Pre-processing and multi-temporal analysis of SAR time series

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ESA–MOST China Dragon 4 Cooperation

2019 ADVANCED INTERNATIONAL TRAINING COURSE IN LAND REMOTE SENSING

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Part 1

Multitemporal Analysis of SAR Backscatter Intensity

Objectives

- Familiarizing with SNAP toolbox
- Familiarizing with Sentinel-1 GRD prodcucts
- Calculation of backscatter intensity from Sentinel-1 detcted products
- Analysis of temporal backscatter signatures for various land cover types
- Change detection over AOI (Beijing Daxing International Airport)

Introduction

Input data: time series of Sentinel-1 GRDH images over China

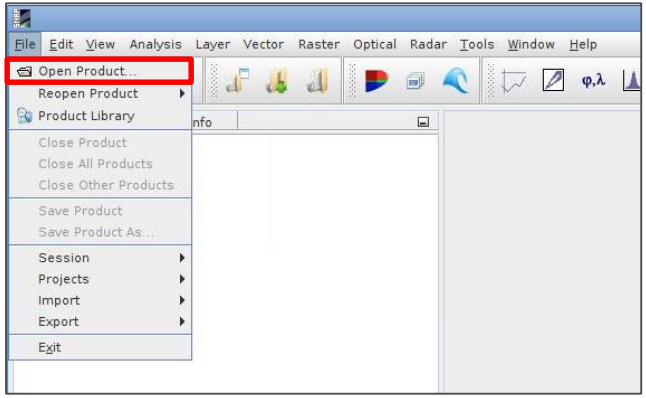
S1A_IW_GRDH_1SDV_20151003T222044_20151003T222111_007994_00B2F6_9374
S1A_IW_GRDH_1SDV_20160611T222046_20160611T222112_011669_011DDC_7FB0
S1B_IW_GRDH_1SDV_20171115T222014_20171115T222041_008298_00EAE8_2415
S1B_IW_GRDH_1SDV_20181110T222021_20181110T222048_013548_019131_A556
S1B_IW_GRDH_1SDV_20190930T222028_20190930T222054_018273_022698_C498

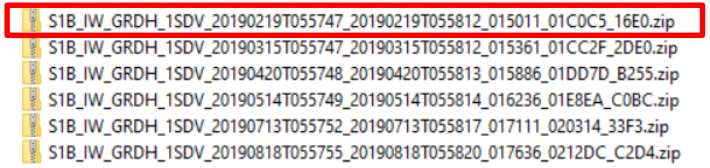
Output:

- temporal backscatter signatures for various land cover types
- change detection

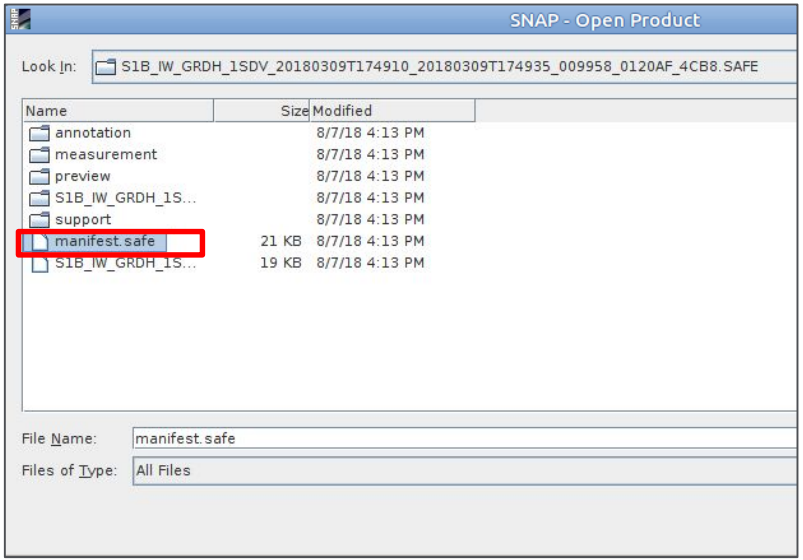
Data preparation

1. Opening the S1 data





For unzipped products



Data processing

- Creating a subset of S1 GRDH images
  Spatial subset depending on the AOI
- Updating orbits
- Radiometric calibration
  Conversion of image intensity to sigma0 providing the radar backscatter
- Terrain correction
  Compensate for geometric distortions caused by topographical variations of a scene and the tilt of satellite sensor
- Creating a multitemporal stack
  Collocation spatially overlapping products (based on geolocation)
- Speckle filtering
  Filtering the inherent salt and pepper like texturing called speckles
- Linear to dB conversion
  Compensate for very high dynamic range in visualisation
- Stack statistics and analysis of temporal backscatter signatures

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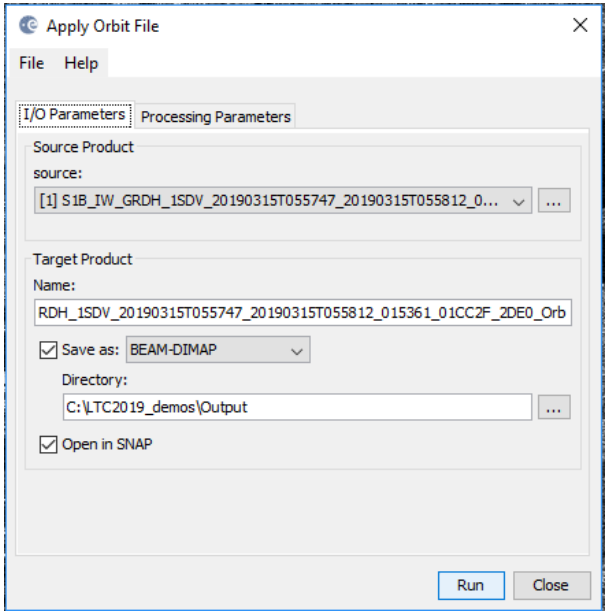
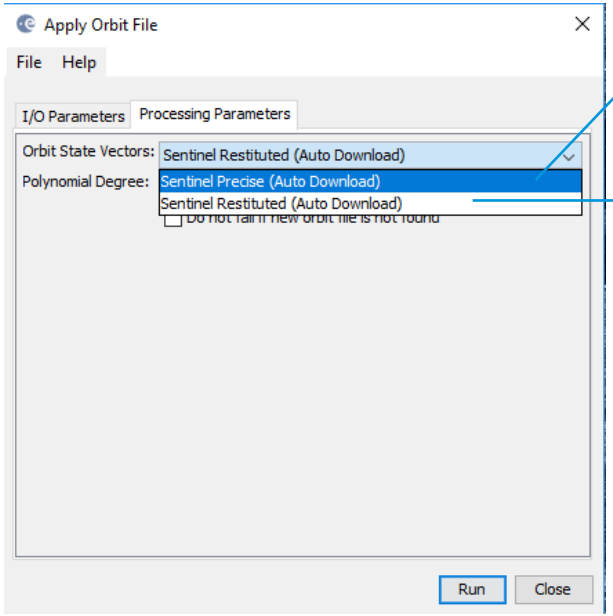
Updating orbits

Radar / Apply orbit file

The orbit file provides accurate satellite position and velocity information. Based on this information, the orbit state vectors in the abstract metadata of the product are updated.





POEORB - few weeks after acq.

RESORB – within few hours

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Radiometric Calibration

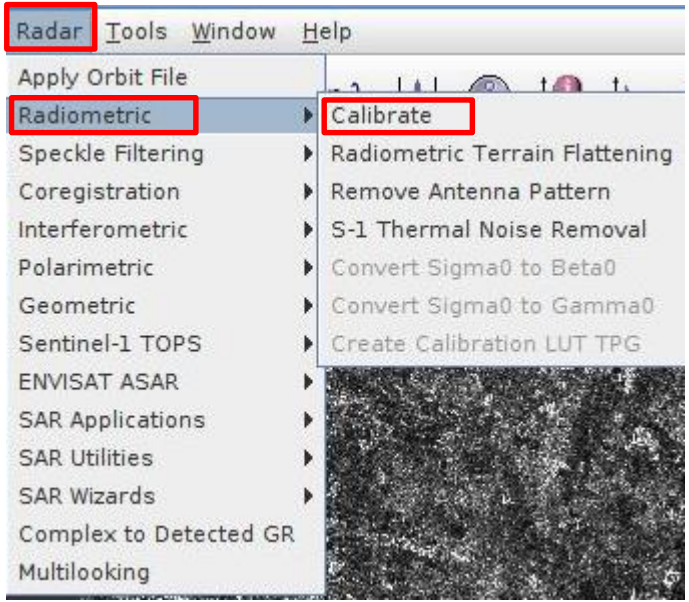
From image pixel values or digital numbers (DNs) we can derive:

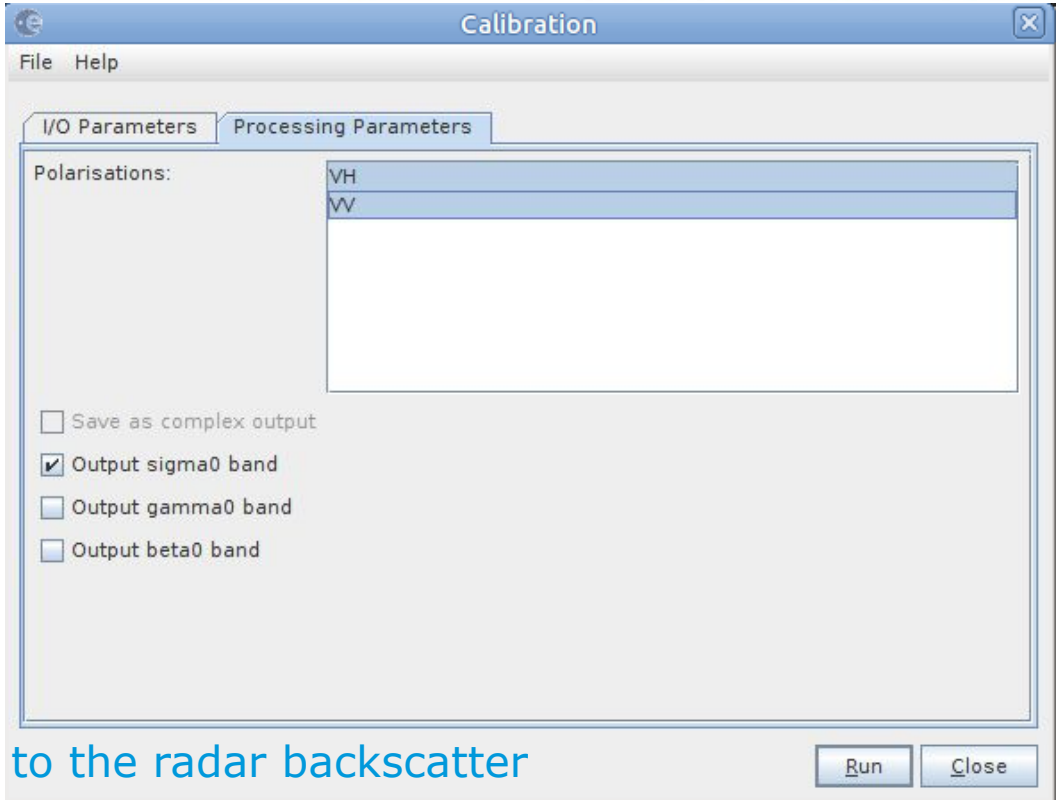
Beta Naught – radar brightness coefficient, reflectivity per unit area in slant range which is dimensionless

Sigma Naught – power returned to the antenna from the ground (distributed scatterer) in dB. A number comparing the strangth of the signal to that expected from and area of one square meter. It is defined with respect to the nominal horisontal plane and is varying with incidence angle, wavelength, polarisation and scattering surface itself

Radiometric Calibration

Radar/Radiometric/Calibrate





Pixel values can be directly related to the radar backscatter

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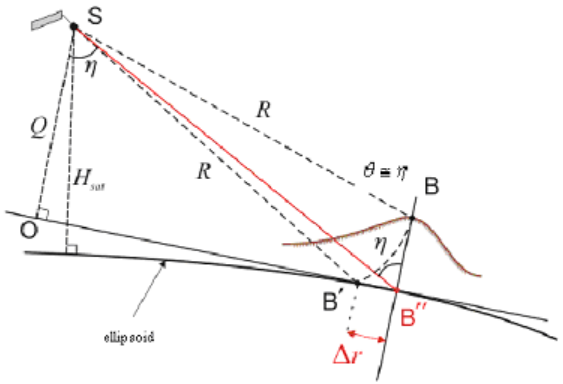
Terrain correction & Geocoding

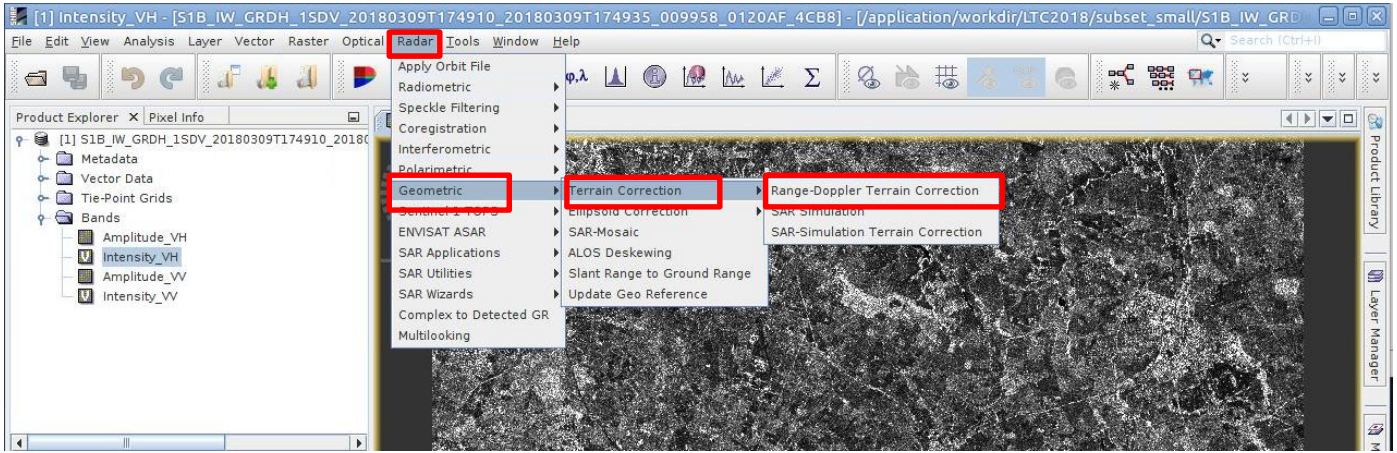


Point **B** with elevation **h** above the ellipsoid is imaged at position **B'** in SAR image, though its real position is **B"**. The offset Δr between **B'** and **B"** exhibits the effect of topographic distortions

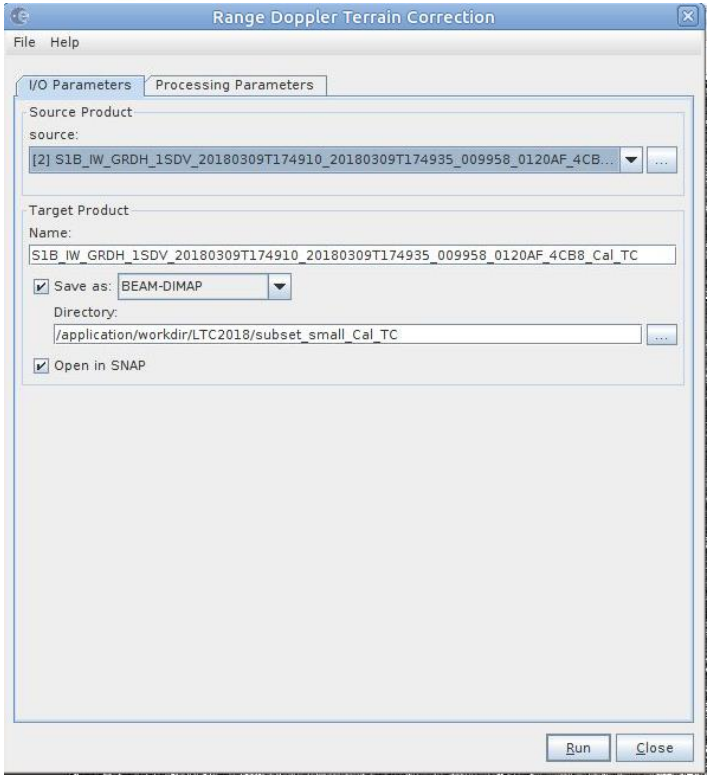
Terrain Correction allows geometric overlays of data from different sensors and/or geometries.

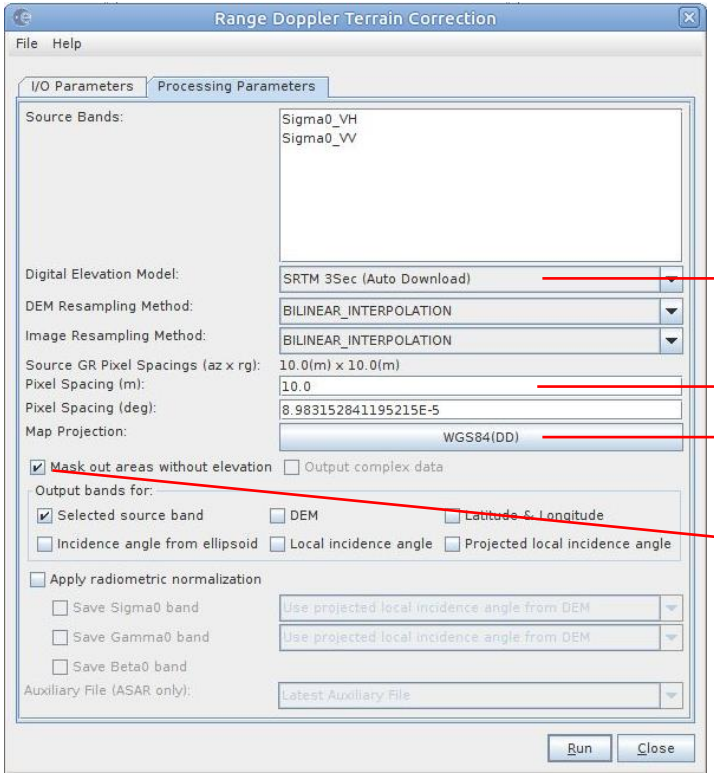
Terrain correction & Geocoding

Radar / Geometric / Terrain Correction / Range Doppler Terrain Correction



Terrain correction & Geocoding





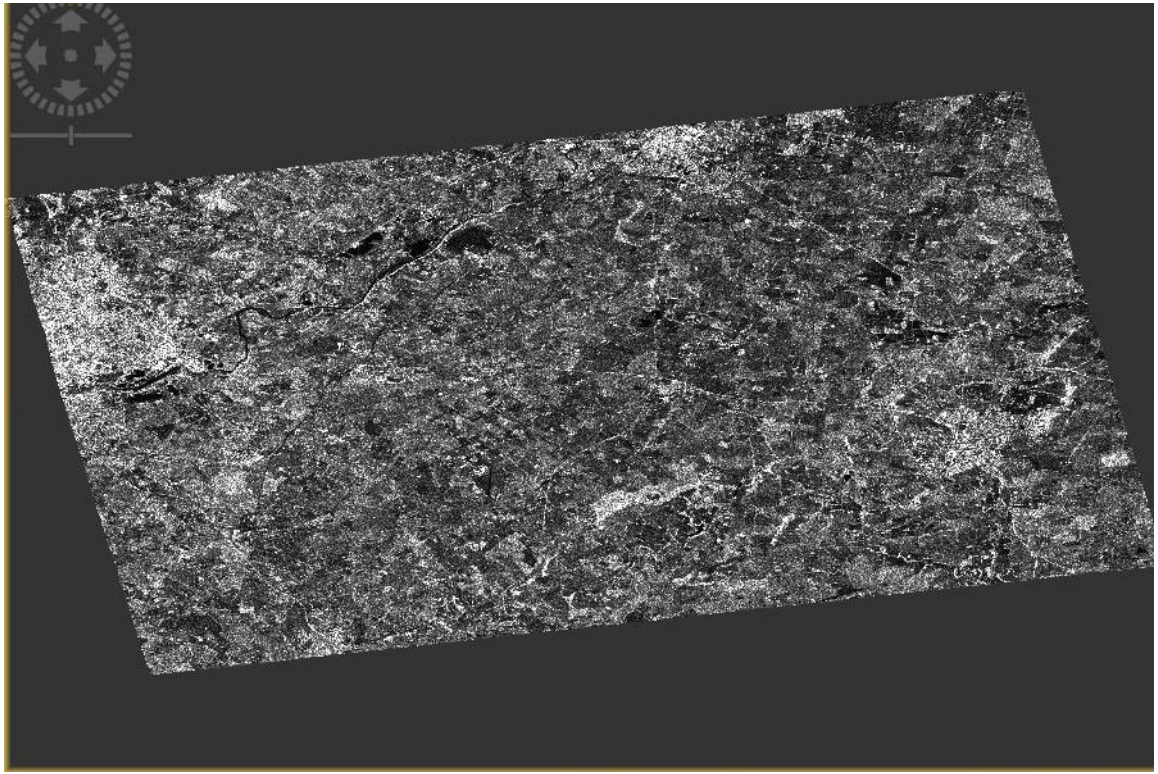
DEM selection

Pixel spacing

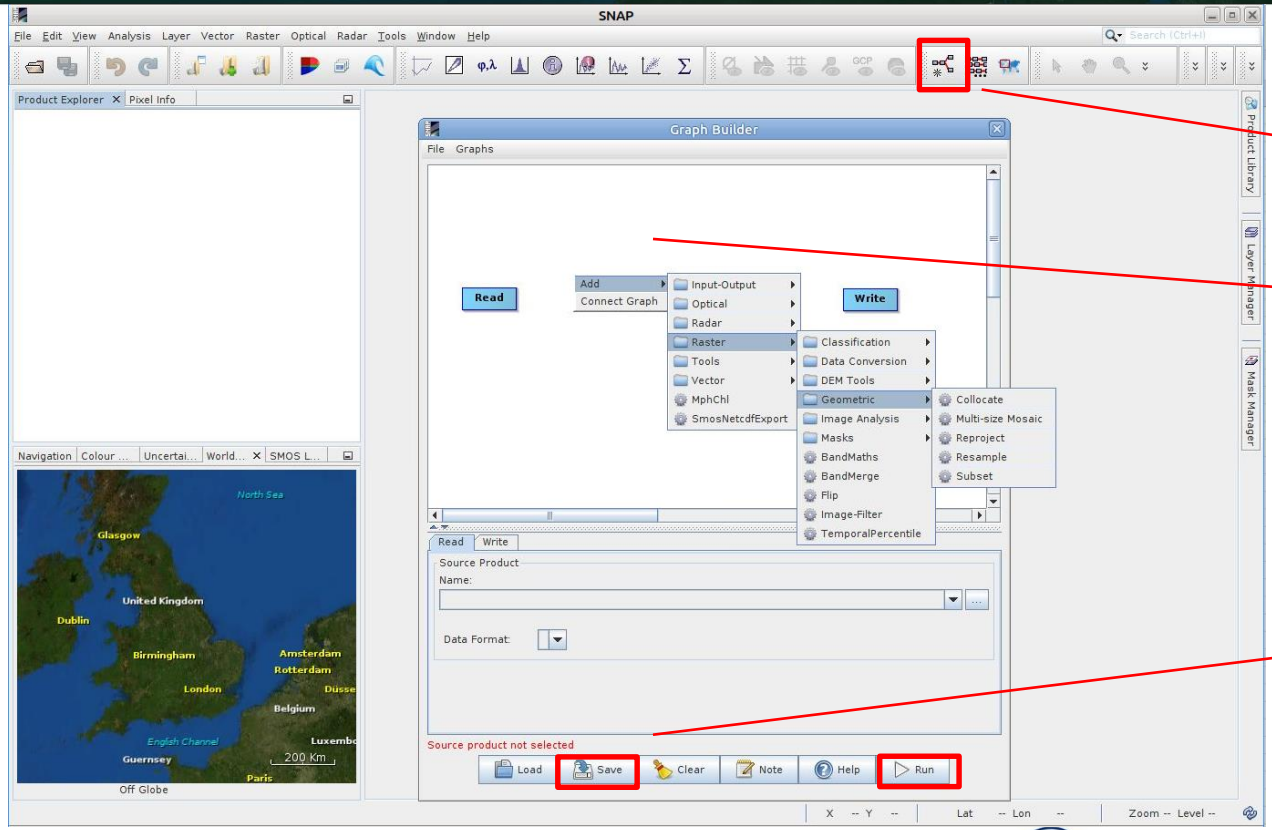
Map projection

Masking areas without elevation

Data check



Automatic Processing with Graph

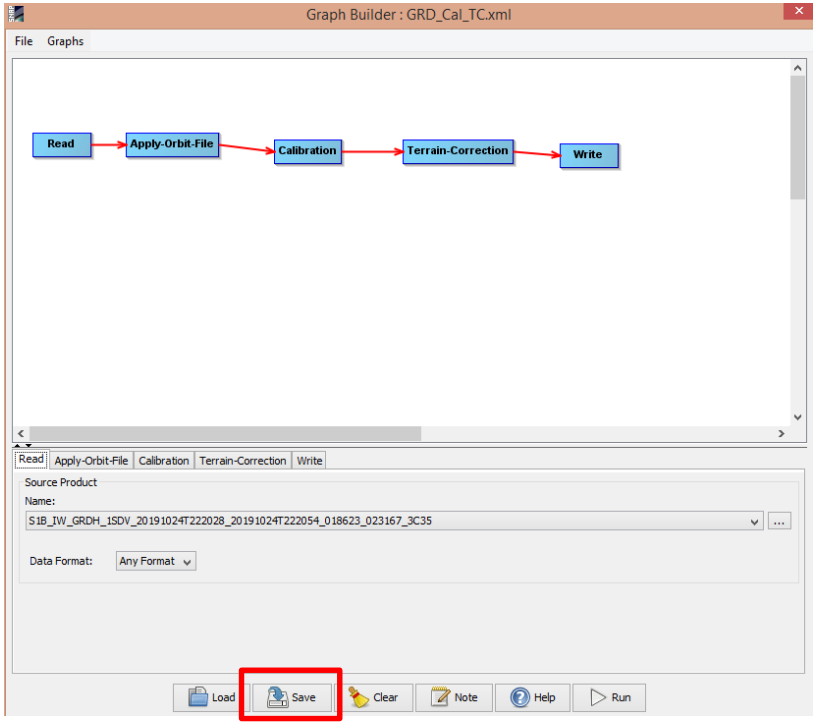


Graph Builder

Inserting blocks with particular processing operators (right mouse button)

Save the graph and/or Run

Automatic Processing with Graph – Calibration Terrain Correction

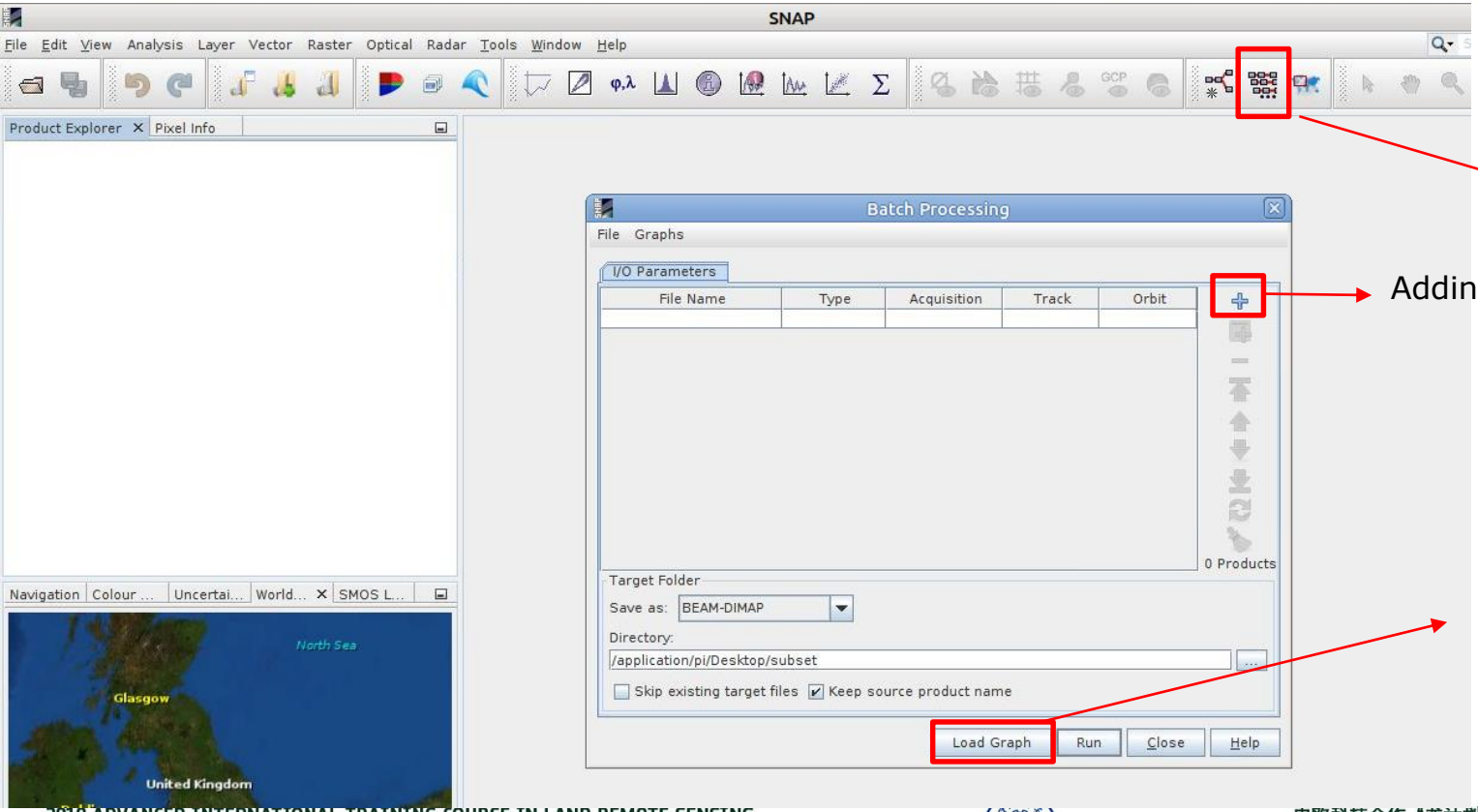


Apply Orbits: Sentinel Precise
Calibration: Output Sigma0
Terrain Correction: pixel spacing 10m

The same settings like in manual processing

save as GRD_Cal_TC.xml

Batch processing

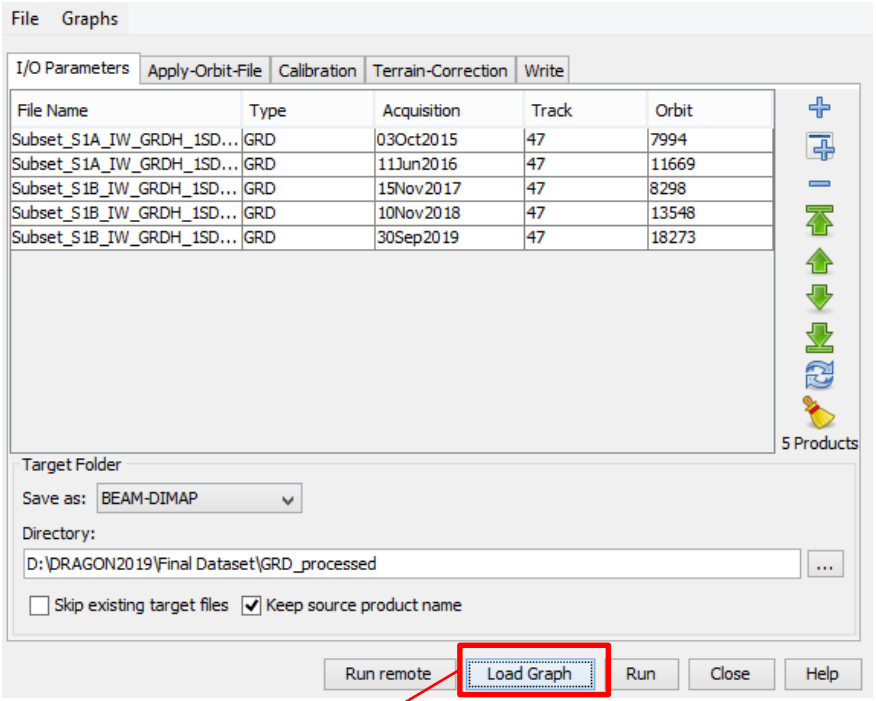


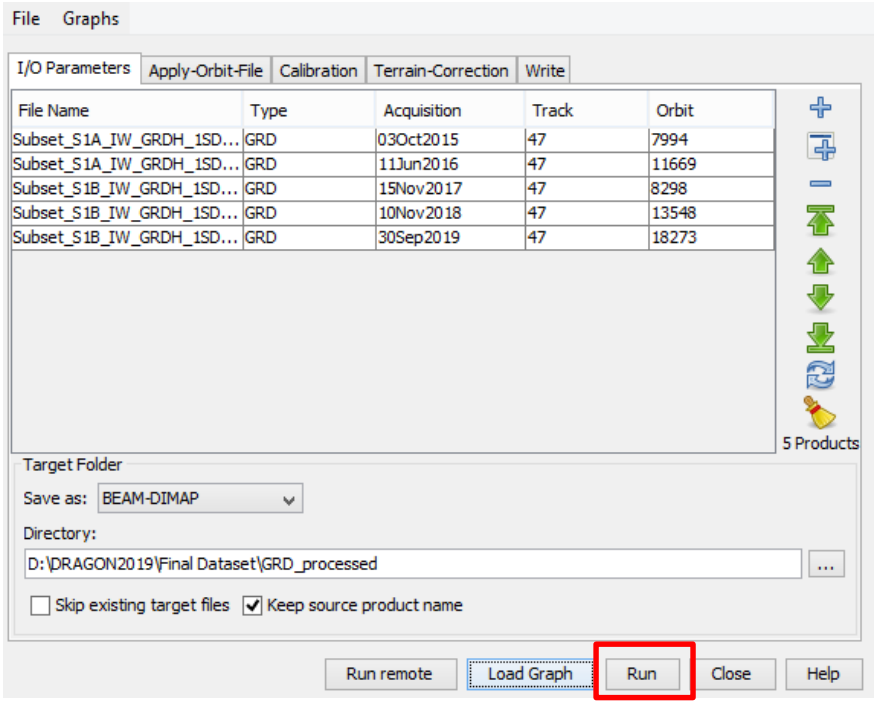
Batch processing tool

Adding data products

Loading the graph

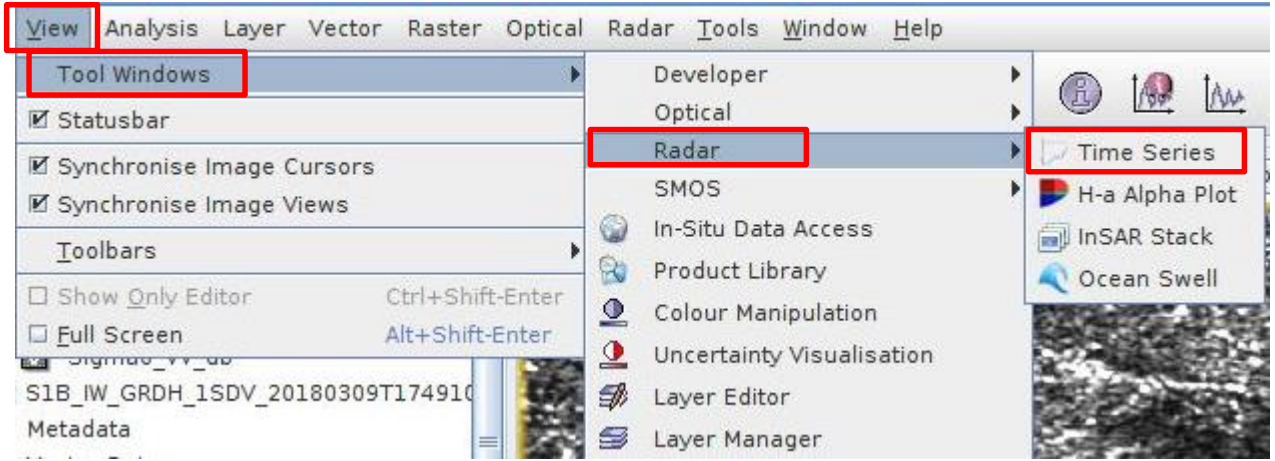
Batch processing

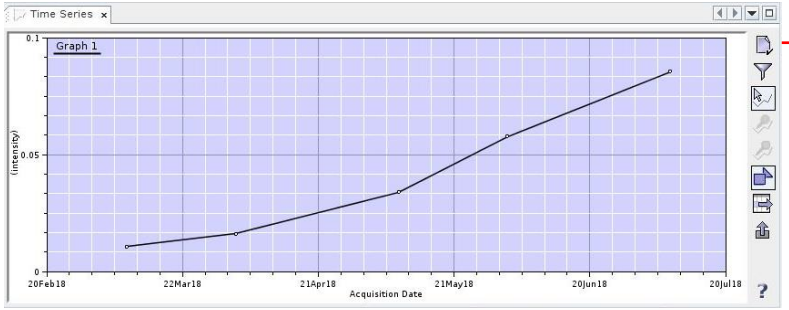




Open previously saved graph GRD_Cal_TC.xml

Time series analysis

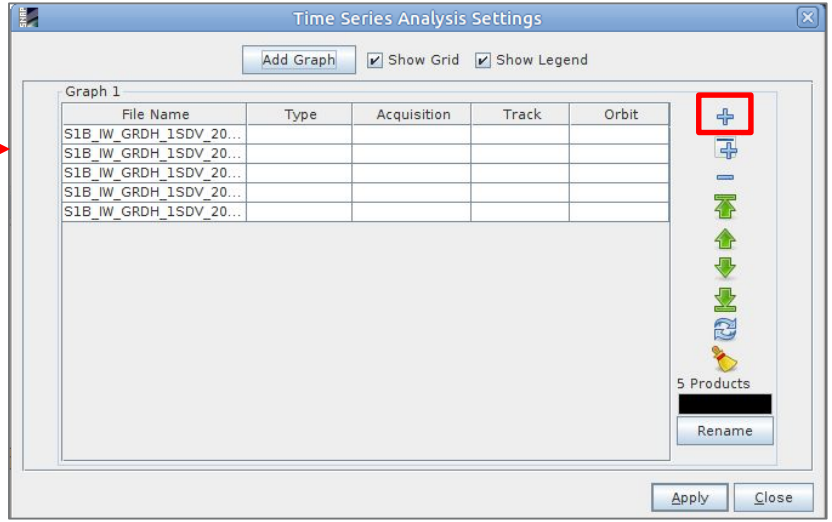




Add your data products

Time series analysis

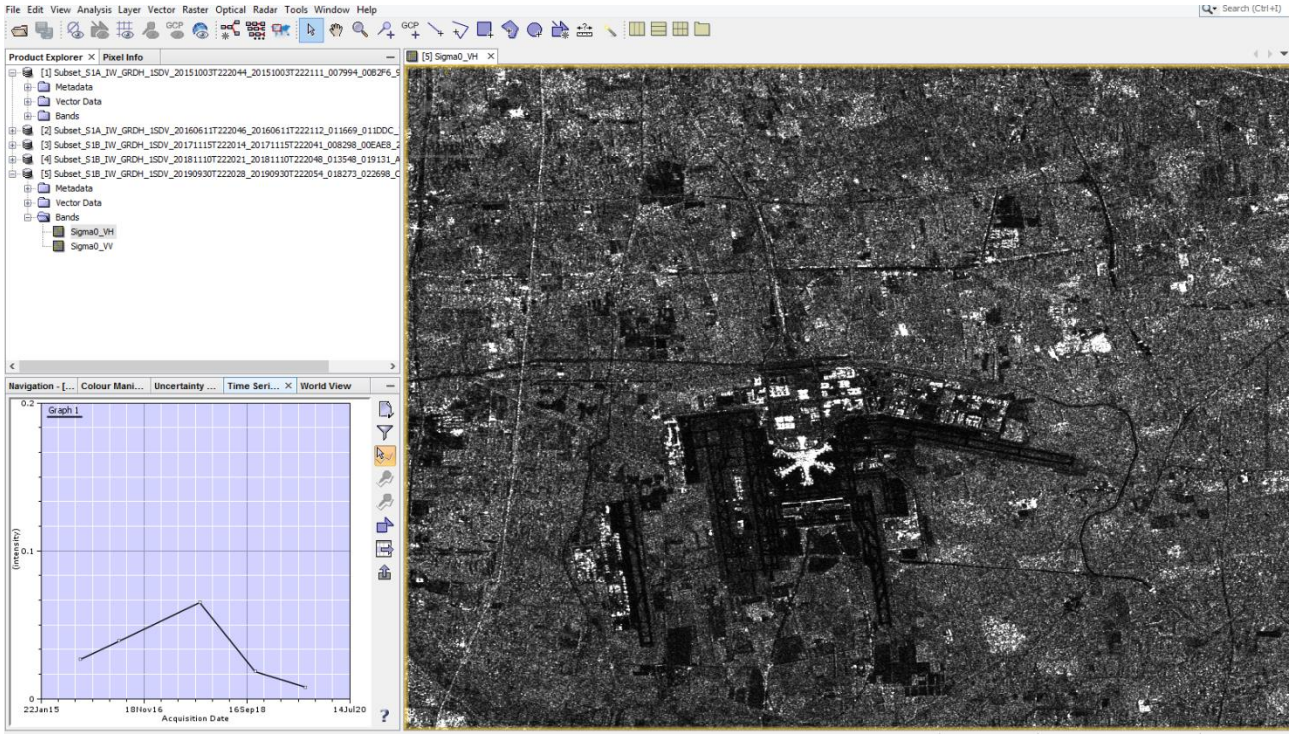
Choose your processed data products



Bands filter

Show plot at cursor position

Time series analysis



One of the plottet bands has to be opened

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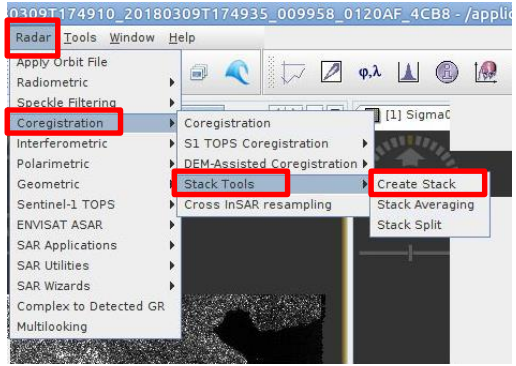
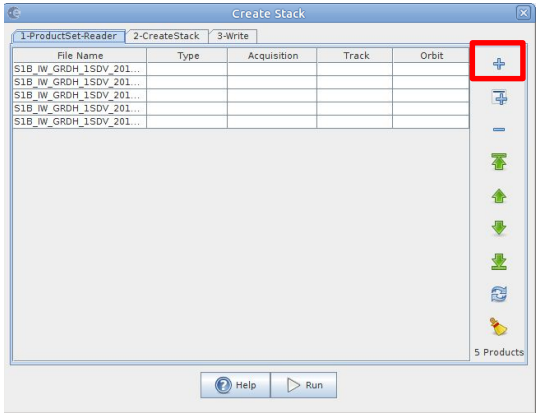
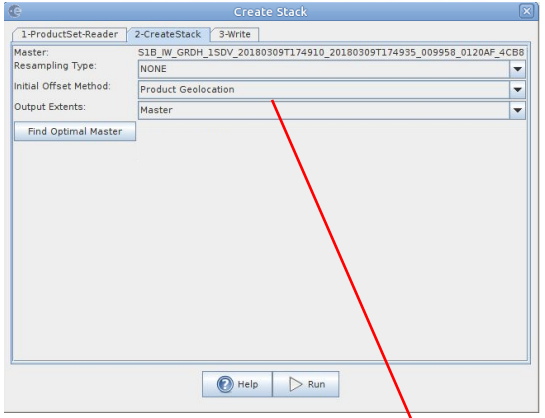
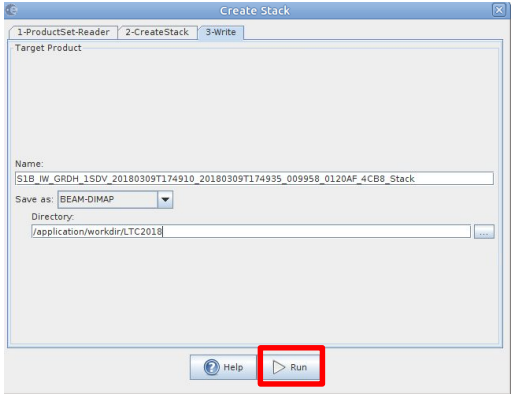
Creating multitemporal stack









Collocating spatially overlapping images

- *Product geolocation (if terrain corrected)*
- *Orbits (if not terrain corrected)*

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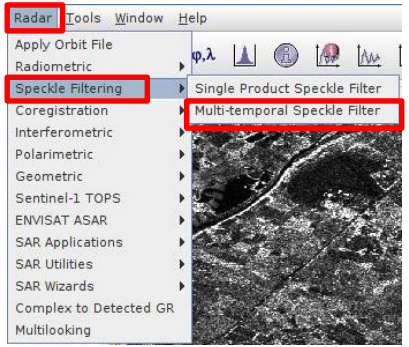
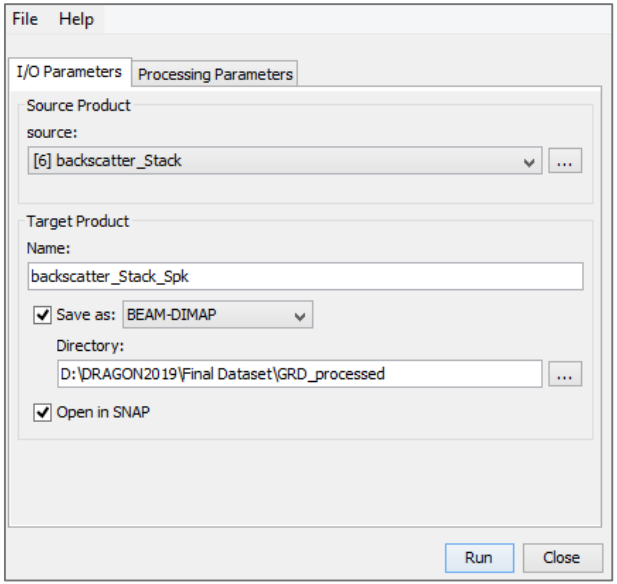
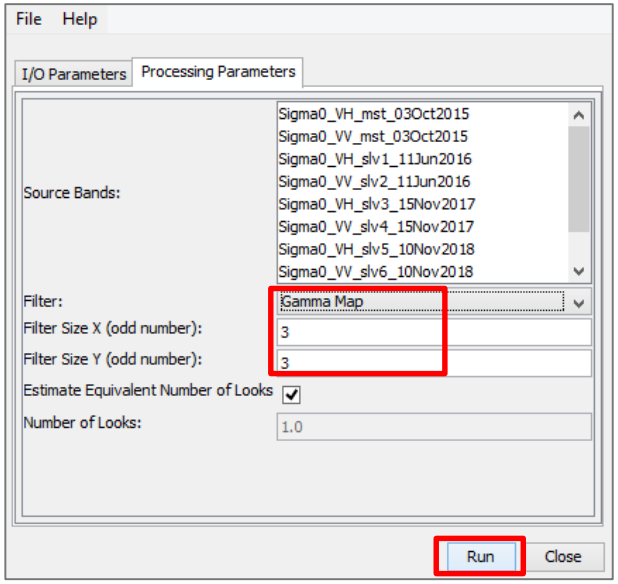
Multitemporal speckle filtering







Spatial filtering with weighted average of selected filter across the images of the time series

Multitemporal speckle filtering

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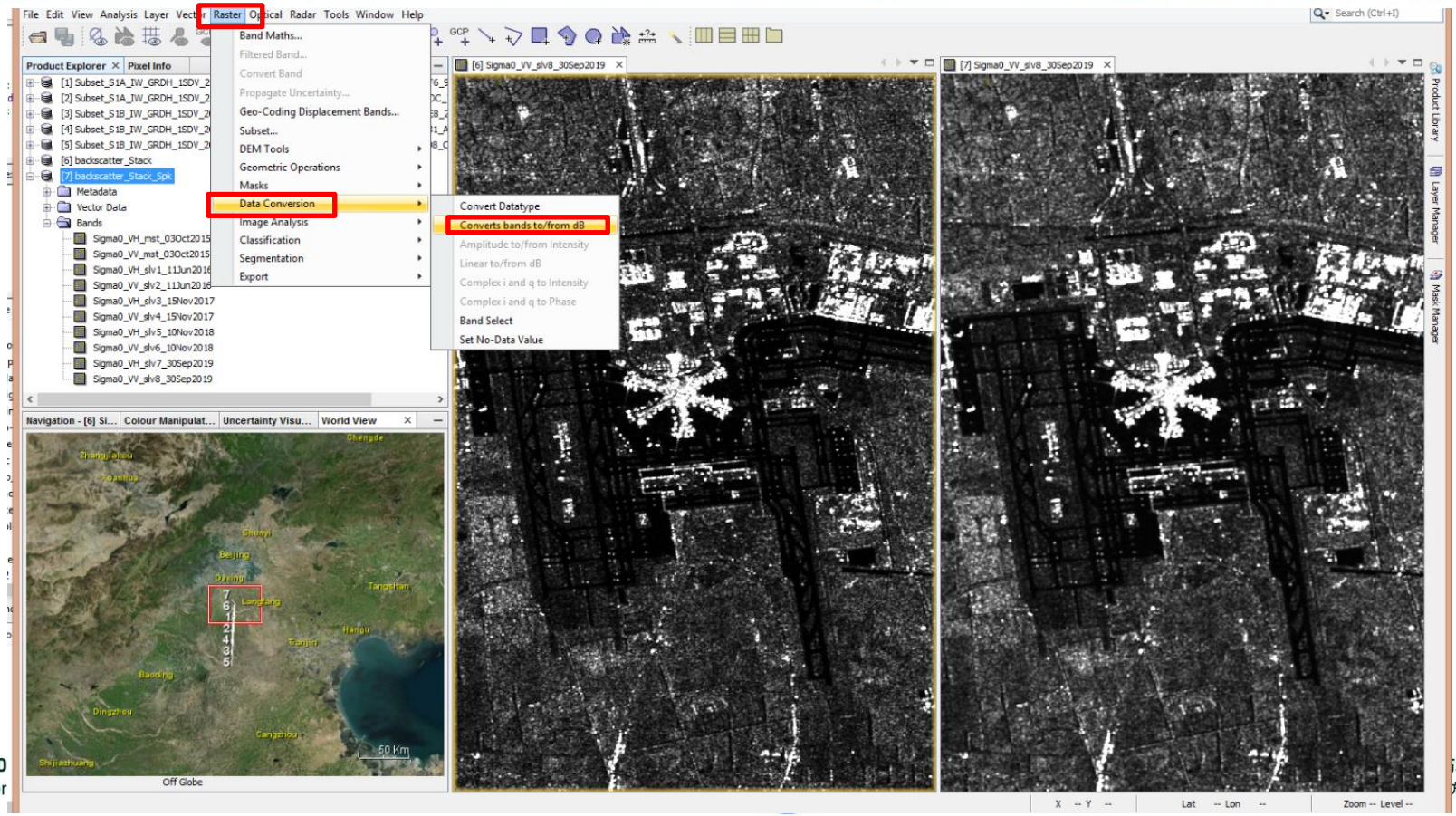
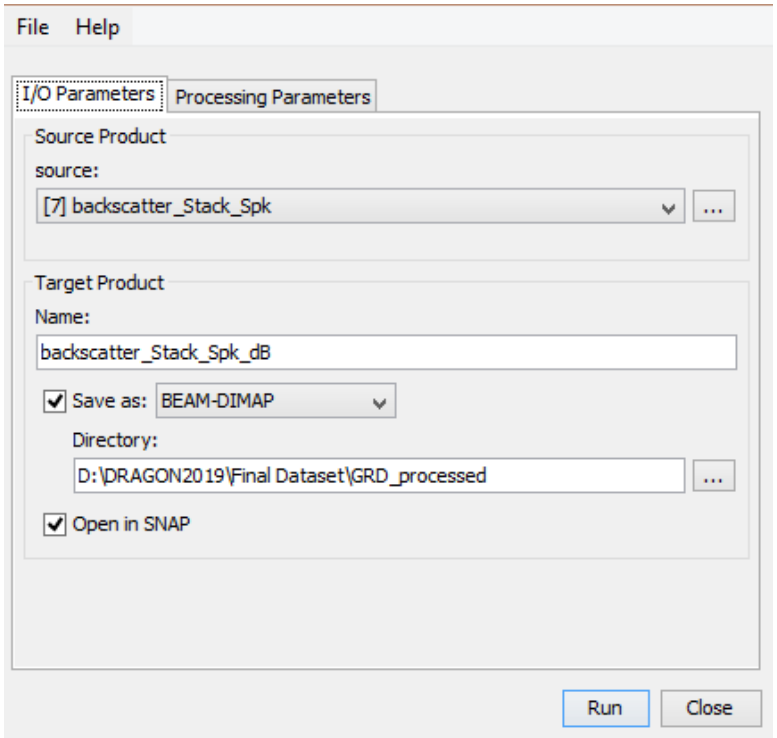
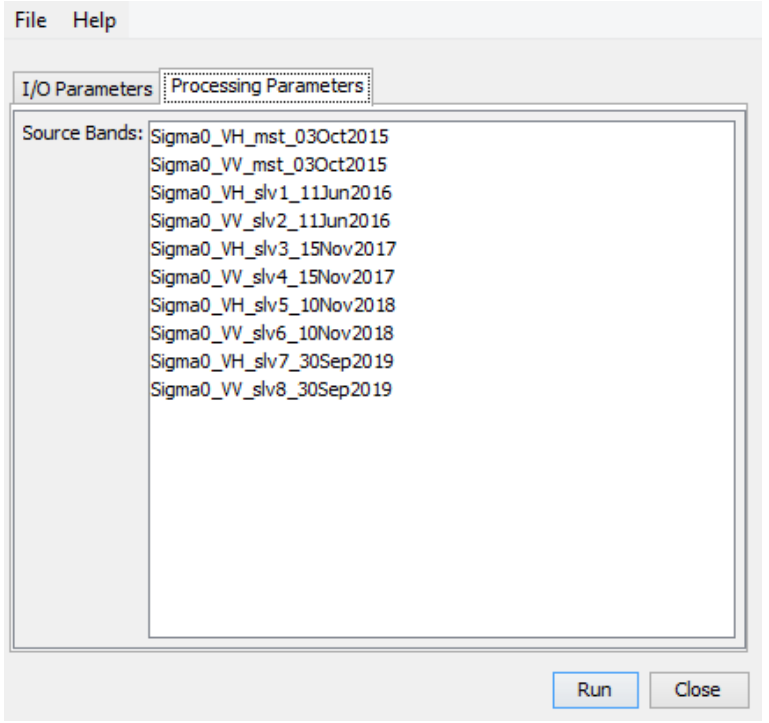
Conversion from linear to dB

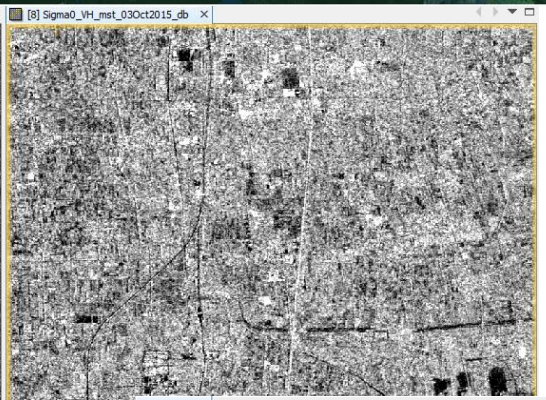


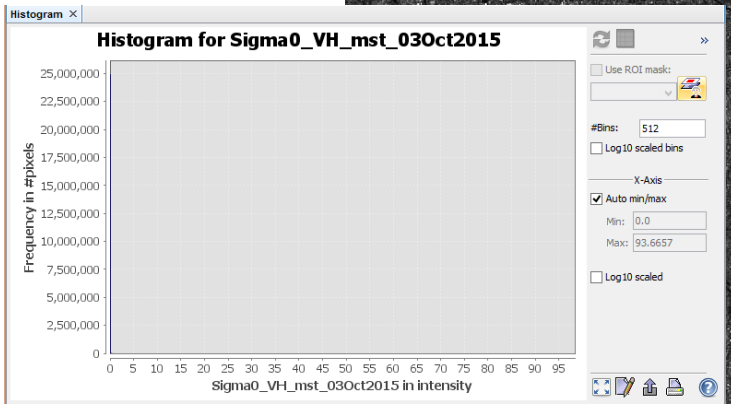
Conversion from linear to dB

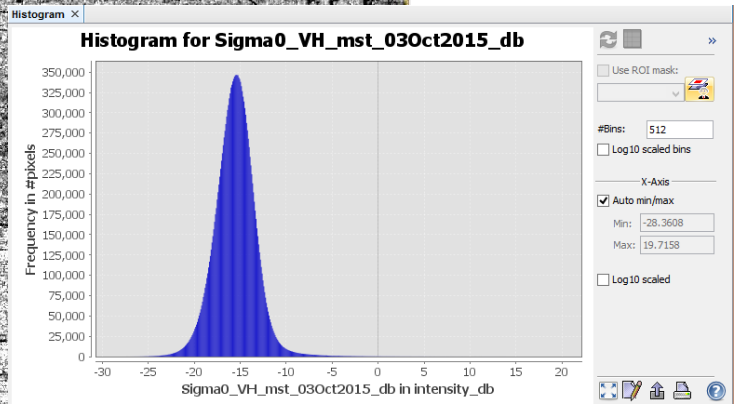




Linear vs dB comparison







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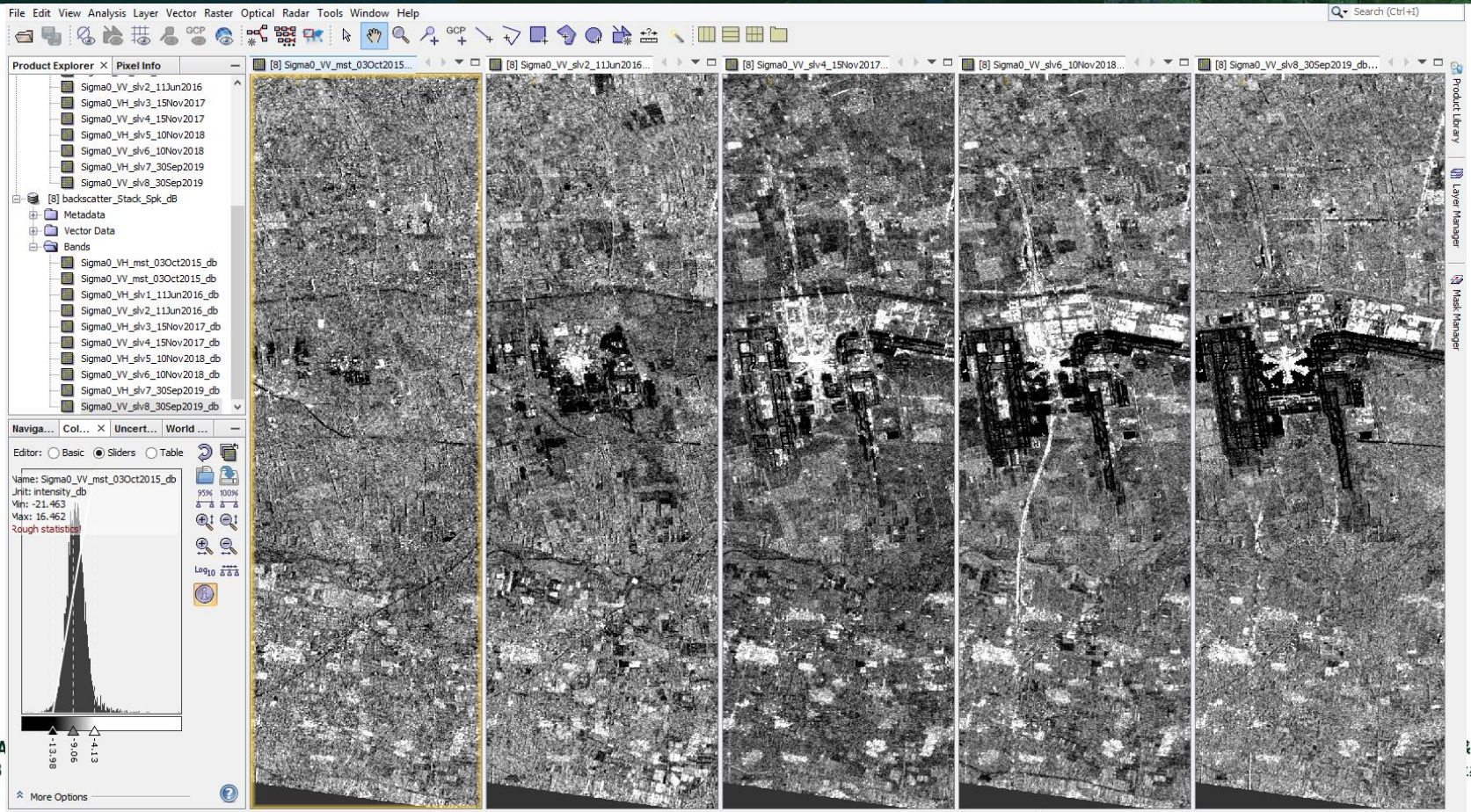
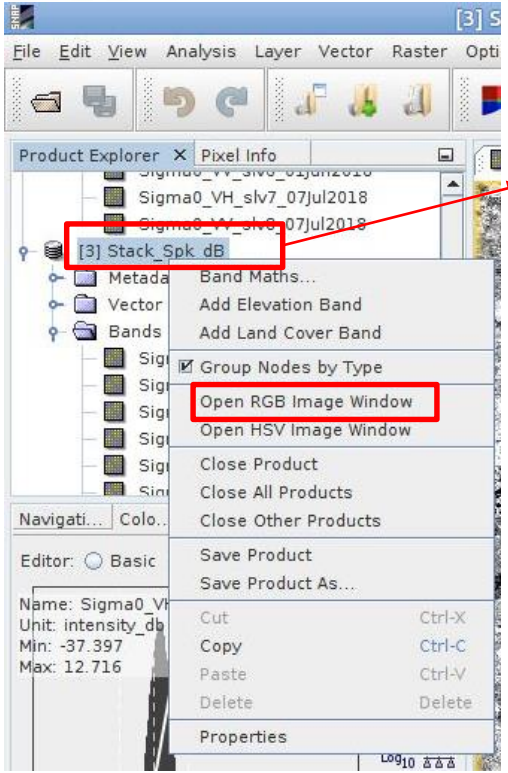
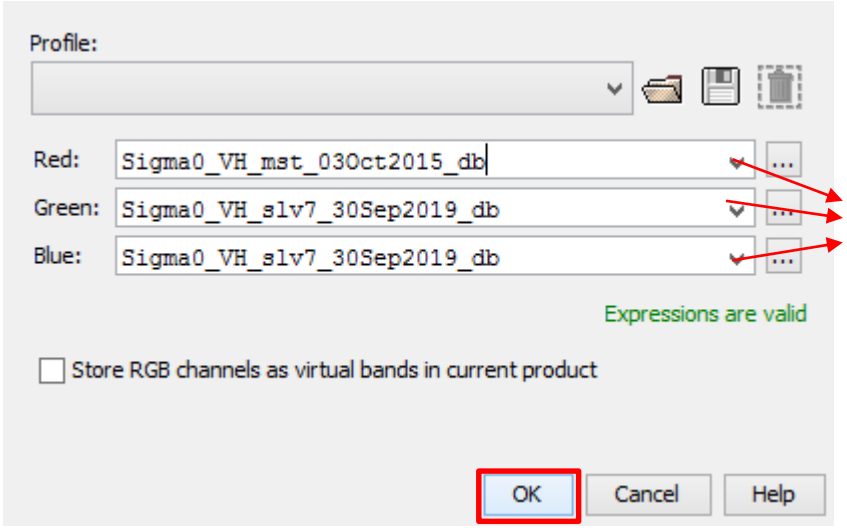
Visual inspection of the time series



RGB Composite

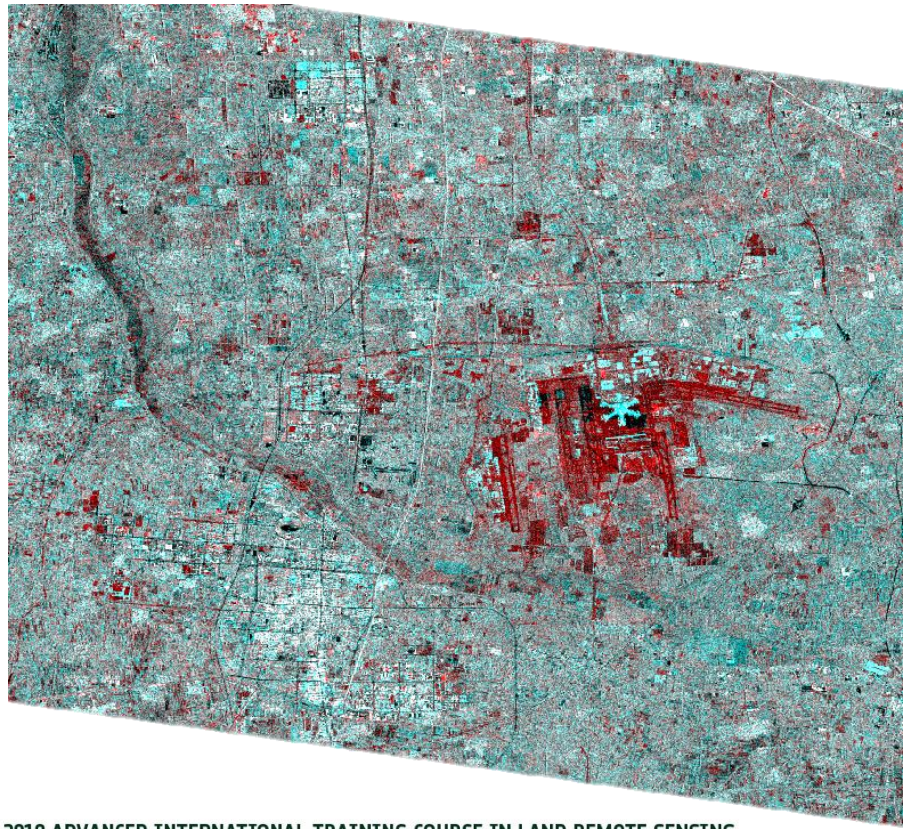


Right click on the product

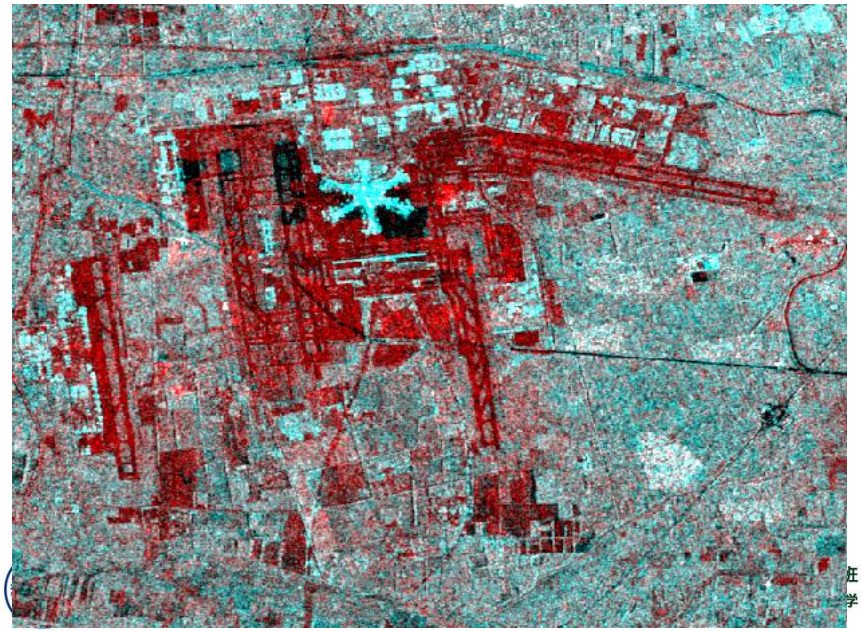


Band selection

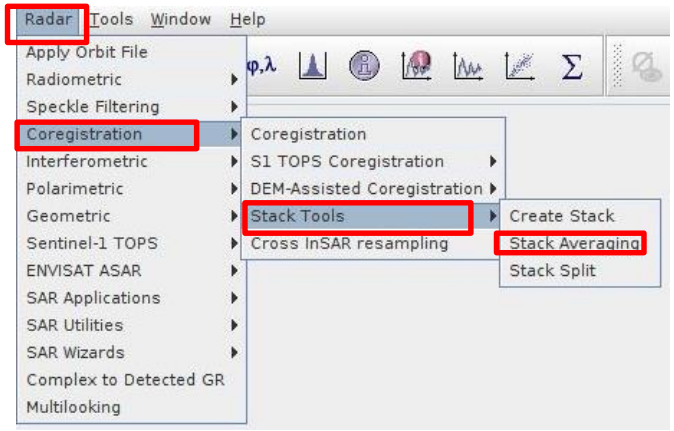
RGB Composite

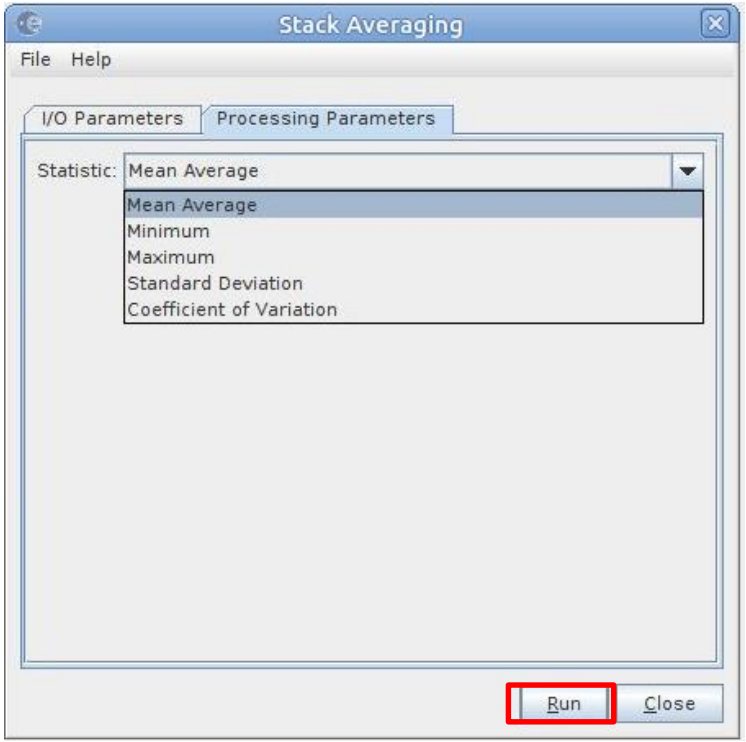


Red – high backscatter in 2015, low backscatter in 2019
Cyan – low backscatter in 2015, high in 2019



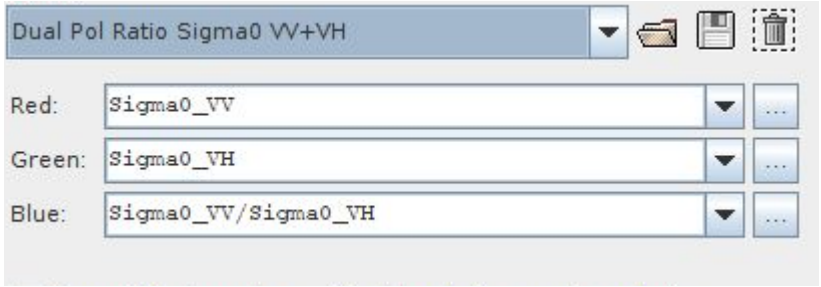
Stack averaging

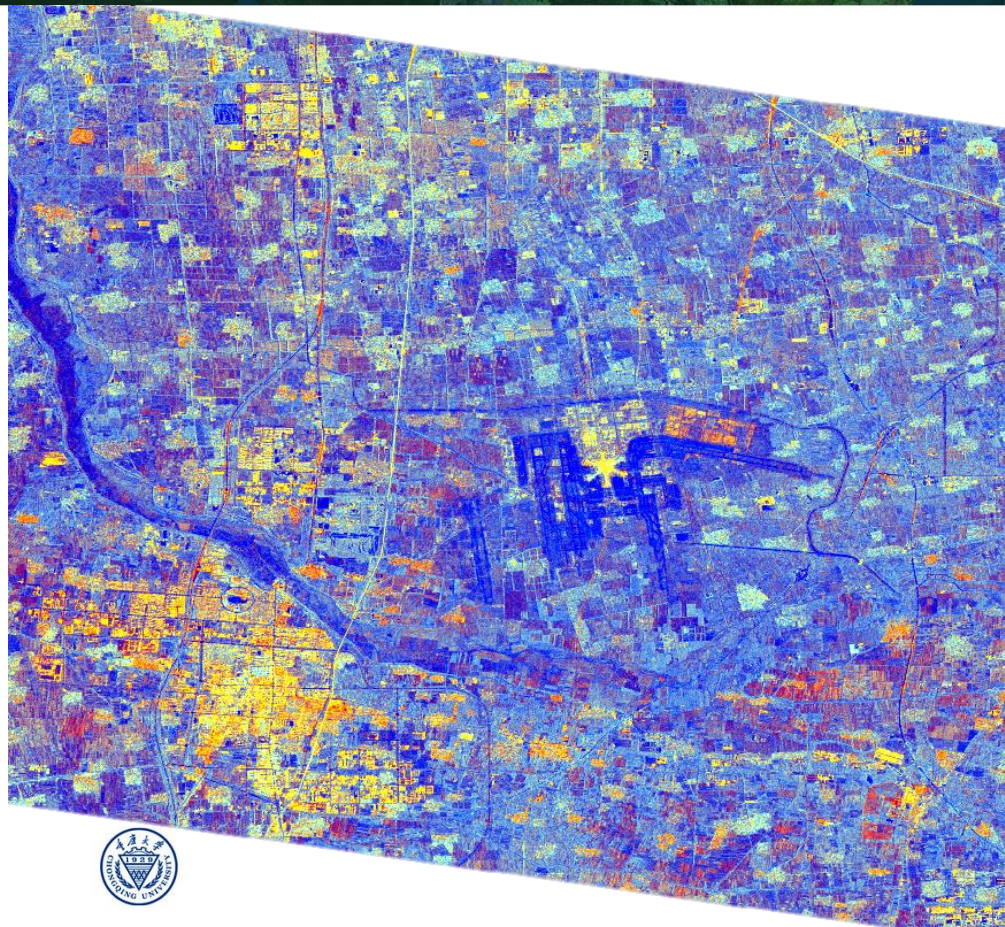




Stack averaging – RGB Composite

RGB combination for land cover classification





Part 1

Multitemporal Analysis using SAR Coherence-Intensity composites

Objectives

- Familiarizing with Sentinel-1 SLC prodcucts
- Calculation of backscatter intensity from Sentinel-1 SLC products
- Calculation of interferometric coherence
- Analysis of coherence and intensity false colour composites

Introduction

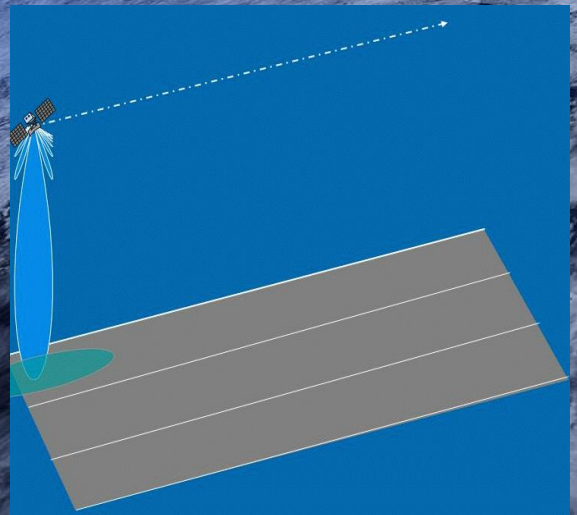
Input data: set of two Sentinel-1 SLCs

S1A_IW_SLC__1SDV_20151003T222043_20151003T222111_007994_00B2F6_4C0E.zip
S1A_IW_SLC__1SDV_20171115T222013_20171115T222041_008298_00EAE8_F7A2.zip

Output: coherence – intensity false colour composites for land cover mapping and change detection

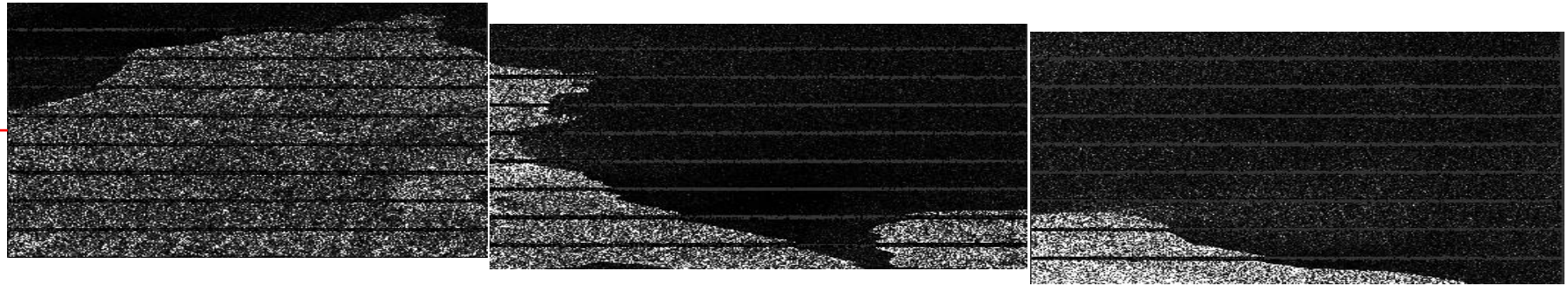
Sentinel-1 data acquisition

Terrain **O**bservation
by **P**rogressive **S**cans
(TOPS)



Sentinel-1 TOPS Data Handling and Processing

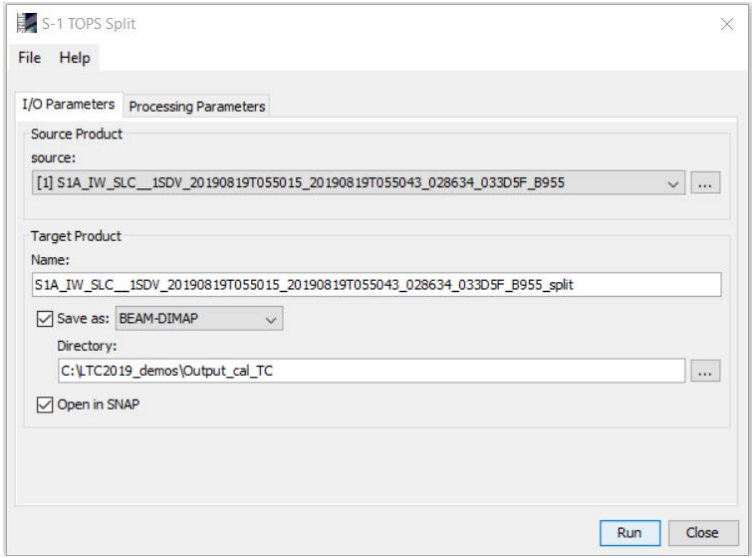
Bursted IW SLC

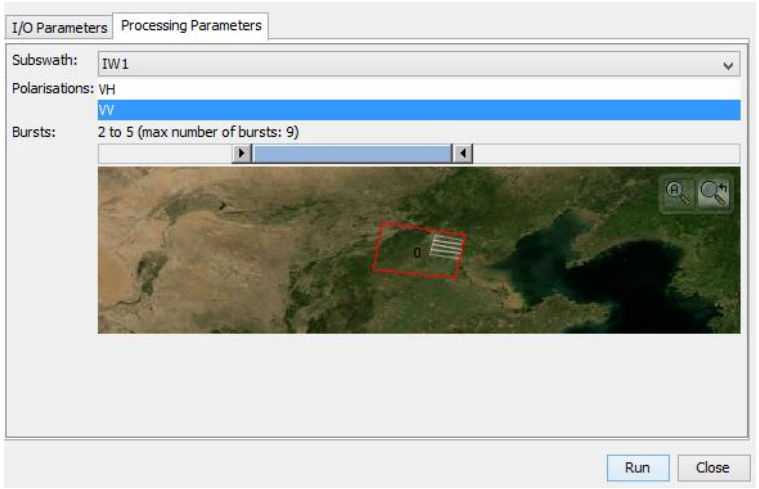


TOPSAR Split to choose a subswath and bursts for the AOI

Sentinel-1 TOPSAR Split

Radar/Sentinel-1 TOPS/S-1 TOPS Split





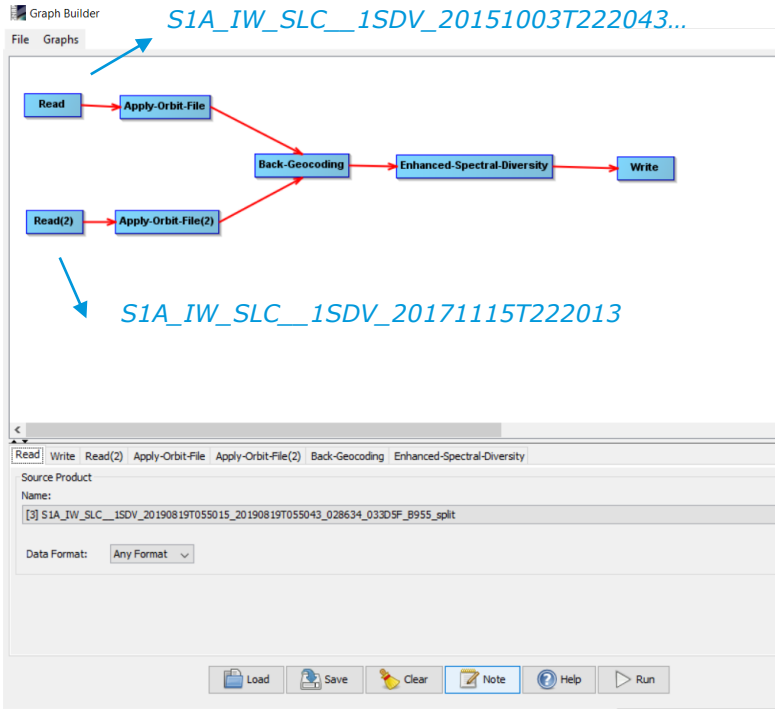
- Selection of subswath
- Selection of polarization
- Selection of bursts

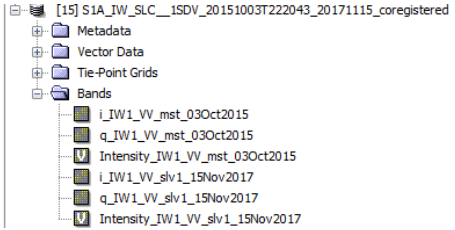
IW1
VV
2-5

TOPS Split applied to both S-1 SLCs

STEP 1
Interferometric Coherence

Coregistration





Coregistered bands in one product

Co-registration of two S-1 SLC split products (master and slave) of the same sub-swath using the orbits of the two products and a Digital Elevation Model (DEM).

ESD estimates the range and azmiuth offset (exploiting the data at the overlapped area of the adjacent bursts) and performs range and azimuth corrections for every burst in the slave image

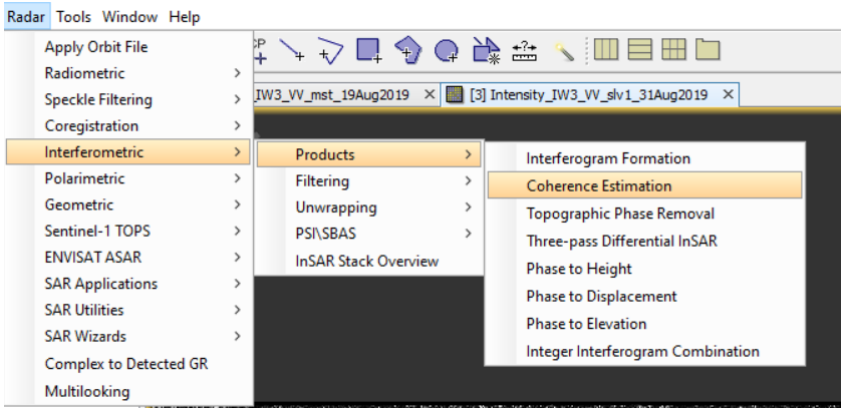
Interferometric Coherence

COHERENCE

Measure of correlation between phase in two SAR complex images
Ranging from 0 (no correlation) to 1

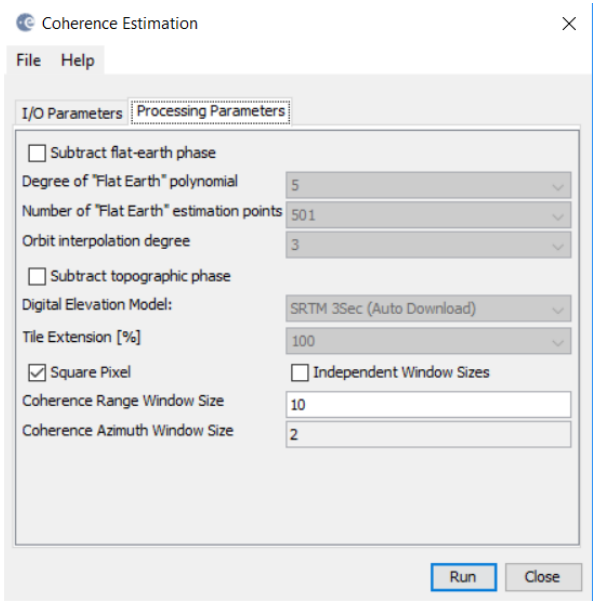
Coherence may be affected by:

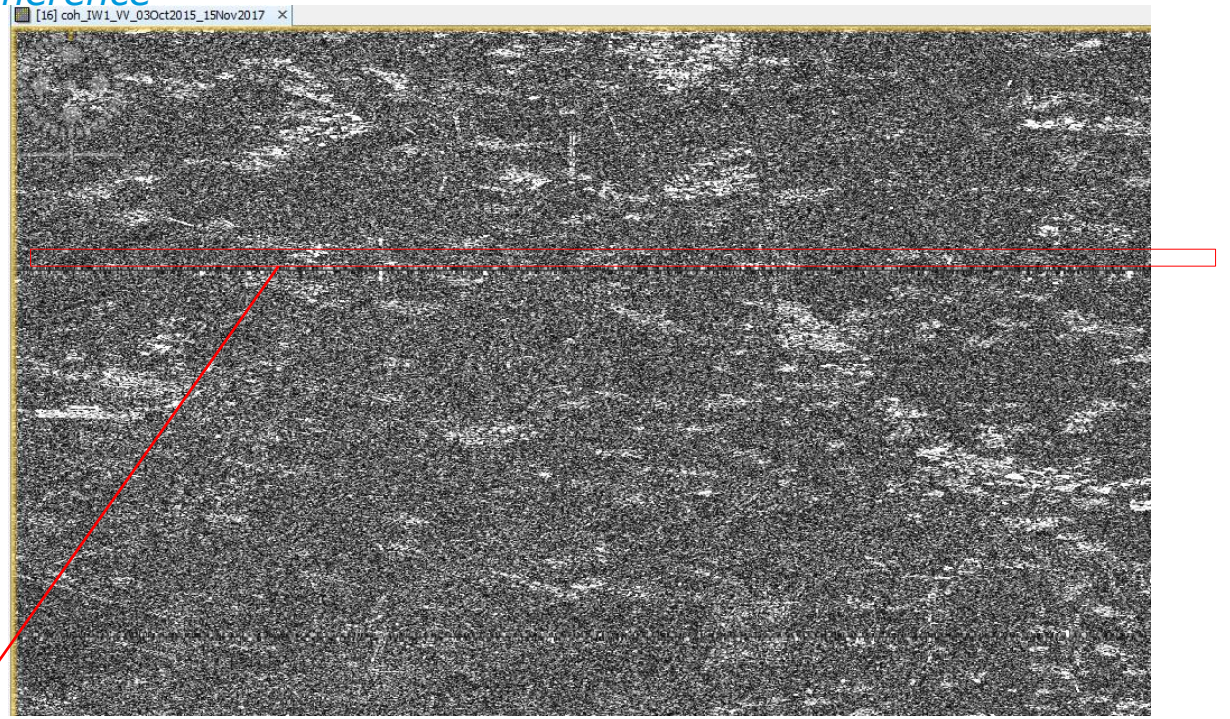
- Local slope
- Properties of the surface
- Time lag between acquisitions
- The perpendicular baseline
- Poor coregistration



Interferometric Coherence

Radar/Interferometric/Products/Coherence

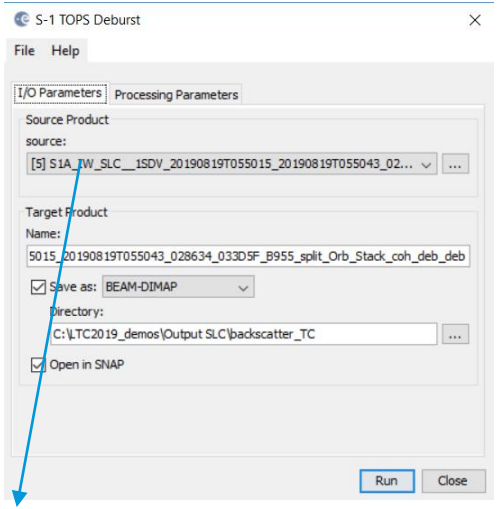




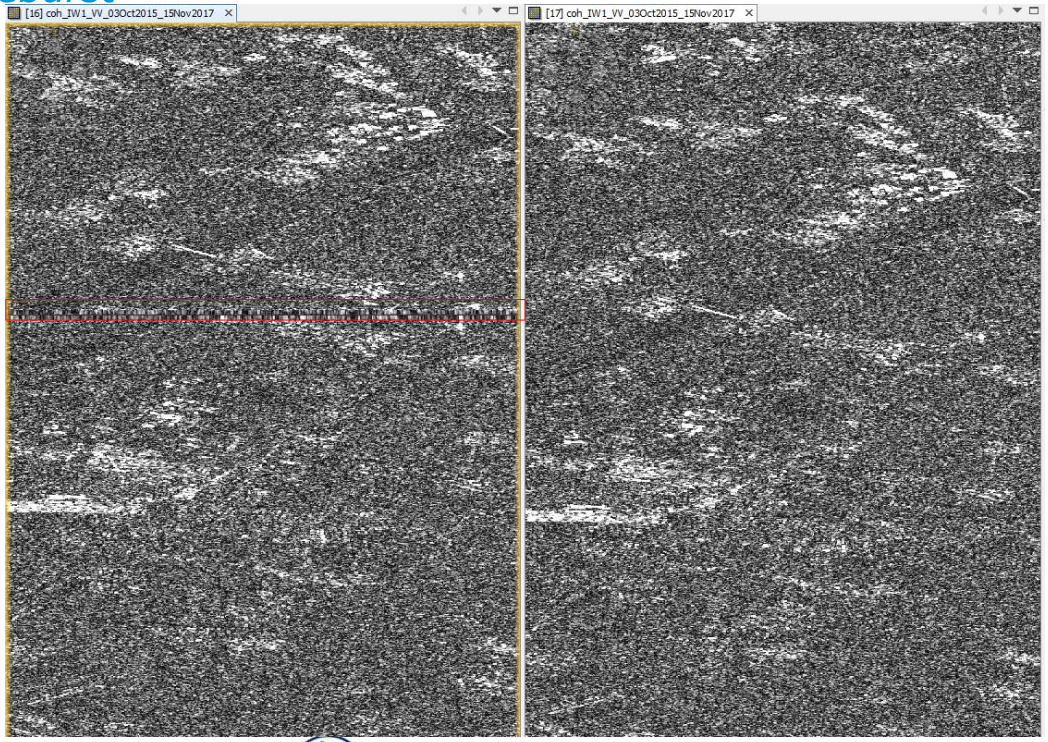
Demarcation black-filled line between bursts

S-1 TOPS Debursting

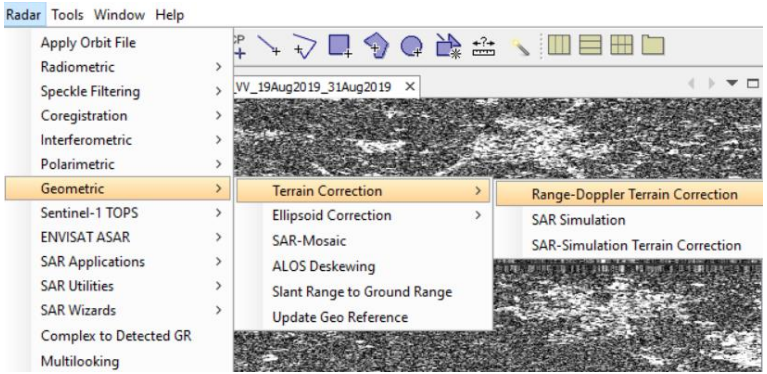
Radar/Sentinel-1 TOPS/S-1 TOPS Deburst



Input: Coherence

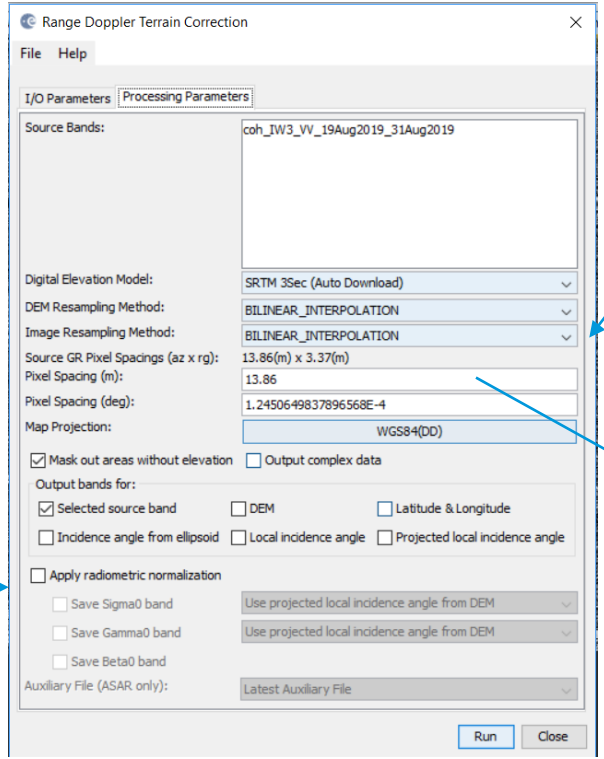


Terrain Correction



Compensate for geometric distortions caused by topographical variations of a scene and the tilt of satellite sensor

+ Geocoding



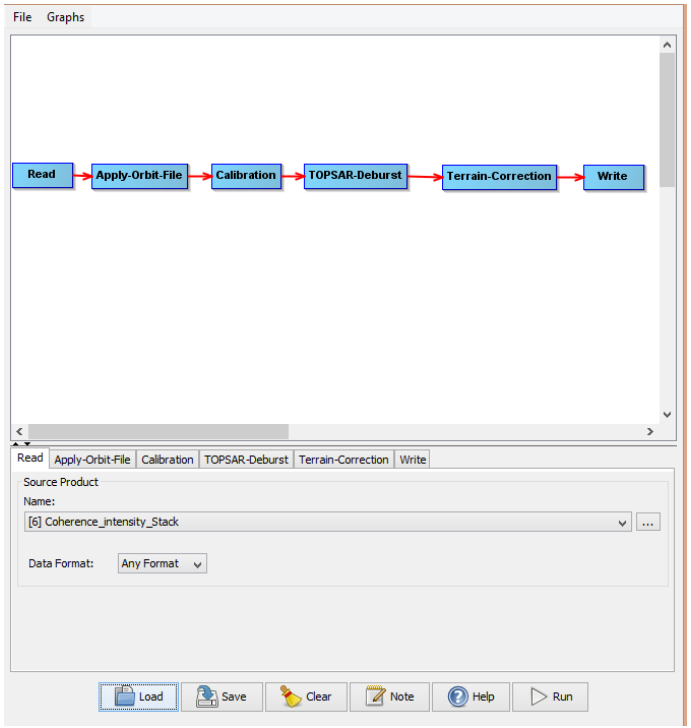
Select:
- DEM
- Resampling
- Pixel spacing
- Projection

Pixel spacing 20m

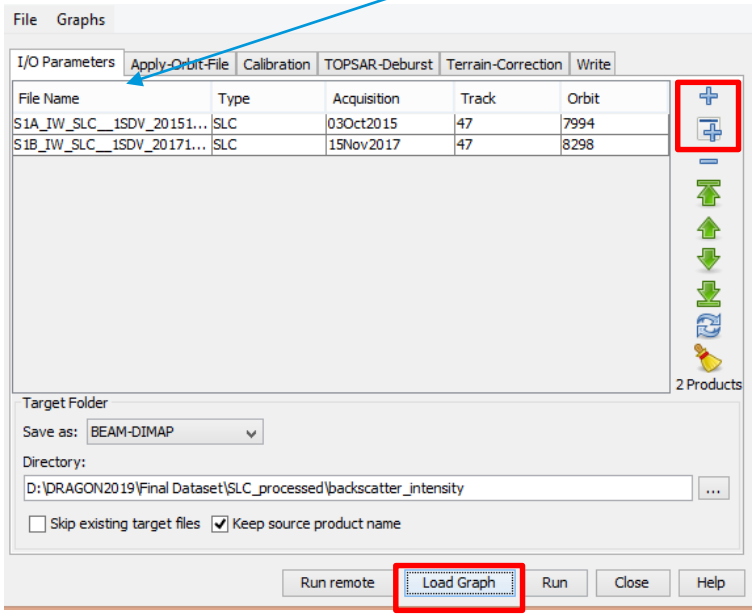
STEP 2
Backscatter Intensity

Backscatter Intensity product

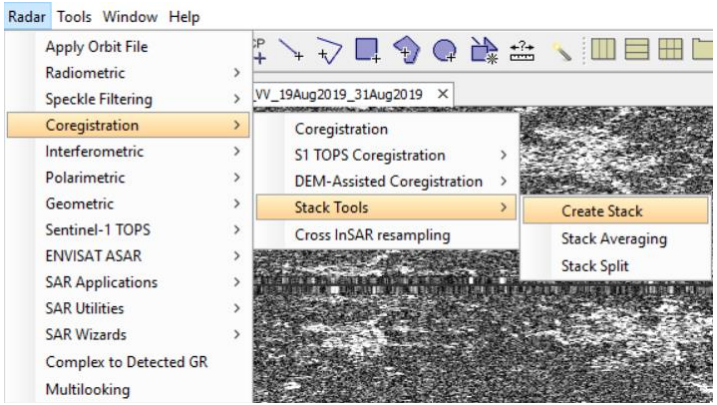
MENU: *Graph Builder + Batch processing tool*



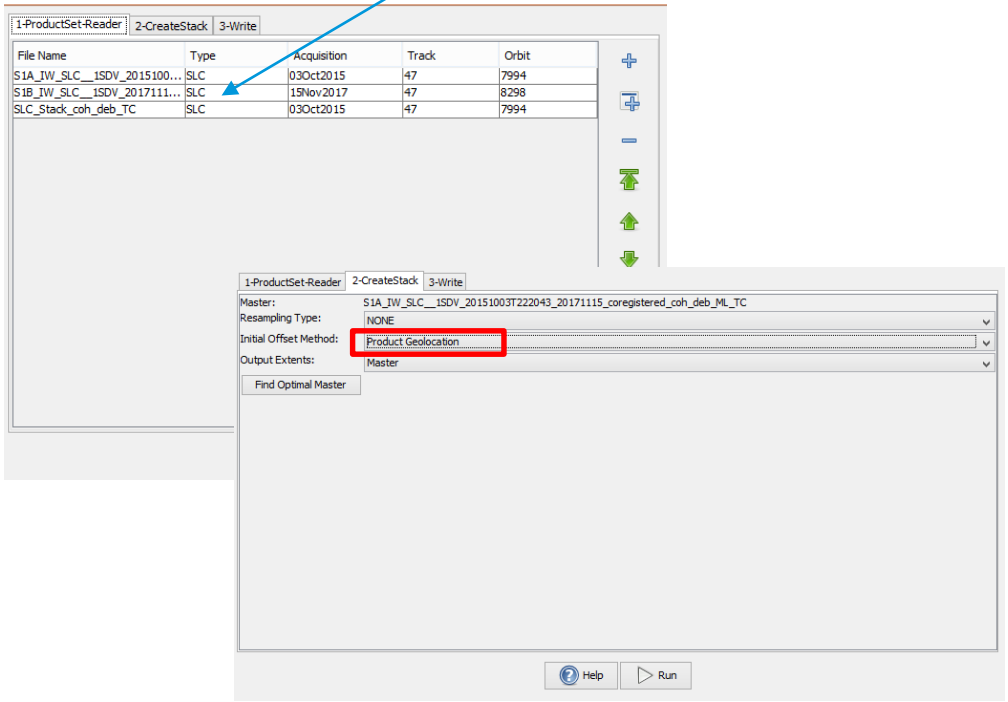
Input: Two splitted SLCs



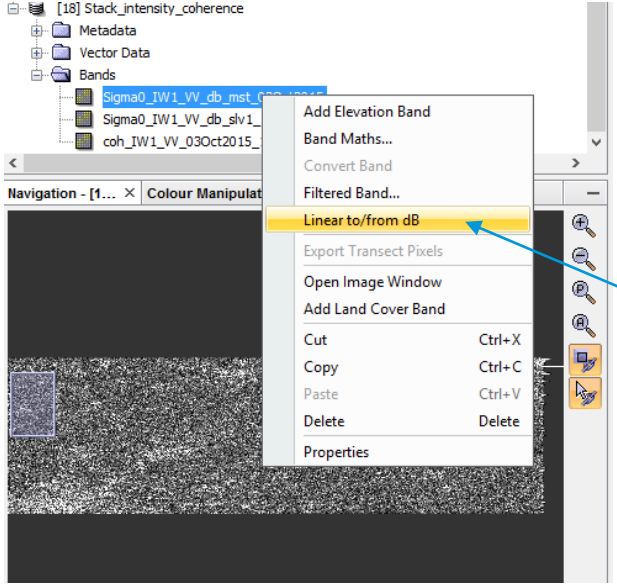
Creating a stack



Input: Coherence from STEP 1
Intensity backscatter for 2 SLCs from STEP 2

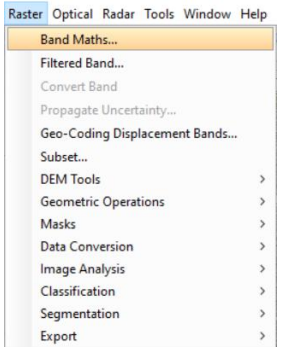


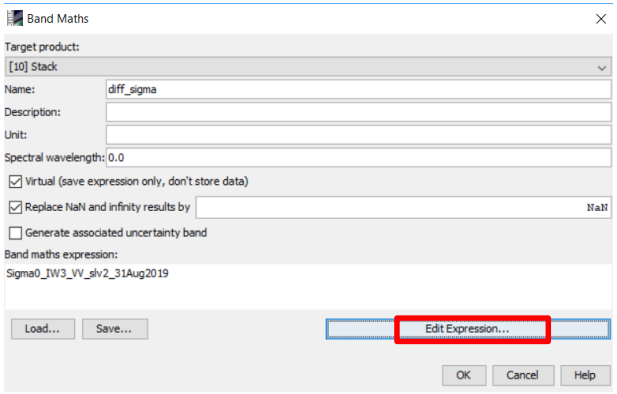
Conversion of sigma0 to db



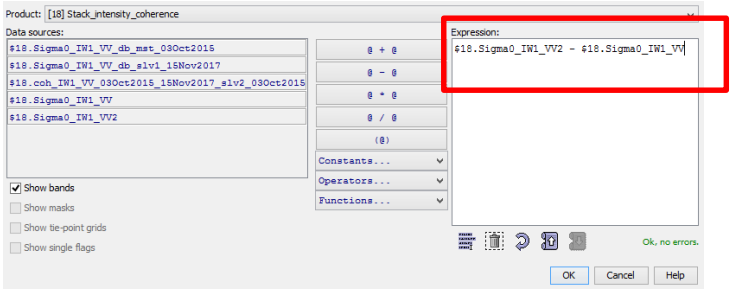
- Right click on the sigma0 band
- Conversion linear to/from db
- Right click on the sigma0_db virtual band
- Select „convert band”
- Save the product: File/Save product

Band math: average sigma 0 and difference

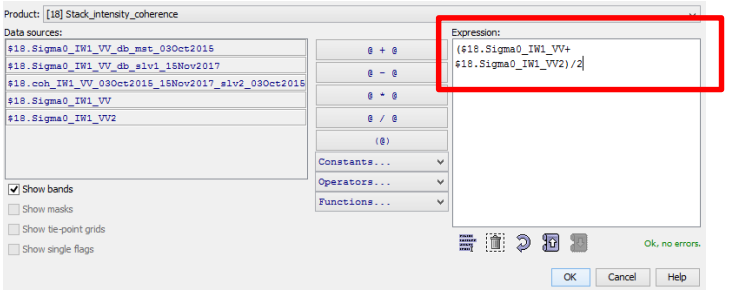




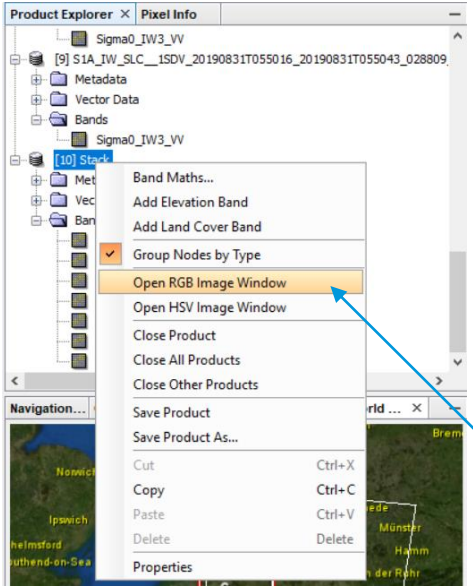
Sigma0 difference

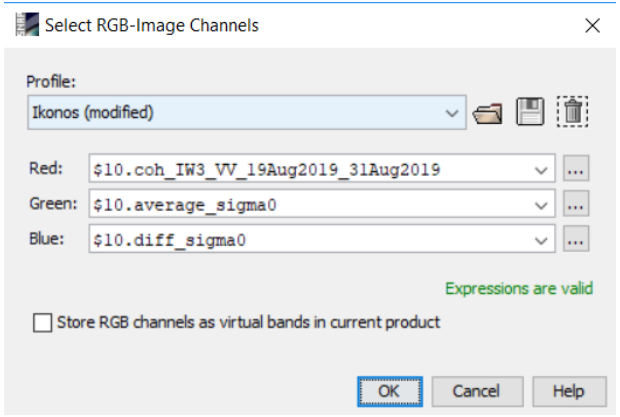


Sigma0 average



Creating RGB false composite



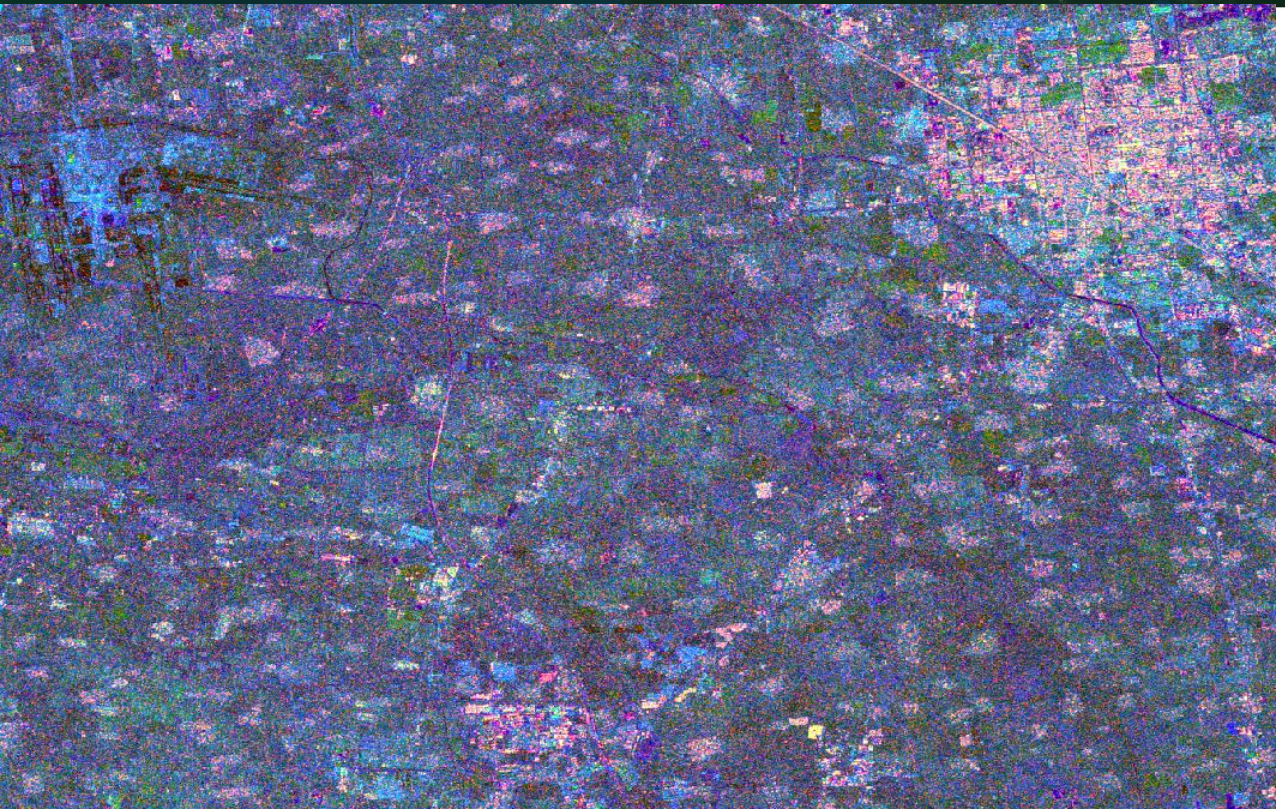


Select RGB bands:

R: coherence
G: average sigma0
B: difference sigma0

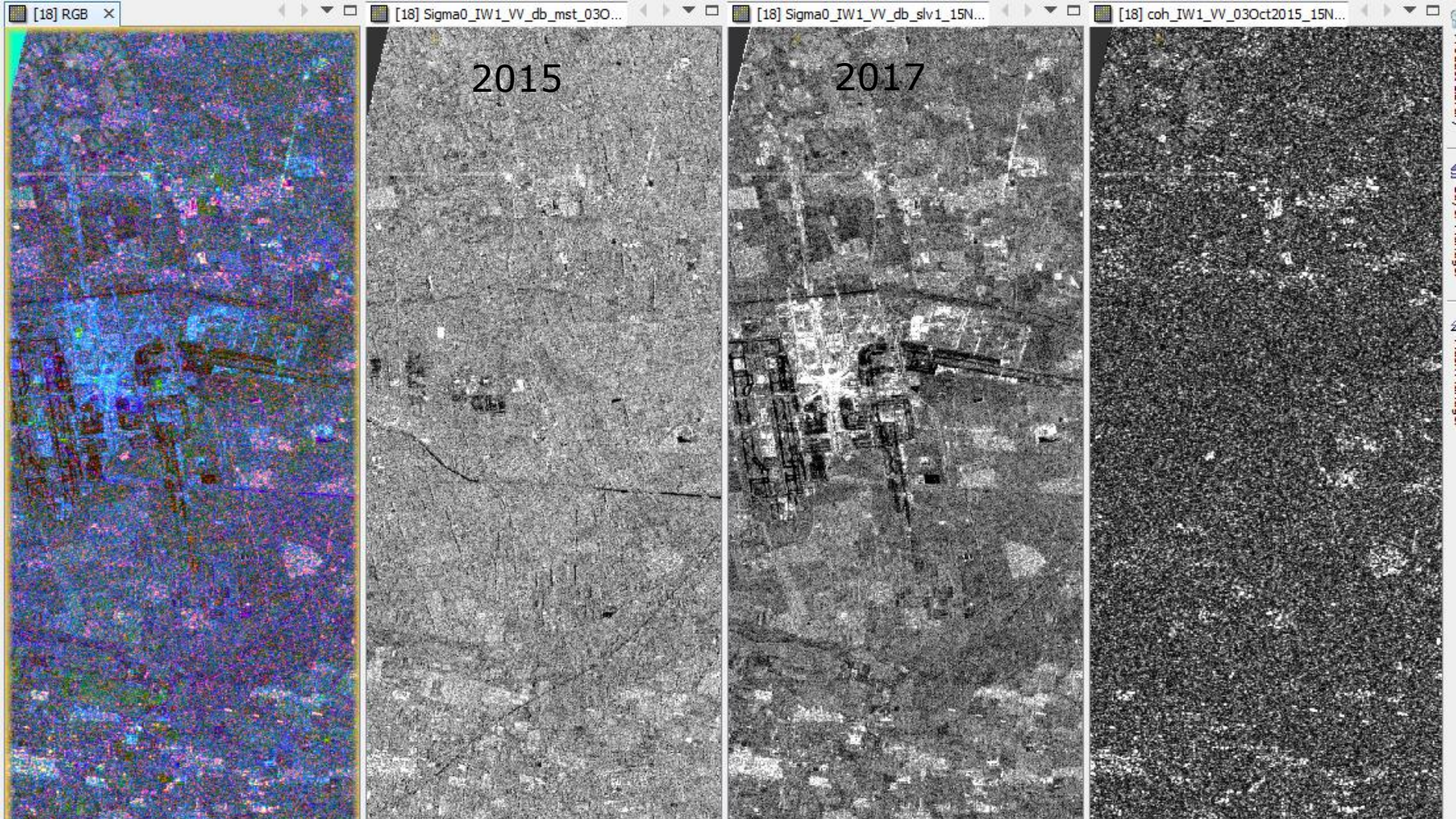
- Right click on the stack product
- Open RGB Image Window

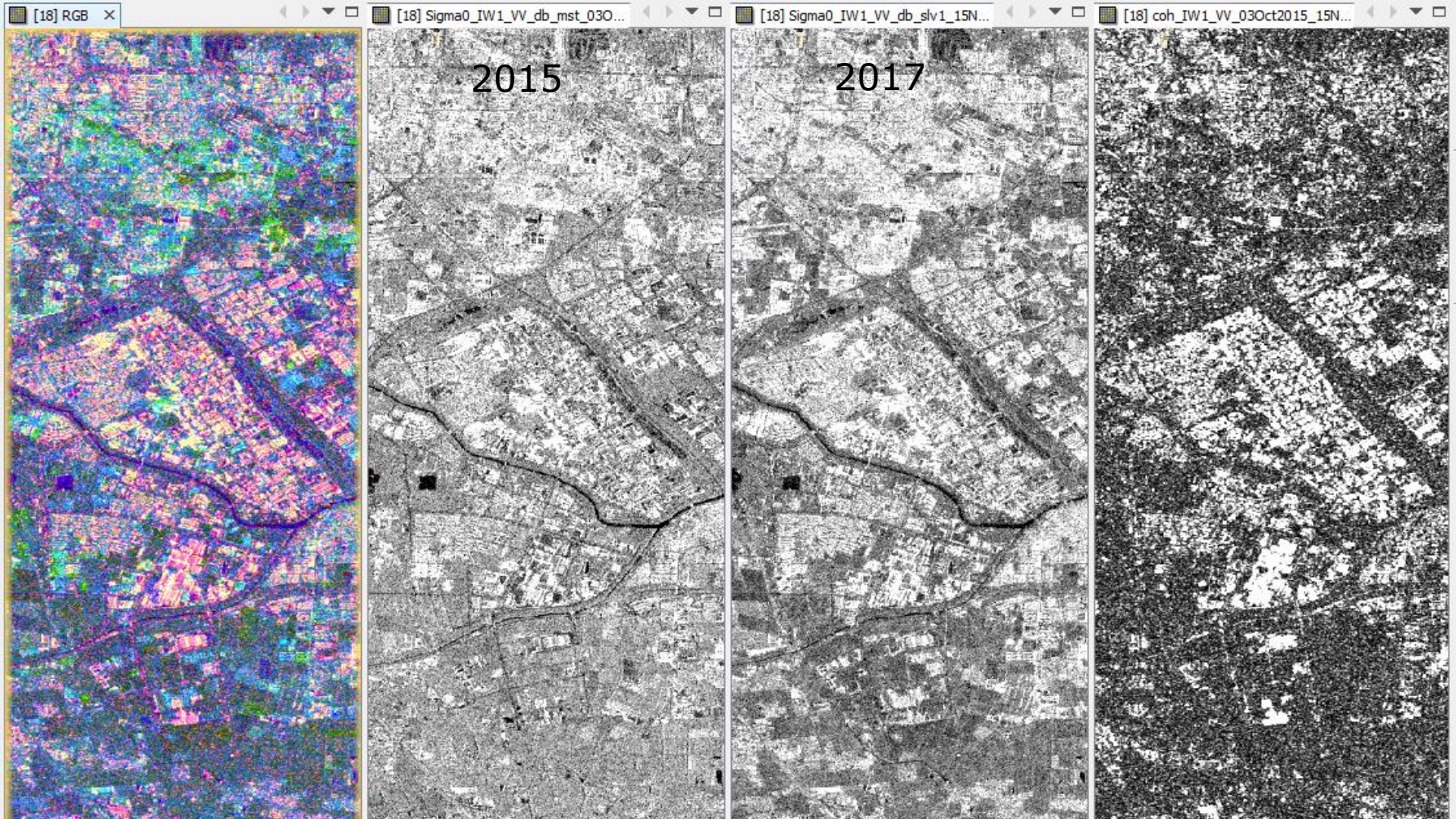
Resulting RGB false composite



Multi-temporal product (2015-2017)

Yellow: Urban centers
Magenta: objects not changing
Green: Vegetated lands and forests
Blue: objects that changed


[18] RGB
[18] Sigma0_IW1_VV_db_mst_03O...
2015
[18] Sigma0_IW1_VV_db_slv1_15N...
2017
[18] coh_IW1_VV_03Oct2015_15N...


[18] RGB
[18] Sigma0_IW1_VV_db_mst_03O...
[18] Sigma0_IW1_VV_db_slv1_15N...
[18] coh_IW1_VV_03Oct2015_15N...
2015
2017