

Land Cover Change Detection with S-1TBX: Create an RGB from Multi-Temporal Sentinel-1 Data

Adapted from the 2015 European Space Agency's Advanced Training course on Land Remote Sensing.

In this data recipe, you will learn how to create a coherencebased multi- temporal color composite of land coverage using the ESA Sentinel-1 Toolbox.

In this document you will find

A. System RequirementsB. BackgroundC. Materials ListD. Steps for GeneratingComplex Sentinel-1 RGBComposite

- Part 1 Process SLC images
- Part 2 TOPS InSAR Coherence
- Part 3 –
 Generate RGB
 Composite
- E. Resulting Image

RGB – R: Coherence, **G**: Average Sigma0 & **B**: Difference Sigma0



Contains modified Copernicus Sentinel data (2015) processed by ESA

A) System Requirements

The Sentinel-1 Toolbox is a very computer resource intensive program and some steps can take a very long time to complete. Here are some hints to help speed things up and keep the program from freezing.

- At least 16 GB memory (RAM)
- Close other applications
- Do not use the computer while a product is being processed

B) Background

The Sentinel-1 mission comprises a constellation of two polar-orbiting satellites, Sentinel-1A and Sentinel-1B, which provide all-weather, day-and-night radar imaging for land and ocean surfaces, monitoring the marine environment, vegetation mapping, and other major applications.

With multi-temporal analyses, remote sensing gives a unique perspective of how cities evolve. The key element for mapping rural to urban land use change is the ability to discriminate between rural uses (farming, pasture, forests) and urban use (residential, commercial, recreational). Remote sensing methods can be employed to classify types of land use in a practical, economical and repetitive fashion, over large areas.

A Word on Sentinel-1 Interferometric Wide Swath (IW) Data

The Interferometric Wide (IW) swath mode is the main acquisition mode over land for Sentinel-1. It acquires data with a 250km swath at 5m x 20m spatial resolution (single look). IW mode captures three sub-swaths using the Terrain Observation with Progressive Scans SAR (TOPSAR) acquisition principle.

With the TOPSAR technique, in addition to steering the beam in range as in ScanSAR, the beam is also electronically steered from backward to forward in the azimuth direction for each burst, avoiding scalloping and resulting in homogeneous image quality throughout the swath. A schematic of the TOPSAR acquisition principle is shown below in Figure 1.

The TOPSAR mode replaces the conventional ScanSAR mode, achieving the same coverage and resolution as ScanSAR, but with nearly uniform image quality (in terms of Signal-to-Noise Ratio and Distributed Target Ambiguity Ratio).

IW Single Look Complex (SLC) products contain one image per sub-swath and one per polarization channel, for a total of three (single polarization) or six (dual polarization) images in an IW product.



Figure 1: TOPSAR acquisition principle

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, similar to ENVISAT ASAR Wide ScanSAR SLC products.

C) Materials List

- Windows or Mac OS X
- Multi-Temporal Sentinel-1A SLC Products

Sample Pair 1

- <u>S1A_IW_SLC_1SDV_20150610T042103_20150610T042131_006306_0</u> 0847C_8E6C
- <u>S1A_IW_SLC_1SDV_20150610T042129_20150610T042156_006306_0</u> 0847C_9361

Sample Pair 2

- <u>S1A_IW_SLC_1SDV_20150622T042104_20150622T042131_006481_0</u> 08979_946E
- <u>S1A_IW_SLC_1SDV_20150622T042129_20150622T042156_006481_0</u> 08979_7B20
- Sentinel-1 Toolbox (Version 5.0.0)

Note: You will be prompted for your Earthdata Login username and password, or must already be logged in to Earthdata before the download will begin.

D) Steps for Generating Complex Sentinel-1 RGB Composites

Part 1: Process SLC Image Pairs

- 1. Download software and data
- 2. Open data in Sentinel-1 Toolbox (S-1TBX)
- 3. TOPS Slice Assembly
- 4. Splitting Sub-Swaths
- 5. Applying Precise Orbits
- 6. Radiometric Calibration
- 7. TOPS Debursting
- 8. Speckle Reduction
- 9. SAR Multilooking

Part 2: TOPS Coregistration and InSAR Coherence

- 10. Open assembled SLC images
- 11.S1 TOPS Coregistration
- 12. InSAR Coherence Estimation
- 13. TOPS Debursting
- 14. Multilooking

Part 3: Generate RGB Composite

- 15. Open Processed images, Coherence stack
- 16. Create Data Stack
- 17.17.Create Spatial Subset over AOI
- 18. Range-Doppler Terrain Correction
- 19. Band Math Tool
- 20. RGB Composite Generation
- 21. Re-project to Geographic Coordinates
- 22. Export to Google Earth

Part 1: Process SLC Images – 9 Steps (x2)

Part 1 must be completed for <u>each pair of images</u>. You will do Part 1 twice - once for each pair.

Part 1: Process SLC Image Pair

- 1. Download software and data
- 2. Open data in Sentinel-1 Toolbox
- 3. TOPS Slice Assembly
- 4. Splitting Sub-Swaths
- 5. Applying Precise Orbits
- 6. Radiometric Calibration
- 7. TOPS Debursting
- 8. Speckle Reduction
- 9. SAR Multilooking

1. Download Software and Data

Download the Materials

- Download and install the <u>Sentinel-1 Toolbox</u> (Select the correct version for your operating system)
- Create a working folder for the Sentinel-1 sample images and intermediary products created during processing
- Download the sample images from the <u>Materials List</u> and place them in the new working folder

2. Open Data in Sentinel-1 Toolbox

In order to create an RGB composite, the input products should be two or more SLC products over the same area acquired at different times, such as the sample images provided in this data recipe.

Open the products

Use the **Open Product** button in the top toolbar and browse for the location of the Sentinel-1 Interferometric Wide (IW) SLC products. *To start, we will be working with both images from 6/10/2015*, as seen in the file name.

Note: <u>Do not</u> unzip the downloaded files.

Press and hold the **Ctrl** button on your keyboard and select the files. Click **Open** to load the files into the toolbox.

View the products

- In the *Product Explorer* window, you will find the products
- Double-click on each product to expand the view
- Double-click *Bands* to expand the folder

In the Bands folder, you will find bands containing the real (i) and

 Product Explorer
 Pixel Info

 Il SIA_W_SLC_ISDV_20150610T042129_20150610T042156_006306_00847C_9361

 Metadata

 Vector Data

 Il Quicklooks

 Bands

 Il [2] SIA_W_SLC_ISDV_20150610T042103_20150610T042131_006306_00847C_8E6C

 Metadata

 Vector Data

 Il Quicklooks

 Il Bands

 Il Quicklooks

 Bands

imaginary (q) parts of the complex data. The I and q bands are the bands that are actually in the product, and represent amplitude and phase. The Virtual Intensity or V band is there to assist you in working with and visualizing the complex data.

Note that in Sentinel-1 IW SLC products, you will find three subswaths labeled IW1, IW2, and IW3. Each subswath is for an adjacent acquisition by the TOPS mode.

View a band

To view the data, double-click on the **Intensity_IW2_VV** band of one of the images. Zoom-in on the image and pan by using the tools in the Navigation window below the Product Explorer window.



Within a subswath, TOPS data are acquired in bursts. Each burst is separated by a demarcation zone. Any 'data' within these demarcation zones can be considered invalid and should be zero-filled, but may also contain garbage values.

3. TOPS Slice Assembly

Ś	snap	File	Edit	View	Analysis	Layer	Vector	Raster	Optica	al	Radar	Tools	Window	Н	lelp	
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											ENVIS	SAT ASA	R	•	S-1 Slice Assembly	
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											SAR V	Vizards		•	S-1 TOPS Merge	
											Comp	lex to D	etected G	R	S-1 Remove GRD Border Noi	se
											Multil	ooking			S-1 EAP Phase Correction	

Assemble the images

- In the top menu, navigate to Radar
 Sentinel-1 TOPS > S-1 Slice
 Assembly
- In the *ProductSet-Reader* tab, add both products acquired on 06-10-2015 by using the add button (+). See below
- In the *SliceAssembly* tab, select the VV polarization
- In the Write tab, save the resulting product to a folder of your choice (e.g., 20150610_assembled)

The resulting product will automatically be appended with _*Asm*.

	ProductSet-Re	ader SliceAs	sembly W	rite	
File Name SIA_W_SLC_1SDV_201 SIA_W_SLC_1SDV_201	Туре 50610 50610	Acquisition	Track	Orbit	
					2 Products

4. Splitting Sub-Swaths

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[2] 5	1A_IW_SL	C_1SDV	_2015	0610T0	42103_201	50610T0	42131_00	6306_00	847C_8E6C	Geon	netric		•	
[3] S	1A_IW_SL	C_1SD\	_2015	0610T0	42103_201	50610T0	42156_00	6306_00	847C_8E6C	Senti	nel-1 TC	PS		S-1 SLC to GRD
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										SAR	Applicati	ons	•	S-1 TOPS Split
										SAR	Utilities		•	S-1 TOPS Deburst
										SAR	Wizards		•	S-1 TOPS Merge
										Com	olex to D	etected GI	R	S-1 Remove GRD Border Noise
										Multil	looking			S-1 EAP Phase Correction

Split assembled sub-swath

- In the top menu, navigate to Radar
 Sentinel-1 TOPS > S-1 TOPS
 Split
- In I/O Parameters, for Source Product select the product from the previous step (appended with _Asm)
- In Processing Parameters, select IW2 as your Subswath
- For Polarizations, select VV
- Click Run

The resulting product will be appended with _Asm_split

		S-1	TOPS Spl	it			
ile Help							
		I/O Parameters	Process	ing Paramet	ers		
Subswath:	IW2						0
Polarisation	IS: VV						
Bursts:	1 to 18						
	F						1
			Ž				
						Run	Close

5. Applying Precise Orbits (POD)

Orbit auxiliary data contain information about the position of the satellite during the acquisition of SAR data. Orbit data are automatically downloaded by SNAP and no manual search is required by the user.

The Precise Orbit Determination (POD) service for Sentinel-1 provides Restituted orbit files and Precise Orbit Ephemerides (POE) orbit files. POE files cover approximately 28 hours and contain orbit state vectors at fixed time steps of 10-second intervals. Files are generated one file per day and are delivered within 20 days after data acquisition.

If Precise orbits are not yet available for your product, you may select the Restituted orbits, which may not be as accurate as the Precise orbits but will be better than the predicted orbits available within the product.

Ś	snap	File	Edit	View	Analysis	Layer	Vector	Raster	Optical	Radar	Tools	Window	He
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	[2] S1A_	IW_SLC	_1SDV	_201506	10T042103	3_201506	510T0421	31_00630	6_00847C	Geon	netric		
	[3] S1A_	IW_SLC	_1SDV	_201506	10T042103	201506	510T0421	56_00630	6_00847C	Senti	nel-1 TC	PS	
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Apply Orbit File

- In the top menu, navigate to Radar > Apply Orbit File
- In *I/O Parameters*, for *Source Product* select the product from the previous step (appended with _*Asm_split*)
- Click Run

The resulting product will be appended with _Asm_split_Orb

6. Radiometric Calibration

Radiometric calibration corrects a SAR image so that the pixel values truly represent the radar backscatter of the reflecting surface.

The corrections applied during calibration are mission-specific, therefore the software will automatically determine what kind of input product you have and what corrections need to be applied based on the product's metadata.

Calibration is essential for quantitative use of SAR data.

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1 [1] S1A_IW_	SLC_1	SDV_201	1506107	042129_	20150610	T042156	_006306_	00847C_93	Interf	erometri	ic	•	S-1 Thermal Noise Removal
1 [2] \$1A_IW_	SLC_1	SDV_201	1506107	042103	20150610	T042131	_006306_	00847C_8E	Geon	netric		•	Convert Sigma0 to Beta0
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14] S1A_IW_	SLC_1	SDV_201	1506101	042103	20150610	T042156	_006306_	00847C_8E	ENVIS	SAT ASA	R	•	Create Calibration LUT TPG
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										Comp	olex to Dooking	etected G	R	

Calibrate Sentinel-1 image

- In the top menu, navigate to Radar > Radiometric > Calibrate
- In I/O Parameters, for Source Product select the product from the previous step (appended with _Asm_split_Orb)
- In Processing Parameters, select VV
- Select Output sigma0 band
- Click Run

The resulting product will be appended with _Asm_split_Orb_Cal

	I/O Parameters	Processing Parameters
Polarisatio	ons:	VV
-		
Save a	as complex output	t
Outpu	it sigma0 band	
Outpu	ut gamma0 band	
Outpu	ut beta0 band	

7. TOPS Debursting

To seamlessly join all burst data into a single image, apply the TOPS Deburst operator from the Sentinel-1 TOPS menu.

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 [1] S1A_W_SLC_1SDV_20150610T042129_20150610T042156_006306_00847C_93 [2] S1A_W_SLC_1SDV_20150610T042103_20150610T042131_006306_00847C_8E 	Interferometric	
[3] S1A_IW_SLC_1SDV_20150610T042103_20150610T042156_006306_00847C_8E	Sentinel-1 TOPS	S-1 SLC to GRD
[4] S1A_IW_SLC_1SDV_20150610T042103_20150610T042156_006306_00847C_8E	ENVISAT ASAR	S-1 Slice Assembly
 [5] SIA_W_SLC_ISDV_201506101042105_201506101042155_000506_00847C_5E [6] SIA_W_SLC_ISDV_20150610T042103_20150610T042156_006306_00847C_8E 	SAR Applications	S-1 TOPS Split S-1 TOPS Deburst
	SAR Wizards	S-1 TOPS Merge
	Complex to Detected GR Multilooking	S-1 Remove GRD Border Noise S-1 EAP Phase Correction

Deburst Image

- In the top menu, navigate to Radar
 > Sentinel-1 > S-1 TOPS Deburst
- In I/O Parameters, for Source Product select the product from the previous step (appended with _Asm_split_Orb_Cal)
- In Processing Parameters, select VV
- Click Run

	0	S-1 T	OPS Deburst	
File	Help			
		I/O Parameters	Processing Parameter	5
				_
P	olarisatio	ns: VH		
		VV		
			Run	Close
_				

The resulting product will be appended with _Asm_split_Orb_Cal_deb

8. Speckle Reduction

Speckle is caused by random constructive and destructive interference resulting in salt and pepper noise throughout the image. Speckle filters can be applied to the data to reduce the amount of speckle at the cost of blurred features or reduced resolution.

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Speckle Filtering

- In the top menu, navigate to Radar > Speckle Filtering > Single Product Speckle Filter
- In I/O Parameters, for Source Product select the product from the previous step (appended with _Asm_split_Orb_Cal_deb)
- In Processing Parameters, set Filter to Gamma Map
- Click Run

The resulting product will be appended with _Asm_split_Orb_Cal _deb_Spk



The Gamma Map filter assumes that the scene reflectivity of an image has a Gaussian distribution. Therefore, this filter uses *a priori* knowledge of the probability density function (PDF) of the scene when suppressing the speckle of the image.

9. SAR Multi-looking

Multi-look processing can be used to produce a product with nominal image pixel size.

Multiple looks may be generated by averaging over range and/or azimuth resolution cells improving radiometric resolution but degrading spatial resolution. As a result, the image will have less noise and approximate square pixel spacing after being converted from slant range to ground range.

🗯 snap File Edit View Analysis Layer Vector Raster Optical	Radar Tools Window He
[8] S1A_IW_SLC_1SDV_20150610T042103_20150610T042156_006306	Apply Orbit File
	Radiometric ►
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Product Explorer 😒 Pixel Info	Coregistration
[1] S1A_IW_SLC_1SDV_20150610T042129_20150610T042156_006306_00847C_1	Interferometric
[2] S1A_IW_SLC_1SDV_20150610T042103_20150610T042131_006306_00847C_3	Geometric 🕨
[3] S1A_IW_SLC1SDV_20150610T042103_20150610T042156_006306_00847C_3	Sentinel-1 TOPS
[4] S1A_IW_SLC1SDV_20150610T042103_20150610T042156_006306_00847C_	E ENVISAT ASAR
[5] S1A_IW_SLC1SDV_20150610T042103_20150610T042156_006306_00847C_	SAR Applications
[6] S1A_IW_SLC1SDV_20150610T042103_20150610T042156_006306_00847C_4	SAR Utilities
[7] S1A_IW_SLC_1SDV_20150610T042103_20150610T042156_006306_00847C_3	SAR Wizards
[8] S1A_W_SLC1SDV_20150610T042103_20150610T042156_006306_00847C_3	Complex to Detected GR
	Multilooking

Multi-look the Image

- In the top menu, navigate to Radar > Multilooking
- In I/O Parameters, for Source Product select the product from the previous step (appended with
 - _Asm_split_Orb_Cal_deb_Spk)
- In the Processing Parameters tab, change Number of Range Looks to 8.
 Notice that the Number of Azimuth Looks automatically changes to 2.
- Click Run

 I/O Parameters
 Processing Parameters

 Source Bands:
 Sigma0_W2_VV

 Image: CR Square Pixel
 Independent Looks

 Number of Range Looks:
 8

 Number of Azimuth Looks:
 2

 Mean GR Square Pixel:
 28.680649

 Note: Detection for complex data is done without resampling.

The resulting product will be appended with _Asm_split_Orb_Cal _deb_Spk_ML

Note: You must now repeat the steps in *Part 1* for the second pair of images acquired on 06-22-2015.

Remove all products from the Product Explorer window by selecting the products, then right-click and choose *Close All Products*.

Part 2: TOPS Coregistration and InSAR Coherence – 5 Steps

- 10. Open Assembled SLC Images
- 11.S1 TOPS Coregistration
- 12. InSAR Coherence Estimation
- 13. TOPS Debursting
- 14. Multi-looking

10. Open Assembled SLC Images

In order to create the bands necessary for the RGB composite image, you will have to co-register the images created in Step 3 of Part 1 (<u>S-1 Slice Assembly</u>). These assembled SLC products will allow you to estimate the coherence between the two images.



Open the products

Use the Open Product button in the top toolbar and browse to the location of the assembled SLC products. These images will have the suffix *_asm.dim* (if you did not choose to create a custom file name).

11. S-1 TOPS Coregistration

For interferometric processing (coherence estimation), two or more images must be coregistered into a stack. One image is selected as the master and the other images are the 'slaves'. The pixels in 'slave' images will be moved to align with the master image to sub-pixel accuracy.

Coregistration ensures that each ground target contributes to the same (range, azimuth) pixel in both the master and the 'slave' image. For TOPSAR InSAR, S-1 TOPS Coregistration is used.



Co-register the images

Navigate to Radar > Coregistration > S1 TOPS Coregistration > S1 TOPS Coregistration

0.				S1	TOPS Coregistration			
	Read I	Read(2)	TOPSAR-Split	TOPSAR-Split(2)	Apply-Orbit-File	Apply-Orbit-File(2)	Back-Geocoding	Write
Targe	t Product							
S1A	IW_SLC1SD	V_201506	10T042103_201	150610T042156_00	6306_00847C_8E6C	_Asm_Orb_Stack		
2 S D	ave as: BEA rectory:	AM-DIMAP						
1	Users/jahicke	èγ						
	pen in SNAP							
					🕑 Help 🕞 Run			

- In the Read tab, select the first product -this will be your master image
- In the Read(2) tab select the other product -this will be your 'slave' image
- In the **TOPSAR-Spli**t tabs, select the IW2 subswath for each of the products
- In the **Apply-Orbit-File** tabs select the Sentinel Precise Orbit State Vectors
- In the Back-Geocoding tab leave all parameters to default
- In the Write tab, set the Directory path to your working directory
- Click Run to begin co-registering the data

The resulting coregistered stack product will appear in the *Product Explorer* window with the suffix _*Asm_Orb_Stack*

12. InSAR Coherence Estimation

The coherence band shows how similar each pixel is between the slave and master images in a scale from 0 to 1. Areas of high coherence will appear bright. Areas with poor coherence will be dark.

🗯 snap File Edit View Analysis Layer Vector Raster Optical	Radar Tools Window Help	
	Apply Orbit File [Empty] Radiometric Speckle Filtering Correctification	1
 I] SIA_W.SLC_ISDV_20150610T042103_20150610T042156_006306_00847C I] SIA_W.SLC_ISDV_20150622T042104_20150622T042156_006481_008979 I] SIA_W_SLC_ISDV_20150622T042104_20150622T042156_006481_008979 I] SIA_W_SLC_ISDV_20150622T042104_20150622T042156_006481_008979 	Interferometric Products Interferogr Geometric Filtering Coherence Sentinel-1 TOPS Unwrapping Topograph ENVISAT ASAR PSI\SBAS Three-pass SAR Applications InSAR Stack Overview Phase to E SAR Utilities Phase to E Phase to E Complex to Detected GR Integer Inte	am Formation Estimation ic Phase Removal s Differential INSAR leight lisplacement levation erferogram Combination

Coherence Estimation

- In the top menu, navigate to Radar > Interferometric > Products > Coherence Estimation
- In I/O Parameters, for Source Product select the product from the previous step (appended with _Asm_Orb_Stack)
- Click Run



The resulting product will be appended with _Asm_Orb_Stack_coh



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13. TOPS Debursting

Ś.	snap	File I	dit Viev	Analysis	Layer	Vector	Raster	Optical	Radar	Tools	Window	Help				
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									SAR /	Applicati Jtilities	ons		S-1 TO	PS Split	t urst	
									SAR V Comp Multil	Wizards blex to D ooking	etected GF	*	S-1 TO S-1 Re S-1 EA	PS Mer move G P Phase	ge RD Bord Correc	der Noise

Deburst the Image

- In the top menu, navigate to Radar > Sentinel-1 TOPS > S-1 TOPS Deburst
- In I/O Parameters, for Source Product select the product from the previous step (appended with _Asm_Orb_Stack_coh)
- Click Run

The resulting product will be appended with _Asm_Orb_Stack_coh_deb

	S-1 TOPS Deburst		
File Help			
	I/O Parameters Processing P	arameters	
Polarisatio	ns: VV		
		Run	Close



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14. Multilooking

Ś	snap	File	Edit	View	Analysis	Layer	Vector	Raster	Optical	Radar	Tools	Window	He
•	[8] S1A_IW_SLC_1SDV_20150610T042103_20150610T042156_006306_C Apply Orbit File												
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Produ	uct Explore	er 🖸 📃	Pixel Inf	fo						Coreg	gistration	۱	
9 [1] S1A_IW	_SLC	1SDV_2	0150610	T042129	2015061	0Т042156	6_006306_	00847C_9	Interf	erometri	ic	
9 [2] S1A_IW	_SLC	1SDV_2	0150610	T042103	2015061	0T042131	_006306_	00847C_8	Geor	netric		
9 [3] S1A_IW	_SLC	1SDV_2	0150610	T042103	2015061	0T042156	6_006306_	00847C_8	Senti	nel-1 TC	PS	
9	4] S1A_IW	_SLC_1	1SDV_2	0150610	T042103	2015061	0T042156	6_006306_	00847C_8	ENVIS	SAT ASA	R	
9 [5] S1A_IW	SLC_	1SDV_2	0150610	T042103	2015061	0T042156	5_006306_	00847C_8	SAR A	Applicati	ons	
9 [6] S1A_IW	_SLC	1SDV_2	0150610	T042103	2015061	0T042156	5_006306_	00847C_8	SARU	Jtilities		
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										Multil	ooking		

Multilook the Image

- In the top menu, navigate to Radar > Multilooking
- In I/O Parameters, for Source Product select the product from the previous step (appended with _Asm_Orb_Stack_coh_deb)
- In the Processing Parameters tab, change the Number of Range Looks to 8; the number of Azimuth Looks automatically changes to 2.
- Click Run

The resulting product will be appended with _Asm_Orb_Stack_coh_deb_ML

Note: Before proceeding with Part 3, remove all products from the Product Explorer window except for the final, multi-looked product (ending with _*ML*). Left-click on the _*ML* product to highlight it, then from the top menu select *File > Close Other Products*.

● ● M File Help	lultilooking
I/O Parameters	Processing Parameters
Source Bands:	Sigma0_IW2_VV
GR Square Pixel Number of Range Looks: Number of Azimuth Looks:	Independent Looks 8 2
Mean GR Square Pixel:	28.680649 Note: Detection for complex data

Part 3: Generate RGB Composite – 8 Steps

- 15. Open Processed Images, Coherence Stack
- 16. Create Data Stack
- 17. Create Spatial Subset over AOI
- 18. Range-Doppler Terrain Correction
- 19. Band Math Tool
- 20. RGB Composite Generation
- 21. Reproject to Geographic Coordinates
- 22. Export to Google Earth

15. Open Processed Images, Coherence Stack

For this part, we will use the final two products we created in <u>Part 1</u> (appended with _*ML*) and the final product in <u>Part 2</u> (also appended with _*ML*) to generate our complex Sentinel-1 TOPS RGB composite.



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Open Final Products

Navigate to the folder you chose to store the products created in Parts 1 and 2. Open the products with the filename ending in *_ML.dim*.

- Use the Open Product button to add the products into the Product Explorer
- You may view the products by double clicking on each item and expand the *Bands* folder

16. Create Data Stack

Creating a data stack will tie each of your final products together and create a single product with multiple bands. Each band will represent the single band present in each of your products. We will use these three bands to generate our composite image.

Image: snap File Edit View Analysis Layer Vector Raster Optical Image: snap [1] S1A_IW_SLC_1SDV_20150622T042104_20150622T042156_006481_C Image: snap [3] Sa_k [3] Sa_k	Radar Tools Window H Apply Orbit File Radiometric	telp ih_deb_ML - [/Users/jahickey/S1A_IW_SLC_1SDV_20150622T0421
Product Explorer [©] Pixel Info ▶ (1) S1A. W. SLC_1SDV_20150622T042104_20150622T042156_006481_008979 ▶ (2) S1A. W. SLC_1SDV_20150610T042103_20150610T042156_006306_00847C ▶ (3) S1A. I.W. SLC_1SDV_20150622T042104_20150622T042156_006481_008979	Coregistration Content of the second	Coregistration S1 TOPS Coregistration DEM-Assisted Coregistration ► Stack Tools ► Create Stack Cross InSAR resampling Stack Averaging Stack Split

Create Stack

- Navigate to Radar > Coregistration > Stack Tools > Create Stack
- In Create Stack, add the three products to the ProductSet-Reader by clicking on the Add Opened button (the second + sign on the right)
- In the CreateStack tab, set the Resampling Type to NEAREST NEIGHBOUR
- In Write, set the directory to store the product
- Create Stack

 I-ProductSet-Reader
 Z-CreateStack
 3-Write

 Master:
 S1A_IW_SLC_ISDV_20150622T042104_20150622T042156_006481
 Resampling Type:
 NEAREST_NEIGHBOUR
 Initial Offset Method:
 Orbit
 Output Extents:
 Master

 Find Optimal Master

 Master

• Click Run

Your product will appear in the *Product Explorer* and will have all three bands.

17. Create Spatial Subset over AOI

In this particular example, our area of interest will be the capital of Romania, Bucharest, and the surrounding area. This step is not necessary, but is useful if you are only interested in a particular region and desire to crop the image.

🗯 snap File Edit View Analysis Layer Vector	Raster Optical Radar Tools Wi	ndow Help
	Band Maths Filtered Band Convert Band	ack - [/Users/jahi] 🕤 📿 È
Product Explorer Pixel Info Pixel A INFO Pixel	Propagate Uncertainty	
[1] SIA_IW_SLC_ISDV_201506221042104_2015062210421 [2] SIA_IW_SLC_1SDV_20150610T042103_20150610T0421	Subset	on_deb_ML I_deb_Spk_ML
► 🗑 [3] S1A_IW_SLC1SDV_20150622T042104_20150622T0421	Geometric Operations	l_deb_Spk_ML
 [4] 20150610_20150622_Stack [4] Metadata 	DEM Tools	
Vector Data	Data Conversion	
Tie-Point Grids Rands	Image Analysis	
coh_W2_VV_22Jun2015_10Jun2015	Classification Export	
 Sigma0_W2_VV_slv1_10Jun2015 Sigma0_W2_VV_slv2_22Jun2015 		

Create Subset

- Double-click on the opened product to view the product bands
- Double-click on any of the bands inside of the product
- Zoom in using the mouse wheel and dragging the left mouse button
- Once you have zoomed and panned to your area of interest, right click and select **Spatial Subset from View** in the context menu.



You may also access this option via the Raster menu by selecting Subset...

The subset dialog box will automatically select the area you were viewing. To adjust the extent of your subset image, you may drag the bounding box, enter the pixel coordinates, or add geo coordinates.

	Speci	fy Product Subset			
Spatial Subset	Band Subset	Tie-Point Grid Subs	et Metadata S	ubset	
		Pixel Coordinates	Geo Coordinat	25	
	Scene start X:			70	0
	Scene start Y:			3255	0
	Scene end X:			3110	0
and the second second	Scene end Y:			9800	•
5	icene step X:				1 0
State of the second second	cene step Y:				1 2
	ubset scene widt	n:		30	41.0
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	jource scene heigh	nt:		12	2162
		-	Fix full wid	:h	
	Use	Preview	Fix full heig	iht	
			Estimated	, raw storage size	: 56.9
			ОК	Cancel	lelp

Click \mathbf{OK} to create your subset image

When the new subset product appears in the Product Explorer.

- Right-click on the product
- Select Save Product in the context menu
- Select **Yes** to convert the product to the BEAM-DIMAP format

18. Range-Doppler Terrain Correction

Terrain Correction will geocode the image by correcting SAR geometric distortions using a digital elevation model (DEM) and produce a map projected product.



Figure 2: Slant Range geometric image distortions

Geocoding converts an image from Slant Range, or Ground Range, Geometry into a Map Coordinate System. Terrain Geocoding involves using a Digital Elevation Model (DEM) to correct inherent geometry effects such as *foreshortening, layover* and *shadow.*

Foreshortening

- The period of time a slope is illuminated by the transmitted pulse of the radar energy determines the length of the slope on radar imagery.
- This results in shortening of a terrain slope on radar imagery in all cases except when the local angle of incidence () is equal to 90 degrees ().

Layover

- When the top of the terrain slope is closer to the radar platform than the bottom the former will be recorded sooner than the latter.
- The sequence at which the points along the terrain are imaged produces an image that appears inverted.
- Radar layover is dependent on the difference in slant range distance between the top and bottom of the feature.

Shadow

• The back-slope is obscured from the imaging beam causing to return no area of radar shadow.

The effects of these distortions can be seen in Figure 2. The distance between 1 and 2 can appear shorter than it should and the return for 4 can occur before the return for 3 due to the elevation.



Terrain Correction

- Highlight the subset product in Product Explorer
- In the top menu, navigate to Radar > Geometric > Terrain Correction > Range-Doppler Terrain Correction

By default, the terrain correction will use the SRTM 3 sec DEM. The software will automatically determine the DEM tiles needed and download them from internet servers.

 In Processing Parameters leave all parameters as default

Note: You may choose a projection of your liking, however, you will not be able to export to Google Earth unless you have Lat/Long coordinates.

Click Run



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19. Band Math Tool

This step will allow us to create meaningful bands used in our composite RGB image. This is a three step process and will create several virtual bands.



Create Average Backscatter Band

- In the top menu, navigate to Raster > Band Maths
- In the Band Maths window (see Figure 3):
 - Select the terrain corrected subset product (_TC)
 - Name the band **ave_sigma0**
- Click on the *Edit Expression*... button
 - In the Band Maths Expression Editor:
 - Click the @ + @ operator
 - Click on the two Sigma0 products in *Data sources* and they will be added to the expression
 - Click OK
- In the Band Maths expression: box
 - Add parenthesis around the expression and type / 2 (divided by 2)

The expression should look like: (Sigma0_06-22-2015 + Sigma0_06-10-2015) / 2

• Click **OK** to create virtual band

	Band Maths			Pro
Target product:			Band Maths Expression	n Editor
[2] subset_0_c	of_20150610_20150622_Stack_TC	Data sources: coh_IW2_VV_22Jun2015_10Jun2015	6 + 6	Expression: Sigma0_IW2_VV_slv1_10Jun2015 +
Name:	ave_sigma0	Sigma0_IW2_VV_slv1_10Jun2015 Sigma0_IW2_VV_slv2_22Jun2015	e – e	51gmd0_1#2_44_3142_220012015
Description: Unit:			e + e	
Spectral wavelength: 0.0			(0)	-
 ✓ Virtual (save ✓ Replace NaN 	expression only, don't store data) and infinity results by	Show bands	Constants	3
Generate ass	ociated uncertainty band	Show tie-point grids	Operators	
Band maths expr Sigma0 IW2 VV	ression: slv2 22Jun2015	Show single flags	Functions	Ok, no errors.
				OK Cancel Help
Load	Save Edit Express	ion		
	OK Cancel	Help		

	Band Maths						
Target product:	Target product:						
[2] subset_0_of_2	20150610_20150622_Stack_TC	\$					
Name:	ave_sigma0						
Description:							
Unit:							
Spectral wavelength:	: 0.0						
🗹 Virtual (save exp	pression only, don't store data)						
🗹 Replace NaN and	d infinity results by	NaN					
🗌 Generate associa	ated uncertainty band						
Band maths expressi	ion:						
(Sigma0_IW2_VV_slv1_10Jun2015 + Sigma0_IW2_VV_slv2_22Jun2015)/2							
Load Sa	ave Edit Expression						
	OK Cancel He	٩ŀ					

Figure 3: Band Maths dialog and Expression Editor interface

Create Backscatter Difference Band

- In the top menu, navigate to *Raster > Band Maths*
- In the Band Maths window
 - Select the terrain corrected subset product (_TC)
 - Name the band, diff_sigma0
- Open the Band Maths Expression Editor by clicking the <Edit Expression...> button
 - In the Band Maths Expression Editor
 - Delete the contents of the *Expression:* box
 - Click the @ @ operator
 - Click on the two Sigma0 products in *Data sources* and they will be added to the expression
 - Click OK

Your final expression should look like this: older Sigma0 - newer Sigma0

• Click **OK** to create virtual band

Linear to dB Scale Conversion

- Double-click on the terrain corrected subset product (_*TC*) in Product Explorer
- Open the bands folder
- Right-click on the band named ave_sigma0
- Click Linear to/from dB
- When prompted, click **Yes** to create a new virtual band

Note: You may also find this function in Raster > Data Conversion > Linear to/from dB

OPTIONAL: Save Virtual Bands

To permanently save virtual bands within your product file

- In the Product Explorer right-click on the newly created virtual bands (e.g., ave_sig0)
- From the context menu, select Convert Band



20. RGB Composite Generation

Open RGB Image

- Right-click on the terrain corrected subset product (_TC) in Product Explorer
- Select Open RGB Image Window

In the Select RGB-Image Channels window:

- Click on the <...> button next to Red
 - Delete the contents of the *Expression:* box
 - In Edit Red Expression, click the coherence product (coh_) in Data sources
 - Click **OK**
- Repeat for Green and select ave_sigma0_dB
- Repeat for Blue and select diff_sigma0
- Optional: Check Store RGB channels as virtual bands in current product
- Click OK to see results

Product Explorer 🛞 Pixel Info		Select RGB-Image Channels
 Image: Sigma 0, S	D 20150622 Stack TC Band Maths Add Elevation Band Add Land Cover Band ✓ Group Nodes by Type Open RGB Image Window Open HSV Image Window Close Product	Profile: Red: coh_IW2_VV_22Jun2015_10Jun2015 Green: ave_sigma0_db Blue: diff_sigma0] Expressions are valid
	Close All Products Close Other Products	Store RGB channels as virtual bands in current product OK Cancel Help

The resulting image may seem a little too light. To adjust color settings, click on the *Color Manipulation* tab below *Product Explorer*, or from the top menu, *View > Tool Windows > Color Manipulation*. The following values are suggested for each band rendering, but can be adjusted to meet your needs.







Green: -12.17 to -5.0



Blue: -0.16 to 9.31E-2



22. Export to Google Earth

Export Your Image

In the top menu, navigate to File > Export > Other > View as Google Earth KMZ

In addition to GeoTIFF and HDF5 formats, KMZ and various specialty formats are supported. Figure 5 shows a KMZ-formatted RGB composite image overlaid on Google Earth.

The resulting image also works in a GIS environment because it is geocoded.

E) Resulting Image



Figure 4: Geocoded RGB Composite Image of Bucharest, Romania in Google Earth. Credit: ASF DAAC 2017; Contains modified Copernicus Sentinel data [2015] processed by ESA

Multi-temporal color composite images give us an idea of an area's land cover and use. Different colors show changes that occurred over the period of coverage.

The blues across the entire image represent strong changes in bodies of water or agricultural activities such as ploughing. The yellows represent urban centers, with the capital city of Bucharest very distinct. Vegetated fields and forests appear in green. The reds and oranges represent unchanging features such as bare soil or possibly rocks that border the forests.

In this data recipe, a 12-day repeat interval is used, as we are using only Sentinel-1A data. With the launch of Sentinel-1B in early 2016, this repeat cycle is reduced to 6 days, as the satellites share the same orbit. C-band coherence is significantly lower over the image after 12 days (Sentinel-1A) as compared to 6 days, which makes it more ideal to separate agricultural areas and forest, which is ideal for temperate regions.