



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

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

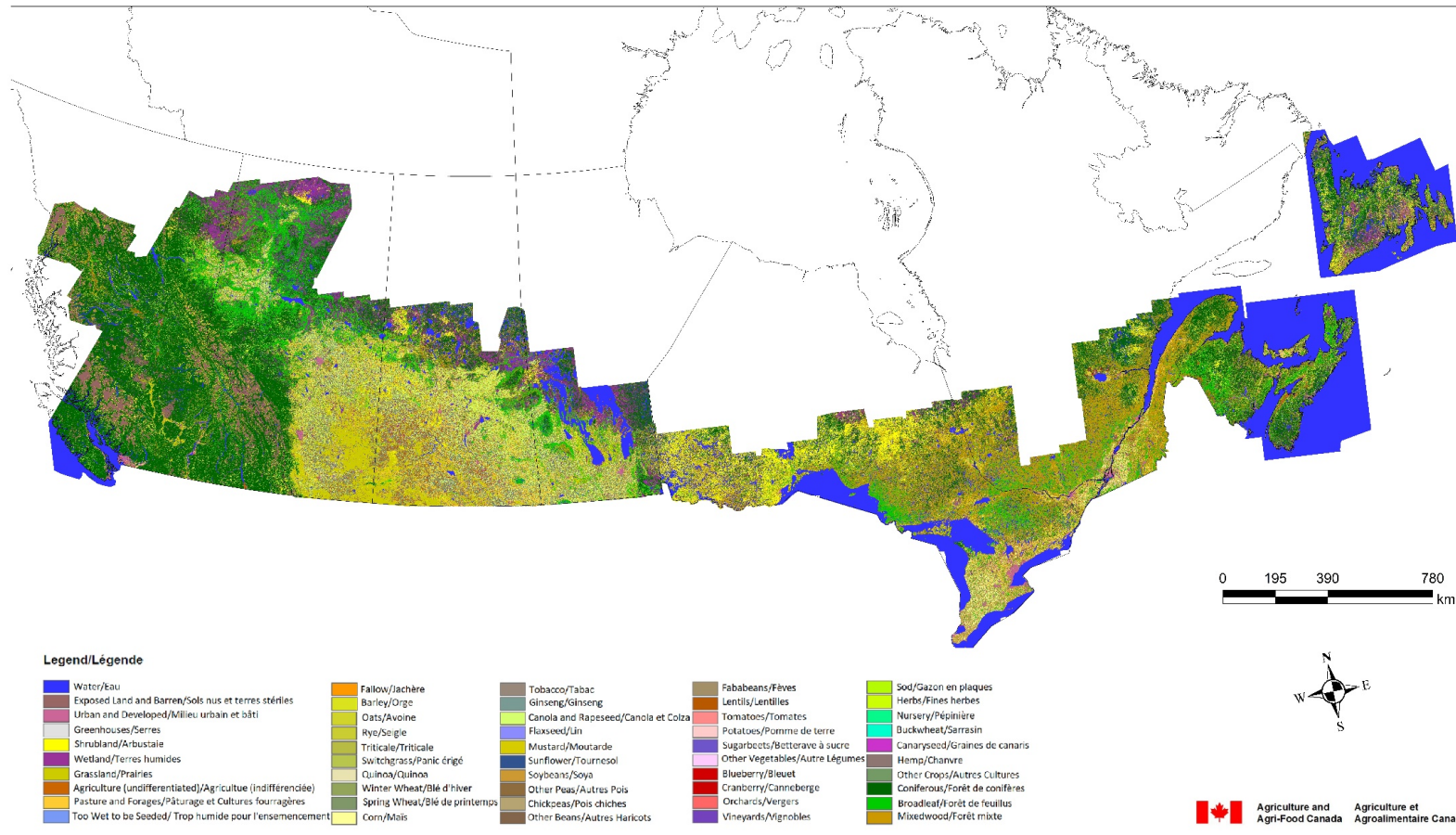
- Canada's agricultural landscape is large and complex: 193,492 farms and 64 million hectares
- In 2009, AAFC began generating annual crop type digital maps for the Prairie Provinces using satellite imagery and expanded the Annual Crop Inventory (ACI) to the entire agricultural extent of Canada in 2011.
- 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)

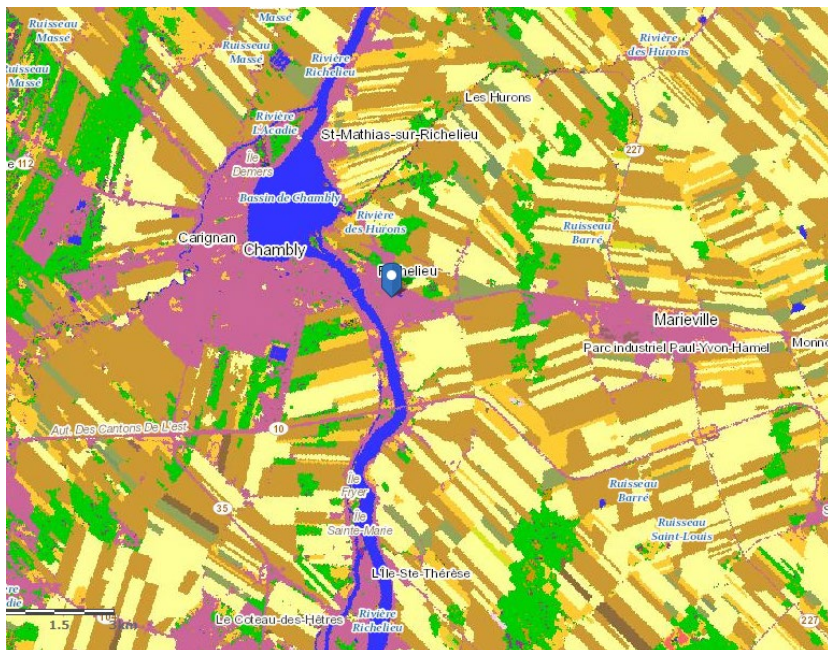
Crop Type Mapping in Canada (2020) Cartographie des types de cultures au Canada (2020)

Agroclimate, Geomatics and Earth Observation Division / Division de l'agroclimatique, de la géomatique et de l'observation de la terre
Science & Technology Branch / Direction générale des sciences et de la technologie



AAFC Annual Crop Inventory (ACI)

Richelieu River, Québec



Central Prince Edward Island



Near Taber, Alberta



Courtesy: Agriculture and Agri-Food Canada



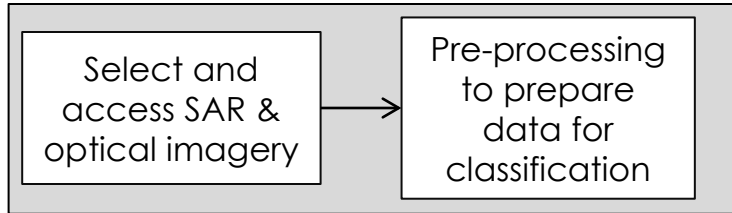
Roadmap for Producing an Annual Crop Inventory

- 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

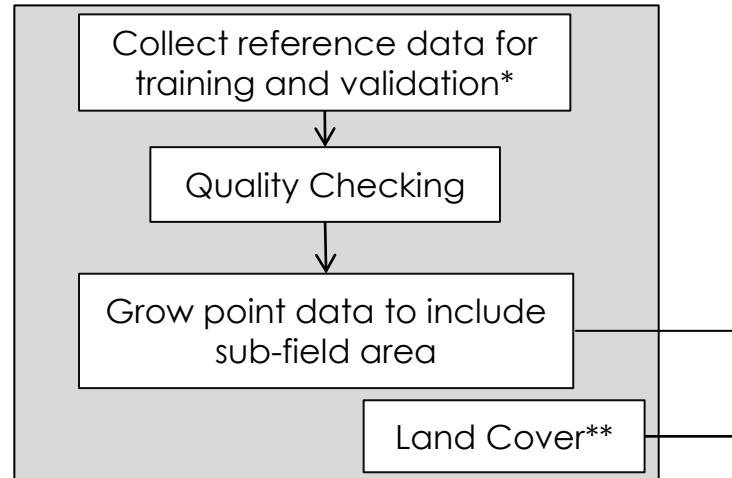


Crop Inventory Operational Methodology

1. Acquire and Process Satellite Imagery



2. Training/Validation Data



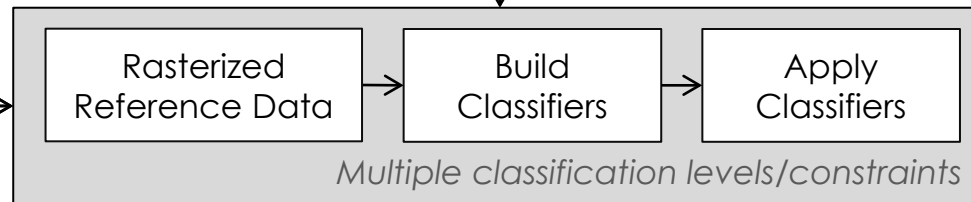
* Potential Sources:

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

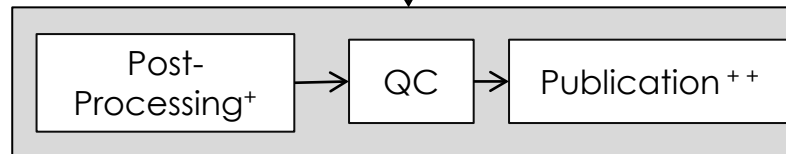
** AAFC does not generate land cover classes during this classification flow, but integrates land cover maps updated every 5 years.

3. Region Creation

4. Classification



5. Final Product



+Thematic filter
Mosaic

++GoC Open Data Portal
AAFC Geospatial Viewer

Courtesy: Agriculture and Agri-Food Canada

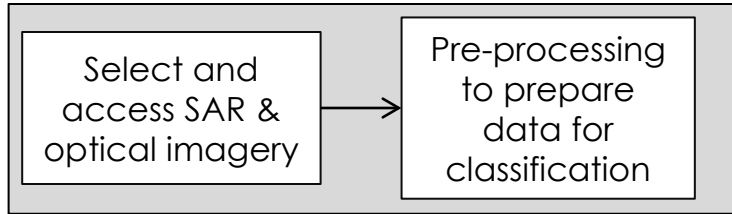




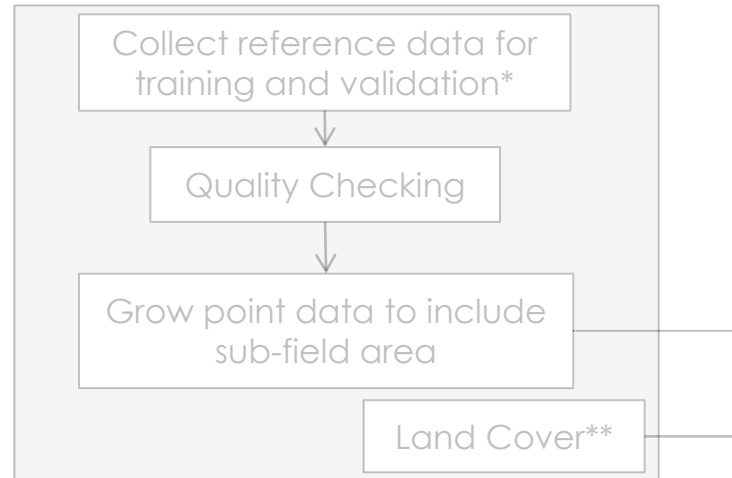
1. Acquire and Pre-process Sentinel-1 & Sentinel-2 Data

Crop Inventory Operational Methodology

1. Acquire and Process Satellite Imagery

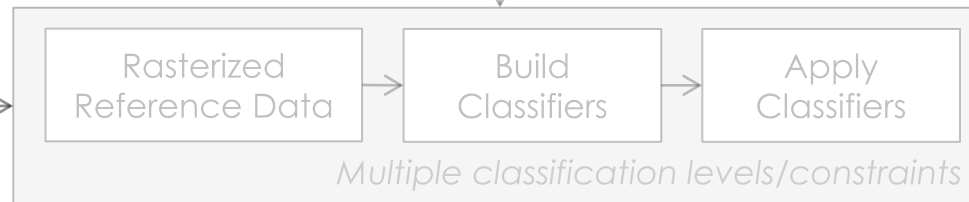


2. Training/Validation Data



3. Region Creation

4. Classification



5. Final Product



SAR Image Selection

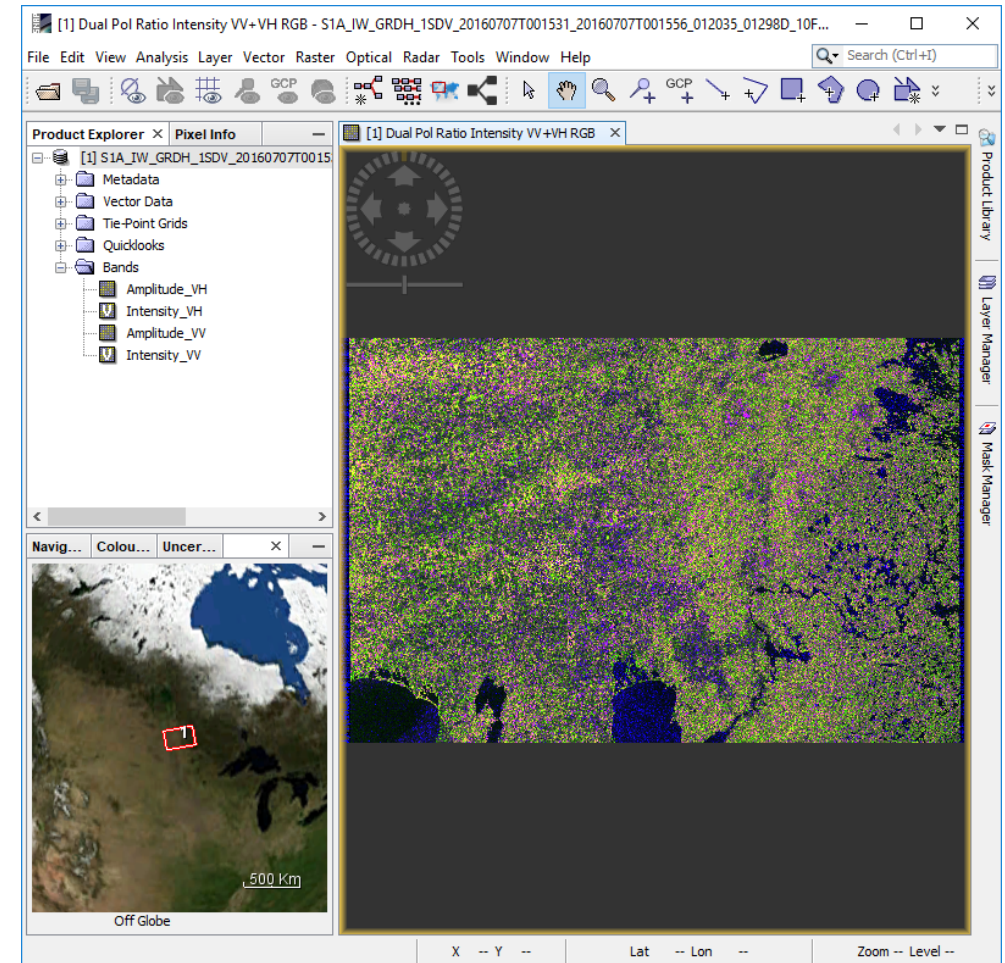
- AAFC uses ~1 SAR image per month, but research has demonstrated that dense stacks of SAR imagery through the season will improve classification accuracies.
- C-Band data are available from Sentinel-1 satellites: A (2014) and B (2016).
- Each Sentinel-1 satellite has a 12-day exact repeat. The two-satellites 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



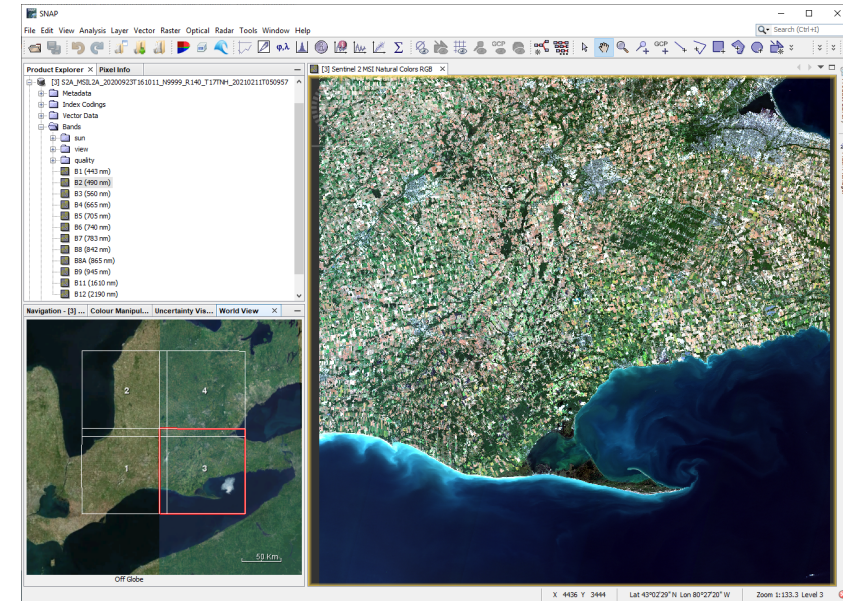
Optical Image Selection

- 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 km² ortho-images in UTM/WGS84 projection.

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

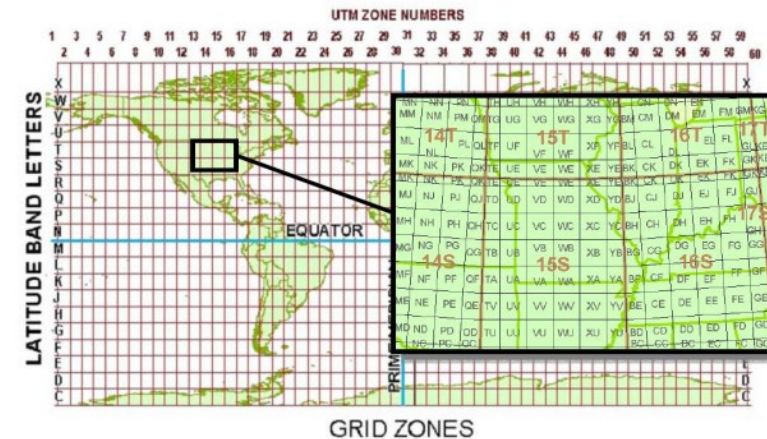


Figure 6: Example of tiling (100x100km²) within the UTM15 zone

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.



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		Spatial resolution (m)
	Central wavelength (nm)	Bandwidth (nm)	Central wavelength (nm)	Bandwidth (nm)	
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>

The screenshot displays the Copernicus Open Access Hub search interface. The top navigation bar includes the ESA and Copernicus logos, the title "Copernicus Open Access Hub", and user icons. A search bar at the top left contains the text "Insert search criteria...".

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

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

Under the Sentinel-1 mission, 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 the Sentinel-1 section, there is a section for Sentinel-2:

- Mission: Sentinel-2
- 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 search panel is a map of a region in Quebec, Canada, with a yellow rectangular area highlighting a specific geographic region. The map shows various towns and cities, including Ottawa, Saint-Jérôme, Montreal, and Cornwall.



Access via ASF

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

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 1 | Contact

Geospatial | Granule | Missions

Geographic Region

Option 1: Click on map and move cursor
Option 2: Enter coordinates:
-98.28,49.71,-98.73,49.06,-97.44,49.06,-97.52,49.7,-98.28,49
e.g., -102,37.59,-94,37,-94,39,-102,39,-102,37.59
Counterclockwise, decimal degrees, (long,lat)

Date

Seasonal Search

Start Date (yyyy-mm-dd)
2016-06-01

End Date (yyyy-mm-dd)
2016-08-01

Dataset

Select: All | None

World Map | South Polar

Satellite
 Map

Showing 1 to 36 of 36 entries

Sentinel-1A EW 2016-08-01
S1A_EW_RAW_0...
Path 85, Frame 423, HH+HV
Flight Direction Descending
Absolute Orbit 12407
Data source ESA
Details Queue Baseline

Sentinel-1A IW 2016-07-31
S1A_IW_RAW_0...
Path 63, Frame 159, VV+VH
Flight Direction Ascending
Absolute Orbit 12385
Data source ESA
Details Queue Baseline

Sentinel-1A IW 2016-07-31
S1A_IW_RAW_0...

Show 100 entries Previous Next

Add to Queue by Type

Number of Frames

1 2-5 6-15 16-20 21+

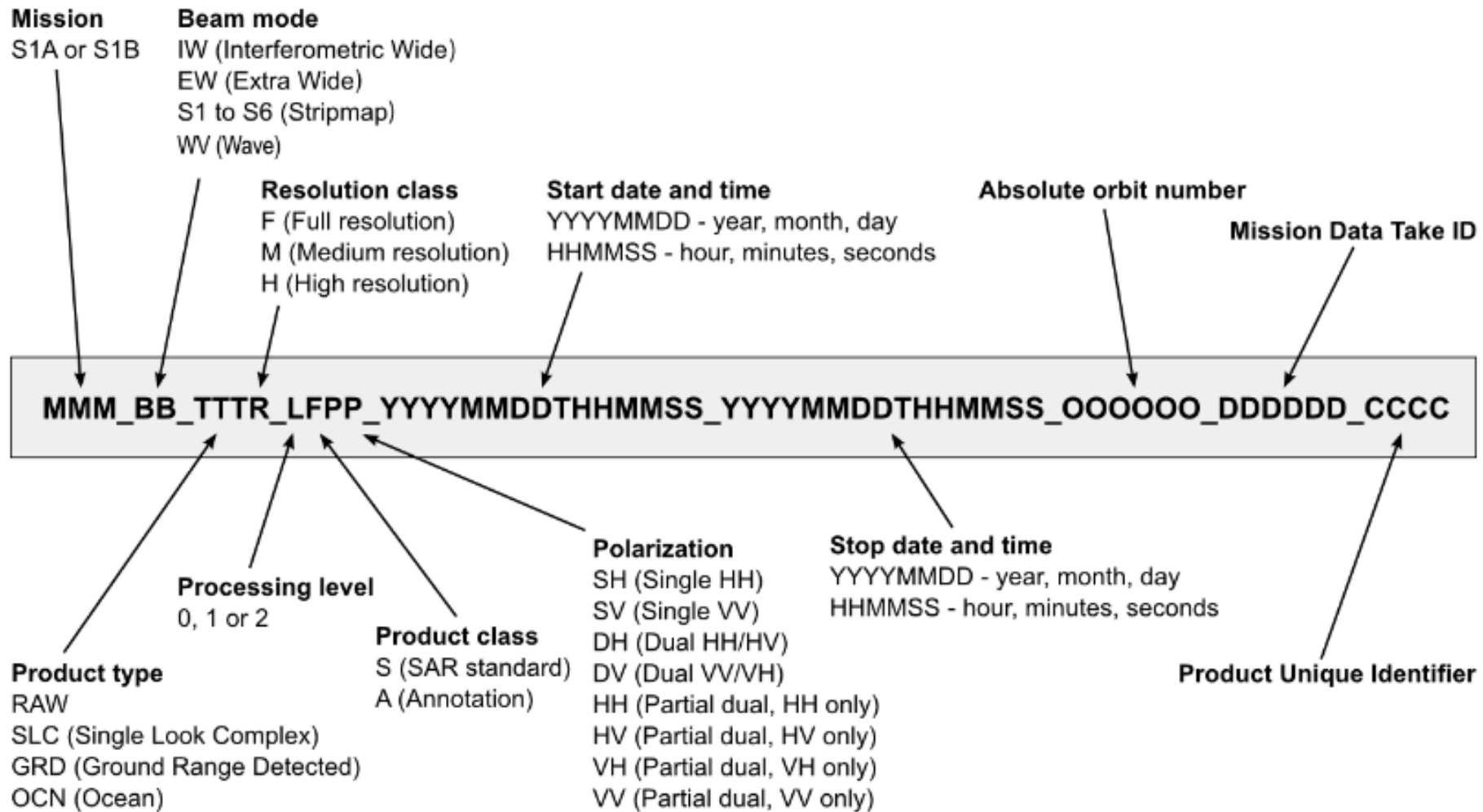
Copyright © 2018 Alaska Satellite Facility
Vertex: ASF's Data Portal V2.58.00-45
Phone: (907) 474-5041 Contact

Vertex

UA is an AA/EEO employer and educational institution and prohibits illegal discrimination against any individual:
www.alaska.edu/nondiscrimination



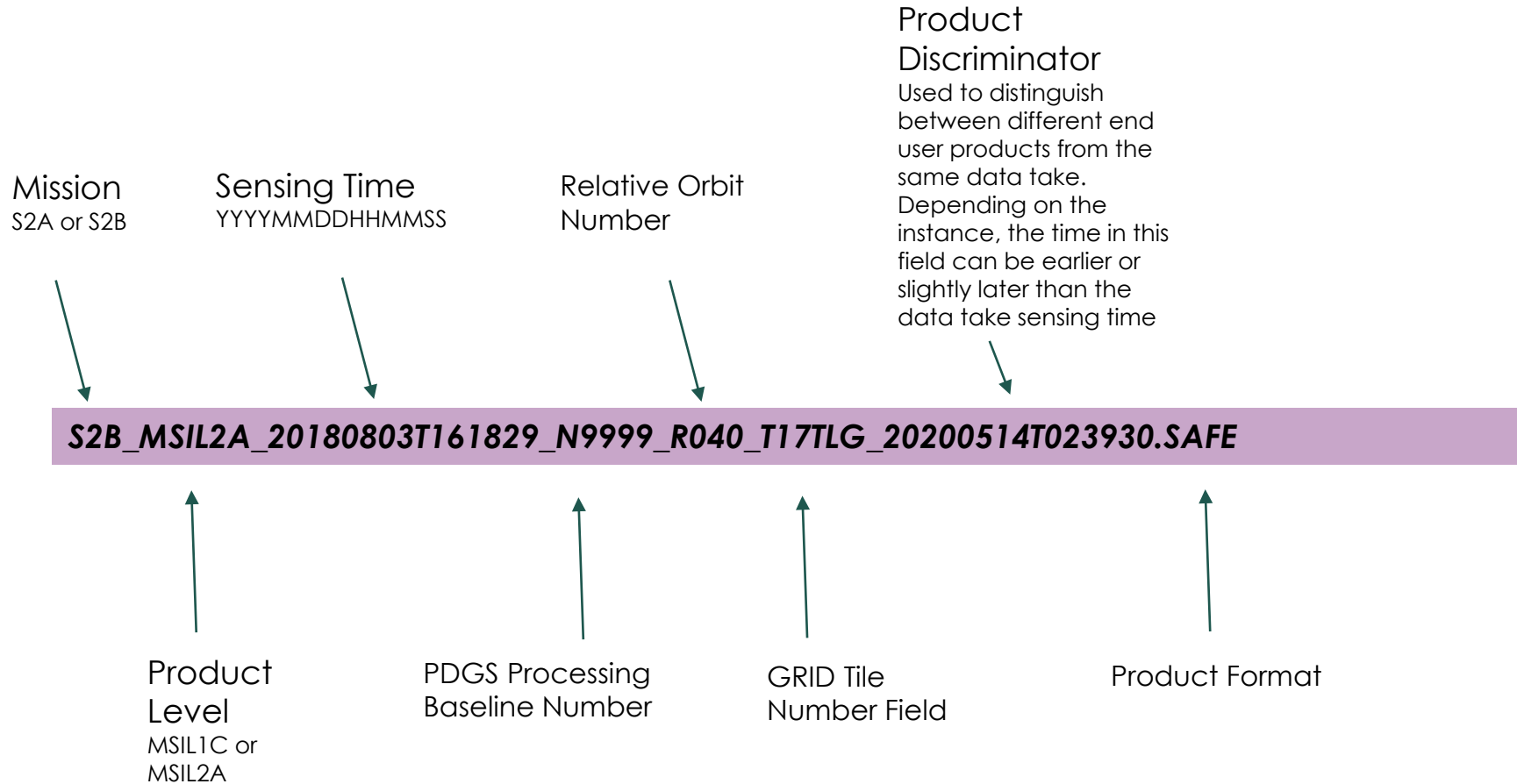
Sentinel-1 Naming Convention



S1A_IW_GRDH_1SDV_20160731T001533_20160731T001558_012385_0134FE_1CFC.zip



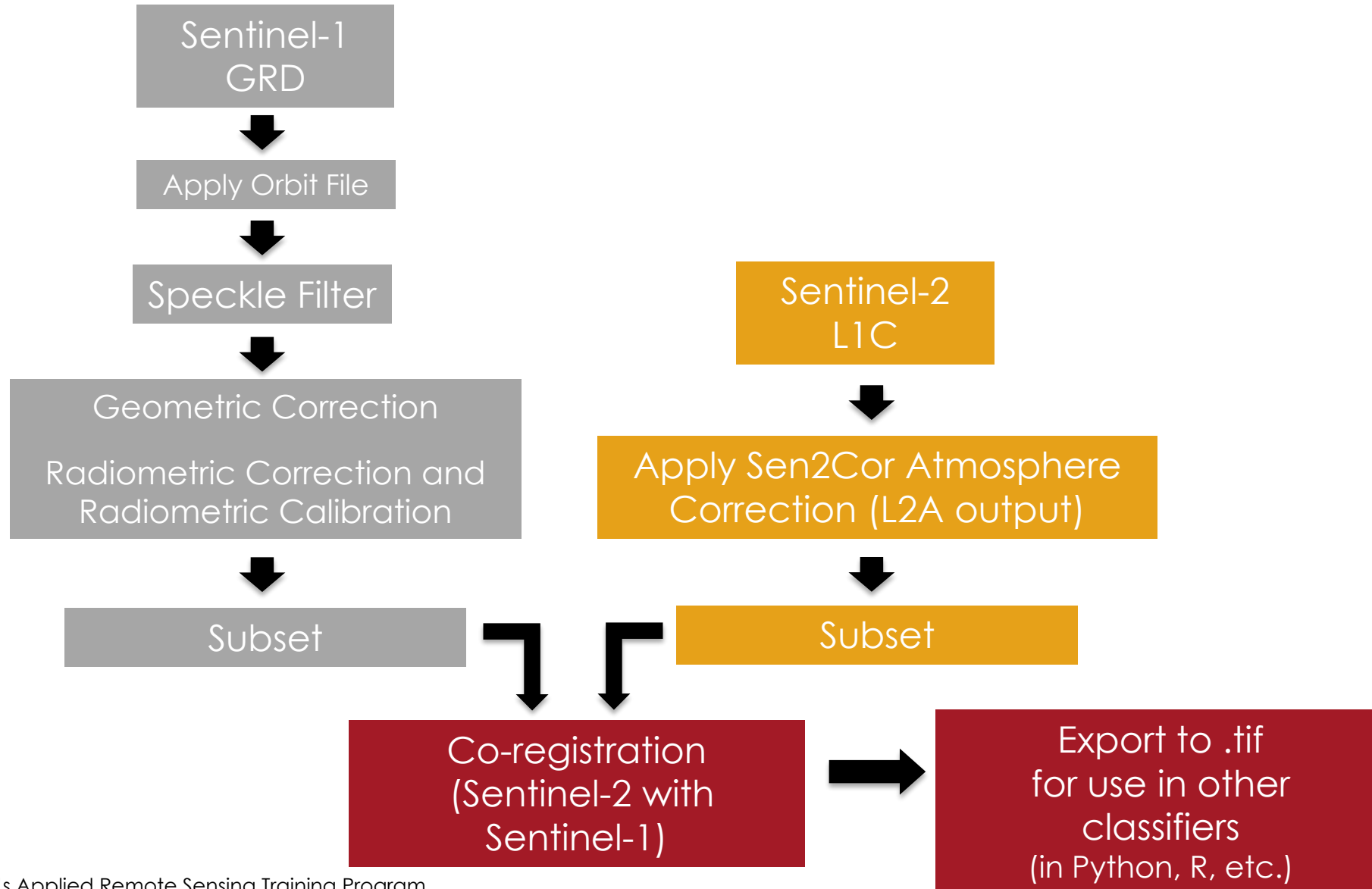
Sentinel-2 Naming Convention



<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

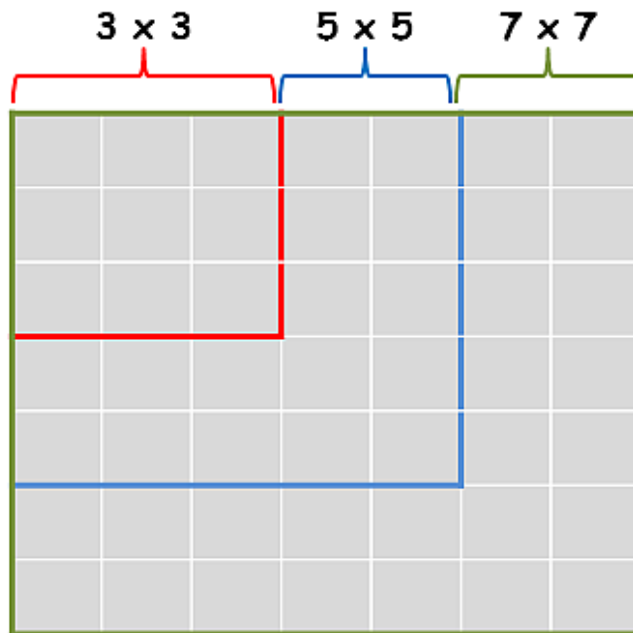
- Satellite positions are recorded by a Global Navigation Satellite System (GNSS).
- To assure a fast delivery of Sentinel-1 products, orbit information generated by an on-board navigation solution is stored within the Sentinel-1 Level-1 products.
- The orbit positions are later refined by the Copernicus 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?

Rice Paddy



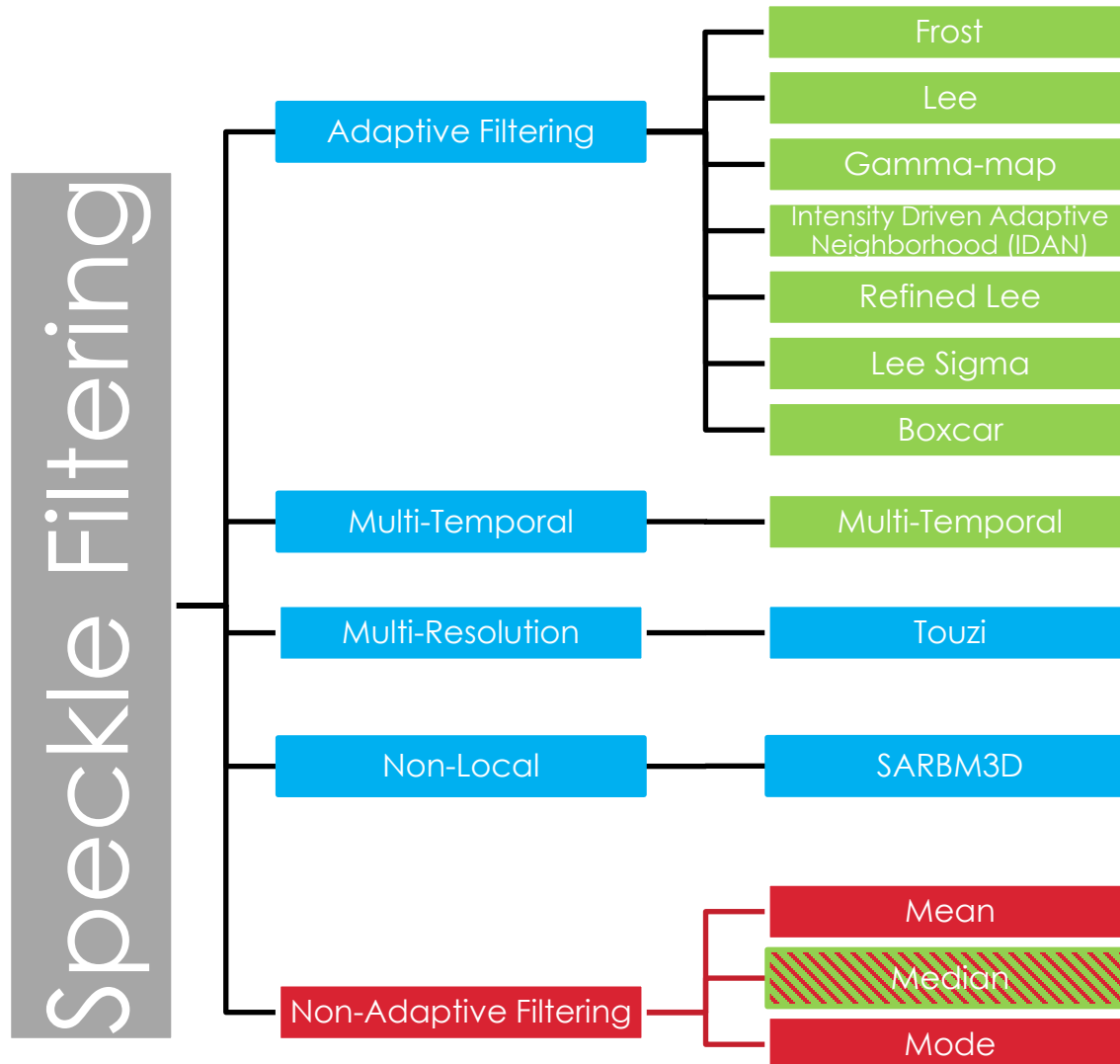
Wheat Field



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.



Available in SNAP



Radar speckle filtering categories & examples

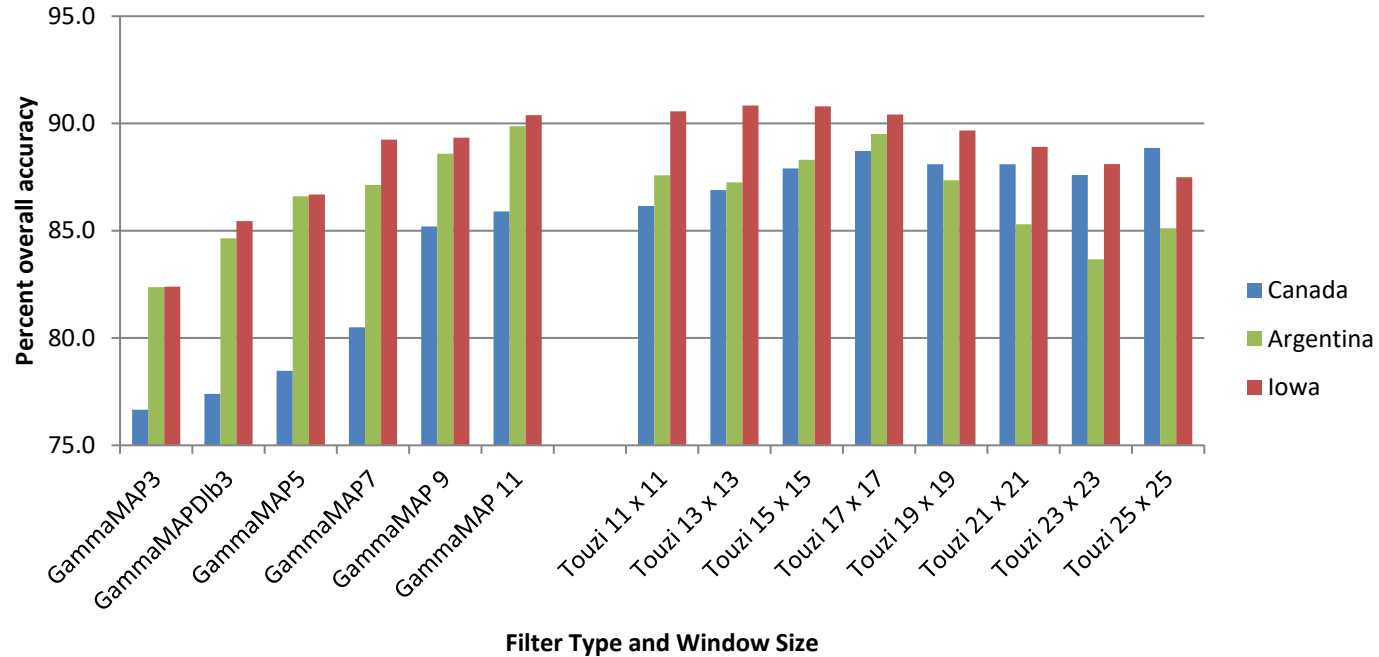


Do not use for radar (including green striped)



Speckle Filter Testing

Comparison of different SAR filters and window sizes based upon the percent overall accuracy of AAFC's operational Decision Tree Classifier and SAR Only data.



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 Abelleira, 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](https://doi.org/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 default¹.
- 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 (A_{dn}) and calibration coefficient (K), and a conversion for local incidence angle (α).

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

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



Applying Sentinel-1 LUT

The radar cross-section (A_σ , A_β or A_γ) 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 structure¹.

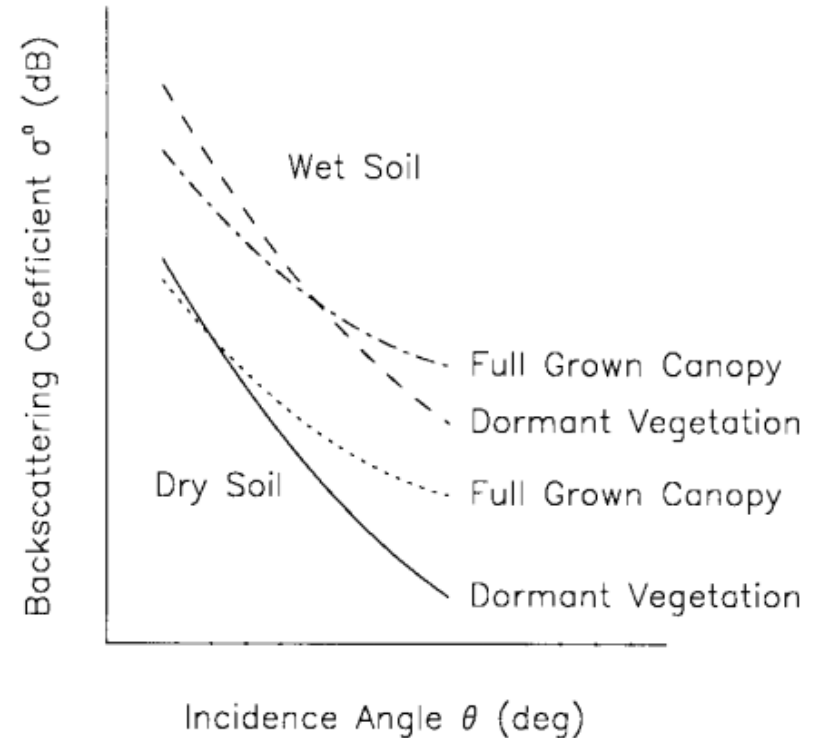


Image Source: W. Wagner, G. Lemoine, M. Borgeaud, and H. Rott. A study of vegetation cover effects on ERS scatterometer data. *IEEE Transactions on Geoscience and Remote Sensing*, 37(2):938–948, Mar 1999. doi:10.1109/36.752212.

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



Terrain Correction

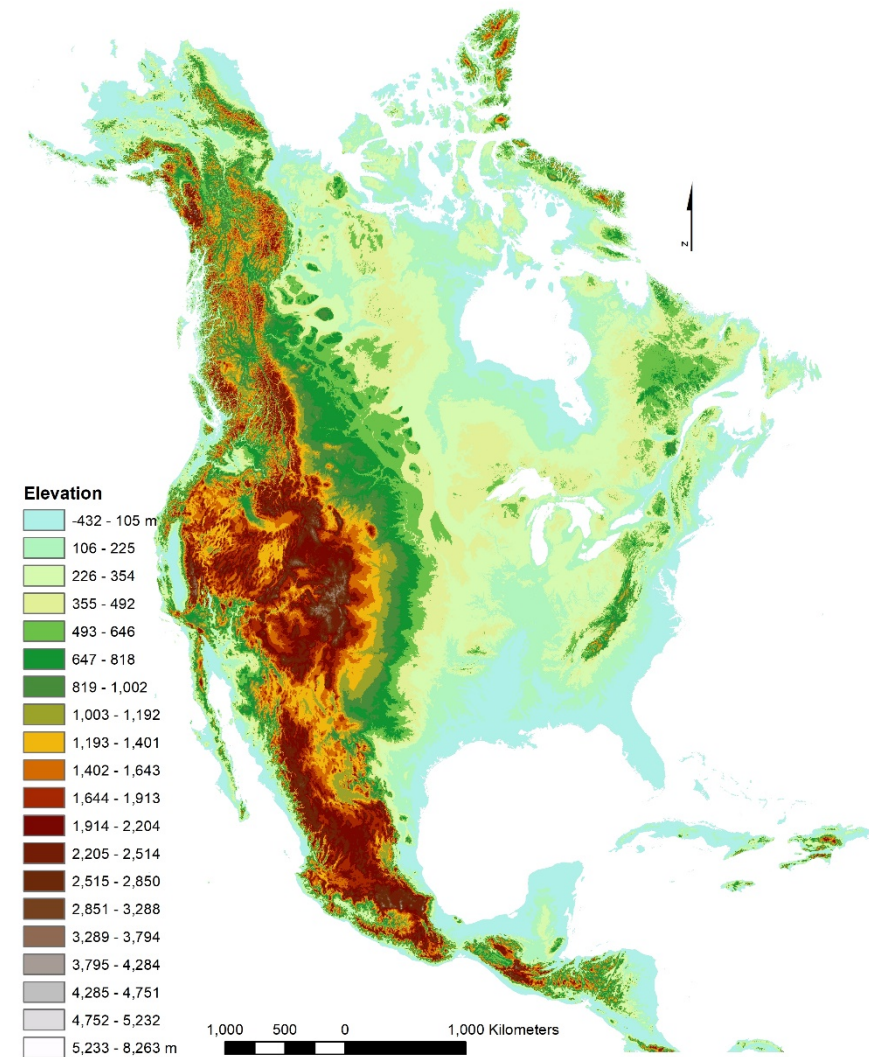
Terrain Correction

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.



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 Estadística Geográfica e Informática (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).

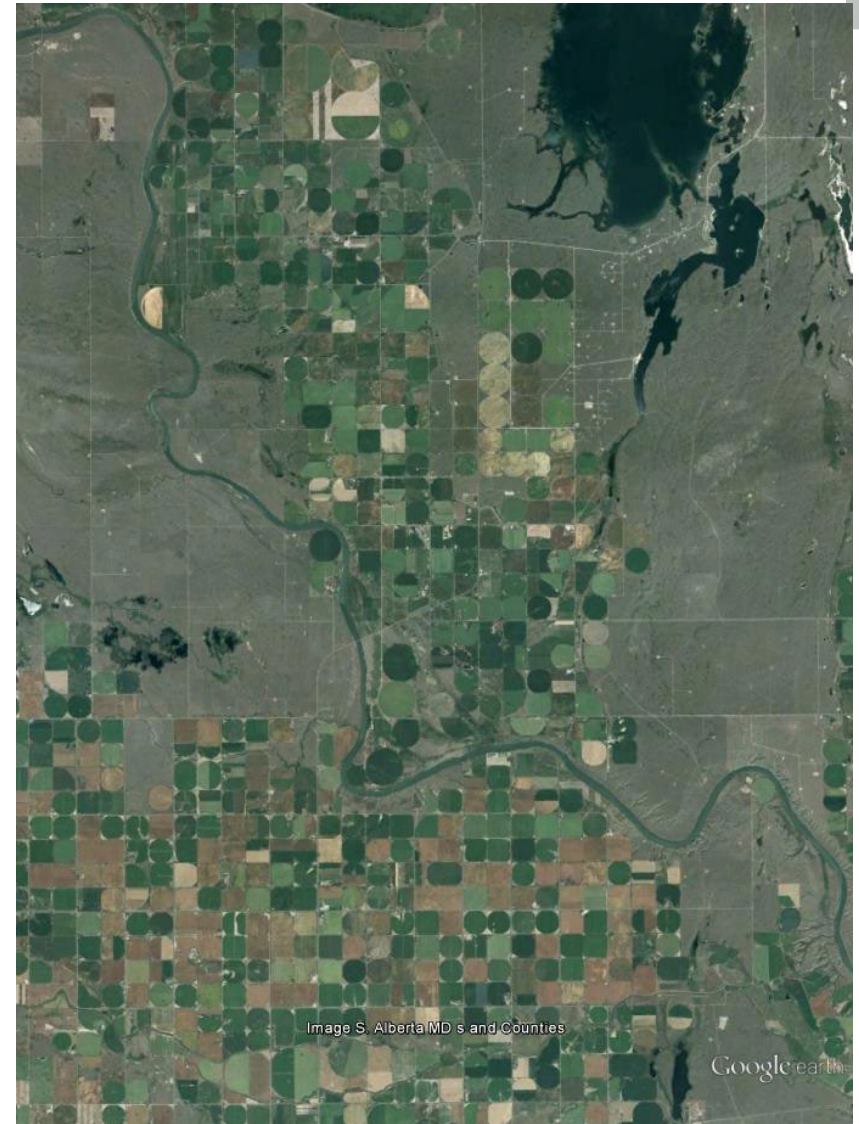


Sentinel-2: Optical Data Pre-Processing

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.

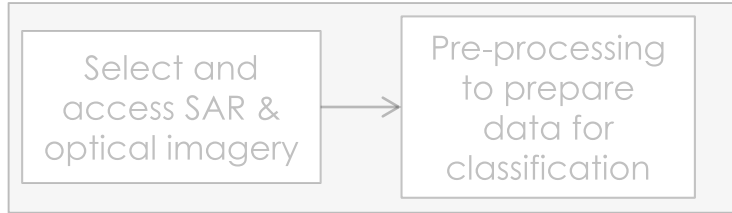




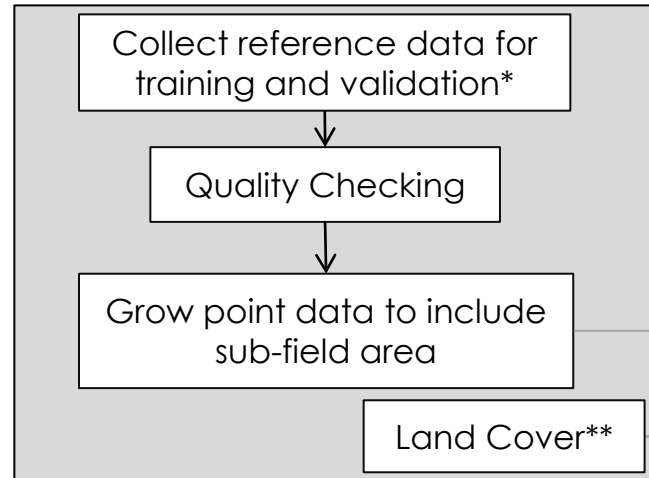
2. Collecting Training and Validation Data

Crop Inventory Operational Methodology

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2. Training/Validation Data



* Potential Sources:

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

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3. Region Creation

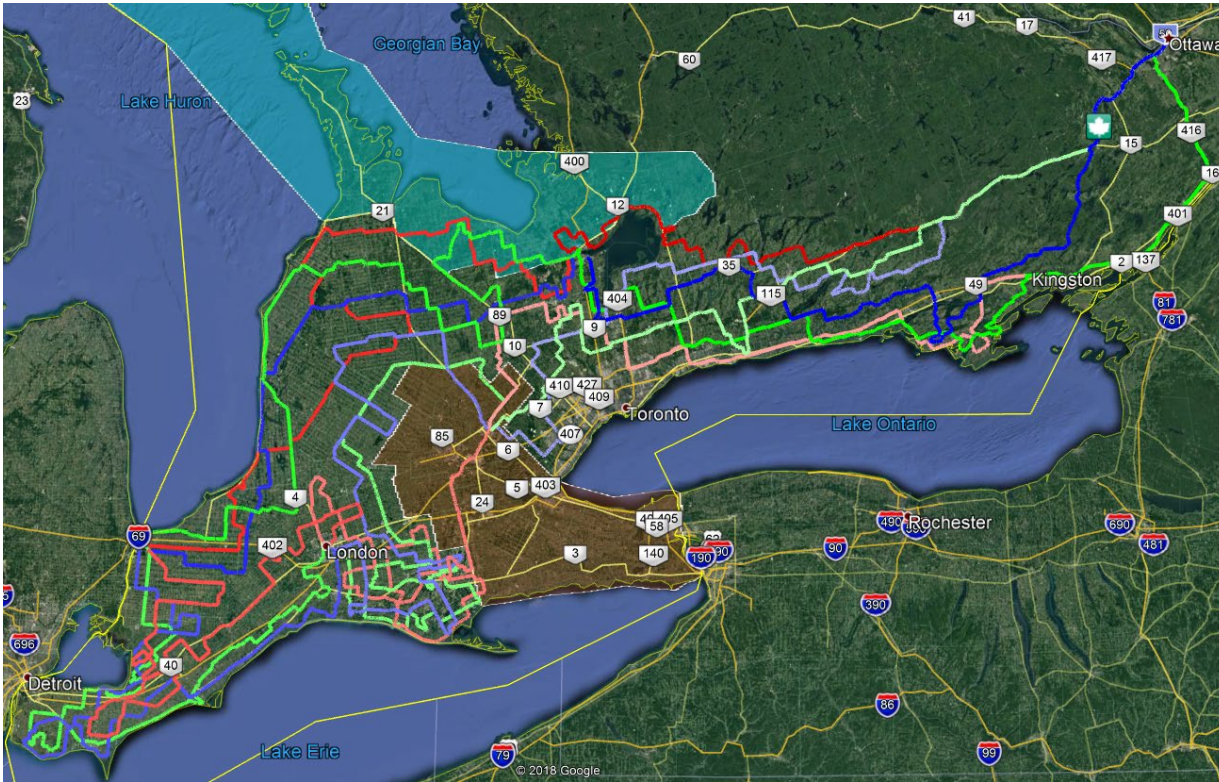
4. Classification



5. Final Product



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!**

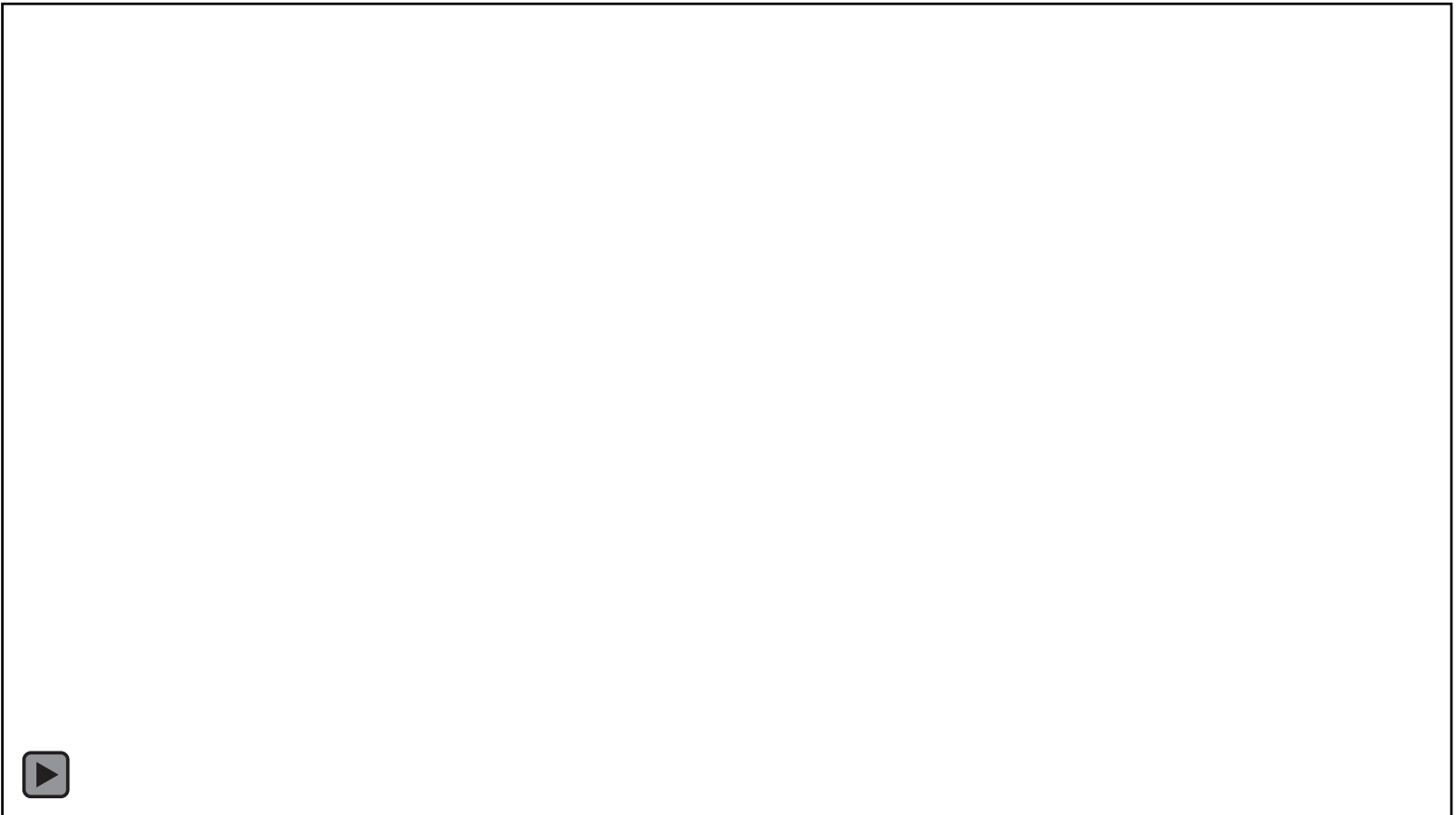


Fieldwork Training

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:

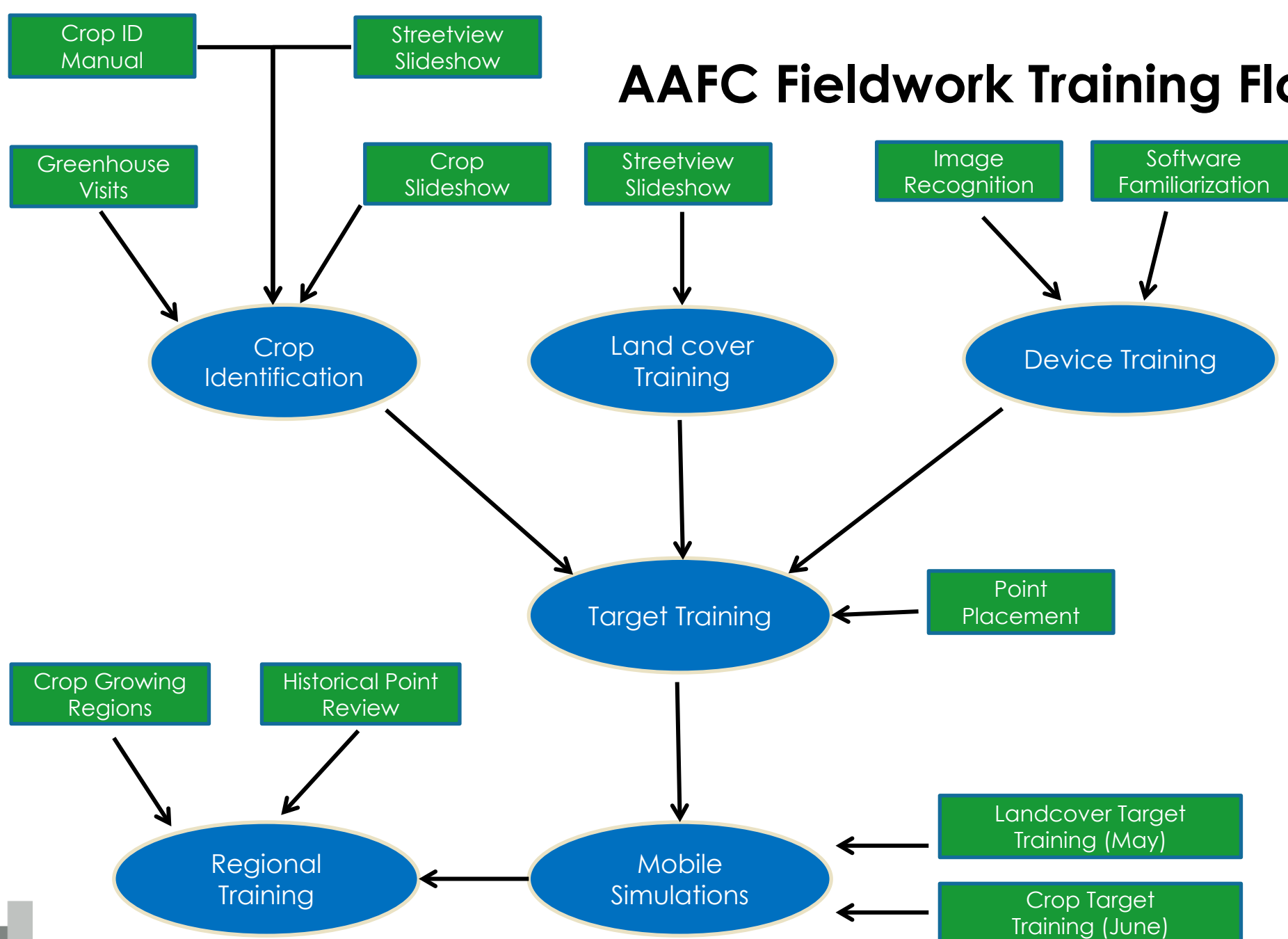
- ESRI – Survey 123
- NGA MAGE – USDA



Courtesy: Agriculture and Agri-Food Canada



AAFC Fieldwork Training Flowchart



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?



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?

0 12.5 25 50 Kilometers
|-----|-----|-----|

Courtesy: Agriculture and Agri-Food Canada

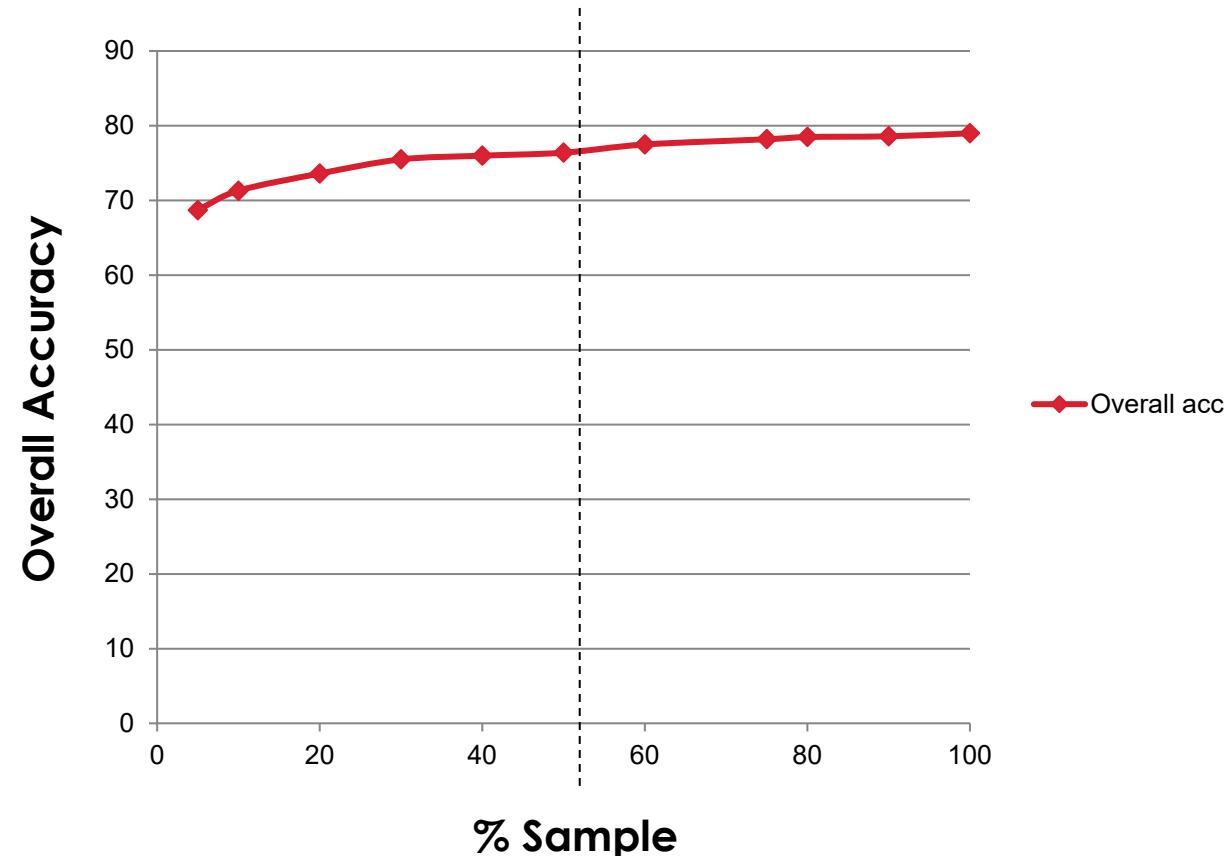
NASA's Applied Remote Sensing Training Program



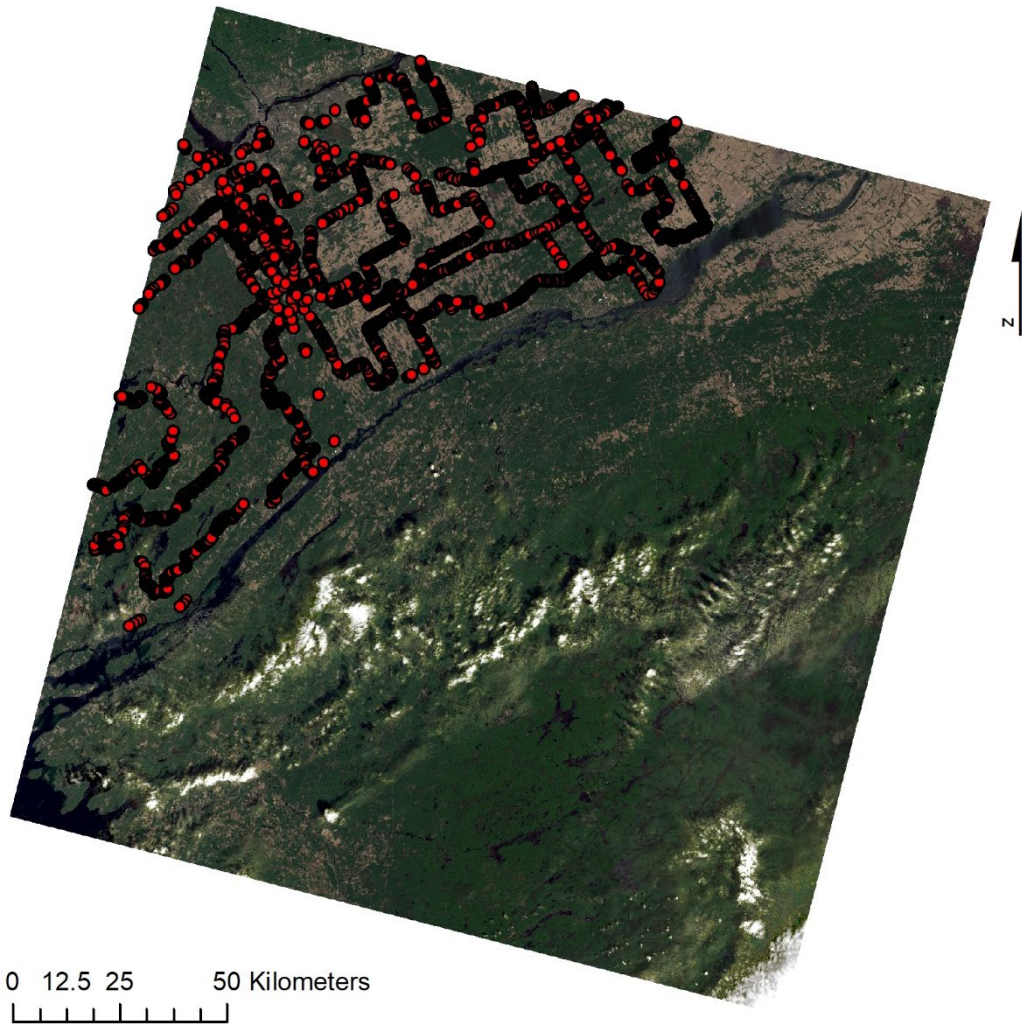
Reducing In Situ Sampling

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



Reducing In Situ Sampling – Subset Testing



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.

Eastern Ontario

Courtesy: Agriculture and Agri-Food Canada
NASA's Applied Remote Sensing Training Program



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.

A AFC 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.)

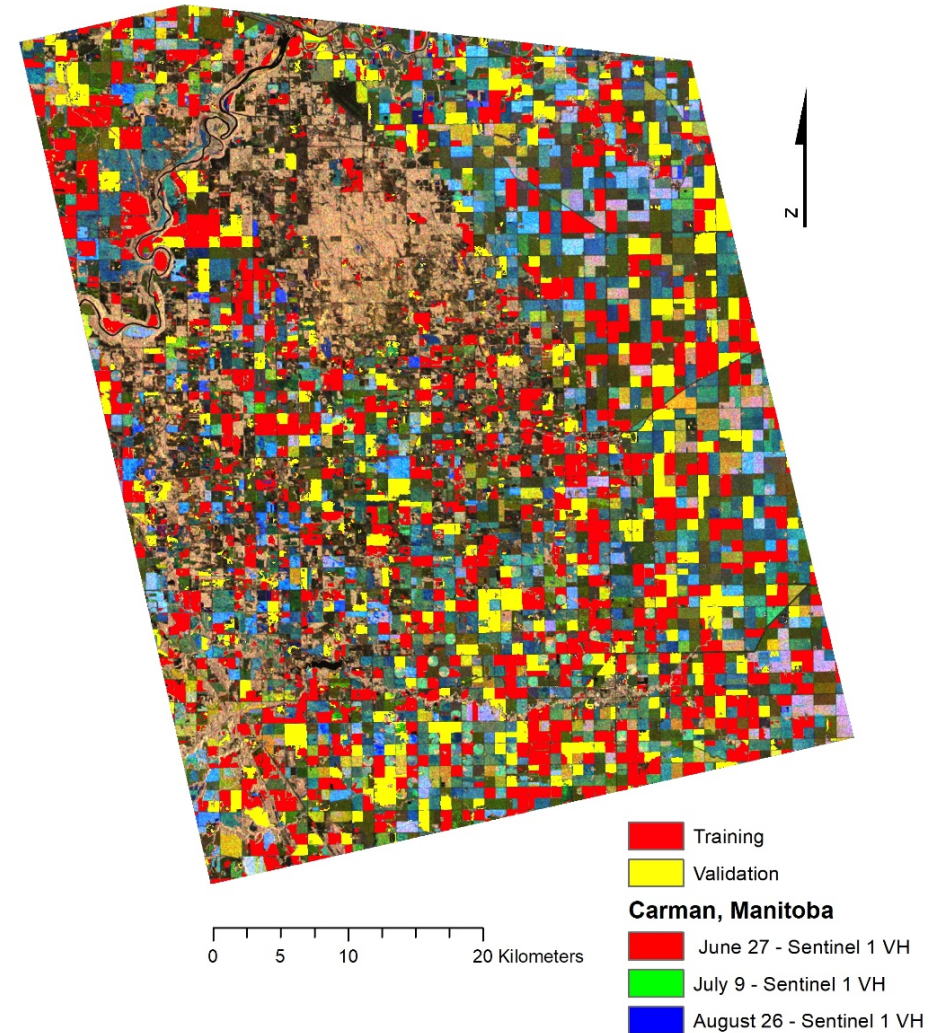
Courtesy: Agriculture and Agri-Food Canada



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)



Hands-On Exercise



Open and Pre-Process Imagery with SNAP



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

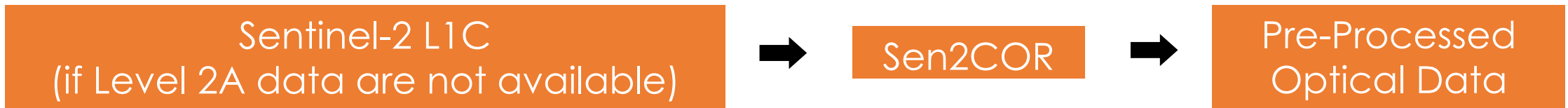


Geometric Correction with
Range Doppler Model

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



Steps for Optical Pre-processing



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>

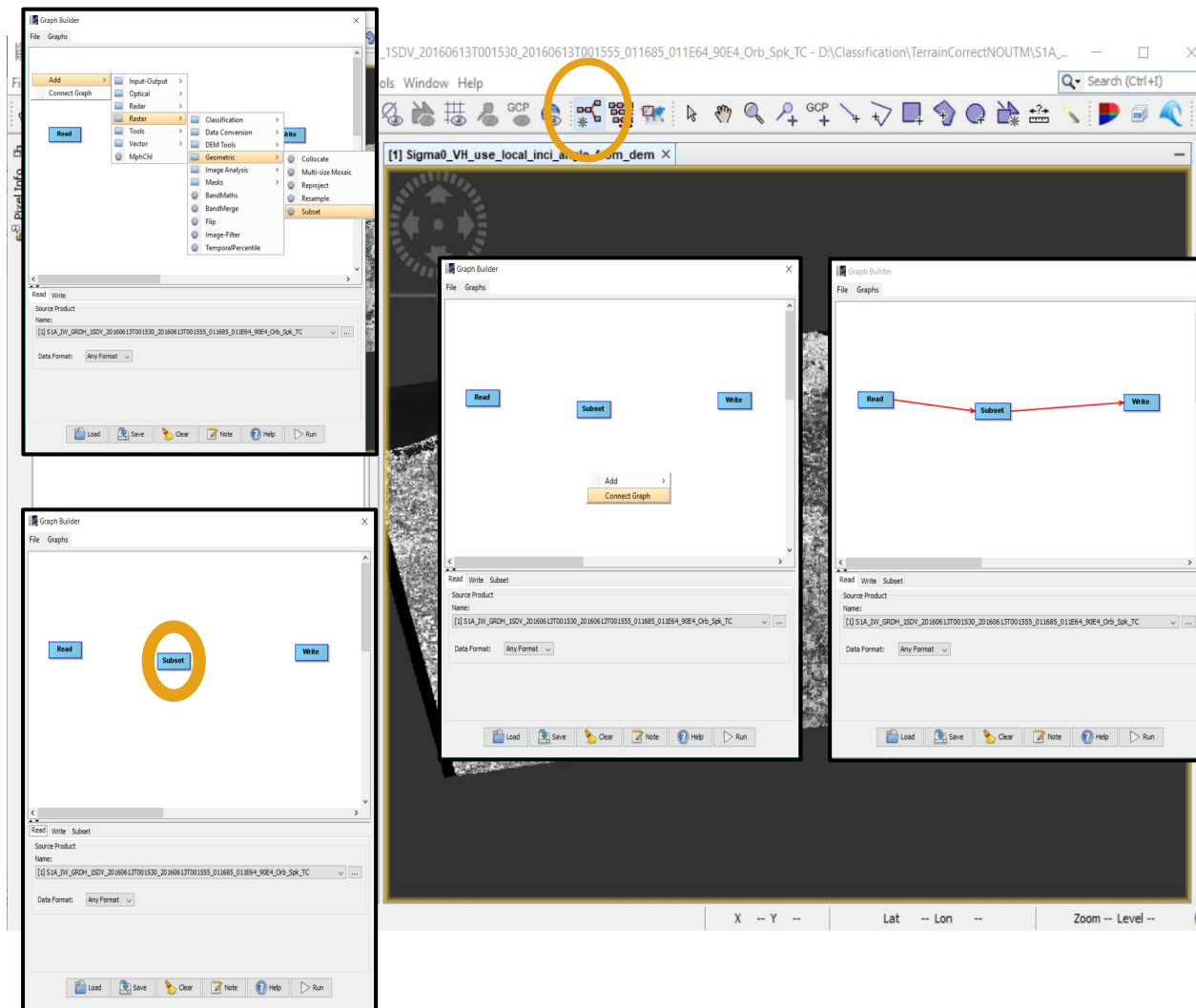


Subsetting, Co-registration & Exporting Files



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. Fiset, H. McNairn and B. Daneshfar. 2017. *Detailed crop mapping using remote sensing data (Crop Data Layers)*. In: J. Delincé (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](https://twitter.com/NASAARSET)





Thank You!

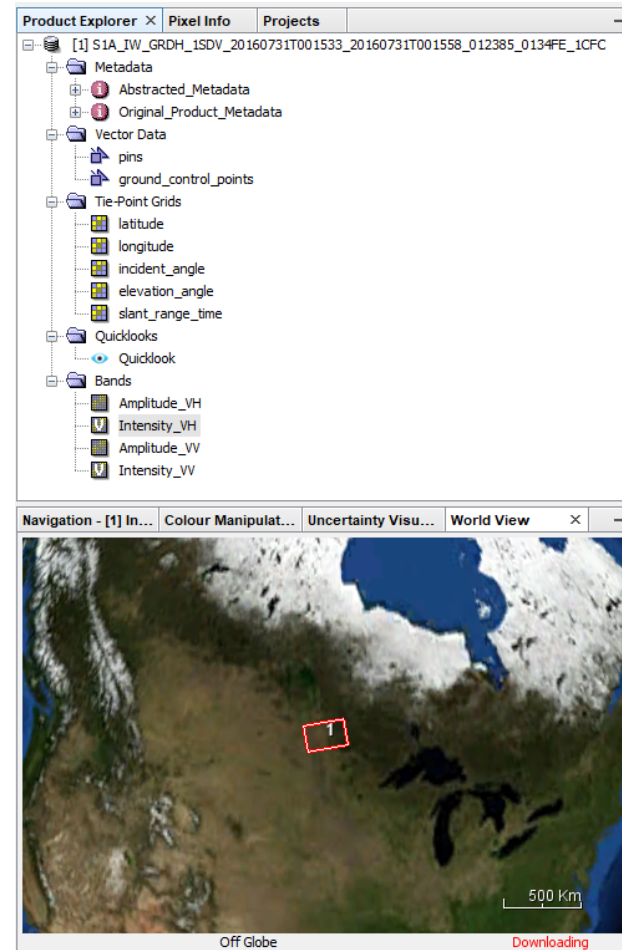




Appendix

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

The screenshot displays the QGIS desktop environment. The main window, titled "[1] Intensity_VH", shows a grayscale Synthetic Aperture Radar (SAR) image of a coastal region. The image is characterized by a dense, granular texture with varying shades of gray, representing different surface features. A navigation toolbar is visible in the top-left corner of the main window, featuring a compass rose and directional arrows.

On the left side, the "Product Explorer" panel is open, showing a hierarchical tree structure for the project "[1] S1A_IW_GRDH_1SDV_20160731T001533_20160731T001558_012385_0134FE_1CFC". The tree includes folders for "Metadata", "Vector Data", "Tie-Point Grids", "Quicklooks", and "Bands". Under the "Bands" folder, four items are listed: "Amplitude_VH", "Intensity_VH" (which is selected), "Amplitude_VV", and "Intensity_VV".

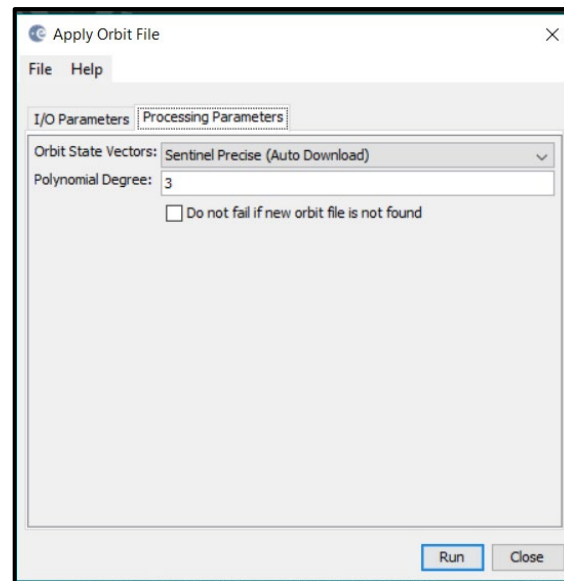
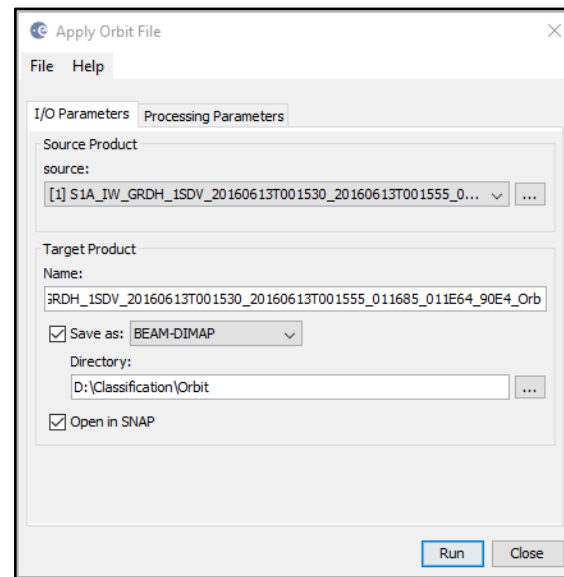
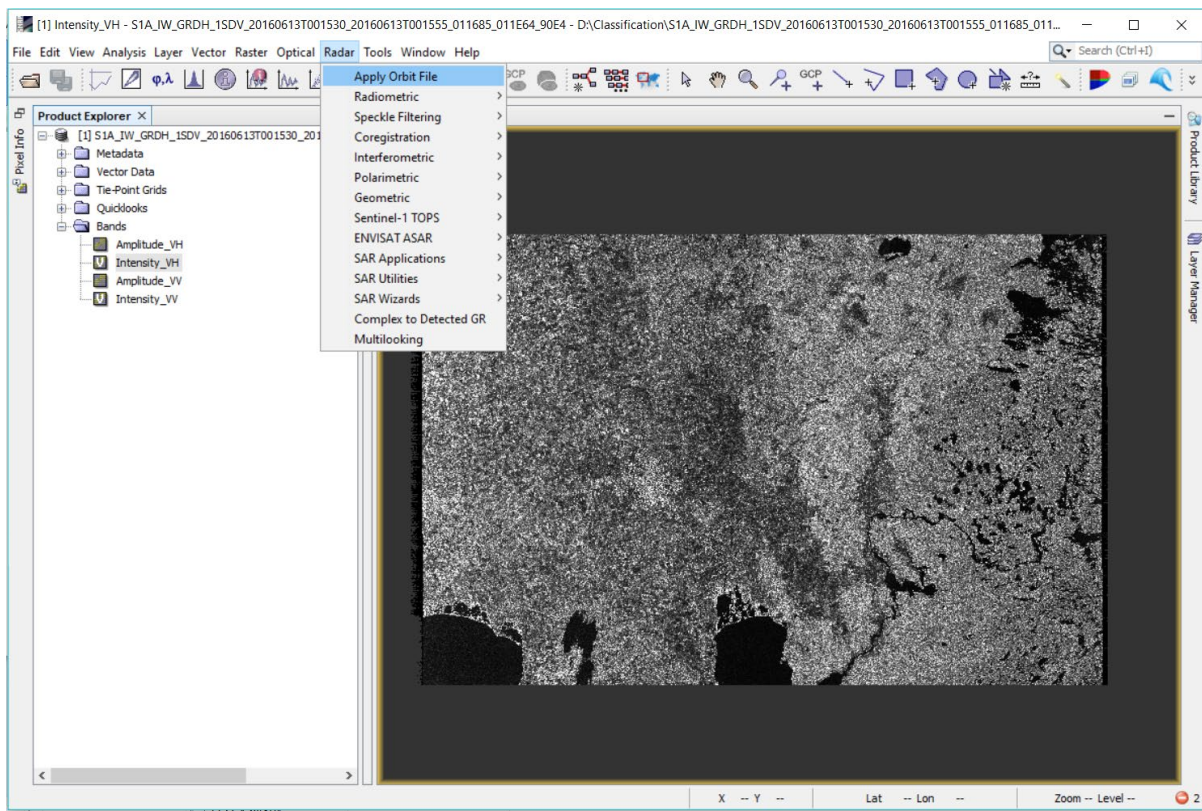
At the bottom left, a "World View" panel shows a satellite-style map of the Earth. A red rectangular box on the map indicates the geographic location of the SAR image. A scale bar at the bottom right of the World View panel shows "500 Km". The text "Off Globe" is visible below the World View panel.

The top of the QGIS window shows the standard menu bar (File, Edit, View, Analysis, Layer, Vector, Raster, Optical, Radar, Tools, Window, Help) and a search bar with the text "Search (Ctrl+I)".

Apply Orbit File

1. Go to Radar Menu >> Apply Orbit File:

- I/O Parameters tab: source → Raw image + Target Product
- Processing Parameters tab: Orbit State Vectors → Sentinel Precise Auto Download; Polynomial Degrees → 3
- Click Run and Close window when completed

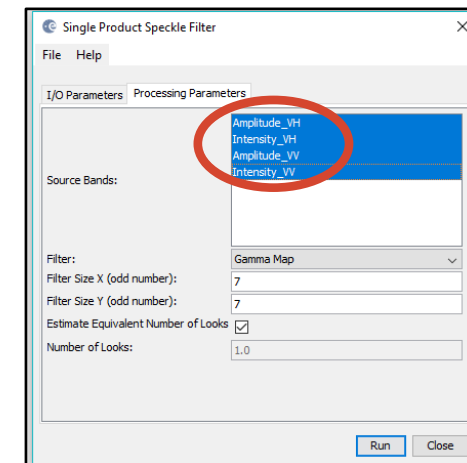
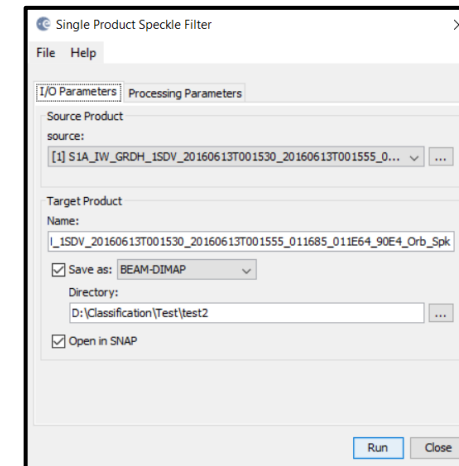
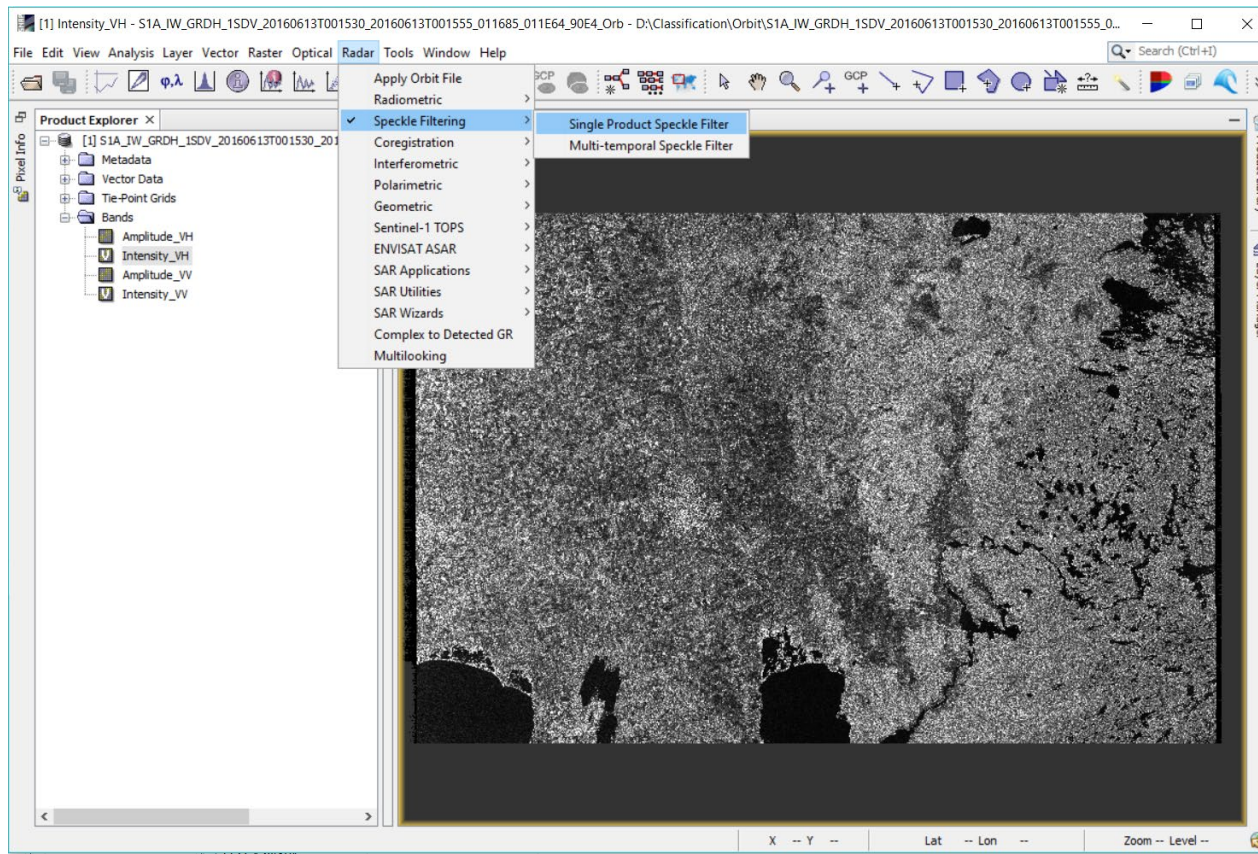


Apply Orbit File

The image shows the SNAP (Sentinel Application Platform) software interface. The main window displays a SAR image with a menu open over the 'Radar' tab. The 'Apply Orbit File' option is highlighted, and a red arrow points from it to the 'Apply Orbit File' dialog box in the foreground. The dialog box has two tabs: 'I/O Parameters' and 'Processing Parameters'. The 'I/O Parameters' tab is active, showing 'Orbit State Vectors' set to 'Sentinel Precise (Auto Download)' and 'Polynomial Degree' set to '3'. There is a checkbox for 'Do not fail if new orbit file is not found' which is currently unchecked. The 'Processing Parameters' tab is also visible, showing 'Source Product' as '[1] S1A_IW_GRDH_1SDV_20160613T001530_20160613T001555_0...', 'Target Product' Name as 'S1A_IW_GRDH_1SDV_20160613T001530_20160613T001555_011685_011E64_90E4_Orb', 'Save as' set to 'BEAM-DIMAP', and 'Directory' set to 'D:\Classification\Orbit'. The 'Open in SNAP' checkbox is checked. Both dialog boxes have 'Run' and 'Close' buttons at the bottom.

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 x 7
 - c) Click Run and Close window when completed



Apply Speckle Filter

The image shows the SNAP (Scientific Data Processing) software interface. The main window displays a SAR image with a speckle filter applied. The 'Radar' menu is open, showing the 'Speckle Filtering' option selected. Below it, the 'Single Product Speckle Filter' dialog box is open, showing the 'Processing Parameters' tab. The 'Source Product' is set to '[1] S1A_IW_GRDH_1SDV_20160613T001530_20160613T001555_011685_011E64_90E4_Orb'. The 'Target Product' name is '_1SDV_20160613T001530_20160613T001555_011685_011E64_90E4_Orb_Spk'. The 'Save as' option is checked and set to 'BEAM-DIMAP'. The 'Directory' is 'D:\Classification\Test\test2'. The 'Open in SNAP' option is also checked. The 'Processing Parameters' tab shows the 'Source Bands' list with 'Amplitude_VH', 'Intensity_VH', 'Amplitude_VV', and 'Intensity_VV' selected. The 'Filter' is set to 'Gamma Map', 'Filter Size X' is 7, 'Filter Size Y' is 7, 'Estimate Equivalent Number of Looks' is checked, and 'Number of Looks' is 1.0.

File Edit View Analysis Layer Vector Raster Optical Radar Tools Window Help

Search (Ctrl+I)

Product Explorer

- [1] S1A_IW_GRDH_1SDV_20160613T001530_20160613T001555_011685_011E64_90E4_Orb
 - Metadata
 - Vector Data
 - Tie-Point Grids
 - Bands
 - Amplitude_VH
 - Intensity_VH
 - Amplitude_VV
 - Intensity_VV

Apply Orbit File
Radiometric
✓ Speckle Filtering

- Single Product Speckle Filter
- Multi-temporal Speckle Filter

- Coregistration
- Interferometric
- Polarimetric
- Geometric
- Sentinel-1 TOPS
- ENVISAT ASAR
- SAR Applications
- SAR Utilities
- SAR Wizards
- Complex to Detected GR
- Multilooking

Single Product Speckle Filter

File Help

I/O Parameters Processing Parameters

Source Product

source:

[1] S1A_IW_GRDH_1SDV_20160613T001530_20160613T001555_011685_011E64_90E4_Orb

Target Product

Name:

_1SDV_20160613T001530_20160613T001555_011685_011E64_90E4_Orb_Spk

Save as: BEAM-DIMAP

Directory:

D:\Classification\Test\test2

Open in SNAP

Run Close

Single Product Speckle Filter

File Help

I/O Parameters Processing Parameters

Source Bands:

- Amplitude_VH
- Intensity_VH
- Amplitude_VV
- Intensity_VV

Filter: Gamma Map

Filter Size X (odd number): 7

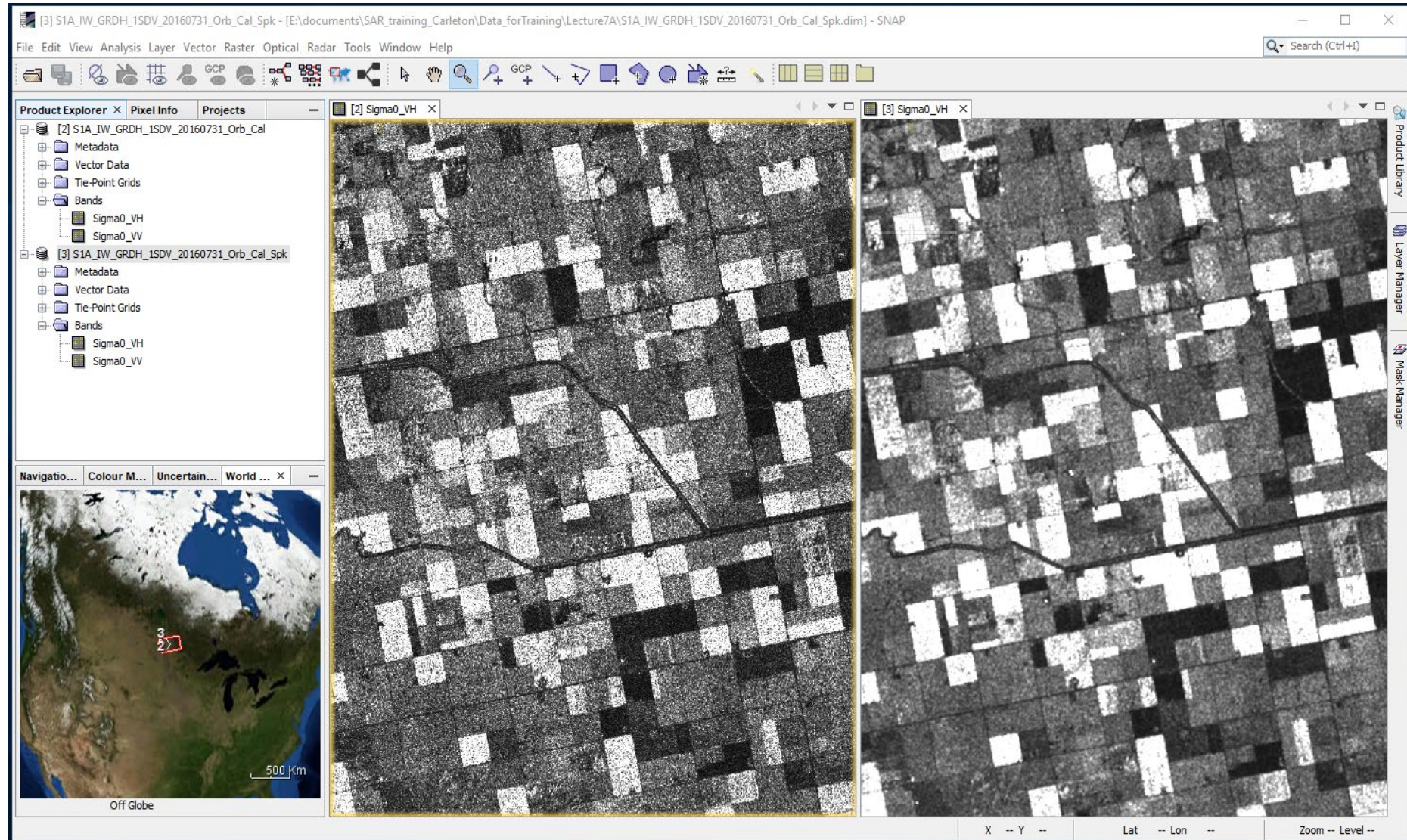
Filter Size Y (odd number): 7

Estimate Equivalent Number of Looks

Number of Looks: 1.0

Run Close

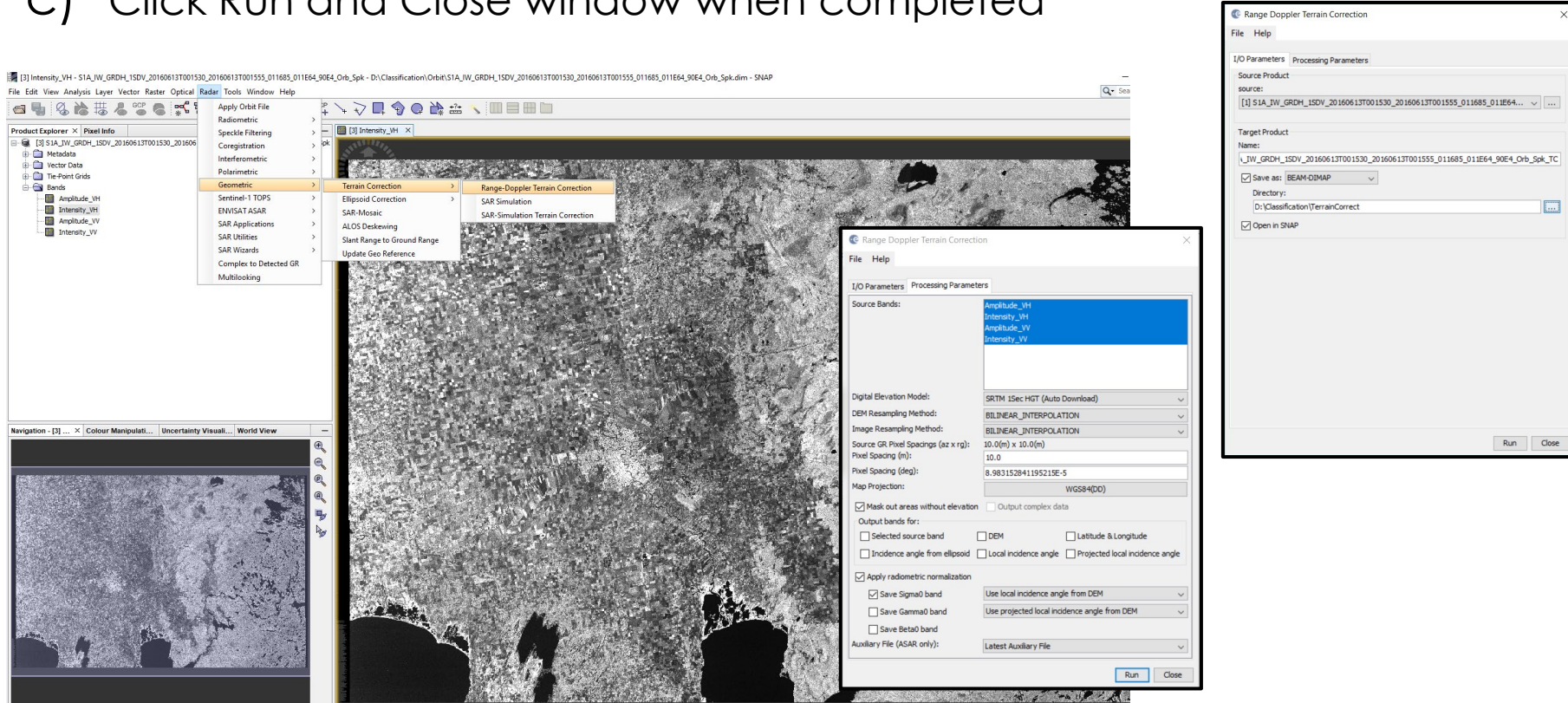
Speckle Filter the Sentinel-1 Image



Terrain Correction

1. Go to Radar Menu >> Geometric >> Terrain Correction >> Range Doppler Terrain Correction

- I/O Parameters tab: source → Speckle image + Target product
- 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
- Click Run and Close window when completed



Terrain Correction

[3] Intensity_VH - S1A_IW_GRDH_1SDV_20160613T001530_20160613T001555_011685_011E64_90E4_Orb_Spk - D:\Classification\Orbit\S1A_IW_GRDH_1SDV_20160613T001530_20160613T001555_011685_011E64_90E4_Orb_Spk.dim - SNAP

File Edit View Analysis Layer Vector Raster Optical Radar Tools Window Help

Product Explorer X Pixel Info

- [3] S1A_IW_GRDH_1SDV_20160613T001530_20160613T001555_011685_011E64_90E4_Orb_Spk
 - Metadata
 - Vector Data
 - Tie-Point Grids
 - Bands
 - Amplitude_VH
 - Intensity_VH
 - Amplitude_VV
 - Intensity_VV

Apply Orbit File
Radiometric
Speckle Filtering
Coregistration
Interferometric
Polarimetric
Geometric > Terrain Correction > Range-Doppler Terrain Correction

- SAR Simulation
- SAR-Simulation Terrain Correction

- Sentinel-1 TOPS >
- ENVIASAT ASAR >
- SAR Applications >
- SAR Utilities >
- SAR Wizards >
- Complex to Detected GR
- Multilooking

Navigation - [3] ... X Colour Manipulati... Uncertainty Visuali... World View

Range Doppler Terrain Correction

File Help

I/O Parameters Processing Parameters

Source Bands: Amplitude_VH
Intensity_VH
Amplitude_VV
Intensity_VV

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): 10.0(m) x 10.0(m)

Pixel Spacing (m): 10.0

Pixel Spacing (deg): 8.983152841195215E-5

Map Projection: WGS84(DD)

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 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

Run Close

Range Doppler Terrain Correction

File Help

I/O Parameters Processing Parameters

Source Product

source: [1] S1A_IW_GRDH_1SDV_20160613T001530_20160613T001555_011685_011E64...

Target Product

Name: _IW_GRDH_1SDV_20160613T001530_20160613T001555_011685_011E64_90E4_Orb_Spk_TC

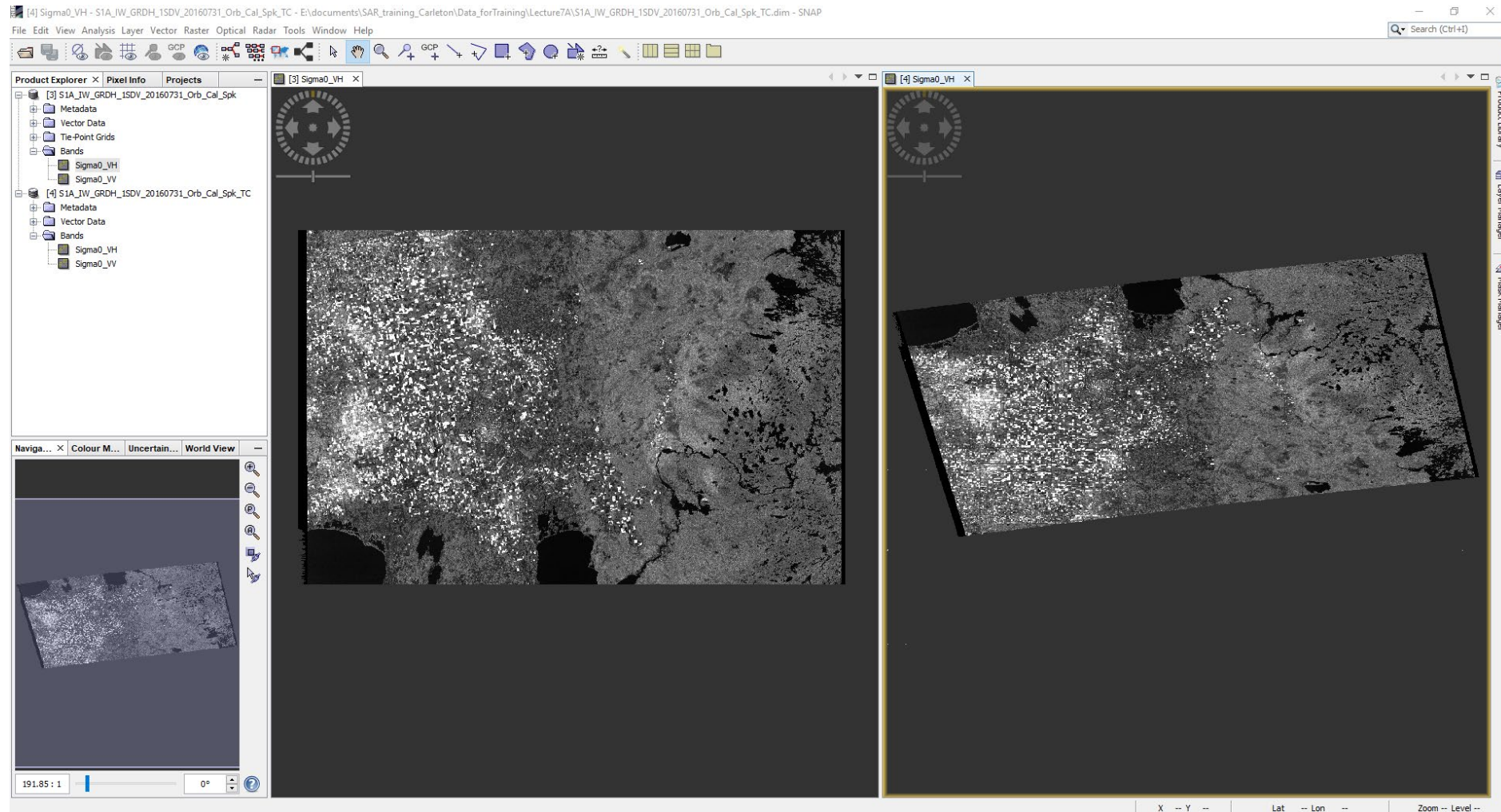
Save as: BEAM-DIMAP

Directory: D:\Classification\TerrainCorrect

Open in SNAP

Run Close

Geometric Correction Sentinel-1 Image

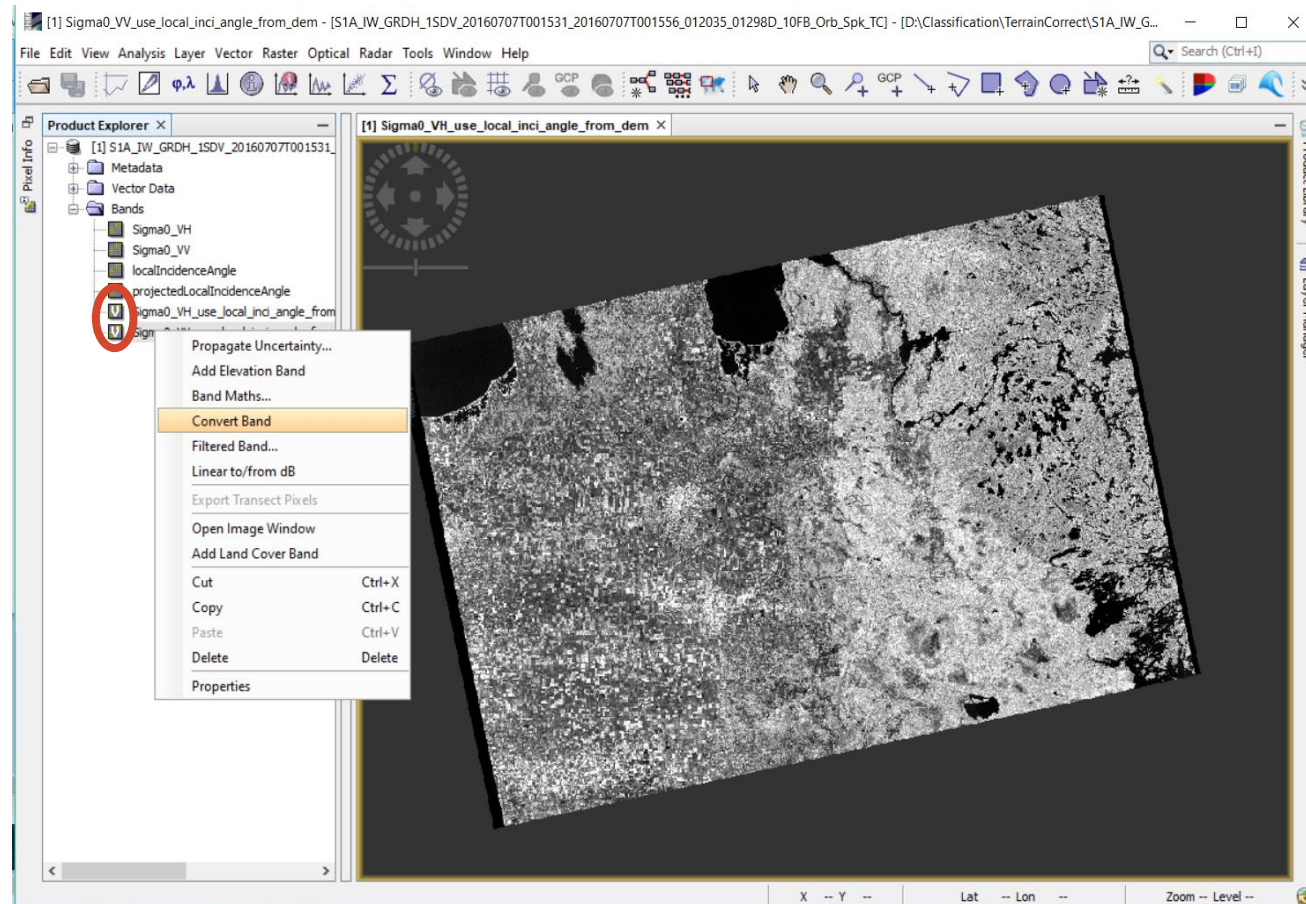


Speckle filtered image

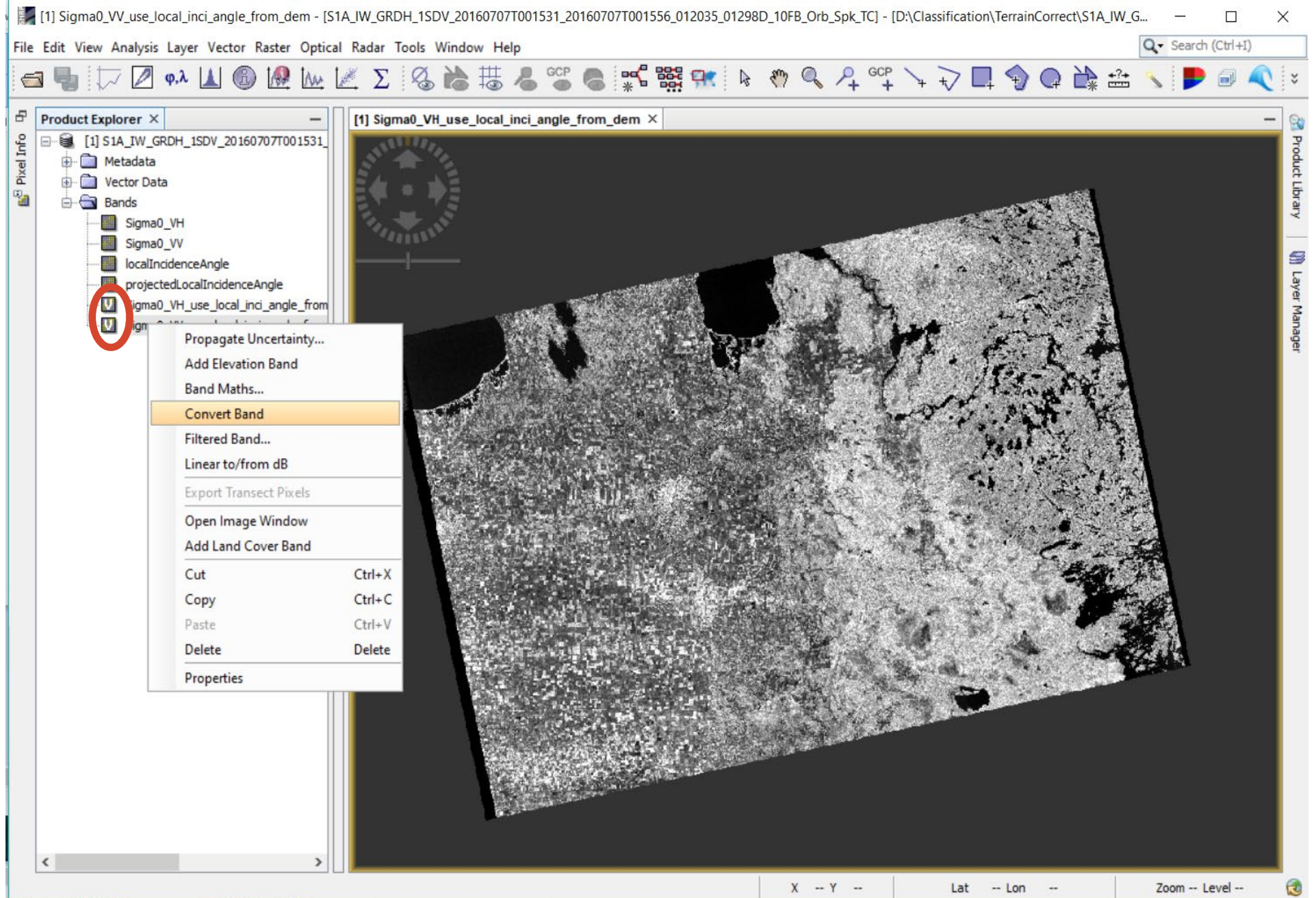
Speckle filtered image geocoded to the
WGS 84 reference system

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

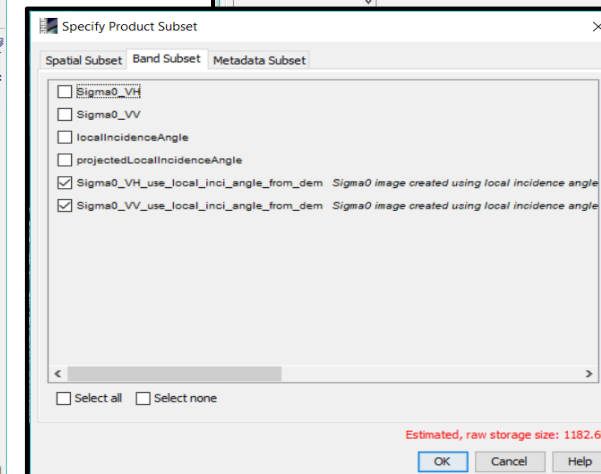
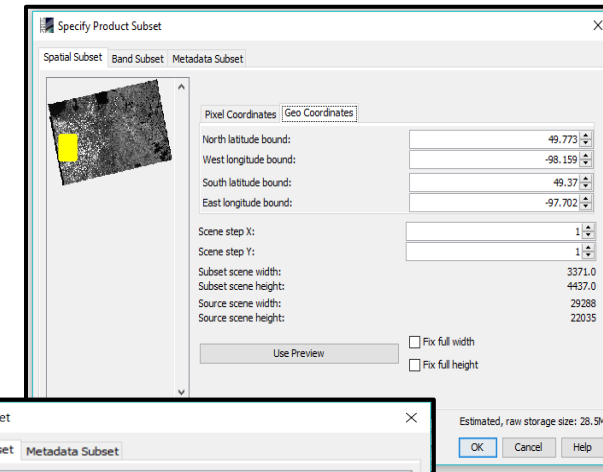
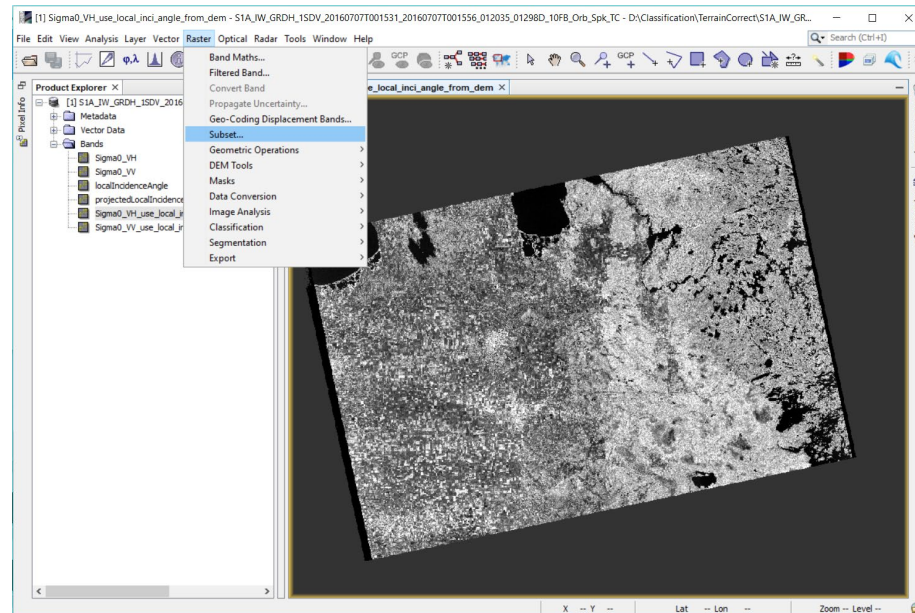


Convert Virtual Bands



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)

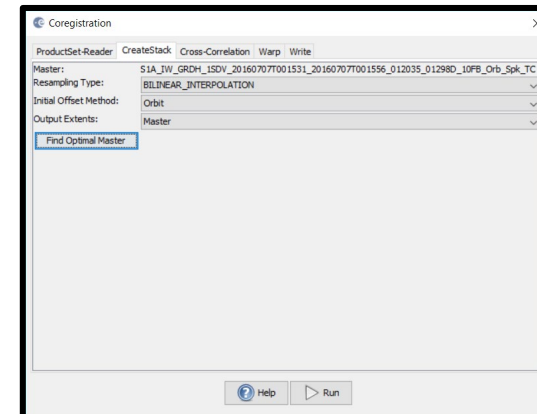
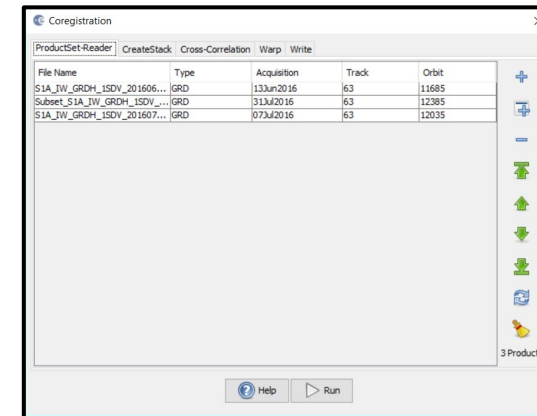
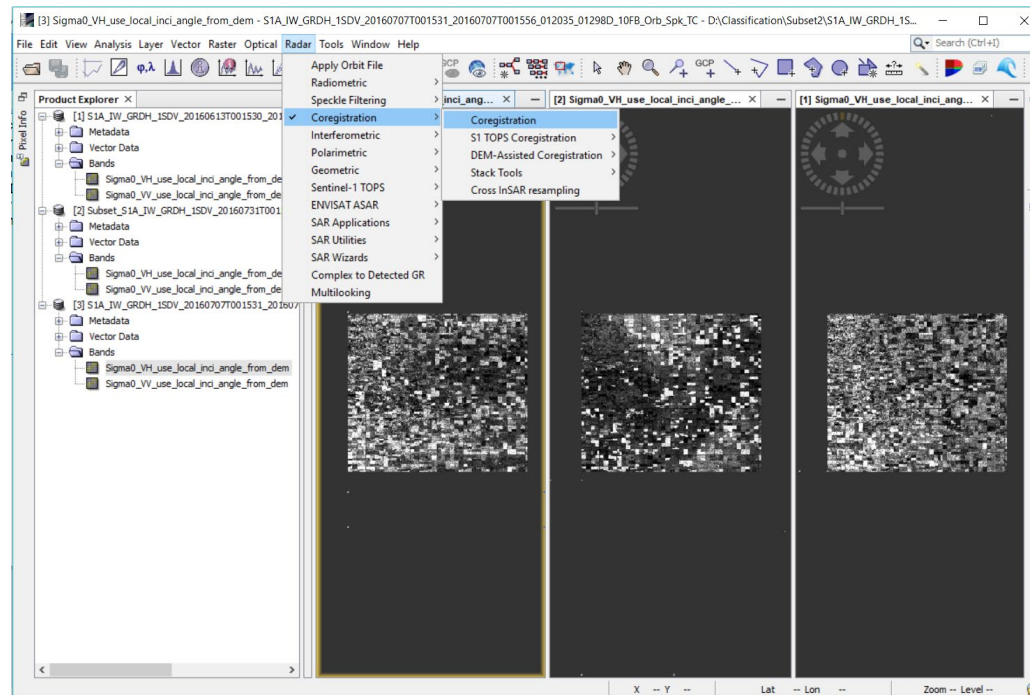
The image shows a screenshot of the Sigma0 software interface. The main window displays a grayscale satellite image of a terrain. A menu is open, showing the 'Subset...' option highlighted. Two dialog boxes are overlaid on the image:

- Specify Product Subset (Left):** This dialog has three tabs: 'Spatial Subset', 'Band Subset', and 'Metadata Subset'. The 'Band Subset' tab is active. It lists several bands with checkboxes. Two bands are checked: 'Sigma0_VH_use_local_inci_angle_from_dem' and 'Sigma0_VV_use_local_inci_angle_from_dem'. Below the list, there are 'Select all' and 'Select none' options. At the bottom, there are 'OK', 'Cancel', and 'Help' buttons. A red text label at the bottom right of the dialog reads: "Estimated, raw storage size: 1182.6M".
- Specify Product Subset (Right):** This dialog has the same three tabs. The 'Spatial Subset' tab is active. It shows a preview of the selected area on the main image, highlighted in yellow. To the right of the preview are input fields for 'Pixel Coordinates' (set to 'Geo Coordinates') and bounding box values: North latitude bound: 49.773, West longitude bound: -98.159, South latitude bound: 49.37, East longitude bound: -97.702. Below these are 'Scene step X' and 'Scene step Y' (both set to 1), and 'Subset scene width' (3371.0), 'Subset scene height' (4437.0), 'Source scene width' (29288), and 'Source scene height' (22035). There are 'Use Preview', 'Fix full width', and 'Fix full height' options. At the bottom, there are 'OK', 'Cancel', and 'Help' buttons. A red text label at the bottom right of the dialog reads: "Estimated, raw storage size: 28.5M".

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

The screenshot displays the SAR software interface with the 'Radar' menu open. The 'Coregistration' option is selected, and a sub-menu is visible with options: Coregistration, S1 TOPS Coregistration, DEM-Assisted Coregistration, Stack Tools, and Cross InSAR resampling. Two dialog boxes are overlaid on the main interface:

- Coregistration (Left):** Shows a table of products to be processed.
- Coregistration (Right):** Shows configuration options for the coregistration process.

File Name	Type	Acquisition	Track	Orbit
S1A_IW_GRDH_1SDV_20160613T001530_20160613T001531	GRD	13Jun2016	63	11685
Subset_S1A_IW_GRDH_1SDV_20160731T001531_20160731T001532	GRD	31Jul2016	63	12385
S1A_IW_GRDH_1SDV_20160707T001531_20160707T001532	GRD	07Jul2016	63	12035

Coregistration Configuration:

- ProductSet-Reader: CreateStack | Cross-Correlation | Warp | Write
- Master: S1A_IW_GRDH_1SDV_20160707T001531_20160707T001532_012035_01298D_10FB_Orb_Spk_TC
- Resampling Type: BILINEAR_INTERPOLATION
- Initial Offset Method: Orbit
- Output Extents: Master
- Find Optimal Master

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>

The screenshot displays the SNAP (Software for Near-Range Applications) interface. On the left, the 'File' menu is open, and the 'Export' option is highlighted with a red '1'. The 'Export' submenu is also visible, showing options like 'GeoTIFF / BigTIFF', 'BEAM-DIMAP', and 'ENVI'. In the center, a satellite image is displayed. On the right, a Windows File Explorer window is open, showing a folder named 'vector_data' with a red '2' next to it. Below the folder, a list of files is shown, including 'Sigma0_VH_use_local_inci_angle_from_dem_mst_13Jun2016.hdr' and 'Sigma0_VH_use_local_inci_angle_from_dem_mst_13Jun2016'. A tooltip is visible over one of the files, showing its type as 'Disc Image File' and its size as '58.3 MB'.

Name	Date modified	Type	Size
vector_data	1/25/2019 12:40 PM	File folder	
Sigma0_VH_use_local_inci_angle_from_dem_mst_13Jun2016.hdr	1/25/2019 12:19 PM	HDR File	2 KB
Sigma0_VH_use_local_inci_angle_from_dem_mst_13Jun2016	1/25/2019 12:19 PM	Disc Image File	59,726 KB
Sigma0_VH_use_local_inci_angle_from_dem_mst_13Jun2016	1/25/2019 12:19 PM	HDR File	2 KB
Sigma0_VH_use_local_inci_angle_from_dem_mst_13Jun2016	1/25/2019 12:19 PM	Disc Image File	59,726 KB
Sigma0_VH_use_local_inci_angle_from_dem_mst_13Jun2016	1/25/2019 12:19 PM	HDR File	2 KB
Sigma0_VH_use_local_inci_angle_from_dem_slv3_31Jul2016	1/25/2019 12:19 PM	Disc Image File	59,726 KB
Sigma0_VV_use_local_inci_angle_from_dem_mst_13Jun2016.hdr	1/25/2019 12:19 PM	HDR File	2 KB
Sigma0_VV_use_local_inci_angle_from_dem_mst_13Jun2016	1/25/2019 12:19 PM	Disc Image File	59,726 KB
Sigma0_VV_use_local_inci_angle_from_dem_slv2_07Jul2016	1/25/2019 12:19 PM	HDR File	2 KB
Sigma0_VV_use_local_inci_angle_from_dem_slv2_07Jul2016	1/25/2019 12:19 PM	Disc Image File	59,726 KB
Sigma0_VV_use_local_inci_angle_from_dem_slv4_31Jul2016	1/25/2019 12:19 PM	HDR File	2 KB
Sigma0_VV_use_local_inci_angle_from_dem_slv4_31Jul2016	1/25/2019 12:19 PM	Disc Image File	59,726 KB

Exporting Data Stacks Out of SNAP

The screenshot shows the SNAP (Sentinel Application Platform) interface. The 'File' menu is open, and the 'Export' option is selected. The 'Export' submenu is also open, showing various file formats. The 'GeoTIFF / BigTIFF' option is highlighted. A red '1' is placed next to the 'Export' menu item.

Below the main interface, a file explorer window is open, showing a list of files. The file 'Sigma0_VH_use_local_inci_angle_from_dem_mst_13Jun2016' is selected. A red '2' is placed next to the file name. A tooltip is visible over the selected file, showing its properties: Type: Disc Image File, Size: 58.3 MB, Date modified: 1/25/2019 12:19 PM.

Name	Date modified	Type	Size
vector_data	1/25/2019 12:40 PM	File folder	
Sigma0_VH_use_local_inci_angle_from_dem_mst_13Jun2016.hdr	1/25/2019 12:19 PM	HDR File	2 KB
Sigma0_VH_use_local_inci_angle_from_dem_mst_13Jun2016	1/25/2019 12:19 PM	Disc Image File	59,726 KB
Sigma0_VH_use_local_inci_angle_from_dem_mst_13Jun2016.hdr	1/25/2019 12:19 PM	HDR File	2 KB
Sigma0_VH_use_local_inci_angle_from_dem_mst_13Jun2016	1/25/2019 12:19 PM	Disc Image File	59,726 KB
Sigma0_VH_use_local_inci_angle_from_dem_slv3_31Jul2016	1/25/2019 12:19 PM	Disc Image File	59,726 KB
Sigma0_VV_use_local_inci_angle_from_dem_mst_13Jun2016.hdr	1/25/2019 12:19 PM	HDR File	2 KB
Sigma0_VV_use_local_inci_angle_from_dem_mst_13Jun2016	1/25/2019 12:19 PM	Disc Image File	59,726 KB
Sigma0_VV_use_local_inci_angle_from_dem_slv2_07Jul2016.hdr	1/25/2019 12:19 PM	HDR File	2 KB
Sigma0_VV_use_local_inci_angle_from_dem_slv2_07Jul2016	1/25/2019 12:19 PM	Disc Image File	59,726 KB
Sigma0_VV_use_local_inci_angle_from_dem_slv4_31Jul2016.hdr	1/25/2019 12:19 PM	HDR File	2 KB
Sigma0_VV_use_local_inci_angle_from_dem_slv4_31Jul2016	1/25/2019 12:19 PM	Disc Image File	59,726 KB