Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada

National Aeronautics and Space Administration
Developed in collaboration with Agriculture and Agri-Food Canada.

Agricultural Crop Classification with Synthetic Aperture Radar and Optical Remote Sensing

Part 3: A Crop Inventory Roadmap

Laura Dingle Robertson (AAFC) - October 12, 2021

APPLIED REMOTE SENSING TRAINING PROGRAM
TRAIN - EMPOWER - ADVANCE

Training Outline

October 5, 2021

Synthetic Aperture Radar (SAR) Refresher

October 7, 2021

Optical Remote Sensing Refresher and Introduction to SNAP

October 12, 2021

Operational Crop Classification Roadmap using Optical and SAR Imagery (Part 1)

October 14, 2021

Operational Crop Classification Roadmap using Optical and SAR Imagery (Part 2)

October 19, 2021

Biophysical Variable Retrieval using Optical Imagery to Support Agricultural Monitoring Practices

Training Objectives

By the end of this training attendees will learn:

- Access and selection of Sentinel-1 SAR images
- Sentinel-1 Preprocessing steps
- Field training and adequate field data collection
- Use of SNAP for preprocessing of Sentinel-1 images and subsetting and stacking data

Homework and Certificate

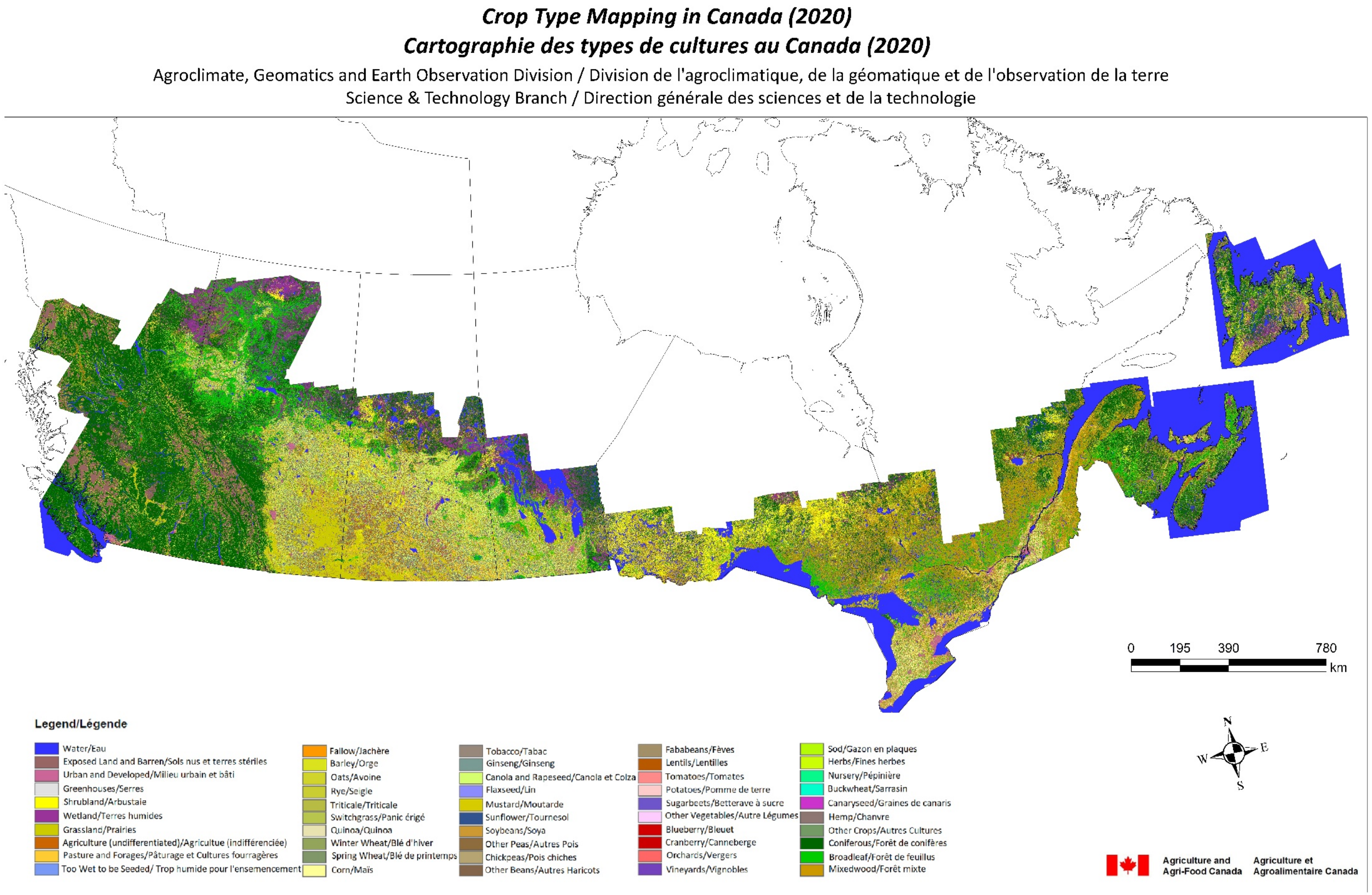
- Homework Assignment:
  - Answers must be submitted via Google Form.
  - Due Date: November 2, 2021
- A certificate of completion will be awarded to those who:
  - Attend all live webinars
  - Complete the homework assignment by the deadline (access from website)
  - You will receive a certificate approximately two months after the completion of the course from: marines.martins@ssaihq.com

A Crop Inventory Roadmap

Monitoring Canadian Agriculture

- Canada's agricultural landscape is large and complex: 193,492 farms and 64 million hectares
- In 2009, AAFC began generating annual crop type digital maps for the Prairie Provinces using satellite imagery and expanded the Annual Crop Inventory (ACI) to the entire agricultural extent of Canada in 2011.
- ACI is an annual crop inventory.
  - Overall target accuracy of at least 85%
  - Final spatial resolution of 30 m
  - National in scale
  - Operational program, with a mostly automated workflow
- Crop inventories published on Government of Canada Open Data Portal (open.canada.ca/en/open-data) and include an AAFC Geospatial viewer

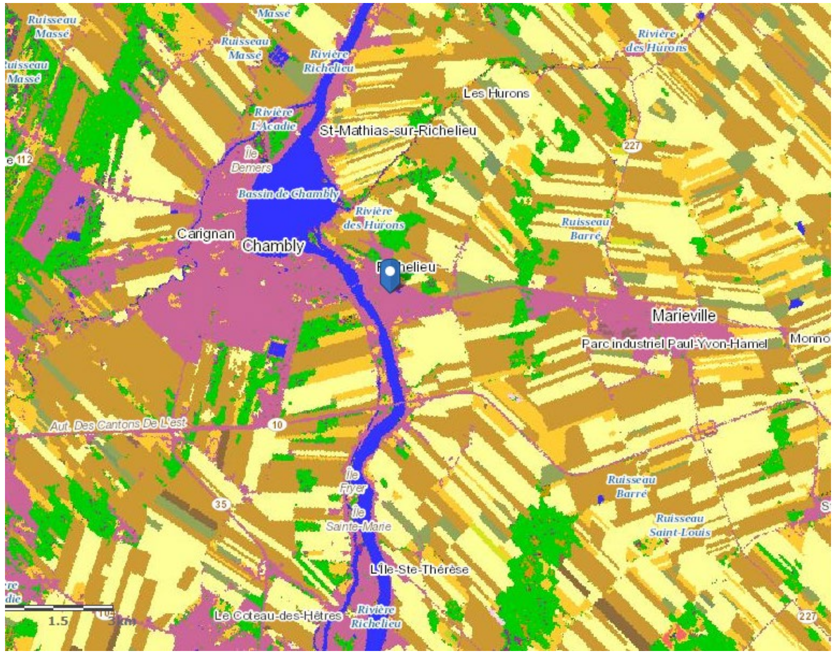
Crop Type Mapping in Canada (2020)



Courtesy: Agriculture and Agri-Food Canada

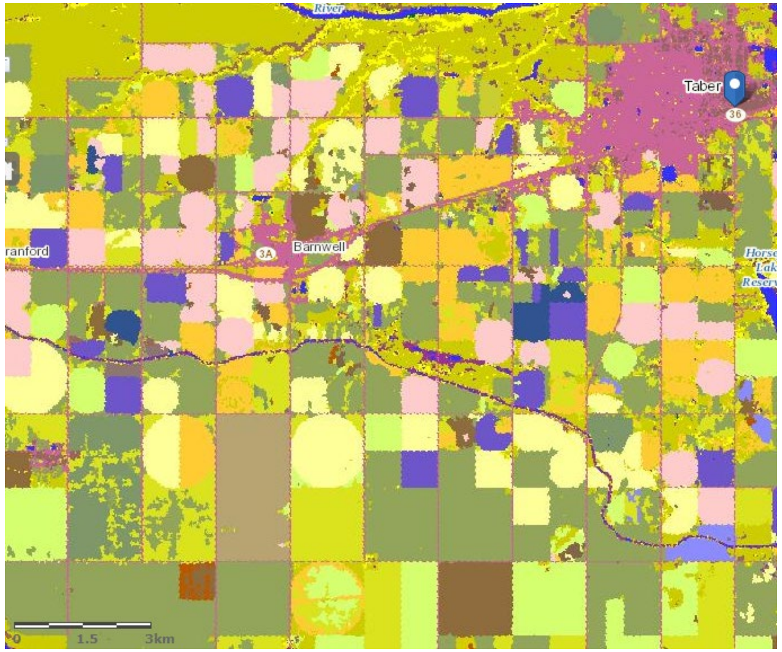
AAFC Annual Crop Inventory (ACI)

Richelieu River, Québec



Central Prince Edward Island

Near Taber, Alberta

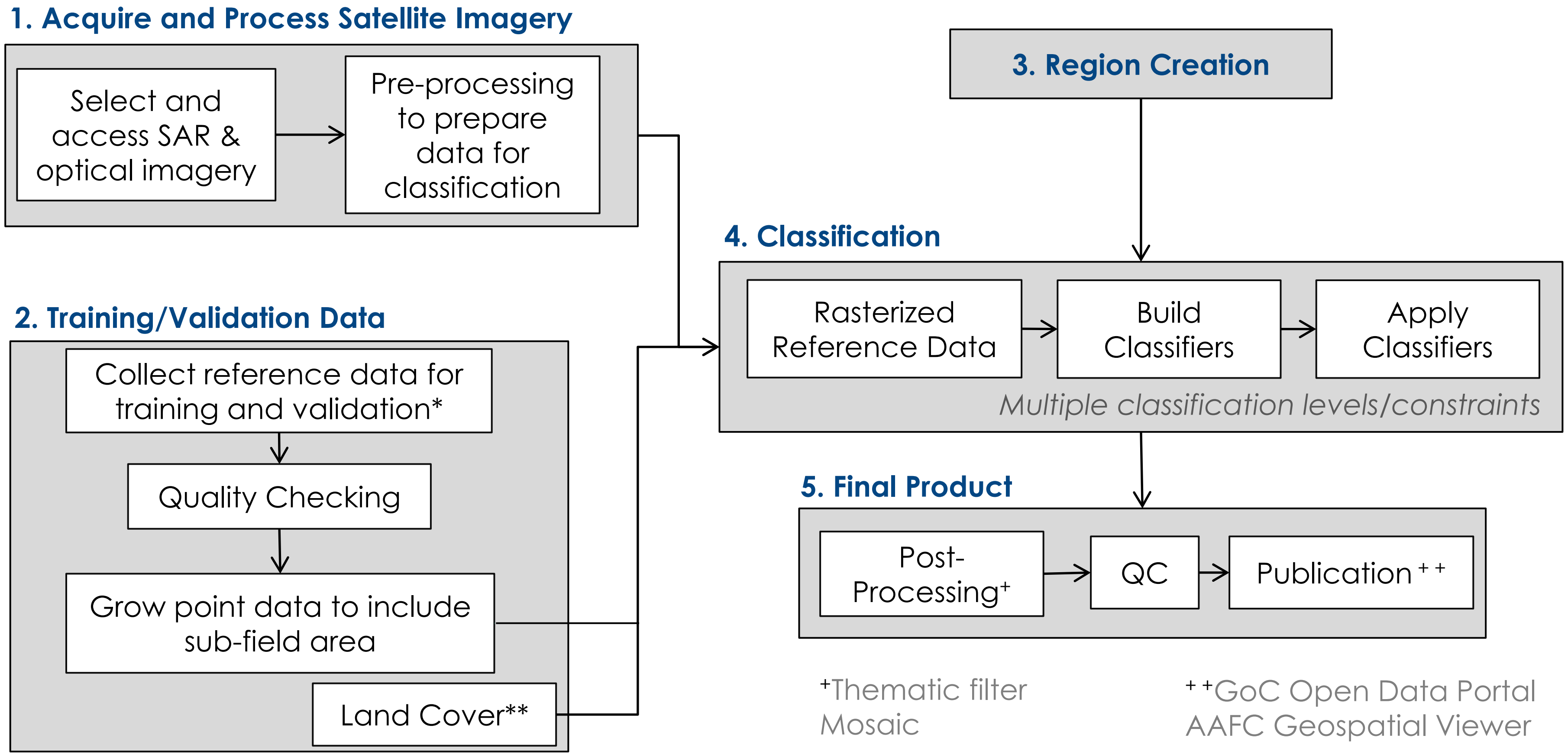


Courtesy: Agriculture and Agri-Food Canada

Roadmap for Producing an Annual Crop Inventory

- The AAFC method relies on the integration of data from Canadian RADARSAT SAR satellites and optical satellites (Landsat-8 and Sentinel-2); Sentinel-1 is currently being integrated.
- This ARSET training will use Sentinel-1 and Sentinel-2 data given global access to these data.
- Participants will use open-source SNAP software.
- Adaptations to AAFC methods will be required depending on local cropping systems.
  - Growing Season
  - Crop Mixes
  - Crop Management Practices
  - Field/Parcel Sizes
  - Field Data Collection Strategies

Crop Inventory Operational Methodology



* Potential Sources:

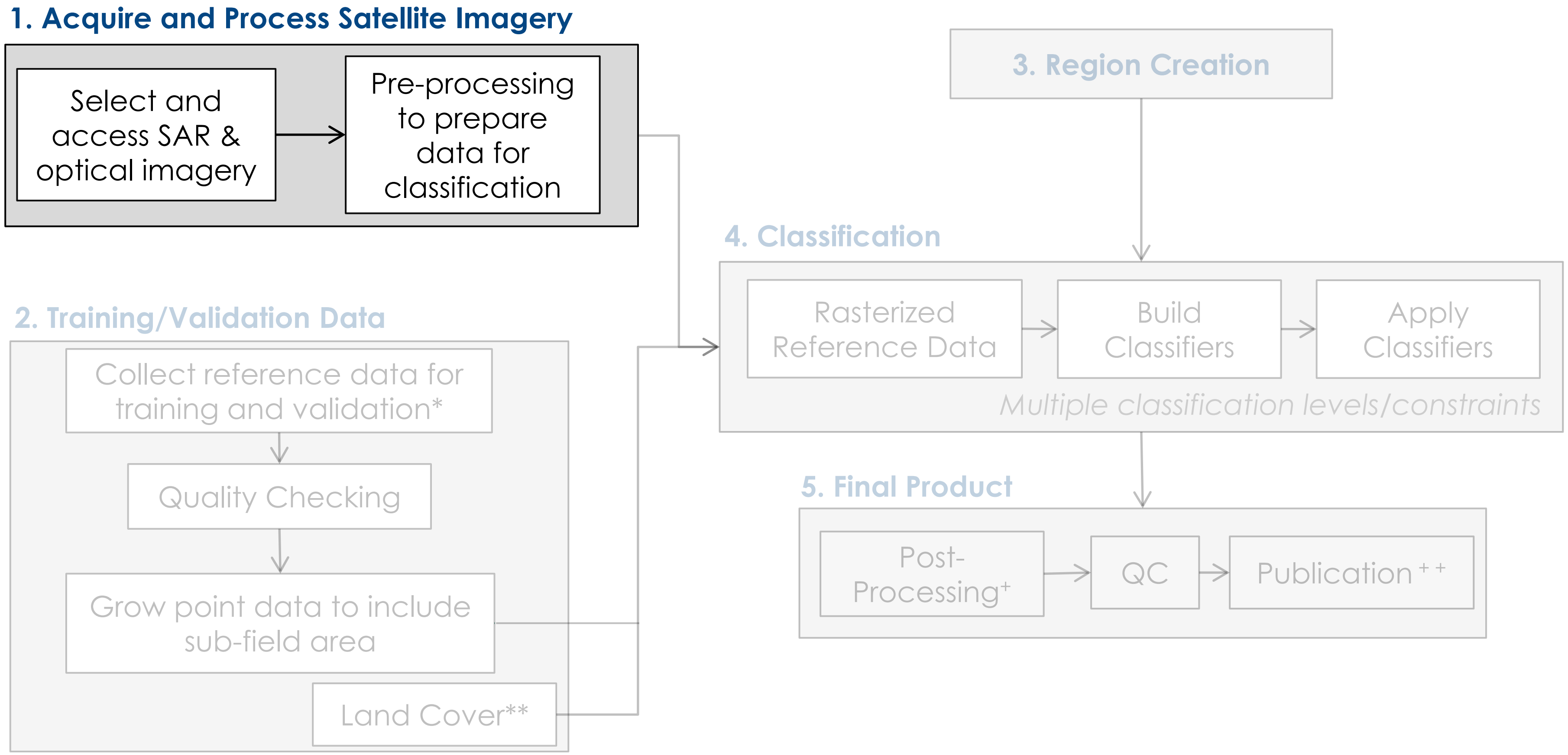
- **Field Surveys**
- Crop Insurance
- Partnerships

** AAFC does not generate land cover classes during this classification flow, but integrates land cover maps updated every 5 years.

Courtesy: Agriculture and Agri-Food Canada

1. Acquire and Pre-process Sentinel-1 & Sentinel-2 Data

Crop Inventory Operational Methodology



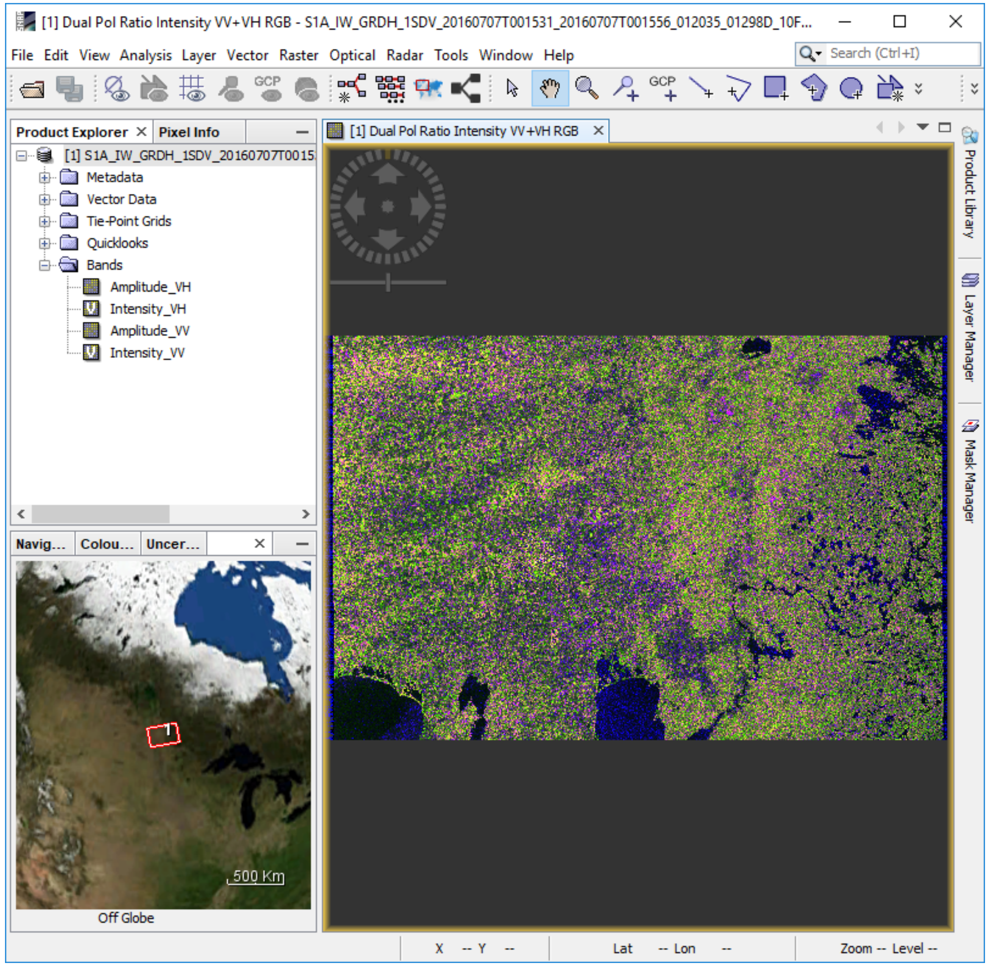
SAR Image Selection

- AAFC uses ~1 SAR image per month, but research has demonstrated that dense stacks of SAR imagery through the season will improve classification accuracies.
- C-Band data are available from Sentinel-1 satellites: A (2014) and B (2016).
- Each Sentinel-1 satellite has a 12-day exact repeat. The two-satellites provide a 6 day repeat at the equator in the Interferometric Wide (IW) swath mode.
- **SLC** -**Single Look Complex**: Slant range Single Look Complex product
- **GRD**-**Ground Range Detected**: Ground range multi-looked that can be in one of three resolutions: Full, High, and Medium Resolution
- The best results are using VV+VH polarizations, which can be derived from SLC or GRD products. To simplify processing, we will use IW GRD data.
- Research has demonstrated that polarimetric parameters and multiple frequencies improve accuracies.

Sentinel-1 Ground Range Detected (GRD) Data

IW mode GRD product:

- Nominal Resolution: 20 m (Range) * 22 m (Azimuth)
- 250 km Swath
- Dual Polarization (HH/HV, or VV/VH)
- GRDH: Ground range detected, high resolution, multi-looked: 5 (Range)*1 (Azimuth) and projected to ground range
- Phase information is lost



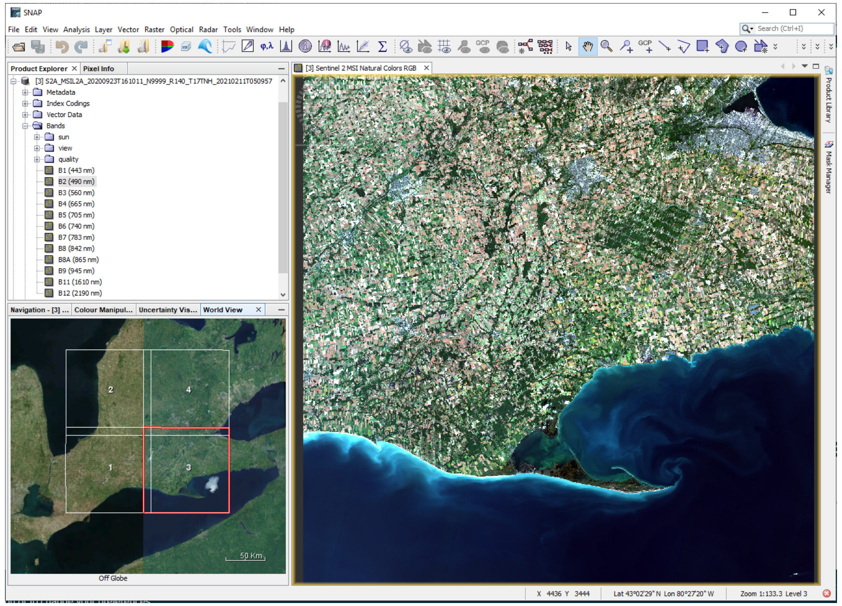
Sentinel-1 GRDH dual pol data acquired on July 7, 2016 over Carman, MB, Canada

Optical Image Selection

- AAFC uses all optical images with minimal cloud cover.
- The number of images with minimal cloud cover varies by region of Canada and by year.
- Integration of radar with optical ensures full spatial and temporal coverage during the growing season.
- Data are available from Landsat 8 & Sentinel 2A (2015) and B (2017) satellites.
- Sentinel-2 has a revisit time of 10 days at the equator with one satellite, and 5 days with 2 satellites; 2- to 3-day repeat (Sentinel 2A/B) at mid-latitudes.
- Landsat 8 has a 16-day exact repeat coverage.
- Some areas will have higher revisits where orbits overlap, providing additional acquisitions.

Sentinel-2 Optical Data

- Available as Level-1C and Level-2A
  - If Level 2A (Bottom of Atmosphere reflectance) is not available, Level 1C can be processed to Level 2A using Sen2Cor (SNAP).



The MGRS is derived from the UTM grid system and the UPS (Universal Polar Stereographic) grid system, but uses a different labelling convention. The MGRS is used for the entire earth.

- Granules, also called tiles, are 100 x 100 km^2 ortho-images in UTM/WGS84 projection.

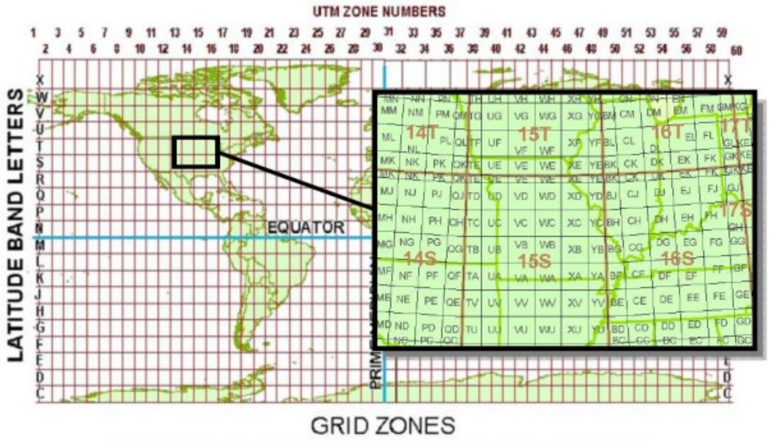


Figure 6: Example of tiling (100x100km²) within the UTM15 zone

Hence, the ortho-rectified products (Level-1C) are tiled according to this grid (approximately 100kmx100km). The UTM zone is selected according to each Tile of the product.

https://sentinel.esa.int/documents/247904/685211/Sentinel-2-Products-Specification-Document

Sentinel 2 Level 2A Data

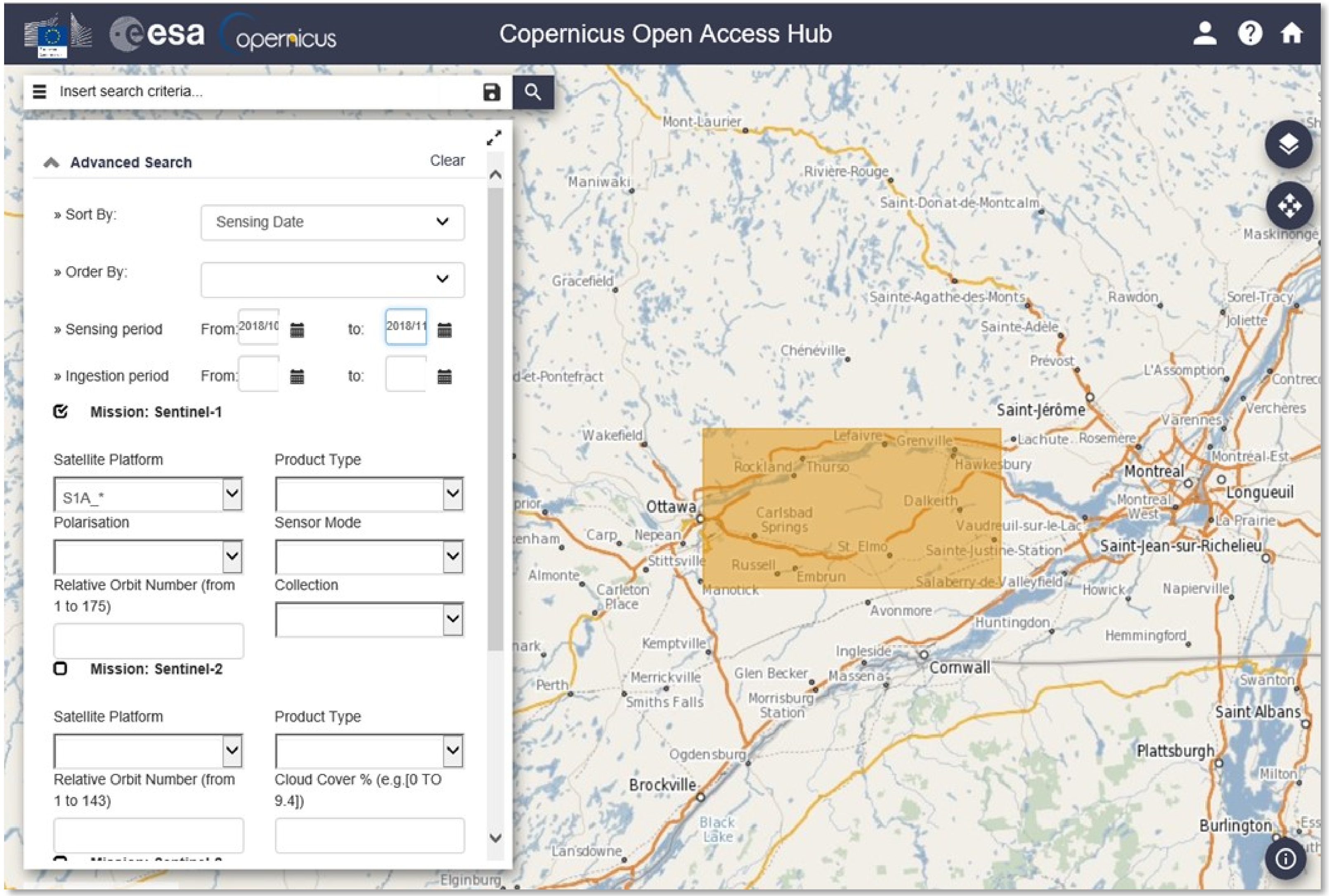
- Download both at Copernicus Hub & USGS EarthExplorer
- The Sen2Cor standalone application is a processor for generating the Level 2A products (bottom of atmosphere reflectance) and is provided by the European Space Agency (ESA). The processing algorithm used can be found at:
  https://step.esa.int/main/third-party-plugins-2/sen2cor/
  https://sentinel.esa.int/web/sentinel/technical-guides/sentinel-2-msi/level-2a/algorithm
- This tool can be used as a function in SNAP or separately using the command line.

Sentinel-2 bands	Sentinel-2A		Sentinel-2B		
	Central wavelength (nm)	Bandwidth (nm)	Central wavelength (nm)	Bandwidth (nm)	Spatial resolution (m)
Band 1 – Coastal aerosol	442.7	21	442.2	21	60
Band 2 – Blue	492.4	66	492.1	66	10
Band 3 – Green	559.8	36	559.0	36	10
Band 4 – Red	664.6	31	664.9	31	10
Band 5 – Vegetation red edge	704.1	15	703.8	16	20
Band 6 – Vegetation red edge	740.5	15	739.1	15	20
Band 7 – Vegetation red edge	782.8	20	779.7	20	20
Band 8 – NIR	832.8	106	832.9	106	10
Band 8A – Narrow NIR	864.7	21	864.0	22	20
Band 9 – Water vapour	945.1	20	943.2	21	60
Band 10 – SWIR – Cirrus	1373.5	31	1376.9	30	60
Band 11 – SWIR	1613.7	91	1610.4	94	20
Band 12 – SWIR	2202.4	175	2185.7	185	20

Bands included in the ACI

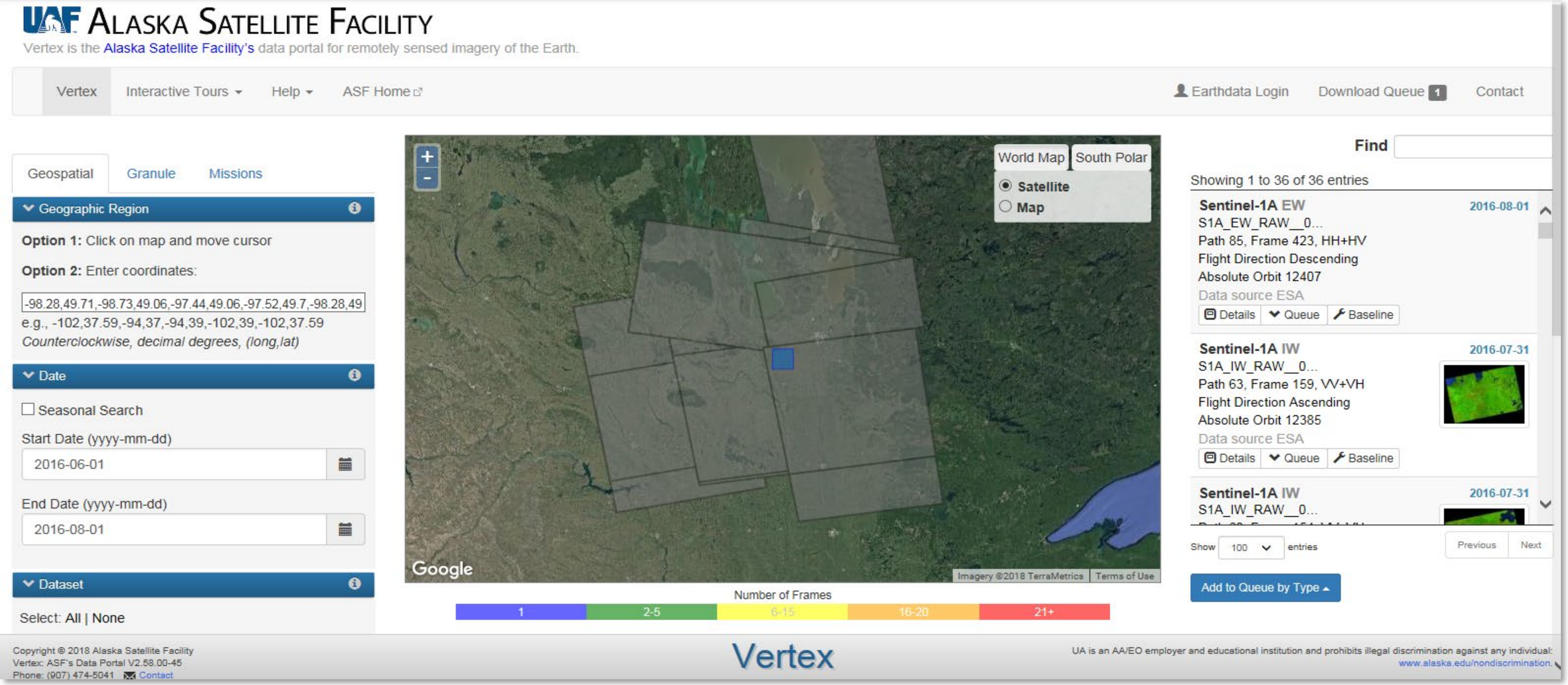
Access via Copernicus

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

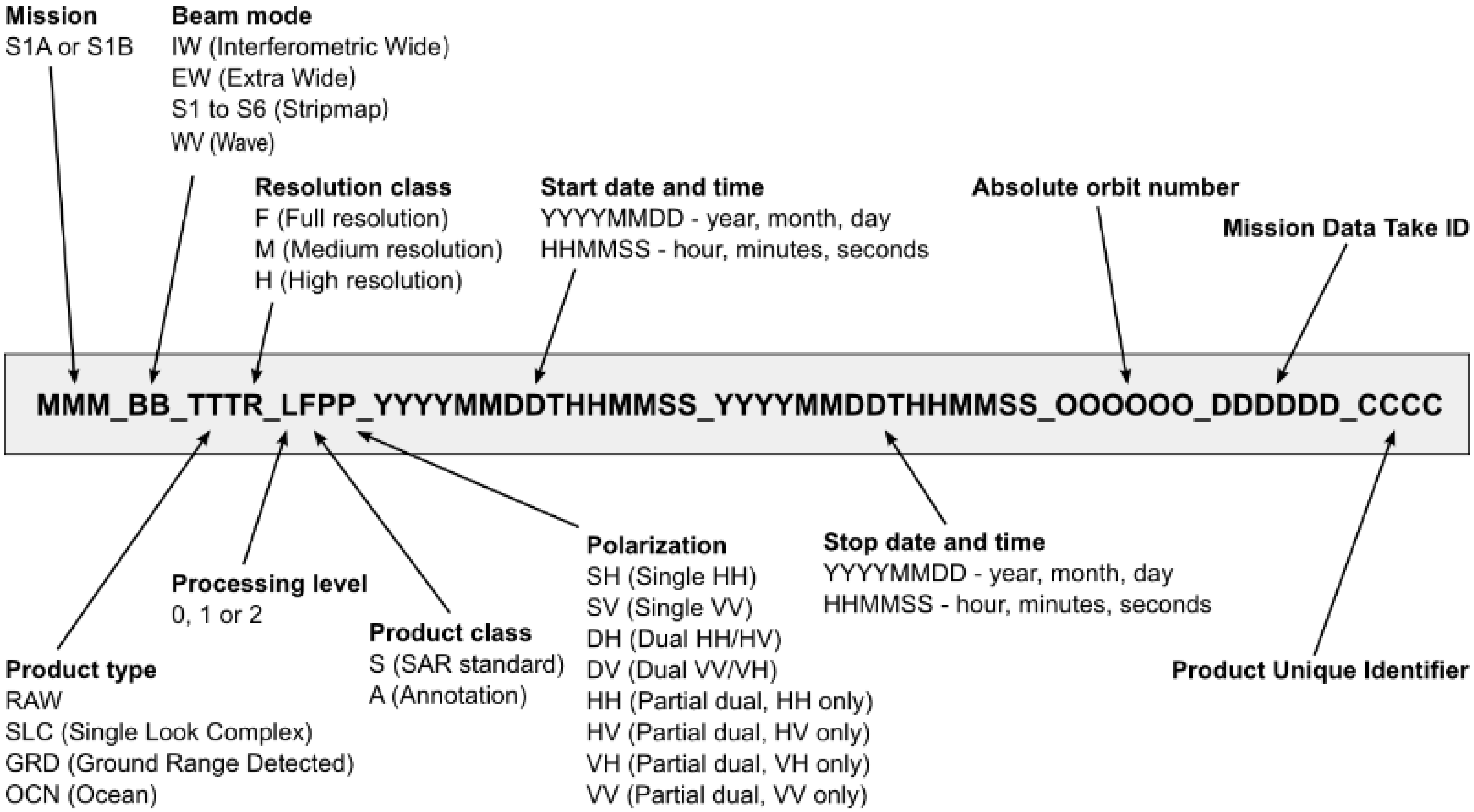


Access via ASF

https://search.asf.alaska.edu/#/



Sentinel-1 Naming Convention



S1A_IW_GRDH_1SDV_20160731T001533_20160731T001558_012385_0134FE_1CFC.zip

Sentinel-2 Naming Convention

Mission
S2A or S2B

Sensing Time
YYYYMMDDHHMMSS

Relative Orbit Number

Product Discriminator
Used to distinguish between different end user products from the same data take. Depending on the instance, the time in this field can be earlier or slightly later than the data take sensing time

S2B_MSIL2A_20180803T161829_N9999_R040_T17TLG_20200514T023930.SAFE

Product Level
MSIL1C or MSIL2A

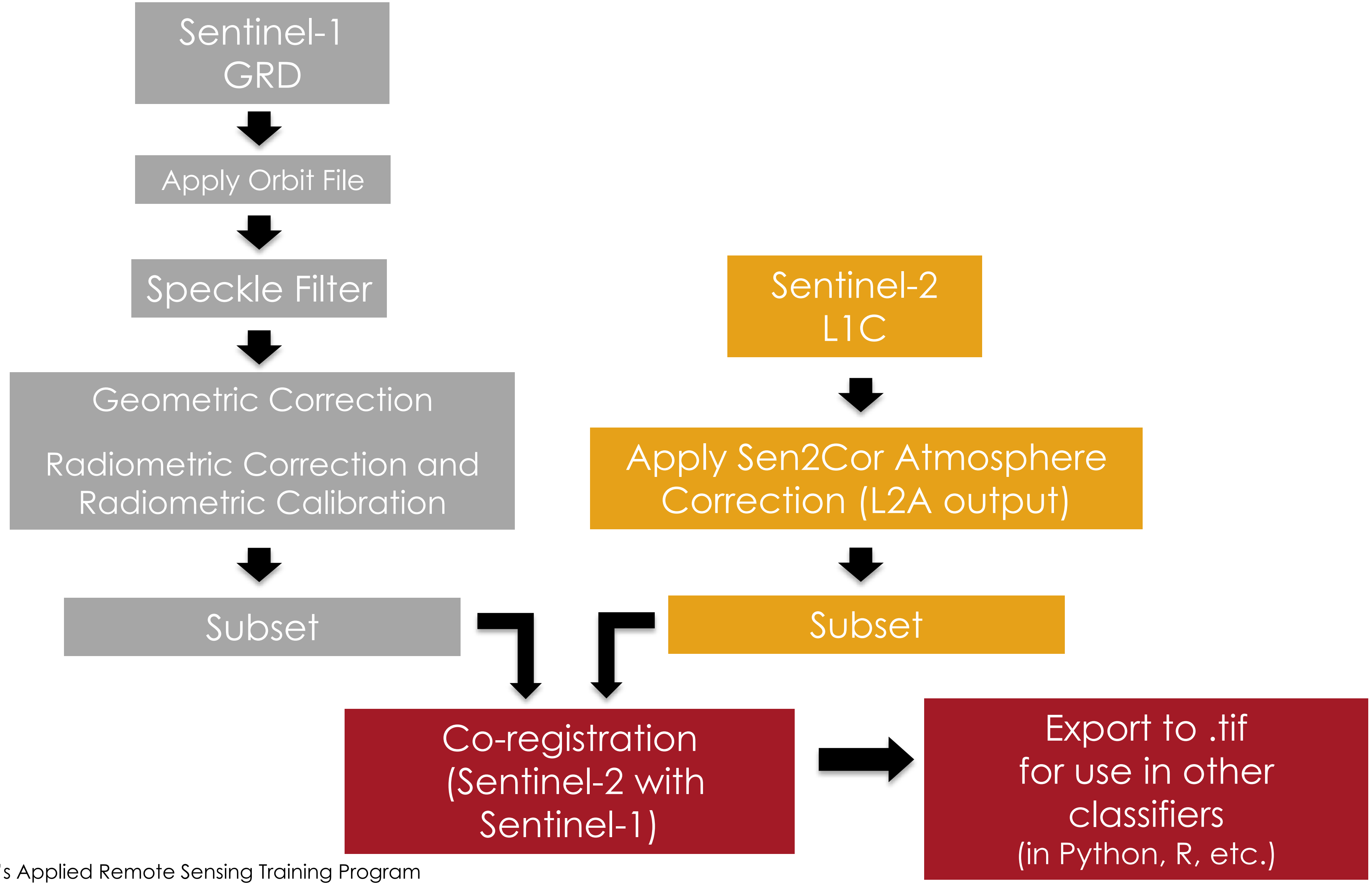
PDGS Processing Baseline Number

GRID Tile Number Field

Product Format

https://sentinels.copernicus.eu/web/sentinel/user-guides/sentinel-2-msi/naming-convention

Sentinel Pre-Processing Road Map



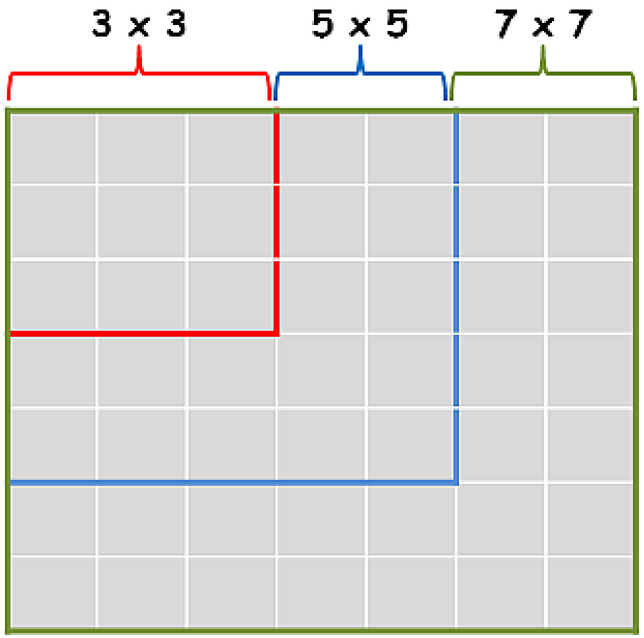
Sentinel-1: Apply the Precise Orbit File

- 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.
- The orbit information of Sentinel-1 can be downloaded from the ESA website.

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

Selecting Speckle Filter Size

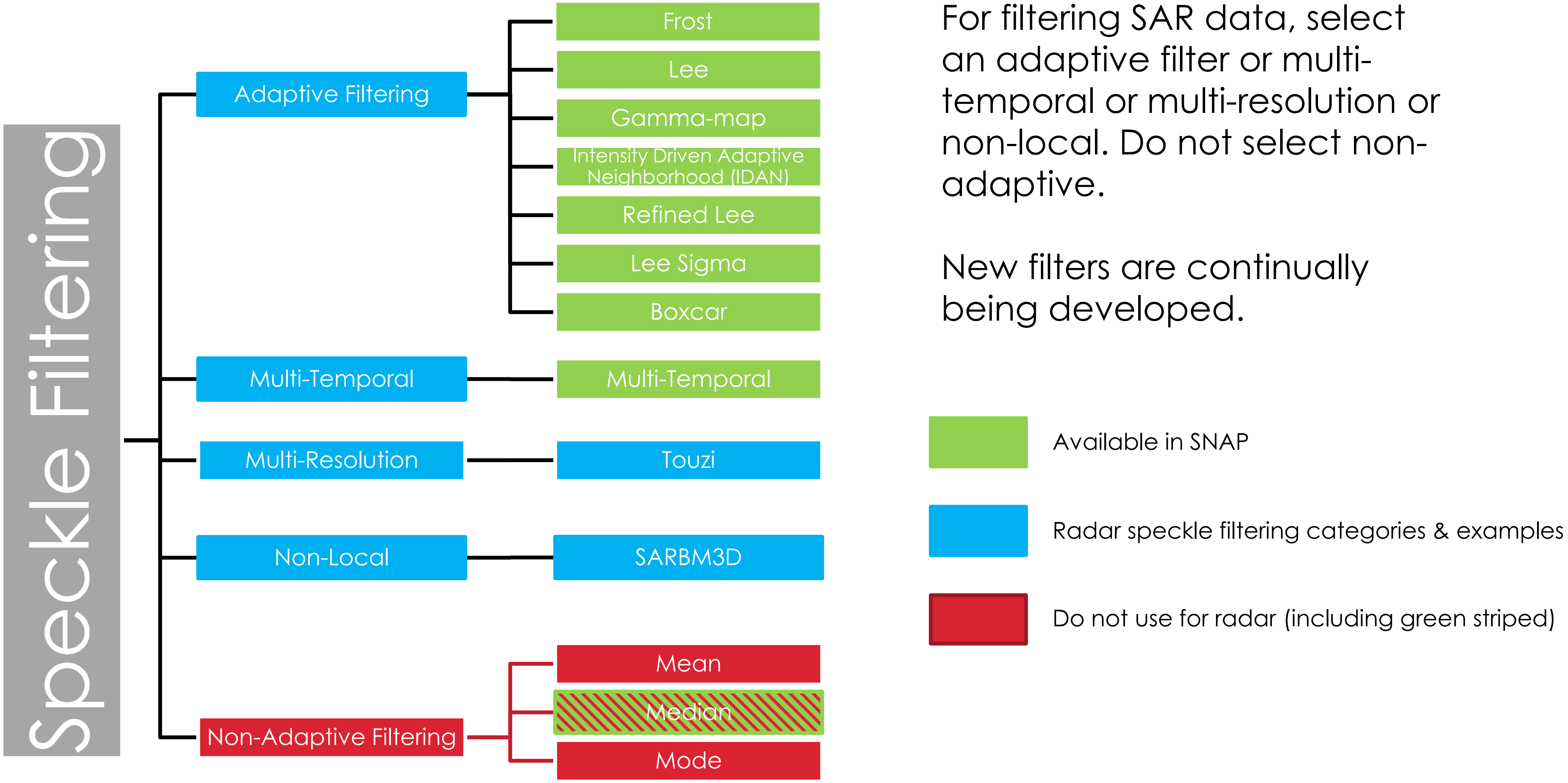
- There is **no** simple answer.
- Choice depends on the targets (point target, distributed target) and the target size (for example field sizes)



What is the target?

Let the target dictate the filter size.

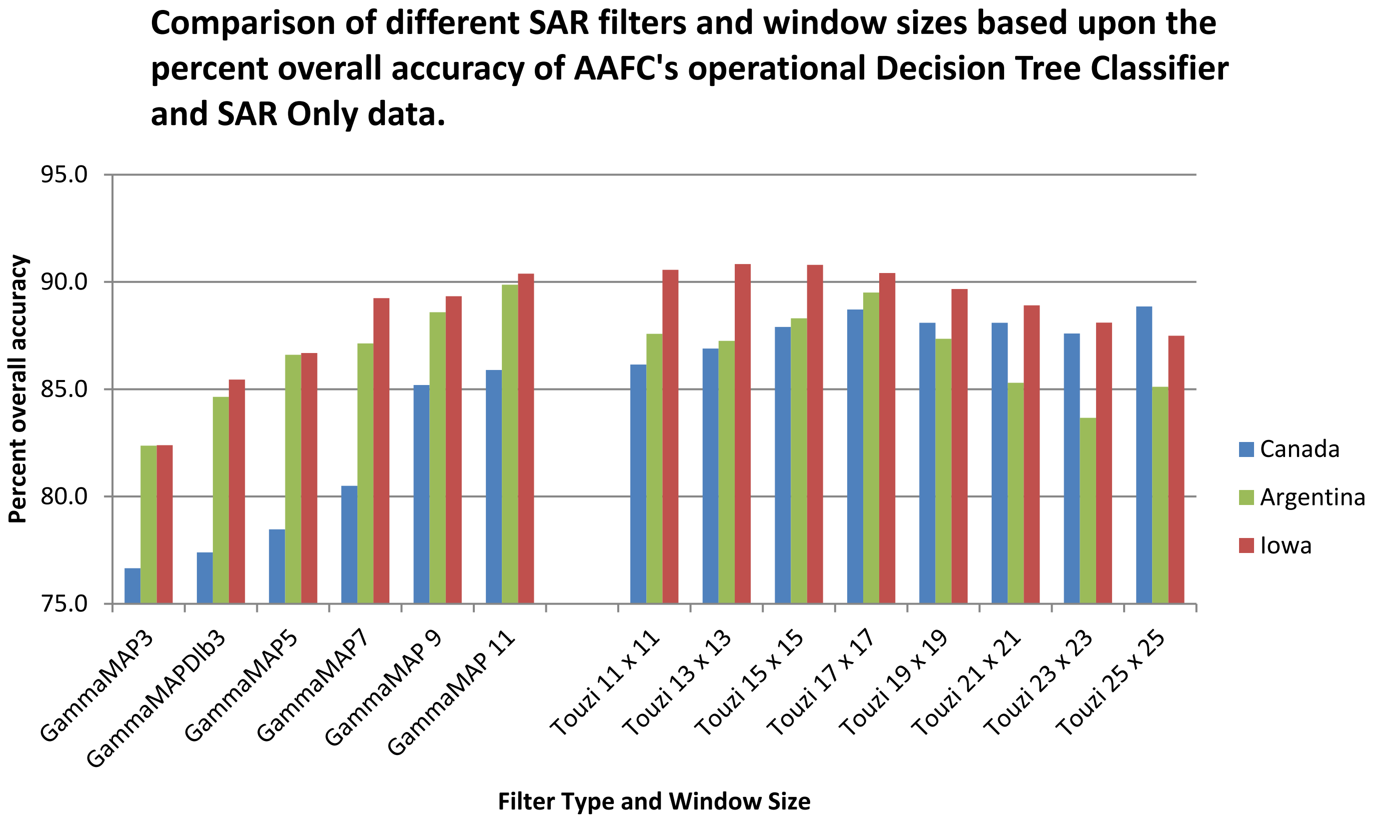
Selecting Speckle Filter Size



For filtering SAR data, select an adaptive filter or multi-temporal or multi-resolution or non-local. Do not select non-adaptive.

New filters are continually being developed.

Speckle Filter Testing



Overall classification accuracies and response can change with changing speckle filter size and type due to different field sizes, shapes, & configurations.

It's important to run tests on which filter size, shape, & type works best for particular regions.

Laura Dingle Robertson, Andrew Davidson, Heather McNairn, Mehdi Hosseini, Scott Mitchell, Diego De Abelleyra, Santiago Verón & Michael H. Cosh (2020) Synthetic Aperture Radar (SAR) image processing for operational space-based agriculture mapping, International Journal of Remote Sensing, 41:18, 7112-7144, DOI: 10.1080/01431161.2020.1754494

Sentinel-1: Gamma MAP Filter

- Gamma MAP used by AAFC
- Based on the assumption that the (unspeckled) intensity of the underlying scene is Gamma distributed
- Filter minimizes loss of texture information better than Frost or Lee filters within gamma distributed scenes

HV Polarization Multi-Looked Unfiltered Image

Gamma Map Filter (7 by 7 window size)

Radiometric Conversion & Calibration

- S1 Level-1 products are not radiometrically corrected or calibrated, by default[1].
- Radar reflectivity is stored as Digital Numbers (DNs) in S1 products, and these must be converted to physical units (radar backscatter).
- To apply radiometric correction and calibration, a Calibration Annotation Data Set (CADS) with 4 Look Up Tables (LUTs) is provided within the S1 products (XML files)[2].
- The S1 Instrument Processing Facility automatically applies corrections for the elevation antenna pattern and range spreading loss.
- These LUTs then apply a product scaling factor (Adn) and calibration coefficient (K), and a conversion for local incidence angle (a).

[1]buildmedia.readthedocs.org/media/pdf/multiply-sar-pre-processing/get_to_version_0.4/multiply-sar-pre-processing.pdf

[2]sentinel.esa.int/documents/247904/685163/S1-Radiometric-Calibration-V1.0.pdf

Applying Sentinel-1 LUT

The radar cross-section (Aσ, Aβ or Aγ) LUT can be simplified and contains the area normalization factor and calibration constant.

$$A_\sigma = \sqrt{\frac{A_{dn}^2 \cdot K}{\sin(\alpha)}}$$

$$A_\beta = \sqrt{A_{dn}^2 \cdot K}$$

$$A_\gamma = \sqrt{\frac{A_{dn}^2 \cdot K}{\tan(\alpha)}}$$

Data are calibrated using these formulas.

$$\sigma^o = \frac{DN^2}{A_\sigma^2}$$

$$\beta^o = \frac{DN^2}{A_\beta^2}$$

$$\gamma^o = \frac{DN^2}{A_\gamma^2}$$

Radiometric Normalization

- If a more precise σ^0 is required, knowledge of local slope is needed through a digital elevation model (DEM) (Raney 1998). This process is known as a radiometric normalization, and a SAR image can be normalized to a local incidence angle, a projected local incidence angle, or incidence angle derived from an ellipsoid.
- To reduce the effect of changes in backscatter across swath due to incidence angle, a cosine correction can be applied.
- However, the weighting factor (*n*) in this correction is target dependent, with the drop in backscatter across the range being dependent on roughness and vegetation structure[1].

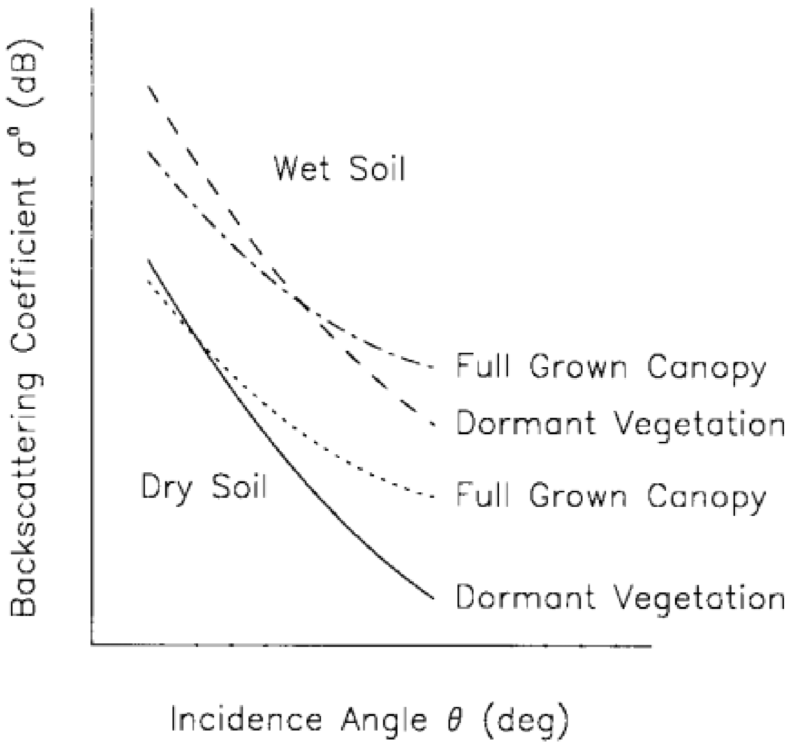


Image Source: W. Wagner, G. Lemoine, M. Borgeaud, and H. Rott. A study of vegetation cover effects on ERS scatterometer data. *IEEE Transactions on Geoscience and Remote Sensing*, 37(2):938–948, Mar 1999. doi:10.1109/36.752212.

[1]buildmedia.readthedocs.org/media/pdf/multiply-sar-pre-processing/get_to_version_0.4/multiply-sar-pre-processing.pdf

Terrain Correction

Terrain correction (ortho-rectification) refers to the correction of the image to a known coordinate system and removes effects of angle and terrain. This type of correction requires a DEM.

Terrain Correction

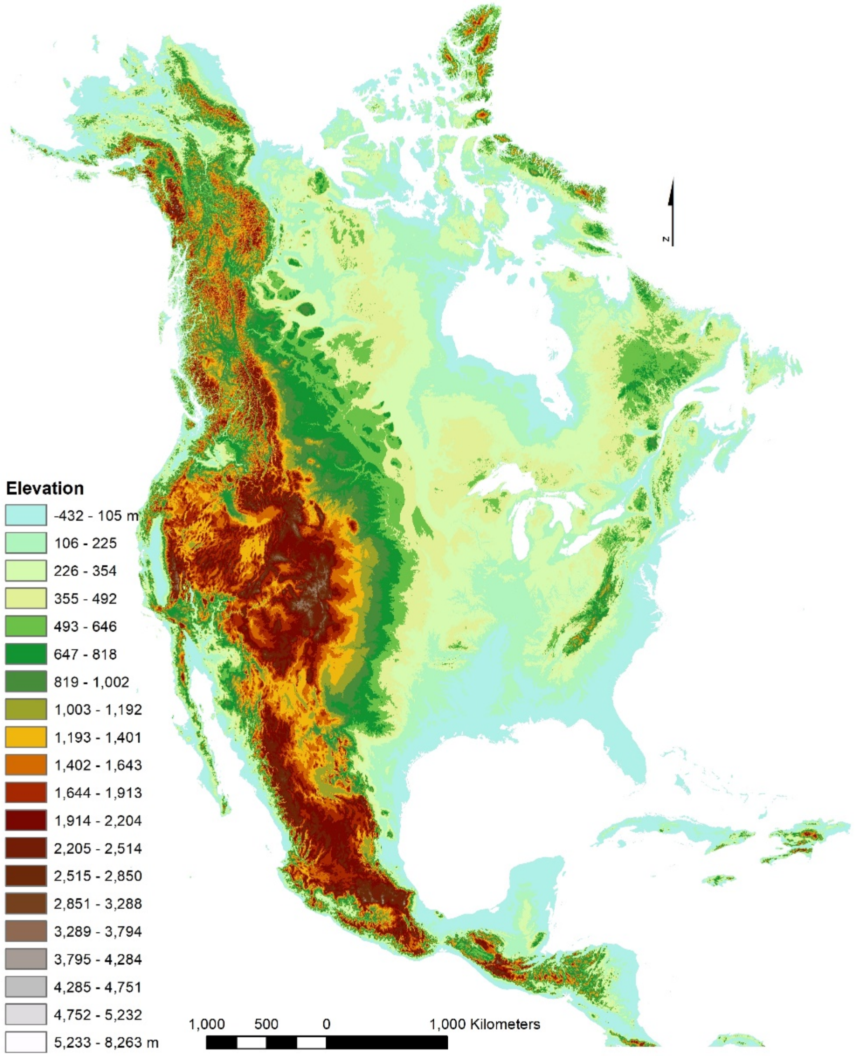
- Range-Doppler
- Rational Polynomial Coefficients (RPC)
- SAR Simulation Model
- Elevation Derivation Model (EDM)

Available in SNAP (Range-Doppler, SAR Simulation Model)

Other types of terrain corrections (Rational Polynomial Coefficients (RPC), Elevation Derivation Model (EDM))

Sentinel-1: Terrain Correction

- The Sentinel-1 GRDH image does not have geographic coordinates. Images must be converted into a map coordinate system.
- 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.



GTOPO30 - DEM

Global digital elevation model (DEM) with a horizontal grid spacing of 30 arc seconds (approximately 1 kilometer) derived from several raster and vector sources of topographic information.

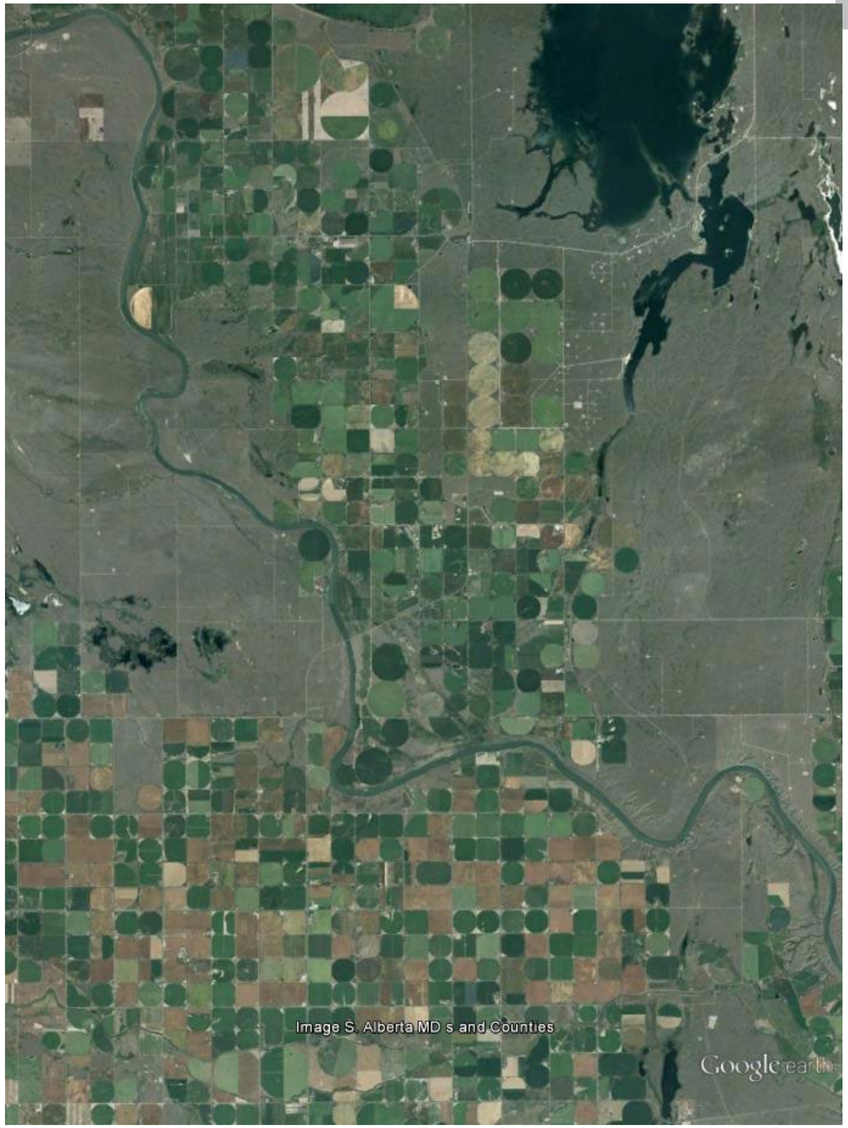
National Aeronautics and Space Administration (NASA), the United Nations Environment Programme/Global Resource Information Database (UNEP/GRID), the U.S. Agency for International Development (USAID), the Instituto Nacional de Estadistica Geografica e Informatica (INEGI) of Mexico, the Geographical Survey Institute (GSI) of Japan, Manaaki Whenua Landcare Research of New Zealand, and the Scientific Committee on Antarctic Research (SCAR).

Sentinel-2: Optical Data Pre-Processing

AAFC Operational Pre-Processing Methods:

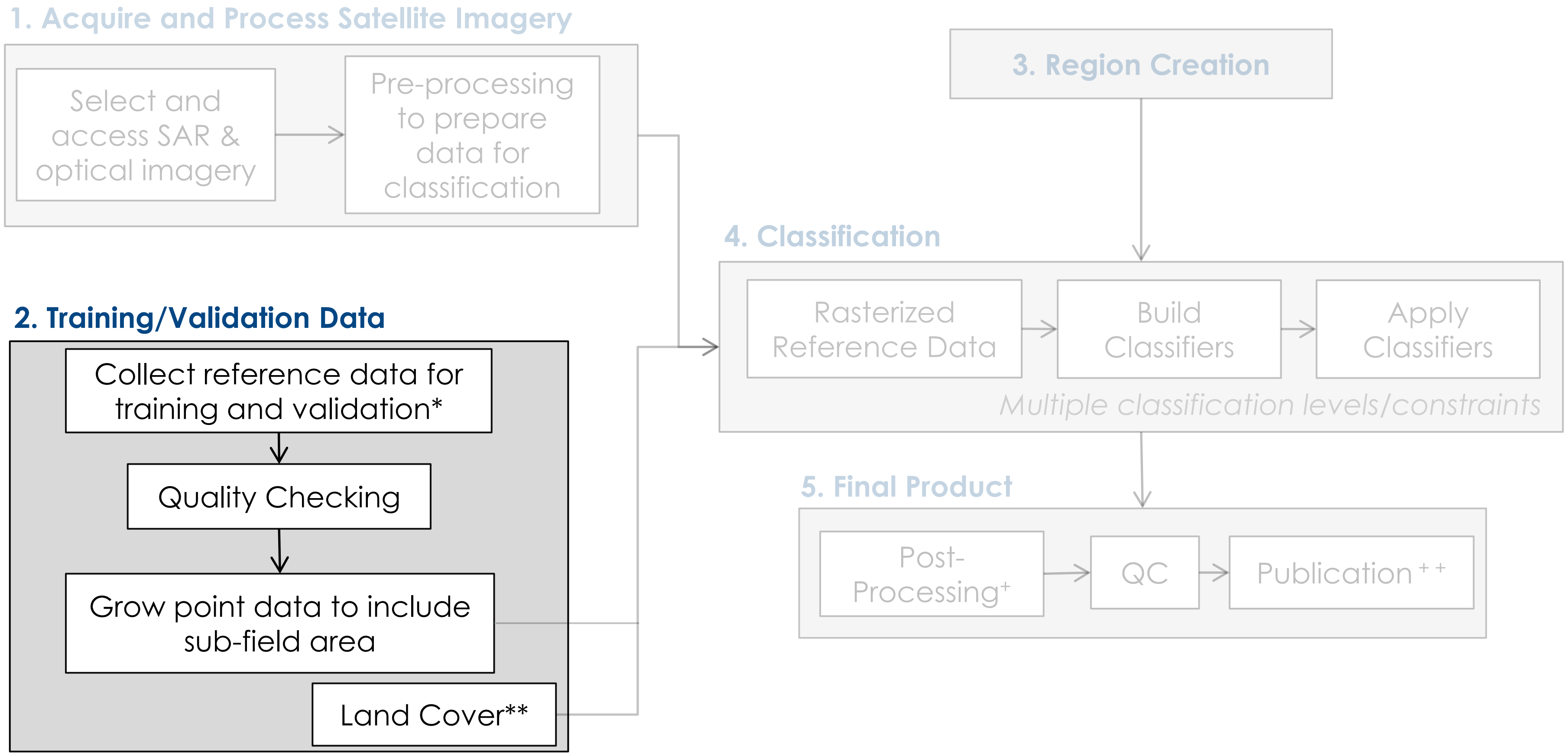
- Manual review of imagery for cloud cover and image quality.
- If part of the image has limited cloud cover over regions of agriculture, then an image can be included in the classification regardless of whether the entire image has a high percentage of cloud cover.

If desired, ESA has methodologies to remove cloud cover, including some available in SNAP. However, this will increase overall processing effort.



2. Collecting Training and Validation Data

Crop Inventory Operational Methodology

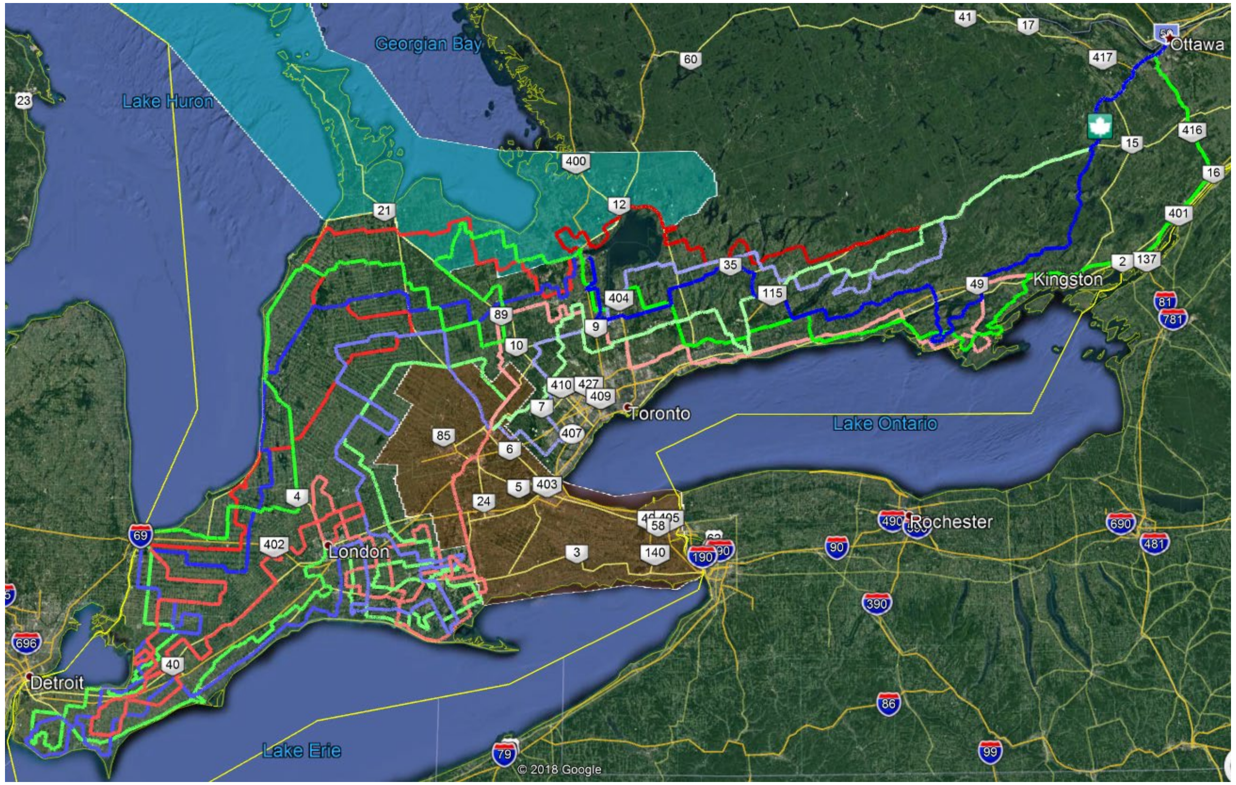


* Potential Sources:

- **Field Surveys**
- Crop Insurance
- Partnerships

** AAFC does not generate land cover classes during this classification flow, but integrates land cover maps updated every 5 years.

Synthetic Aperture Radar (SAR)



3 Teams (Red, Green, Blue) - Coloured lines get paler each day to help distinguish daily routes.

Courtesy: Agriculture and Agri-Food Canada

AAFC collects field data for training and testing **using 2 approaches**:

1. Partnerships with crop insurance agencies for some provinces
2. Sending crews to collect *in situ* observations

Guiding principles for *in situ* observations:

- Coverage – Well dispersed to cover areas of interest
- Large quantities of samples especially for rare and unusual crop types
- Classification success highly dependent on quality of ground data inputs

Poor ground data = poor classification!

Fieldwork Training

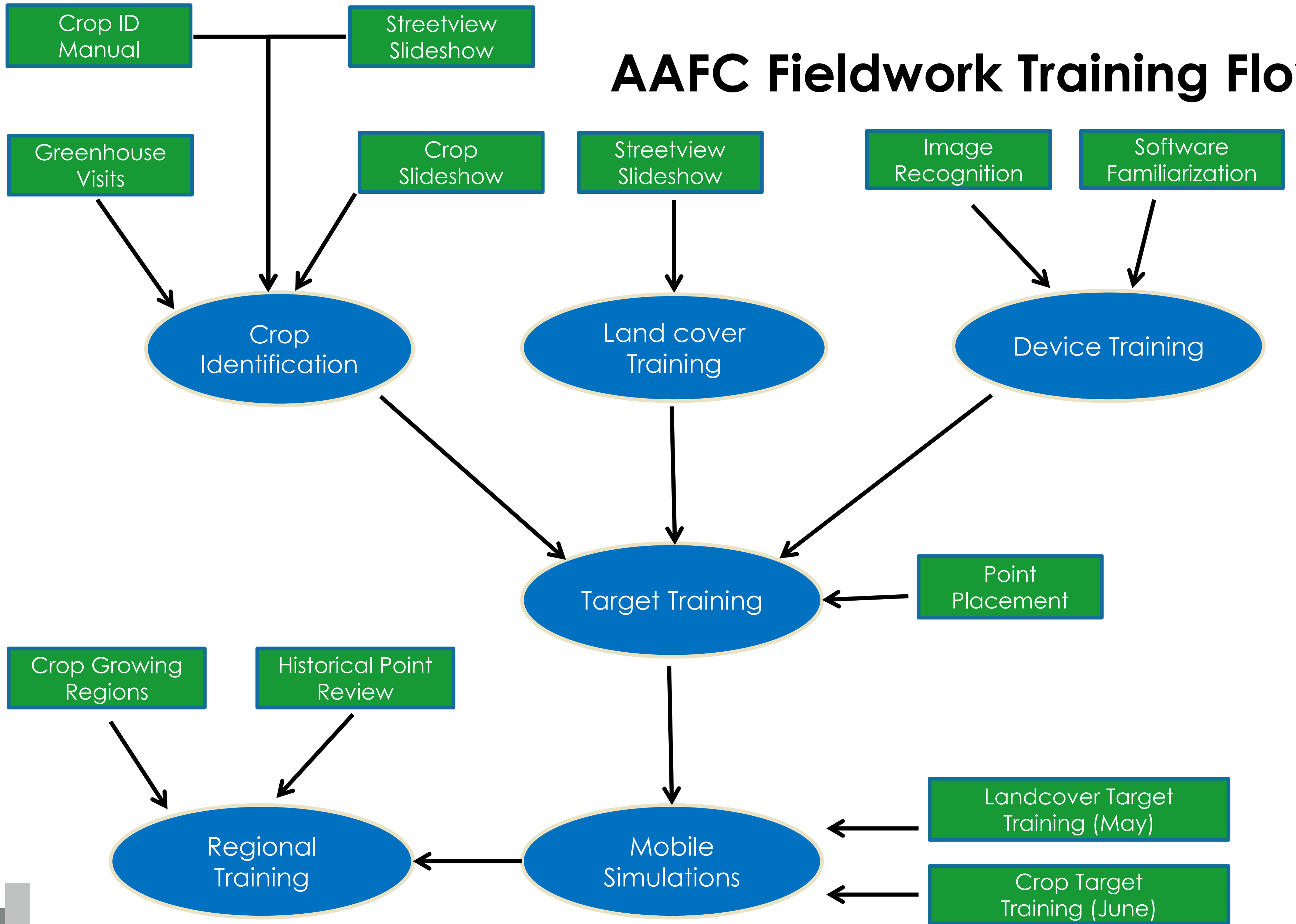
To gather **high quality** field data, AAFC devised a thorough training system to help new staff or students become familiar with data collection methods.

Data collector systems:

- ESRI – Survey 123
- NGA MAGE – USDA

Courtesy: Agriculture and Agri-Food Canada

AAFC Fieldwork Training Flowchart



Courtesy: Agriculture and Agri-Food Canada

AAFC Training for Field Crews

- **Visit Greenhouses**: Staff visit greenhouses to watch crops in various stages of growth
- **Crop Manual**: Staff review a training manual, which documents photos of all crops grown in Canada
- **Regional Training**: Staff familiarize themselves with the types of crops grown in their assigned fieldwork region
- **Historical Point Review**: Staff look at past data collection years to see which minor crops have been spotted in previous years
- **Streetview Slideshow**: Using Google Maps, staff "drive" virtual paths and are asked to identify crops in fields
- **Crop Slideshow**: AAFC created a "rapid" slideshow of crop photos and staff are required to quickly identify crops as they are displayed

Street View Crop Type and Land Cover Training

"Drive" in Streetview from Point A to Point B

Mark the various land cover types on the satellite image as they are passed on Streetview

Training on Collection Device

Image Recognition: Review satellite background imagery to become accustomed to how these images appear

Device Familiarization:

- Spend time learning the different functions of the software (how to delete points, load layers, etc.)
- Read through the Help files that were created

Point Placement:

- Work on being able to correctly position data on top of background imagery
- Run through a static identification of targets in the office (within a background image find: 10 water features, 6 barns, 7 forest classes, 2 golf courses, etc.)

Mobile Simulations

Land Cover & Crop Target Training (prior to field season)

- Take the trainee on a known route where they will be asked to collect land cover & crop target data
- Trainee judged on correct identifications, positional accuracies, and volume of points

Courtesy: Agriculture and Agri-Food Canada

How many samples are needed to train and validate?

Courtesy: Agriculture and Agri-Food Canada

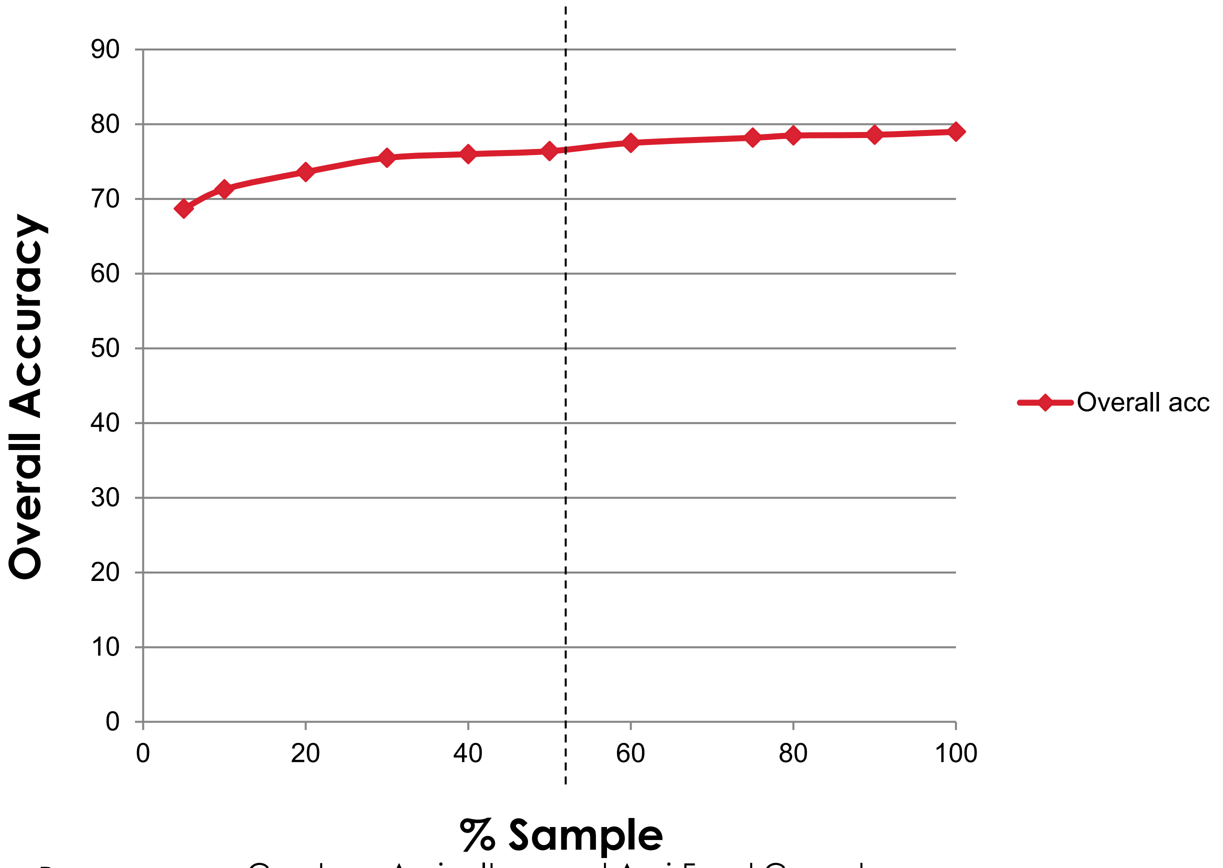
In this southwestern region of Canada's Province of Ontario, crews collected 16,700 field observations.

Can this number be reduced to reduce resources and time for fieldwork?

Reducing In Situ Sampling

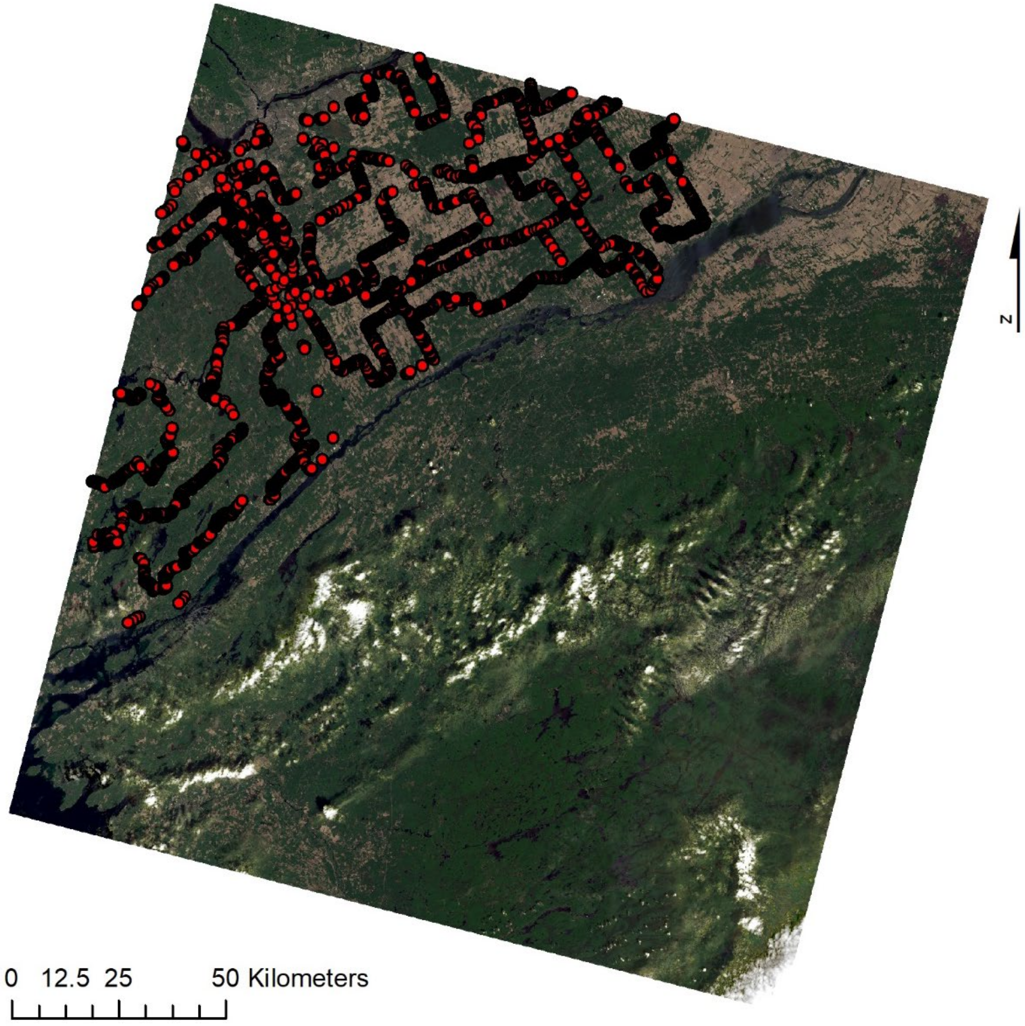
AAFC ran an experiment to test the impact on accuracies of reducing the number of field data points used to train the classifier.

- Sample field data at: 5%, 10%, 20%, 30%, …, 100%
- Classify with new sampled datasets
- Assess accuracy



Courtesy: Agriculture and Agri-Food Canada

Reducing In Situ Sampling – Subset Testing



Eastern Ontario

Courtesy: Agriculture and Agri-Food Canada

100% (6,700 samples): 85.4%
50% (3,350 samples): 84.3%
5% (335 samples): 81.1%

Spatially dispersed and representative of all crop types

After 10 years of experience, AAFC has determined optimum sampling numbers for mapping crops **across Canada**.

New operational groups should acquire maximum amount of samples possible in the first years, but can use these data to run a similar experiment to determine requirements for their regions.

Quality Checking of In Situ Data

Scan attribute file for any flagged items and read all comments.

Users may not know all crop categories and place crops in the wrong class (i.e., other fruit with a written comment of blueberry).

If there are questions, use photos to reconcile.

Minor/rare crops: highlight on map and check that they are in expected locations.

For example, if berries cannot grow in a region, this is an erroneous observation.

Scroll along driving routes to make sure point placements are within fields.

For example, points should not be on roads, in forests, on buildings, or in riparian zones.

Adjust point locations, if possible, otherwise delete point. TIP: Use Google Earth.

If multiple points have been placed in a field, make sure crop types match.

While scrolling, if crop type is easily identifiable (orchard, vineyard, ginseng, etc.), verify crop class is correct.

Cross check points where surveyors' data collections overlap.

AAFC overlaps field routes to assist with quality control.

If observations differ, select the majority observation (i.e., if 2 out of 3 surveyors agreed).

Review dates to determine if one surveyor's observation was taken at a better time for crop determination.

Consider historical inaccuracies of the surveyor.

When in doubt – throw it out!

Ground Data Pre-Processing

A 500m buffer is created around each sampling point. This limits the area that will be segmented around the sample.

Within each buffer area, optical data are segmented

Segment around sampling point is then extracted and will be considered as the field boundary.

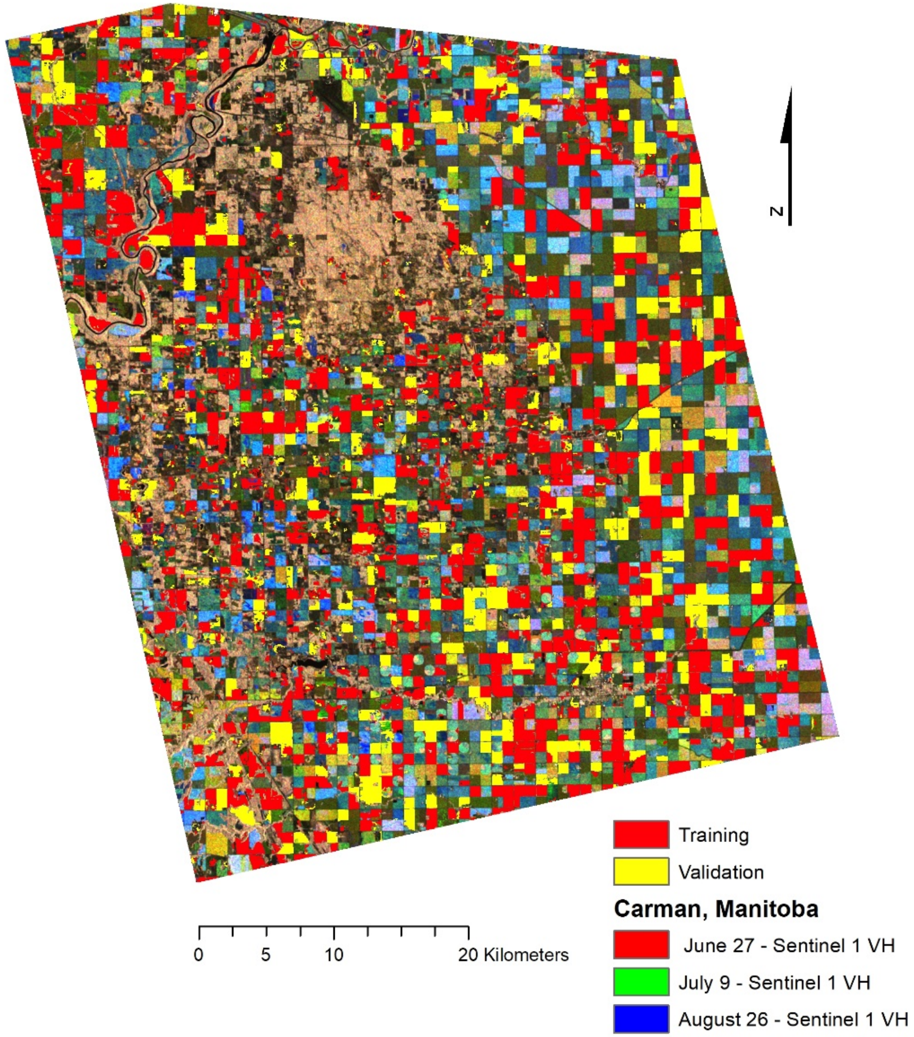
AAFC uses eCognition software to segment imagery; but there are other open-source options available (e.g., QGIS, Python, etc.)

Courtesy: Agriculture and Agri-Food Canada

Creating Training & Validation Sets from Field Data

- Split field data using Stratified Random Sampling method (30% validation, 70% training)
- Rasterize vector samples (training & validation)
- Add to the satellite co-registered data stacks

AAFC uses all in-house tools to do this, but these processes are available in R and Python.



Courtesy: Agriculture and Agri-Food Canada

Region Building

- Region building separates the data into manageable areas of interest.

- Can be based on:
  - Grid
  - Imagery Overlaps
  - State/Province
  - Whole Country

- Region building occurs just before the classification.

- AAFC's new system now iterates regions to ensure each pixel is given the best coverage of images.

AAFC Staffing Resources

Keeping in mind that Canada has **64 million hectares** of farm land to map

Technical staff required for data processing (**excluding** field work): 4 permanent (75% of their time)

Resources needed to collect in situ data (for 6 provinces, 8.5 million hectares): Budget: ~$45 000 CDN/year (excluding salary)

STAFF / PROVINCE	NFLD	NB	PEI	NS	ON	BC	ALL
Farm Acreage 2016 (hectares)	28,327	337,913	232,694	370,287	4,997,058	2,589,988	8,556,267
AAFC (Earth Observation Team)		1(5)	1(5)	1(5)	5(37)	1(5)	6(57)
AAFC Students					3(15)		3(15)
AAFC In Province	1(4)	1(5)	1(5)	1(5)	4(20)	1(5)	9(44)
Statistics Canada					4(20)		4(20)
OMAFRA					2(12)		2(12)
BC Government						2(20)	2(20)
TOTAL	1(4)	2(10)	2(10)	2(10)	18(104)	4(30)	**26(168)**

First Number: Number of individuals; Second Number (in bracket): Summation of field work days for all individuals

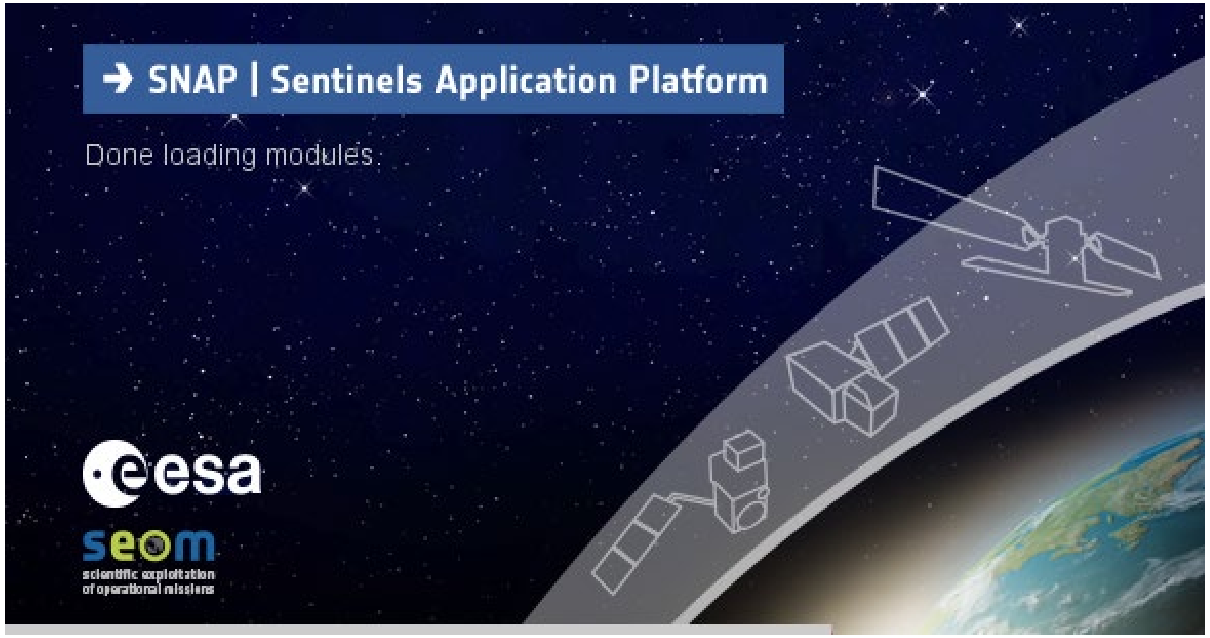
To collect ground data for the entire country: 26 people for a total of 168 days (or an average of 6.5 days per person)

Courtesy: Agriculture and Agri-Food Canada

Hands-On Exercise

Image Source: https://www.esa.int/spaceinimages/Images/2014/02/Sentinel-1

SNAP: Sentinel's Application Platform



- ESA's 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/

Steps for SAR Pre-processing

Sentinel-1 (IW, GRDH) ➡ Apply Orbit-File ➡ Speckle Filter ➡ Geometric Correction ➡ Pre-Processed SAR Data

Geometric Correction with Range Doppler Model

At this point, radiometric normalization and conversion to Sigma0 occurs.

Steps for Optical Pre-processing

Sentinel-2 L1C (if Level 2A data are not available) → Sen2COR → Pre-Processed Optical Data

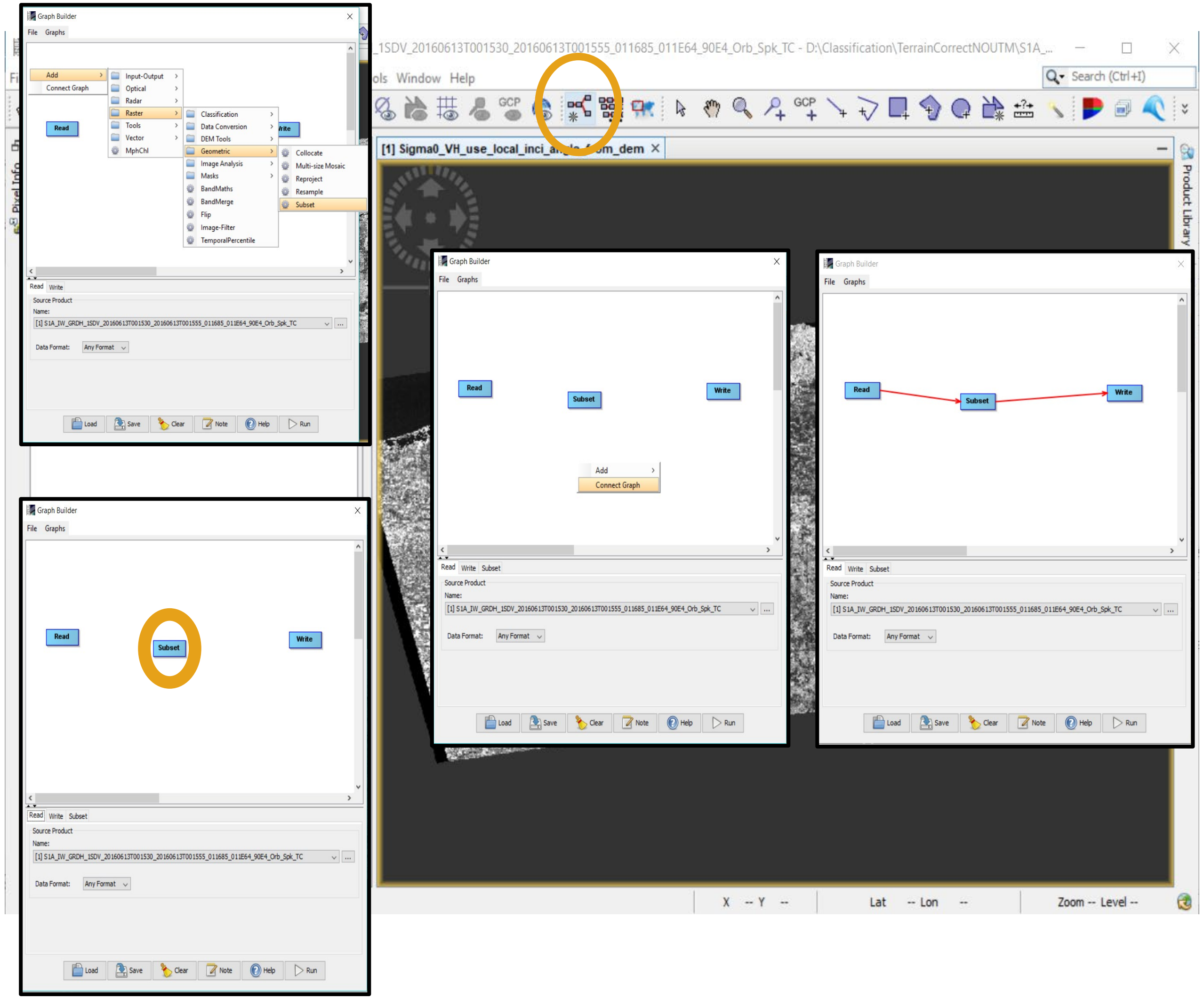
Refer to the NASA ARSET training by ESA for detailed instructions on how to apply optical image pre-processing: https://appliedsciences.nasa.gov/join-mission/training/english/arset-agricultural-crop-classification-synthetic-aperture-radar-and

Subsetting, Co-registration & Exporting Files

Subset ➧ Co-registration ➧ Export Files

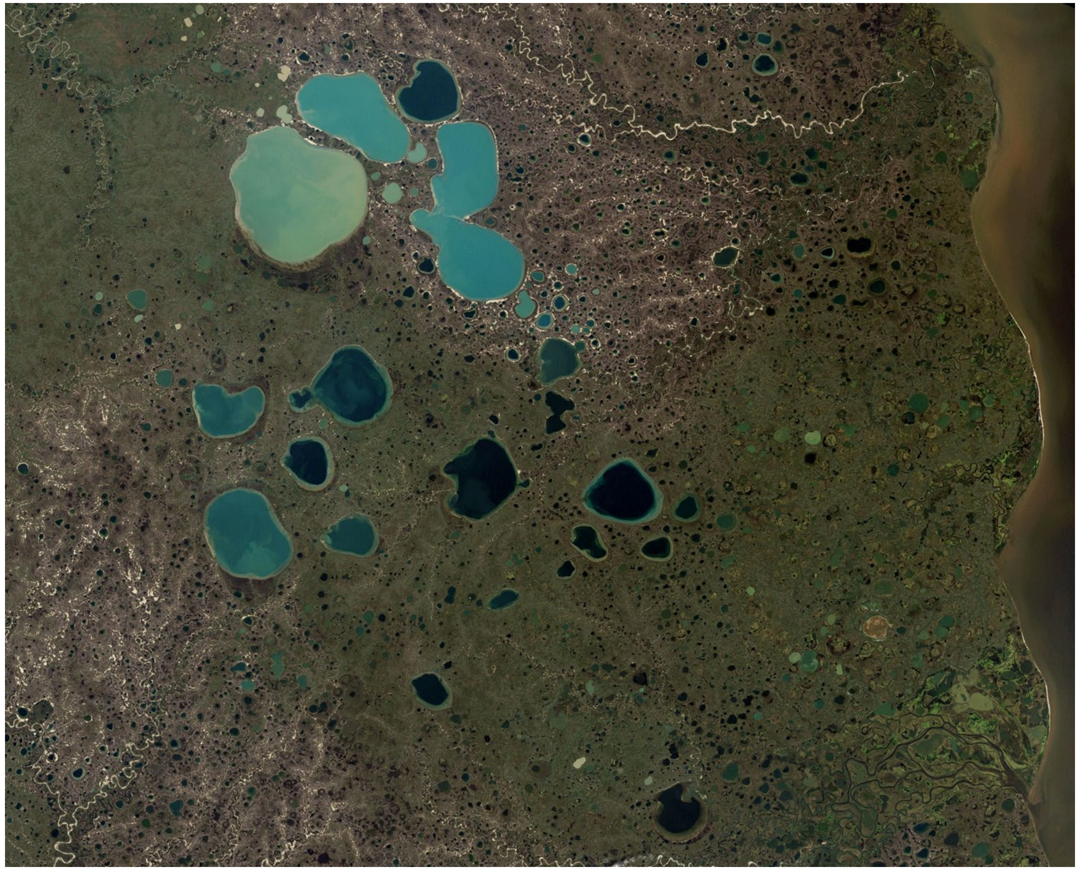
Bulk Image Pre-processing

- ESA has provided training in this ARSET series:
  - Introduction to SNAP
  - How to create graphs in SNAP for bulk processing of stacks of data



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

- Trainer:
  - Dr. Laura Dingle Robertson, Agriculture and Agri-food Canada: Laura.Dingle-Robertson@AGR.GC.CA

Further Reference Material: A.M. Davidson, T. Fisette, H. McNairn and B. Daneshfar. 2017. *Detailed crop mapping using remote sensing data (Crop Data Layers)*. In: J. Delince (ed.), Handbook on Remote Sensing for Agricultural Statistics (Chapter 4). Handbook of the Global Strategy to improve Agricultural and Rural Statistics (GSARS): Rome. [Full Text]

- Training Webpage:
  - https://appliedsciences.nasa.gov/join-mission/training/english/arset-agricultural-crop-classification-synthetic-aperture-radar-and
- ARSET Website:
  - https://appliedsciences.nasa.gov/what-we-do/capacity-building/arset
- Twitter: @NASAARSET

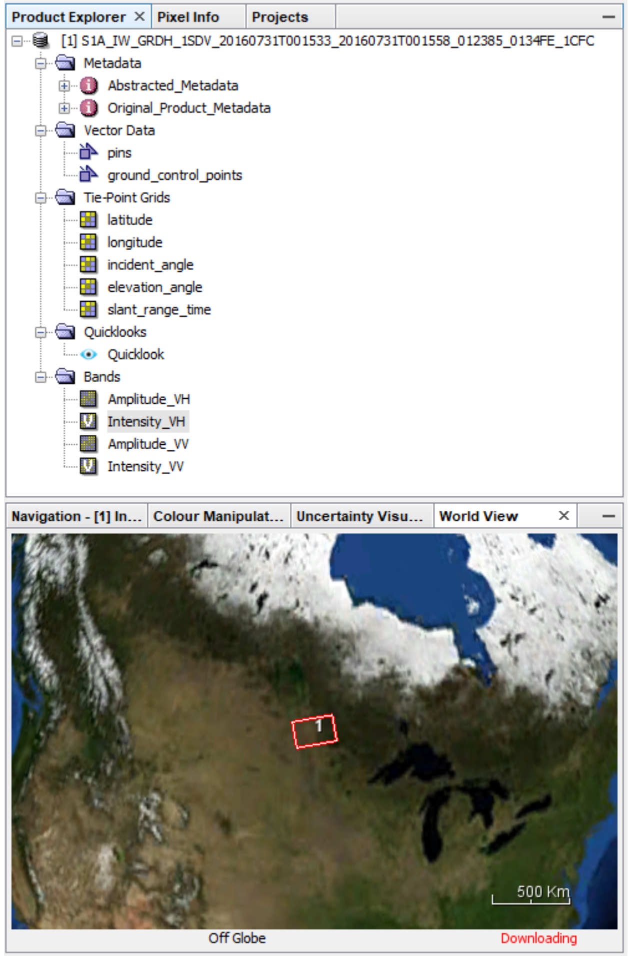
APPLIED REMOTE SENSING TRAINING PROGRAM
TRAIN - EMPOWER - ADVANCE

Thank You!

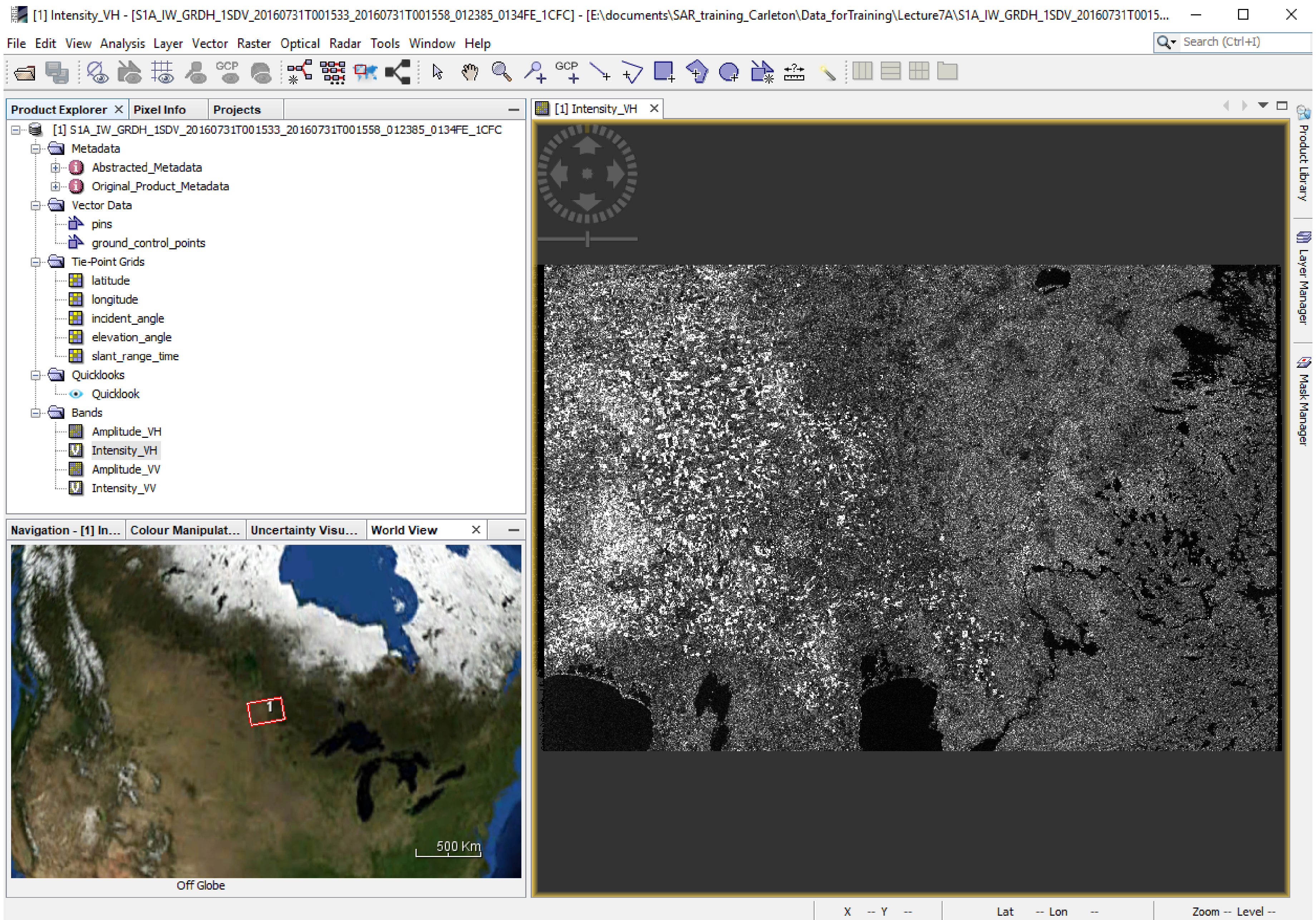
Appendix

Open and Display Sentinel-1 Image

1. Initiate the SNAP tool
2. In the SNAP interface, go to File menu >> Open Product
3. Select the folder that contains the Sentinel-1 data
4. Click on the .zip file (S1A_IW_GRDH_1SDV_20180929T093145_20180929T093210_023911_029C3F_F315.zip)
5. Open the image
6. Double click the file name to view the directories within the file, including:
   - Metadata: parameters related to the orbit and data
   - Tie Point Grids: interpolation of latitude/longitude, incidence angle, etc.
   - Bands: two bands for each polarization (intensity and amplitude)
7. The Worldview window (in the lower, left-hand side) shows the coverage of the image opened
8. Double click *Intensity_VH*

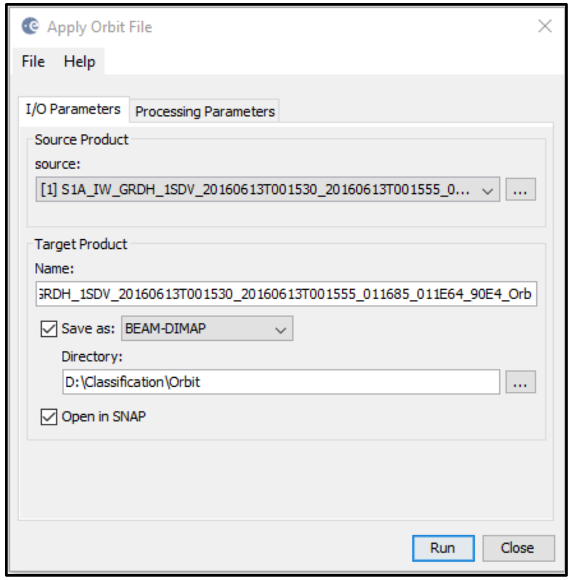


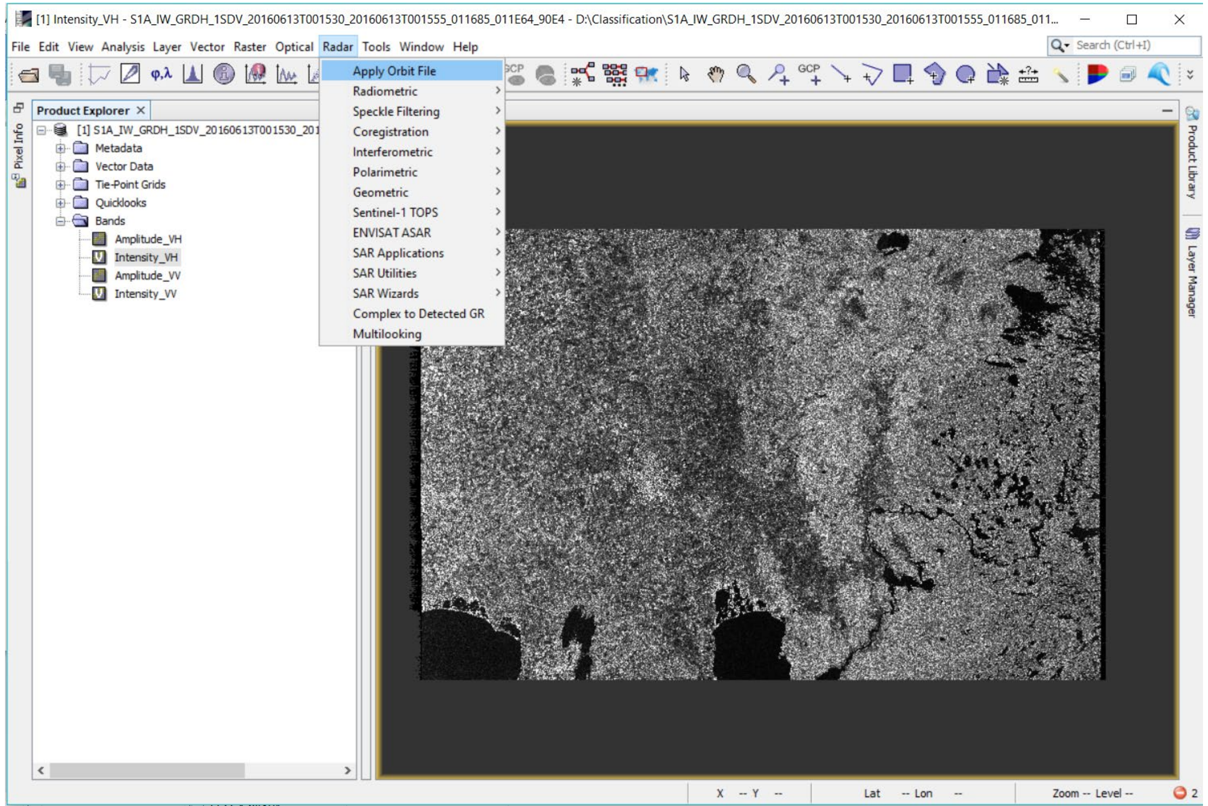
Open and Display Sentinel-1 Image

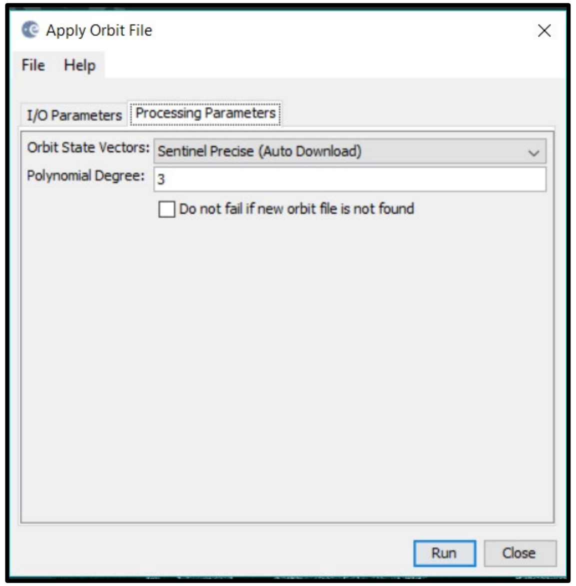


Apply Orbit File

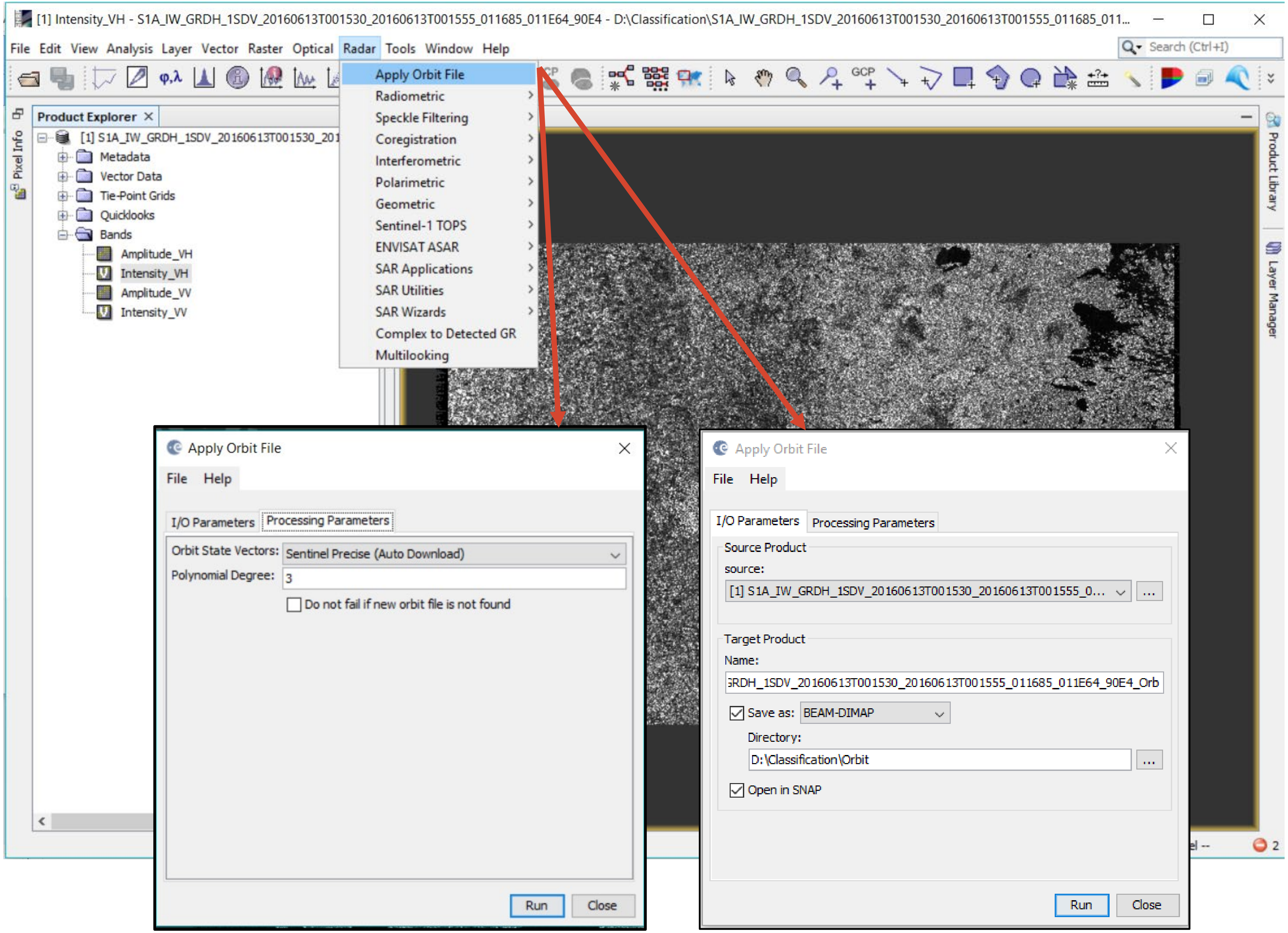
1. Go to Radar Menu >> Apply Orbit File:
   a) I/O Parameters tab: source → Raw image + Target Product
   b) Processing Parameters tab: Orbit State Vectors→ Sentinel Precise Auto Download; Polynomial Degrees → 3
   c) Click Run and Close window when completed





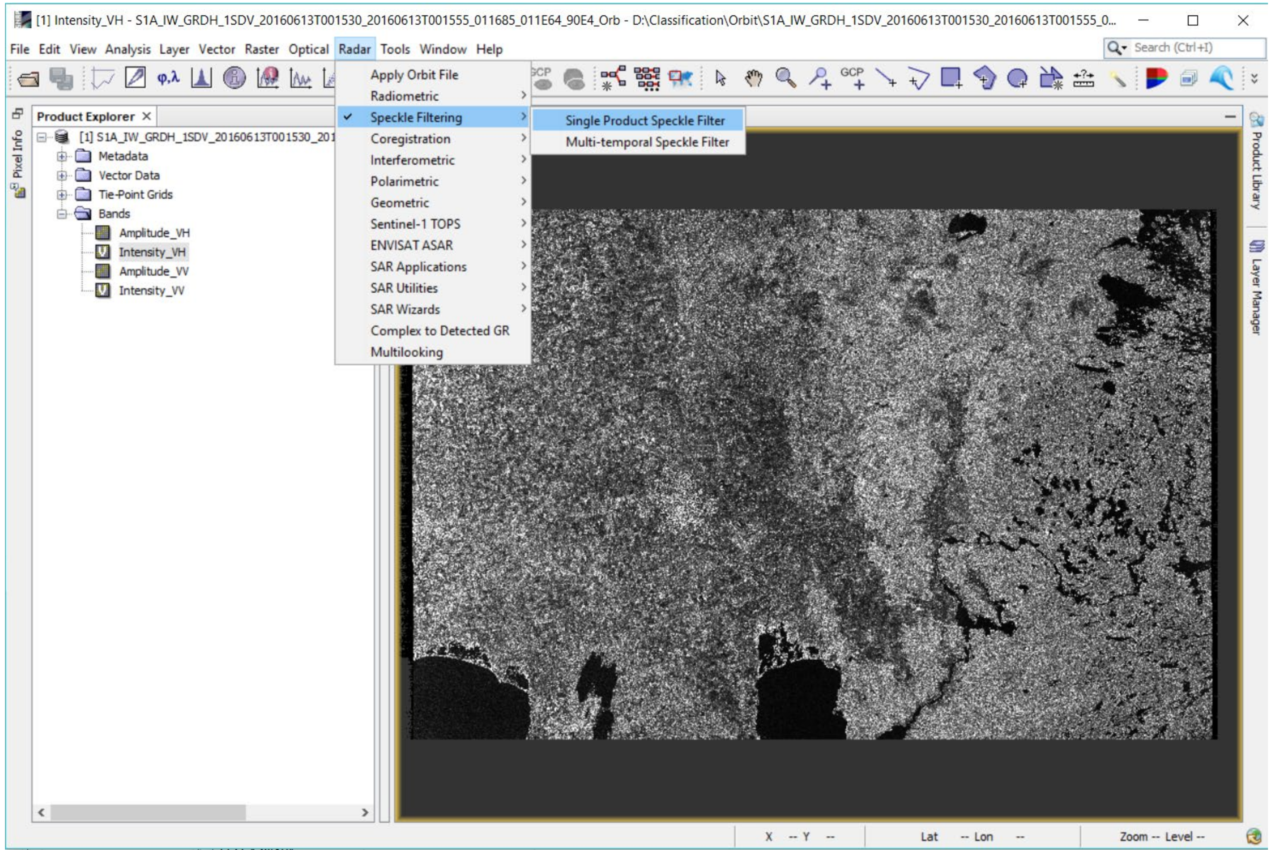


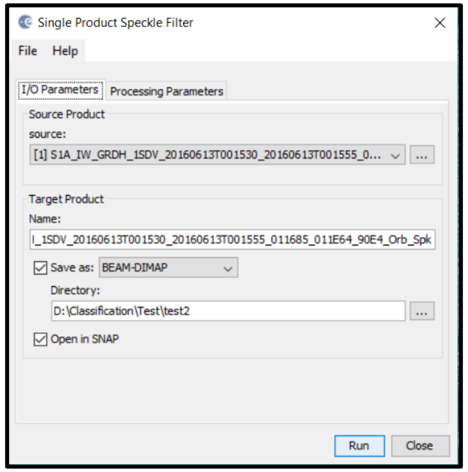
Apply Orbit File

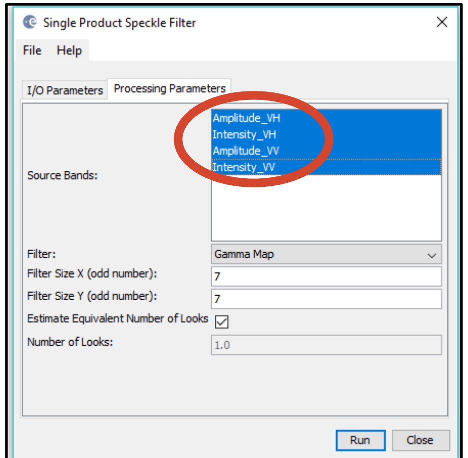


Apply Speckle Filter (Gamma MAP 7 x 7)

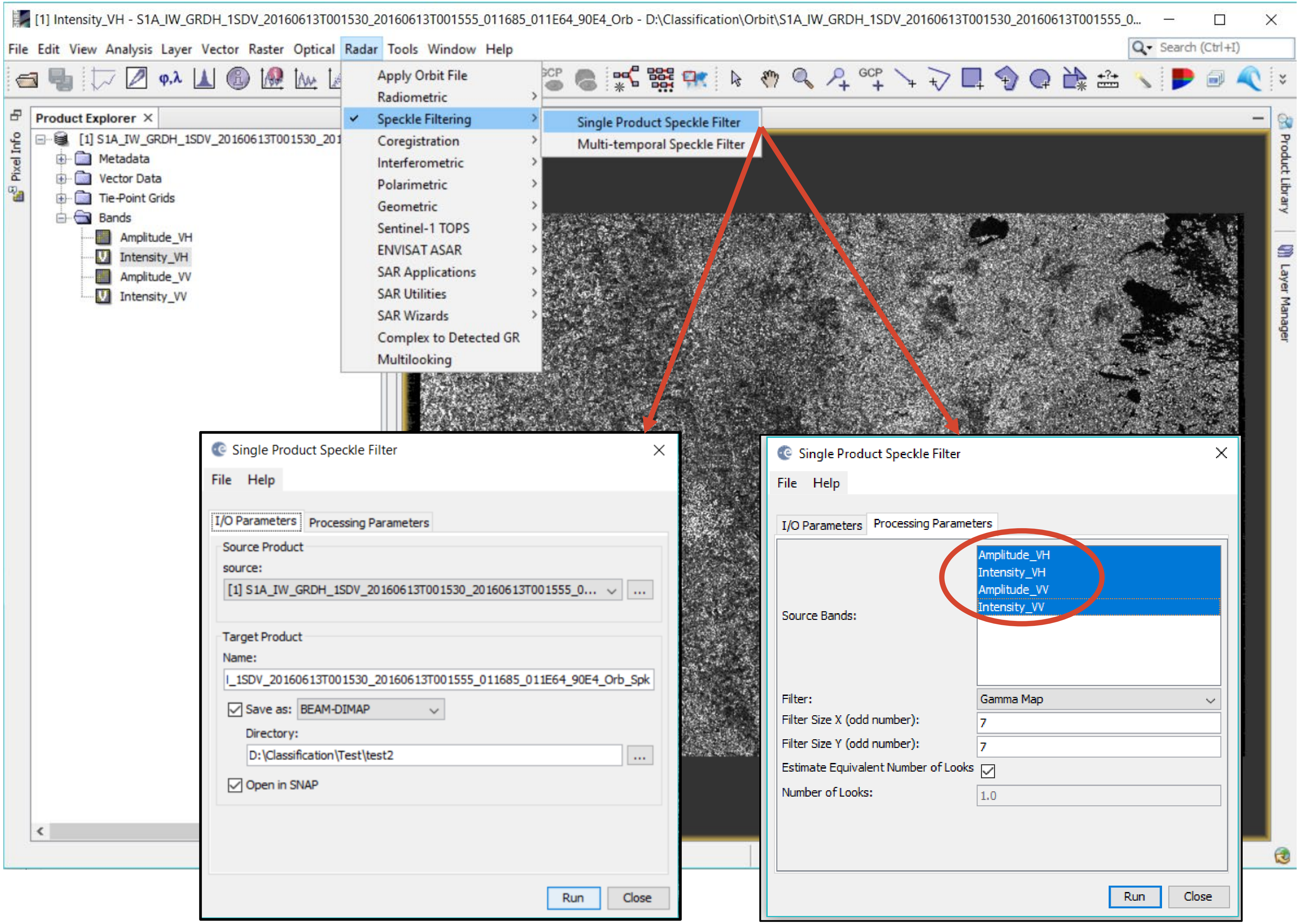
1. Go to Radar Menu >> Speckle Filtering >> Single Product Speckle Filter:
   a) I/O Parameters tab: source → Apply Orbit Image + Target product
   b) Processing Parameters tab: Source Bands → Ensure all selected; Filter → Gamma Map → Window Size → 7 x7
   c) Click Run and Close window when completed



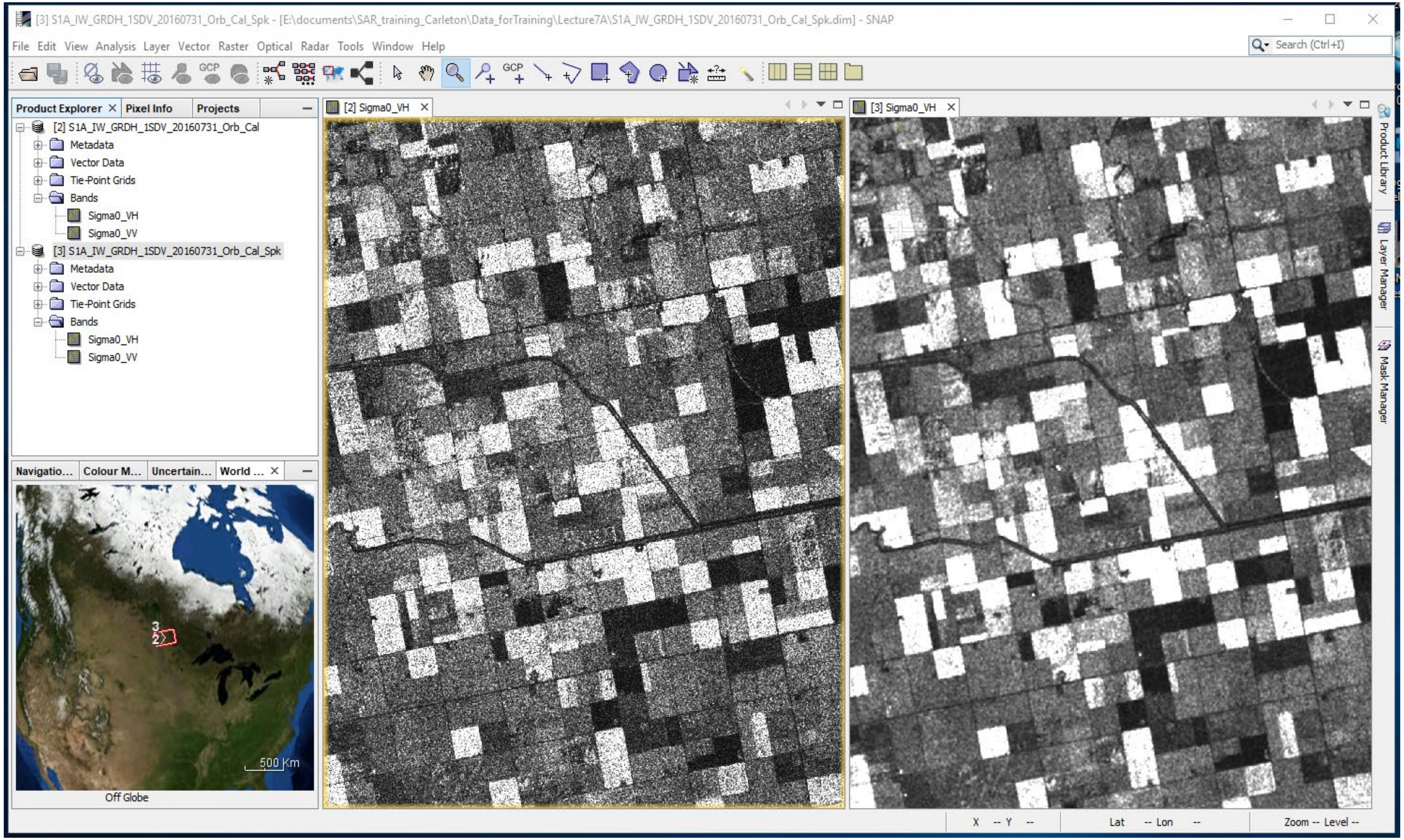




Apply Speckle Filter

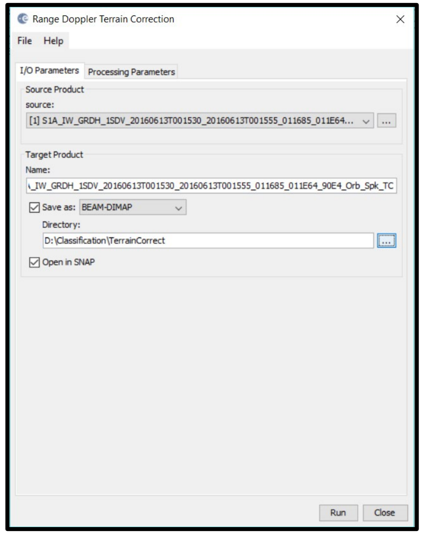


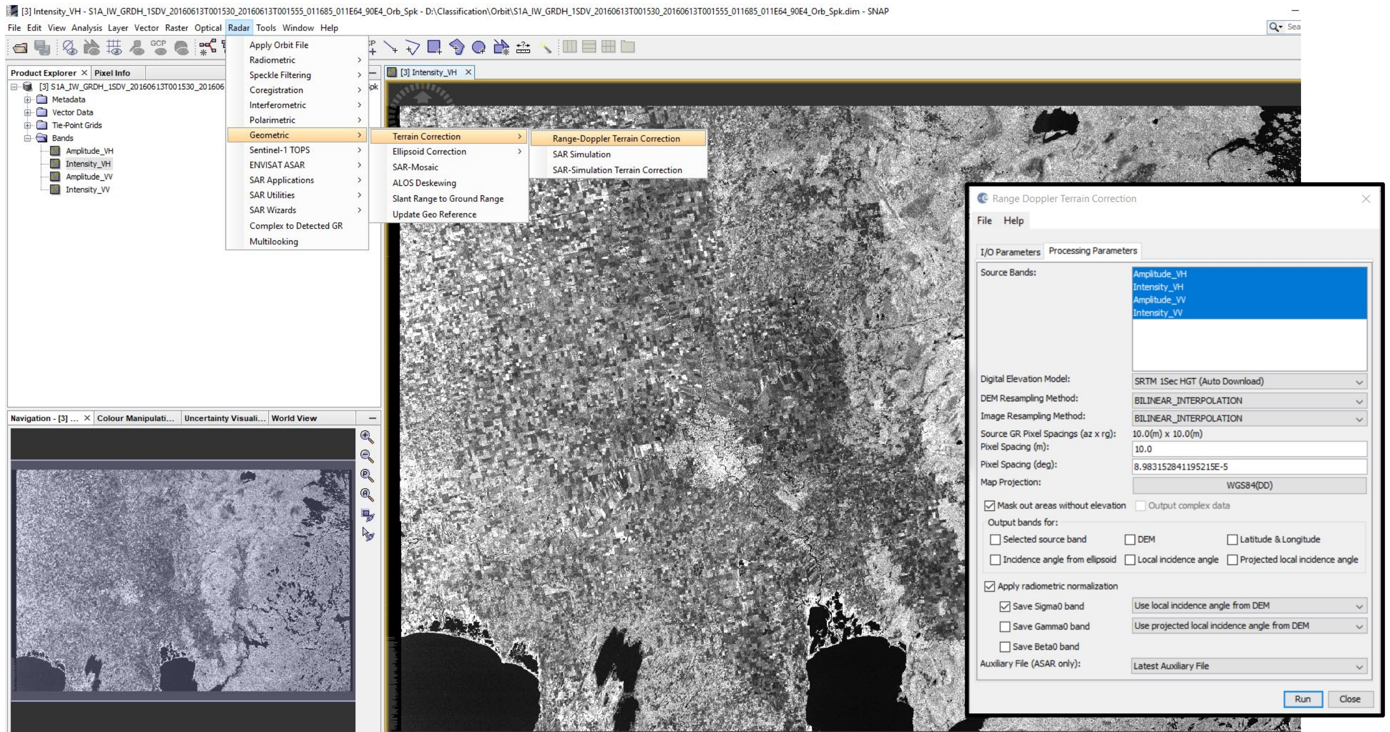
Speckle Filter the Sentinel-1 Image



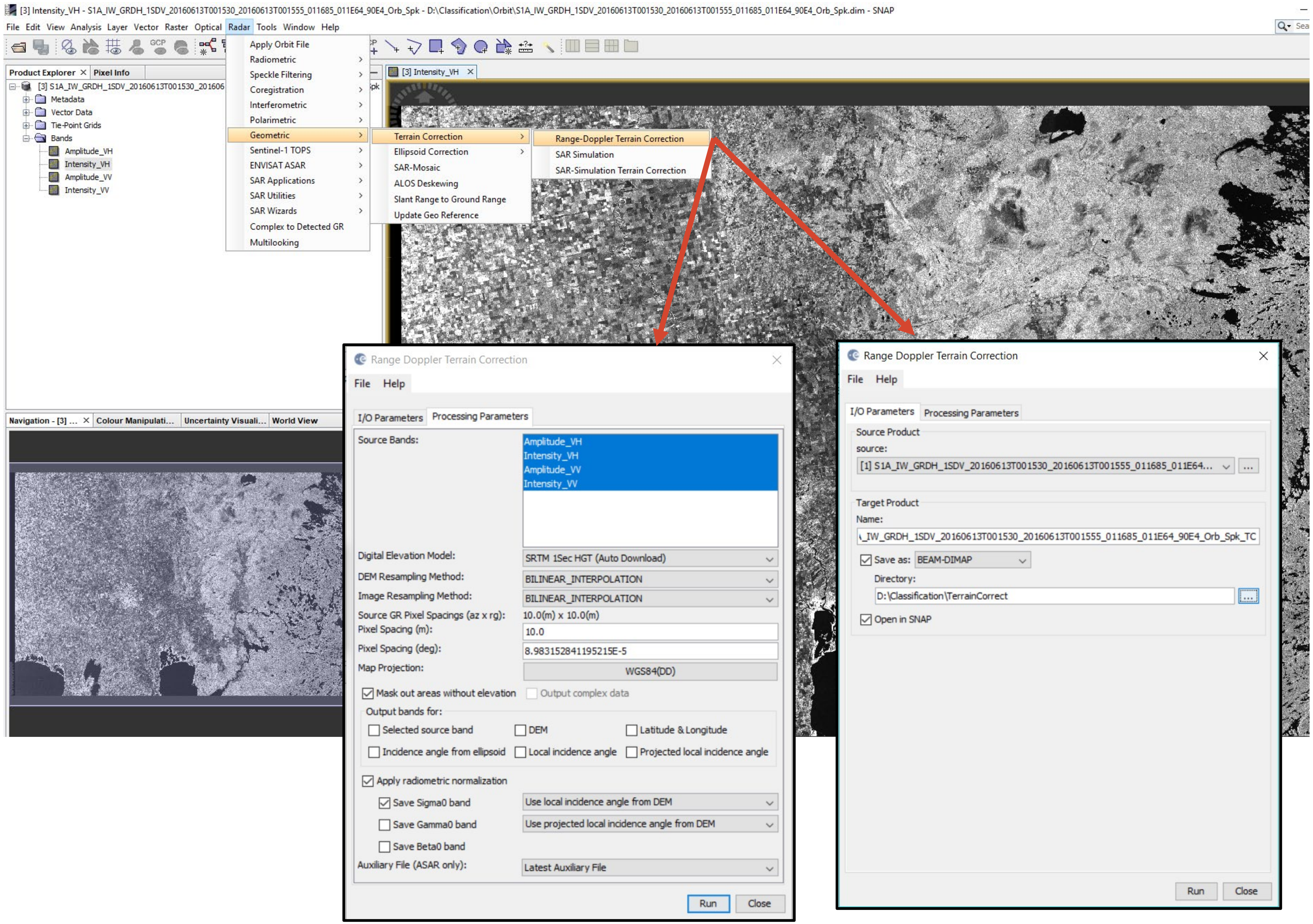
Terrain Correction

1. Go to Radar Menu >> Geometric >> Terrain Correction >> Range Doppler Terrain Correction:
   a) I/O Parameters tab: source → Speckle image + Target product
   b) Processing Parameters tab: Source Bands → Ensure all selected; Digital elevation model → SRTM 1Sec HGT (AutoDownload); Select Apply Radiometric Normalization → Save Sigma0 band → Use local incidence angle from DEM
   c) Click Run and Close window when completed

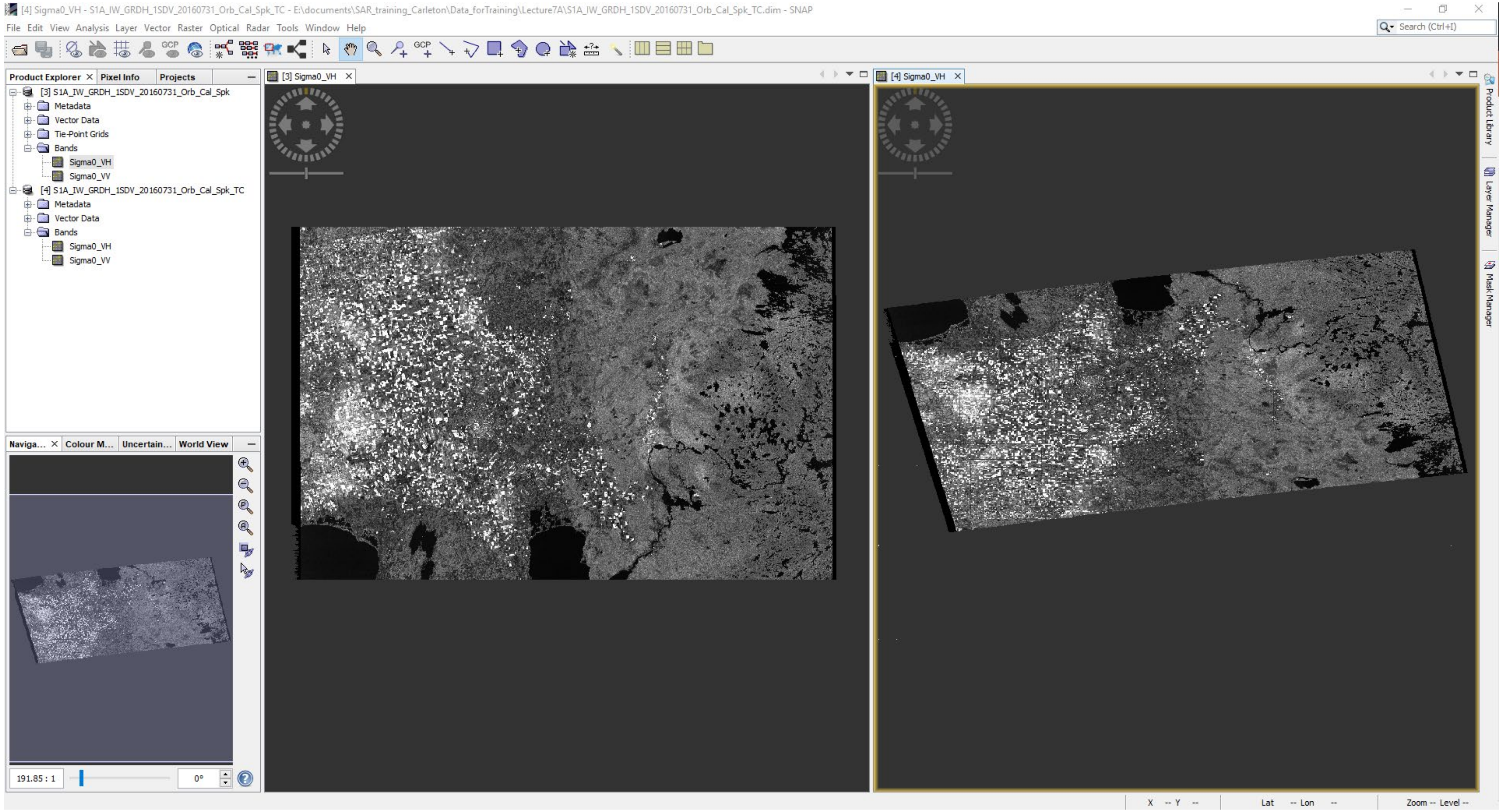




Terrain Correction



Geometric Correction Sentinel-1 Image

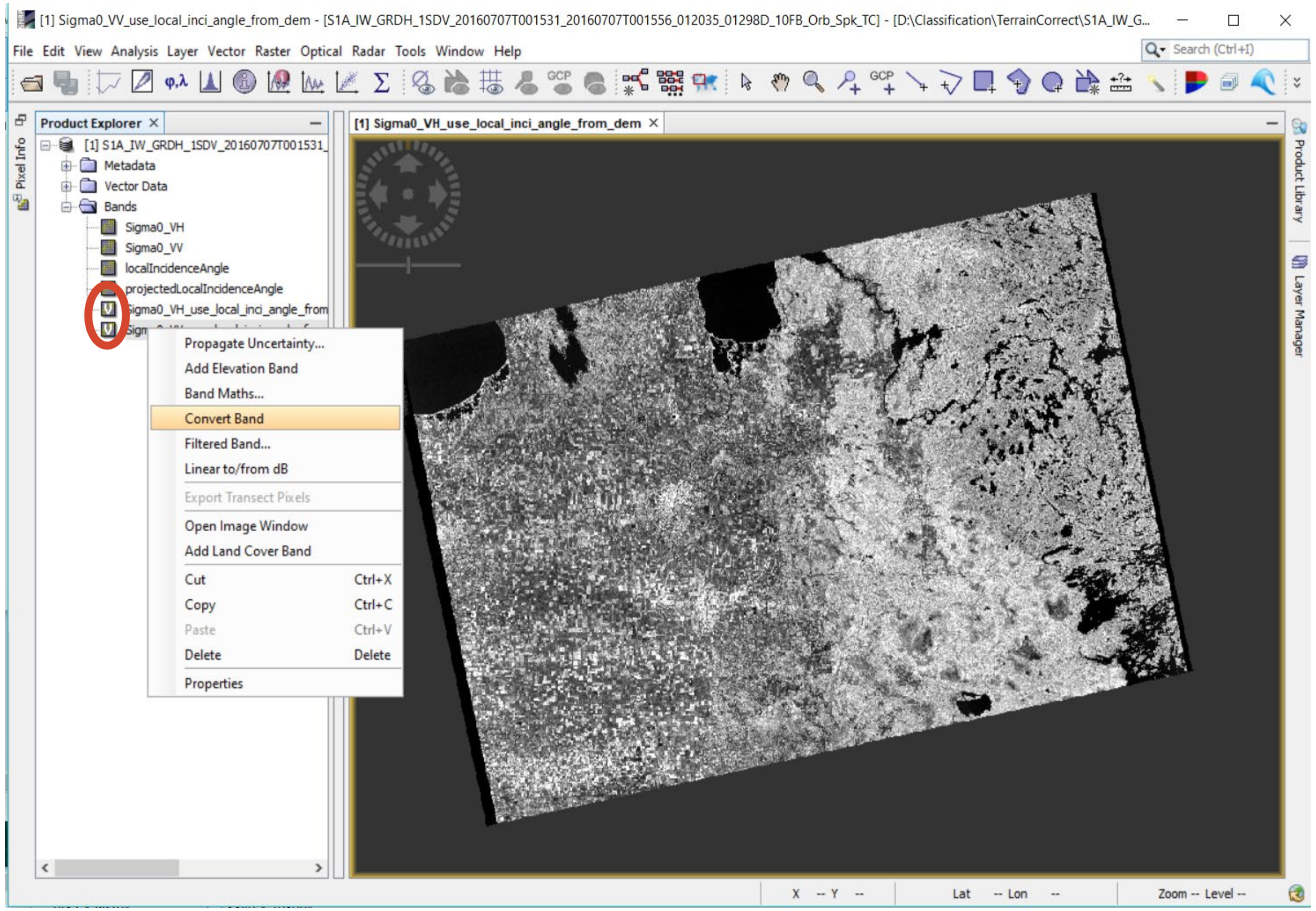


Speckle filtered image

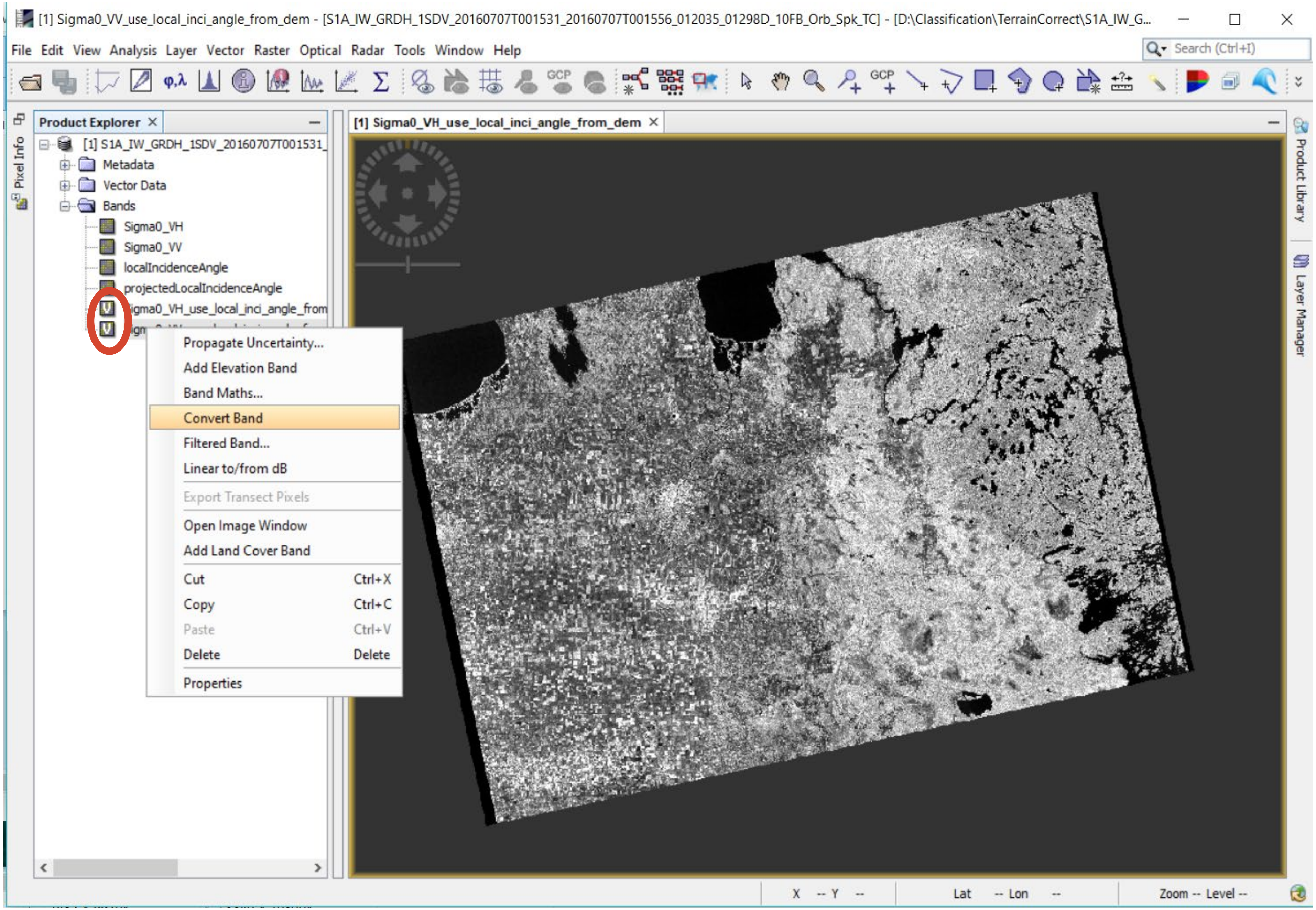
Speckle filtered image geocoded to the WGS 84 reference system

Convert Virtual Bands

1) Right click on ‘Virtual’ band and select Convert
2) Can then apply the Subset tool (without saving)
   a) Saving the converted bands at this point (entire image) takes a long time
   b) However, if you do not save the file, the converted band will not be saved but the virtual band (lookup table) will still be available

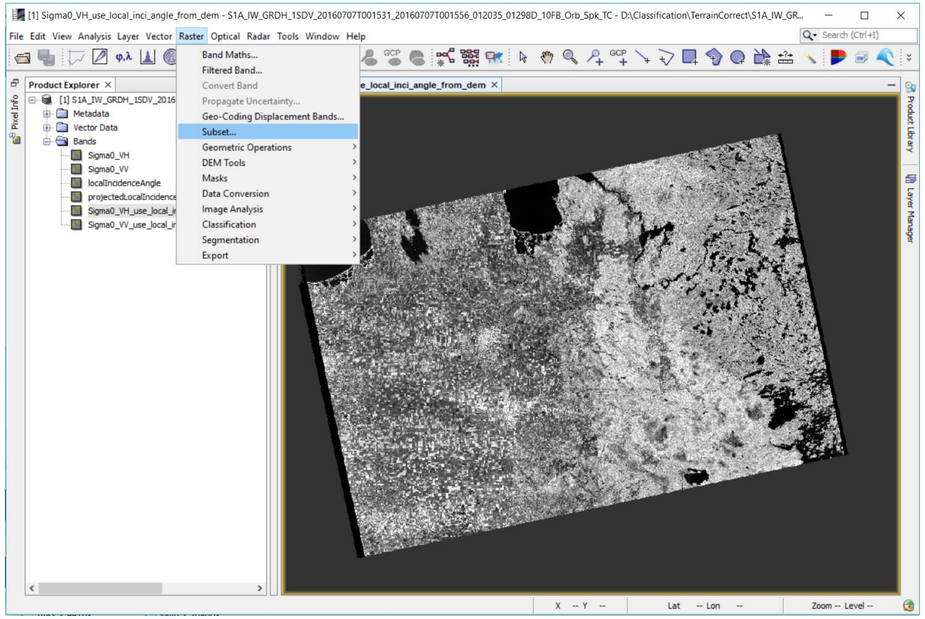


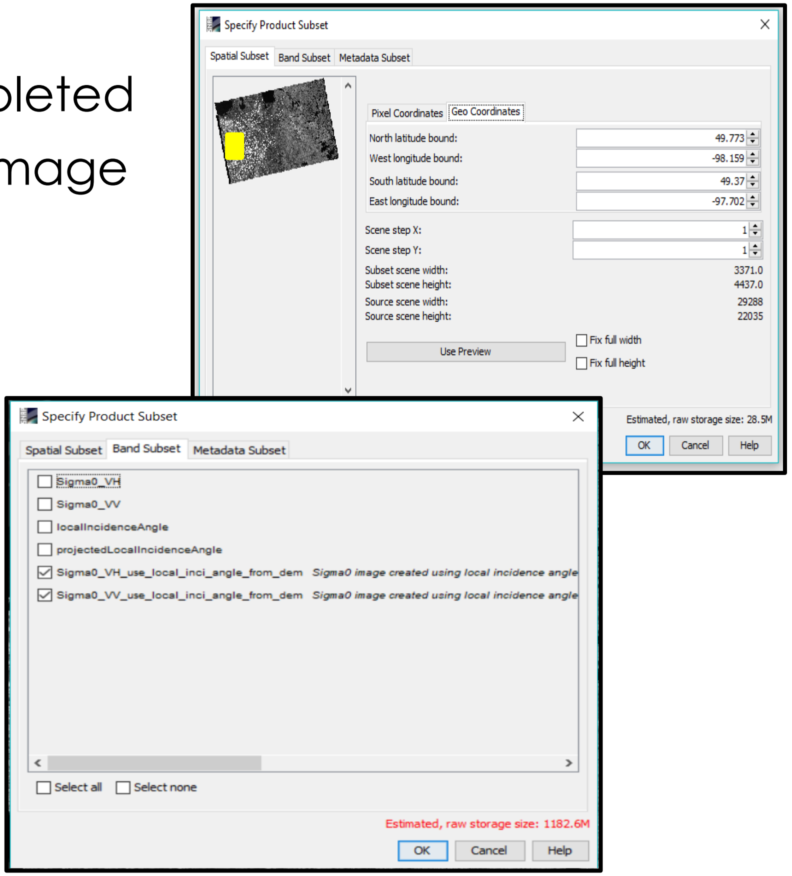
Convert Virtual Bands



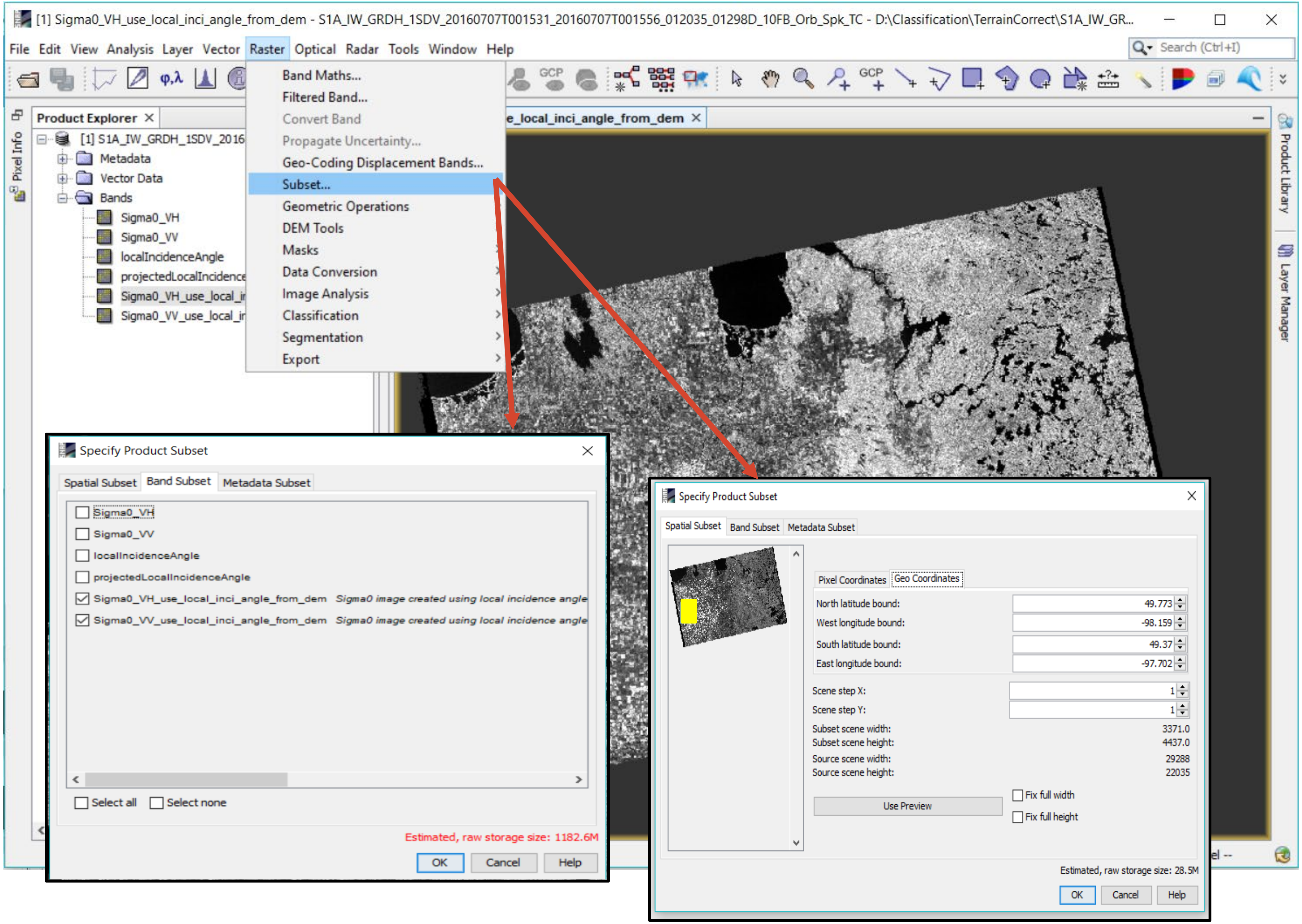
Subset Raster to AOI (Per Image)

1) Go to Raster Menu >> Subset:
   a) Spatial Subset tab → enter the upper left and lower right coordinate under Geo Coordinates
   b) Band Subset → select the bands that you wish to subset "Sigma0_VH/VV_use_local_inci_angle_from_dem"
   c) Metadata Subset: leave as default
   d) Click Okay and Close window when completed
   e) You will need to "Save" the newly subset image





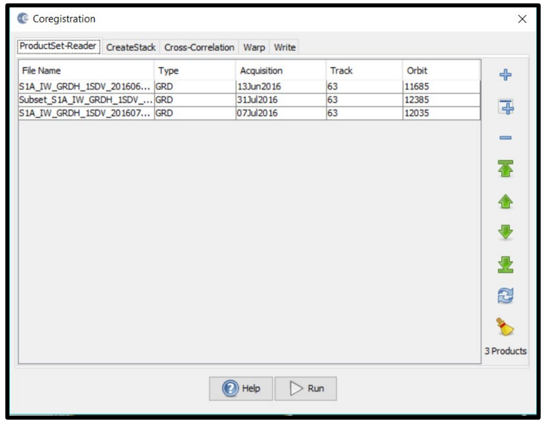
Subset Raster to AOI (Per Image)

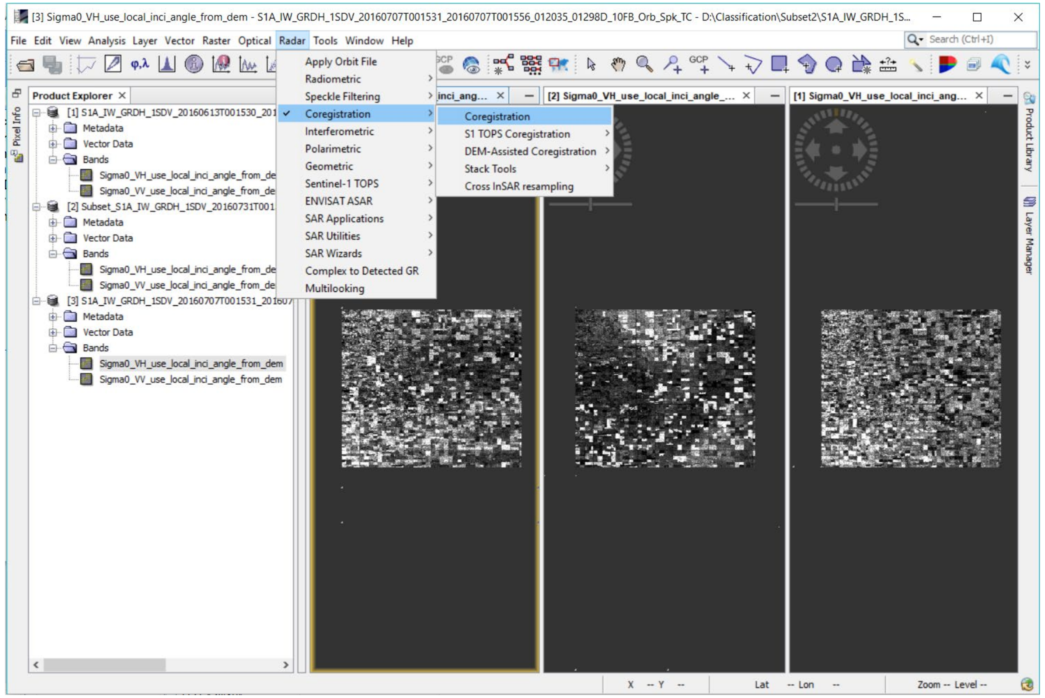


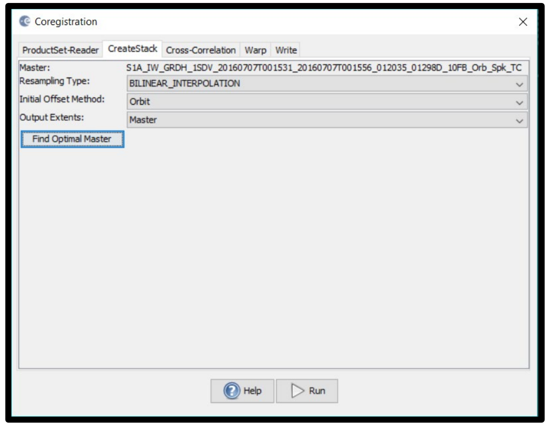
Co-Registration

Spatial alignment of images acquired on June 13th, July 7th and July 31st, 2016

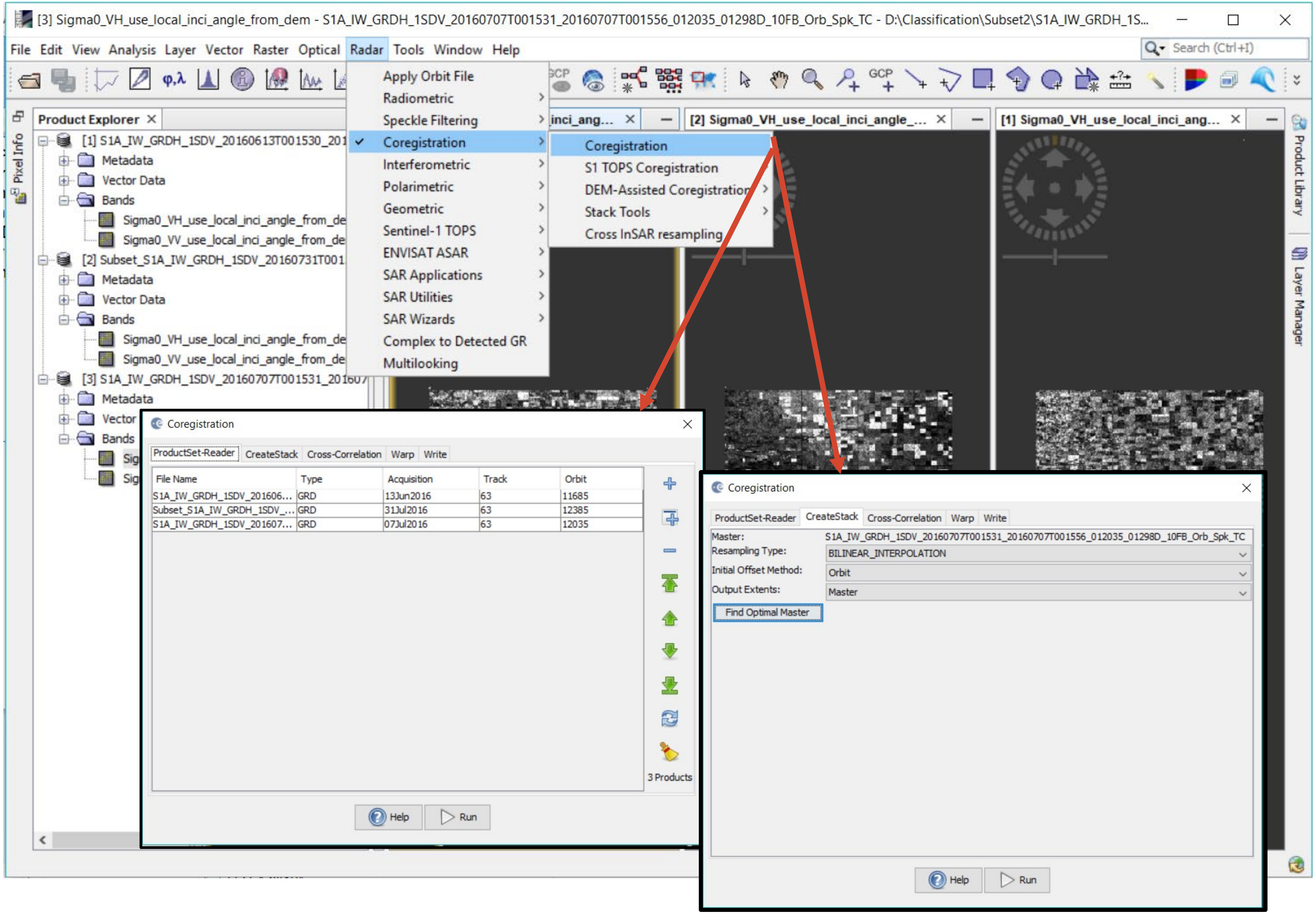
1. Go to Radar Menu >> Coregistration >> Coregistration:
   a) ProductSet-Reader: Click Plus sign with line over top adds all open imagery → Click Revolving Arrows to refresh metadata
   b) Create Stack: Resampling Type → Bilinear_Interpolation → Click Find Optimal Master
   c) Other tabs: leave as default;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





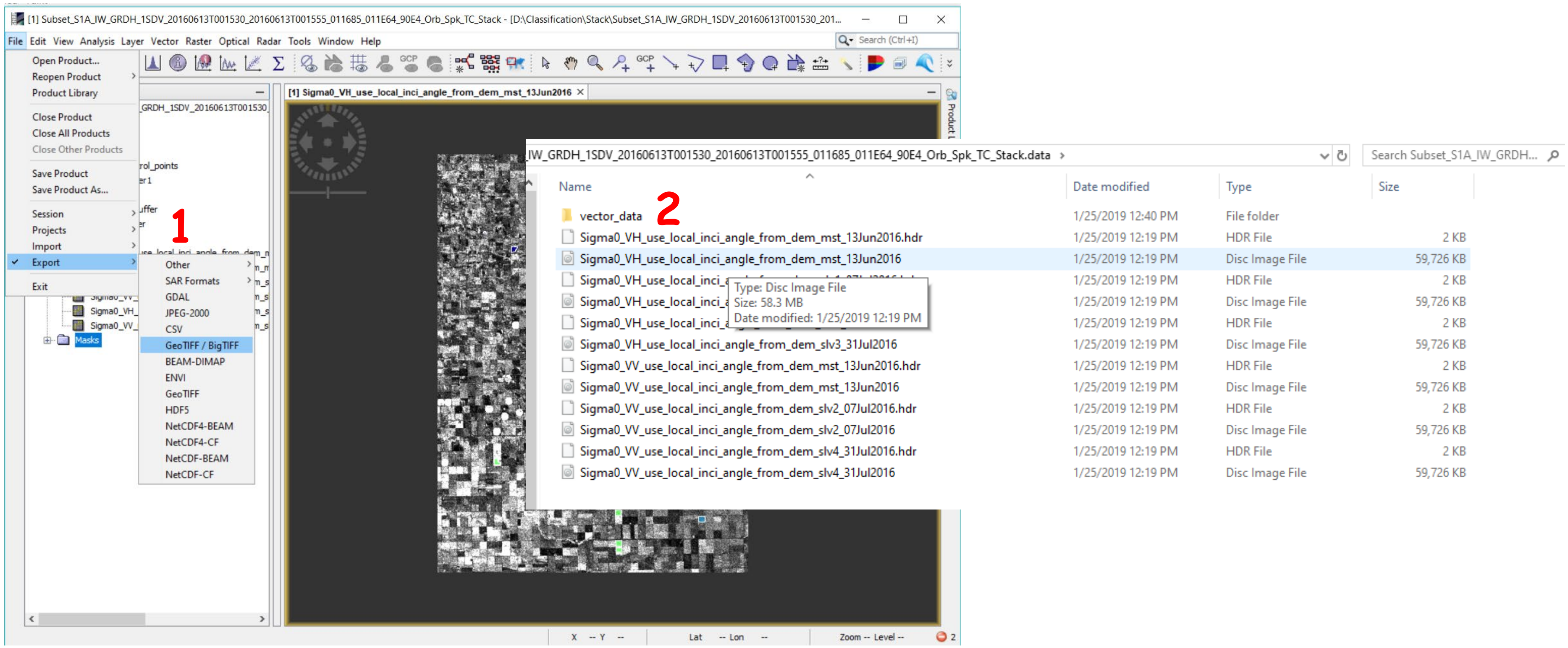


Co-Registration



Exporting Data Stacks Out of SNAP

- Limited functionality in SNAP; opportunity to customize classifiers
- Two ways to 'export'
  - SNAP → File → Export (**1**)
  - Windows File Explorer → use the .img files in the associated BEAM DIMAP folder (**2**)
- Can use .tifs in R, Python etc. (RandomForest, R https://cran.r-project.org/web/packages/randomForest/randomForest.pdf)



Exporting Data Stacks Out of SNAP