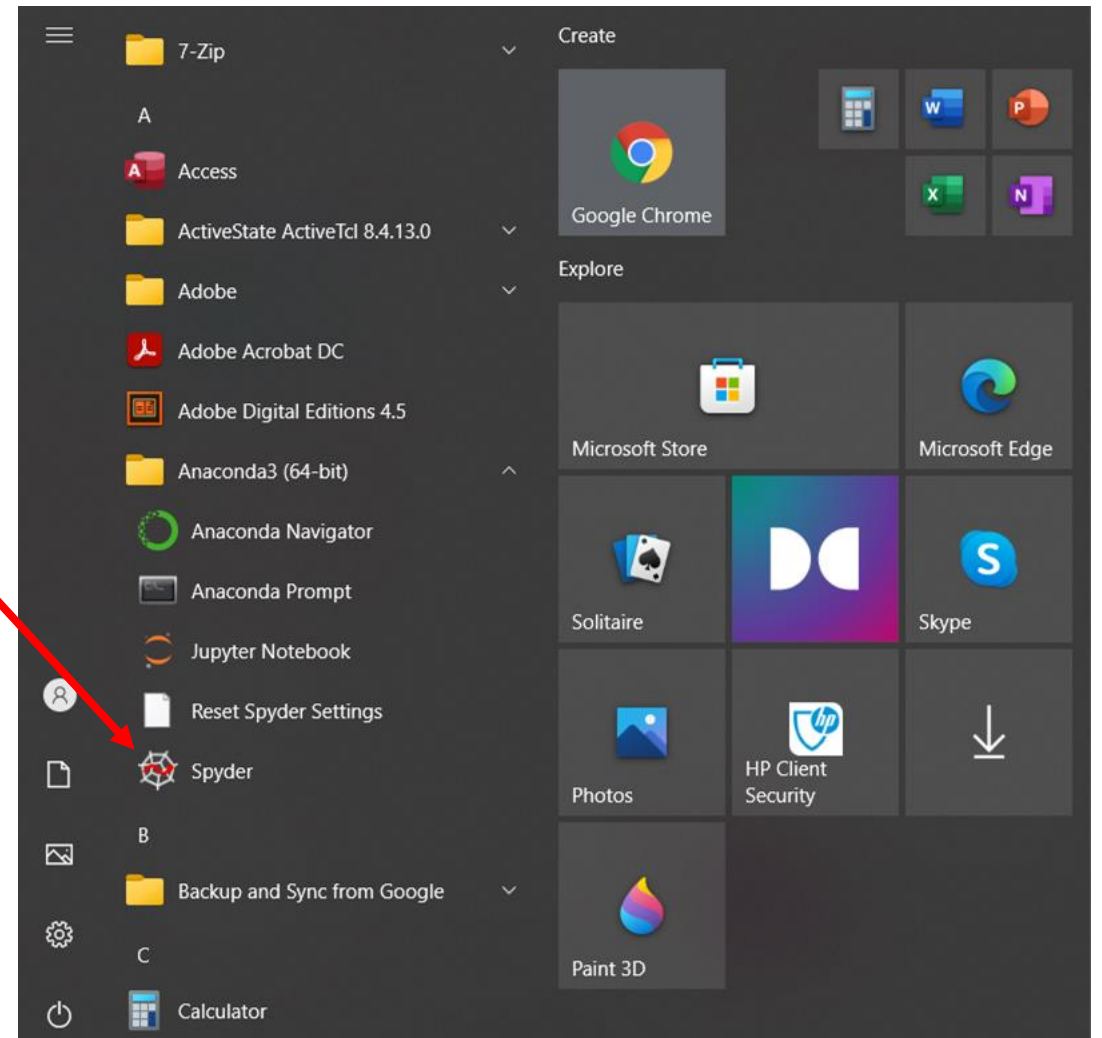


# Spyder

Anaconda will install the Python editor **Spyder** and you should see the icon below.



Spyder is a handy editor, and you may want to use it when you are scripting **operational/automatic processing stacks**.

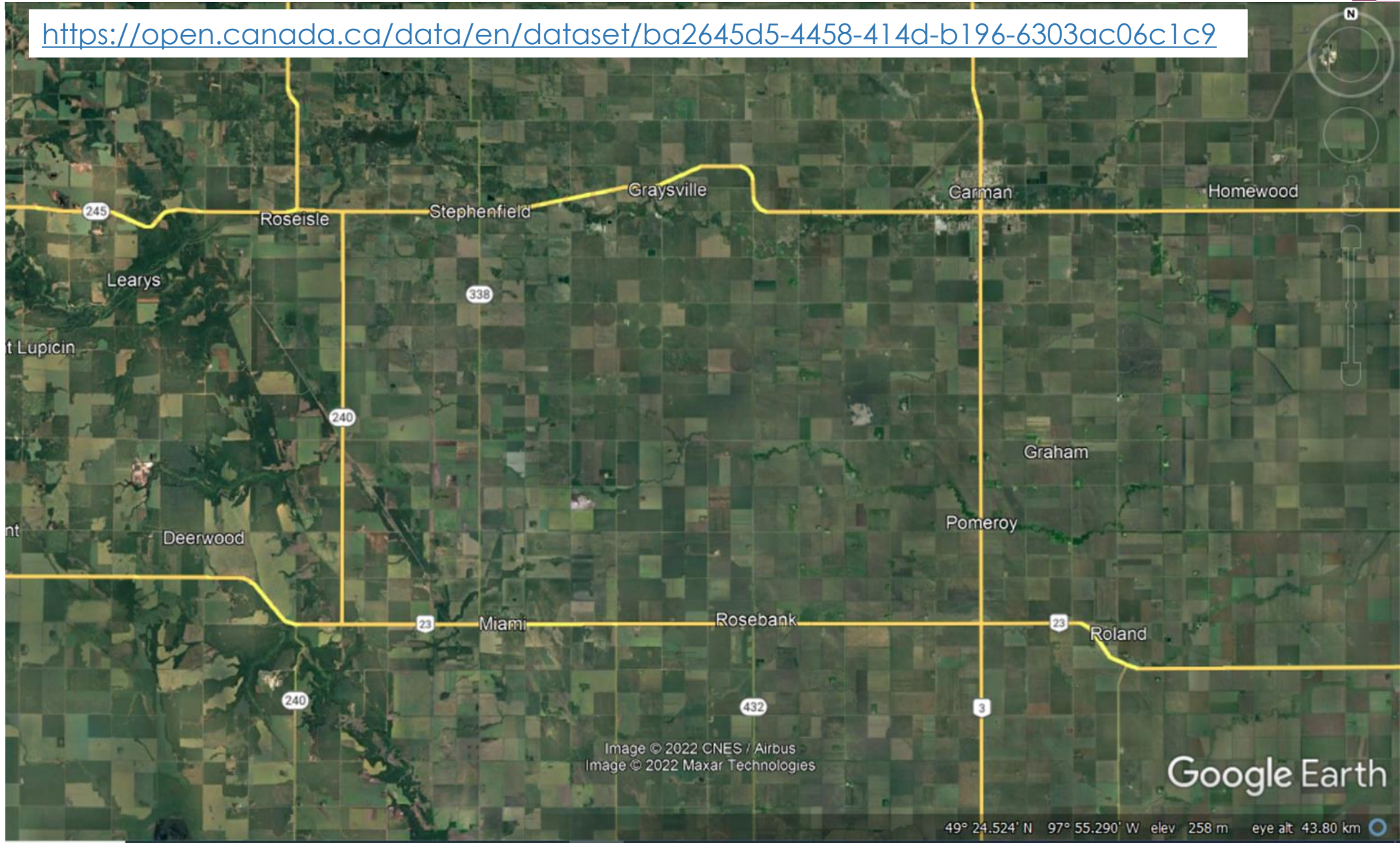


# Data: RCM; Location: Carman, Manitoba, Canada



The **crops** are:  
forage, canola,  
flaxseed,  
sunflower,  
soybeans, corn,  
barley, spring  
wheat, winter  
wheat, rye, oat,  
canary seed,  
potato and field  
pea.

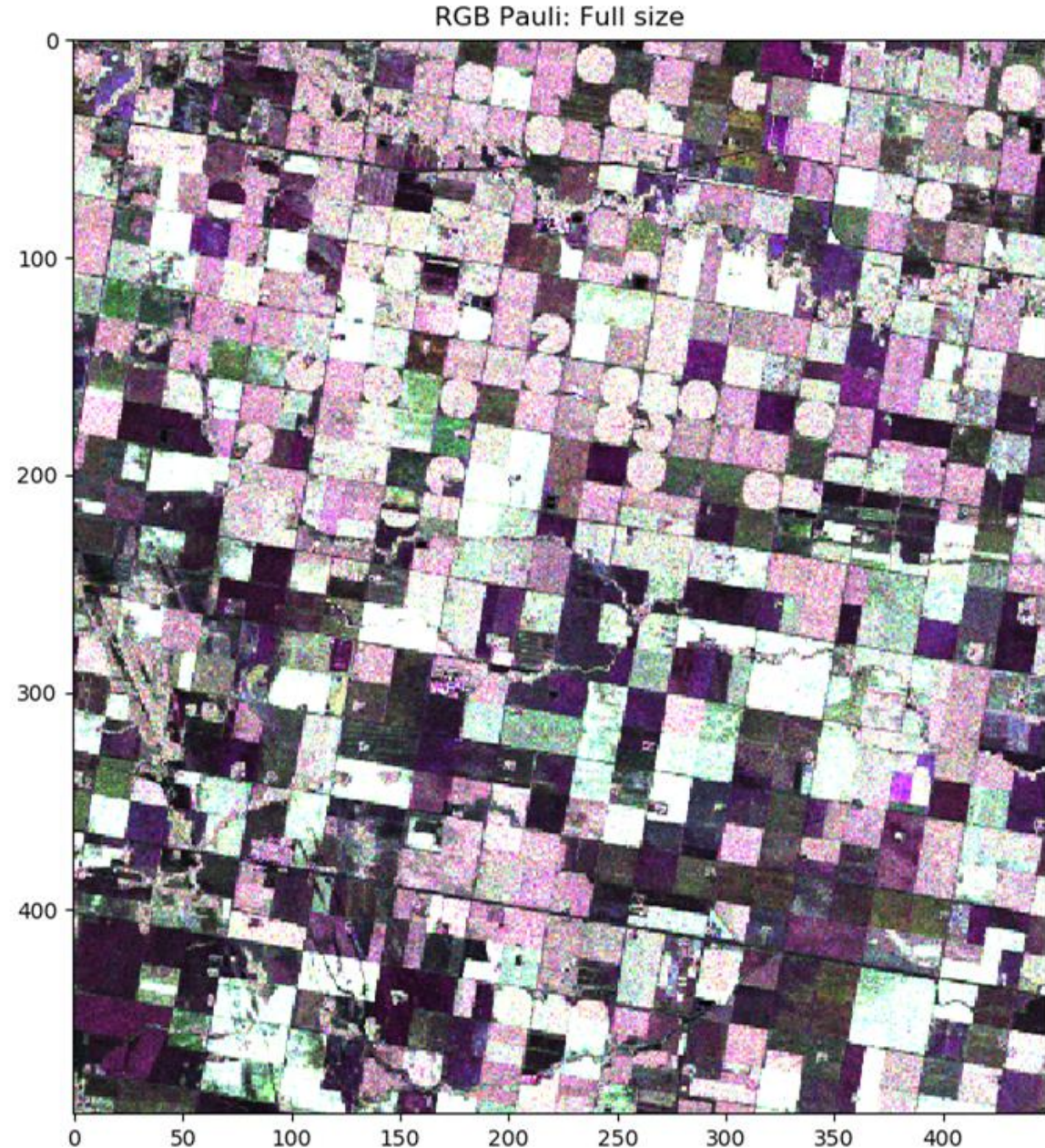
Info on crops  
can be found at  
the link provided  
by Agriculture  
and Agri-Food  
Canada, Gov.  
Canada.



# Data: RCM; Location: Carman, Manitoba, Canada

Pauli RGB for 24<sup>th</sup> August 2020.  
Carman, Manitoba, Canada.  
Multi-looked 7x14, not geocoded.

RADARSAT Constellation Mission Imagery ©  
Government of Canada (2020). RADARSAT is an  
official mark of the Canadian Space Agency.



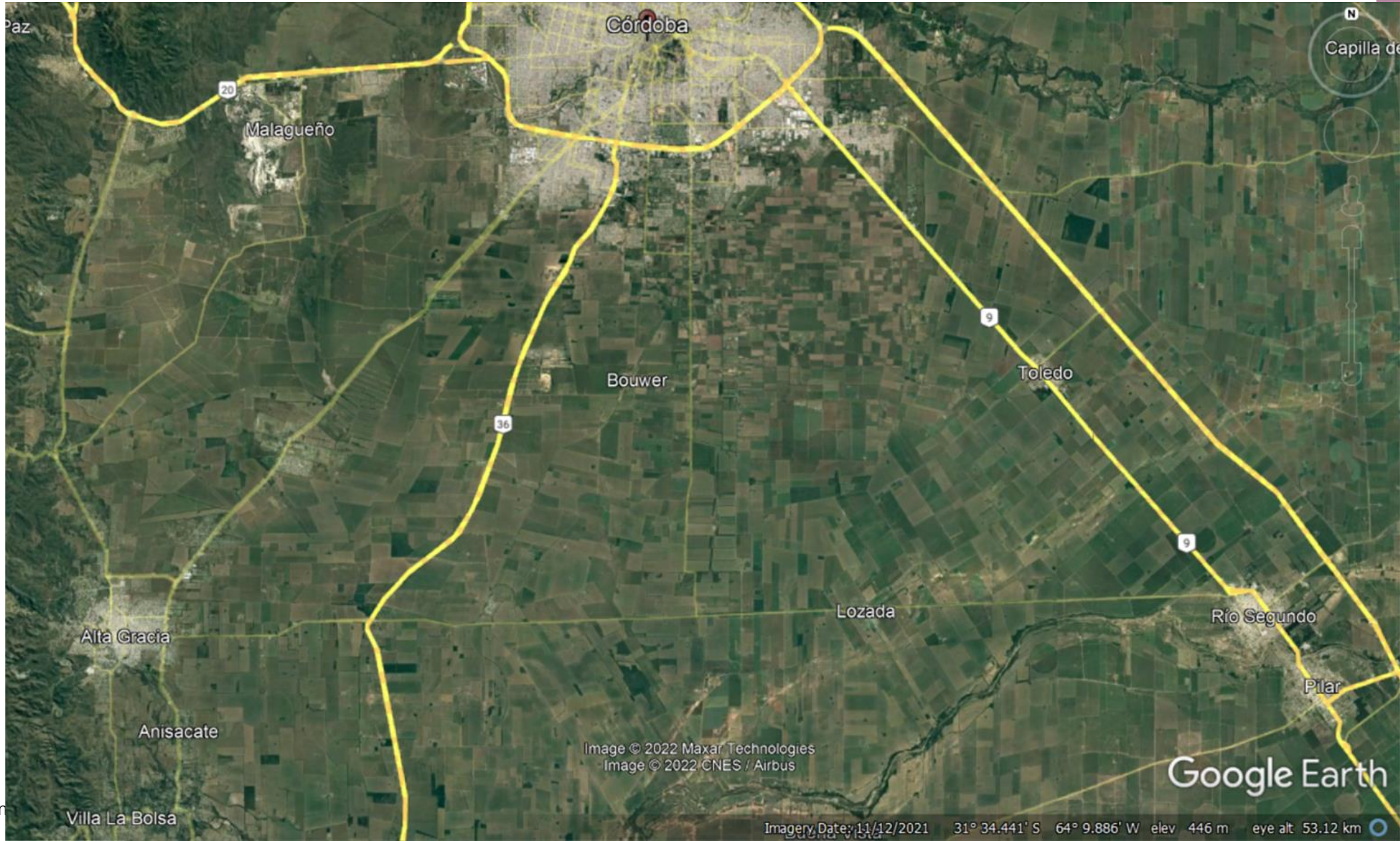
# Data: SAOCOM; Location: Cordoba, Argentina



The **crops** are mostly corn and soybean.

SAOCOM  
(Argentine Space Agency)

These data can be used for training purposes only.



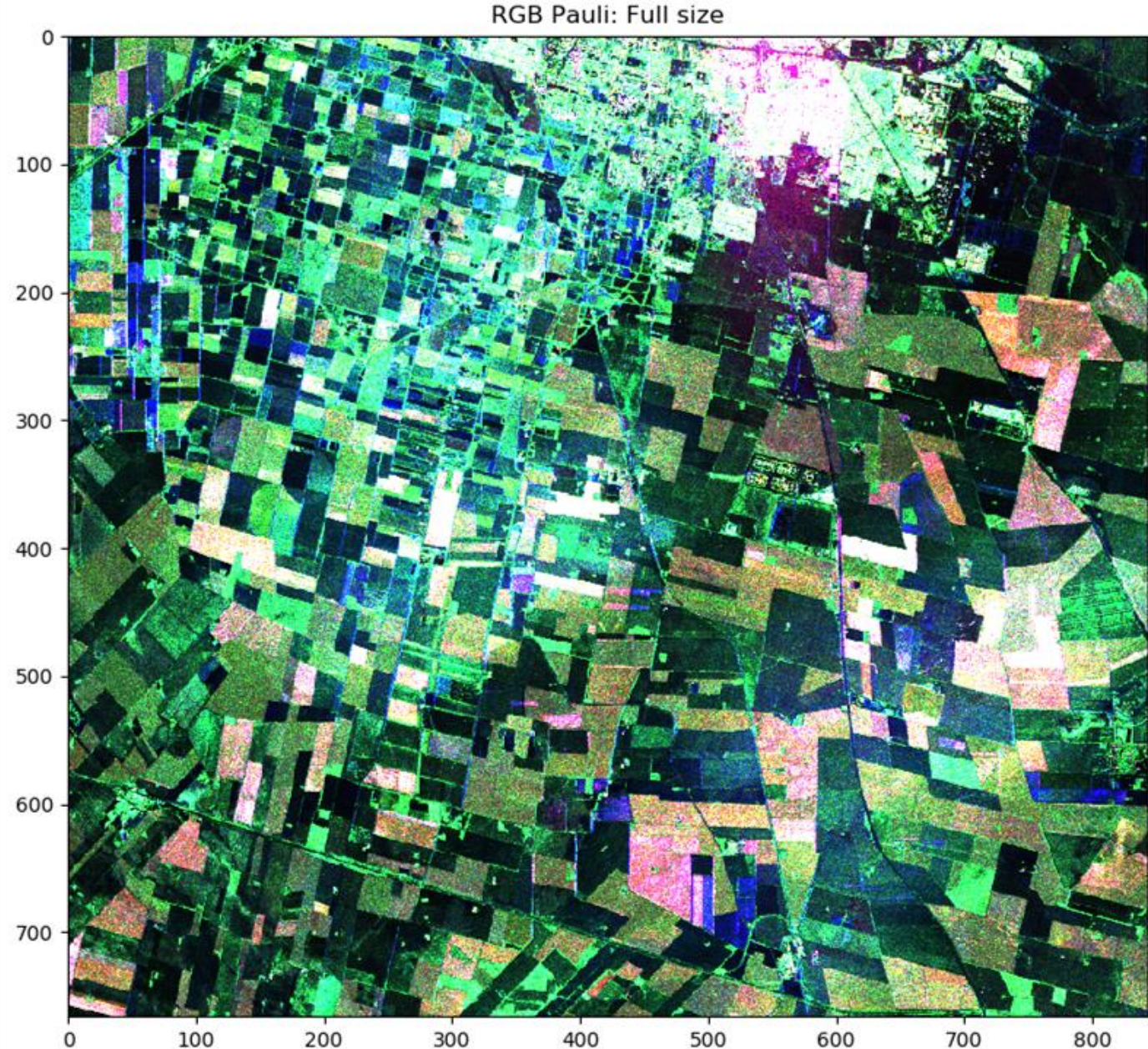


# Data: SAOCOM; Location: Cordoba, Argentina

Pauli RGB for 11<sup>th</sup> March 2020.  
Cordoba, Argentina.  
Multi-looked 5x8, not  
geocoded.

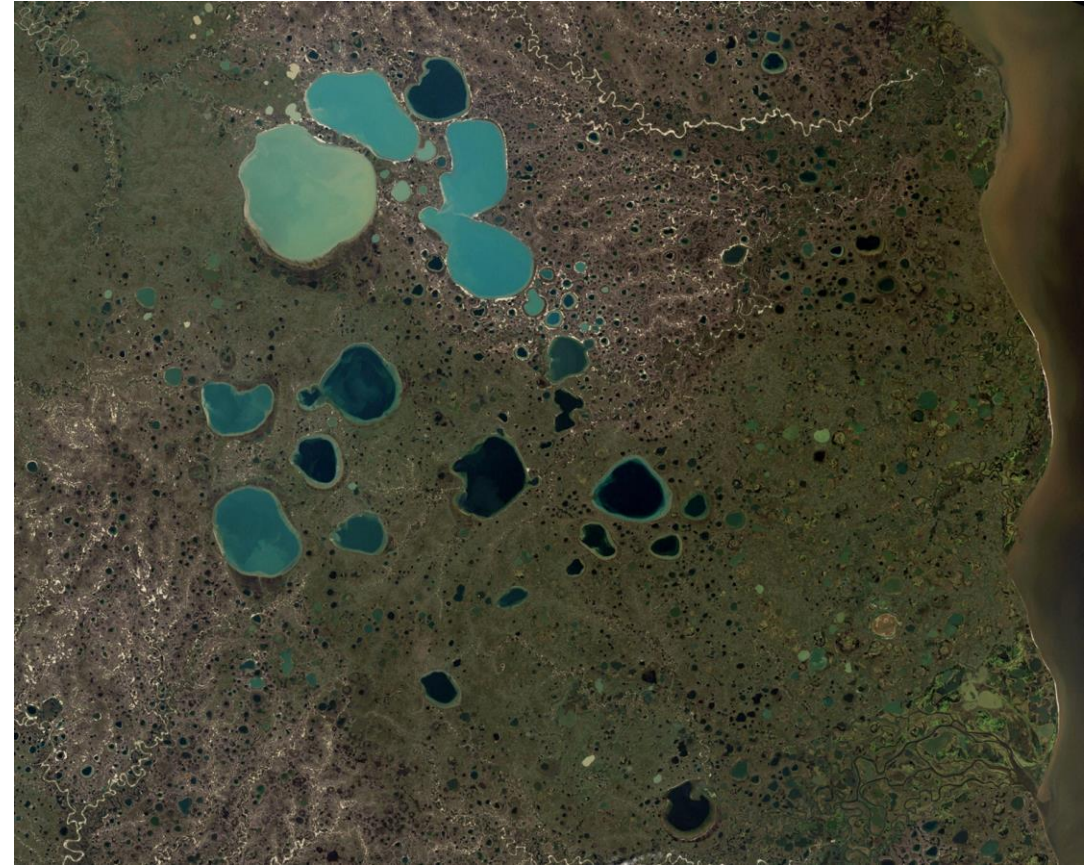
SAOCOM® product – ©CONAE –  
(2020). All rights reserved. CONAE is  
the Argentine Space Agency.

These data can be used for training  
purposes only.



# Questions?

- Please enter your questions in the Q&A box. We will answer them in the order they were received.
- We will post the Q&A to the training website following the conclusion of the webinar.



<https://earthobservatory.nasa.gov/images/6034/pothole-lakes-in-siberia>



# Contacts

- Trainers:
  - Laura Dingle-Robertson: [laura.dingle-robertson@AGR.GC.CA](mailto:laura.dingle-robertson@AGR.GC.CA)
  - Armando Marino: [armando.marino@stir.ac.uk](mailto:armando.marino@stir.ac.uk)
- Training Webpage:
  - <https://appliedsciences.nasa.gov/join-mission/training/english/arset-mapping-crops-and-their-biophysical-characteristics>
- ARSET Website:
  - <https://appliedsciences.nasa.gov/what-we-do/capacity-building/arset>
- Twitter: [@NASAARSET](https://twitter.com/NASAARSET)





**Thank You!**

