





# **TRAINING KIT – HAZA03**

# LAND SUBSIDENCE WITH SENTINEL-1 using SNAP









Research and User Support for Sentinel Core Products

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## **1** Introduction

The Research and User Support for Sentinel core products (RUS) service provides a free and open scalable platform in a powerful computing environment, hosting a suite of open source toolboxes pre-installed on virtual machines, to handle and process data derived from the Copernicus Sentinel satellites constellation. In this tutorial we will employ RUS to identify and map land subsidence in Mexico City using Sentinel-1 data.



Mexico City's buildings are seriously leaning due to land subsidence. Photo credit: JOSH HANER/THE NEW YORK TIMES (http://www.sciencemag.org)

Land subsidence in Mexico City caused by groundwater overexploitation over the last century has been more than 9 meters, resulting in damages to buildings, streets, sidewalks, sewers, storm water drains and other infrastructure [1]. Previous studies of SAR Interferometry using ERS data showed a maximum subsidence rate larger than 30 cm/year over parts of the city [2].

Due to the fact that the city is partially built on the area of a former lake (Lago Texcoco), it rests on the heavily saturated clay which is collapsing due to

the over-extraction of groundwater. Current subsidence rates using Sentinel-1 SAR data approximate 2.5 cm/month [3].

# 2 Training

Approximate duration of this training session is two hours.

The Training Code for this tutorial is HAZA03. If you wish to practice the exercise described below within the RUS Virtual Environment, register on the <u>RUS portal</u> and open a User Service request from Your RUS service  $\rightarrow$  Your dashboard.

#### 2.1 Data used

 Two Sentinel-1A images acquired on June 6, 2016 and September 10, 2016. [downloadable @ <u>https://scihub.copernicus.eu/</u>]

*S*1A\_*IW\_SLC\_\_1SSV\_20160606T122537\_20160606T122601\_011590\_011B5B\_E555.zip S*1A\_*IW\_SLC\_\_1SSV\_20160910T122542\_20160910T122606\_012990\_0148FA\_76D7.zip* 

Auxiliary data stored locally
 @/shared/Training/HAZA03\_LandSubsidence\_MexicoCity\_TutorialKit/AuxData

#### 2.2 Software in RUS environment

Internet browser, SNAP + Sentinel-1 Toolbox, (Extra steps: Google Earth)

# 3 Register to RUS Copernicus

To repeat the exercise using a RUS Copernicus Virtual Machine (VM), you will first have to register as a RUS user. For that, go to the RUS Copernicus website (<u>www.rus-copernicus.eu</u>) and click on *Login/Register* in the upper right corner.

CORRUS Research and User Support	lagin/Register 🔒
The RUS Service The RUS Offer The RUS Library The RUS Community	
	Search
	News from RUS
	One year on!
	Copernicus Info Session – Reykjavik – 19 September 2018
	SPIE Remote Sensing 2018 – Berlin (Germany) – 11-12 September 2018
	SIWI World Water Week 2018 – Stockholm – 26-31 August 2018
	MedRIN Kick-off Meeting – Chania – 13 & 14 July 2018
	RUS Webinar – Special edition "AskRUS – Sentinel-1" – 12 July 2018
<ul> <li>Welcome to Research and User Support</li> </ul>	RUS Training Session - Valencia - 22 July 2018
	IGARSS 2018 - Valencia - 22-27 July 2018
Welcome to the Copernicus Research and User Support (RUS) Service portal!	▼ The RUS agenda
The RUS Service is the "New Expert Service for Sentinel Users" funded by the European Commission,	Conferences & Workshops

Select the option *Create my Copernicus SSO account* and then fill in ALL the fields on the **Copernicus Users' Single Sign On Registration**. Click *Register*.



Within a few minutes you will receive an e-mail with activation link. Follow the instructions in the email to activate your account.

You can now return to <u>https://rus-copernicus.eu/</u>, click on *Login/Register*, choose *Login* and enter your chosen credentials.

Login / Register	Credentials			_
The registration system to access the RUS service platform has moved toward the COPERNICUS Single Sign On authentication server. • New Users who have not yet registered to the RUS portal shall first create a COPERNICUS SSO account.	CDS-SSO ID Password			0
Note that your Copernicus SSO account will be activated only after the reception of the third email sent by the Copernicus service. We advise you to consult this document and this page to facilitate your registration procedure.	Max Idle Time	half a day	Ŧ	0
REGISTER COPERNICUS SSO account	Max Session Time	Until browser close	Ŧ	0
Users who already have a COPERNICUS SSO account can login here:		Login		]
Close		Forgot your password?		

Upon your first login you will need to enter some details. You must fill all the fields.

The RUS Service = The RUS C	Do you want to	o subscribe for a new RUS account?		
Your ESA	-SSO subscription	datac		
Your RUS service Login				Q 1
This section gathers pages related to ye First Nam	e.			
Your profile displays your person     Last Name	e	Contraction of Contra		US
Email		and the second se		Bit Forum - Stratpolurg - 28 & 29 Nov.
Your dashboard allows you to ac     Organizat	tion			
Your training allows you to regist     Country				
	Additio	nal subscription information		
	mplete the following			
Where did RUS servit	d you hear about the	outreach event colleagues	- 1	
Select one		newsletter	_	
		conference social media		
		other	~	
Institution		Select one item	~	nda
Phone nur Italy (IT):	mber	+39		
Title		Select one Item	v	

### 4 Request a RUS Copernicus Virtual Machine

Once you are registered as a RUS user, you can request a RUS Virtual Machine to repeat this exercise or work on your own projects using Copernicus data. For that, log in and click on **Your RUS Service** → **Your Dashboard**.

CORRUS Research and User Support	
	Hello, Miguel 😩
	/our RUS service >
	Your profile You are here: Home > Your RUS service
✓ Your RUS service	four dashboard earch
This section gathers pages related to your RUS services:	/our training
Your profile: displays your personal information linked to your ESA SSO and RUS accounts,	<ul> <li>News from RUS</li> </ul>
	One year on!
<ul> <li>Your dashboard: Illows you to access your private dashboard,</li> </ul>	Copernicus Info Session – Reykjavik – 19 September 2018
• Your training: allows you to register to a training session you have been invited to participate	Pin. SPIE Remote Sensing 2018 - Berlin (Germany) - 11-12 September 2018
	SIWI World Water Week 2018 – Stockholm – 26-31 August 2018
	MedRIN Kick-off Meeting - Chania - 13 & 14 July 2018
	RUS Webinar – Special edition "AskRUS – Sentinel-1" – 12 July 2018
	RUS Training Session - Valencia - 22 July 2018
	IGARSS 2018 - Valencia - 22-27 July 2018

Click on *Request a new User Service* to request your RUS Virtual Machine. Complete the form so that the appropriate cloud environment can be assigned according to your needs.

CORRUS Research and User Support	Hello, Miguel
The RUS Service The RUS Offer The RUS Library The RUS Community Your RUS Service Y	You are here: <b>Home &gt; Your RUS service &gt;</b> Your dashboard
★ Your dashboard	
Request a new User Service	Chat with Support Desk
Copyright © 2017 Research and User Support	Conlact Us Terms and conditions Glassary Acronyms FAQ

If you want to repeat this tutorial (or any previous one) select the one(s) of your interest in the appropriate field.

Step 1/3 Your experience	
Please help us learn more about your background by answeri information will be stored in your User Profile.	ing a few questions. Th
How many years of experience in Remote Sensing do you have?	
Choose one Item	•
Have you already downloaded Copernicus data via the Copernicus Open	access hubs?
® Yes	
© No.	
Have you already handled/processed Copernicus data?	
W Yes	
© No-	
Do you wish to practice a tutorial exercise shown in a RUS webinar? If yes (hold down CTRL key for multiple selections).	s, please select your choice
HAZA01 - Flood Mapping in Malawi	
HAZA02 - Burned Area Mapping in Portugal HYDR01 - Water Bodies Mapping over Northern Poland	
LAND01 - Crop Mapping in Seville	
LAND04 - Land Monitoring in Cyprus OCEA01 - Ship Detection in Guit of Trieste	*
If you wish to request another tutorial exercise that doesn't appear in the	above list, please type here
its name or code. Note that you can request multiple tutorial exercises.	

Complete the remaining steps, check the terms and conditions of the RUS Service and submit your request once you are finished.

Summary information on your request:		
This is a collection of information selected		
You can go back and edit this information	if necessary.	
General information on your request:		
Years of experience in Remote Sensing	5-10 years	
Downloaded Copernicus data?	1	
Handled/processed Copernicus data?	1	
Webinar codes	HAZA02, LAND04	
About your RUS project:		
Thematic area	Cryosphere (ice and snow)	
Operations to perform on RUS	Algorithm development	
Preference for downloading process	Self-downloading	
Foreseen activities and support needs	Develop a land cover classification	
Project name	RUS_Project1	
Earth Observation Data information:		
Type of Earth Observation Data:		
Sentinel-1	V	
	S1-Product 1	
S1 - Product type	GRD	
S1 - Sensor mode		
S1 - Polarisation	a	
S1 - Orbit direction	1.1.4	
Sentinel-2	x	
Sentinel-3	X	
Other	x	
I don't know	×	
Region of Interest: Min Latitude	39.3303	
Max Latitude	40.5877	
Min Longitude	-4.6736	
Max Longitude	-2.7205	
Reference polygons		
Data acquisition date(s):		
None		
Additional data specifications		
I have read and agree to the Terms and	conditions of RUS Service.	

Further to the acceptance of your request by the RUS Helpdesk, you will receive a notification email with all the details about your Virtual Machine. To access it, go to **Your RUS Service** → **Your Dashboard** and click on **Access my Virtual Machine**.

							You are here: Home >	Your RUS service > Your dash
Your dashboard								
Request a new L	lser Servio	ce						Chat with Support Desk
Project Name	ID	Date of submission	Status		Actions		Virtual	Environment
	200			Follow my project	Get support	Close my service	Access my Virtual Machine(s)	Access my CPU monitoring dashboard
RUS_training1	231	2017-08-31	Open		Get a webinar kit	Rate my service	Freeze my Virtual Machine(s)	Report a technical incident

Fill in the login credentials that have been provided to you by the RUS Helpdesk via email to access your RUS Copernicus Virtual Machine.



This is the remote desktop of your Virtual Machine.

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(Albume	Documentois Ou			erar cui	C Jupytar Notebook	alontevere!
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		opernicus				

## 5 Step by step

#### 5.1 Data download – ESA SciHUB

In this step we will download two Sentinel-1 scenes from the Copernicus Open Access Hub using the online interface (Applications  $\rightarrow$  Network  $\rightarrow$  Firefox Web Browser or click the link below).

Go to <a href="https://scihub.copernicus.eu/">https://scihub.copernicus.eu/</a>



Go to "**Open HUB**", if you do not have an account please register by going to "**Sign-up**" in the LOGIN menu in the upper right corner.

	Co	pernicus Open Access Hub		
Time to search oriteria.	Remeries Remeri	A second	Allowing and a state of the sta	Access our es
	i - P	Copernicus Open Access Hub		201
		Register new account	199	
	Sentinel data access is free and open to all.			

Usemane field accepts only lowercase alphanumenc characters plus ",", "," and "," Password field accepts only aphanumenc characters plus "," $[0]$ " $w$ ", $[0]$	$\Theta_{ij}$ , $\omega_{ij}$ , $Q_{ij}$ , $\omega_{ij}$ , $\omega_{ij}$ , $M_{ij}$ , $\omega_{ij}$ , $\delta_{ij}$ ,		
Furstname	Lastnered		
Testuradi			
Pageoned	Chroline (Polywaied		
E-mail	(Caroliny) Borran		
Select Domain			
Sulect Usaga •	· · · · ·		
Select your country			
Falset Unaga			

After you have filled in the registration form, you will receive an activation link by e-mail. Once your account is activated or if you already have an account, "LOGIN".



Select the "Pan" icon in the lower left corner of the map and navigate over Mexico City.

Switch to "Box" icon and draw a search rectangle approximately as indicated above (approximate area – blue rectangle). Open the search menu ( $\equiv$ ) and specify the following parameters. Press the search button ( $\bigcirc$ ) after that.

Sensing period: From 2016/06/06 to 2016/06/06 Check Mission: Sentinel-1A Satellite Platform: S1A\_\* Product Type: SLC Sensor Mode: IW





In our case the search returns 1 result depending on the exact search area defined. Download the scene:

S1A\_IW\_SLC\_\_1SSV\_20160606T122537\_20160606T122601\_011590\_011B5B\_E555

Repeat the steps for the second image September 10, 2016, by changing accordingly the sensing period range. Download the scene:

S1A\_IW\_SLC\_\_1SSV\_20160910T122542\_20160910T122606\_012990\_0148FA\_76D7

Data will be downloaded to */home/rus/Downloads* as zip archives. Move the archives to: */shared/Training/HAZA03\_LandSubsidence\_MexicoCity\_TutorialKit/Original*.

#### 5.2 SNAP - open and explore data

Launch SNAP (icon on desktop ). When SNAP opens, click **Open product** , navigate to **/shared/ Training/HAZA03\_LandSubsidence\_MexicoCity\_TutorialKit/Original** and open the \*.zip files.

The opened products will appear in the **Product Explorer** window on the left. Expand the first image to the left and then expand **Bands**. Right-click on the "*Intensity\_IW3\_VV*" band and select **Open Image Window** to create and visualize the image of the band (or double-click on it). (See  $\square$  NOTE 1).



The image appears in the upper left corner of the view window. Repeat the same steps for the second product. To synchronize the views, go to **Navigation** tab in the lower left (red arrow) and make sure the cursor  $\boxed{2}$  and the views  $\boxed{3}$  are linked.

NOTE 1: The Interferometric (IW) swath mode Wide captures three sub-swaths using Terrain Observation with SAR Progressive Scans (TOPSAR). Each sub-swath image consists of a series of bursts. The input product contains 3 IW bands, and 8 bursts. Mexico City is located on the IW3 sub-swath of the Sentinel-1 images.



Credits: ESA User Guides for Sentinel-1 SAR

#### 5.3 Pre-processing

Since the area of interest is included in 3 bursts of the Sentinel-1 image, there is no need to process the whole sub-swath with the 8 bursts (See  $\square$  NOTE 2). The extraction of Sentinel-1 TOPS bursts will be made per acquisition and per sub-swath. This process will reduce the processing time in the following processing steps and is recommended when the analysis is focused only over a specific area and not the complete scene. Go to Radar  $\rightarrow$  Sentinel-1 TOPS  $\rightarrow$  S-1 TOPS Split.



Now, let's set the parameters. In the source product select the opened image:

S1A\_IW\_SLC\_\_1SSV\_20160606T122537\_20160606T122601\_011590\_011B5B\_E555.zip

Then, define the output directory in:

/shared/Training/HAZA03\_LandSubsidence\_MexicoCity\_TutorialKit/Processing.

In the **I/O Parameters** tab, leave the default output name for the target product name. The system inserts automatically the suffix of the split process in order to discriminate the split product from the original data.

	S-1 TOPS Split	- E >
le Help		-
I/O Parameters	Processing Parameters	
Source Product		
[1] SIA_IW_SLC_	_1SSV_20160606T122537_20160606T122601_011590_011B5B_E555	<b>*</b> 100
Target Product Name:		
SIA_IW_SLC_15	SV_20160606T122537_20160606T122601_011590_011B5B_E555_split	
Save as: BE	AM-DIMAP	
Directory //shared/Train	ing/HAZA03_LandSubsiderice_MexicoCity_TutorialKit/Processing	1
Dpen in SNA	2	
		1
	Bun	Close

In the **Processing Parameters** tab, select the following parameters:

Subswath: IW3 Polarisations: VV Bursts: 3 to 5

In **Bursts** selection click on the arrows and drag up to the specified number of bursts. Then click **RUN**.

	S-1 TOPS Split	+ = ×
File Help		
I/O Parame	ters Processing Parameters	
Subswath:	IW3	-
Polarisation	s.w	
Bursts:	3 to 5 (max number of hursts: 8)	
		<u>R</u> un <u>C</u> lose

Repeat the split process for the second Sentinel-1 image using same processing parameters:

#### S1A\_IW\_SLC\_\_1SSV\_20160910T122542\_20160910T122606\_012990\_0148FA\_76D7

NOTE 2: The extraction of bursts in a sub-swath covering the area of interest may differ in Sentinel-1 images acquired on different dates.

#### 5.4 Graph Builder

Although data processing could follow a manual step-by-step process, **Graph Builder** tool available in SNAP allows the automatic processing of the images.

R	SHEP	F = 2 X
Ele Edit View Analysis Layer Vector Raster Optical Radar Tools )	Vindow Rein	Q.
📾 😼 🦻 🦉 🔏 👪 📕 🗩 🔍 🔅	Graph Builder	
Product Explorer × Pixel Info		
<ul> <li></li></ul>	Read Write Hight click here to add an operator	To brance through the second sec
×		
Navigation × Colour Manipu. Uncertainty VI. World View	Read Write	
e.	- Source Product Name	Contraction of the second s
e.	[3] SIA_IW_SLC_155V_201606067122537_201606067122601_011590_011858_E555_split	
	Data Format: Any Format 💌	
1:715 ••• ••• ••• •••	🖆 Load 🛛 📚 Sever 💊 Clear 😨 Note 🕢 Help. 🕞 Run	
		X - Y Lat - Lon Zoom Level 🧿

The **Graph Builder** tool allows the user to assemble graphs from a list of available operators and connect operator nodes to their sources. Therefore, the processing chain we will follow, will be represented by a graph and saved as an **XML** file.

In order to add **Graph Builder** tool, go to **Tools** → **GraphBuilder**.

Initially, the graph has two operators: **Read** (to read the input) and **Write** (to write the output) (See NOTE 3). With right-click on the top panel you can add an operator, while a corresponding tab is created and added on the bottom panel.

Since pre-processing split process has preceded, in the **Read** tab select the name of the split product:

<b>S1A</b>	IW SLC	1SSV	20160606T122537	20160606T122601_	011590	011B5B	E555 sı	olit.dim.

[3] S1A_IW_SLC_1SSV_20160606T122537_2010	50606T122601_011590_011858_E555_split
Jata Format	
Aig romat	

NOTE 3: In case split process is already applied, input image in the Read tab will be the splitted product of the Sentinel-1 image.

Before adding the rest operators, **delete** the **Write** operator (right-click on it  $\rightarrow$  Delete) to avoid confusion in the sequence of the graph and we will add it at the end.

#### 5.5 Co-registration

The first processing step is to apply the orbit files in Sentinel-1 products in order to provide accurate satellite position and velocity information. To add the operator right-click on the top panel to the right of the existing operator and go to Add  $\rightarrow$  Radar  $\rightarrow$  Apply-Orbit-File.

A new operator rectangle appears in our graph and a new tab appears below. Now connect the new **Apply-Orbit-File** operator with the **Read** operator by clicking to the right side of the **Read** operator and dragging the red arrow towards the **Apply-Orbit-File** operator.

Read		Apply-Orbit-File
	12	

In the Apply-Orbit File tab select the parameters:

**Orbit State Vectors**: Sentinel Precise (Auto Download) **Check** "Do not fail if new orbit file is not found"

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

Now, we have to repeat the same steps for the second image. First we need to add a new **Read(2)** operator. Right-click and go to Add  $\rightarrow$  Input-Output  $\rightarrow$  Read. In the Read(2) tab, select the split product:

S1A\_IW\_SLC\_\_1SSV\_20160910T122542\_20160910T122606\_012990\_0148FA\_76D7\_split.dim

Then, go to  $Add \rightarrow Radar \rightarrow Apply-Orbit-File$  and select the same parameters as in the first product and then connect the Apply-Orbit-File(2) to the Read(2) operator.

Read Apply-Orbit-File
Back-Geocoding Enhanced-Spectral-Diversity Interferogram TOPSAR-Deburst Write
Read(2) Apply-Orbit-File(2)

Next step will be to co-register the two Sentinel-1 images. For this reason the second image (slave) will be co-registered with respect to the first image (master). **Sentinel-1 Back Geocoding** operator co-registers two S-1 split products (master and slave) of the same sub-swath using the orbits of the two products and a Digital Elevation Model (DEM).

Rght-clicking right of the Apply-Orbit-File operator and go to Add  $\rightarrow$  Radar  $\rightarrow$  Coregistration  $\rightarrow$  S-1 TOPS Coregistration  $\rightarrow$  Back-Geocoding. Connect the Back-Geocoding operator with the Apply-Orbit-File operators.



In the **Back-Geocoding** tab use default parameters, but also **check** "Output Deramp and Demod Phase" option (See NOTE 4).



In this step, **Enhanced Spectral Diversity (ESD)** operator follows **Back-Geocoding**. The ESD approach exploits the data at the overlapped area of the adjacent bursts, and then performs range and azimuth correction for every burst. In the same manner, go to Add  $\rightarrow$  Radar  $\rightarrow$  Coregistration  $\rightarrow$  S-1 TOPS Coregistration  $\rightarrow$  Enhanced-Spectral-Diversity and then connect ESD and Back-Geocoding operators.

		_
Read(2) Apply-Orbit-File(2)	Spectral-Diversity Interferagram TOPSAR-Deburst	> Write

In the Enhanced-Spectral-Diversity tab use the default parameters.

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:		10
Use user supplied shifts (please enter th	em below)	
The overall azimuth shift in pixels:		0.0
The overall range shift in pixels.		0.0
E Load 3	Save Save Clear 📝 Note 🔞 Help 🕞 Run	

#### 5.6 Interferometric Processing

At this stage, we will produce an Interferogram between the interferometric pair (master and slave), while a coherence image estimation from the stack of the coregistered complex images is included. To add the Interferogram operator go to Add  $\rightarrow$  Radar  $\rightarrow$  Interferometric  $\rightarrow$  Products  $\rightarrow$  Interferogram add then connect the Interferogram operator to Enhanced-Spectral-Diversity operator.

ead Apply-Orbit-File Back-Geocoding Enhanced-Spectral-Diversity Interferogram TOPSAR-Deburst Write	
ad(2) Apply-Orbit-File(2)	

In the Interferogram tab set the following parameters:

#### Coherence Range Window Size: 20 Coherence Azimuth Window Size: 5

Read Apply-Orbit-File Read(2)	Apply-Orbit-File(2)	Back-Geocoding	Enhanced-Spectral-Diversity	Interferogram
Subtract flat-earth phase				
Degree of "Flat Earth" polynomial	5			
Number of "Flat Earth" estimation po	nts 501			-
Orbit interpolation degree	3			-
🔲 Subtract topographic phase				
Digital Elevation Model:	and the second			
Tile Extension [%]				
Dutput Elevation				
Output Orthorectified LatiLon				
Include coherence estimation				
Square Pixel	🔲 Independent Win	dow Sizes		
Coherence Range Window Size	20			
Coherence Azimuth Window Size	5			

We continue the processing steps with Sentinel-1 TOPSAR Deburst. We have seen that each subswath 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. There is sufficient overlap between adjacent bursts and between sub-swaths to ensure the continuous 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.

To add **TOPSAR-Deburst** operator, go to **Add**  $\rightarrow$  **Radar**  $\rightarrow$  **Sentinel-1 TOPS**  $\rightarrow$  **TOPSAR-Deburst**.



In the TOPSAR-Deburst tab select Polarizations: VV.



Finally add the Write operator, go to Add  $\rightarrow$  Input-Output  $\rightarrow$  Write and connect it with the TOPSAR-Deburst operator. in the Write tab define the output directory as:

/shared/Training/HAZA03\_LandSubsidence\_MexicoCity\_TutorialKit/Processing

Set the name of the output product as: **S1A\_20160606\_S1A\_20160910\_Split\_Orb\_Coregi\_ESD\_Ifg\_Deb** 

Back-Geocoding	Enhanced-Spectral-Diversity	Interferogram	TOPSAR-Deburst	Write	al
Target Product					
Name:					
Name:	1A 20160910 split Orb Coregi	ESD IFA Dab			
		Lab ing beb			
Save as: BEAM-D	IMAP 🔻				
Directory:					
/shared/Traini	ng/HAZA03_LandSubsidence_Me	exicoCity_TutorialK	it/Processing		
	1	1		1	
Ē	Load 💽 Save 🍾	Clear No	ote 🕢 Help	D Run	

At this moment, save the graph as *Graph\_process\_1.xml* in */shared/Training/HAZA03\_Land Subsidence\_MexicoCity\_TutorialKit/Processing* by clicking **Save** at the bottom of the window.

Then click **Run.** The new product will appear in the **Product Explorer** window. *This might take approximately 40 minutes depending on your machine.* 



Now open a new **Graph Builder** window to create a new graph for the next processing steps. In the **Read** operator define as input name the previously produced interferogram:

S1A\_20160606\_S1A\_20160910\_Split\_Orb\_Coregi\_ESD\_Ifg\_Deb

Read Source Product	
Name:	
S1A_20160606_S1A_20160910_Split_Orb_Coregi_ESD_lfg_Deb	7

The next step is to remove the topographic induced phase from the debursted interferogram. To do so, we have to add the **TopoPhaseRemoval** operator. Go to **Add**  $\rightarrow$  **Radar**  $\rightarrow$  **Interferometric**  $\rightarrow$  **Products**  $\rightarrow$  **TopoPhaseRemoval**, keep the default parameters, and **select** the "Output topographic phase band" option.

Read	TopoPhaseRemoval Multilook GoldsteinPhaseFiltering SinaphuExport	Write
Read TopoPhaseRem	toval	
Orbit Interpolation Degree	er [3	
Digital Elevation Model:	SRTM 3Sec (Auto Download)	
Tile Extension [%]	100	
	Output topographic phase band	
	Output elevation band	
	Output orthorectified Lat/Lon hands	

As the original SAR image contains inherent speckle noise, multilook processing is applied at this moment to reduce the speckle appearance and to improve the image interpretability. To add the **Multilook** operator go to Add  $\rightarrow$  Radar  $\rightarrow$  Multilook.

> Multilook	GoldsteinPhaseFiltering	> Write
	SnaphuExport	

In the **Multilook** tab set the following parameters:

# Number of Range Looks: 8

#### Number of Azimuth Looks: 2

Source Bands:	i_ifg_VV_06jun2016_10Sep2016 q_ifg_VV_06jun2016_10Sep2016 Intensity_ifg_VV_06jun2016_10Sep2016_ifg_srd_VV_06jun2016_10Sep2016 Phase_ifg_srd_VV_06jun2016_10Sep2016 topo_phase_VV_06jun2016_10Sep2016 coh_iW3_VV_06jun2016_10Sep2016
GR Square Pixel	I Independent Looks
Number of Range Looks:	8
Number of Azimuth Looks:	2
Mean GR Square Pixel:	27.337015
Output Intensity	
	Note: Detection for complex data is done without resampling.

At this stage we will perform phase filtering of the interferogram in order to reduce phase noise e.g., for visualization or to aid the phase unwrapping which will be shown in the next step. The filtering method we will implement in this operator is *Goldstein method* proposed by Goldstein & Werner in 1998 [4]. To add the **GoldsteinPhaseFiltering** operator go to Add  $\rightarrow$  Radar  $\rightarrow$  Interferometric  $\rightarrow$  Filtering  $\rightarrow$  GoldsteinPhaseFiltering. Connect it to the Multilook operator.

Read TopoPhaseRemoval	Multilook	GoldsteinPhaseFiltering	Write
		SnaphuExport	

In the GoldsteinPhaseFiltering tab set the parameters as defined below:

#### Adaptive Filter Exponent in (0,1]: 1.0 FFT Size: 128

Read TopoPhaseRe	moval Multilook GoldsteinPhaseFiltering	
Adaptive Filter Exponent	t in (0,1]:	1.0
FFT Size:	128	•
Window Size:	3	-
Use coherence mas	k	
Coherence Threshold in	1 [0,1]:	0.2

In this step we have to save the output, which is the multilooked and filtered differential interferogram. Add the Write operator by going to Add  $\rightarrow$  Input-Output  $\rightarrow$  Write and connect it with the GoldsteinPhaseFiltering operator.

Read	> TopoPhaseRemoval	> Multilook	SoldsteinPhaseFiltering	> Write
			SnaphuExport.	

In the Write tab define the output directory as:

#### /shared/Training/HAZA03\_LandSubsidence\_MexicoCity\_TutorialKit/Processing

Set the name of the output product as:

S1A\_20160606\_S1A\_20160910\_Split\_Orb\_Coregi\_ESD\_Ifg\_Deb\_DInSAR\_ML\_Flt (See 🛄 NOTE 5)

Read	TopoPhaseRemoval	Multilook	GoldsteinPhaseFiltering	Write	
Target	Product				
Name:					
rearris.					
	0160606_S1A_2016091	0_split_Orb_	Coregi_ESD_Ifg_Deb_DInSAI	ML_Flt	
S1A_20	0160606_S1A_2016091 s: BEAM-DIMAP	0_split_Orb_	Coregi_ESD_Ifg_Deb_DInSAI	L_ML_Flt	
SIA_20		1	Corégi_ESD_Ifg_Deb_DInSAI	_ML_Flt	

NOTE 5: For each new operator in the GraphBuilder a corresponding suffix is added in the output product name.

The final step in this processing part is to export the data for **SNAPHU** processing in order to apply phase unwrapping. For a general reference on phase unwrapping see Ghiglia and Pritt [5], Constantini [6]. To export data (bands) in the format compatible for SNAPHU processing, go to Add  $\rightarrow$  Radar  $\rightarrow$  Interferometric  $\rightarrow$  Unwrapping  $\rightarrow$  SnaphuExport and connect it with the GoldsteinPhaseFiltering operator as well.



In the **SnaphuExport** tab specify the full path to "Target folder" and save in */shared/Training/HAZA03\_LandSubsidence\_MexicoCity\_TutorialKit/Processing/SNAPHU*. In this case, you will have to create a folder with the File name "SNAPHU" in the processing folder. Also, set the parameters as indicated below (See NOTE 6):

Statistical-cost mode: DEFO Initial method: MCF Number of Tile Rows: 1 Number of Tile Columns: 1 Row Overlap: 0 Column Overlap: 0

In the Target Folder, the following path will be created: /shared/Training/HAZA03\_LandSubsidence \_MexicoCity\_TutorialKit/Processing/SNAPHU.

Target folder:	/shared/Training/HAZA03_LandSubs	sidence_MexicoCity_TutorialKit/Pro	cessing/SNAPHU			
Statistical-cost mode:	DEFO		-		Select	* .
Initial method:	MCF		-	Look In: Pro	essina	
Number of Tile Rows:			1	reserve The line		
Number of Tile Columns:			1	Backup_proce		
Number of Processors:			4	Preprocessed		
Row Overlap:			0			
Column Overlap:			0			
Tile Cost Threshold:			500			
				File Name: SN/	APHU_	
				Files of Type: A	l Files	•
E Loa	ad 🏝 Save 🗞 Clear	Note 🕜 Help	> Run			Select Cancel

At this moment, save the graph as *Graph\_process\_2.xml* in */shared/Training/HAZA03\_Land Subsidence\_MexicoCity\_TutorialKit/Processing* by clicking **Save** at the bottom of the window.

Then click Run. This will take approximately 2 minutes depending on your VM.

Now, we can close the **GraphBuilder** window. In the **Product Explorer** window, the new (multilooked) output product has been added. We can expand the **Bands** folder and select the *"Phase\_ifg\_VV\_06Jun2016\_10Sept2016"* band. In the **View** window we can see the output differential interferogram, where the phase is represented in the form of fringes (-pi, pi).



#### 5.7 Phase Unwrapping – Displacement Map

We are about to proceed with phase unwrapping via SNAPHU. Open a Linux terminal and navigate to:

cd /shared/Training/HAZA03\_Land\_Subsidence\_MexicoCity\_TutorialKit/Processing/SNAPHU/S1A\_20160606\_S1A\_20160910\_Split\_Orb\_Coregi\_ESD\_Ifg\_Deb\_DInSAR\_ML\_Flt

TIP: Write the first few letters of each folder name and click **Tab** to auto-complete. For example, "cd /sh" + **Tab**  $\rightarrow$  "cd /shared/"  $\rightarrow$  "cd /shared/Tr" + **Tab**  $\rightarrow$  "cd /shared/Tr" - "cd /s

Now, open configuration file "snaphu.conf" and copy the following command to call "snaphu": snaphu -f snaphu.conf Phase\_ifg\_VV\_06Jun2016\_10Sept2016.snaphu.img 2959

and paste it in the Terminal. Also, add the comment (#) before "LOGFILE". Proceed by executing the command. The results are stored in the above-mentioned folder.



Now, open a new **Graph Builder** window to create a new graph for the next processing steps. Now, add one more **Read** operator. Right click and go to **Add**  $\rightarrow$  **Input-Output**  $\rightarrow$  **Read**.

Read	
	Snaphulmport PhaseToDisplacement Write
Read(2)	

In the **Read** tab select the opened differential interferogram, saved in: shared/Training/HAZA03\_LandSubsidence\_MexicoCity\_TutorialKit/Processing: S1A\_20160606\_S1A\_20160910\_Split\_Orb\_Coregi\_ESD\_Ifg\_Deb\_DInSAR\_ML\_Flt

Source Name:	e Product				
S1A_2	0160606_5	1A_20160910_Spl	it_Orb_Coregi_ESD_Ifg_De	b_DINSAR_ML_FIt	•

In the Read(2) tab select the following: UnwPhase\_ifg\_VV\_06Jun2016\_10Sep2016.snaphu.hdr from the /shared/Training/HAZA03\_LandSubsidence\_MexicoCity\_TutorialKit/Processing/SNAPHU/S1A\_ 20160606\_S1A\_20160910\_Split\_Orb\_Coregi\_ESD\_Ifg\_Deb\_DInSAR\_ML\_Flt/ folder.

Source Product	
Name: UnwPhase ifg VV 06jun2016 10Sep2016.snaphu	<b>•</b>

The first step is to import the results from SNAPHU processing and to construct the interferometric product that contains the unwrapped phase band, and the metadata of the source interferometric product. Go to Add  $\rightarrow$  Radar  $\rightarrow$  Interferometric  $\rightarrow$  Unwrapping  $\rightarrow$  Snaphu Import and connect it with the two Read operators.

Read				
	Snaphulmport	PhaseToDisplacement	}{	Write
Read(2)				

In the **Snaphulmport** tab select the "Do NOT save Wrapped Interferogram in the target product" option.

Read Read(2	Snaphulmport	PhaseToDisplacement	Write	
Do NOT save	Wrapped interferog	ram in the target product		
-				

The second step is to convert the interferometric phase to displacement and to produce the displacement product. Go to Add  $\rightarrow$  Radar  $\rightarrow$  Interferometric  $\rightarrow$  Products  $\rightarrow$  PhaseToDisplacement and connect it with the Snaphulmport operator.

Read	
Snaphulmport	PhaseToDisplacement     Write
Read(2)	

In the **PhaseToDisplacement** tab there are no parameters to specify.

Finally, add the Write operator by going to Add  $\rightarrow$  Input-Output  $\rightarrow$  Write and connect it with the **PhaseToDisplacement** operator.

Read			06-	
Sn	aphulmport	PhaseToDispla	cement	> Write
Read(2)				

In the **Write** tab define the output unwrapped product as below:

**Name**: *S1A\_20160606\_S1A\_20160910\_Split\_Orb\_Coregi\_ESD\_Ifg\_Deb\_DInSAR\_ML\_Flt\_Unw\_Disp* **Directory**: /shared/Training/HAZA03\_LandSubsidence\_MexicoCity\_TutorialKit/Processing

Name: S1A_20160606_S1A_20160910_Split_Orb_Coregi_ESD_Ifg_Deb_DInSAR_ML_Fit_Unw_Disp Save as: BEAM-DIMAP	
ave as: BEAM-DIMAP	
Directory:	
/shared/Training/HAZA03_LandSubsidence_MexicoCity_TutorialKit/Processing	

Click Run.

In the **Product Explorer** window select the "displacement" band from the new opened product to open the displacement product in the view window.

3	SNAP	• = E ×
Elle Edit View Analysis Layer Vector Raster Optical Radar	ools Window Help	Q- Search (Crite))
a 🖣 🦻 🥐 🔏 👍 🕨 🔍		P <sub>+</sub> GCP ≈ ≈ ≈ ≈
Product Explorer × Pixel info	[1] displacement x	
<ul> <li></li></ul>	6_DINSAR_H	Product Library
	the second	Luyer Manager
Anvigation - [1]. Colour Mant. X Uncertainty Vis World View     Editor: @ Dasic O Stilders O Table		d wask Harager
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Min: Ma 0 1 0 1 Range from Pile Range from Data	· · · · · · · · · · · · · · · · · · ·	Terring
	X Y Lat Lon	Zoom Level 🧕

#### 5.8 Geocoding

Due to topographical variations of a scene and the tilt of the satellite sensor, distances can be distorted in the SAR images. Terrain corrections are intended to compensate for these distortions, so that the geometric representation of the image will be as close as possible to the real world. For geocoding the Sentinel-1 products we will use the **Range Doppler Terrain Correction** operator that implements the Range Doppler orthorectification method [7].

Go to Radar  $\rightarrow$  Geometric  $\rightarrow$  Terrain Correction  $\rightarrow$  Range-Doppler Terrain Correction.

In the I/O Parameters tab, set the following:

Input: S1A\_20160606\_S1A\_20160910\_ Split\_Orb\_Coregi\_ESD\_Ifg\_Deb\_DInSAR\_ML\_Flt\_Unw\_Disp Output:

*S1A\_20160606\_S1A\_20160910\_Split\_Orb\_Coregi\_ESD\_Ifg\_Deb\_DInSAR\_ML\_Flt\_Unw\_Disp\_TC* **Directory**: /shared/Training/HAZA03\_LandSubsidence\_MexicoCity\_TutorialKit/Processing

	Range Doppler Terrain Correction	1 * E ×
e Help		
I/O Parameters	Processing Parameters	
Source Product source:		
[2] S1A_201606	06_51A_20160910_Split_Orb_Coregi_ESD_Ifg_Deb_DinSAR_t	4L_Fit_Un
Target Product Name:		
Name:	S1A_20160910_Split_Orb_Coregi_ESD_lfg_Deb_DInSAR_ML_1	Flt_Unw_Disp_TC
Name:		Ht Unw Disp_TC
Name: S1A_20160606_		Flt_Unw_Disp_TC

In the **Processing Parameters** tab, set the following (See 1 NOTE 7):

Pixel Spacing (m): 100 Map Projection: WGS84(DD)

Parameters Processing Param	eters		
Source Bands:	displacement		
Digital Elevation Model:	SRTM 3Sec (Auto Download)		
DEM Resampling Method: Image Resampling Method: Source GR Pixel Spacings (az x rg): Pixel Spacing (m): Pixel Spacing (deg): Map Projection:	BICUBIC_INTERPOLATION		
	BISINC_5_POINT_INTERPOLATION		
	27.94(m) × 26.74(m)		
	100		
	8.983152841195215E-4 WGS84(DD)		
<ul> <li>Mask out areas without elevation</li> <li>Output bands for:</li> <li>Selected source band</li> </ul>		e	
Incidence angle from ellipsoid	🔲 Local incidence angle 🔲 Projected local incid	dence angle	
Apply radiometric normalization			
Save Sigma0 band	and the set of the set of the set of the	-	
🔲 Save Gemmal hand	Contract Contract Const Fred Fred		
Save Betab hand			
Auxiliary File (ASAP only)	Lead Section	-	

NOTE 7: The pixel spacing in meters can be specified for the orthorectified image. Alternatively, default pixel spacing computed from the source SAR image is used.

Now, click Run.

In the **Product Explorer** window select "displacement\_VV" band to see the new geocoded product in the **View** window.



By appropriate post-processing of the displacement product, like for example the masking of the incoherent values, more accurate displacement measurements can be produced.



# 6 Extra steps

#### 6.1 Downloading the outputs from VM

Press **Ctrl+Alt+Shift.** A pop-up window will appear on the left side of the screen. Click on bar below **Devices**, the folder structure of your VM will appear. Navigate to the folders you have saved the files you want to download and **double click any file you want to download.** The downloading process to your local computer will start automatically.

front_vnc	<b>L</b> user_usr-3304 •		-
Clipboard			SNAP
Text copied/cut within Guacat the text below will affect the	mole will appear here. Changes to remote clipboard.		
		~	Quale Quale
Devices			CO RATIGUI
A /home/rus			Electronic and the second
Input method			 •
None			Firster-
No input method is used. Ke connected, physical keyboar	eyboard input is accepted from a rd.		
Text input			
Allow typing of text, and em keyboard events based on th	he typed		

#### 6.2 Export as KMZ (Google Earth)

If we want to view the products in Google Earth we have to export to **KMZ** format, readable by Google Earth and then download results to our local PC for visualization, as the RUS VM does not

support Google Earth installation. Readable KMZ format by Google Earth is **WGS 84 Lat/Lon** coordinate system (EPSG 4326). If during the geocoding you have used a different coordinates system, you need to reproject the final product in SNAP accordingly by going to Raster  $\rightarrow$  Geometric Operations  $\rightarrow$  Reprojection.

Since our results are already in WGS 84, we proceed to the export of KMZ layer. In SNAP, go to **File**  $\rightarrow$  **Export**  $\rightarrow$  **Other**  $\rightarrow$  **View as Google Earth KMZ** (only the active band open in the view window will be saved).

Save to the *Processing* folder as: *Mexico\_disp.kmz*.

Download the KMZ files to your laptop following the instructions in section 6.1.

Open Google Earth. Go to File  $\rightarrow$  Open and open the downloaded layer. The new layer will appear as overlay in the Places panel on the left (activate and deactivate layer and legend) with the name of the original band (not the saved KMZ).



# THANK YOU FOR FOLLOWING THE EXERCISE!

# 7 Further reading and resources

SENTINEL-1 SAR User Guide Introduction – link

ESA Sentinel Online - link

Science Toolbox Exploitation Platform (STEP) – link

### 8 References

- 1. Figueroa Vega G.E., Subsidence of the City of Mexico, a Historical Review, Proc. Anaheim Symposium, IAHS Publication Nr. 121, pp. 35-38, 1976.
- 2. D Strozzi, T. and U. Wegmüller. Land subsidence in Mexico City mapped by ERS differential SAR interferometry, Geoscience and Remote Sensing Symposium (IGARSS) 1999 IEEE International, 1999.
- 3. ESA INSARAP project (http://www.esa.int/spaceinimages/Images/2014/12/Mexico\_City\_subsidence).
- 4. Goldstein R.M. and C.L. Werner, "Radar Interferogram Phase Filtering for Geophysical Applications", Geophysical Research Letters, 25, 4035-4038, 1998.
- 5. Ghiglia D. and M. Pritt (1998), Two-dimensional phase unwrapping: theory, algorithms, and software, 512pp.
- 6. Constantini M. (1998), A novel phase unwrapping method based on network programming , IEEE Tran. on Geoscience and Remote Sensing, 36, 813-821.
- 7. Small D. and Schubert A., Guide to ASAR Geocoding, RSL-ASAR-GC-AD, Issue 1.0, March 2008.

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