



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

ESA-MOST China Dragon 4 Cooperation

2019 ADVANCED INTERNATIONAL TRAINING COURSE IN LAND REMOTE SENSING 中欧科技合作"龙计划"第四期 **2019**年陆地遥感高级培训班





Part 1

Multitemporal Analysis of SAR Backscatter Intensity



Objectives

- Familiarizing with SNAP toolbox
- Familiarizing with Sentinel-1 GRD products
- 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)



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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

1						
<u>File Edit V</u> iew And	alysis Layer	Vector Ra	ster Optical	Radar <u>T</u>	ools <u>W</u> indov	w <u>H</u> elp
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Save Product Save Product As.	40					
Session	•					
Projects	•					
Import	•					
Export	•					
Exit						

 S1B_IW_GRDH_1SDV_20190219T055747_20190219T055812_015011_01C0C5_16E0.zip

 S1B_IW_GRDH_1SDV_20190315T055747_20190315T055812_015361_01CC2F_2DE0.zip

 S1B_IW_GRDH_1SDV_20190420T055748_20190420T055813_015886_01DD7D_B255.zip

 S1B_IW_GRDH_1SDV_20190514T055749_20190514T055814_016236_01E8EA_C0BC.zip

 S1B_IW_GRDH_1SDV_20190713T055752_20190713T055817_017111_020314_33F3.zip

 S1B_IW_GRDH_1SDV_20190818T055755_20190818T055820_017636_0212DC_C2D4.zip

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For unzipped products

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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





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.





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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

Radar Tools Window	v <u>H</u> elp
Apply Orbit File	
Radiometric	Calibrate
Speckle Filtering	Radiometric Terrain Flattening
Coregistration	Remove Antenna Pattern
Interferometric	S-1 Thermal Noise Removal
Polarimetric	Convert Sigma0 to Beta0
Geometric	Convert Sigma0 to Gamma0
Sentinel-1 TOPS	Create Calibration LUT TPG
ENVISAT ASAR	
SAR Applications	
SAR Utilities	
SAR Wizards	
Complex to Detected C	GR DAVIS
Multilooking	the second se

9	Calibration	×
File Help		
I/O Parameters Proc	essing Parameters	
Polarisations:	VH VV	
Save as complex ou	tput	
Output gamma0 bar	ıd	
Output beta0 band		
the radar	backscattor	

Pixel values can be directly related to the radar backscatter

Run	Close
1000	

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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.



Radar / Geometric / Terrain Correction / Range Doppler Terrain Correction





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Terrain correction & Geocoding



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Data check







Automatic Processing with Graph





Automatic Processing with Graph – Calibration

d BNS		Graph Builder : GRD_Cal_TC.xml	×
File	Graphs		
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			v
Re	ad Apply-Orbit-File	Calibration Terrain-Correction Write	>
Se N	ource Product ame: GIB_IW_GRDH_1SDV	_20191024T222028_20191024T222054_018623_023167_3C35 V	
C	Data Format: An	y Format 🗸	
		Load Save 🏷 Clear 📝 Note 🕢 Help 🕞 Run	

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

The same settings like in manual processing

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save as GRD_Cal_TC.xml

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Batch processing





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Batch processing



File Graphs

	eters Apply-Orbit-	File Calibration	Terrain-Correction	Write		
File Name		Туре	Acquisition	Track	Orbit	÷
Subset_S1A	_IW_GRDH_1SD	GRD	03Oct2015	47	7994	
Subset_S1A	_IW_GRDH_1SD	GRD	11Jun2016	47	11669	
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Subset_S1B	IW_GRDH_1SD	GRD	10Nov2018	47	13548	
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File Graphs I/O Parameters Apply-Orbit-File Calibration Terrain-Correction Write ╬ File Name Acquisition Track Orbit Type 4 Subset S1A IW GRDH 1SD... GRD 03Oct2015 47 7994 Subset_S1A_IW_GRDH_1SD... GRD 11Jun2016 47 11669 Subset_S1B_IW_GRDH_1SD... GRD 15Nov2017 47 8298 Subset S1B IW GRDH 1SD... GRD 10Nov2018 47 13548 * Subset S1B IW GRDH 1SD... GRD 47 18273 30Sep2019 V ⊻ B ٩, 5 Products Target Folder Save as: BEAM-DIMAP v Directory: D:\DRAGON2019\Final Dataset\GRD_processed Skip existing target files 🗸 Keep source product name Close Run remote Load Graph Run Help

Open previously saved graph GRD_Cal_TC.xml

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Time series analysis





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Add your data products



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Time series analysis

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data products —	S1B_IW_GRDH_1SDV_20
	S1B_IW_GRDH_1SDV_20
	S1B_IW_GRDH_1SDV_20
	S1B_IW_GRDH_1SDV_20
	S Products Rename
	Apply Close



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Time series analysis



One of the plottet bands has to be opened

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Creating multitemporal stack

Radar Tools Windo	w <u>H</u> elp	
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Polarimetric	DEM-Assisted Coregistrati	ion 🕨
Geometric	Stack Tools	Create Stack
Sentinel-1 TOPS	Cross InSAR resampling	Stack Averaging
ENVISAT ASAR	•	Stack Split
SAR Applications	•	
SAR Utilities	•	
SAR Wizards		
Complex to Detected Multilooking	GR	

Collocating spatially overlapping images

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



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Multitemporal speckle filtering

Radar Tools Windo	w <u>H</u> elp		E 1 111	
Apply Orbit File Radiometric	, φ,λ 🔝 🛞 😥 Μ. Ι		File Help	
Speckle Filtering	Single Product Speckle Filter	I/O Parameters Processing Parameters	I/O Parameters Processing Par	ameters
Coregistration Interferometric Polarimetric Geometric Sentinel-1 TOPS ENVISAT ASAR SAR Applications SAR Utilities SAR Wizards Complex to Detected Multilooking	GR Hulti-temporal Speckle Filter	Source Product source: [6] backscatter_Stack Target Product Name: backscatter_Stack_Spk Save as: BEAM-DIMAP Directory: D:\pRAGON2019\Final Dataset\GRD_processed Open in SNAP	Source Bands: Filter: Filter Size X (odd number): Filter Size Y (odd number): Estimate Equivalent Number of L Number of Looks:	Sigma0_VH_mst_03Oct2015 Sigma0_VV_mst_03Oct2015 Sigma0_VV_slv1_11Jun2016 Sigma0_VV_slv2_11Jun2016 Sigma0_VV_slv3_15Nov2017 Sigma0_VV_slv4_15Nov2017 Sigma0_VV_slv6_10Nov2018 Sigma0_VV_slv6_10Nov2018 Samma Map 3 3 1.0
		Run Close		Run Close

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



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Multitemporal speckle filtering





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Conversion from linear to dB

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Conversion from linear to dB





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Linear vs dB comparison



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Visual inspection of the time series



Q - Search (Ctrl+I)

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RGB Composite





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RGB Composite





2019 ADVANCED INTERNATIONAL TRAINING COURSE IN LAND REMOTE SENSING 18–23 November 2019 | Chongging, P.R. China Red – high backscatter in 2015, low backscatter in 2019 Cyan – low backscatter in 2015, high in 2019



Stack averaging



Apply Orbit File Radiometric Speckle Filtering	*	р.л 🗼 🕼 🕼	1	Σ
Coregistration	•	Coregistration		Ţ
Interferometric	•	S1 TOPS Coregistration		
Polarimetric		DEM-Assisted Coregistration	1 1	
Geometric	- > [Stack Tools		Create Stack
Sentinel-1 TOPS	•	Cross InSAR resampling		Stack Averaging
ENVISAT ASAR	• •]			Stack Split
SAR Applications	•			
SAR Utilities				
SAR Wizards				
Complex to Detected Multilooking	GR			





Stack averaging – RGB Composite



RGB combination for land cover classification

Dual Po	l Ratio Sigma0 VV+VH	
Red:	Sigma0_VV	•
Green:	Sigma0_VH	•
Blue:	Sigma0_VV/Sigma0_VH	•



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Part 1

Multitemporal Analysis using SAR Coherence-Intensity composites



Objectives



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







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



<u>Terrain</u> <u>O</u>bservation by <u>P</u>rogressive <u>S</u>cans (TOPS)

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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

S-1 TOPS Split		
File Help	I/O Parameters Processing Parameters	
I/O Parameters Processing Parameters Source Product source: [1] S1A_IW_SLC_1SDV_20190819T055015_20190819T055043_028634_033D5F_B955 v Target Product Name: S1A_IW_SLC_1SDV_20190819T055015_20190819T055043_028634_033D5F_B955_split S1A_IW_SLC_1SDV_20190819T055015_20190819T055043_028634_033D5F_B955_split Save as: BEAM-DIMAP v Directory: C:\LTC2019_demos\Output_cal_TC Open in SNAP	Subswath: IW1 Polarisations: VH Bursts: 2 to 5 (max number of bursts: 9)	 Selection of subswath Selection of polarization Selection of bursts IW1 VV 2-5
Dum Class	Run Close	
Run Close		

TOPS Split applied to both S-1 SLCs

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STEP 1 Interferometric Coherence



Coregistration



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Coregistered bands in one product

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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

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

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

Rada	r Tools Window Help								
	Apply Orbit File								
	Radiometric	>							
	Speckle Filtering	>	IW3_VV_mst_19Aug2019 >	< 🔳 [3] Intensity_IW3_VV_slv1_31Aug2019 ×				
	Coregistration	>							
	Interferometric	>	Products	>	Interferogram Formation				
	Polarimetric	>	Filtering	>	Coherence Estimation				
	Geometric	>	Unwrapping	>	Topographic Phase Removal				
	Sentinel-1 TOPS	>	PSI\SBAS	>	Three-pass Differential InSAR				
	ENVISAT ASAR	>	InSAR Stack Overvie	N	Phase to Height				
	SAR Applications	>			Phase to Displacement				
	SAR Utilities	>			Phase to Displacement				
	SAR Wizards	>			Phase to Elevation				
	Complex to Detected GR				Integer Interferogram Combination				
	Multilooking								



Interferometric Coherence



Radar/Interferometric/Products/Coherence

Coherence Estimation	×
I/O Parameters Processing Parameters	2 million and a million and
Subtract flat-earth phase	
Degree of "Flat Earth" polynomial	5 🗸
Number of "Flat Earth" estimation points	501 🗸
Orbit interpolation degree	3 🗸
Subtract topographic phase	
Digital Elevation Model:	SRTM 3Sec (Auto Download) 🗸 🗸
Tile Extension [%]	100 ~
Square Pixel	Independent Window Sizes
Coherence Range Window Size	10
Coherence Azimuth Window Size	2



Demarcation black-filled line between bursts

Close

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S-1 TOPS Debursting



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

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O Parameters Processing Parameters	
Source Product source:	
Target Froduct Name: 5015_20190819T055043_028634_033D5F_B955_split_Or Seve as: BEAM-DIMAP Directory:	b_Stack_coh_deb_deb
C:\LTC2019_demos\Output SLC\backscatter_TC	
Open in SNAP	

Input: Coherence



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中欧科技合作"龙计划"第四期 2019年陆地遥感高级培训班 培训时间:2019年11月18日-23日 主办方:重庆大学

Terrain Correction



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

+ Geocoding

Range Doppler Terrain Correct	ion	×	
File Help			
I/O Parameters Processing Parame	ters	_	
Source Bands:	coh_IW3_VV_19Aug2019_31Aug2019		
			Select
			> Resampling
Digital Elevation Model:	SRTM 3Sec (Auto Download) 🗸 🗸		
DEM Resampling Method:	BILINEAR_INTERPOLATION ~		
Image Resampling Method:	BILINEAR_INTERPOLATION ~		Projection
Source GR Pixel Spacings (az x rg):	13.86(m) x 3.37(m)		-
Pixel Spacing (m):	13.86		
Maa Drejection	1.2450649837896568E-4		
Map Projection:	WGS84(DD)	\mathbf{H}	
Mask out areas without elevation	n 🗌 Output complex data		
Output bands for:			Pixel spacing
Selected source band	DEM Latitude & Longitude		20m
Incidence angle from ellipsoid	Local incidence angle Projected local incidence angle		20111
Apply radiometric normalization			
Save Sigma0 band	Use projected local incidence angle from DEM $\qquad \bigtriangledown$		
Save Gamma0 band	Use projected local incidence angle from DEM 🛛 🗸		
Save Beta0 band			
Auxiliary File (ASAR only):	Latest Auxiliary File		
	Run Close		

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STEP 2 Backscatter Intensity



Backscatter Intensity product



MENU: Graph Builder + Batch processing tool

File Graphs
Read Apply-Orbit-File Calibration TOPSAR-Deburst Terrain-Correction Write
<
Read Apply-Orbit-File Calibration TOPSAR-Deburst Terrain-Correction Write
Source Product
[6] Coherence_intensity_Stack v
Data Format: Any Format 🗸
Load 🔉 Save 🔪 Clear 🖉 Note 🔞 Help 🕞 Run

Input: Two <u>splitted</u> SLCs

I/O Parameters Ap	ply-Orbit-File	Calibration	TOPSAR-Deburst	Terrain-Correction	Write	
File Name	Т	/pe	Acquisition	Track	Orbit	÷
S1A_IW_SLC1SDV	_20151 SL	C	03Oct2015	47	7994	
S1B_IW_SLC1SDV	_20171 SL	C	15Nov2017	47	8298	
						2 Products
Target Folder						
Save as: BEAM-DI	MAP	~				
Directory:						
D:\DRAGON2019\F	inal Dataset	SLC_processed	l\backscatter_inte	nsity		
Skip existing ta	rget files 🔽	Keep source p	roduct name			
		Ru	n remote	oad Graph Ru	n Close	Help

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File Graphs

Creating a stack



Radar Tools Window Help Apply Orbit File \Rightarrow +7 Radiometric 5 VV_19Aug2019_31Aug2019 × Speckle Filtering 3 Coregistration > Coregistration Interferometric > S1 TOPS Coregistration Polarimetric 5 **DEM-Assisted Coregistration** Geometric Stack Tools > Create Stack Sentinel-1 TOPS Cross InSAR resampling Stack Averaging ENVISAT ASAR Stack Split SAR Applications SAR Utilities SAR Wizards Complex to Detected GR Multilooking

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

1-ProductSet-Reader 2-Create	Stack 3-Wri	ite					
File Name	Type	Acquisition	Track	Orbit	<u>~</u>		
S1A IW SLC 1SDV 2015100	. SLC	03Oct2015	47	7994			
S1B_IW_SLC1SDV_2017111	. SLC 🗡	15Nov2017	47	8298			
SLC_Stack_coh_deb_TC	SLC	03Oct2015	47	7994			
	й В С С	1-ProductSet-Reader 2-4 laster: tesampling Type: initial Offset Method: Dutput Extents: Find Optimal Master	CreateStack 3-Write SIA_JW_SIC1SDV_2 NONE Product Geolocation Master	0151003T222043_201	71115_coregistered_coh_deb	_ML_TC	
					Help 🕞 Run		



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



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Band math: average sigma 0 and difference

Raster	Optical Radar Tools	Window Help
B	and Maths	
F	iltered Band	
C	onvert Band	
р	ropagate Uncertainty	
G	ieo-Coding Displacemen	t Bands
S	ubset	
D	EM Tools	>
G	eometric Operations	>
N	lasks	>
D	lata Conversion	>
Ir	mage Analysis	>
C	lassification	>
S	egmentation	>
E	xport	>

Target product:				
[10] Stack				~
Name:	diff_sigma			
Description:				
Unit:				
Spectral wavelength	: 0.0			
Virtual (save exp	pression only, don't s	tore data)		
Replace NaN an	d infinity results by			Nal
Generate associ	ated uncertainty ban	d		
Band maths express	ion:			
Sigma0_IW3_VV_slv	2_31Aug2019			
Load S	ave		Edit Expression	

Sigma0 difference

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roduct: [18] Stack_intensity_coherence		
lata sources:		Expression:
\$18.Sigma0_IW1_VV_db_mst_03Oct2015	0 + 0	\$18.Sigma0_IW1_VV2 - \$18.Sigma0_IW1_VV
\$18.Sigma0_IW1_VV_db_slv1_15Nov2017	8 - 8	
\$18.coh_IW1_VV_03Oct2015_15Nov2017_s1v2_03Oct2015		
\$18.Sigma0_IW1_VV	6 * 6	
\$18.Sigma0_IW1_VV2	0 / 0	
	(@)	
	Constants	~
Show bands	Operators	~
Show masks	Functions	·
Show tie-point grids		
Show single flags		Ok, no erro
		OK Cancel Help

Sigma0 average

Data sources:		Ex	Expression:						
\$18.Sigma0_IW1_VV_db_mst_03Oct2015	6 + 6	((\$18.Sigma0_IW1_VV+ \$18.Sigma0_IW1_VV2)/2						
\$18.Sigma0_IW1_VV_db_slv1_15Nov2017	0 - 0	ş							
\$18.coh_IW1_VV_03Oct2015_15Nov2017_slv2_03Oct2015	e e								
\$18.Sigma0_IW1_VV	0 * 0								
\$18.Sigma0_IW1_VV2	0 / 0								
	(@)								
	Constants	~							
Show bands	Operators	~							
Show masks	Functions	~							
Show tie-point grids		5	mm (1811 a						
Show single flags				2			Ok, no errors.		



Creating RGB false composite



Profile: Ikonos (modified)	Selec	t RGB-Image Channels X			
Ikonos (modified) Image: Second structure Red: \$10.coh_IW3_VV_19Aug2019_31Aug2019 Image: Second structure Green: \$10.average_sigma0 Image: Second structure Blue: \$10.diff_sigma0 Image: Second structure Expressions are valid Image: Store RGB channels as virtual bands in current product	Profile:				
Red: \$10.coh_IW3_VV_19Aug2019_31Aug2019 Green: \$10.average_sigma0 Blue: \$10.diff_sigma0 Expressions are valid Store RGB channels as virtual bands in current product	Ikonos	Ikonos (modified) - 🗸 📳 🏥			
Expressions are valid Store RGB channels as virtual bands in current product	Red: Green: Blue:	\$10.coh_IW3_VV_19Aug2019_31Aug2019 \$10.average_sigma0 \$10.diff_sigma0	R: G:		
Or Curce Prop	Stor	Expressions are valid re RGB channels as virtual bands in current product OK Cancel Help	D.		

Select RGB bands:

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R: coherence G: average sigma0 B: difference sigma0

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Right click on the stack productOpen 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

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