

Exploiting SAR to Monitor Agriculture

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4 September 2019

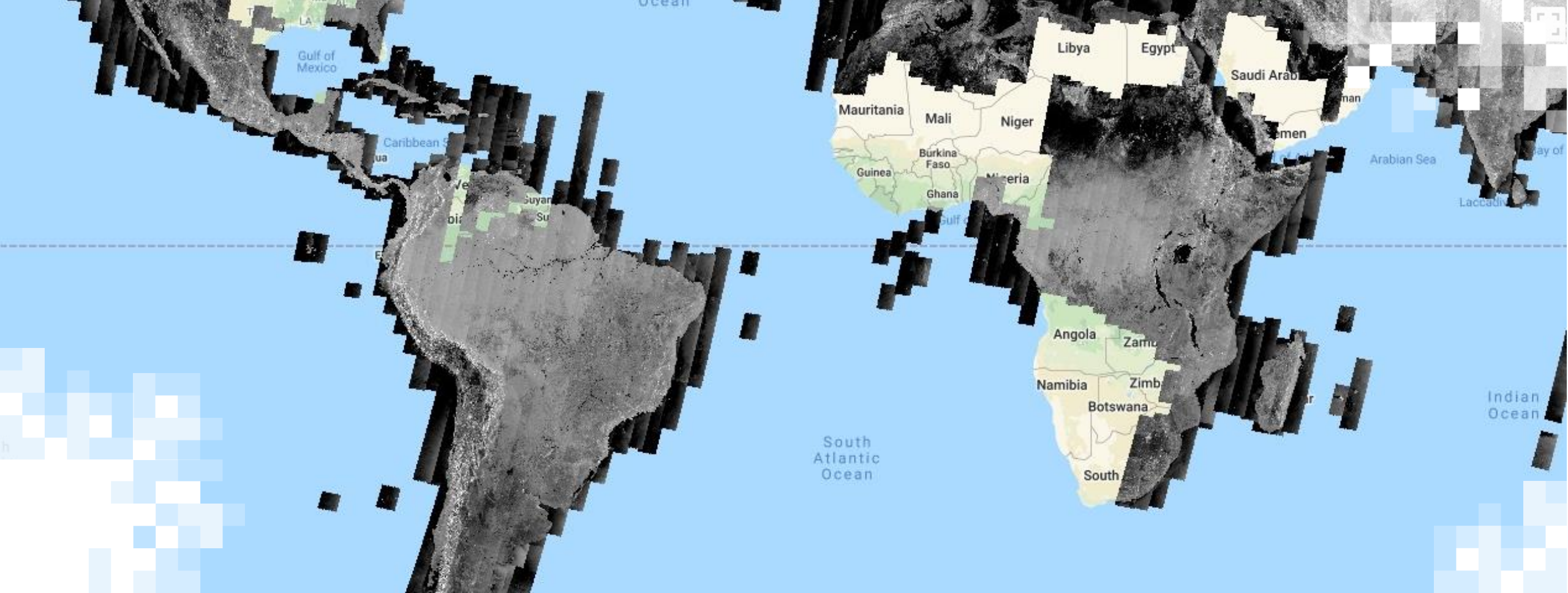
Learning Objectives

- By the end of this presentation, you will be able to understand:
 - how to estimate soil moisture from RADARSAT-2 data
 - how to process multi-frequency data for use in crop classification

SNAP: Sentinel's Application Platform

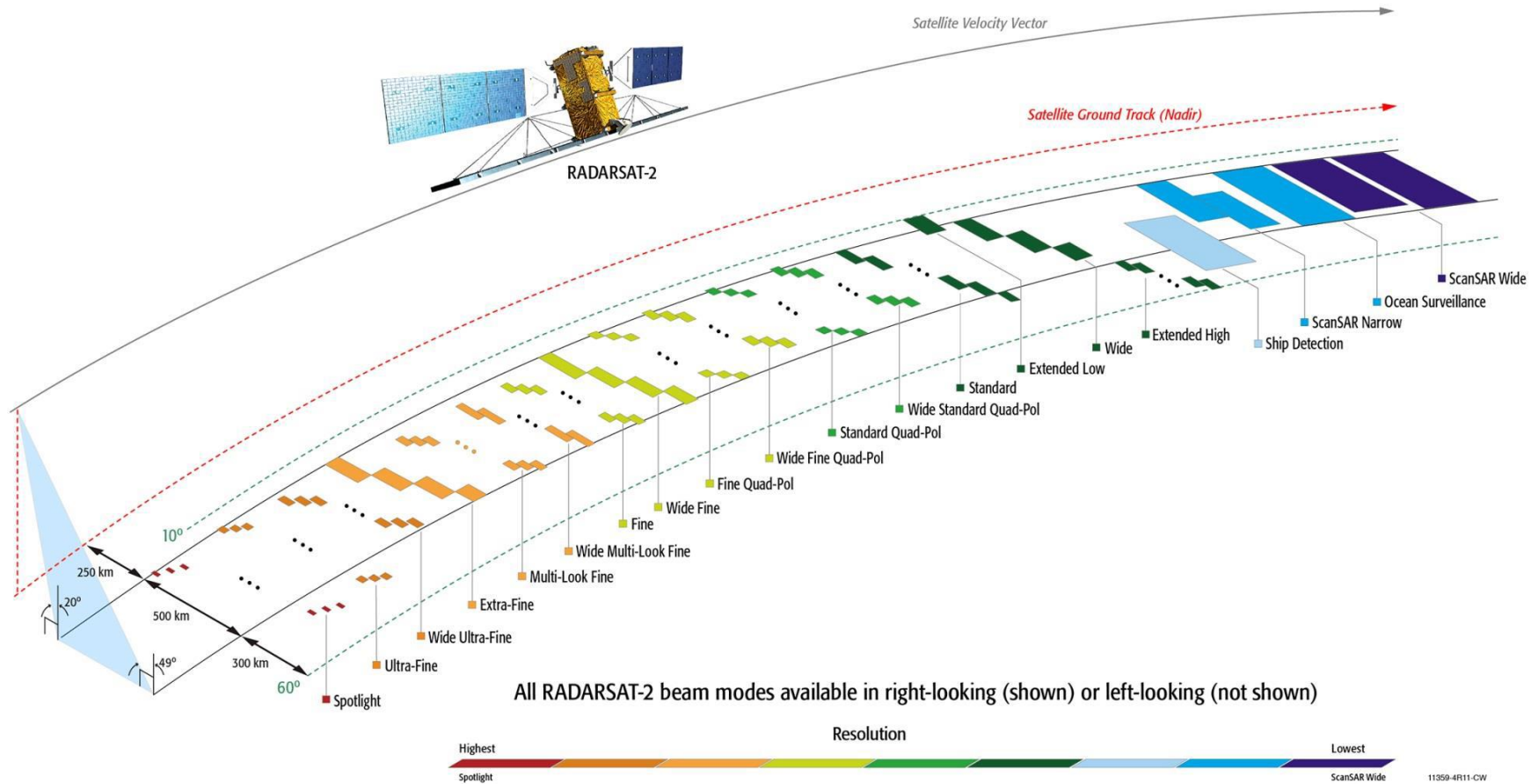


- ESA SNAP is the free and open-source toolbox for processing and analyzing ESA and 3rd part EO satellite image data
- You can download the latest installers for SNAP from:
 - <http://step.esa.int/main/download/snap-download/>



Estimating Soil Moisture from RADARSAT-2 Data

RADARSAT-2



RADARSAT-2 SAR Beam Modes – Revisit time: 24 days

Image Credits: [MDA RADARSAT-2 Product Description](#)

Pre-Processing RADARSAT-2 Data with SNAP

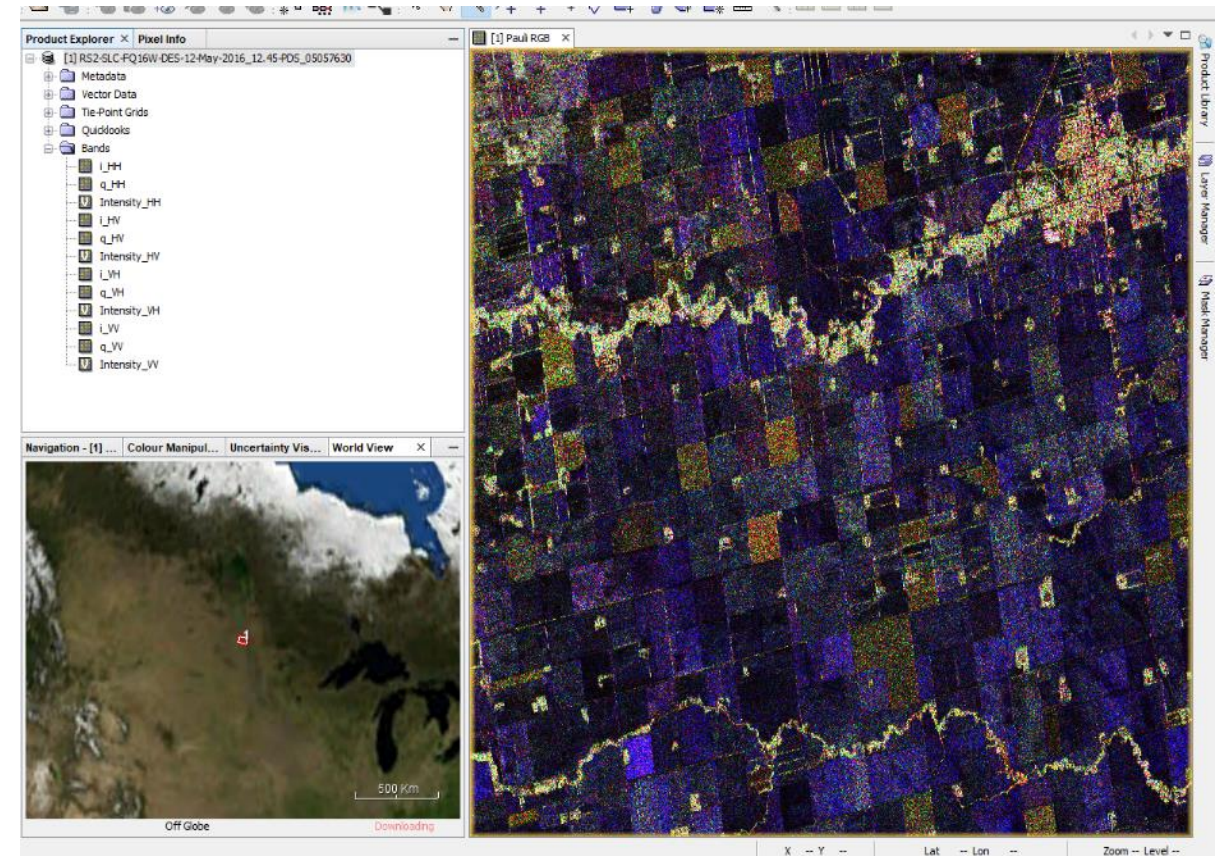
Extract Backscatter



Pre-Processing RADARSAT-2 Data with SNAP

Read Image

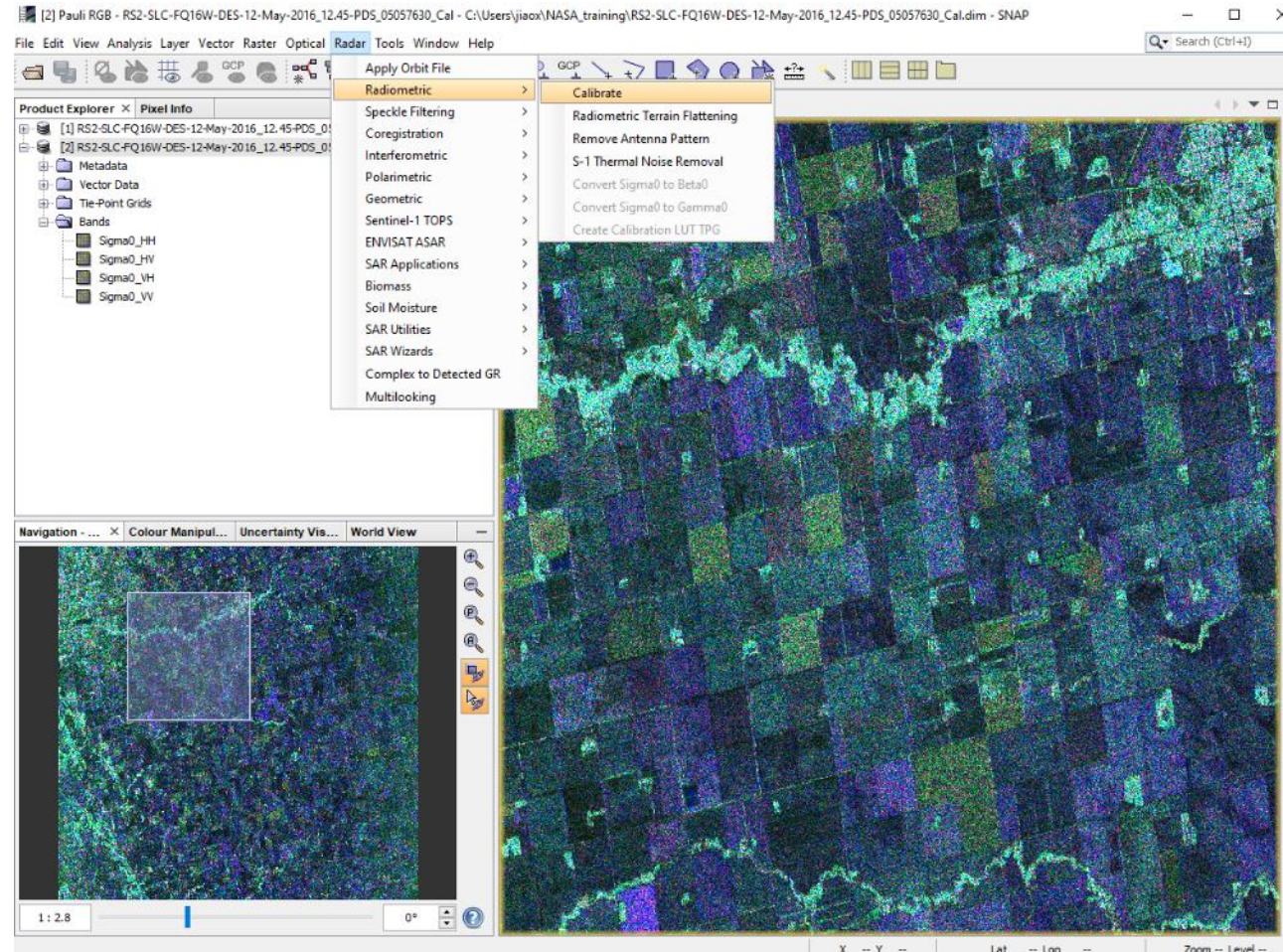
- RADARSAT-2 Wide Fine Quad-Pol single look complex (SLC) product:
 - Nominal Resolution: 5.2m (Range) * 7.6 m (Azimuth)
 - Nominal Scene Size: 50 Km (Range) * 25 Km (Azimuth)
 - Quad (HH, HV, VH and VV) polarizations + phase
 - Slant range single look complex, contains both amplitude and phase information



RADARSAT-2 Wide Fine Quad-Pol FQ16W descending SLC data acquired on May 12, 2016, over Carman, Manitoba, Canada

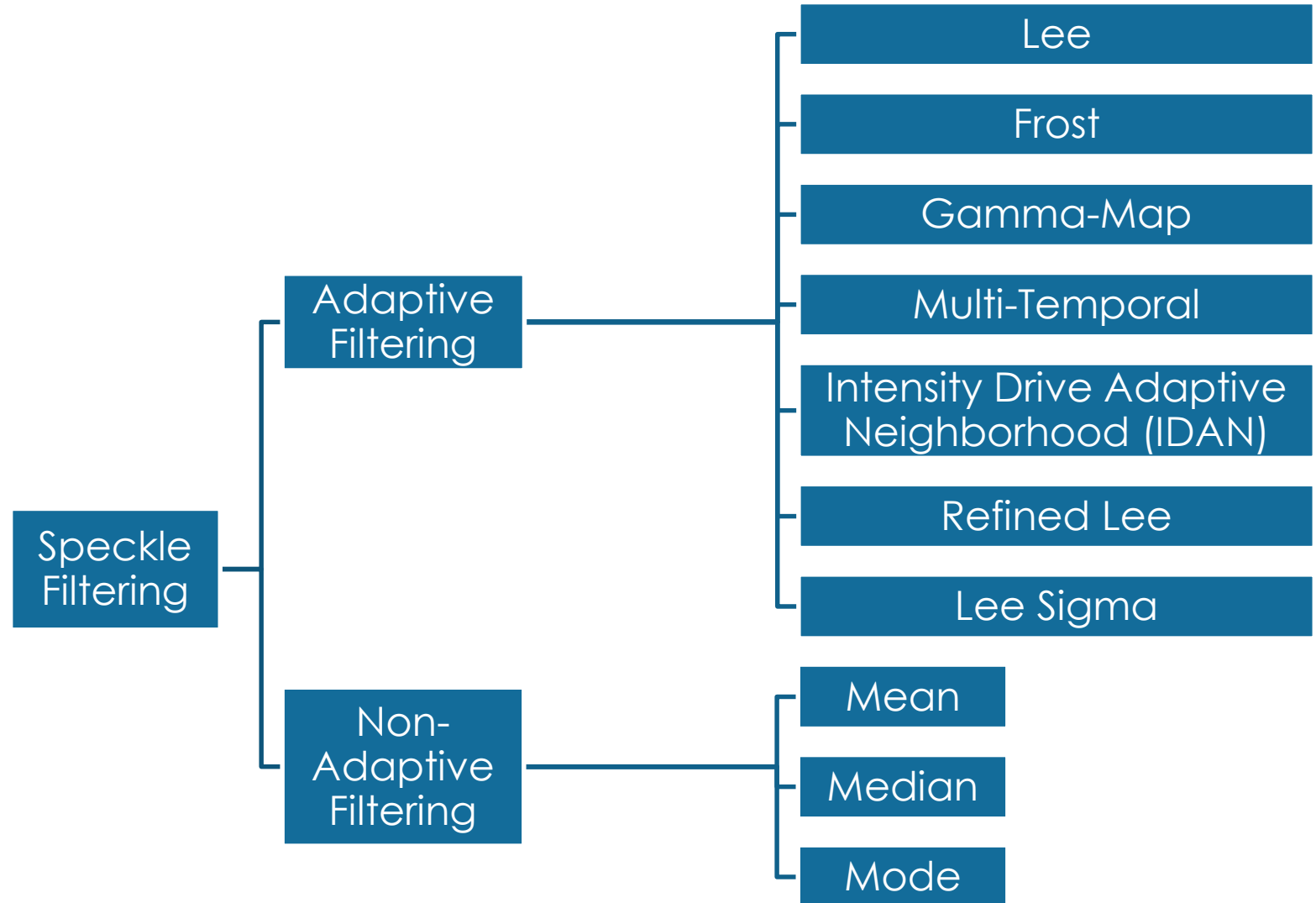
Pre-Processing RADARSAT-2 Data with SNAP

Calibration: Convert Pixel Values to Radar Backscatter



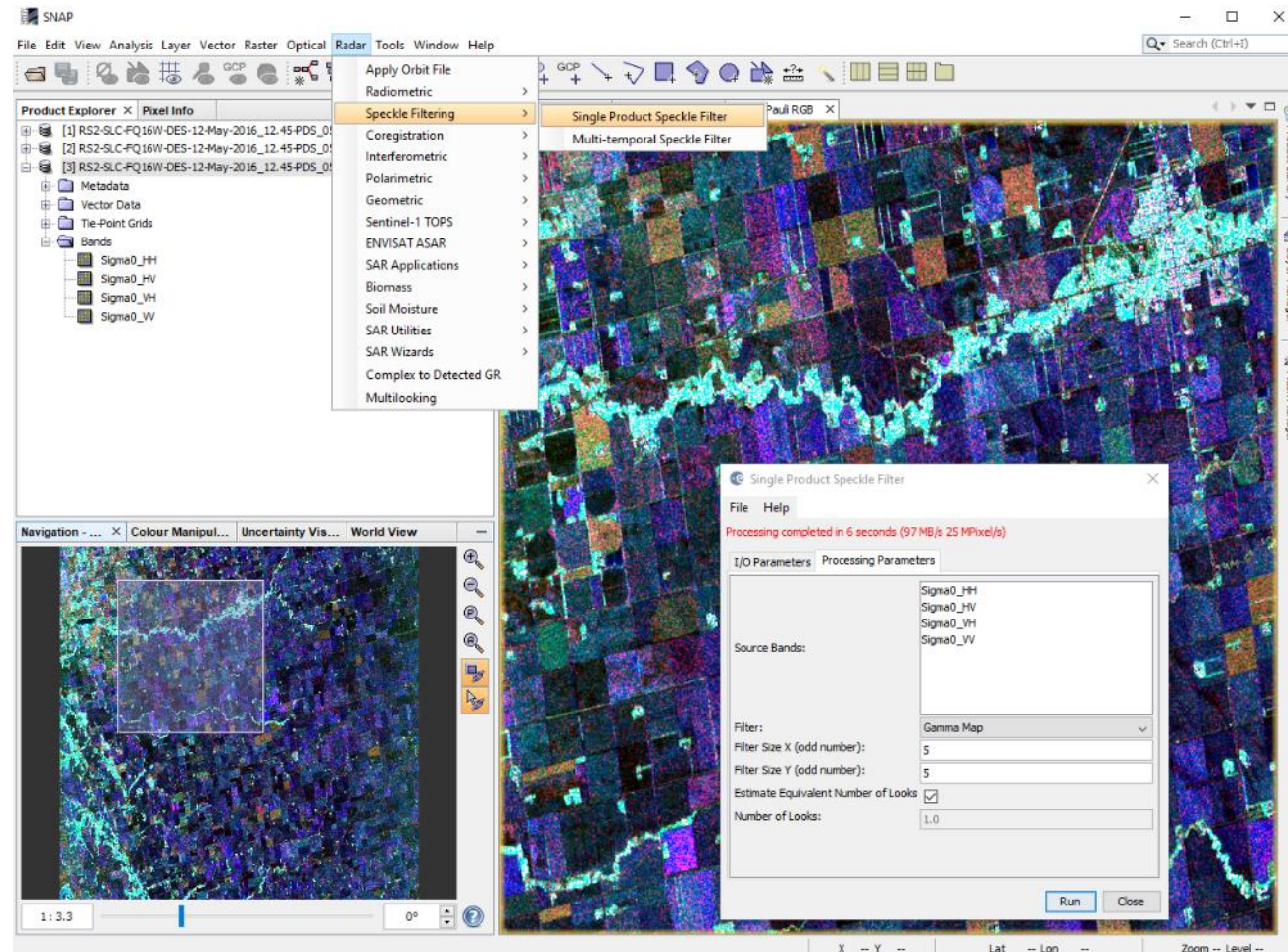
Speckle Filtering

- Speckle filtering is not an exact science → image and target dependent
- An ideal speckle filter will:
 - reduce speckle
 - preserve edge sharpness
 - preserve line and point target contrast
 - retain mean values in homogeneous regions
 - retain texture information



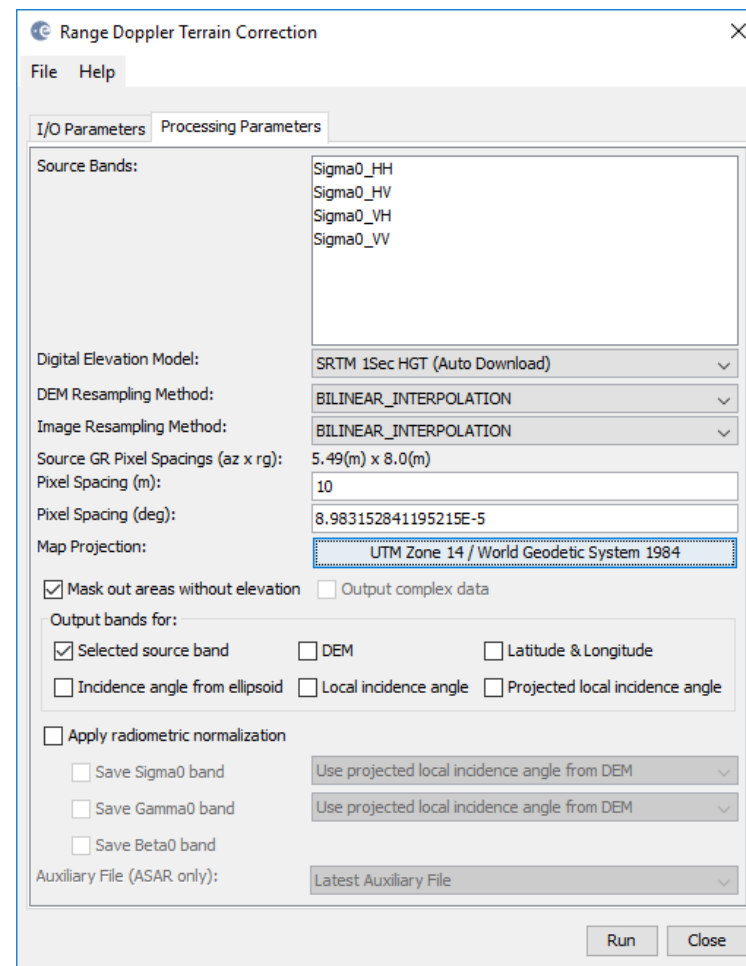
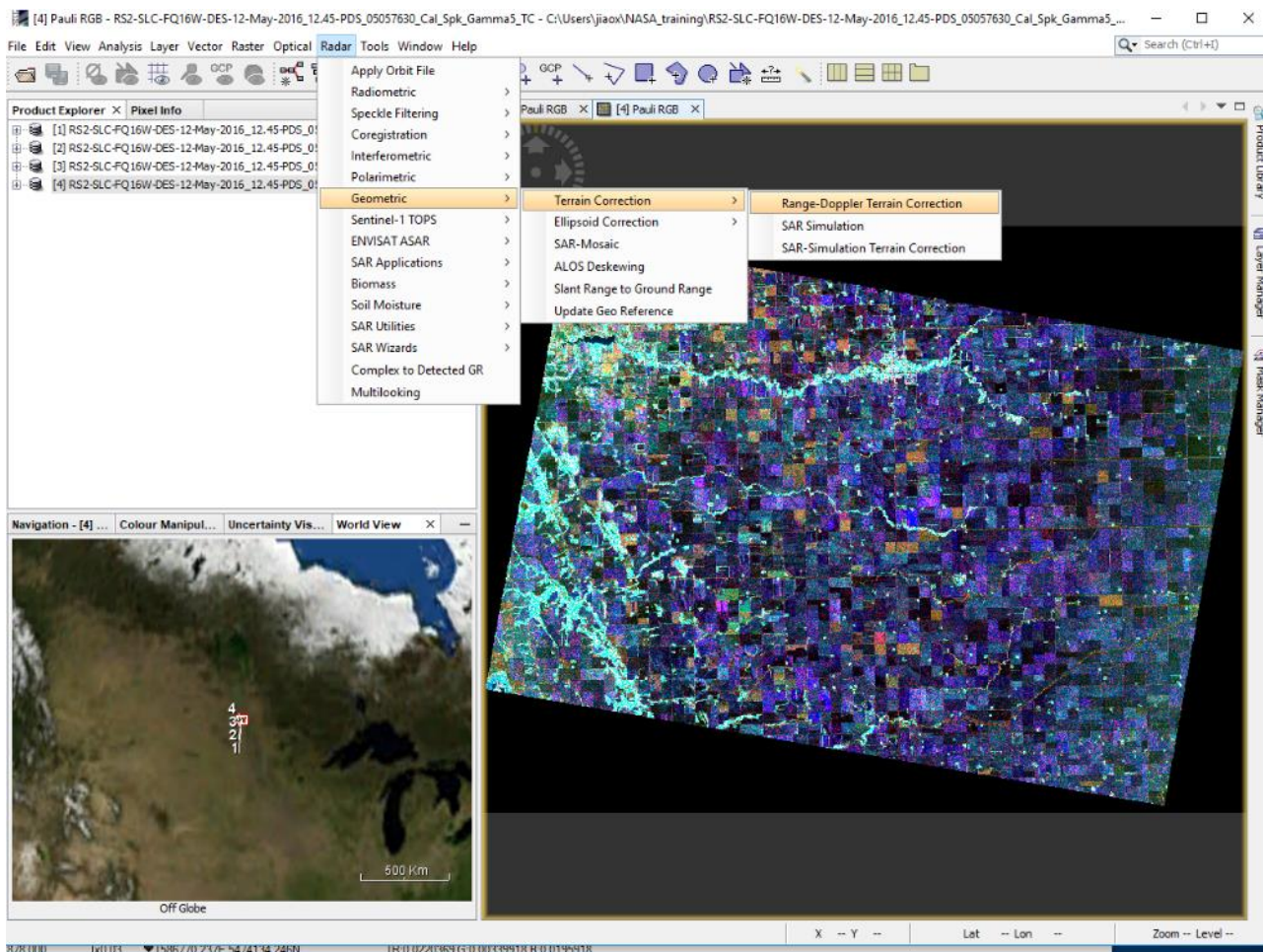
Pre-Processing RADARSAT-2 Data with SNAP

Speckle Filter – 5 by 5 Gamma Map

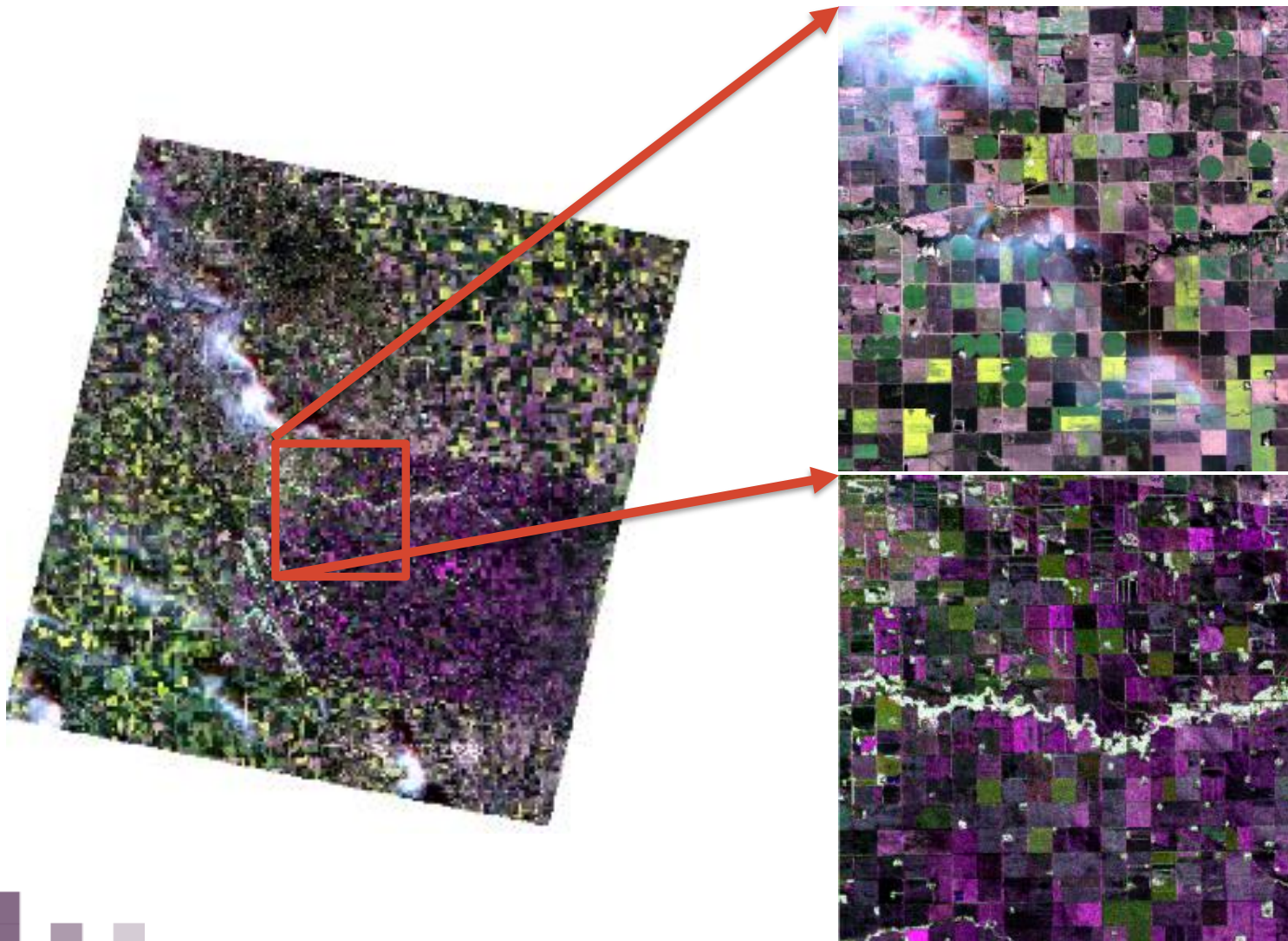


Pre-Processing RADARSAT-2 Data with SNAP

Terrain Correction



Pre-Processing RADARSAT-2 Data with SNAP



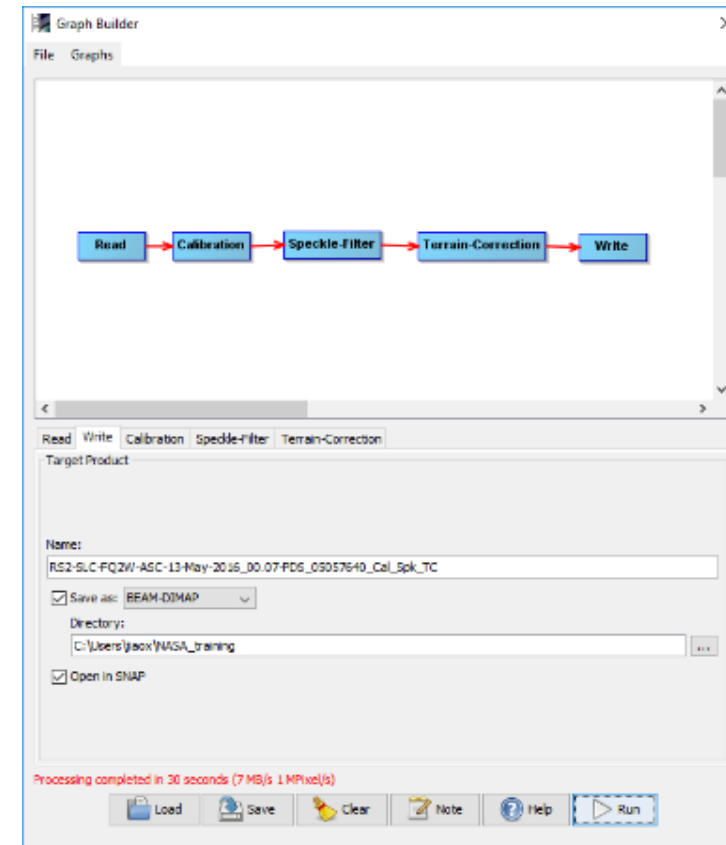
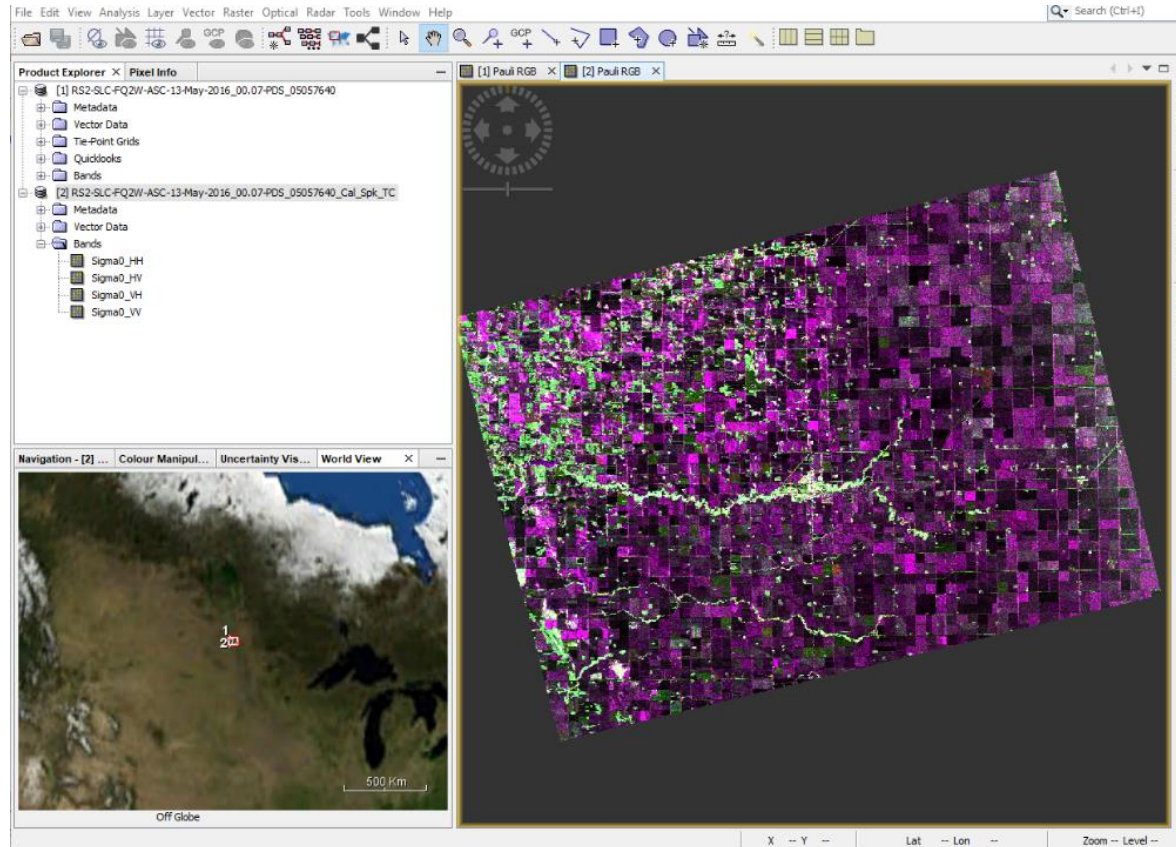
RapidEye natural color image
acquired on July 4, 2016

RGB color composite of
RADARSAT-2 image acquired
May 12, 2016

(**R=HH**, **G=HV**, **B=VV**)

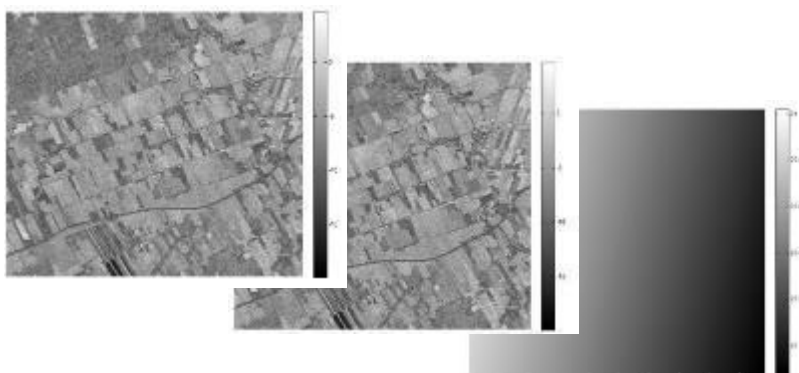
Pre-Processing RADARSAT-2 Data with SNAP

- Graph builder: used for batch processing and customized processing chains



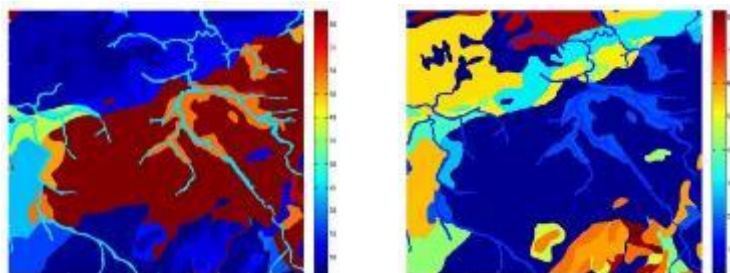
Physical Modeling Approach for Soil Moisture Estimation

RADARSAT-2 Data



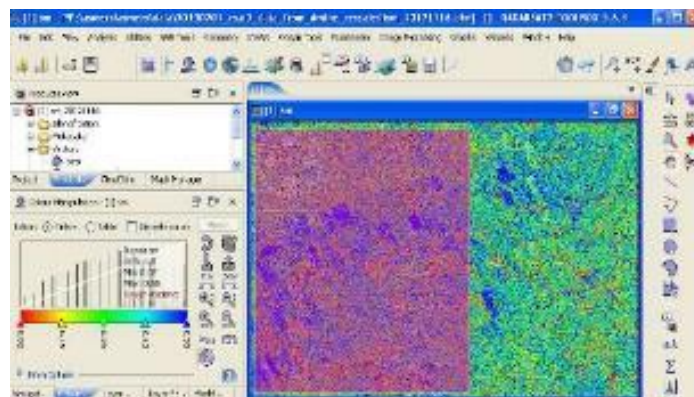
Radar Data
(HH and VV Backscatter)
(Radar Angle)

Soils Data
(Clay and Sand Fractions)



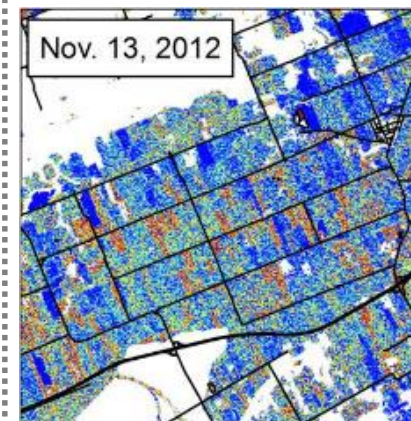
Data Processing

SNAP Soil Moisture Tool Box



- Uses Integral Equation Model (IDEM)
- No a priori information is needed
- Soil moisture is retrieved using only SAR data (backscatter and incidence angle)

Output and Validation



Soil Moisture
55% 2%

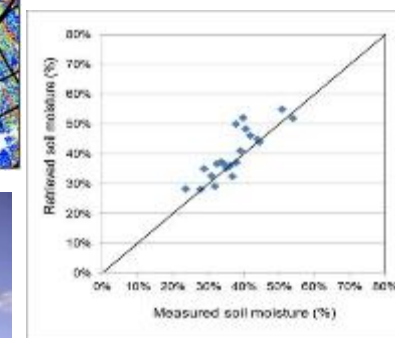
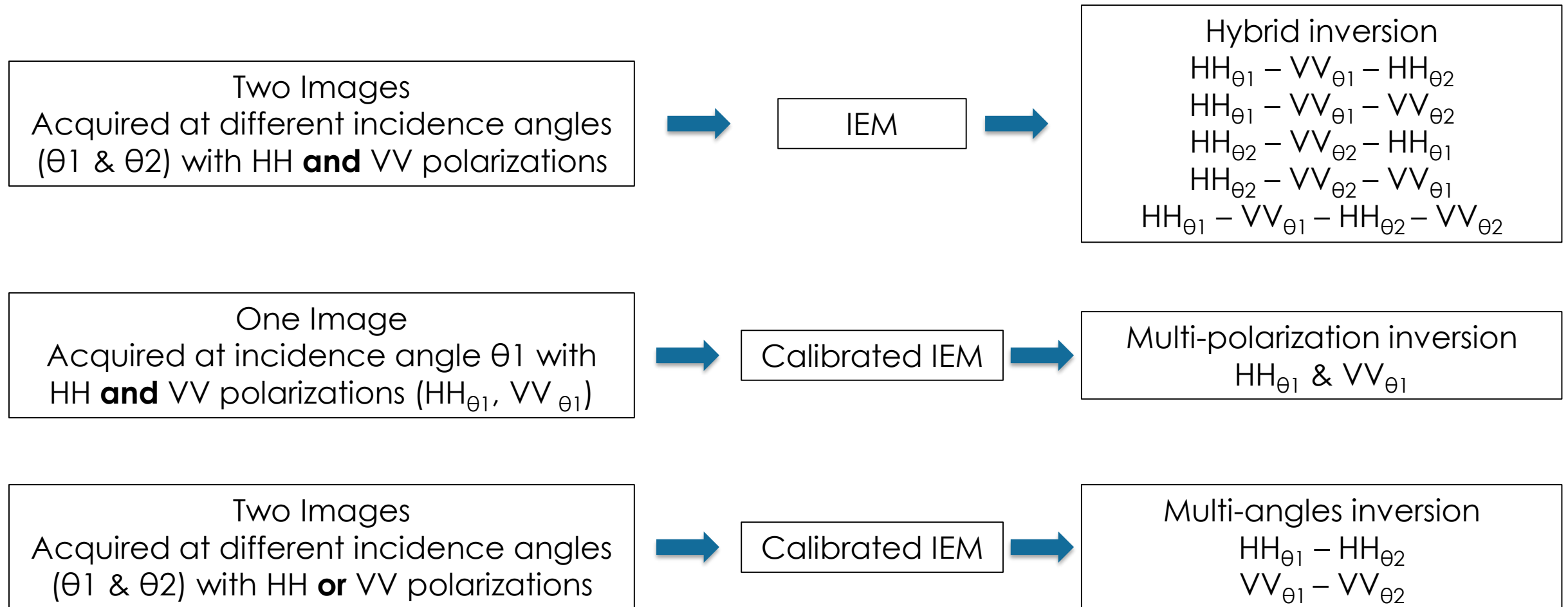


Image Source: Merzouki and McNairn, 2015

Backscatter Model Inversion Schemes



Soil Moisture Processing with the Soil Moisture Toolbox in SNAP – Hybrid Scheme

- Soil moisture map derived from one a.m. RADARSAT-2 acquisition and one p.m. RADARSAT-2 acquisition, 12 hours apart

2016-05-12 RADARSAT-2 Acquisition Pair (FQ16-FQ2)

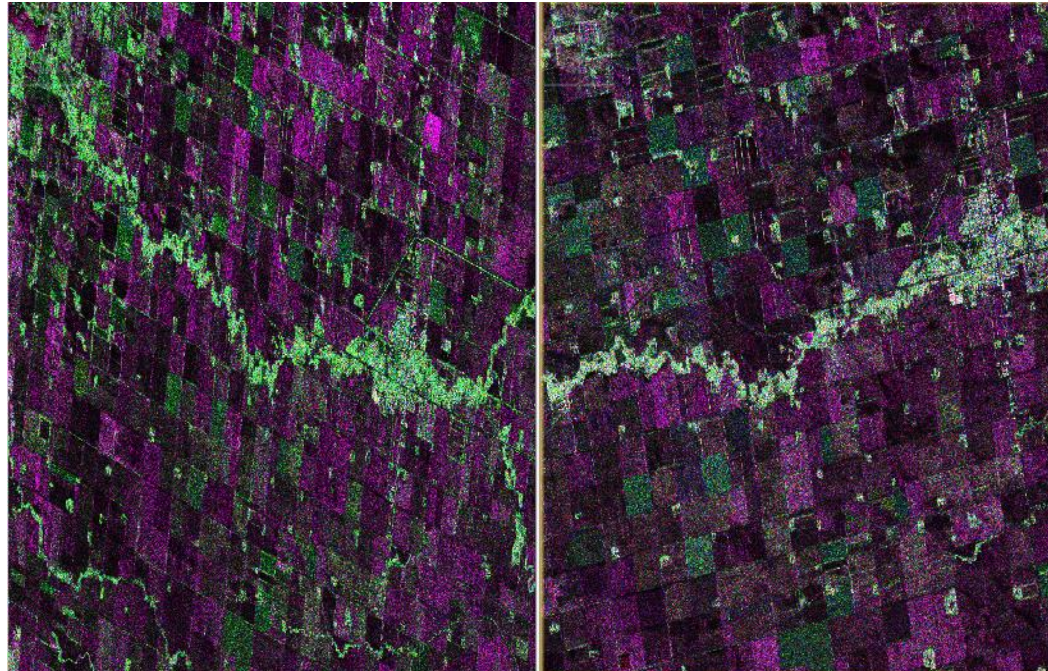
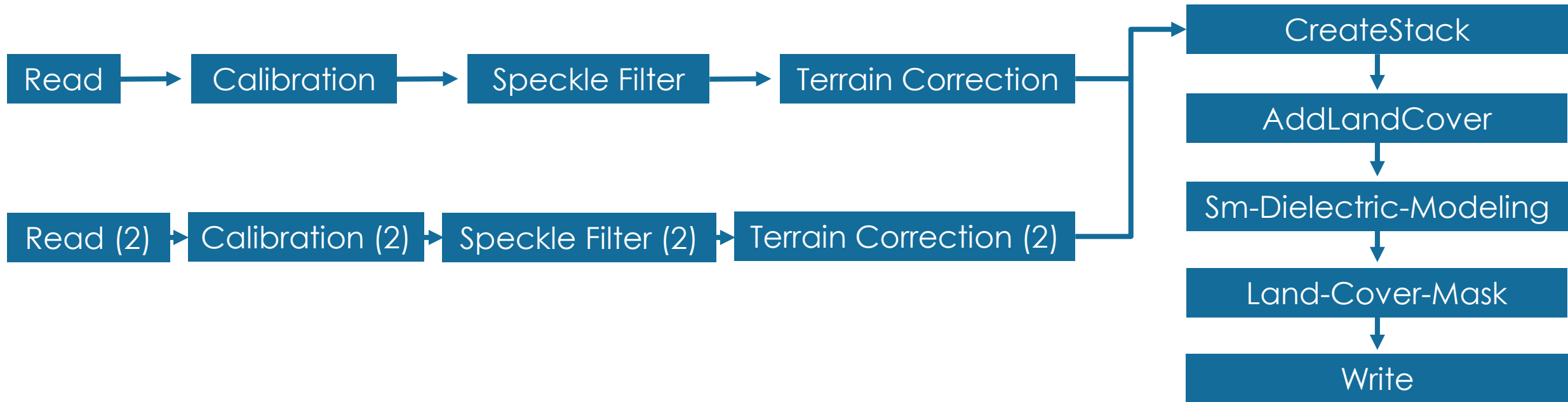


Image acquired on May 12, 2016,
FQ16W Descending pass

Image acquired on May 13, 2016,
FQ2W Ascending pass

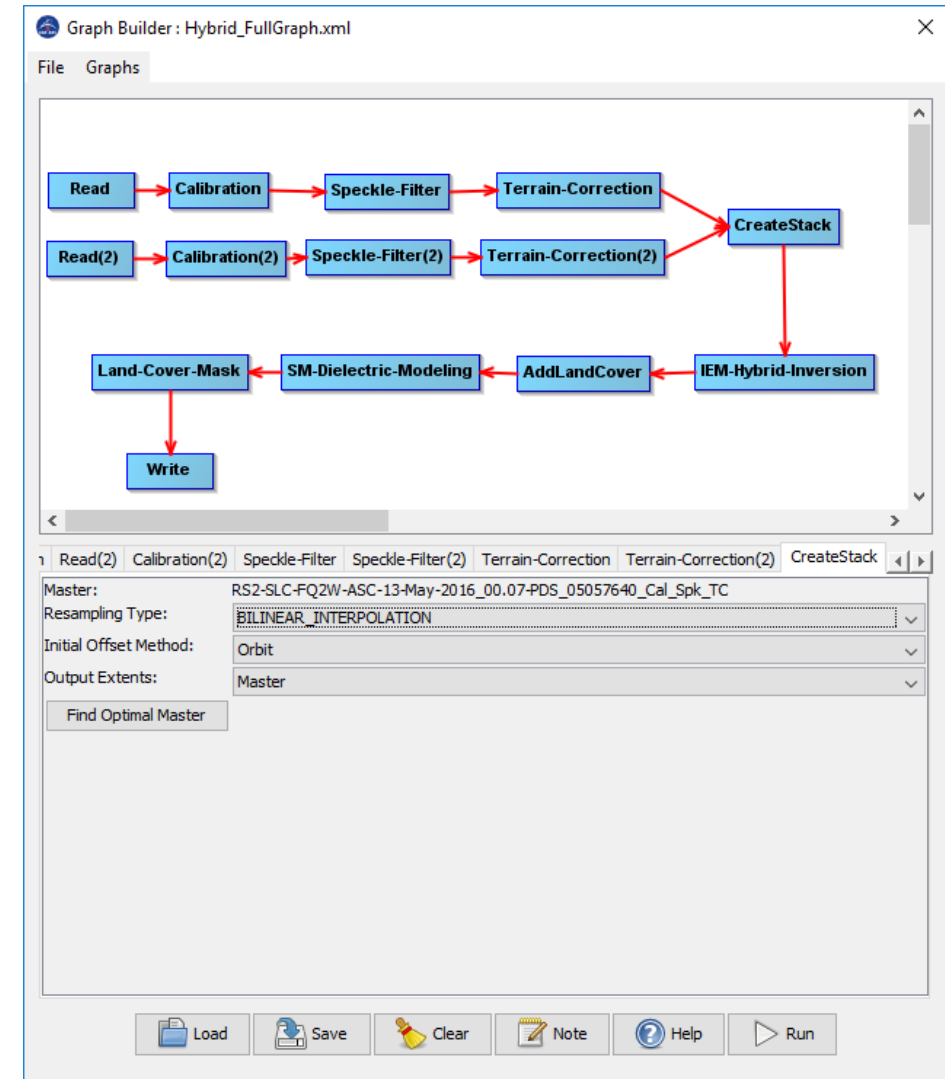
Soil Moisture Processing with the Soil Moisture Toolbox in SNAP – Hybrid Scheme

- using a hybrid inversion approach, the inversion method is performed on the overlapping geographic area



Soil Moisture Processing with the Soil Moisture Toolbox in SNAP – Hybrid Scheme

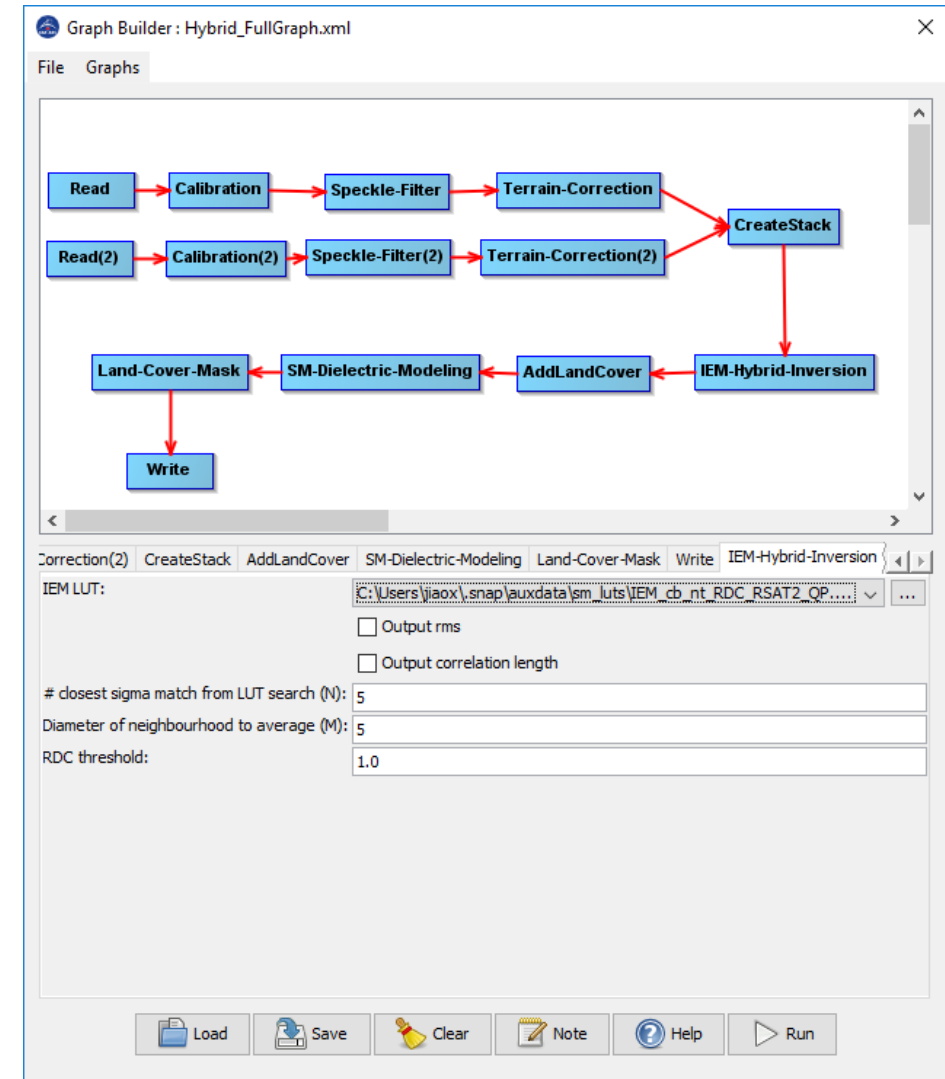
- Spatial alignment of images acquired in the morning and evening
- Create Stack:
 1. Resampling Type: Bilinear Interpolation
 2. Click **Find Optimal Master**



Soil Moisture Processing with the Soil Moisture Toolbox in SNAP – Hybrid Scheme

IEM Hybrid Inversion

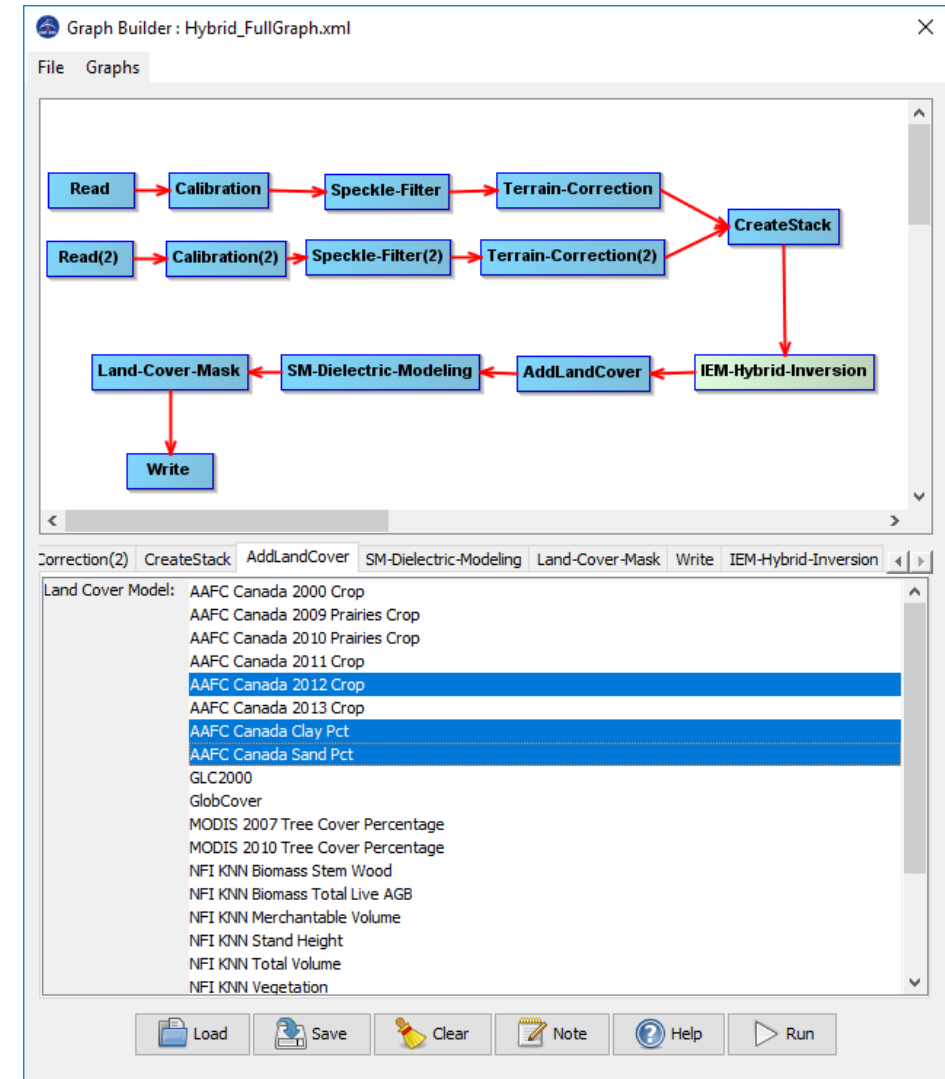
1. Select calibrated IEM LUT
2. Use the default setting for the other parameters



Soil Moisture Processing with the Soil Moisture Toolbox in SNAP – Hybrid Scheme

Add Land Cover

1. Select the land cover file
2. Select sand and clay fractions maps

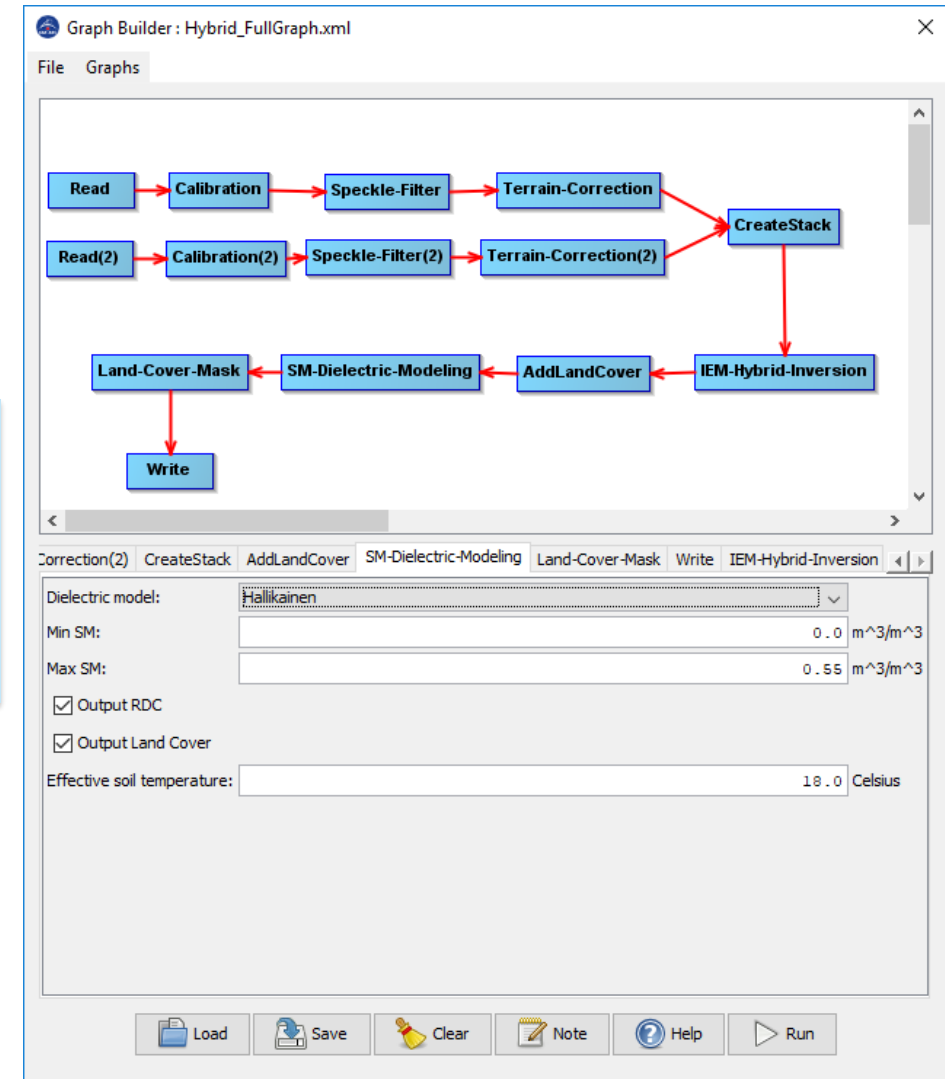


Soil Moisture Processing with the Soil Moisture Toolbox in SNAP – Hybrid Scheme

SM Dielectric Modeling:

1. Select **Hallikainen** mixture model
2. Use the default values for the other parameters

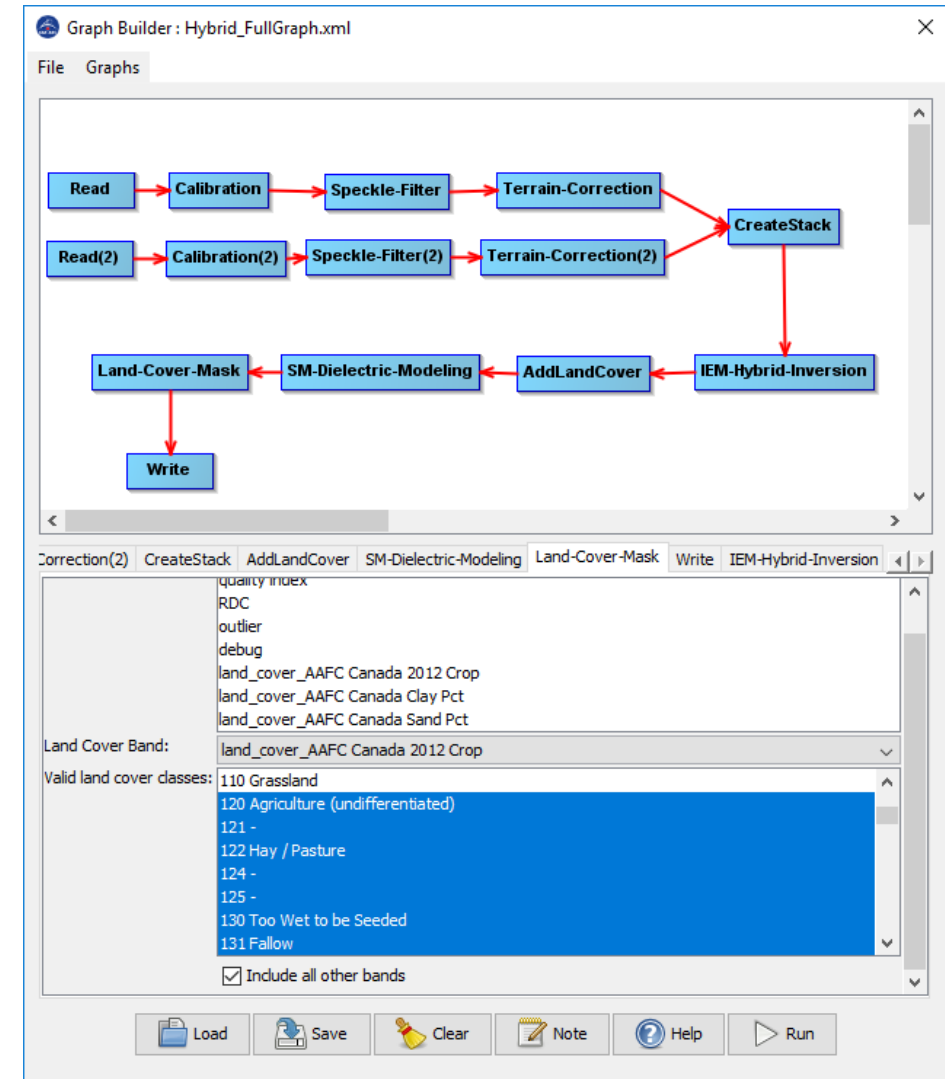
The Hallikainen model was used to estimate the volumetric soil moisture, which is based on retrieved dielectric values. This model requires the soil texture information (clay and sand fractions)



Soil Moisture Processing with the Soil Moisture Toolbox in SNAP – Hybrid Scheme

Land Cover Mask

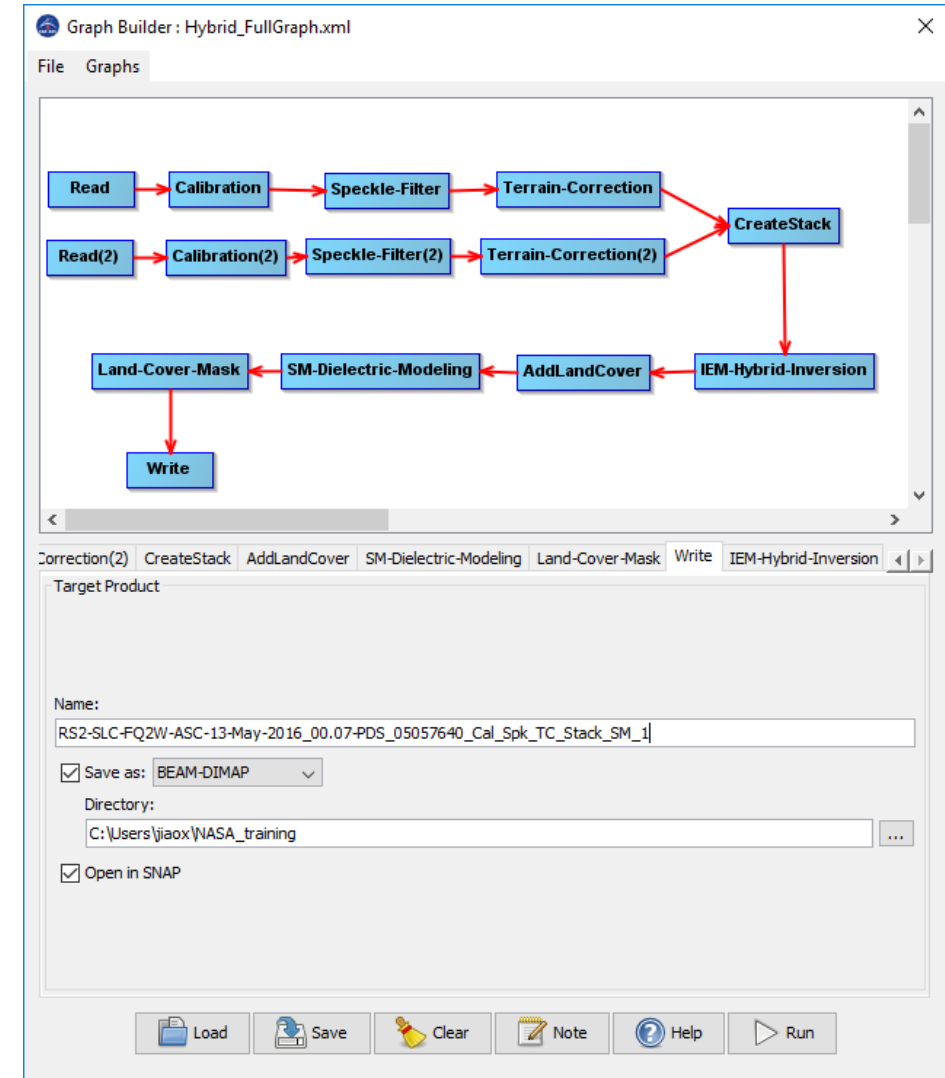
1. Select land cover valid agriculture classes
2. Check **Exclude all other bands**



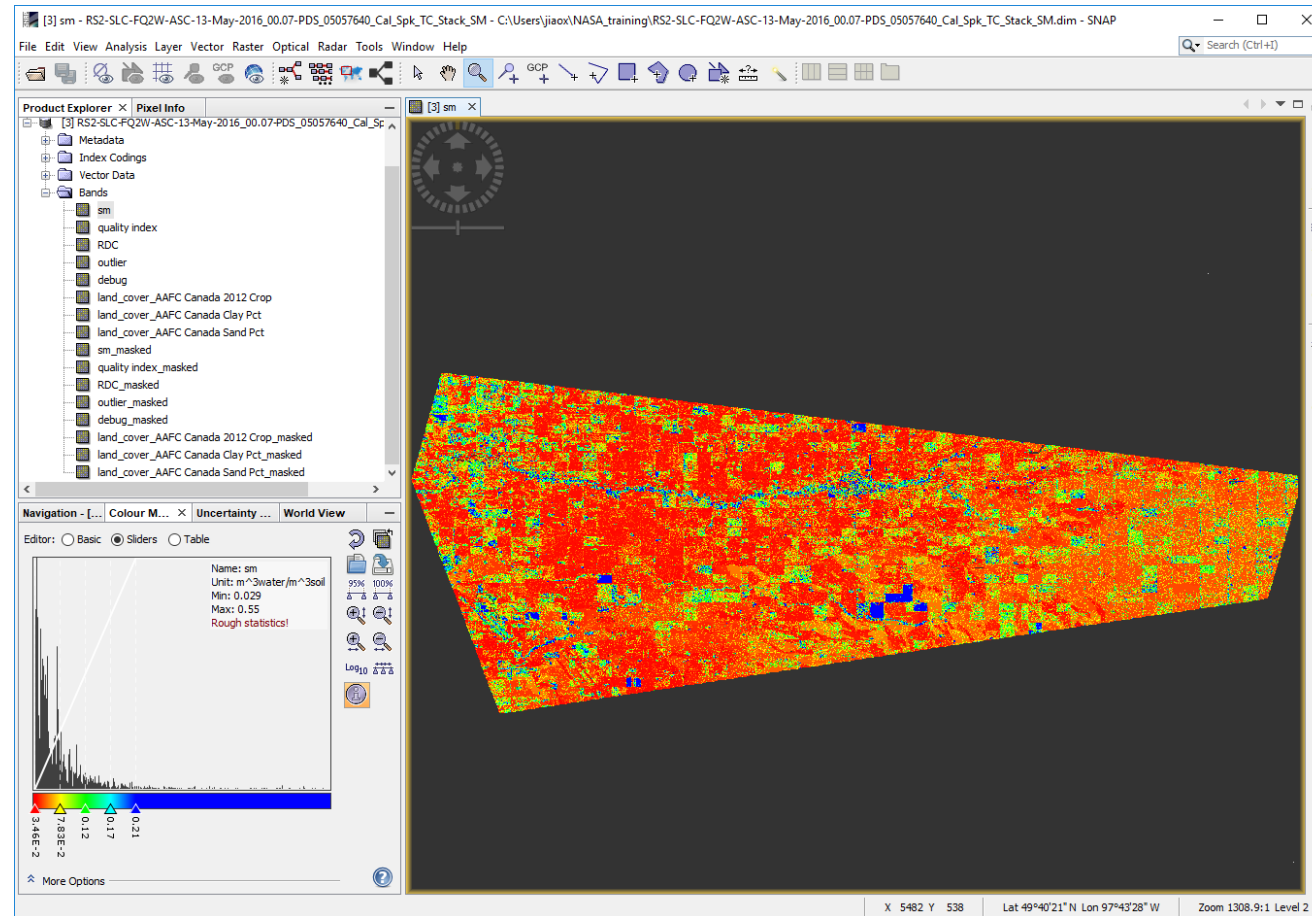
Soil Moisture Processing with the Soil Moisture Toolbox in SNAP – Hybrid Scheme

Write Output

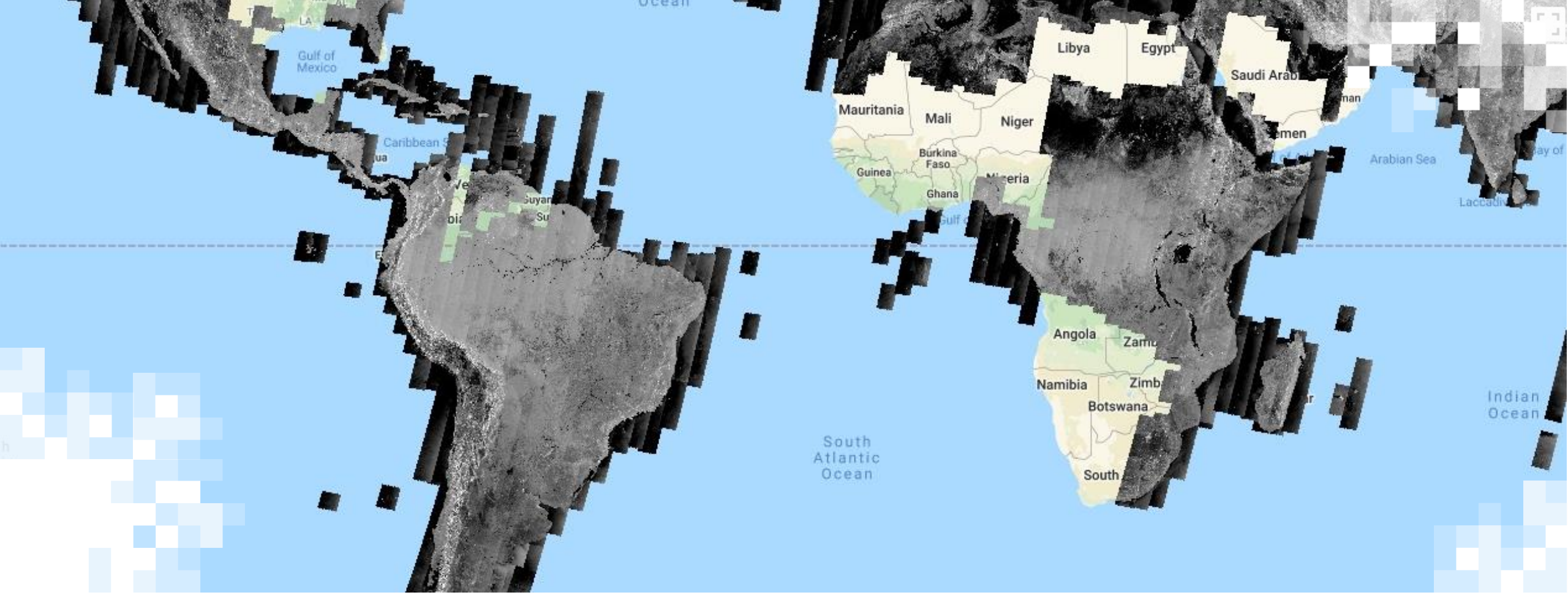
1. Browse and name the output file
2. Select the appropriate format for the retrieved soil moisture product
3. Run the module



Soil Moisture Processing with the Soil Moisture Toolbox in SNAP – Hybrid Scheme

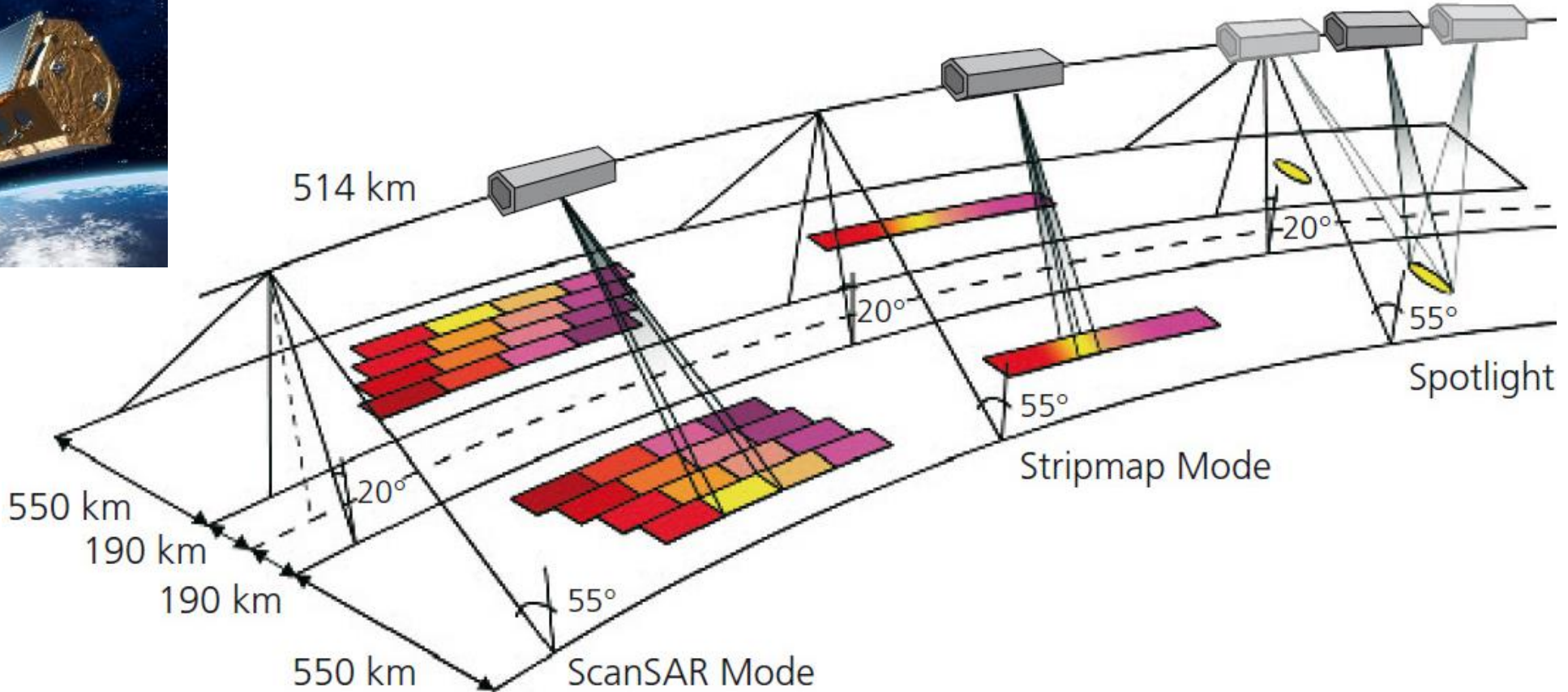


Soil moisture map obtained by inverting the IEM and using a pair of RADARSAT-2 images acquired May 12/13, 2016, in Southern Manitoba



Processing Multi-Frequency Data for Use in Crop Classification

TerraSAR-X



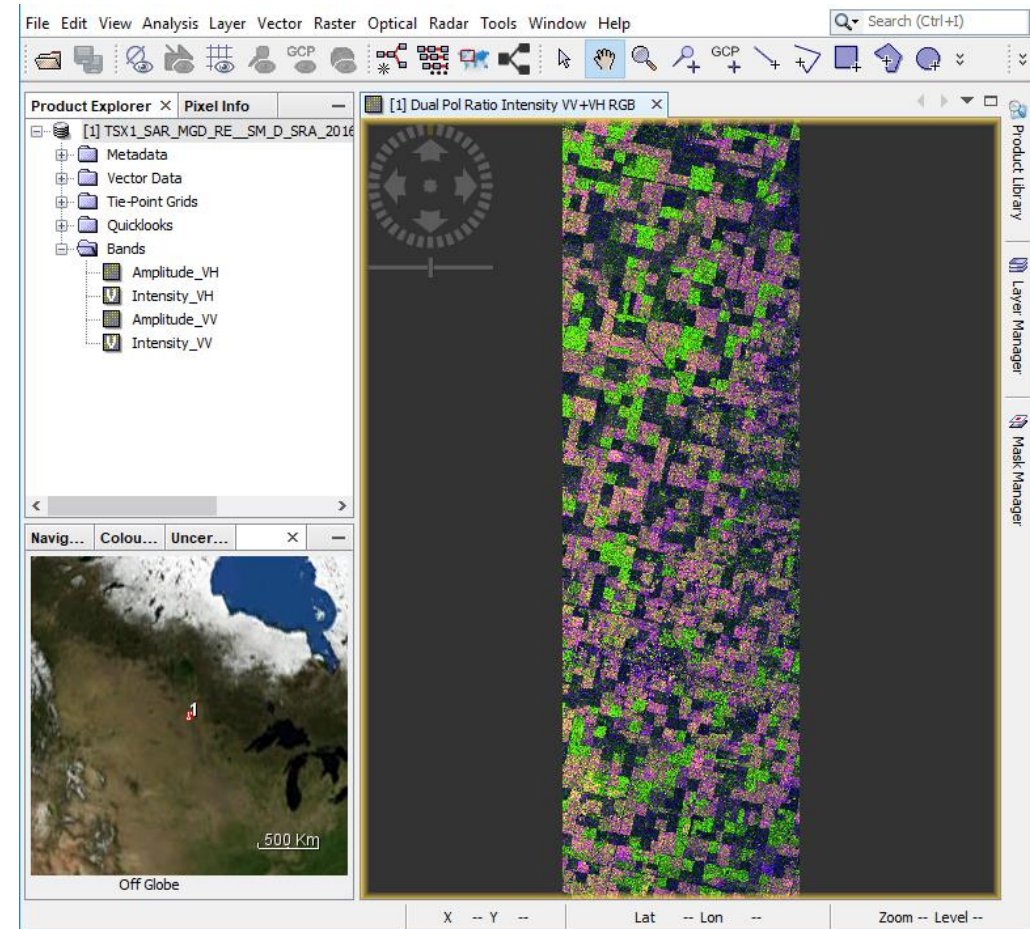
Overview of the TerraSAR-X Scanning Modes - Revisit time: 11 days

Image Credits: [DLR](#)

TerraSAR-X StripMap Dual Pol Data

TerraSAR-X StripMap dual polarization Multi-Look Ground Range Detected (MGD) product

- Nominal Resolution: 1.2 m (range) * 6.6 m (azimuth)
- Nominal Scene Size: 15 km (range) * 50 km (azimuth)
- Dual Polarization: HH&VV, HH&HV, or VV and HH



TerraSAR-X StripMap dual pol MGD data acquired on July 27, 2016, over Carman, Manitoba, Canada

Pre-Processing RADARSAT-2 Data with SNAP

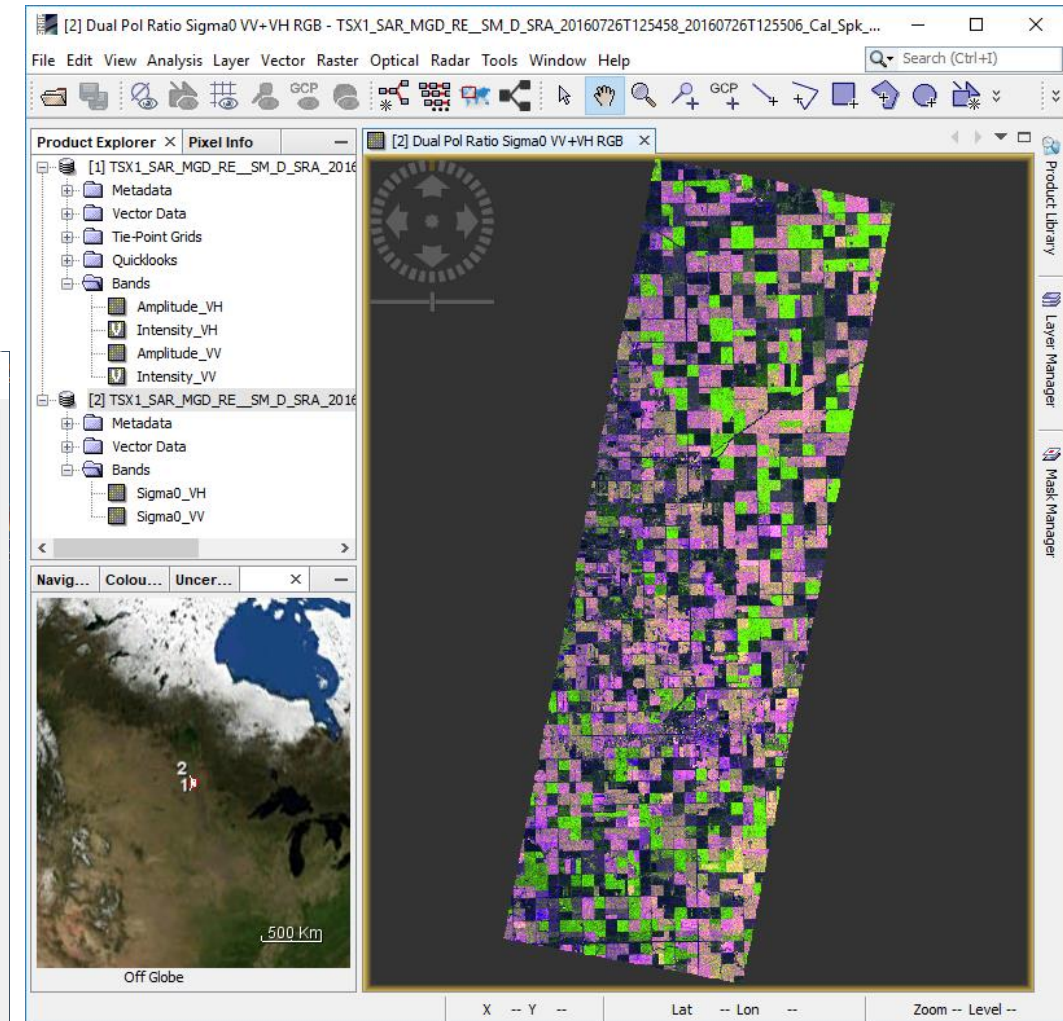
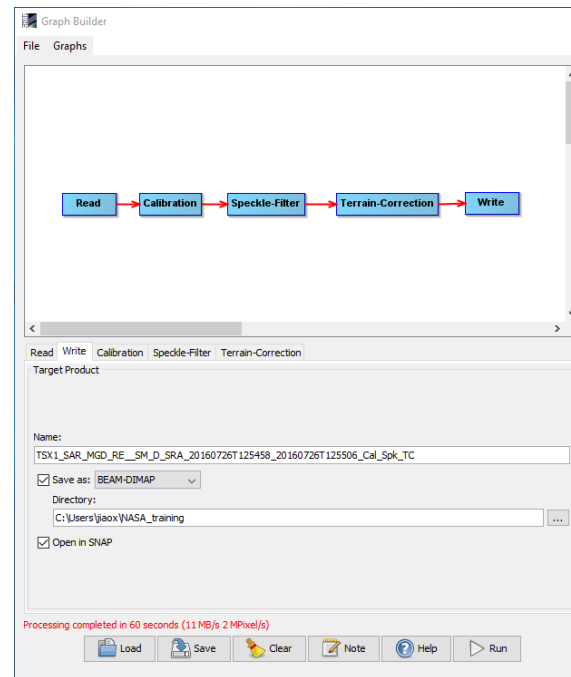
Extract Backscatter



Pre-Processing TerraSAR-X Data with SNAP

Graph Builder

- Import the data
- Calibrate pixel value to radar backscatter
- Gamma map filtering, 7 by 7 window size
- Terrain Correction:
 - bilinear interpolation resampling
 - 5 m pixel spacing
 - UTM zone 14 projection



Sentinel-1

- Coverage
 - Sentinel-1 consists of two satellites: A (2014) and B (2016)
 - Each Sentinel-1 satellite has a 12 day repeat cycle
 - The two satellites offer a 6-day exact repeat cycle at the equator in the interferometric wide swath mode of acquisition

Extra Wide Swath (EW)	Interferometric Wide Swath (IW)	Stripmap (SM)	Wave (WV)
Acquired with TOPSAR using 5 sub-swaths instead of 3, resulting in lower resolution (20m-x-40m). Intended for maritime, ice, and polar zone services requiring wide coverage and short revisit times.	Acquired with TOPSAR. Default mode over land; 250km swath width; 5m-x-20m ground resolution.	Used in rare circumstances to support emergency-management services, 5m-x-5m resolution over an 80km swath width.	Default mode over oceans; WV polarization. Data acquired in 20km-x-20km vignettes, 5m-x-20m resolution, every 100km along the orbit.

Product Type for IW Mode:

Acq. Mode	Product Type	Resolution Class	Resolution ^{1,2} [Rng x Azi] ³ [m]	No. Looks [Rng x Azi]
IW	SLC		2.7 x 22 to 3.5 x 22	1
	GRD	HR	20 x 22	5 x 1
		MR	88 x 87	22 x 5



Satellite Image Credit: [ESA/ATG medialab](#)

Access Sentinel-1 SAR Data from Vertex

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

The screenshot displays the Vertex Alaska Satellite Facility website. At the top, the logo for the Alaska Satellite Facility (ASF) is visible, along with the text "ALASKA SATELLITE FACILITY" and "Vertex is the Alaska Satellite Facility's data portal for remotely sensed imagery of the Earth." Navigation links include "Vertex", "Interactive Tours", "Help", and "ASF Home". On the right, there are links for "Earthdata Login", "Download Queue 1", and "Contact".

The main interface is divided into several sections:

- Geospatial**: Includes "Granule" and "Missions" tabs. A "Geographic Region" section offers two options: "Option 1: Click on map and move cursor" and "Option 2: Enter coordinates:". A text input field contains the coordinates: "-98.28,49.71,-98.73,49.06,-97.44,49.06,-97.52,49.7,-98.28,49" with an example "e.g., -102,37.59,-94,37,-94,39,-102,39,-102,37.59" and a note "Counterclockwise, decimal degrees, (long,lat)".
- Date**: Includes a "Seasonal Search" checkbox and two date input fields: "Start Date (yyyy-mm-dd)" with "2016-06-01" and "End Date (yyyy-mm-dd)" with "2016-08-01".
- Dataset**: Includes a "Select: All | None" option.

The central map shows a satellite image of a coastal area with several overlapping gray polygons representing data granules. A blue square highlights a specific granule. The map includes a "World Map" and "South Polar" view selector, and radio buttons for "Satellite" (selected) and "Map". A "Google" logo is visible in the bottom left of the map area, and "Imagery ©2018 TerraMetrics Terms of Use" is in the bottom right.

Below the map is a "Number of Frames" legend with five color-coded categories: 1 (blue), 2-5 (green), 6-15 (yellow), 16-20 (orange), and 21+ (red).

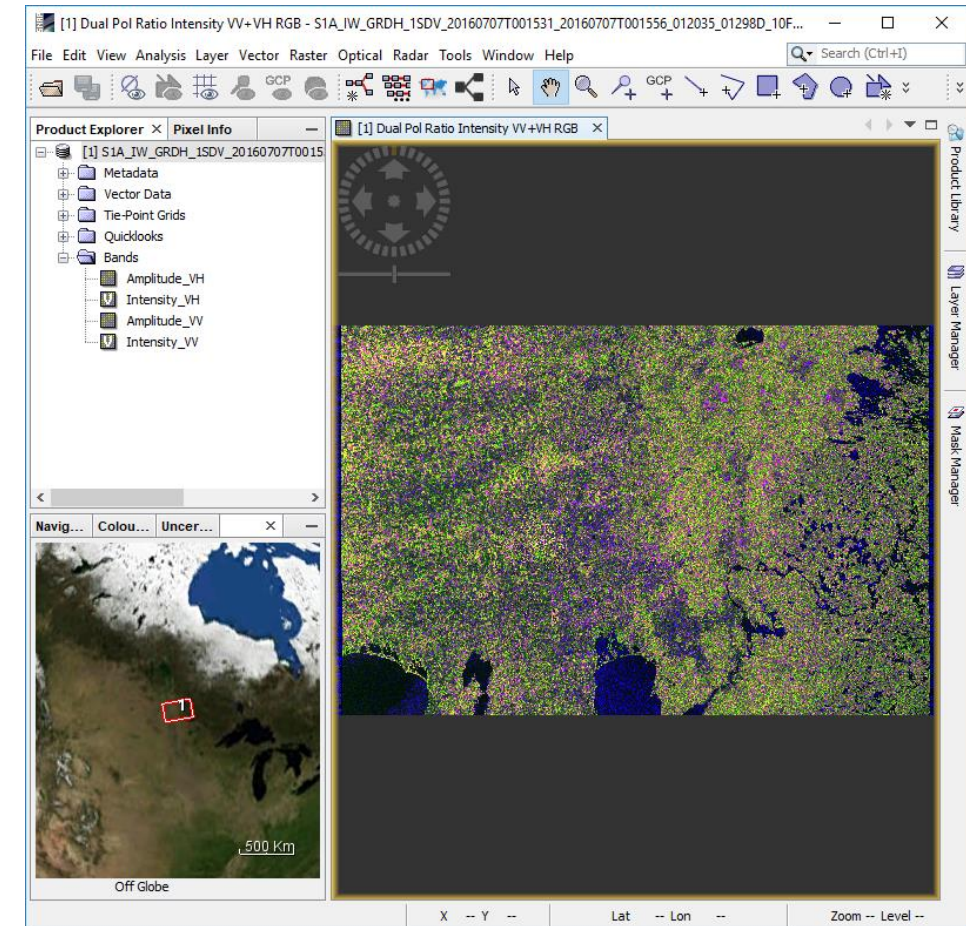
On the right side, there is a "Find" search bar and a list of search results. The first result is "Sentinel-1A EW" dated "2016-08-01", with details: "S1A_EW_RAW_0...", "Path 85, Frame 423, HH+HV", "Flight Direction Descending", "Absolute Orbit 12407", and "Data source ESA". The second result is "Sentinel-1A IW" dated "2016-07-31", with details: "S1A_IW_RAW_0...", "Path 63, Frame 159, VV+VH", "Flight Direction Ascending", "Absolute Orbit 12385", and "Data source ESA". Each result has "Details", "Queue", and "Baseline" buttons. At the bottom of the results list, there are "Show 100 entries", "Previous", "Next", and "Add to Queue by Type" buttons.

At the bottom of the page, there is a copyright notice: "Copyright © 2018 Alaska Satellite Facility. Vertex: ASF's Data Portal V2.58.00-45. Phone: (907) 474-5041. Contact". The "Vertex" logo is centered, and a disclaimer on the right states: "UA is an AA/EEO employer and educational institution and prohibits illegal discrimination against any individual: www.alaska.edu/nondiscrimination".

Sentinel-1 Ground Range Detected Data

Sentinel-1 IW mode ground range detected product:

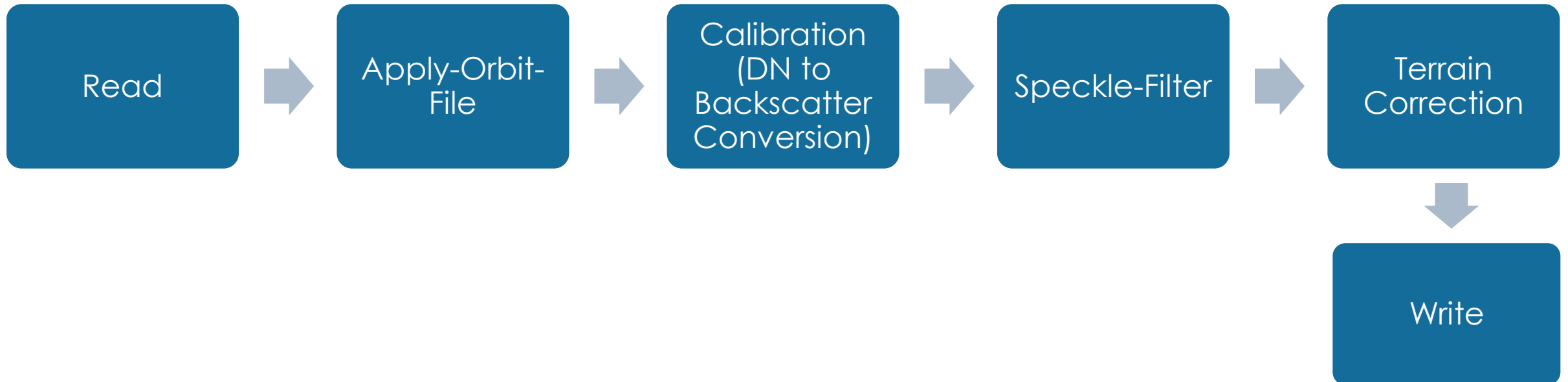
- Nominal Resolution: 20 m (range) * 22 m (azimuth)
- 250 km swatch
- Dual Polarization: HH /HV, or VV/VH
- GRDH:
 - ground range detected
 - high resolution
 - Multi-Looked: 5 (range)*1 (azimuth)
 - Number of looks and project to ground range
- Phase information is lost



Sentinel-1 GRDH dual pol data acquired on July 7, 2016, over Carman, MB, Canada

Pre-Processing Sentinel-1 SAR GRDH Data with SNAP

Extract Backscatter



Apply the Precise Orbit File

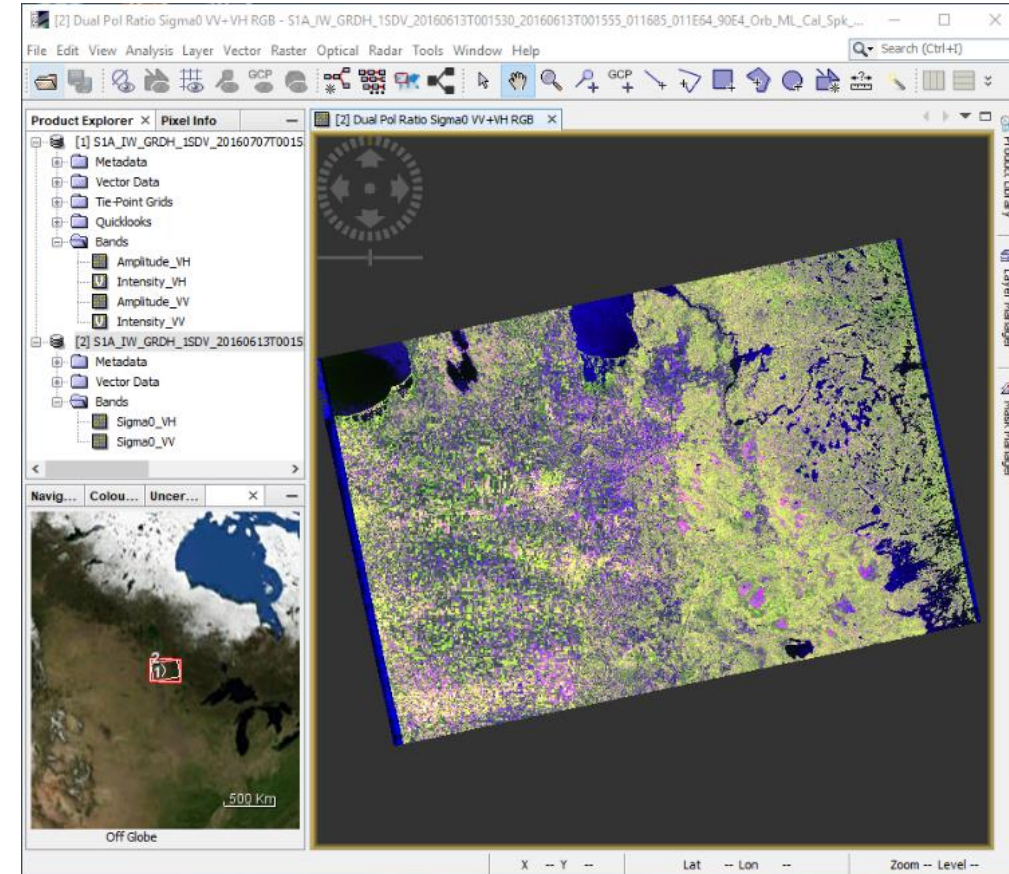
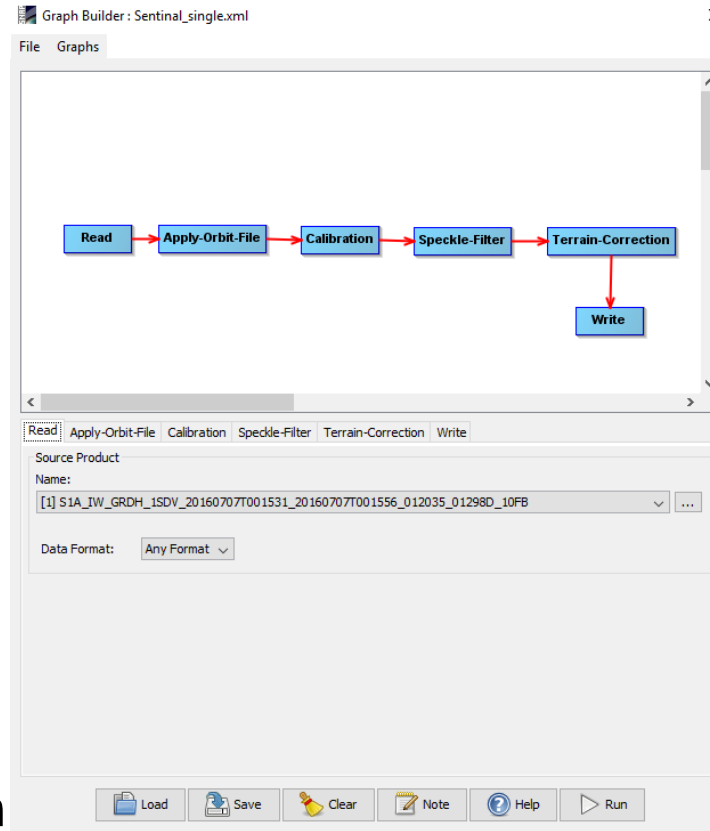
- For Sentinel-1:
 - During the acquisition the satellite position is recorded by a Global Navigation Satellite System (GNSS)
 - To assure fast delivery of Sentinel-1 products orbit information generated by an on-board navigation solution are stored within the Sentinel-1 Level-1 products
 - The orbit 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
 - The orbit information of Sentinel 1 can be downloaded from the ESA website (<https://qc.sentinel1.eo.esa.int/>)

SNAP downloads orbit files and stores these into the folder .../auxdata/Orbits/Sentinel-1/
<https://www.asf.alaska.edu/sentinel/data/>

Pre-Processing Sentinel-1 SAR GRDH Data with SNAP

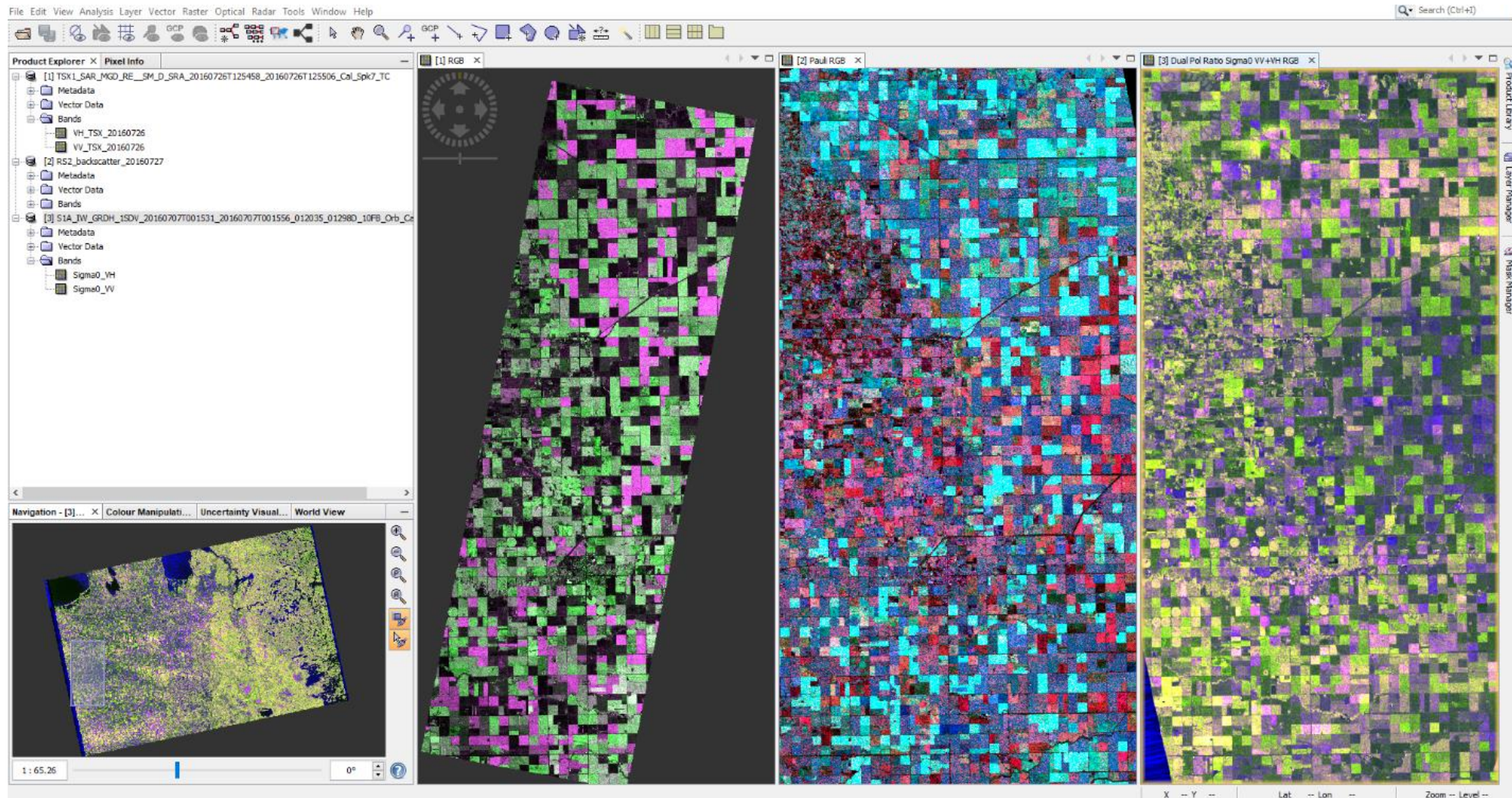
Graph Builder

- Import the data
- Apply orbit file
- Calibrate pixel value to radar backscatter
- Gamma Map filtering, 3 by 3 window size
- Terrain Correction:
 - Bilinear interpolation resampling
 - 30 m pixel spacing
 - UTM Zone 14 Projection



Images Feed Into the Classifier

- RADARSAT-2 Wide Fine Quad-Pol images acquired on July 3rd 2016, July 27th and August 20th 2016
- TerraSAR-X StripMap dual pol MGD images acquired on July 26th and August 17th, 2016
- Sentinel-1 IW mode GRDH images acquired on July 13th, July 7th and July 31th, 2016



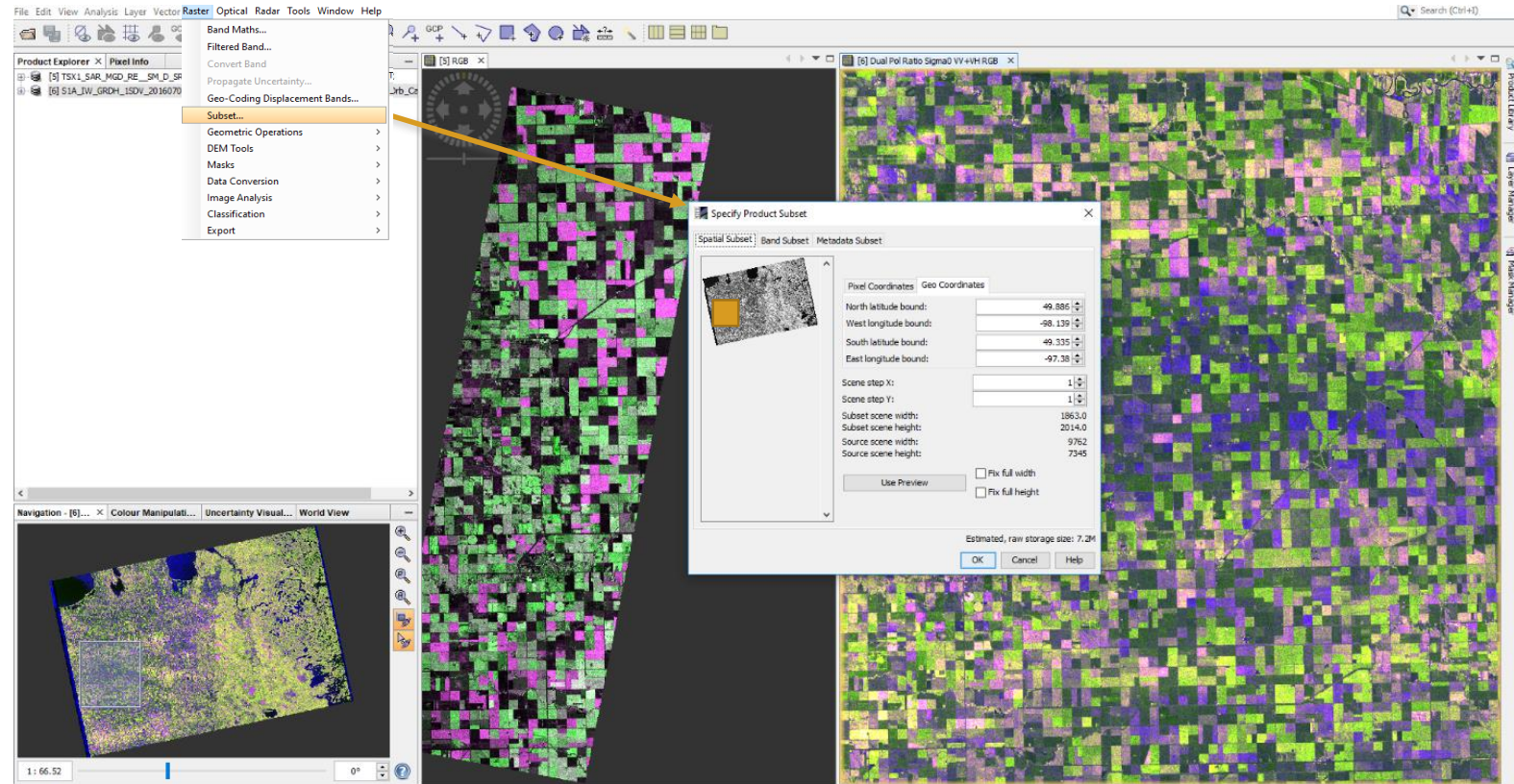
TerraSAR-X StripMap
dual pol MGD images
acquired on Jul 26
and Aug 7, 2016

RADARSAT-2 Wide Fine
Quad-Pol images
acquired on Jul 3, Jul
27, and Aug 20, 2016

Sentinel-1 IW mode
GRDH images
acquired on Jul 13, Jul
7, and Jul 31, 2016

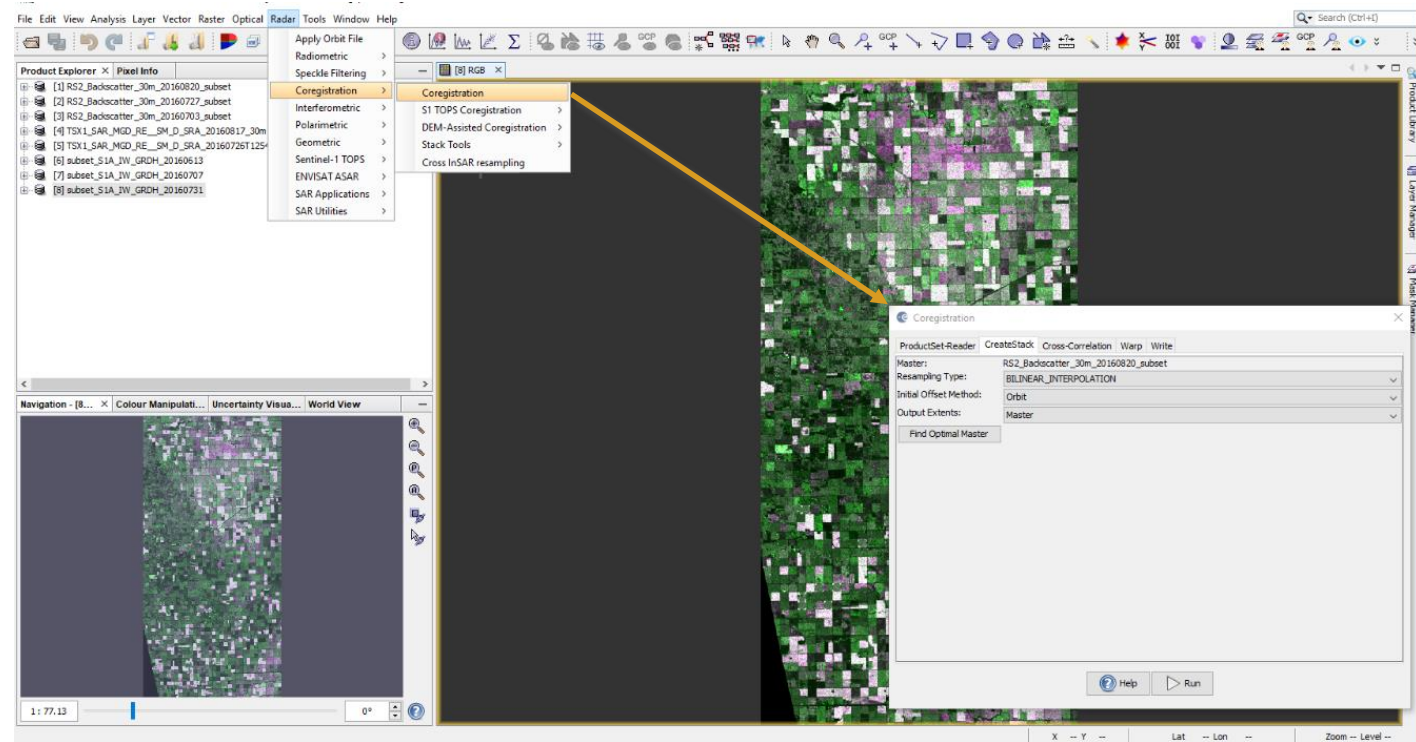
Subset Raster to AOI

- Go to Raster Menu >> Subset:
 - a) Spatial Subset tab → enter the upper left and lower right coordinate under geo coordinates
 - b) Band Subset → select bands you wish to subset
 - c) Metadata Subset: leave as default



Co-Registration of Subset Images

- Spatial alignment of images
- Go to Radar Menu >> Coregistration >> Coregistration:
 - a) ProductSet-Reader: Click Plus sign with line over top adds all open imagery → Click Revolving Arrows refreshes metadata
 - b) Create Stack: Resampling Type → Bilinear_Interpolation → Click Find Optimal Master
 - c) Other tabs: leave as default; ensure Write folder is not over-writing previous files
 - d) Click Run and Close window when completed



Exporting Data Stacks Out of SNAP

- Spatial alignment of images
 - Go to Radar Menu >> File >> export >> select file format .tif
- Can use .tif in R, Python etc.

