

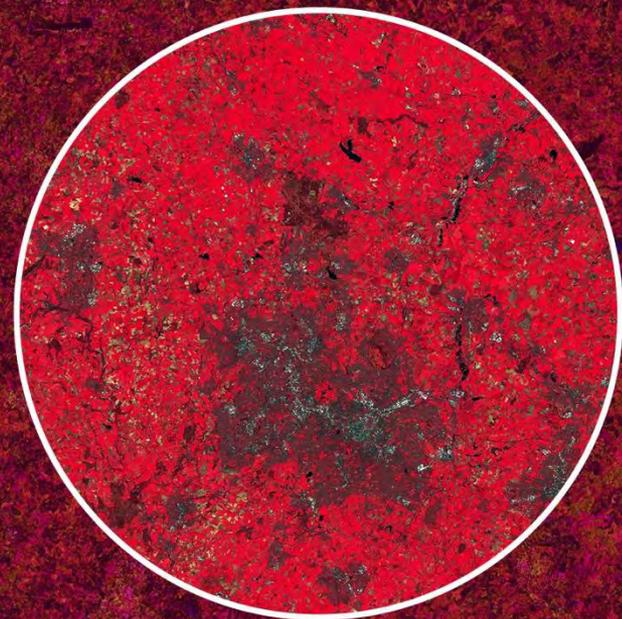
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10–14 September 2018
University of Leicester | United Kingdom

DIInSAR with Copernicus Sentinel-1 IW TOPS

Dr. Andrea Minchella (Airbus DS, Intelligence UK)

11/09/2018



Background:

- Earthquake which took place on the 25th August 2015 in Chile
- Sentinel-1 TOPS pair acquired before (24 August) and after the event (17 September)

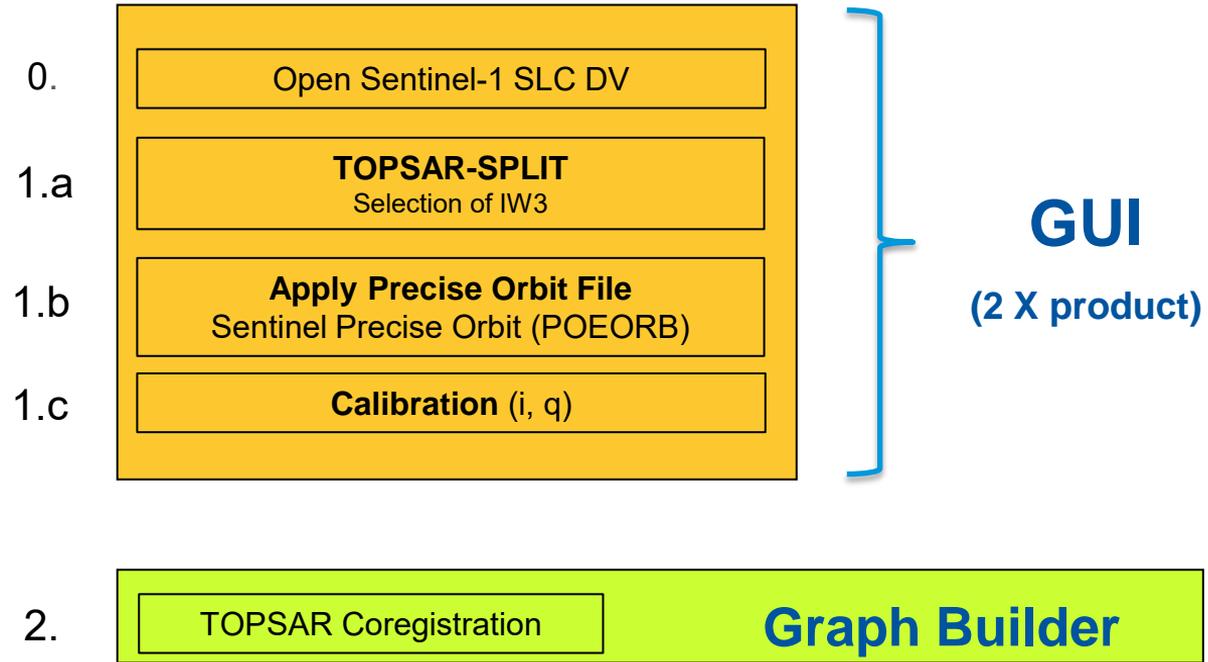
Objective is to show:

- Ex.#1 how coregister the pair (24 days apart) of Sentinel-1 TOPS SLC images
- Ex.#2 how to generate a wrapped DInSAR (co-seismic) interferogram from the Sentinel-1 TOPS pair providing information about the earthquake.

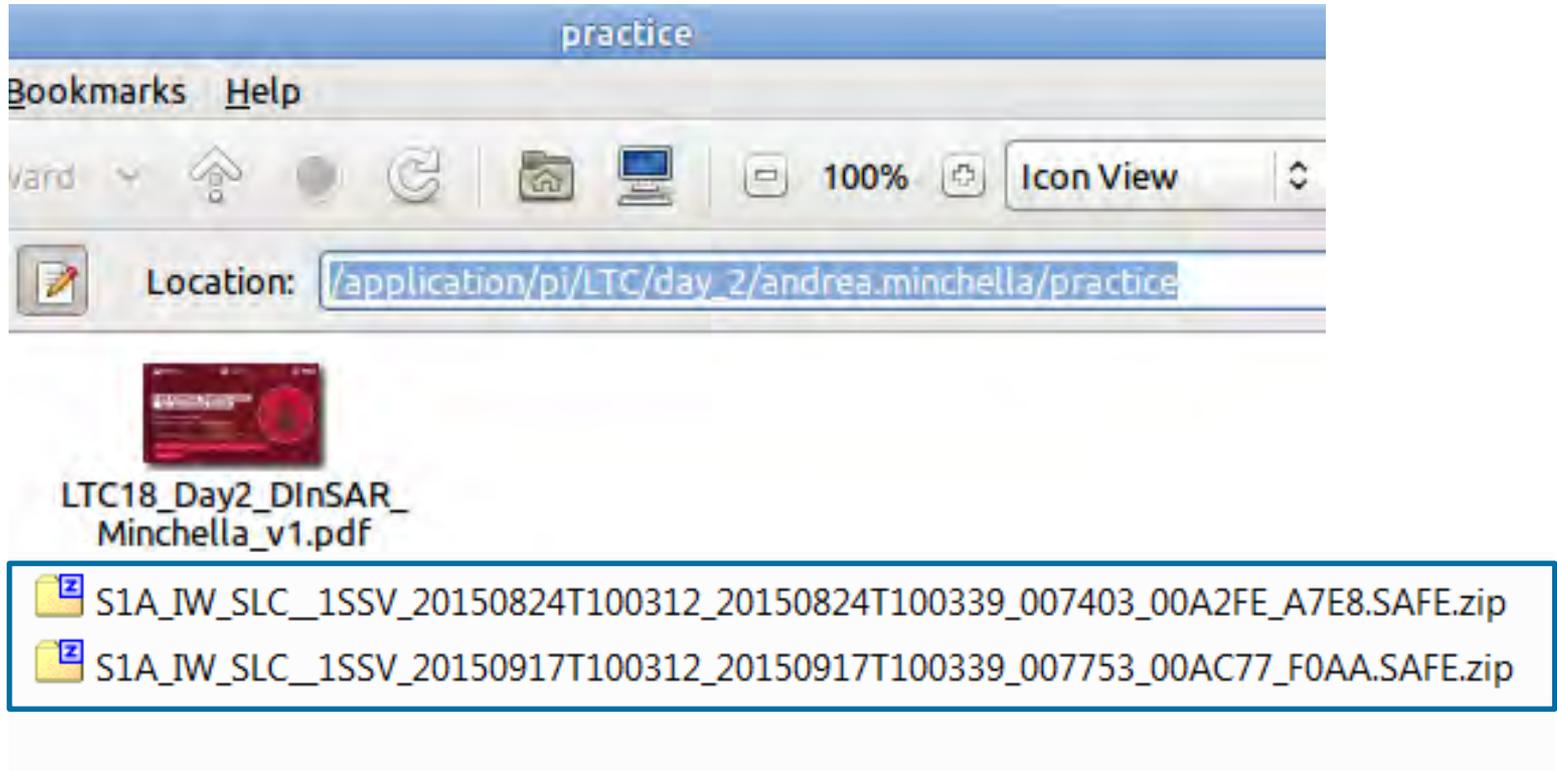
In particular:

- IW3 swath with VV polarisation only will be exploited
- Exercises will use GUI and Graph Builder Tool

Processing Steps: Ex.#1

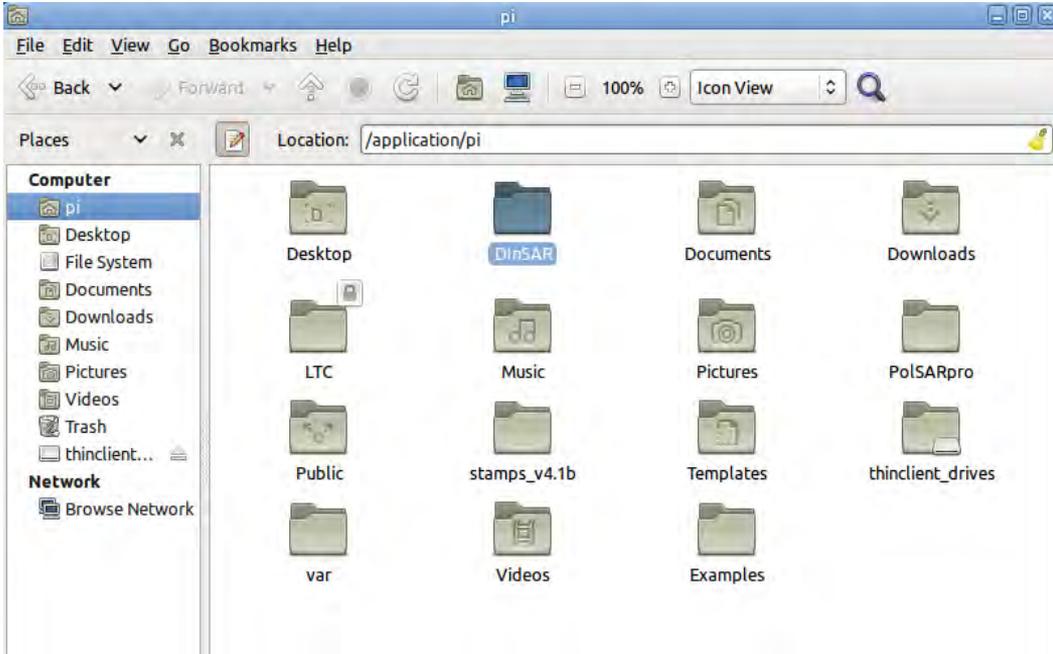


Where are the data



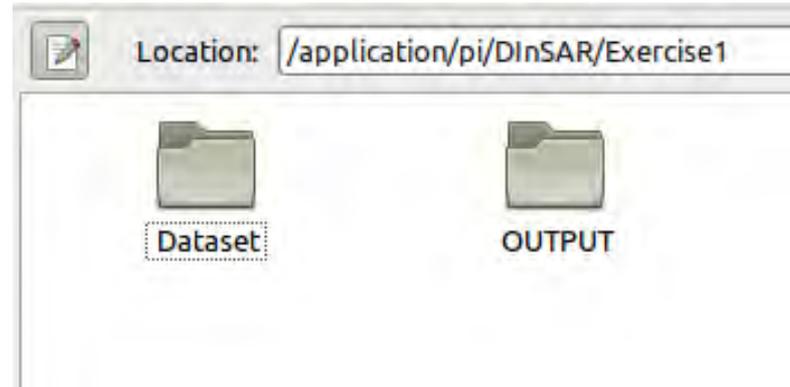
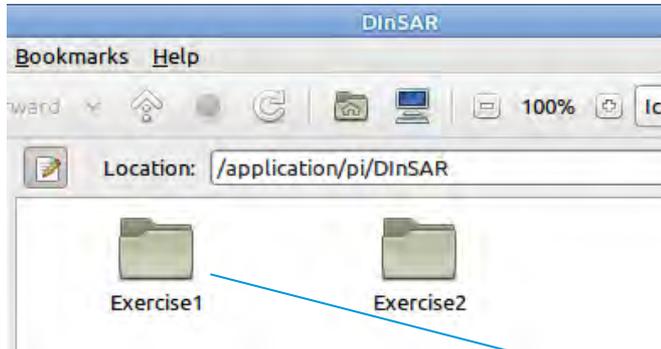
Where are the data

Creation of a new folder called **“DInSAR”** within **./application/pi**



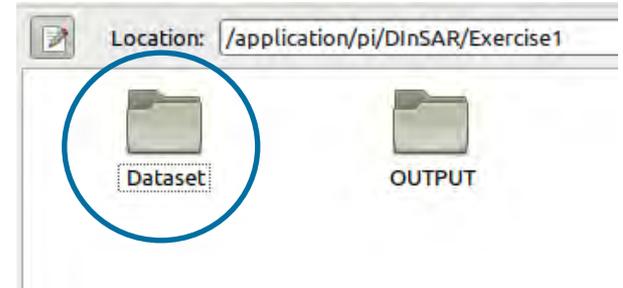
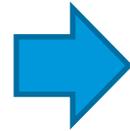
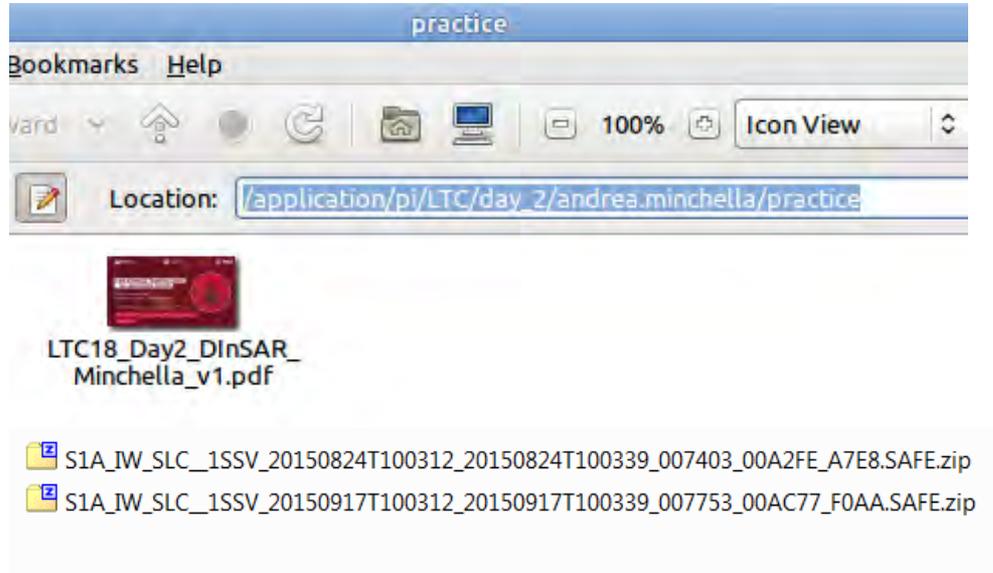
Where are the data

Within ./DinSAR create the following two folders



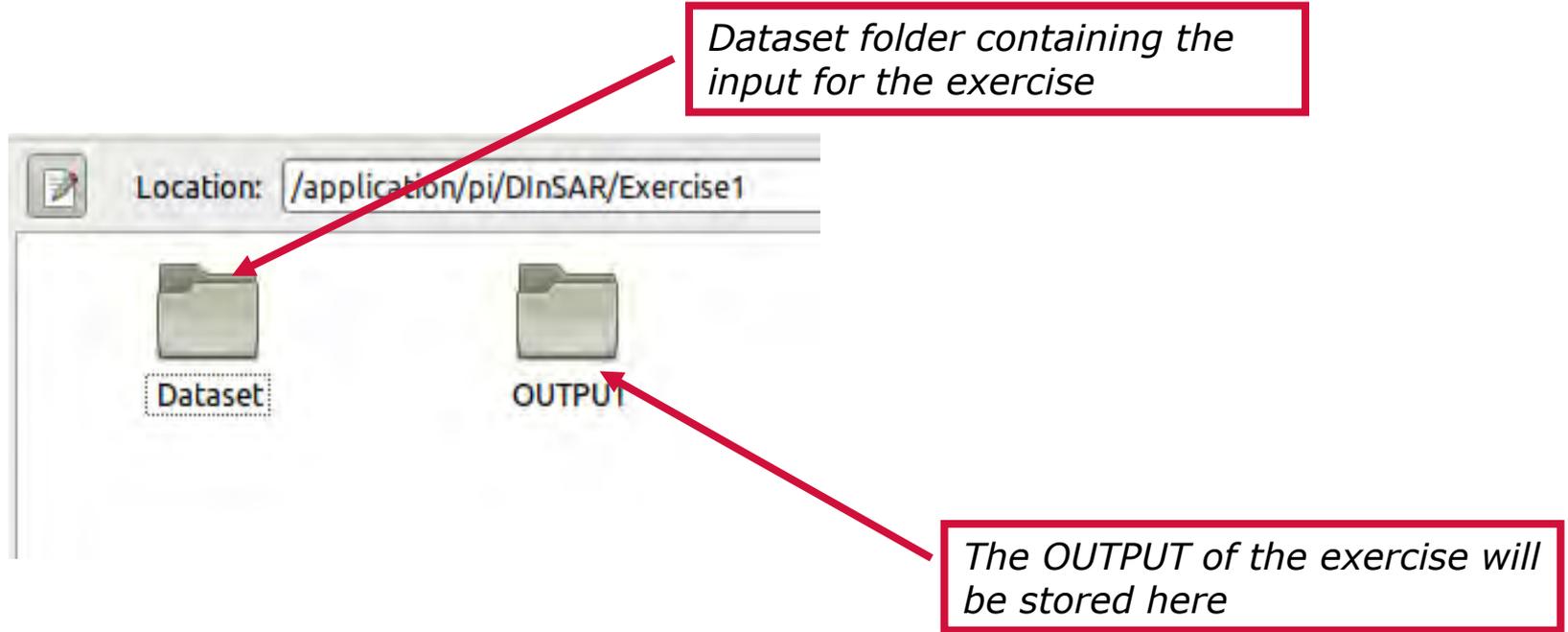
Where are the data

Copy the 2 Sentinel-1 images from



Exercise folders

./LTC2018/DInSAR/Exercise1



Dataset



Name	Size	Date modified
 S1A_IW_SLC_1SSV_20150824T100312_20150824T100339_007403_00A2FE_A7E8.SAFE.zip	2,231,889 KB	11/10/2016 15:30
 S1A_IW_SLC_1SSV_20150917T100312_20150917T100339_007753_00AC77_F0AA.SAFE.zip	2,232,074 KB	11/10/2016 15:45

Product type: IW_SLC_1SSV

Acquisition mode: Interferometric wide swath

Product type: SLC

Polarisation: VV

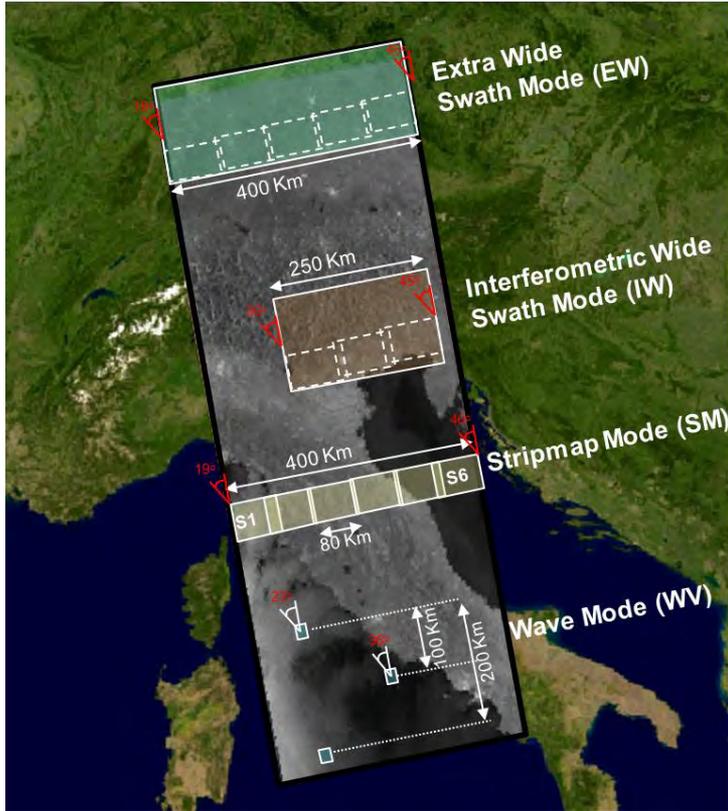
Orbit: Ascending

Location: Chile



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10–14 September 2018 | University of Leicester | United Kingdom



Sentinel-1 SAR can be operated in **4 exclusive imaging modes** with different resolution and coverage:

Mode Rate	SAR Mode
High Bit Rate (HBR)	IW
	EW
	SM (S1 → S6)
Low Bit Rate (LBR)	WV

Polarisation schemes for IW, EW and SM:

- single polarisation: HH or VV
- dual polarisation: HH+HV or VV+VH

For Wave mode: HH or VV

Sentinel-1 Mission Performance

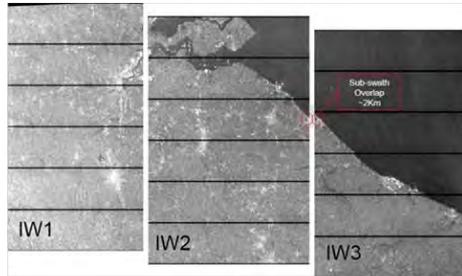
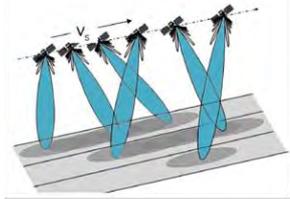


Mode	Access Angle	GR <u>Single Look</u> Resolution	Swath Width	Polarisation
Strip Map	20-45 deg.	Range 5 m Azimuth 5 m	> 80 km	HH or VV or HH+HV or VV+VH
Interferometric Wide Swath	> 25 deg.	Range 5 m Azimuth 20 m	> 250 km	HH or VV or HH+HV or VV+VH
Extra Wide Swath	> 20 deg.	Range 20 m Azimuth 40 m	> 400 km	HH or VV or HH+HV or VV+VH
Wave mode	23 deg. & 36.5 deg.	Range 5 m (TBC) Azimuth 5 m (TBC)	> 20 x 20 km Vignettes at 100 km intervals	HH or VV
For All Modes				
Radiometric accuracy (3 σ)				1 dB
Noise Equivalent Sigma Zero				-22 dB
Point Target Ambiguity Ratio				-25 dB
Distributed Target Ambiguity Ratio				-22 dB

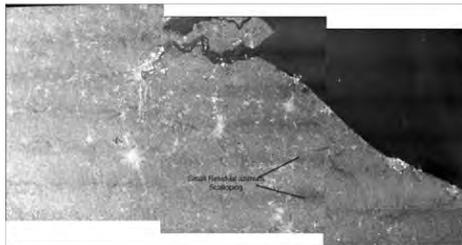
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Terrain Observation with Progressive Scans SAR (TOPSAR) Interferometric Wide Swath



IW Sub-Swaths with Minimal Overlap

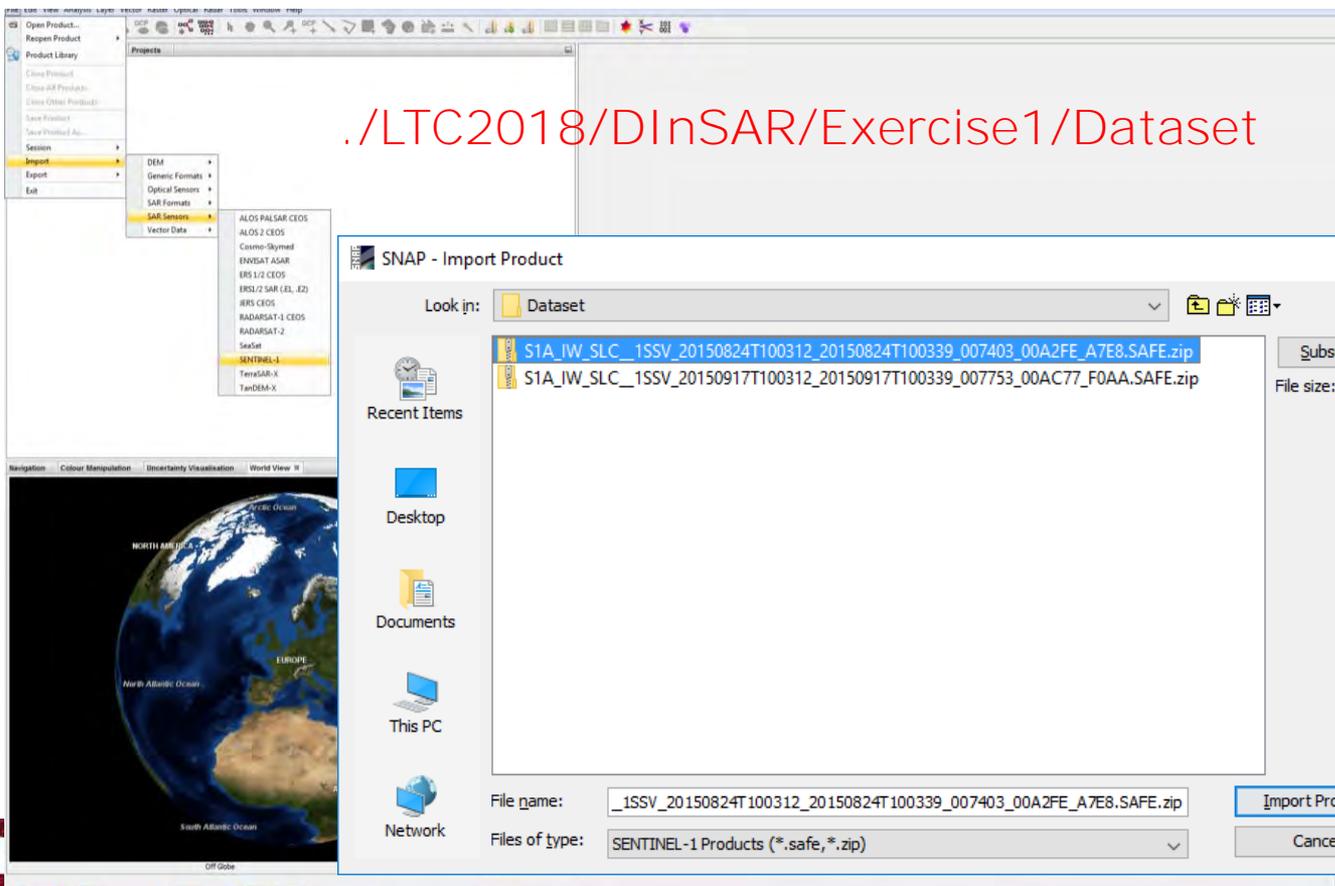


Resulting De-Burst and Merged IW Product

- The Interferometric Wide swath mode is the main acquisition mode over land.
- 250 km swath at 5 m (Range) by 20 (Azimuth) m spatial resolution (single look).
- IW mode captures three sub-swaths using TOPS mode and a IW SLC product contains one image per sub-swath (1 or 2 polarisations)
- Each sub-swath image consists of a series of bursts, where each burst has been processed as a separate SLC image.
- The individually focused complex burst images are included, in azimuth-time order, into a single sub-swath image with black-fill demarcation in between (overlap in azimuth by just enough to provide contiguous coverage of the ground)
- The images for all bursts in all sub-swaths are resampled to a common pixel spacing grid in range and azimuth while preserving the phase information (de-burst and merge)

<https://sentinel.esa.int/web/sentinel/user-guides/sentinel-1-sar/acquisition-modes/interferometric-wide-swath>

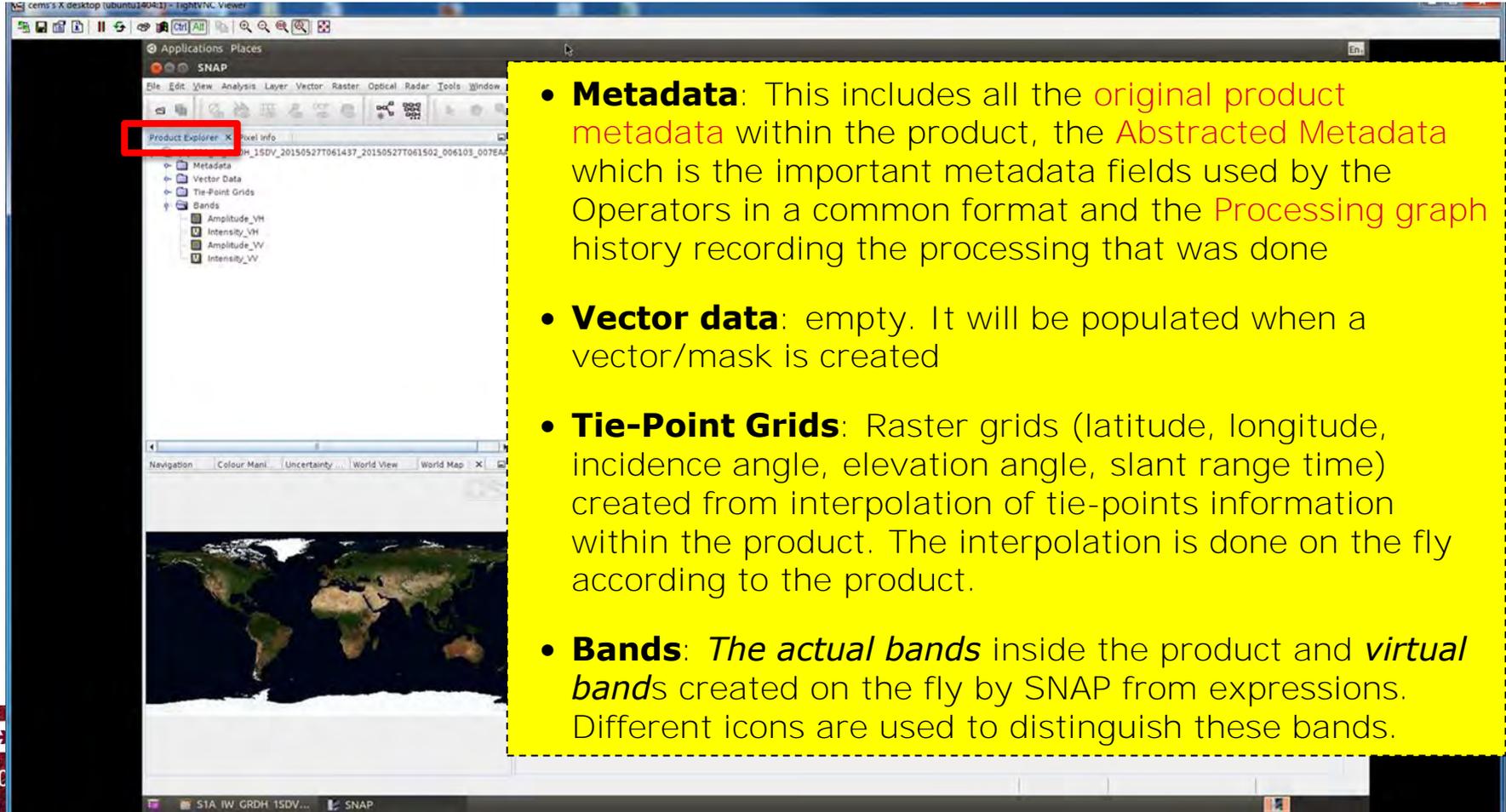
Step 0: Open product (24/08/2015)



./LTC2018/DInSAR/Exercise1/Dataset

- 1) Browse the product in **zip** format directly
- 2) Click over "Import product"

Exercise 1 - Step 1: Inspect the product



The screenshot shows the SNAP (Sentinel Applications) software interface. The 'Product Explorer' panel is visible on the left, showing a tree structure of metadata and bands. The 'Product Explorer' tab is highlighted with a red box. The main window displays a world map with a navigation toolbar at the bottom.

- **Metadata:** This includes all the **original product metadata** within the product, the **Abstracted Metadata** which is the important metadata fields used by the Operators in a common format and the **Processing graph** history recording the processing that was done
- **Vector data:** empty. It will be populated when a vector/mask is created
- **Tie-Point Grids:** Raster grids (latitude, longitude, incidence angle, elevation angle, slant range time) created from interpolation of tie-points information within the product. The interpolation is done on the fly according to the product.
- **Bands:** *The actual bands* inside the product and *virtual bands* created on the fly by SNAP from expressions. Different icons are used to distinguish these bands.

Inspecting the abstracted metadata

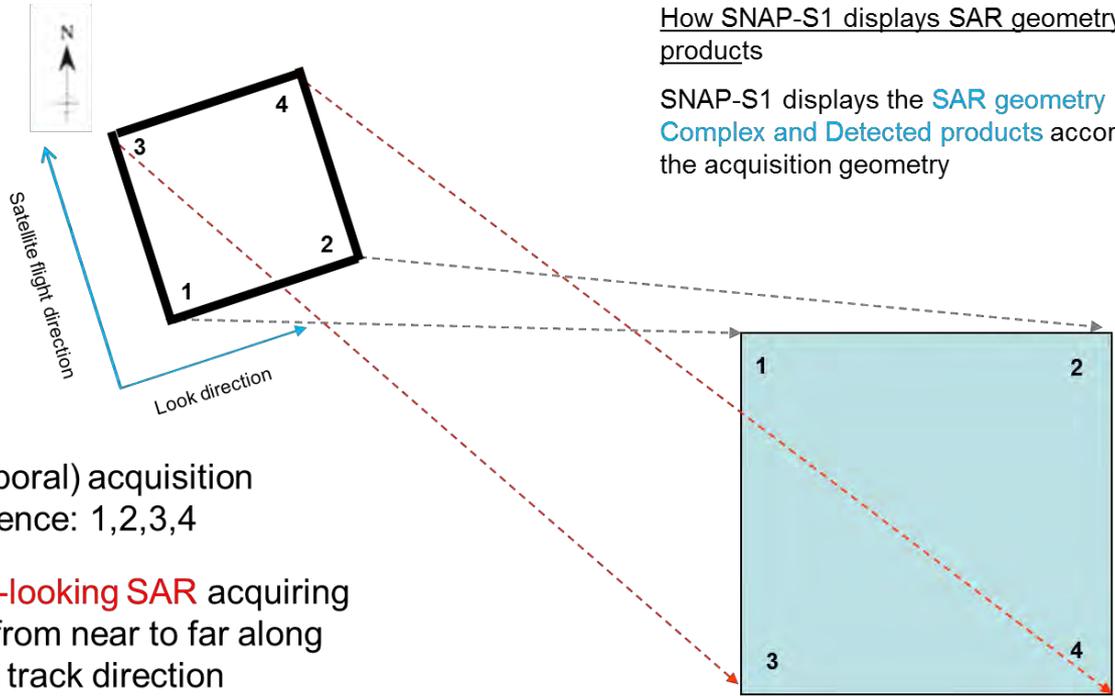


Name	Value	Type	Unit	Description
PRODUCT	S1A_IW_SLC__1SSV_20150824T100312_20150824T100339_007403_00429E	ascii		Product name
PRODUCT_TYPE	SLC	ascii		Product type
SPH_DESCRIPTOR	Sentinel-1 IW Level-1 SLC Product	ascii		Description
MISSION	SENTINEL-1A	ascii		Satellite mission
ACQUISITION_MODE	IW	ascii		Acquisition mode
antenna_pointing	right	ascii		Right or left facing
BEAMS	-	ascii		Beams used
SWATH	-	ascii		Swath name
PROC_TIME	24-AUG-2015 14:00:33.11916Z	uint32	utc	Processed time
Processing_system_identifier	DLR Sentinel-1 SPP 002.53	ascii		Processing system identifier
orbit_cycle	56	int32		Cycle
REL_ORBIT	156	int32		Track
ABS_ORBIT	7403	int32		Orbit
STATE_VECTOR_TIME	24-AUG-2015 10:03:10.247000	uint32	utc	Time of orbit state vector
VECTOR_SOURCE	-	ascii		State vector source
incidence_near	99.999	float64	deg	
incidence_far	99.999	float64	deg	
slice_num	13	int32		Slice number
data_take_id	41736	int32		Data take identifier
first_time_time	24-AUG-2015 10:02:12.247297	uint32	utc	First zero doppler azimuth time
last_time_time	24-AUG-2015 10:03:39.201806	uint32	utc	Last zero doppler azimuth time
first_near_lat	-30.738	float64	deg	
first_near_long	-69.363	float64	deg	
first_far_lat	-30.063	float64	deg	
first_far_long	-71.957	float64	deg	
last_near_lat	-32.221	float64	deg	
last_near_long	-69.811	float64	deg	
last_far_lat	-31.535	float64	deg	
last_far_long	-72.417	float64	deg	
PASS	DESCENDING	ascii		ASCENDING or DESCENDING
SAMPLE_TYPE	COMPLEX	ascii		DETECTED or COMPLEX
mb1_tx_rx_polar	VV	ascii		Polarization
mb2_tx_rx_polar	VV	ascii		Polarization
mb3_tx_rx_polar	-	ascii		Polarization

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10–14 September 2018 | University of Leicester | United Kingdom

Ascending passage – Right looking SAR



How SNAP-S1 displays SAR geometry products

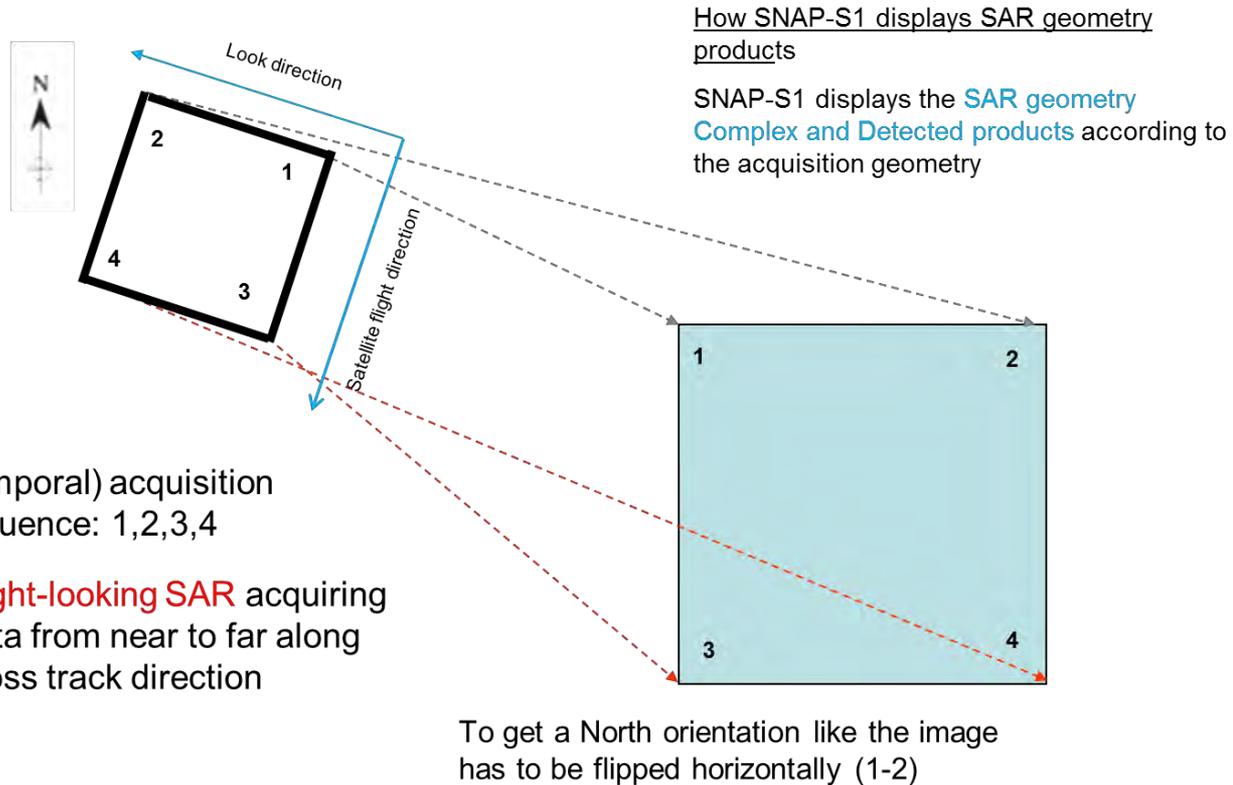
SNAP-S1 displays the **SAR geometry Complex and Detected products** according to the acquisition geometry

(temporal) acquisition sequence: 1,2,3,4

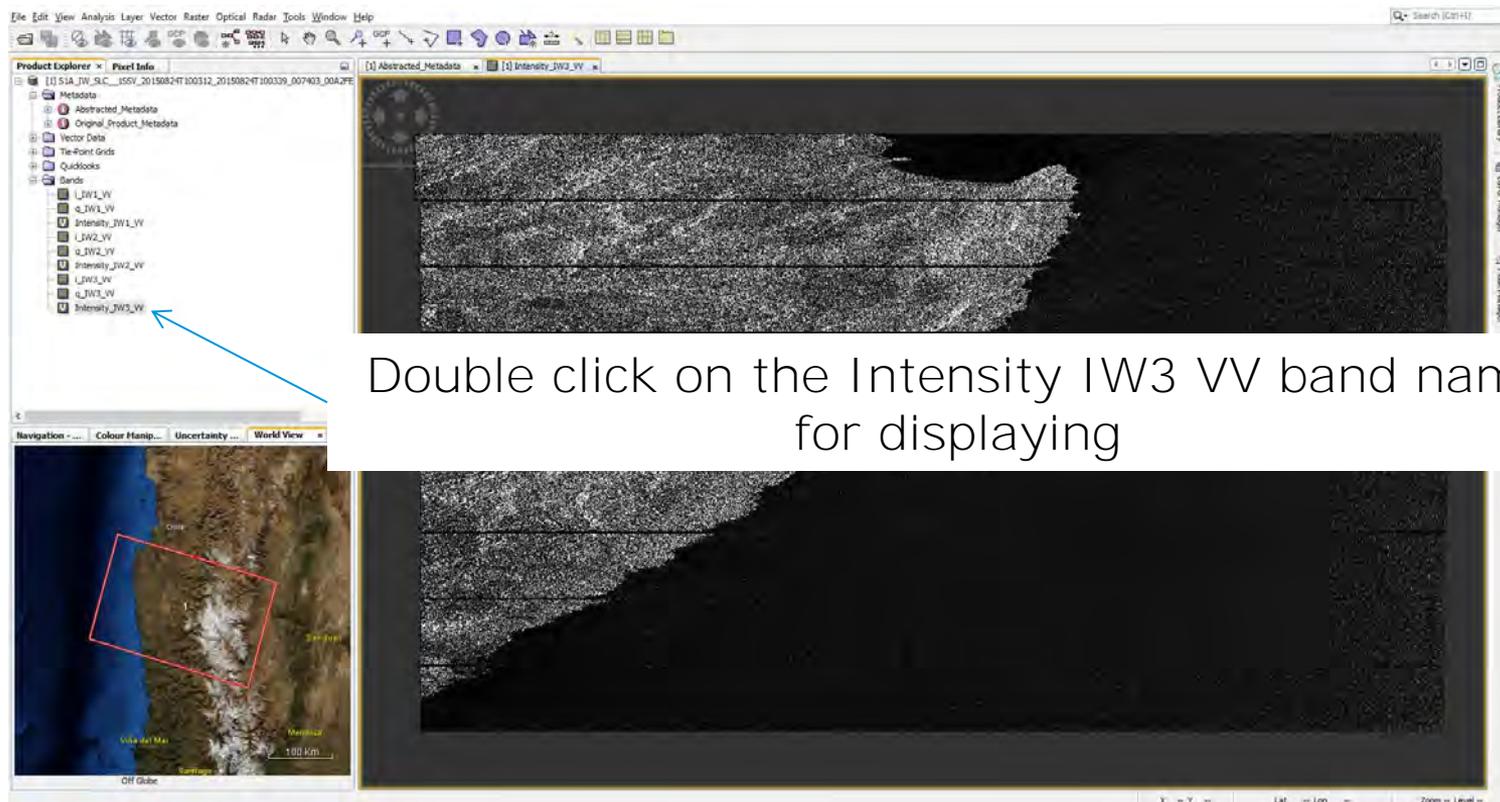
Right-looking SAR acquiring data from near to far along cross track direction

To get a North orientation like the image has to be flipped vertically (1-3)

Descending passage – Right looking SAR

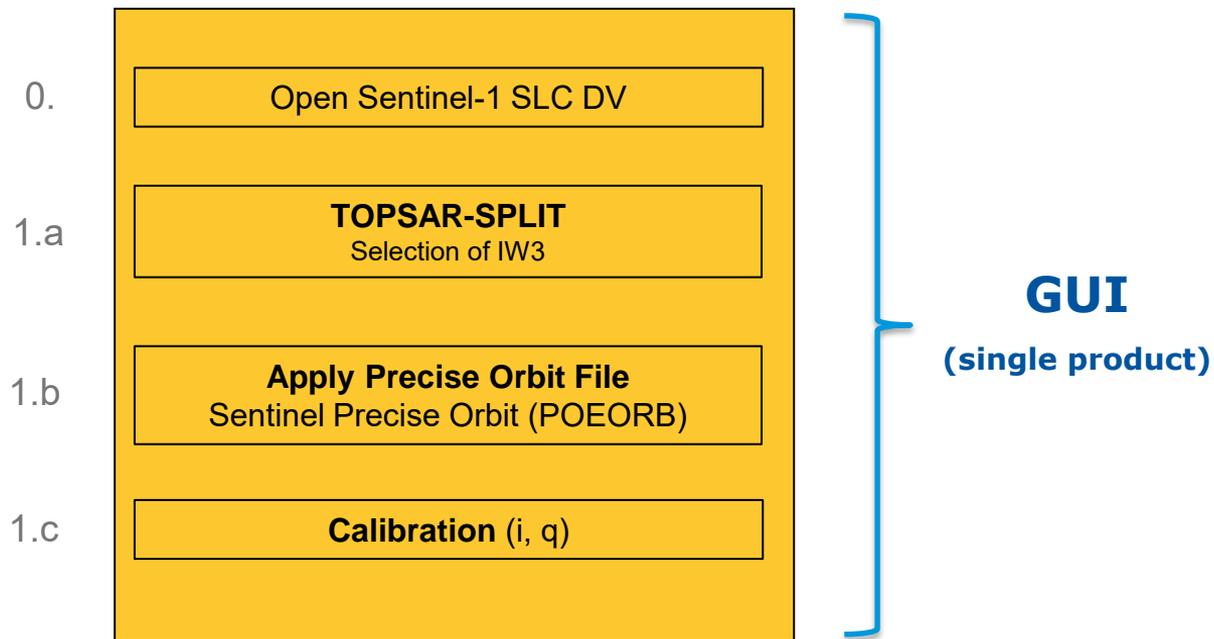


Display a band (Intensity VV)



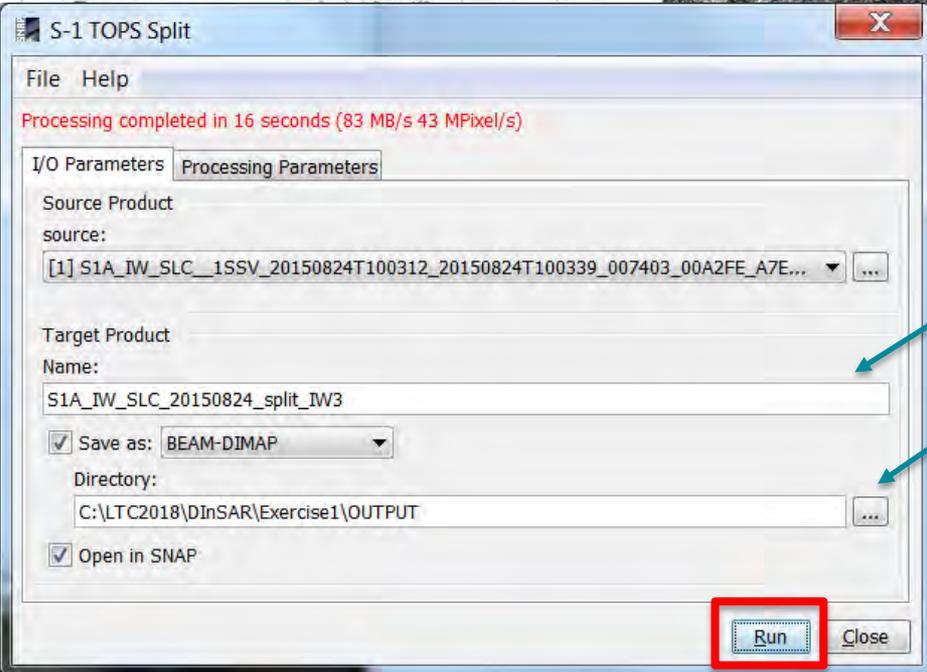
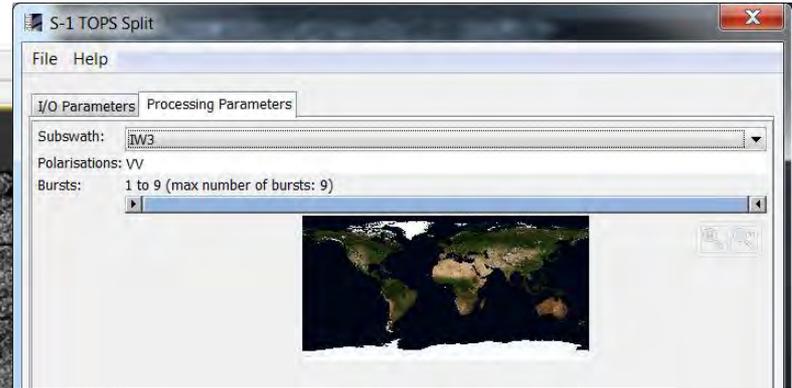
Double click on the Intensity IW3 VV band name for displaying

Step 1 (a,b,c) with image on 24/08/2015



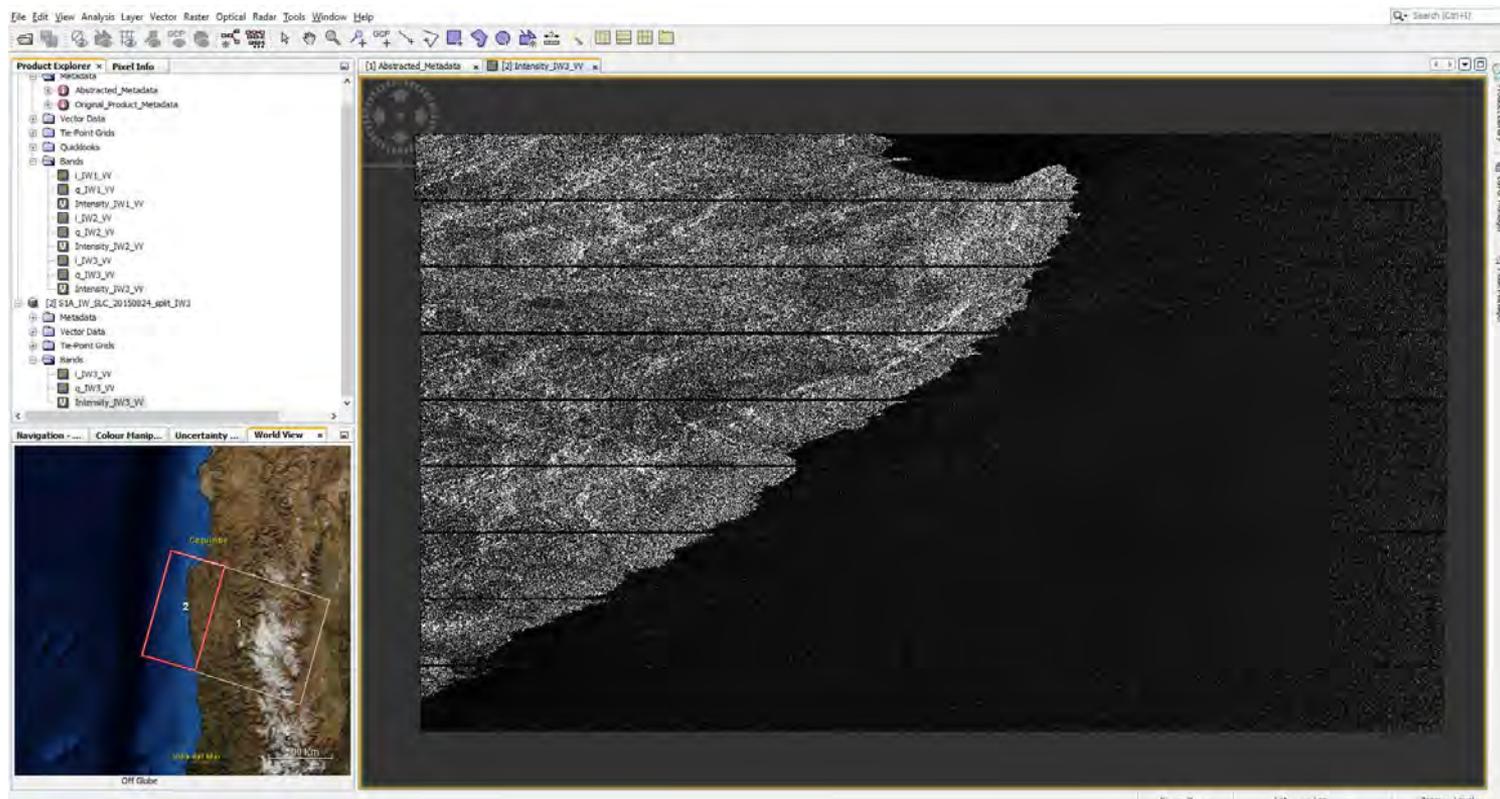
 S1A_IW_SLC__1SSV_20150824T100312_20150824T100339_007403_00A2FE_A7E8.SAFE.zip

Step 1.a: TOPSAR-SPLIT



1. Processing Parameters
2. output name
3. Select the directory: **./Exercise1/OUTPUT**
4. Click Run

Step 1.a: TOPSAR-SPLIT



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10–14 September 2018 | University of Leicester | United Kingdom

Step 1.b: Apply Precise Orbit



The screenshot shows the SNAP software interface with the 'Apply Orbit File' dialog box open. The dialog is divided into two tabs: 'I/O Parameters' and 'Processing Parameters'. The 'I/O Parameters' tab is selected, showing the following configuration:

- Source Product: [2] S1A_IW_SLC_20150824_split_IW3
- Target Product Name: S1A_IW_SLC_20150824_split_IW3_Orb
- Save as: BEAM-DIMAP
- Directory: C:\LTC2018\DInSAR\Exercise1\OUTPUT
- Open in SNAP:

The 'Processing Parameters' tab is also visible, showing:

- Orbit State Vectors: Sentinel Precise (Auto Download)
- Polynomial Degree: 3
- Do not fail if new orbit file is not found:

Buttons for 'Run' and 'Close' are located at the bottom of the dialog.

Sentinel-1 Quality Control



Website: <https://qc.sentinel1.eo.esa.int>

Sentinel-1 QC Quality Disclaimers IPF ADF Orbit Files Sign in

Sentinel-1 Quality Control

On this website you will find all information that is published by the Sentinel-1 Quality Control Subsystem.

Quality Disclaimers

Quality Disclaimers affecting Sentinel-1 products

IPF Auxiliary Data Files

L1 Processor Parameters	AUX_PP1	latest S1A (ICID=5)
Calibration Auxiliary Data	AUX_CAL	latest S1A (ICID=5)
Instrument Auxiliary Data	AUX_INS	latest S1A (ICID=5)
L2 Processor Parameters	AUX_PP2	latest S1A (ICID=5)
Simulated Cross Spectra	AUX_SCS	

Orbit Files

FDS Predicted Orbit	MPL_ORBPRE	(only last 7 days)
POD Precise Orbit Ephemerides	AUX_POEORB	(only last 366 days)
POD Restituted Orbit	AUX_RESORB	(only last 366 days)
POD Residue Attitude	AUX_RESATT	(only last 180 days)

POD Restituted Orbit [AUX_RESORB]

POD Precise Orbit Ephemerides [AUX_POEORB] (most accurate)

Mission Status

<https://sentinel.esa.int/web/sentinel/missions/sentinel-1/mission-status>

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10–14 September 2018 | University of Leicester | United Kingdom

Step 1.b: Apply Precise Orbit



Name	Value	Type	Unit	Description
azimuth_looks	1	float64		
range_looks	1	float64		
range_spacing	2.33	float64	m	Range sample spacing
azimuth_spacing	14.073	float64	m	Azimuth sample spacing
pulse_repetition_frequency	1,717,129	float64	Hz	PRF
radar_frequency	5,405	float64	MHz	Radar frequency
line_time_interval	0.002	float64	s	
total_size	14130748.77	uint32	MB	Total product size
num_output_lines	13599	uint32	lines	Raster height
num_samples_per_line	28809	uint32	samples	Raster width
subset_offset_x	0	uint32	samples	X coordinate of UL corner of subset in original image
subset_offset_y	0	uint32	samples	Y coordinate of UL corner of subset in original image
srg_flag	0	uint8	flag	SRG applied
avg_scene_height	3,125.081	float64	m	Average scene height ellipsoid
map_projection	-	ascii		Map projection applied
is_terrain_corrected	0	uint8	flag	orthorectification applied
DEM	-	ascii		Digital Elevation Model used
geo_ref_system	-	ascii		geographic reference system
lat_pixel_res	99,999	float64	deg	pixel resolution in geocoded image
lon_pixel_res	99,999	float64	deg	pixel resolution in geocoded image
slant_range_to_first_pixel	802,724.523	float64	m	Slant range to 1st data sample
ant_elev_corr_flag	0	uint8	flag	Antenna elevation applied
range_spread_comp_flag	0	uint8	flag	range spread compensation applied
replica_power_corr_flag	0	uint8	flag	Replica pulse power correction applied
abs_calibration_flag	0	uint8	flag	Product calibrated
calibration_factor	99,999	float64	dB	Calibration constant
chirp_power	99,999	float64		Chirp power
inc_angle_comp_flag	0	uint8	flag	incidence angle compensation applied
ref_inc_angle	99,999	float64		Reference incidence angle
ref_slant_range	99,999	float64		Reference slant range
ref_slant_range_exp	99,999	float64		Reference slant range exponent
rescaling_factor	99,999	float64		Rescaling factor
range_sampling_rate	64,345	float64	MHz	Range Sampling Rate
range_bandwidth	56.5	float64	MHz	Bandwidth total in range
azimuth_bandwidth	327	float64	Hz	Bandwidth total in azimuth
multilook_flag	0	uint8	flag	Multilook applied
coregistered_stack	0	uint8	flag	Coregistration applied
external_calibration_file	-	ascii		External calibration file used
orbit_state_vector_file	Sentinel Precise: S1A_OPER_AUX_POEORB_OPOD_20150913T1223	ascii		Orbit file used
metadata_version	0.0	ascii		AbdMetadata version

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10–14 September 2018 | University of Leicester | United Kingdom

Step 1.c: Calibration

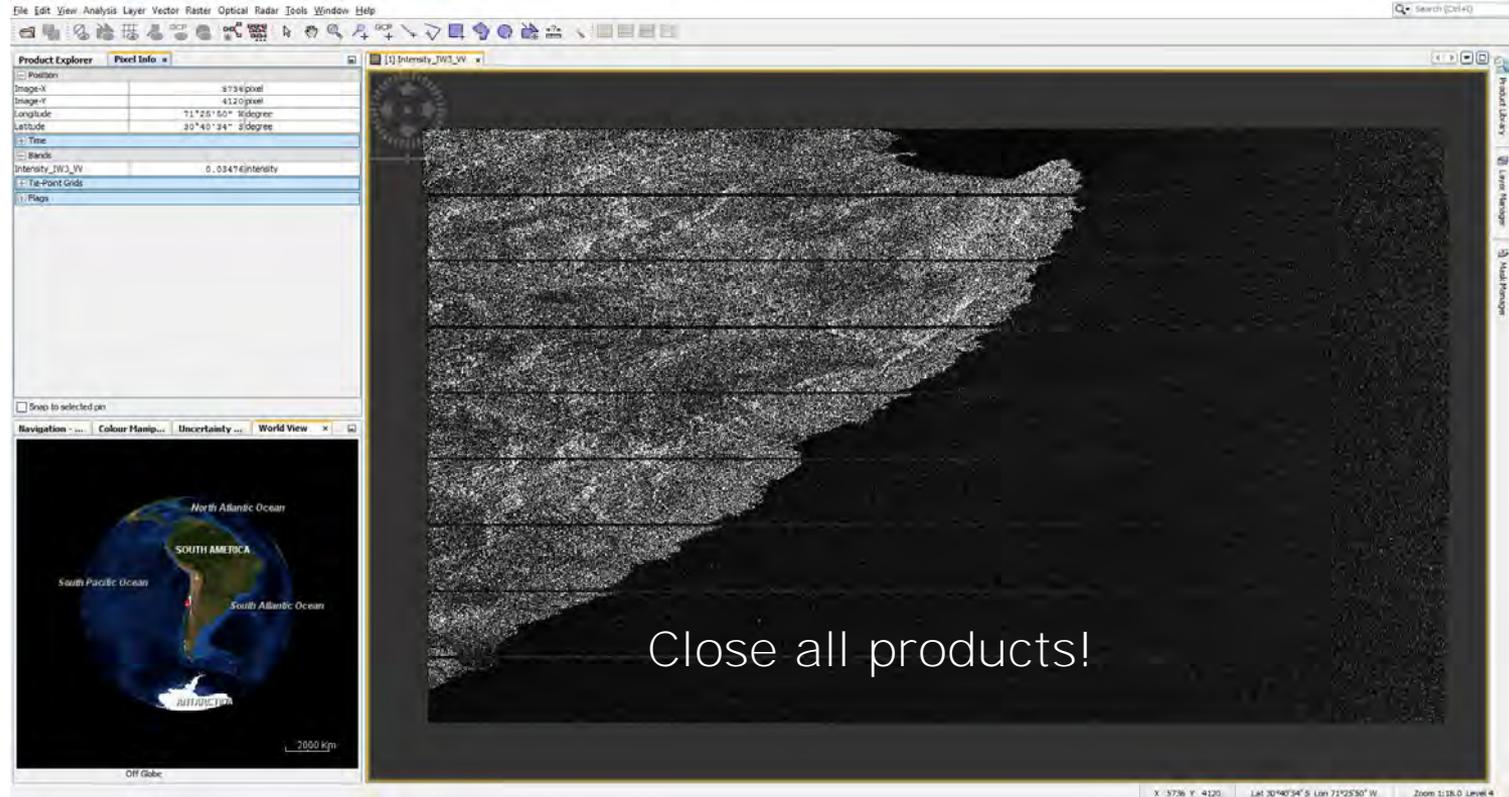


The screenshot shows the SNAP software interface with the 'Calibrate' menu open. The menu options are: Radiometric Terrain Flattening, Remove Antenna Pattern, S-1 Thermal Noise Removal, Convert Signal to Beta0, Convert Signal to Gamma0, and Create Calibration LUT TIG. Two dialog boxes are overlaid on the interface:

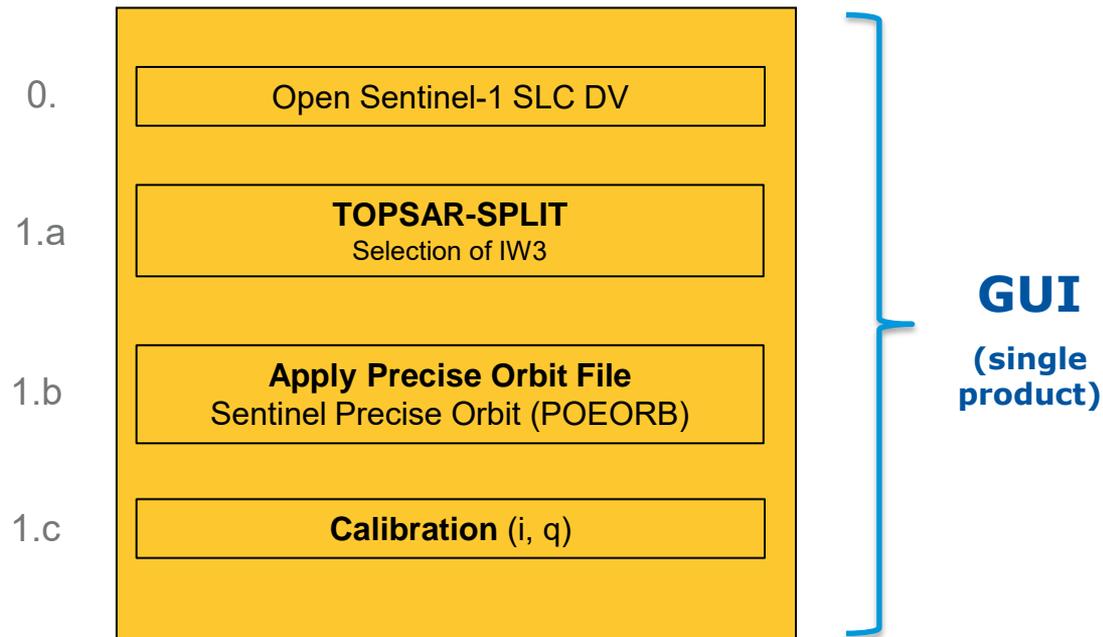
- Calibration Dialog (Left):**
 - Source Product: [3] S1A_IW_SLC_20150824_split_IW3_Orb
 - Target Product Name: S1A_IW_SLC_20150824_split_IW3_orb_Cal
 - Save as: BEAM-DIMAP
 - Directory: C:\LTC2018\DIoSAR\Exercise1\OUTPUT
 - Open in SNAP:
- Calibration Dialog (Right):**
 - Polarisations: vv
 - Save as complex output:
 - Output sigma0 band:
 - Output gamma0 band:
 - Output beta0 band:

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Step 1.c: Calibration

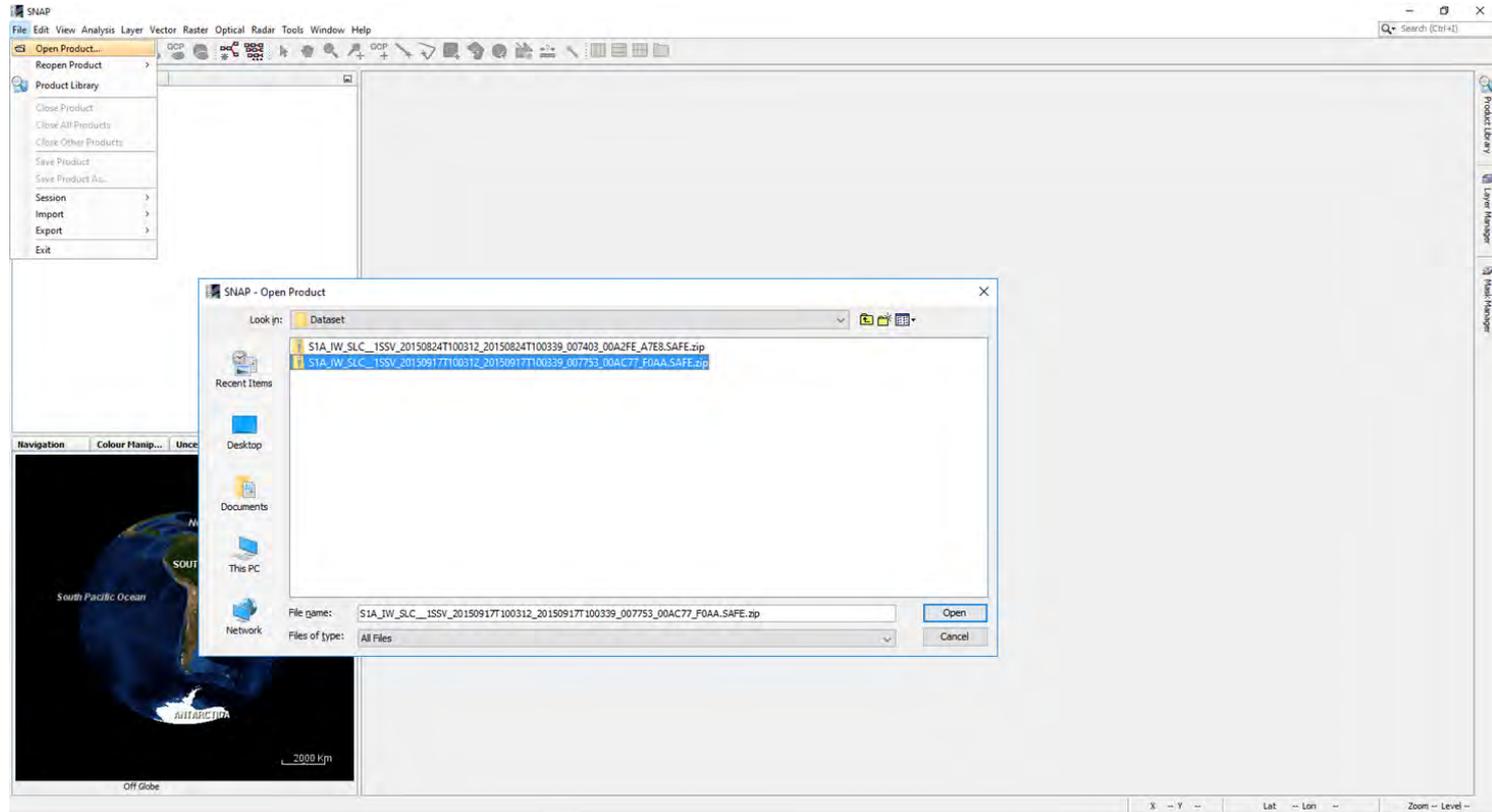


Step 1 (a,b,c) with image on 17/09/2015



 S1A_IW_SLC_1SSV_20150917T100312_20150917T100339_007753_00AC77_F0AA.SAFE.zip

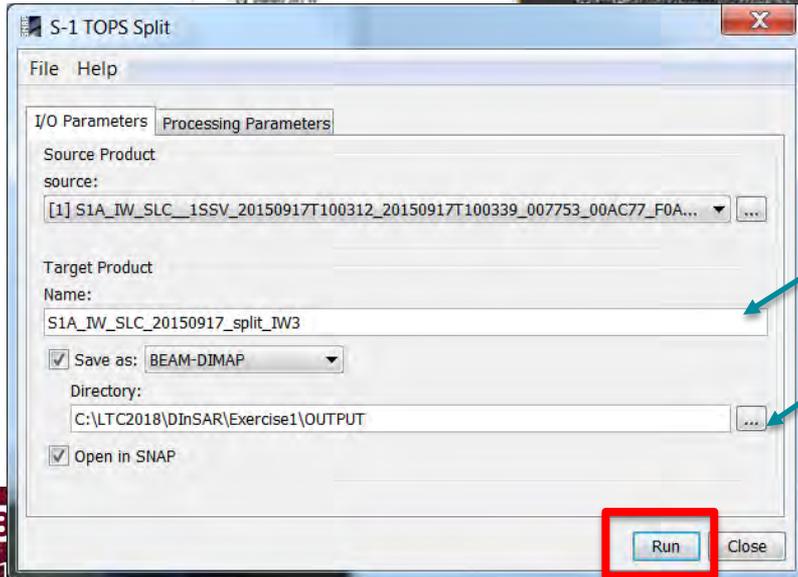
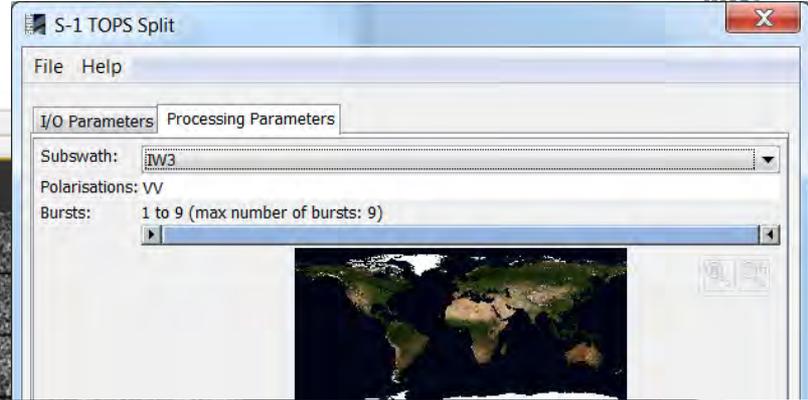
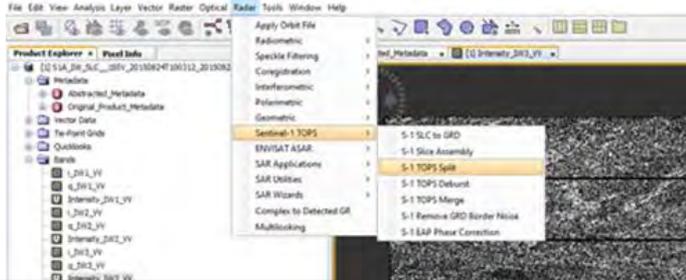
Step 1 (a,b,c) with image on 17/09/2015



→ 8th **ADVANCED TRAINING COURSE ON LAND REMOTE SENSING**

10–14 September 2018 | University of Leicester | United Kingdom

Step 1.a: TOPSAR-SPLIT



1. Processing Parameters
2. output name
3. Select the directory: **./Exercise1/OUTPUT**
4. Click Run

Step 1.b: Apply Precise Orbit



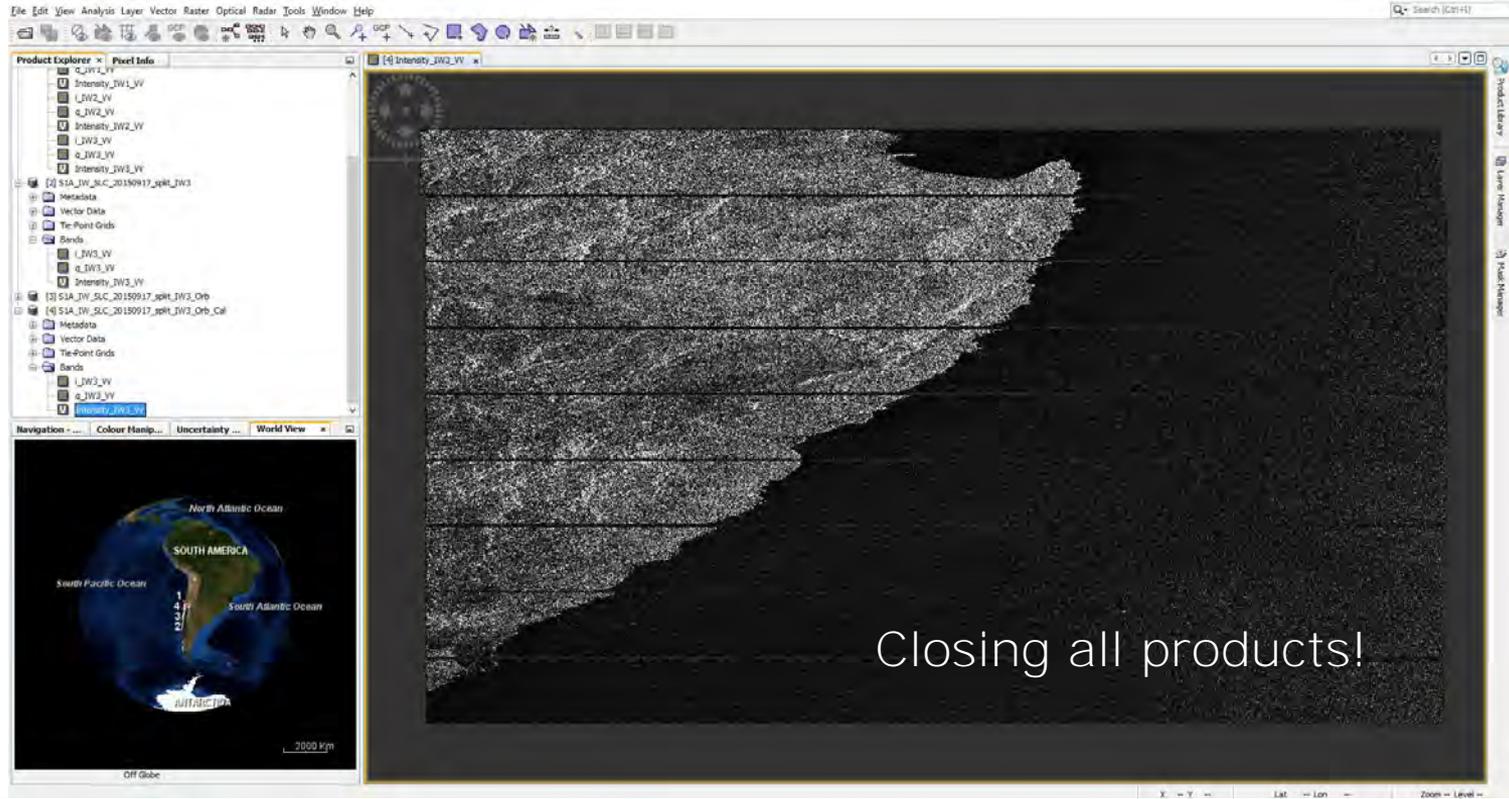
The screenshot displays the SNAP software interface with the 'Apply Orbit File' dialog box open. The dialog is divided into two tabs: 'I/O Parameters' and 'Processing Parameters'.
In the 'I/O Parameters' tab:
- Source Product: [2] S1A_IW_SLC_20150917_split_IW3
- Target Product Name: S1A_IW_SLC_20150917_split_IW3_Orb
- Save as: BEAM-DIMAP (checked)
- Directory: C:\LTC2018\DInSAR\Exercise1\OUTPUT
- Open in SNAP (checked)
In the 'Processing Parameters' tab:
- Orbit State Vectors: Sentinel Precise (Auto Download)
- Polynomial Degree: 3
- Do not fail if new orbit file is not found (unchecked)
Buttons for 'Run' and 'Close' are visible at the bottom of each tab.

Step 1.c: Calibration



The screenshot shows the SNAP software interface with the 'Calibration' dialog box open. The 'I/O Parameters' tab is selected, and the 'Processing Parameters' tab is also visible. The 'Source Product' is set to '[3] S1A_IW_SLC_20150917_split_IW3_Orb'. The 'Target Product' name is 'S1A_IW_SLC_20150917_split_IW3_Cal', saved as 'BEAM-DIMAP' in the directory 'C:\LTC2018\DInSAR\Exercise1\OUTPUT'. The 'Open in SNAP' checkbox is checked. The 'Polarisations' list contains 'VV'. The 'Save as complex output' checkbox is checked, and the 'Output sigma0 band' checkbox is also checked. The 'Output gamma0 band' and 'Output beta0 band' checkboxes are unchecked. The 'Run' and 'Close' buttons are at the bottom of the dialog.

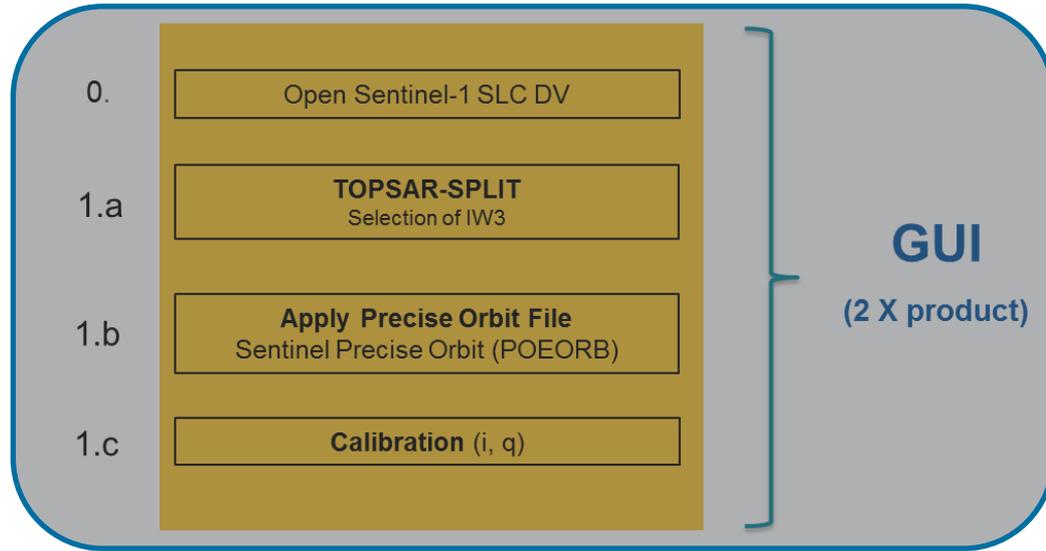
Step 1.c: Calibration



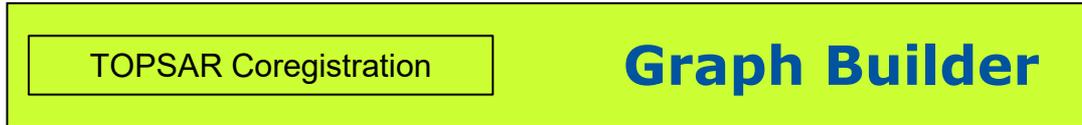
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10–14 September 2018 | University of Leicester | United Kingdom

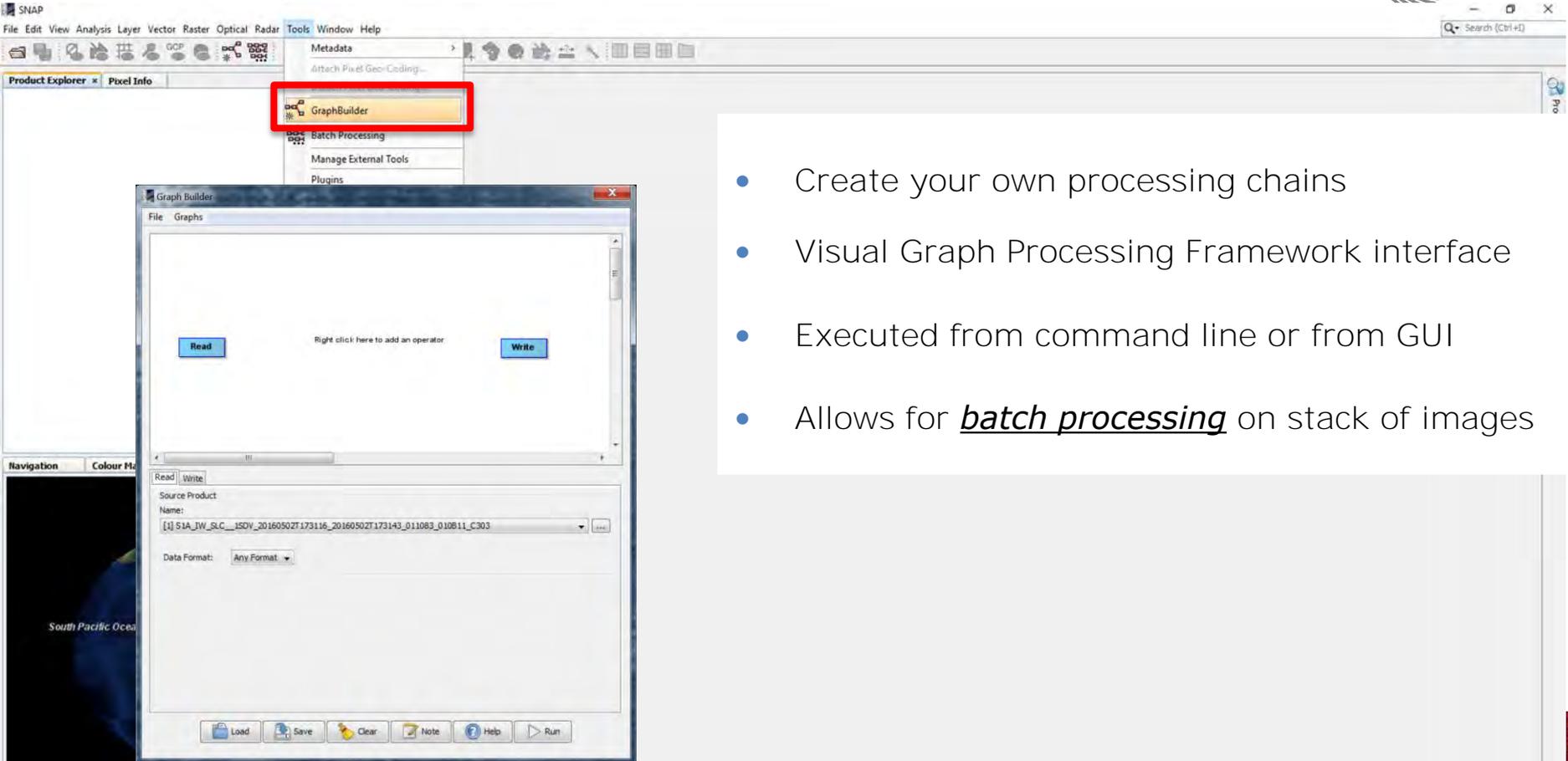
Step 2: TOPSAR Coregistration



2.

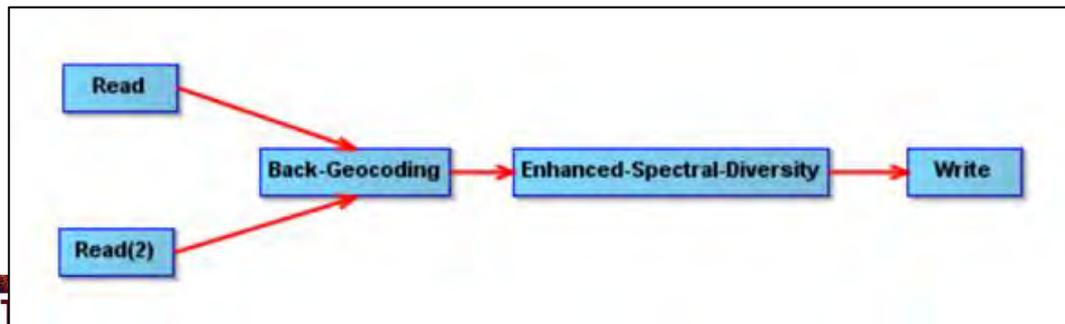
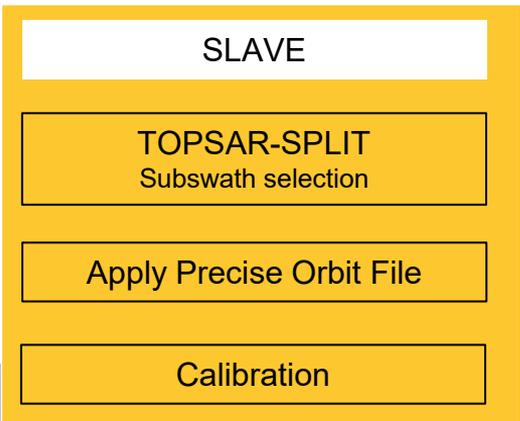
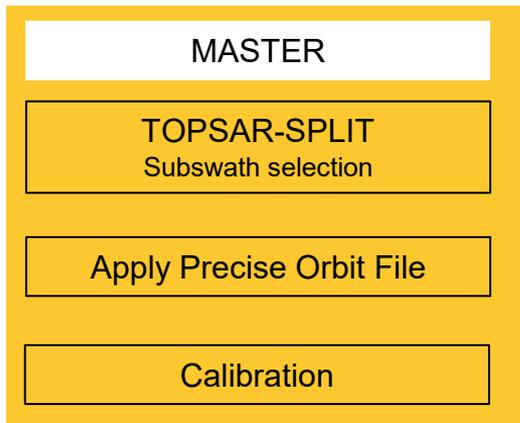


The GRAPH BUILDER



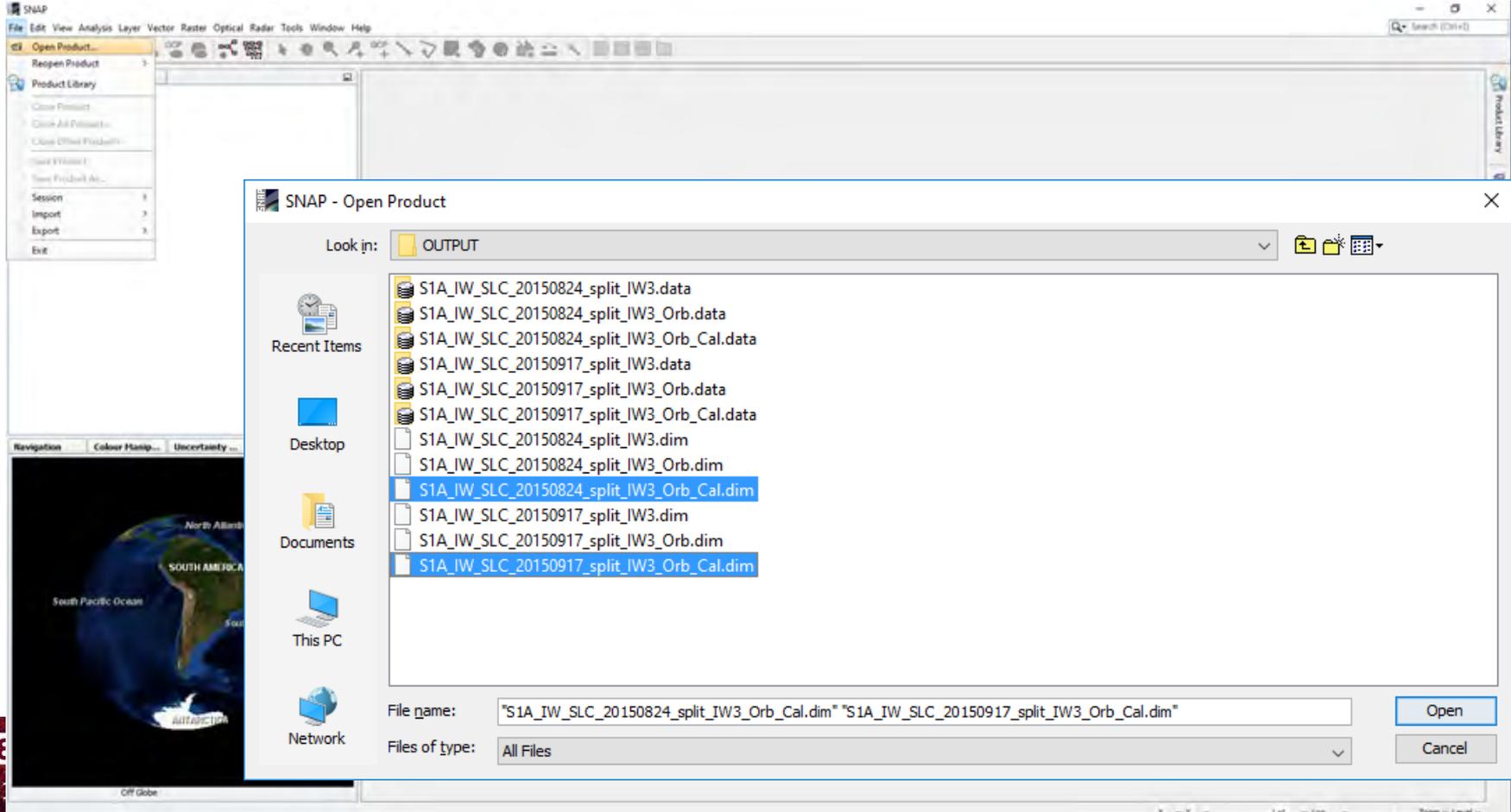
- Create your own processing chains
- Visual Graph Processing Framework interface
- Executed from command line or from GUI
- Allows for ***batch processing*** on stack of images

Step 2: TOPSAR Coregistration



USE ON LAND REMO

Open both pre-processed products



Baseline computation



Stack Overview and Optimal InSAR Master Selection

Input stack

File Name	Type	Acquisition	Track	Orbit	
S1A_IW_SLC_20150824_split_IW3_O...					Add Opened
S1A_IW_SLC_20150917_split_IW3_O...					Clear

Overview

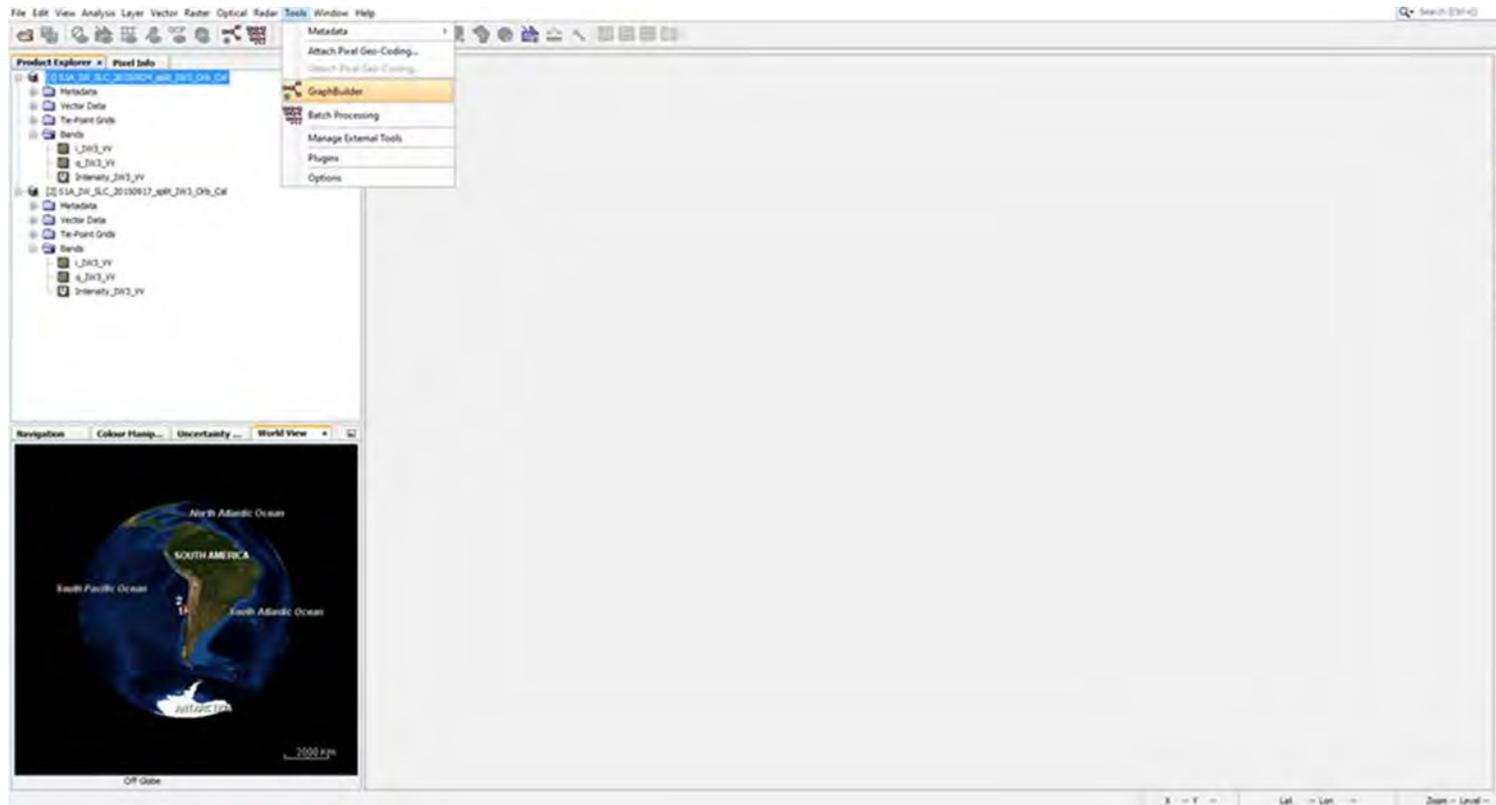
File Name	Mst/Slv	Acquisition	Track	Orbit	Bperp [m]	Btemp [...]	Modeled ...	Height Ambg...	Delta fDC [Hz]	
S1A_IW_SLC_20...	Master	24Aug2015	156	7403	0.00	0.00	1.00	∞	0.00	Open
S1A_IW_SLC_20...	Slave	17Sep2015	156	7753	-110.26	-24.00	0.88	160.86	6.92	

Overview Close Help

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Step2 - TOPSAR Coregistration via GB



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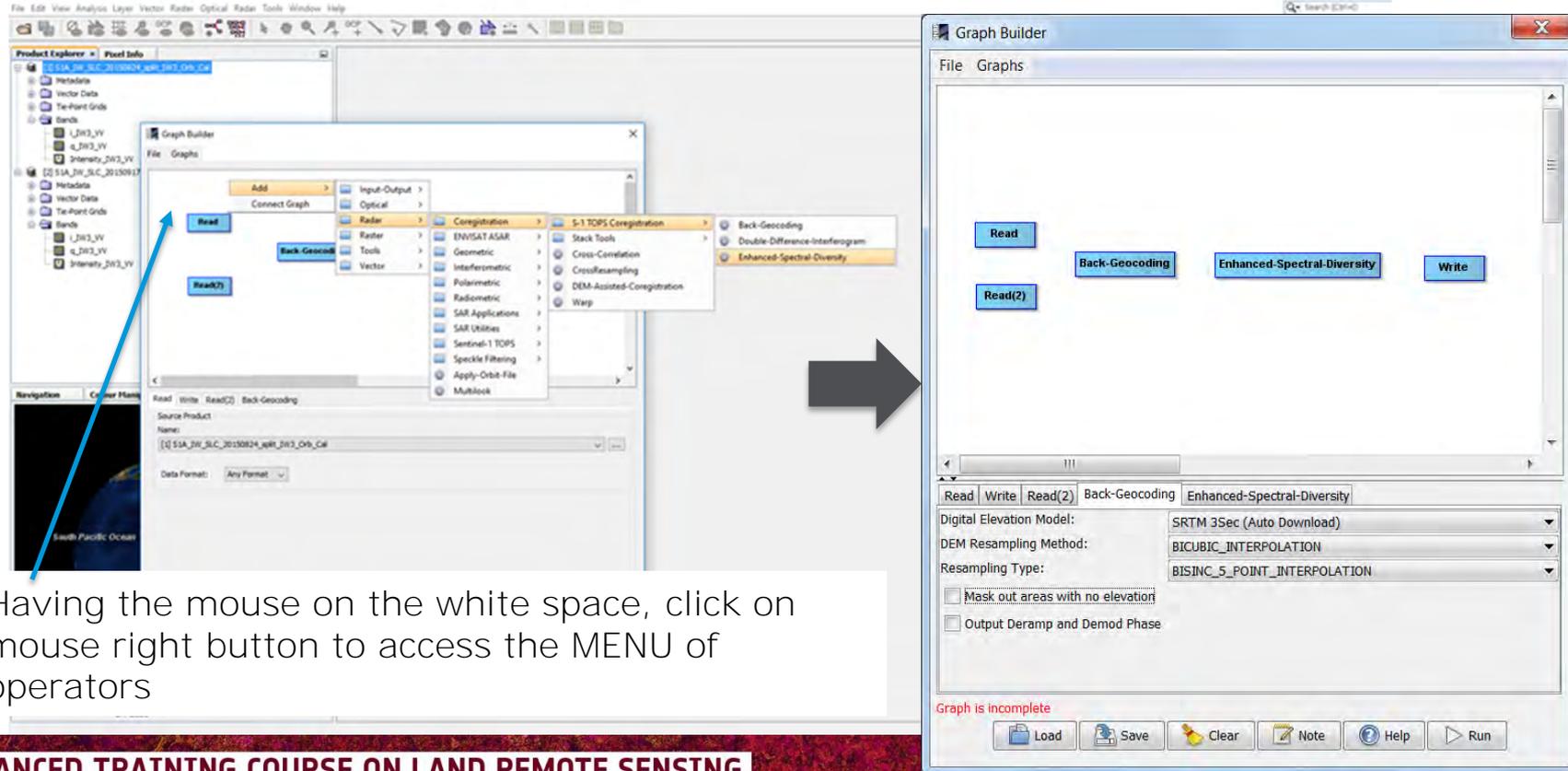
TOPSAR Coregistration via GB: Back-Geocoding OP



The screenshot displays the Graph Builder interface. The 'Product Explorer' on the left shows a tree structure with folders like 'Metadata', 'Vector Data', and 'Bands'. The 'Graph Builder' window is open, showing a 'Graphs' panel with a menu of operators. A blue arrow points from the text below to the 'Back-Geocoding' operator in the menu. A grey arrow points from the menu to a second 'Graph Builder' window showing a graph with 'Read', 'Back-Geocoding', and 'Write' nodes. The bottom of the interface shows a map of South America and a 'Source Product' field with the name '[1] S1A_IW_SLC_20150824_spl11_IW3_Orb_Cal'.

Having the mouse on the white space, click on mouse right button to access the MENU of operators

TOPSAR Coregistration via GB: Enhanced Spectral Diversity



Having the mouse on the white space, click on mouse right button to access the MENU of operators

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GB: Connecting the blocks



Connect the blocks manually

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Inserting the parameters for the chain



Read Write Read(2) Back-Geocoding Enhanced-Spectral-Diversity

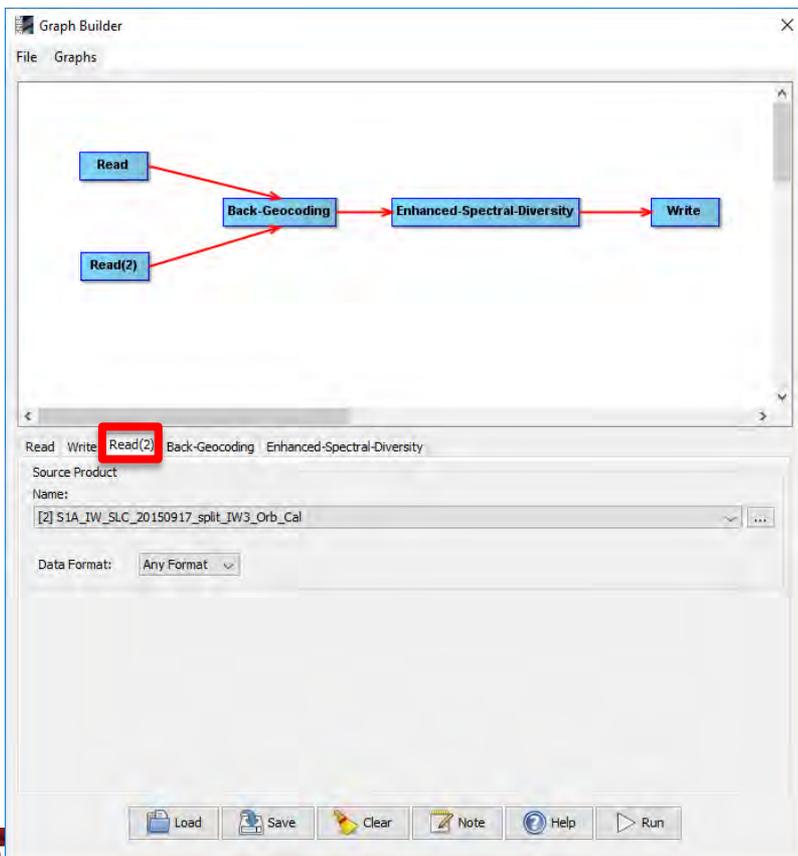
Source Product
Name:
[1] S1A_IW_SLC_20150824_split_IW3_Orb_Cal
Data Format: Any Format

Read Write Read(2) Back-Geocoding Enhanced-Spectral-Diversity

Target Product
Name:
S1A_IW_SLC_M20150824_S20150917_COR
Save as: BEAM-DIMAP
Directory:
C:\LTC2018\DInSAR\Exercise1\OUTPUT

Load Save Clear Note Help Run

Inserting the parameters



Graph Builder

File Graphs

Read → Back-Geocoding → Enhanced-Spectral-Diversity → Write

Read(2) → Back-Geocoding

Read Write **Read(2)** Back-Geocoding Enhanced-Spectral-Diversity

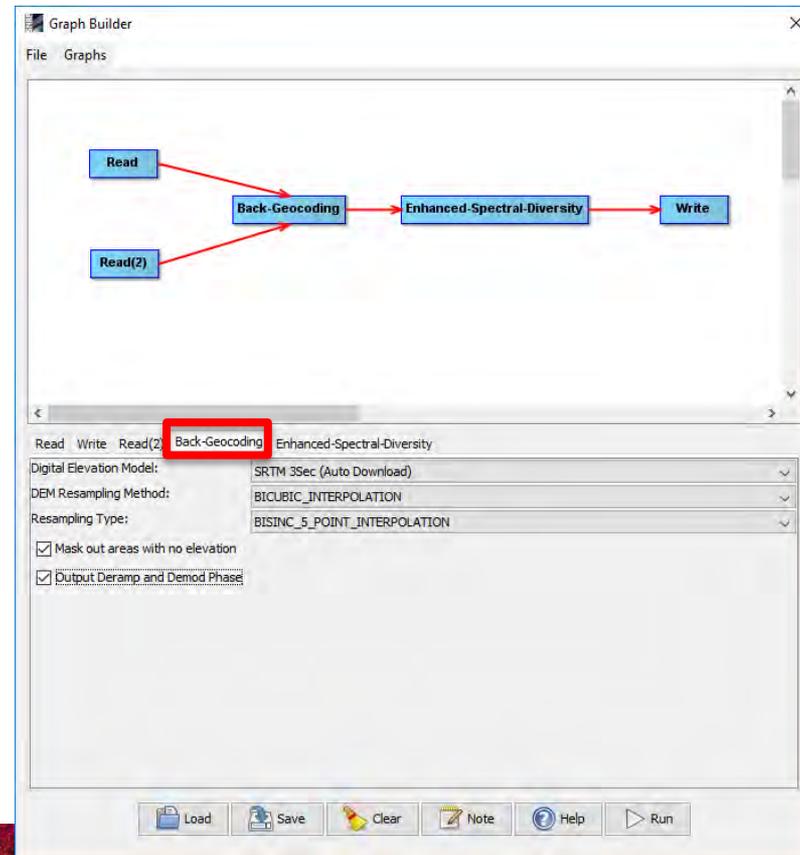
Source Product

Name:

[2] S1A_IW_SLC_20150917_split_IW3_Orb_Cal

Data Format: Any Format

Load Save Clear Note Help Run



Graph Builder

File Graphs

Read → Back-Geocoding → Enhanced-Spectral-Diversity → Write

Read(2) → Back-Geocoding

Read Write Read(2) **Back-Geocoding** Enhanced-Spectral-Diversity

Digital Elevation Model: SRTM 3Sec (Auto Download)

DEM Resampling Method: BICUBIC_INTERPOLATION

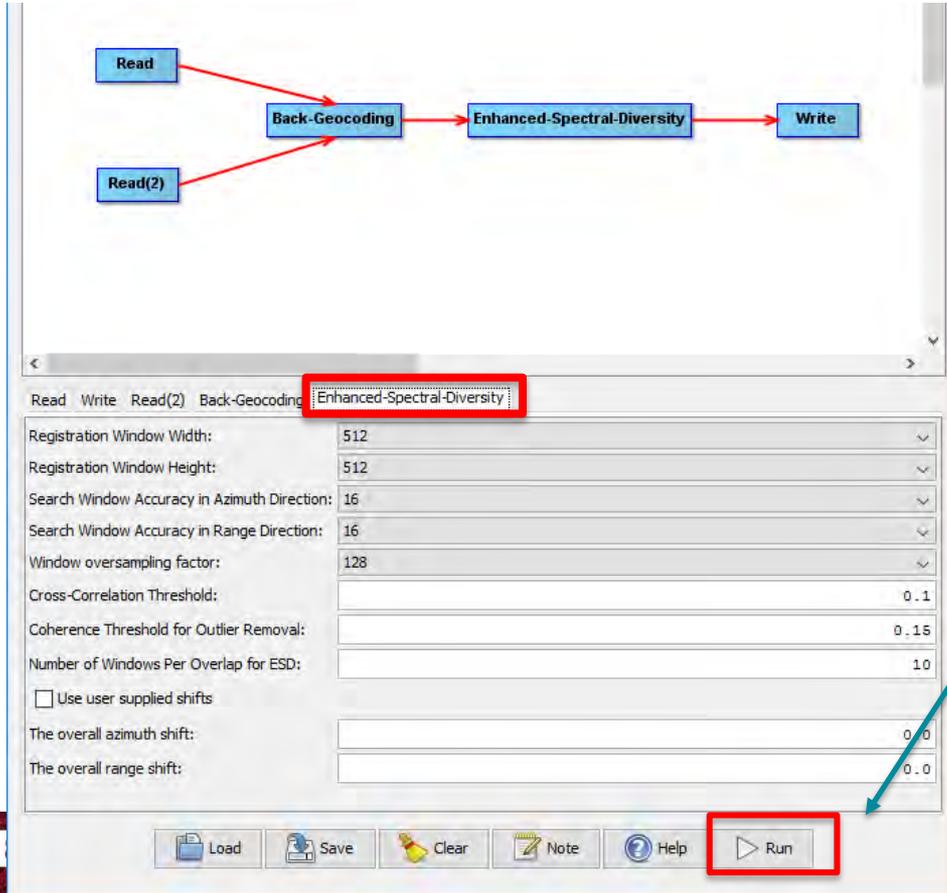
Resampling Type: BISINC_5_POINT_INTERPOLATION

Mask out areas with no elevation

Output Deramp and Demod Phase

Load Save Clear Note Help Run

Inserting the parameters



The screenshot shows a software interface with a workflow diagram at the top and a parameter configuration panel below. The workflow diagram consists of five blue rectangular boxes: 'Read', 'Read(2)', 'Back-Geocoding', 'Enhanced-Spectral-Diversity', and 'Write'. Red arrows indicate the flow: 'Read' and 'Read(2)' both point to 'Back-Geocoding', which then points to 'Enhanced-Spectral-Diversity', which finally points to 'Write'. Below the diagram, the 'Enhanced-Spectral-Diversity' operator is selected and highlighted with a red box. The configuration panel for this operator includes the following fields:

Registration Window Width:	512
Registration Window Height:	512
Search Window Accuracy in Azimuth Direction:	16
Search Window Accuracy in Range Direction:	16
Window oversampling factor:	128
Cross-Correlation Threshold:	0.1
Coherence Threshold for Outlier Removal:	0.15
Number of Windows Per Overlap for ESD:	1.0
<input type="checkbox"/> Use user supplied shifts	
The overall azimuth shift:	0.0
The overall range shift:	0.0

At the bottom of the interface, there is a toolbar with several icons: 'Load', 'Save', 'Clear', 'Note', 'Help', and 'Run'. The 'Run' button, which features a play icon, is highlighted with a red box. A red arrow points from the 'Run' button towards the text on the right side of the slide.

After inserting the parameters in the operators, execute the chain

N.B.: in the backup folder
Graph_TOPSAR_COR.xml

Overlay Master and Slave: the Layer Manager



• Display the MASTER Intensity (24 Aug 2015)

• Click on the LAYER MANAGER

Overlay Master and Slave: the Layer Manager



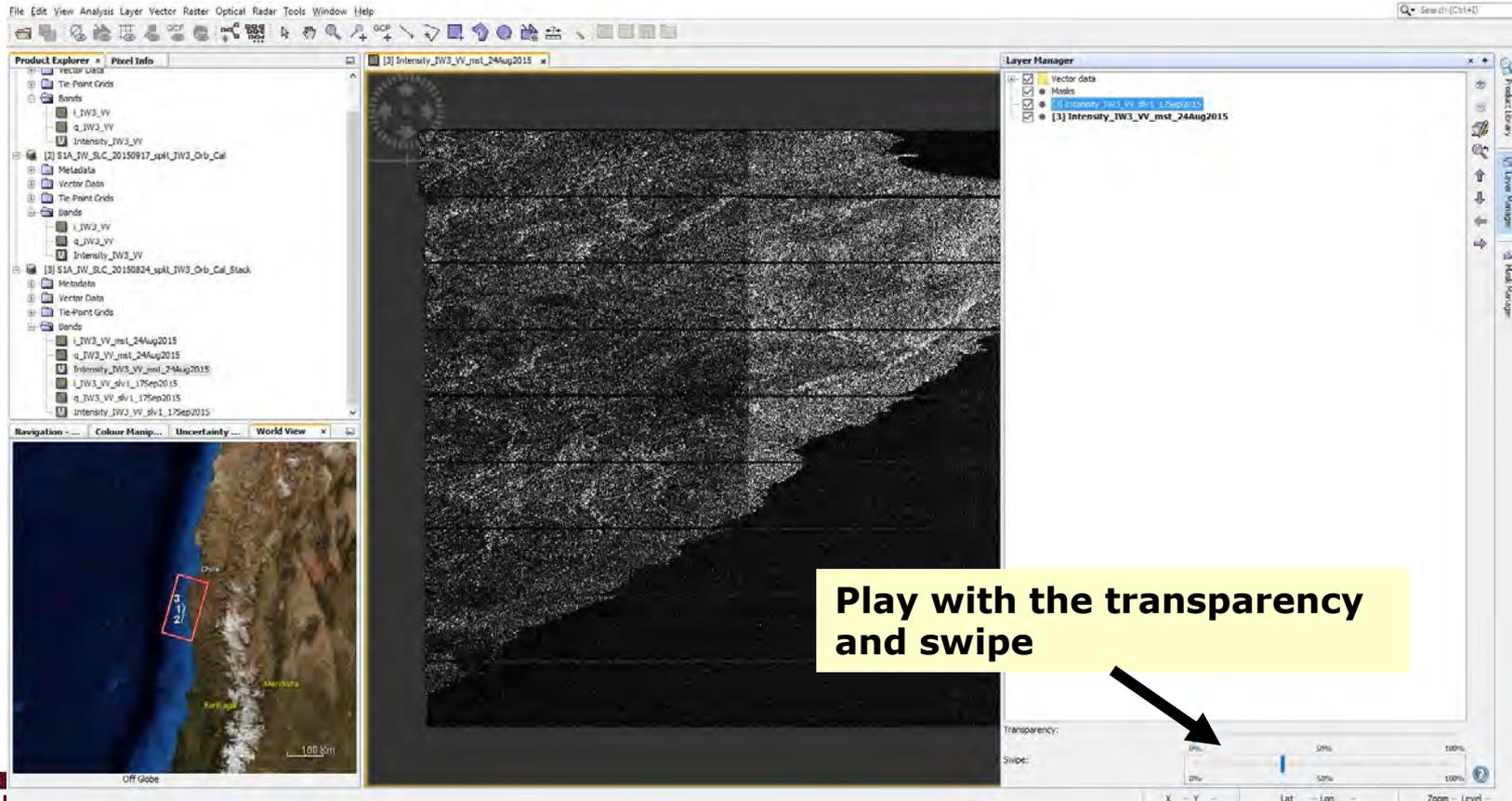
1) Click on +

2) Select Image of Band / Tie-Point Grid and click on Next

3) Select the Slave

4. Click on Finish

Overlay Master and Slave: the Layer Manager



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Exercise 2 – DinSAR processing



Generation of a wrapped differential (co-seismic) interferogram, employing a Sentinel-1 TOPS pair acquired before (24 August) and after the event (17 September) providing information about the earthquake which took place on the 25th August 2015 in Chile

The exercise would consist in:

1. Open the Coregistered Sentinel-1 pair (output of step 2 from Exercise 1)
2. Interferogram Formation and Coherence Estimation
3. TOPS debursting
4. Comparison of interferograms and coherence
5. Interferogram with subtraction of topography
6. Goldstein phase filtering
7. Multilooking for filtered phase
8. Geocoding of ML interferogram
9. Export of results to Google Earth

The exercise will be done using the GUI

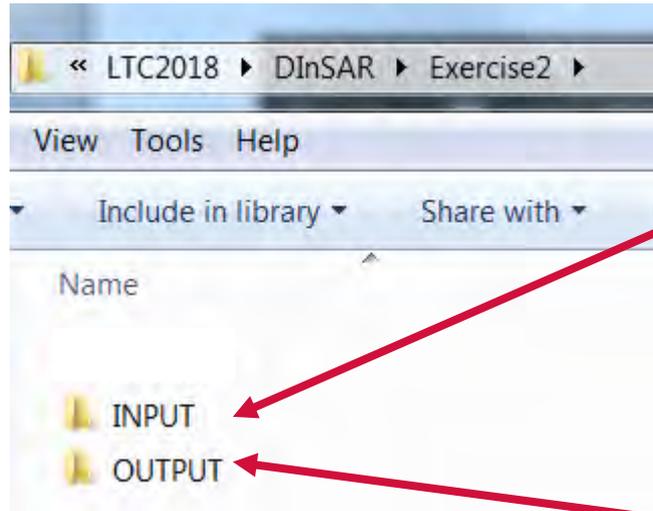
Exercise 2 – DInSAR processing: data location



Copy the following 2 files from **./Exercise1/OUTPUT** to **./Exercise2/INPUT**

S1A_IW_SLC_M20150824_S20150917_COR.data

S1A_IW_SLC_M20150824_S20150917_COR.dim



INPUT folder containing the input for the exercise

The outputs of the exercise will be stored here

Step 1: Open Coregistered product



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

Q Search (Ctrl+F)

Product Library
Layer Manager
Mask Manager

./LTC2018/DInSAR/Exercise2/INPUT

SNAP - Open Product

Look in: INPUT

Recent Items

Desktop

Documents

This PC

Network

S1A_IW_SLC_M20150824_S20150917_COR.data
S1A_IW_SLC_M20150824_S20150917_COR.dim

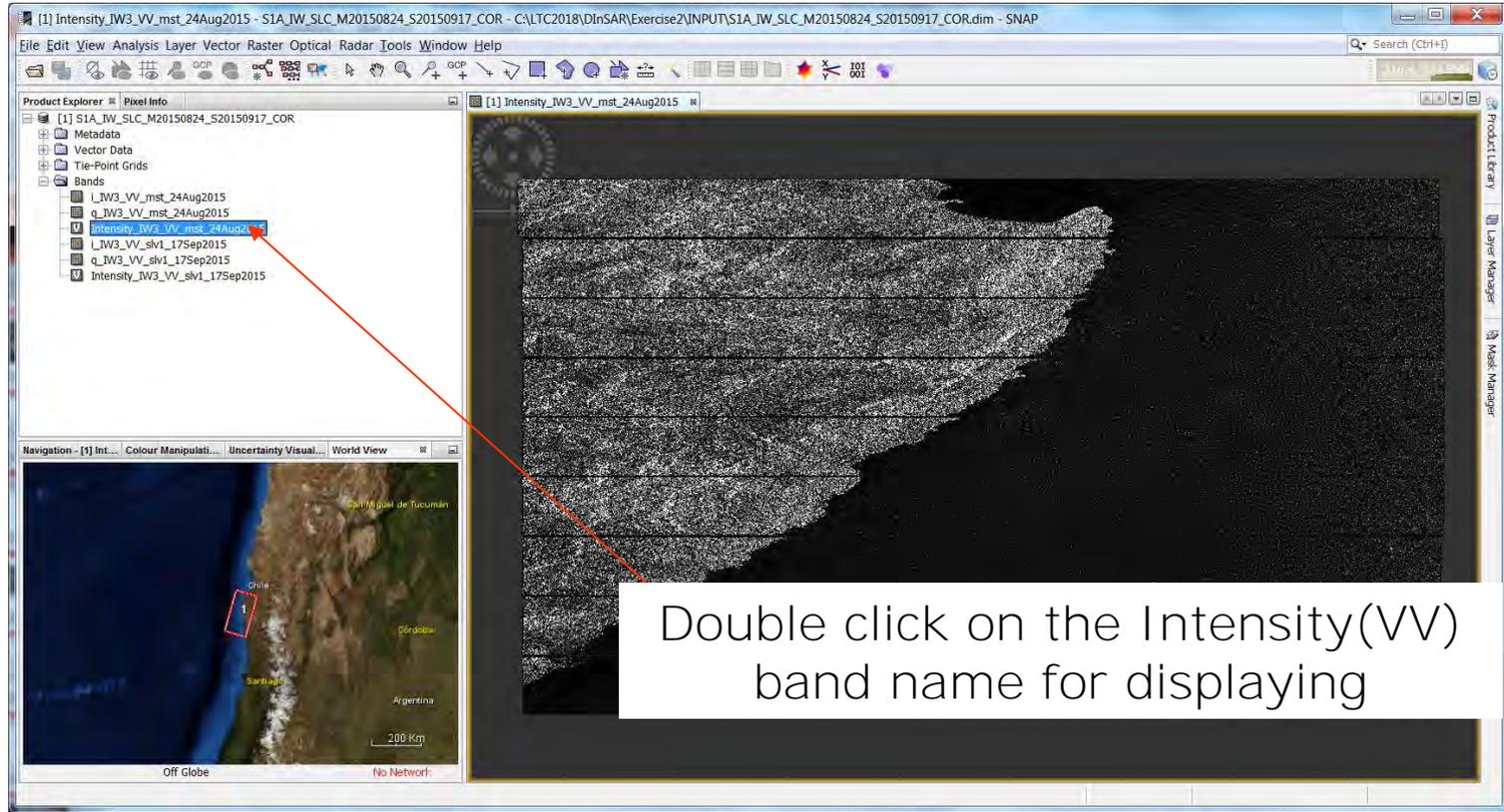
File name: S1A_IW_SLC_M20150824_S20150917_COR.dim

Files of type: All Files

Open Cancel

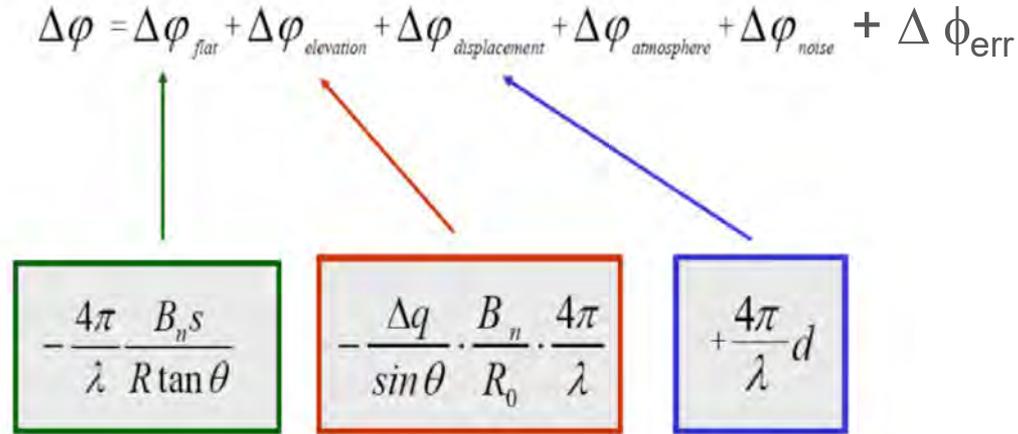
This tool window is used for **colouring of images**. Right now, there is no selection.

Step 1: Open Coregistered product



Double click on the Intensity(VV)
band name for displaying

Interferometric phase contribution

$$\Delta\phi = \Delta\phi_{\text{flat}} + \Delta\phi_{\text{elevation}} + \Delta\phi_{\text{displacement}} + \Delta\phi_{\text{atmosphere}} + \Delta\phi_{\text{noise}} + \Delta\phi_{\text{err}}$$


The diagram illustrates the decomposition of the total interferometric phase change $\Delta\phi$ into six components. Three boxes below the equation are connected to the terms by arrows:

- A green box containing the formula for flat Earth phase: $-\frac{4\pi}{\lambda} \frac{B_n s}{R \tan \theta}$
- A red box containing the formula for topographic contribution: $-\frac{\Delta q}{\sin \theta} \cdot \frac{B_n}{R_0} \cdot \frac{4\pi}{\lambda}$
- A blue box containing the formula for surface deformation contribution: $+\frac{4\pi}{\lambda} d$

- $\Delta\phi_{\text{flat}}$ is called flat Earth phase which is the phase contribution due to the earth curvature.
- $\Delta\phi_{\text{elevation}}$ is the topographic contribution to the interferometric phase.
- $\Delta\phi_{\text{displacement}}$ is the surface deformation contribution to the interferometric phase.
- $\Delta\phi_{\text{atmosphere}}$ is the atmospheric contribution to the interferometric phase. It is introduced due to the atmospheric humidity, temperature and pressure change between the two acquisitions.
- $\Delta\phi_{\text{noise}}$ is the phase noise introduced by temporal change of the scatterers, different look angle, and volume scattering.
- $\Delta\phi_{\text{err}}$ = orbital error, coreg. error, thermal noise, other noise

- A quality measure for the interferometric phase
- Similar to principles of correlation, but for the complex data

→ Also as used in change detection monitoring

$$\gamma = \frac{E\{y_1 y_2^*\}}{\sqrt{E\{|y_1|^2\} \cdot E\{|y_2|^2\}}}$$

Estimation of (degree) coherence

$$|\hat{\gamma}| = \frac{|\sum_{n=1}^N y_1^{(n)} y_2^{(n)}|}{\sqrt{\sum_{n=1}^N |y_1^{(n)}|^2 \sum_{n=1}^N |y_2^{(n)}|^2}} \quad [0,1]$$

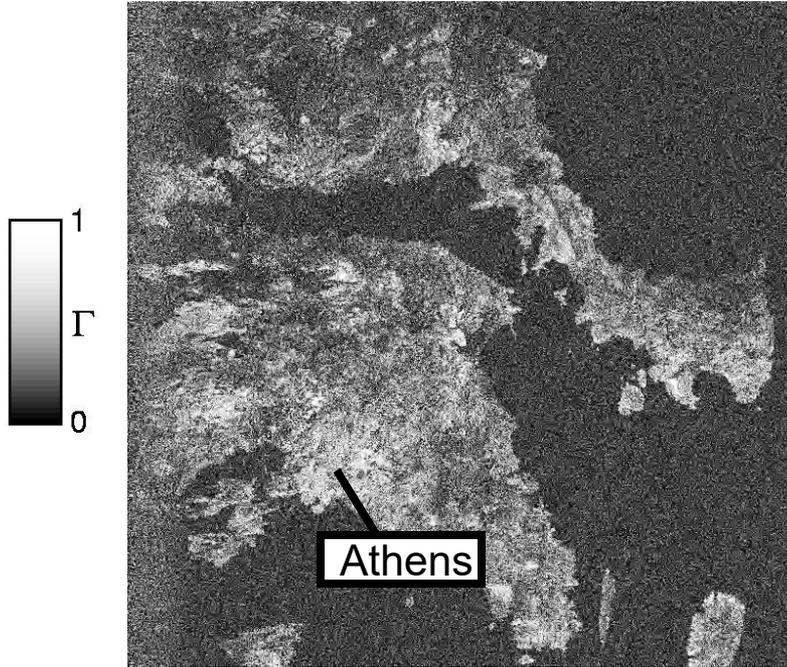
Coherent surface types

- Buildings (towns/cities)
- Bare Rock

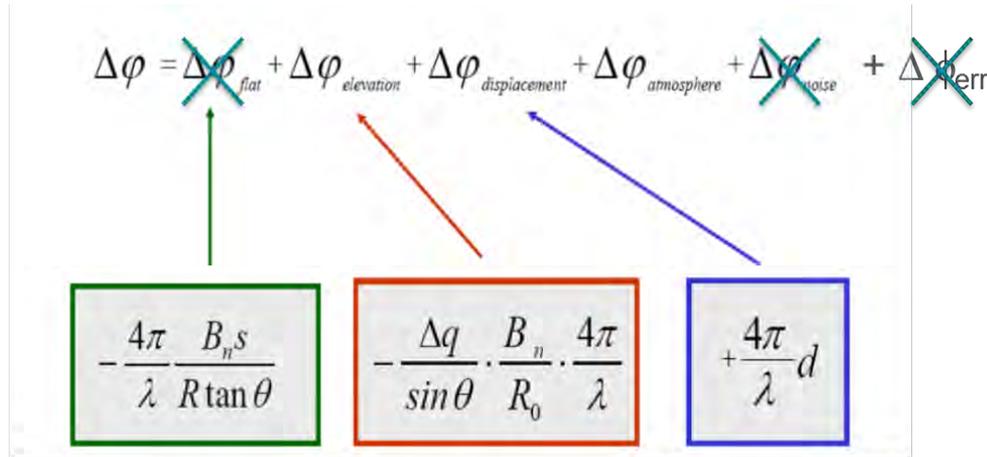
- Grassland
- Agricultural fields
- Ice

Incoherent surface types

- Leafy Trees
- Water



Simplified approximation: Interferogram Formation

$$\Delta\phi = \cancel{\Delta\phi_{\text{flat}}} + \Delta\phi_{\text{elevation}} + \Delta\phi_{\text{displacement}} + \Delta\phi_{\text{atmosphere}} + \cancel{\Delta\phi_{\text{noise}}} + \cancel{\Delta\phi_{\text{err}}}$$

$$\frac{4\pi}{\lambda} \frac{B_n s}{R \tan \theta}$$
$$-\frac{\Delta q}{\sin \theta} \cdot \frac{B_n}{R_0} \cdot \frac{4\pi}{\lambda}$$
$$+\frac{4\pi}{\lambda} d$$

- $\Delta\phi_{\text{flat}}$ is called flat Earth phase which is the phase contribution due to the earth curvature.
- $\Delta\phi_{\text{elevation}}$ is the topographic contribution to the interferometric phase.
- $\Delta\phi_{\text{displacement}}$ is the surface deformation contribution to the interferometric phase.
- $\Delta\phi_{\text{atmosphere}}$ is the atmospheric contribution to the interferometric phase. It is introduced due to the atmospheric humidity, temperature and pressure change between the two acquisitions.
- $\Delta\phi_{\text{noise}}$ is the phase noise introduced by temporal change of the scatterers, different look angle, and volume scattering.
- $\Delta\phi_{\text{err}}$ = orbital error, coreg. error, thermal noise, other noise

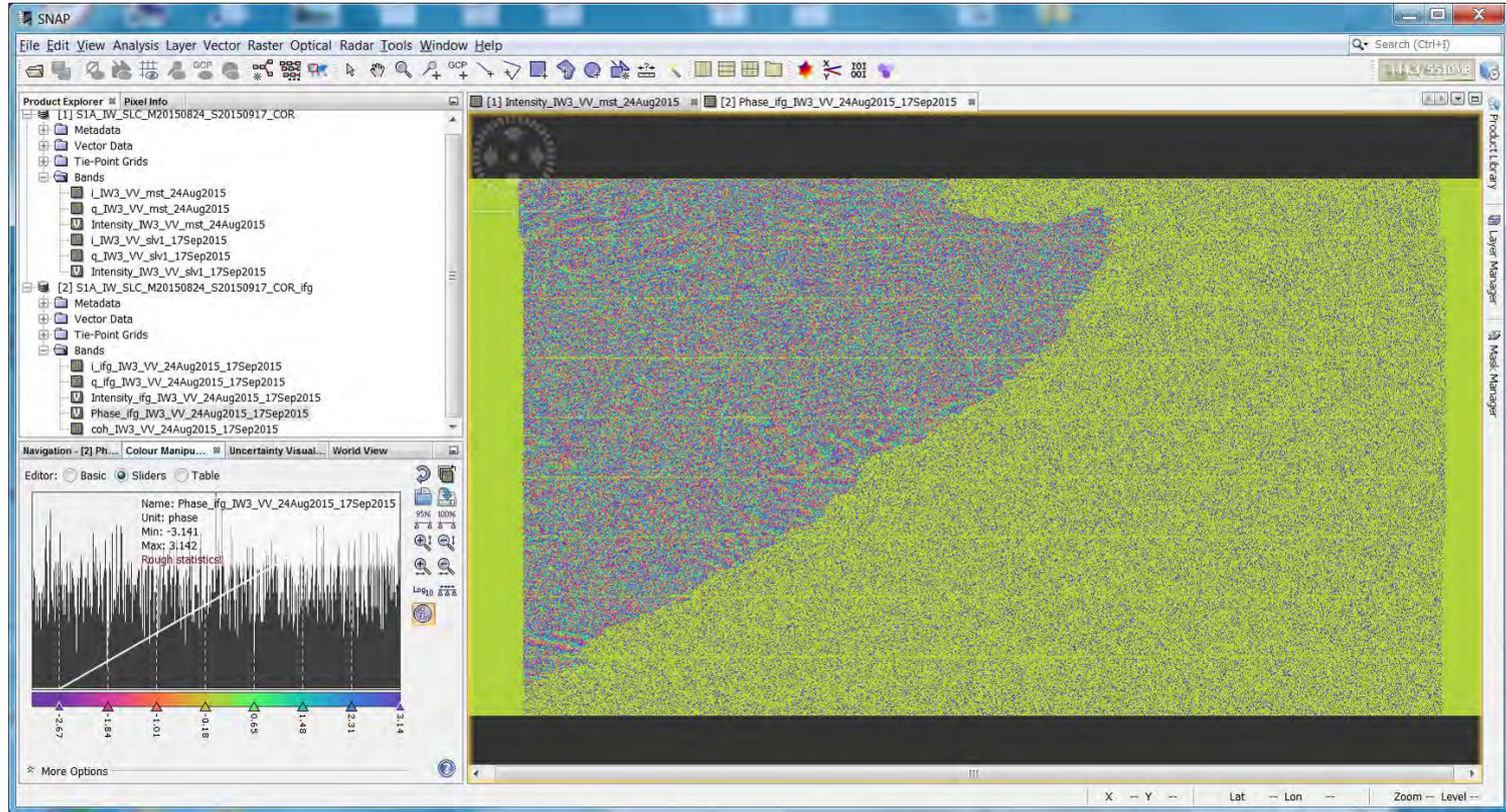
Interferogram Formation and Coherence Estimation



The screenshot displays the SNAP software interface with the 'Interferogram Formation' dialog box open. The dialog is split into two tabs: 'I/O Parameters' and 'Processing Parameters'. In the 'I/O Parameters' tab, the 'Source Product' is 'S1A_IW_SLC_M20150824_S20150917_COR' and the 'Target Product' name is 'S1A_IW_SLC_M20150824_S20150917_COR_ifg'. The 'Save as' dropdown is set to 'BEAM-DIMAP' and the 'Directory' is 'C:\LTC2018\DIInSAR\Exercise2\OUTPUT'. A blue arrow points to the directory field. In the 'Processing Parameters' tab, the 'Include coherence estimation' checkbox is checked. The 'Coherence Range Window Size' is set to 8 and the 'Coherence Azimuth Window Size' is set to 2. A red dashed box highlights these two values. The background shows a radar image with a menu structure on the left and top.

. \LTC2018\DIInSAR\Exercise2\OUTPUT

Interferogram Formation



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(TOPS) debursting



The screenshot shows the SNAP (Scientific SAR Non-destructive Analysis Platform) software interface. The main window displays a SAR image with a menu open over it, highlighting 'S-1 TOPS Deburst'. Two dialog boxes are open: 'S-1 TOPS Deburst' (left) and 'S-1 TOPS Deburst' (right).

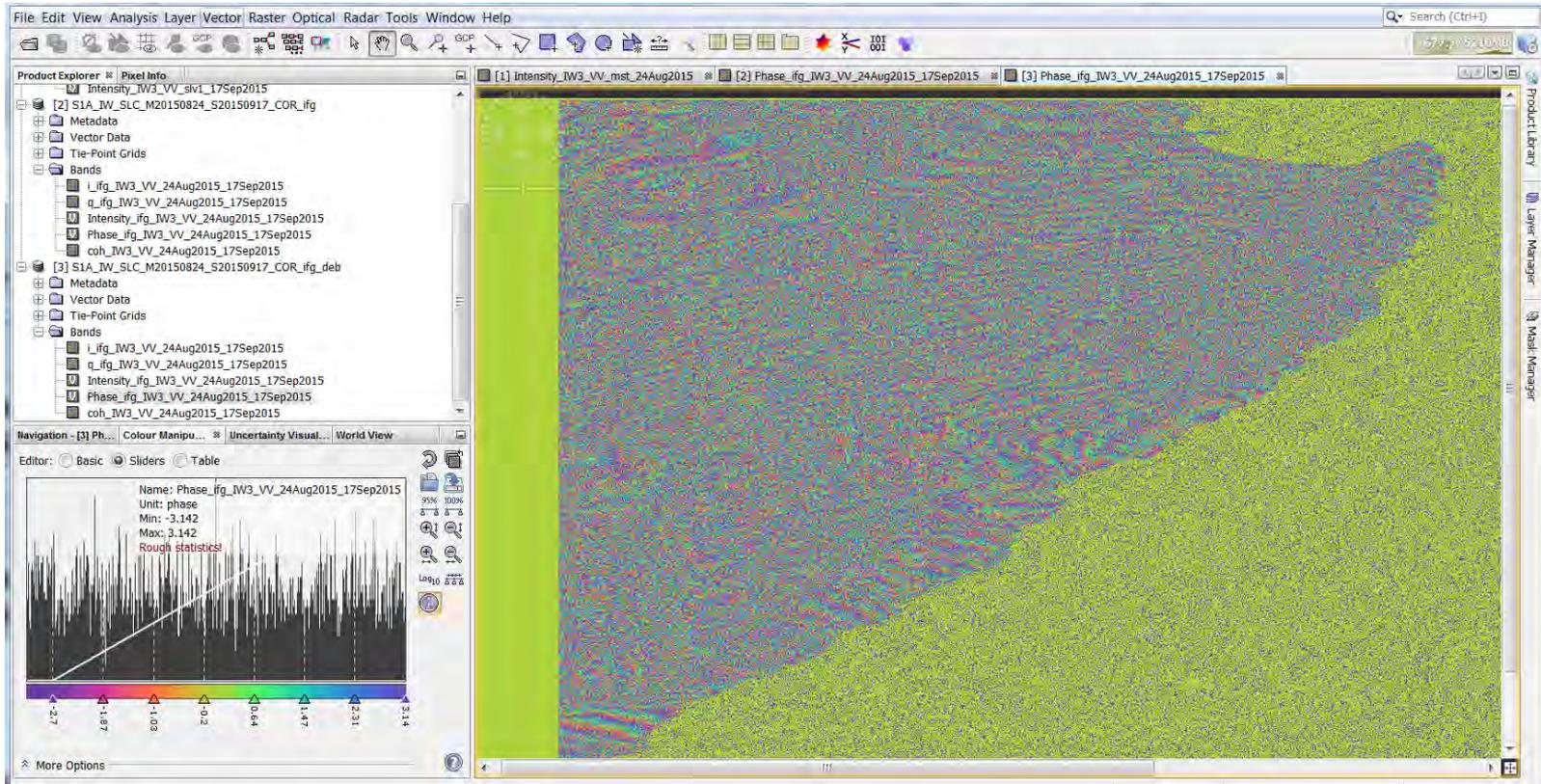
Left Dialog: S-1 TOPS Deburst

- File Help
- I/O Parameters | Processing Parameters
- Source Product
- source: [2] S1A_IW_SLC_M20150824_S20150917_COR_ifg
- Target Product
- Name: S1A_IW_SLC_M20150824_S20150917_COR_ifg_deb
- Save as: BEAM-DIMAP
- Directory: C:\LT2018\DIInSAR\Exercise2\OUTPUT
- Open in SNAP
- Run Close

Right Dialog: S-1 TOPS Deburst

- File Help
- Processing completed in 85 seconds (42 MB/s 11 MPixel/s)
- I/O Parameters | Processing Parameters
- Polarisations: VV
- Run Close

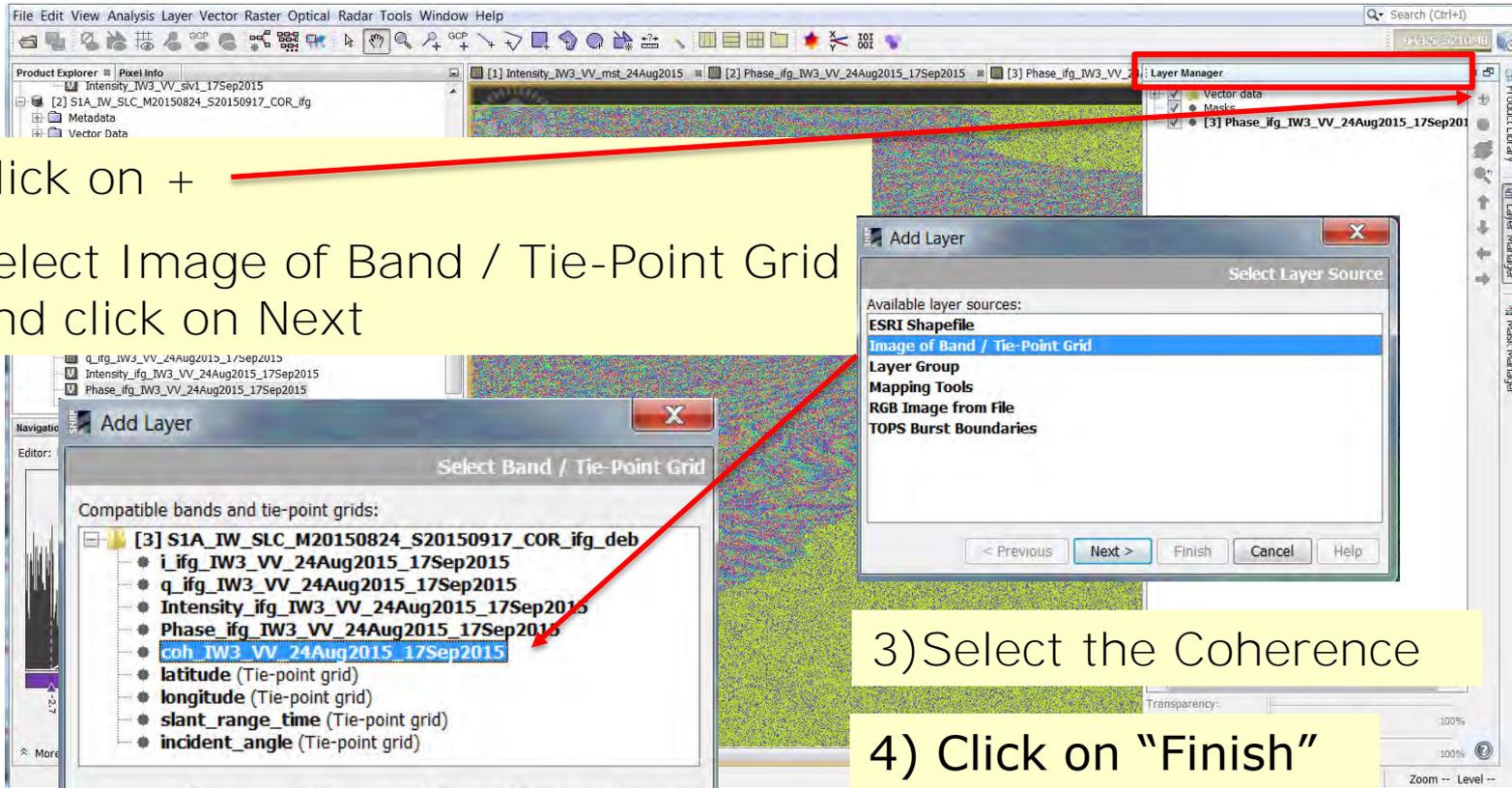
Interferogram visualisation



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Interferogram phase vs. (degree) coherence

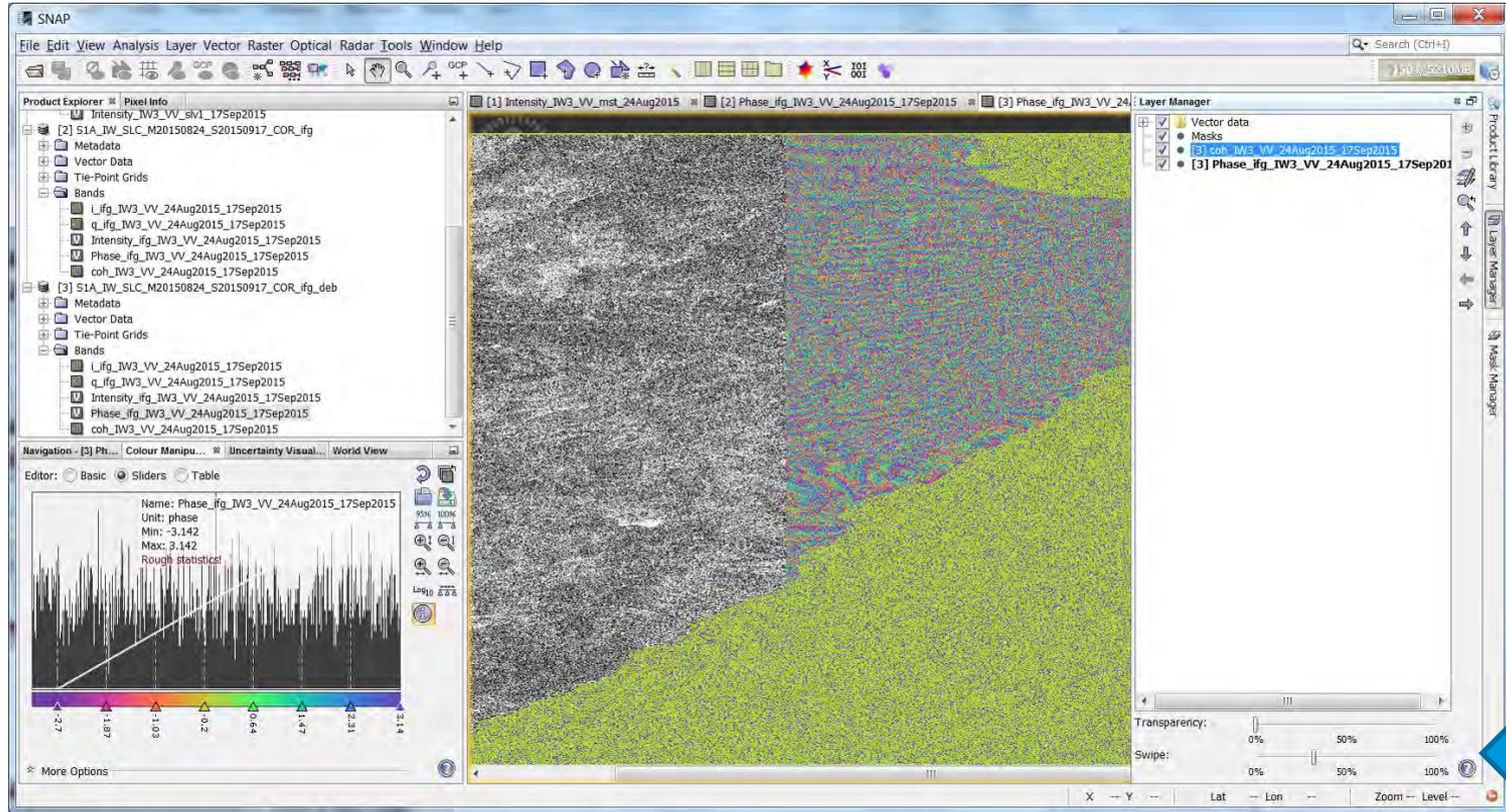


- 1) Click on +
- 2) Select Image of Band / Tie-Point Grid and click on Next

3) Select the Coherence

4) Click on "Finish"

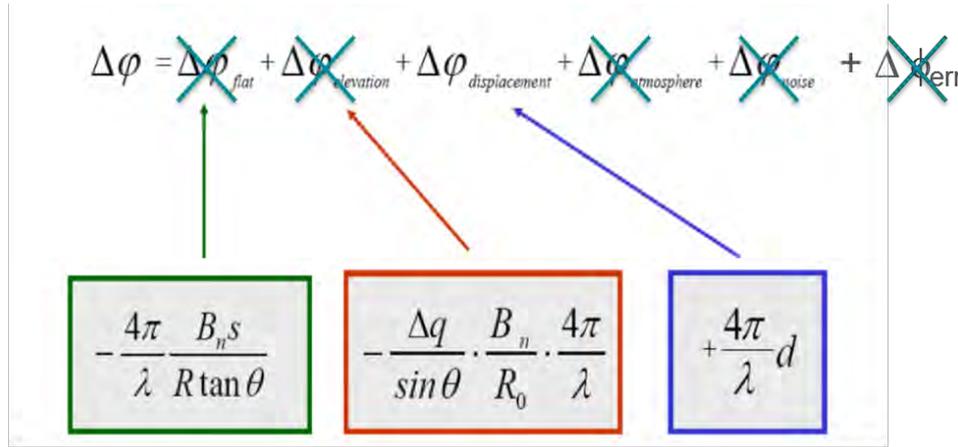
Interferogram phase vs. (degree) coherence



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Simplified approximation: DInSAR interferogram

$$\Delta\phi = \cancel{\Delta\phi_{\text{flat}}} + \cancel{\Delta\phi_{\text{elevation}}} + \Delta\phi_{\text{displacement}} + \cancel{\Delta\phi_{\text{atmosphere}}} + \cancel{\Delta\phi_{\text{noise}}} + \cancel{\Delta\phi_{\text{err}}}$$

$$\frac{4\pi}{\lambda} \frac{B_n s}{R \tan \theta}$$
$$-\frac{\Delta q}{\sin \theta} \cdot \frac{B_n}{R_0} \cdot \frac{4\pi}{\lambda}$$
$$+\frac{4\pi}{\lambda} d$$

- $\Delta\phi_{\text{flat}}$ is called flat Earth phase which is the phase contribution due to the earth curvature.
- $\Delta\phi_{\text{elevation}}$ is the topographic contribution to the interferometric phase.
- $\Delta\phi_{\text{displacement}}$ is the surface deformation contribution to the interferometric phase.
- $\Delta\phi_{\text{atmosphere}}$ is the atmospheric contribution to the interferometric phase. It is introduced due to the atmospheric humidity, temperature and pressure change between the two acquisitions.
- $\Delta\phi_{\text{noise}}$ is the phase noise introduced by temporal change of the scatterers, different look angle, and volume scattering.
- $\Delta\phi_{\text{err}}$ = orbital error, coreg. error, thermal noise, other noise

Topographic phase removal



The image shows the SNAP (Software for Near-Range Applications) interface. The main window displays the Product Explorer on the left, showing a tree structure of data products. The central area shows the 'Interferometric' menu path: **Interferometric** > **Products** > **Topographic Phase Removal**. Two dialog boxes for 'Topographic Phase Removal' are overlaid on the main window.

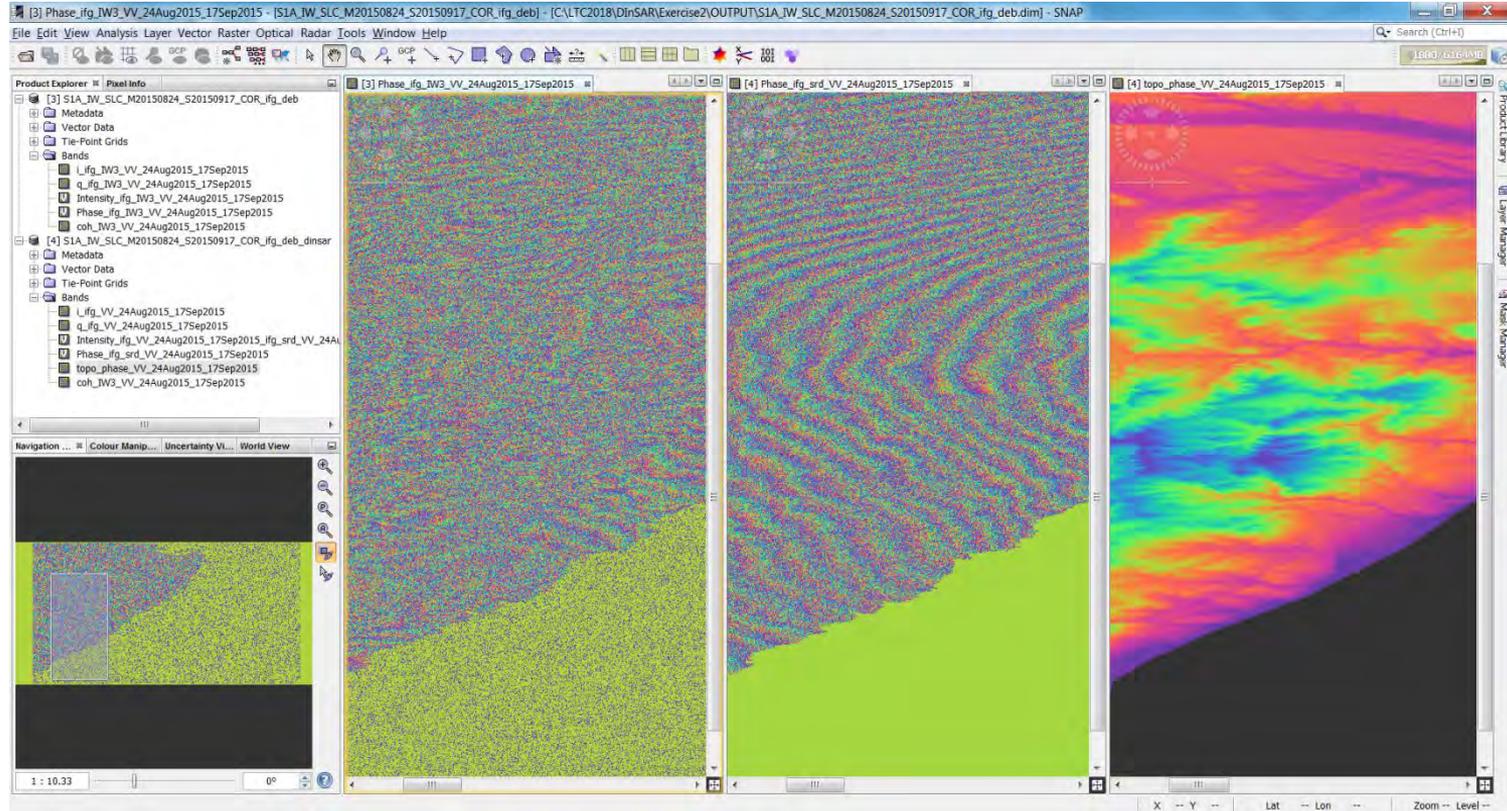
Topographic Phase Removal Dialog (Left):

- File Help**
- I/O Parameters** | **Processing Parameters**
- Source Product**
Source product: [3] S1A_IW_SLC_M20150824_S20150917_COR_ifg_deb
- Target Product**
Name: S1A_IW_SLC_M20150824_S20150917_COR_ifg_deb_dinsar
- Save as: BEAM-DIMAP
- Directory: C:\LTC2018\DInSAR\Exercise2\OUTPUT
- Open in SNAP
- Run** **Close**

Topographic Phase Removal Dialog (Right):

- File Help**
- I/O Parameters** | **Processing Parameters**
- Processing completed in 2.3 minutes (34 MB/s 9 MPixel/s)
- Orbit Interpolation Degree:** 3
- Digital Elevation Model:** SRTM 3Sec (Auto Download)
- Tile Extension [%]:** 100
- Output topographic phase band
- Output elevation band
- Output orthorectified Lat/Lon bands
- Run** **Close**

Topographic phase removal



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Goldstein phase filtering



Goldstein Phase Filtering

File Help

I/O Parameters Processing Parameters

Source Product

Source product:

[4] S1A_IW_SLC_M20150824_S20150917_COR_ifg_deb_dinsar

Target Product

Name:

S1A_IW_SLC_M20150824_S20150917_COR_ifg_deb_dinsarflt

Save as: BEAM-DIMAP

Directory:

C:\LTC2018\DInSAR\Exercise2\OUTPUT

Open in SNAP

Run Close

Goldstein Phase Filtering

File Help

Processing completed in 4.516667 minutes (17 MB/s 4 MPixel/s)

I/O Parameters Processing Parameters

Adaptive Filter Exponent in (0,1): 1.0

FFT Size: 64

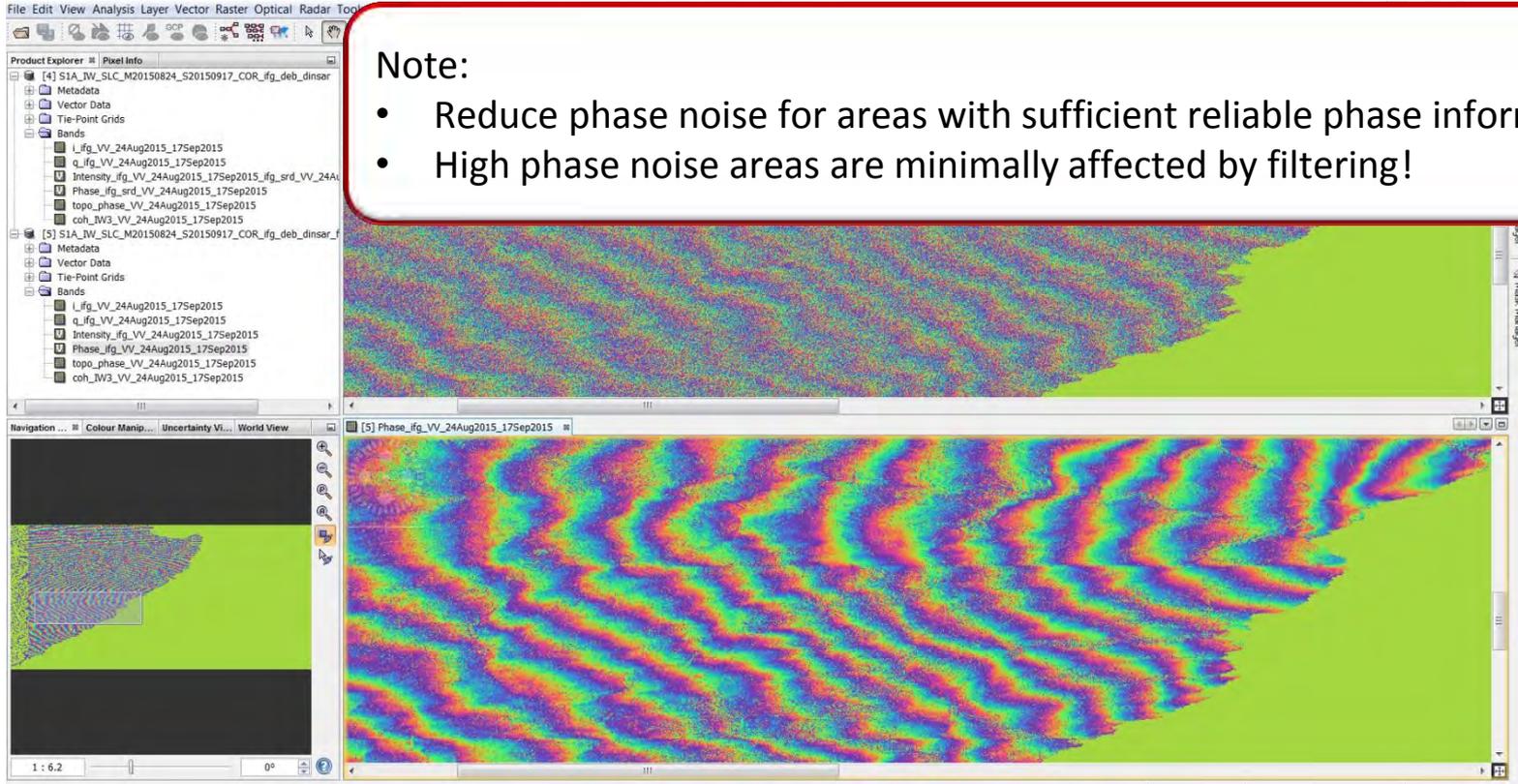
Window Size: 3

Use coherence mask

Coherence Threshold in [0,1]: 0.2

Run Close

Goldstein phase filtering



Multilooking [8 (range); 2 (Azimuth)]



Multilooking

File Help

I/O Parameters Processing Parameters

Source Product
source:
[5] S1A_IW_SLC_M20150824_S20150917_COR_ifg_deb_dinsar_fit

Target Product
Name:
S1A_IW_SLC_M20150824_S20150917_COR_ifg_deb_dinsar_fit_ML

Save as: BEAM-DIMAP

Directory:
C:\LTC2018\DInSAR\Exercise2\OUTPUT

Open in SNAP

Run Close

Multilooking

File Help

I/O Parameters Processing Parameters

Source Bands:
l_ifg_VV_24Aug2015_17Sep2015
q_ifg_VV_24Aug2015_17Sep2015
Intensity_ifg_VV_24Aug2015_17Sep2015
Phase_ifg_VV_24Aug2015_17Sep2015
topo_phase_VV_24Aug2015_17Sep2015
coh_IW3_VV_24Aug2015_17Sep2015

GR Square Pixel Independent Looks

Number of Range Looks: 8

Number of Azimuth Looks: 2

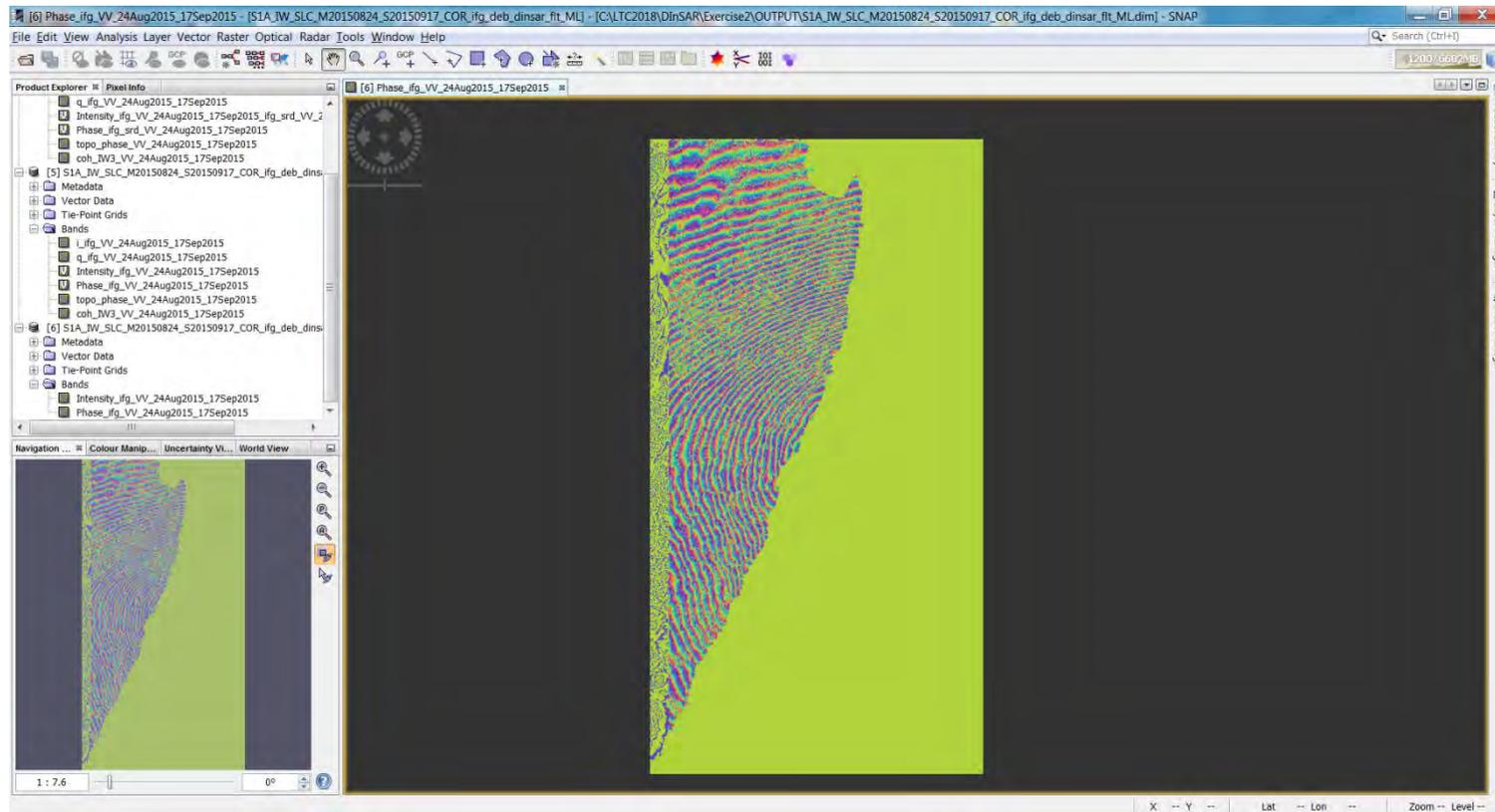
Mean GR Square Pixel: 27.57555

Output Intensity

Note: Detection for complex data is done without resampling.

Run Close

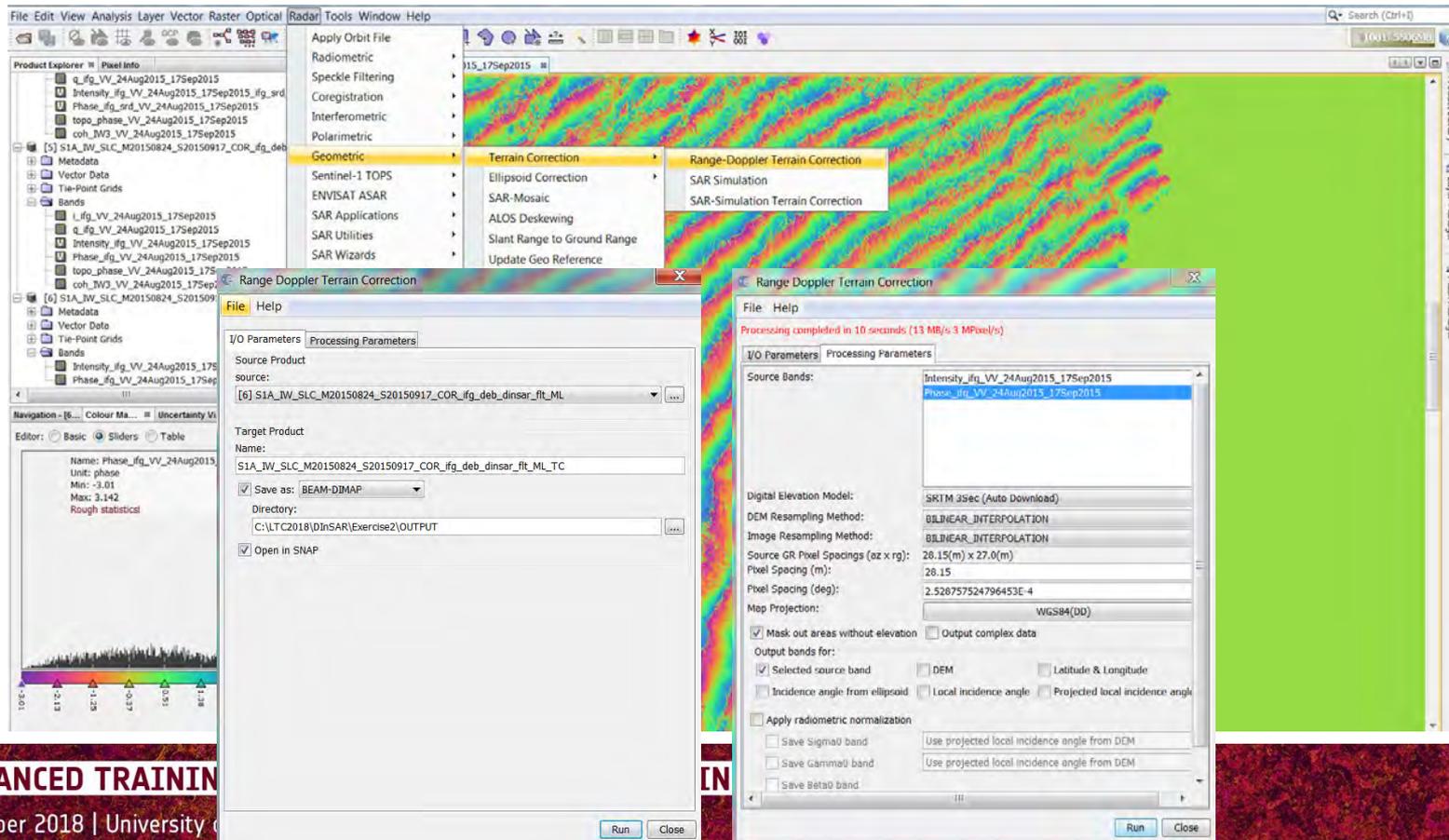
Display Multilooking [8 (range); 2 (Azimuth)]



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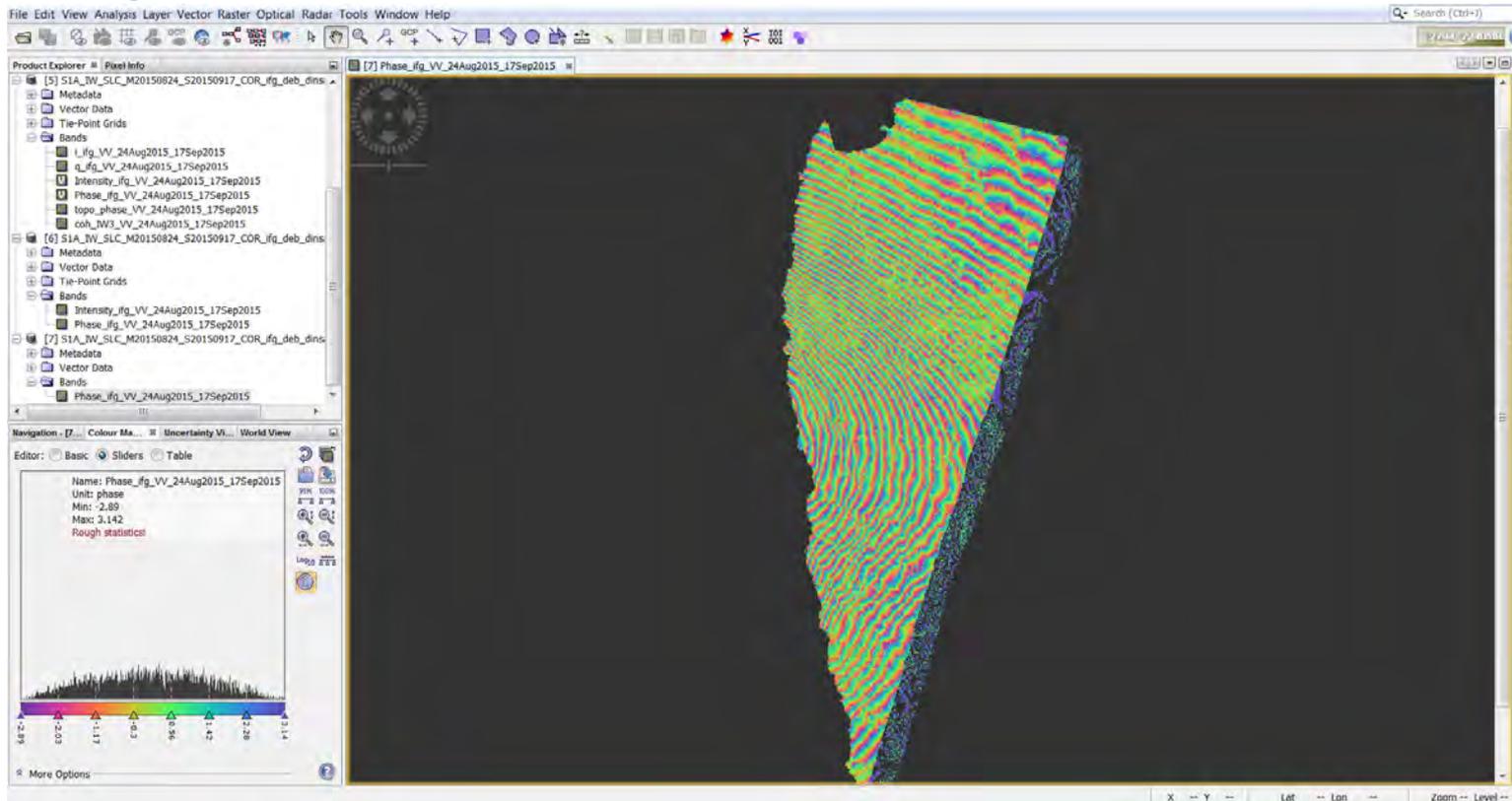
Terrain Correction of the differential wrapped interferogram



The screenshot displays the SNAP (Sentinel Application Platform) software interface. The main window shows a differential wrapped interferogram with a color scale ranging from -3.01 to 3.142. The 'Range Doppler Terrain Correction' dialog box is open, showing the 'Processing Parameters' tab. The 'Source Bands' are set to 'Intensity_ifg_VV_24Aug2015_17Sep2015' and 'Phase_ifg_VV_24Aug2015_17Sep2015'. The 'Target Product' is 'S1A_IW_SLC_M20150824_S20150917_COR_ifg_deb_dinsar_ft_ML_TC'. The 'Save as' is set to 'BEAM-DIMAP' and the 'Directory' is 'C:\LTC2018\Dir\SAR\Exercise2\OUTPUT'. The 'Open in SNAP' checkbox is checked. The 'Processing Parameters' tab shows the following settings:

- Processing completed in 10 seconds (13 MB/s 3 MPixel/s)
- Source Bands: Intensity_ifg_VV_24Aug2015_17Sep2015, Phase_ifg_VV_24Aug2015_17Sep2015
- Digital Elevation Model: SRTM 3Sec (Auto Download)
- DEM Resampling Method: BILINEAR_INTERPOLATION
- Image Resampling Method: BILINEAR_INTERPOLATION
- Source GR Pixel Spacings (az x rg): 28.15(m) x 27.0(m)
- Pixel Spacing (m): 28.15
- Pixel Spacing (deg): 2.528757524796453E-4
- 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
- Save radiometric normalization
 - Save Sigma0 band Use projected local incidence angle from DEM
 - Save Gamma0 band Use projected local incidence angle from DEM
 - Save Beta0 band Use projected local incidence angle from DEM

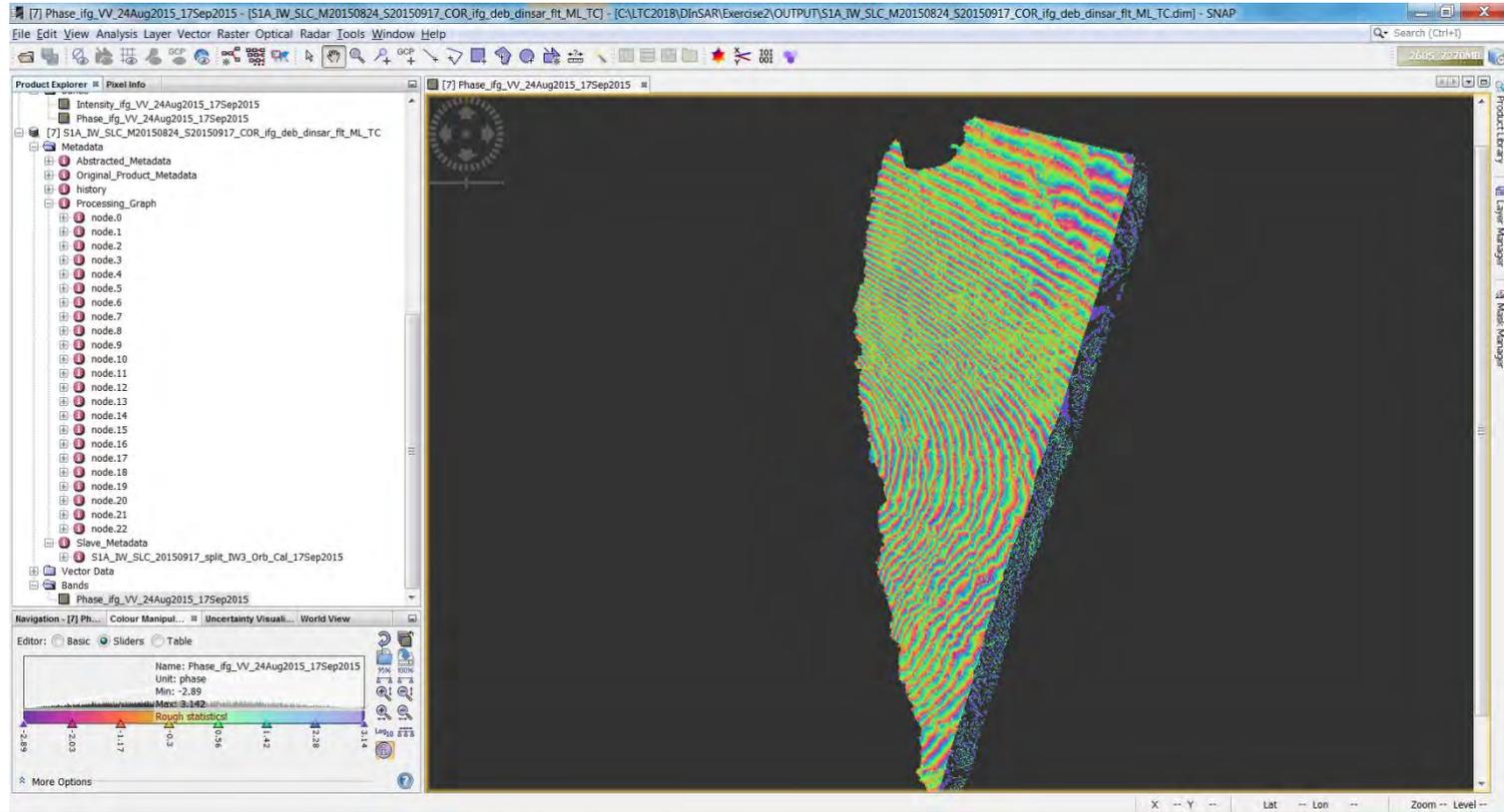
Terrain Correction of the differential wrapped interferogram



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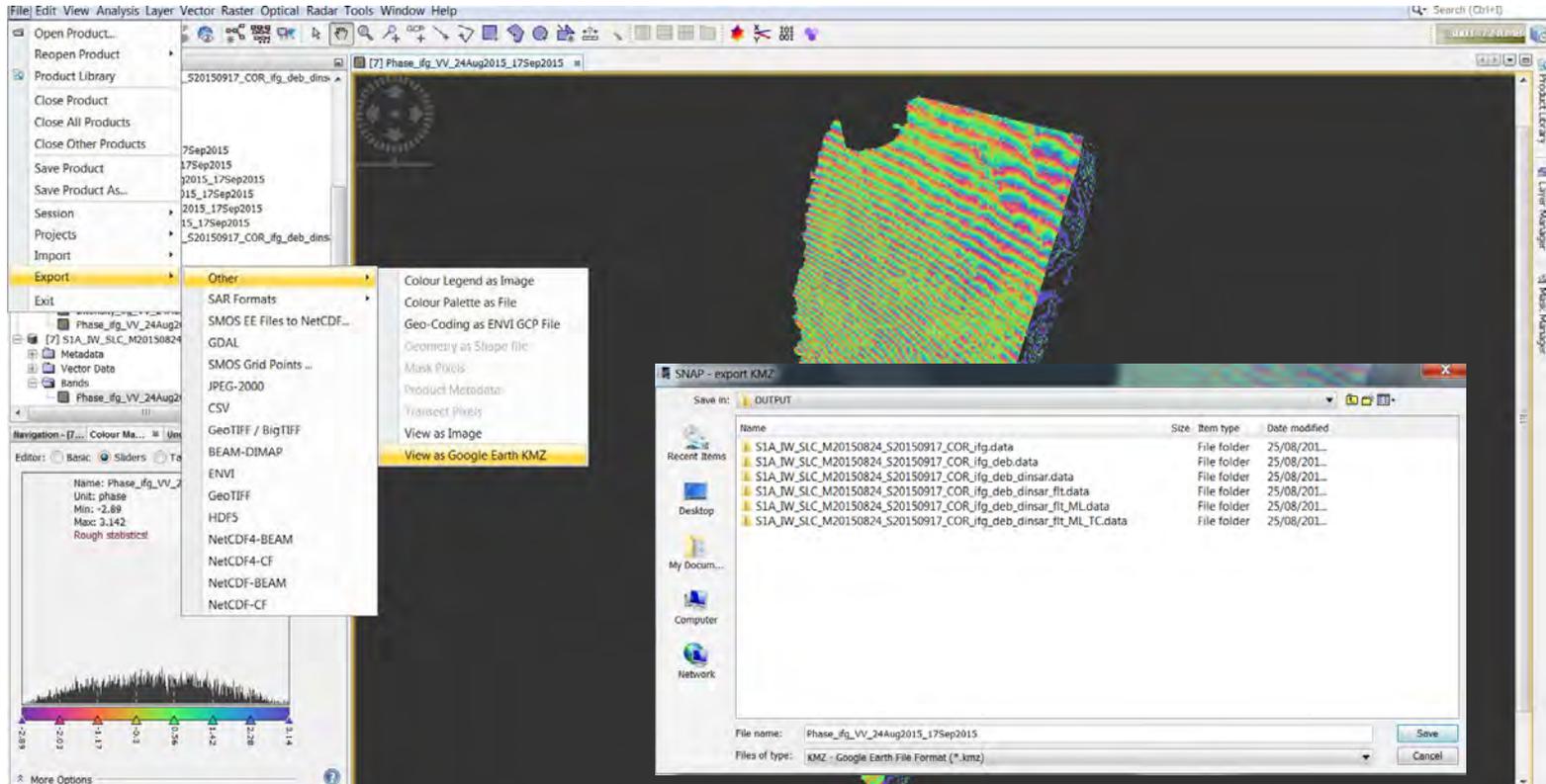
Processing Graph



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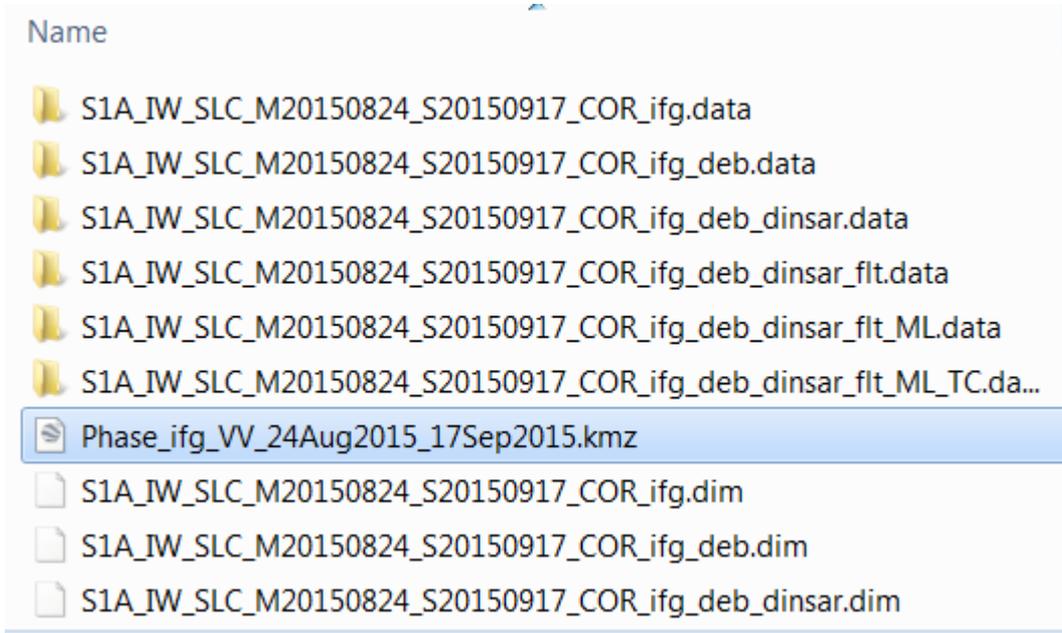
Export to Google Earth



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Thank you for your attention!

Any Question?

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