

COPER RUS Opernicus



TRAINING KIT – GEOL01

LITHOLOGICAL CLASSIFICATION WITH SENTINEL-1 & SENTINEL-2 – SEPTEMBER 2019 (MOROCCO)









Research and User Support for Sentinel Core Products

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Authors would be glad to receive your feedback or suggestions and to know how this material was used. Please, contact us on <u>training@rus-copernicus.eu</u>

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Table of Contents

1	Intr	oduct	action							
2	Tra	raining								
	2.1	Data	a used	. 4						
	2.2	Soft	ware in RUS environment	. 4						
3	Reg	ister t	to RUS Copernicus							
4	Rec	juest a	a RUS Copernicus Virtual Machine							
5	Ste	p by step								
	5.1	Data	a download – ESA SciHUB	. 9						
	5.2	SNA	P – open and explore data	13						
	5.2	1	Create RGB Image	13						
	5.3	Sent	inel-2 Processing	15						
	5.3	1	Resample	15						
	5.3	2	Subset	16						
	5.3	.3	Reproject	17						
	5.3	.4	Unsupervised Classification	18						
	5.3	.5	Supervised Classification	19						
	5.4	Sent	inel-1 Processing	23						
	5.4.	1	Graph Builder	24						
	5.4	.2	Subset	25						
	5.4	.3	Apply Orbit File	25						
	5.4	.4	Thermal Noise Removal	26						
	5.4	.5	Calibration	26						
	5.4	.6	GLCM	27						
	5.4	.7	Speckle Filtering	27						
	5.4	.8	Terrain Correction	28						
	5.4	.9	Subset	30						
	5.4	.10	Unsupervised Classification	31						
	5.4	.11	Supervised Classification	33						
	5.5	Ехро	ort products	35						
6	Visu	ualizat	ion in QGIS	36						
7	Exti	ra Stej	ps	37						
	7.1	Visu	alization in Google Earth	37						
	7.2	Dow	nload files from VM	38						
8	Fur	ther re	eading and resources	39						

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 preinstalled on virtual machines, to handle and process data acquired by the Copernicus Sentinel satellites constellation.

Geologists can employ both SAR and optical remote sensing data in order to extract geological information, depending on the geological setting of area of interest. The use of SAR images is playing an important role in recent years by providing a wealth of information in this field, such as geological structure and lithological mapping. The fusion of radar and optical images can simplify the interpretation and improve the accuracy of recognizing and detecting lithological units.



Stratigraphy of Anti-Atlas Mountains (Source: Soulaimani A. & Burkhard M. Geological Society, London, Special Publications, 297, 433-452, 1 January 2008 <u>https://doi.org/10.1144/SP297.20</u> Morocco consists of very fascinating landforms and landscapes and it is an attractive field for studying geology. It is located at the node of Africa (continent), the Atlantic Ocean and an active plate collision zone - the Alpide belt system. This composition results in a rough topography with terrains spanning from Archean to Cenozoic Era, with diverse tectonic systems.

The Anti-Atlas Mountains formed in the Paleozoic Era as a result of continental collisions and are part of the Atlas

Mountains, with a SW-NE direction. Most of the land is dry and barren with annual precipitation less than 200 mm, thus, the rocky outcrops and lunar landscapes of extreme contrasts are dominant.

2 Training

Approximate duration of this training session is **two** hours.

The Training Code for this tutorial is **GEOL01**. 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

One Sentinel-1A IW GRD image acquired on 8 September 2019 [downloadable at https://scihub.copernicus.eu/]

S1A_IW_GRDH_1SDV_20190908T062923_20190908T062948_028926_03478B_AE88

 One cloud-free Sentinel-2B Level 2A image (Tile ID: T29RNN) acquired on 14 September 2019 [downloadable at <u>https://scihub.copernicus.eu/]</u>

S2B_MSIL2A_20190914T110649_N0213_R137_T29RNN_20190914T142009

2.2 Software in RUS environment

Internet browser, SNAP + Sentinel-1 & Sentinel-2 Toolboxes, QGIS, (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	C A Login/Register &
The RUS Service * The RUS Offer * The RUS Library * The RUS Community *	
	Seattle
	News from RUS
	One year on!
	Copernicus Info Session – Reykjavik – 19 September 2018
	SPIE Remote Sensing 2018 – Berlin (Germany) – 11-12 September 2018
Contraction of the second s	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
Welcome to Research and User Support	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. Note that your Copernicus SSO account will be activated only after the reception of the thrid remail sent by the Copernicus service. We advise you to consult this document and this page to facilitate your registration procedure. REGISTER COPERNICUS SSO account can be adressed to the service of th	CDS-SSO ID Password Max Idle Time Max Session Time	half a day Until browser close	•	0 0 0
Login		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 t	o subscribe for a new RUS account?		
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+ Your RUS service	Login			8
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	Email	transfer and the second se	Est Fortum - Straubourg	
· Your dashbaard: allows you to ac-	Organization		Annual State of the Advancement of	
· Your training allows you to regist	Country		Barrier Works	
	Additio	onal subscription information	arter or series - it Nov.	
	Please complete the followi	ing information:	init - Alexandru - 24 O	
	Where did you hear about the RUS service? Select one or more items	outreach event colleagues pewcletter	atten = Network - Francist Atten = Petiting - 5, 9 40	
		conference social media other	than - Foulonie - 26 to	27 Oct. 2018
	Institution type	Select one item	× nda	
	Phone number Italy (IT):	+39	polatingro-	
	Title	Select one item	~	

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	AN	🚛 🤝 💼 🤤 esa			
~		Hello, Miguel 💲			
The RUS Service * The RUS Offer * The RUS Library * The RUS Communit	y▼ Pur RUS servi				
	A Your profile	You are here: Home > Your RUS service			
Your RUS service	Your dashboard	etim Q			
This section gathers pages related to your RUS services:	Your training				
Your profile: displays your personal information linked to your ESA SSO and RUS a	Your profile: displays your personal information linked to your ESA SSO and RUS accounts				
		One year on! Copernicus Info Session – Reykjavik – 19 September 2018			
 Your dashboard: allows you to access your private dashboard, 					
Your training: allows you to register to a training session you have been invited to p	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			
		IGAR55 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	Sen and see th	Hello, Miguel
The RUS Service * The RUS Offer * The RUS Library	The RUS Community * Star Your RUS service *	
Your dashboard	You	are here: Home > Your RUS service > Your dashboard
Request a new User Service		Chat with Support Desk
Copyright © 2017 Research and User Support	Contact Us	Terms and conditions Glossary Acronyms FAQ

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

Please help us learn more about your background by answer	ing a few questions. Th
information will be stored in your User Profile.	
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?	
* 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	
LAND01 - Crop Mapping in Seville	
LAND04 - Land Monitoring in Cyprus	
OCEA01 - Ship Detection in Gulf 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	d across the USR forms.			
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	1			
	S1-Product 1			
S1 - Product type	GRD			
S1 - Sensor mode	-			
S1 - Polarisation				
S1 - Orbit direction				
Sentinel-2	X			
Sentinel-3	×			
Other	x			
I don't know	×			
Region of Interest: Min Latitude	30 3303			
MaxLatitude	40.5877			
Min Longitude	-4.6736			
MaxLongitude	-2 7205			
Reference polygons				
Data acquicition data(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	Jser Servi	ce					2	Chat with Support Desk
Project Name	ID	Date of submission	Status		Actions		Virtual	Environment
				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

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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		opernicus					
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5 Step by step

5.1 Data download – ESA SciHUB

In this step, we will download the Sentinel-1 scenes from the Copernicus Open Access Hub using the online interface. Go to **Applications** \rightarrow **Network** \rightarrow **Firefox Web Browser** or click the link below.

Go to https://scihub.copernicus.eu/



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.

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Insert source etitions	Read Free series Free series		Please login to access our providence of the second of the
	Copernicus	Open Access Hub	£0+
	Register	new account	圖
	Sentinel data access is free and open to all. On completion of the registration form below you will receive an e-that with a link to val username field access only obvercase aphramomeric characters pais "	tatic your 4-mail address. Following this you can plan to download the data set of $q_1^{-1}q_2^{-1}q_2^{-1}q_1^{-1}q_2^{-1}q_2^{-1}$	
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-	E-mui	(Qendam) Evinau	
-	•		
	• Select Usage		
5	Select your country		
	By registering in this website you are deeme	a to have accepted the T&C for Sentinei data use	RECASTER

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".



Navigate over Morocco (approximate area – green rectangle).

We need to download images over the area of interest for the same date if possible. For <u>Sentinel-1</u> we will select one on <u>8 September 2019</u> and for <u>Sentinel-2</u> one on <u>14 September 2019</u>. There is not a Sentinel-2 image available for the 8th of September, so looking for the closest available which would be the most cloudless, we selected the one on September 14 and not on 9th. Depending on the subset you want to create, you might be able to use the cloud free parts of the image acquired on 9th.

Zoom in to the south-east area of Anti-Atlas Mountains, switch to "**drawing mode**" and draw a search rectangle approximately as indicated below. Open the search menu by clicking to the left part of the search bar. We will first specify the parameters for Sentinel-1 and then for Sentinel-2.

For Sentinel-1:

Sensing period: From 2019/09/08 to 2019/09/08 Select: Mission: Sentinel-1 Product Type: GRD Sensor Mode: IW

	Copernicus Open Access Hub	± 0 A
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Advanced Search	Clear Sets Guerdane	Zagora, 📀
» Sort By: » Order Ingestion Date Desc	By: Anamer will Four way	Zguid Out of Fays 🚱
Sensing period 2019/09/08	2019/09/08	i mos
 Ingestion period Mission: Sentinel-1 	ane Atlas Saphr and Atlas Saphr and Atlas Saphr	W
Satellite Platform Product	Type Tarhjicht icht Mode	
Relative Orbit Number (from 1 to Collect	on ·	
Mission: Sentinel-2		0

Then click on the "**Search**" sicon. The search returns 1 result for the time period we set. Download the image by clicking on the "**Download Product**" icon:

S1A_IW_GRDH_1SDV_20190908T062923_20190908T062948_028926_03478B_AE88



Return to the search menu, deselect Sentinel-1 mission, and apply the following steps.

For Sentinel-2:

Sensing period: From 2019/09/14 to 2019/09/14 Select: Mission: Sentinel-2 Product Type: S2MSI2A



Then click on the "**Search**" icon. The search returns 1 result for the time period we set. Download the image by clicking on the "**Download Product**" icon:

S2B_MSIL2A_20190914T110649_N0213_R137_T29RNN_20190914T142009

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🍸 🗑 Insert search criteria	تاريادي Taibuine تاريخي Taibuine تاريخي Taibuine	1 1 20
Display 1 to 1 of 1 products. 0 products Order By: Ingestion Date 4 29:322(3999/1090264;8:5488/7/150126298 29:01836550855421))) beginPosition:[2019-09-14700:00:00.0002 TO 2019-09-14723:59:59 endPosition:[2019-09-14700:00:00.0002 TO 2019-09-14723:59:59 (platformame:SentineL2 AND producttype:52M5I2A))	Analor * X Sett Guerdane * Sett Guerd	
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Download URL: https://picinub.copernicus.eu/dhu/piodata/J/Piodu/ Mission: Sentinel-2 Instrument: MSI Sensing Date: 2019-09-1471 Products per page: 25 < < < < page:	Cettor 4501255 11:06:49:025 Topemirt Topemirt Topemirt Topemirt Topemirt Topemirt Topemirt Topemirt Topemirt Topemirt Topemirt Topemirt Topemirt Topemirt Topemirt	
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"Tilenizoun		0

The products will be downloaded at */home/rus* as zip files. Move them to: */shared/Training/GEOL01_LithologicalClassification_Morocco_TutorialKit/Original* folder.

5.2 SNAP – open and explore data

Open SNAP software from the icon located on the desktop or go to Applications \rightarrow Processing \rightarrow SNAP Desktop. Click the Open Product icon \frown , navigate to: /shared/Training/GEOL01_Lithological Classification_Morocco_TutorialKit/Original folder and open the <u>Sentinel-2 product</u>:

S2B_MSIL2A_20190914T110649_N0213_R137_T29RNN_20190914T142009.zip

or just open a folder in your VM, navigate to the path mentioned above and then drag the product from the folder and drop it to the **Product Explorer** Window.

5.2.1 Create RGB Image

Go to the opened product in the **Product Explorer** window, right click on it, and select from the menu "**Open RGB Image Window**". Select at **Profile: Sentinel 2 MSI Natural Colors** and at the bands keep on **Red: B4**, Green: B3, Blue: B2. Then click **OK** and the new RGB image of natural colors will appear at the **View Window**.

Product Exp	lorer × Pixel Info	0000 10000	2 D1 27 T20DNN 201		Select RGB-Image Channels	(A)	= ×
0. 9 [T] 3.	Band Maths Add Elevation Band Add Land Cover Band			Profile: Sentine	el 2 MSI Natural Colors 🔷 🥌	m	
	Group Nodes by Type	2 cm				-	
	Open HSV Image Wind	ow		Red:	84	-	
	Close Product Close All Products Close Other Products			Green'	B3	•	uter-
-	Save Product Save Product As			eles:	02	101	110
	Cut	Ctrl-M		Sto	re RGB channels as virtual bands in current product		
	Copy	Ctrl-C					
	Paste	ZBrI-VI					
4	Delete	Déleté	•			1	
Navigation	Properties		rld Map ×		<u>O</u> K <u>C</u> ancel		Help

You can go to the **World Map** tab and zoom in to see the location of the opened product on the globe.



Click on **o** or **+** to expand the contents of product **[1]**, then expand **Bands** folder, then expand the **scl** folder (See **i** NOTE 1) and double click on the following bands to visualize them in the **View** window: **scl_cloud_shadow**, **scl_cloud_medium_proba**, **scl_cloud_high_proba** and **scl_thin_cirrus** in order to see if there are any clouds at the image and the **scl_vegetation** band to check how much of the area is vegetated. The areas with clouds and vegetation will be visualized with white pixels.

Go to **Window** \rightarrow **Tile Evenly** so that you can see all the opened bands at the same time. Go to the **Navigation** tab and click on the two icons shown within the red rectangular below to synchronize the views and the cursor position between the views.



If we zoom in, we will see that there are very few white pixels in all of them: very little clouds and vegetation, meaning that they will not affect our processing. Then you can close all opened views.

NOTE 1: You can find more information about the Scene Classification map (scl folder context) here: <u>https://sentinel.esa.int/web/sentinel/user-guides/sentinel-2-msi/processing-levels/level-2</u>

5.3 Sentinel-2 Processing

Let's start with the Sentinel-2 processing steps. The operators that will be used are the following, and we will explain each one of them more analytically:



5.3.1 Resample

First, we need to resample all the 13 spectral bands of the product in order to have them in the same spatial resolution (See $\stackrel{f}{=}$ NOTE 2).

Go to Optical \rightarrow Geometric \rightarrow S2 Resampling Processor.

In the I/O Parameters tab set as:

Source Product Name: S2B_MSIL2A_20190914T110649_N0213_R137_T29RNN_20190914T142009 Target Product Name: S2B_20190914_s2resampled Directory: /shared/Training/GEOL01_LithologicalClassification_Morocco_TutorialKit/Processing

In the Processing Parameters tab set as:

Output resolution: 10

Upsampling method: Nearest

Keep **the Downsampling method** and the **flag downsampling method** as <u>by default</u>, and make sure that the "**Resample on pyramid levels (for faster imaging)**" option, is selected.

	S2 Resampling	+ = ×	S2 Resam	pling	+ E ×
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[1] S2B_	MSIL2A_20190914T110649_N021	3_R1 👻	Upsampling method:	Nearest	-
-			Downsampling method:	Mean	-
Target Pr	oduct		Flag downsampling method:	First	-
Name: S2B_201	90914 s2resampled		🖌 Resample on pyramid le	vels (for faster i	imaging)
Save Direct	as: BEAM-DIMAP 🔹 tory: assification_Morocco_TutorialKit/F	Processing			
🖌 Open	in SNAP				
		Run <u>C</u> lose		Bu	ın. <u>C</u> lose

Click Run. The new product will appear at the Product Explorer window.

TIP 1: The S2 Resampling processing is quite heavy and time demanding. If you want to complete it faster, select as **Output resolution:** 20 or create a smaller subset.



This operator uses not only the angles bands but also the detector footprints. By using the footprints, it is possible to "isolate" the angles of each detector and interpolate them without using the angle information of the adjacent detectors (which causes the blurring). (SNAP Help)

5.3.2 Subset

Since we do not need to process the whole image, we will create a subset of it over our area of interest.

Go to Raster → Subset.

In the Spatial Subset tab, go to Pixel Coordinates tab and set the following parameters:

```
Scene start X: 1523 Scene start Y: 3875 Scene end X: 6656 Scene end Y: 9426
```

TIP 2: Go to the **Geo Coordinates** tab, and write down the values for the **North latitude bound**, **West longitude bound**, **South latitude bound** and **East longitude bound**, because we will need them for the second subset part of the Sentinel-1 processing, at *5.4.9 Subset* chapter.

	Specify Product Subset	+ = ×	s s	pecify Product Subset	+ = ×
Spatial Subset	Band Subset Metadata Subset		Spatial Subset Band S	ubset Metadata Subset	
	Pixel Coordinates Geo Coordin Scene start X: Scene start Y: Scene end X: Scene end Y: Scene step X: Subset scene height: Subset scene height: Source scene heig	1523 - 3875 - 6656 - 9426 - 1 - 1 - 5134.0 5552.0 10980 10980 10980 c full width c full height		Pixel Coordinates Geo North latitude bound: West longitude bound: South latitude bound: East longitude bound: Scene step X: Scene step X: Subset scene width: Source scene width: Source scene height: Use Preylew	29.481
1	Estimated, raw	storage size: 1046.6M		Estimate	d, raw storage size: 1046.6M K <u>C</u> ancel <u>H</u> elp

Click **OK**. The **subset_0_of_S2b_20190914_s2resampled** product, will appear at the **Product Explorer** window. Right click on it, select **Save Product**, then click **Yes** on the window that appears.

Navigate to */shared/Training/GEOL01_LithologicalClassification_Morocco_TutorialKit/Processing* path and **Save** it with the **File Name:** Subset_S2B_20190914_s2resampled.

Product E	xplorer X Pixel Info			SNAP - Save Produc	ct As	* = ×
	S2B_MSIL2A_20190914T1 S2B_20190914_s2resamp subset_0_of_S2B_201909 Band Maths Add Elevation Band Add Land Cover Band	10649_N0213_R137_T29F oled 014_s2resampled	?	In order to save the product [3] subset_0_of_S2B_20190914_s it has to be converted to the BEAN-1 Depending on the product size the of Do you really want to convert the pr Remember my decision and don	2resampled DIMAP format. :onversion also ma roduct now? I't ask again.	ay take a while. Cancel
	🗹 Group Nodes by Type		5	SNAP - Save Product	t As	I + E ×
	Open RGB Image Wind Open HSV Image Wind	ow	Save In Name	Processing	Size Modified	
	Close Product Close All Products Close Other Products		S2 S2 En Fin Fin S2	B_2019034_s2resampled_20.data B_M312A_20190314_s2resampled_data al_Subset_SIA_W_GRDH_ISDV_2019090 al_Subset_SIA_W_GRDH_ISDV_2019090 al_Subset_SIA_W_GRDH_ISDV_2019090 al_Subset_SIA_W_GRDH_ISDV_2019090. B_20190914_s2resampled_dim	1/31/20 1/28/20 7 MB 1/26/20 21 KB 1/26/20 12 KB 1/27/20 7 MB 1/27/20 29 MB 1/26/20	1:04 PM
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Then go to the subset at the **Product Explorer** window, right click on it, select **Close Product** and then load in SNAP the lately saved subset. Create RGB images for both the original and the subset products, go to **Window** \rightarrow **Tile Horizontally** and view/compare the two images.



5.3.3 Reproject

We need to convert the coordinate reference system of our product from UTM to **Geographic Lat/Lon WGS84**, otherwise we currently cannot continue to the Classification steps.

Go to **Raster** \rightarrow **Geometric Operations** \rightarrow **Reprojection**.

In the I/O Parameters tab set as:

Source Product Name: S2B_20190914_s2resampled Target Product Name: Subset_S2B_20190914_s2resampled_reprojected Directory: /shared/Training/GEOL01_LithologicalClassification_Morocco_TutorialKit/Processing In the Reprojection Parameters tab set:

At <u>Coordinate Reference System (CRS)</u>, under **Custom CRS**, **Projection**: Geographic Lat/Lon (WGS84) **Deselect** the "Reproject tie-point grids" option.

	Reprojection	+ = ×		Reprojection	↑ □ X
File Help		File	Help		
1/O Parameters	Reprojection Parameters	()	/O Parameters Reprojec	tion Parameters	
Source Product Name: [3] Subset_S28	20190914_s2resampled		Coordinate Reference Syst Custom CRS Geodetic datum:	em (CRS)	
Target Product			Projection: Geog	graphic Lat/Lon (WGS 84)	•
Subset_S2B_201	190914_s2resampled_reprojected AM-DIMAP	utorialKit/Processing	Predefined CRS Use CRS of Use CRS of Preserve resolution Output Parameters. Add delta lat/lon bands	Reproject tie-point gri No-data value: Nah Resampling method: Nea	Projection Paramieters. Select
		Run Close	Output Information Scene width: 5857 pixel Scene height: 5553 pixel CRS: WGS84(DD)	Center longitude: Center latitude:	8*34'45" W 29*13'46" N Show WKT Bun <u>C</u> lose

Click **Run**. The new product will appear at the **Product Explorer** window. Now we can continue with the classification steps. Close all the previously opened view windows in SNAP.

5.3.4 Unsupervised Classification

First, we will apply an unsupervised classification by using the K-Means Cluster Analysis. This way, all pixels of our product will be classified in the most appropriate cluster (See 1 NOTE 3).

Go to Raster \rightarrow Classification \rightarrow Unsupervised Classification \rightarrow K-Means Cluster Analysis.

In the I/O Parameters tab set as:

Source Product: Subset_S2B_20190914_s2resampled_reprojected Target Product Name: Subset_S2B_20190914_s2resampled_reprojected_kmeans Directory: /shared/Training/GEOL01_LithologicalClassification_Morocco_TutorialKit/Processing

In the **Processing Parameters** tab, keep the **Number of clusters**, **Number of iterations** and **Random seed** as <u>by default</u>, and at the **Source bands names**, press Ctrl and <u>select only</u> the B2, B3 and B4.

K-Means Cluster Analysis	• = × 🚺	K-	Means Cluster Analysis	+ = ×
File Help	File Hel	p		
1/O Parameters Processing Parameters	1/0 Par	ameters	Processing Parameters	
Source Product	Numbe	r of cluster	s:	14
Source product:	Numbe	r of iteratio	ons:	30
[4] Subset_S2B_20190914_s2resampled_reprojected	Randor	n seed:		31415
Target Product Name: Subset_S2B_20190914_s2resampled_reprojected_kmeans Save as: BEAM-DIMAP Directory: LithologicalClassification_Morocco_TutorialKit/Processin	Source	band nam	B1 B2 B3 B4 B5 B6 B7 B8 B8	
V Open in SNAP	ROI-ma	sk:		Y
Bun	Close			<u>Run</u>

Click **Run**. The new product will appear at the **Product Explorer** window.

NOTE 3: Cluster analysis is the classification of objects into different groups, so that the data in each subset **share** some **common trait**. The **k-means** clustering tool, **randomly chooses k pixels** whose samples define the initial cluster centers, **assign each pixel to the nearest cluster center** as defined by the Euclidean distance and recalculate the cluster centers as the arithmetic means of all samples from all pixels in a cluster (the last two are being repeated until the convergence criterion is met). Finally, the convergence criterion is met when the maximum number of iterations specified by the user is exceeded or when the cluster centers did not change between two iterations. (SNAP Help)

Now go to the Subset_S2B_20190914_s2resampled_ reprojected_kmeans product at the Product Explorer window, expand it, then expand the Bands folder and double click on the class_indices band to visualize it.

You can also go at the **Colour Manipulation** tab and get information about each class, like the frequency.

Navigatio. Colour ... × Uncertaint. World Map Label Colour Value Frequency Description 2 F class 1 14.916% Cluster 0. 10.825% Cluster 1, class 2 11.255% Cluster 2, . class 3 10.927% Cluster 3. class 4 class 5 8.500% Cluster 4, 7.813% Cluster 5, class_6 7.978% Cluster 6, class 7 6.645% Cluster 7 class 8 4.899% Cluster 8. class_9 class 10 4.428% Cluster 9 4.345% Cluster 10.. class 11 class 12 11 3.626% Cluster 11. 3.003% Cluster 12. class_13 class 14 13 0.840% Cluster 13

We can see how all pixels have been classified and export the view in .tif and/or .kmz format for further steps.



5.3.5 Supervised Classification

In order to continue to the supervised classification, we need to import the shapefiles with the geology of the area and then create training data for each different lithology. In this case the training data have already been created and will be loaded on the **Subset_S2B_20190914_s2resampled_reprojected** product. The classifier we will use is **Random Forest Classifier**.

Select the **Subset_S2B_20190914_s2resampled_reprojected** product at the **Product Explorer** window and go to **Vector** → **Import** → **ESRI Shapefile**.

Navigate to **/shared/Training/GEOL01_LithologicalClassification_Morocco_TutorialKit/AuxData** folder, open the **Geology_Morocco** folder and select all shapefiles with numbering from 1 to 14 (<u>apart from the FINAL_GEOLOGY.shp</u>) and click **Open**.

ook In: 📑 Geo	logy_Morocco	-	A C 88
lame		Siz	e Modified
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13.Holocene-	Fluvial.shp	1 KB	1/24/20 1:30 PM
14.Null.shp		2 KB	1/24/20 1:30 PM
2. UpperProte	rozoic(Upper part).shp	1 KB	1/24/20 1:30 PM
3. LowerCamb	rian.shp	1 KB	1/24/20 1:30 PM
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8: LowerDevor	nian.shp	4 KB	1/24/20 1:30 PM
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le <u>N</u> ame: ilur	ian.shp" "8.LowerDevo	nian.shp"	"9.MiddleDevonian.s
les of Type: ES	RI Shapefiles (*.shp)		

In the **Import Geometry** window that will appear, select for each shapefile:

Attribute for mask/layer naming: CODE_DES_1 Click No so that all the polygons that correspond to the same lithology, will be displayed on one layer.

Repeat for all shapefiles until they are all imported.



Now also import the training data. Go again to Vector \rightarrow Import \rightarrow ESRI Shapefile, and from the AuxData folder, select and open all geometry_xx_Polygon. Click No to the Import Geometry window.

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lame	Size Modified
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Go to the **Subset_S2B_20190914_s2resampled_repro jected** product and expand the **Vector Data** folder. You will see that all the shapefiles we have imported are now in that folder as in the following image.

Right click on the product and select **Save Product**, to save the imported data.



Go to Raster \rightarrow Classification \rightarrow Supervised Classification \rightarrow Random Forest Classifier.



In the Feature bands select only B2, B3 and B4.

In the Write tab set as:

Name: Subset_S2B_20190914_s2resampled_reprojected_RF Directory: /shared/Training/GEOL01_LithologicalClassification_Morocco_TutorialKit/Processing

Click **Run**. The new product will appear at the **Product Explorer** window (See 1 NOTE 4).

ProductSet-Reader Random-Førest-Classifier Ursteller Write Classifier Image: Classifier Image: Classifier Image: Classifier Calabitate classifier Image: Classifier Mumber of training samples Socio Name: States classifier States classifier Image: Classifier Vector Training Image: Classifier Vector Training Image: Classifier Peature bands: Image: Classifier States classifier Image: Classifier States classif			Random Forest Classifier	• = ×	Random Forest Classifier
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			Melo D Run		Telp D Rum

Now go to the **Subset_S2B_20190914_s2resampled_reprojected_RF** product at the **Product Explorer** window, expand it, then expand the **Bands** folder and double click on the **LabelledClasses** band to visualize it (See 1 NOTE 5). In case you see the shapefiles imported initially, go to *Vector Data* folder, select them, right-click and **Delete** them.



Open the class_indices band from Subset_S2B_20190914_s2resampled_reprojected_kmeans product as well, go to Window \rightarrow Tile Horizontally and compare the results of the two different classifications. We can see that the results from both Unsupervised and Supervised Classification are quite good, and by creating appropriate training data, the Supervised Classification is more accurate.



*	newClassifier_52.txt - Mousepad	1 - 0 8
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1 Rando	wForest classifier newClassifier S2	
2		
3 Cross	Validation	
4 Number	r of classes = 14	
5 cla	ass 0.0: geometry 10 Polygon	
6 a)	curacy = 0.9115 precision = 0.3836 correlation = 0.3985 erro	orRate = 0.0885
7 Ti	ruePositives = 140.0000 FalsePositives = 225.0000 TrueNegatives	ves = 4411.0000
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8 11	iss 1.0: geometry 11 Polygon	
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19 T)	ruePositives = 142.0000 FalsePositives = 166.0000 TrueNegativ	ves = 4478.0000
False	legatives = 215:0000	
20 cla	ass 5.0: geometry 1 Polygon	
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22 TI	ruePositives = 158.0000 FalsePositives = 149.0000 TrueNegatives	ves = 4487.0000
Falset	Vegatives = 199.0000	
23 cla	ass 6.8: geometry 2 Polygon	The second second
24 01	curacy = 0.9551 precision = 0.7491 correlation = 0.6396 erro	orRate = 8.0449
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NOTE 4: When running Fandom Forest Classification, a .txt file is being created.

It contains information about the classes, like accuracy, precision and correlation of each class/polygon we have created with our training data.

Go to File → Save as. Save the file with name: newClassifier_S2 at this folder: /shared/Training/GEOL01_LithologicalClassifi cation_Morocco_TutorialKit/Processing



NOTE 5: The **Random Forest** algorithm is a **machine learning technique** that can be used for classification or regression. In opposition to parametric classifiers (e.g. Maximum Likelihood), a machine learning approach does not start with a data model but instead learns the relationship between the training and the response dataset. The **Random Forest classifier** is an aggregated model, which means it **uses the output from different models** (trees) **to calculate the response variable**.

Decision trees are predictive models that recursively split a dataset into regions by using a set of binary rules to calculate a target value for classification or regression purposes. Given a training set with n number of samples and m number of variables, a random subset of samples n is selected with replacement (bagging approach) and used to construct a tree. At each node of the tree, a random selection of variables m is used and, out of these variables, only the one providing the best split is used to create two sub-nodes.

By combining trees, the forest is created. Each pixel of a satellite image is classified by all the trees of the forest, producing as many classifications as number of trees. Each tree votes for a class membership and then, the class with the maximum number of votes is selected as the final class. (SNAP Help)

More information about Random Forest can be found in Breiman, 2001.

You will find information on how to export Sentinel-2 and Sentinel-1 products with the classification outputs at the **5.5 Export Products** chapter.

5.4 Sentinel-1 Processing

Now we will continue with the Sentinel-1 processing steps. The operators that will be used are the following, and we will explain each one of them more analytically:



First, close SNAP to empty the cache from all Sentinel-2 processing and open it again. If any window pops up, select **No**.

Navigate to: /shared/Training/GEOL01_LithologicalClassification_Morocco_TutorialKit/Original folder and open the <u>Sentinel-1 product</u>:

S1A_IW_GRDH_1SDV_20190908T062923_20190908T062948_028926_03478B_AE88.zip

Go to the opened product in the **Product Explorer** window, click + or **\sim** to expand the contents of the product, then expand **Bands** folder and double click on *Amplitude_VH* and *Amplitude_VV* bands to visualize them in the **View** window. Go to **Window** \rightarrow **Tile Horizontally** (See **\sim** NOTE 6).

NOTE 6: The RADAR instrument onboard Sentinel-1 carries an antenna that is looking always to the right during its pass. This scene was acquired during **descending** pass (the satellite was moving in direction from north to south) and in this case while looking to the right it was actually looking towards the west. That is why we see that the view of the image appears as if "mirrored", because the view shows the pixels in order of the data acquisition.



5.4.1 Graph Builder

By using the **GraphBuilder** tool, we can define the steps of the process we want to apply and at the end only the final product will be physically saved (this way we will also save disk space since the products of the intermediate steps will not be stored).

Go to **Tools** \rightarrow **GraphBuilder** to build our graph.

We can see that the graph has only two operators: **Read** (to read the input) and **Write** (to write the output). Below there also are the corresponding to the operators' tabs.

First, right-click on the **Write** operator and **Delete** it. The corresponding tab will be removed as well. This is to avoid confusion to the sequence of the graph. The **Write** operator will be added again at the end. Every time an operator is added, we will also define the parameters in the tab.



Read

In the **Read** tab choose the opened in the **Product Explorer** window Sentinel-1 product: **S1A_IW_GRDH_1SDV_20190908T062923_20190908T062948_028926_03478B_AE88**

Read	
Source Product	
Name:	and the second se
S1A_IW_GRDH_1SDV_20190908T062923_20190908T062948_028926_03478B_AE88	
Data Format	
📄 Load 🔉 Save 💊 Clear 📝 Note 🔞 Help 🕞 Run	

5.4.2 Subset

In the next step, we will subset the image by using the same extent as of the Sentinel-2 product. To add the operator right-click on the white area to the right of **Read** and go to Add \rightarrow Raster \rightarrow Geometric \rightarrow Subset. Connect the Read operator to it by dragging the red arrow from the right side of Read operator towards the Subset operator.

Read 🔶 Subset

In the **Subset** tab press **Ctrl** select all bands and then click to select the **Geographic Coordinates** option. Paste the area of interest definition in WKT (well know text) format to the text window below the map.

```
POLYGON((-8.84409523010253929.479896545410156,<br/>8.31403636932373-8.3140363693237329.479896545410156,-8.3140363693237328.977815628051758,<br/>8.844095230102539-8.84409523010253929.479896545410156,-8.84409523010253929.479896545410156,)-8.844095230102539
```

Click **Update** and then click the **Zoom-in** icon to see your subset on the map.

Read Subset	
Source Bands:	Amplitude_VH Intensity_VH Amplitude_VV Intensity_VV
Copy Metadata	
O Pixel Coordinates	© Geographic Coordinates
31403636932373 28	.977815628051758, -8.844095230102539 28.977815628051758, -8.844095230102539 29.479896545410156, -8.844095230102539 29.479896545410156)
	🖆 Load 🔮 Save 🍾 Clear 🏹 Note 💿 Help 🕞 Run

5.4.3 Apply Orbit File

Now we will add the **Apply-Orbit-File** operator by right-clicking and going to $Add \rightarrow Radar \rightarrow Apply-Orbit-File$ (See \square NOTE 7). Connect the **Subset** operator to it.

Read -> Subset -> Apply-Orbit-File

In the **Apply-Orbit-File** tab we will keep the default settings and make sure that you will **select** the "**Do not fail if new orbit file is not found**" option.

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

NOTE 7: The orbit state vectors provided in the metadata of a SAR product are generally not accurate and can be refined with <u>the precise orbit files</u> which are available days-to-weeks after the generation of <u>the product</u>. **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**. In case precise orbits are not found, restituted orbit files will be used. (SNAP Help)

5.4.4 Thermal Noise Removal

Next we will remove the thermal noise of the image (See \square NOTE 8). Add the operator by right-clicking and going to Add \rightarrow Radar \rightarrow Radiometric \rightarrow ThermalNoiseRemoval. Connect the Apply-Orbit-File operator to it.

Read - Subset - Apply-Orbit-File - ThermalNoiseRemoval

In the ThermalNoiseRemoval tab, keep the default parameters.

Read Subset Apply-Orbit-File ThermalNoiseRemoval olarisations: VH W Remove Thermal Noise Re-Introduce Thermal Noise

NOTE 8: Thermal noise in SAR imagery is the background energy that is generated by the receiver itself. It skews the radar reflectivity to towards higher values and hampers the precision of radar reflectivity estimates. Level-1 products provide a noise LUT (Look-Up-Table) for each measurement dataset, provided in linear power, which can be used to remove the noise from the product. (*SNAP Help*)

5.4.5 Calibration

The objective of SAR calibration is to provide imagery in which the pixel values can be directly related to the RADAR backscatter (See \square NOTE 9). To add the operator, right-click and go to Add \rightarrow Radar \rightarrow Radiometric \rightarrow Calibration. Connect the ThermalNoiseRemoval operator to it.

In the Calibration tab, keep the default parameters.

Read	Subset	Apply-Orbit-File	ThermalNoiseRemoval	Calibration
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Sávi	e aŭ comple	n odtaut		
V Outp	out sigma0	band		
Outp	out gamma) band		
Outp	out beta0 ba	and		

NOTE 9: The radiometric correction is necessary for the pixel values to truly represent the radar backscatter of the reflecting surface and therefore for comparison of SAR images acquired with different sensors or acquired from the same sensor but at different times, in different modes, or processed by different processors. Typical SAR data processing, which produces level-1 images, does not include radiometric corrections and significant radiometric bias remains. (SNAP Help)

5.4.6 GLCM

GLCM (Gray Level Co-occurrence Matrix) is a measure of the probability of occurrence of two grey levels separated by a given distance in a given direction. It provides spatial information in the form of texture features that are useful for image classification (See \square NOTE 10). To add the operator, rightclick and go to Add \rightarrow Raster \rightarrow Image Analysis \rightarrow Texture Analysis \rightarrow GLCM. Connect the Calibration operator to it.

Read -> Subset -> Apply-Orbit-File -> ThermalNoiseRemoval -> Calibration -> GLCM

In the **GLCM** tab, keep all the default parameters.

TIP 3: If you want the processing to be completed faster, select **Window Size: 11 x 11**. For lithological classification we will only use the **Contrast**, **Homogeneity** and **GLCM Mean** features. In case you do not know which features you need, select them all and once you have the results, use the most appropriate.

Source Bands:	Sigma0_VH, Sigma0_VV	
Window Size:	9x9	
Angle:	ALL	-
Quantizer.	Probabilistic Quantizer	
Quantization Levels:	32	
Displacement:		4
🗹 Contrast		
Dissimilarity		
Homogeneity		
Angular Second	Moment	
Energy		
Maximum Proba	ability	
Entropy		
GLCM Mean		
GLCM Variance		
GLCM Correlatio	an	

NOTE 10: Texture measures can produce new images by making use of spatial information inherent in the image. It involves the information from neighbouring pixels which is important to characterize the identified objects or regions of interest in an image. The GLCM proposed by Haralik, 1973 is one of the most widely used methods to compute second order texture measures. Each feature models different properties of the statistical relation of pixels co-occurrence, estimated within a given moving window and along predefined directions and inter-pixel distances. (*SNAP Help*)

5.4.7 Speckle Filtering

SAR images have inherent salt and pepper like textures called speckles which degrade the quality of the image and make interpretation of features more difficult. To remove that, we apply **Speckle Filter** (See \frown NOTE 11). To add the operator, right-click and go to Add \rightarrow Radar \rightarrow Speckle Filtering \rightarrow Speckle-Filter. Connect the GLCM operator to it.

Read -> Subset -> Apply-Orbit-File -> ThermalNoiseRemoval -> Calibration -> GLCM -> Speckle-Filter

In the **Speckle-Filter** tab, keep all default parameters.

TIP 4: You can also decrease the Window Size or even select a different filter than Lee Sigma if it meets better the criteria for classifying your area of study. In that case, you will need to adjust accordingly the rest parameters of the filter you will use.

Read Subset	t Apply-Orbit-File ThermalNoiseRemoval Calibration GLCM Speckle-Filter	
Source Bands:	Sigma0_VH_Contrast Sigma0_VH_Dissimilarity Sigma0_VH_AbM Sigma0_VH_Energy Sigma0_VH_Entrgy Sigma0_VH_Entropy Sigma0_VH_Entropy Sigma0_VH_EntCopy	
Filter:	Lee Sigma	-
Number of Looks	5 1	+
Window Size:	7%7	
Sigma:	0.9	
Target Window Si	ize: 3x3	-

NOTE 11: Speckles are caused by random constructive and destructive interference of the de-phased but coherent return waves scattered by the elementary scatters within each resolution cell. Speckle noise reduction can be applied either by spatial filtering or multilook processing. (*SNAP Help*)

5.4.8 Terrain Correction

We need to convert the data that are still in radar geometry, into geographic coordinates. Moreover, this is necessary because the distances can be distorted in the SAR images, due to topographical variations of a scene and the tilt of the satellite sensor (See \square NOTE 12). To add the operator, right-click and go to Add \rightarrow Radar \rightarrow Geometric \rightarrow Terrain Correction \rightarrow Terrain-Correction. Connect the Speckle-Filter operator to it.

Read -> Subset -> Apply-Orbit-File -> ThermalNoiseRemoval -> Calibration -> GLCM -> Speckle-Filter -> Terrain-Correction

In the Terrain-Correction tab, set as:

Digital Elevation Model: SRTM 1Sec HGT (Auto Download) Keep the rest parameters as by default.

Read	Subset	Apply-Orbit-File	ThermalNoiseRemoval Calibration Gl	CM Speckle-Filter Terrain-Correction	
			Source Bands:	Sigma0_VH_Contrast Sigma0_VH_Dissimilarity Sigma0_VH_Homogeneity Sigma0_VH_Energy Sigma0_VH_Energy Sigma0_VH_MAX Sigma0_VH_GhtCopy Sigma0_VH_GLCMMean	
			Digital Elevation Model:	SRTM ISec HGT (Auto Download)	~
			DEM Resampling Method:	BILINEAR_INTERPOLATION	-
			Image Resampling Method:	BILINEAR_INTERPOLATION	•
			Source GR Pixel Spacings (az x rg):	10.0(m) x 10.0(m)	
			Pixel Spacing (deg).	8.983152841195215E-5	
			Map Projection:	WGS84(DD)	
			Mask out areas without elevation Output bands for:	Output complex data	
			Selected source band	DEM Latitude & Longitude	
			Incidence angle from ellipsoid	Local incidence angle Projected local incidence ar	ngle
			Apply radiometric normalization		
			Save Sigmab band	1	1
			Save Gammad band	see	
			Save Beta0 band		
			Auxiliary File (ASAR only).	La stra dilla Fissione	*

NOTE 12: The geometry of topographical distortions in SAR imagery is shown on the right. Here we can see that 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. (SNAP Help)



Finally, we need to add the Write operator to save the output of our processing graph. Right-click and go to Add \rightarrow Input-Output \rightarrow Write. Connect the Terrain-Correction operator to it.

Read -> Subset -> Apply-Orbit-File -> ThermalNoiseRemoval -> Calibration -> GLCM -> Speckle-Filter -> Terrain-Correction -> Write

In the Write tab, set as:

Target Product Name: Subset_S1A_IW_GRDH_1SDV_20190908_Orb_NR_Cal_GLCM_Spk_TC (we see that all suffixes from the operators added at the processing chain, have been added but we will shorten the name a bit).

Directory: /shared/Training/GEOL01_LithologicalClassification_Morocco_TutorialKit/Processing





Navigate to */shared/Training/GEOL01_LithologicalClassifi cation_Morocco_TutorialKit/Processing* folder Save the graph with the **File Name:** Processing_Graph_S1.

Then click **Run.**

The new product will appear at the **Product Explorer** window.

Go to the new product in the **Product Explorer** window, click + or **b** to expand the contents of the product, then expand **Bands** folder. We can see that the folder contains 20 bands, that refer to the 10 GLCM features for both VH and VV polarizations. Double click on a band, e.g. *Sigma0_VH_Contrast* to visualize it in the **View** window. You can explore the other bands as well.



5.4.9 Subset

We can see that the extent of the image is larger than the one of the Sentinel-2 subset (marked in red in the previous image) although we have used the exact coordinates. This is because we have performed the Subset before we have projected (assigned coordinate system) the product. We will now correct this by using a Subset again.

TIP 5: For this Subset we will use the **Geo Coordinates** mentioned at **5.3.2 Subset** chapter for the Sentinel-2 product, and we will save the product following the same steps.



Select the Subset_S1A_IW_GRDH_1SDV_2019 0908_Orb_NR_Cal_GLCM_Spk_TC product and go to Raster → Subset.

In the **Spatial Subset** tab, go to **Geo Coordinates** tab and set the following parameters:

North latitude bound:	29.481
West longitude bound:	-8.843
South latitude bound:	28.978
East longitude bound:	-8.317

Click OK.

The **subset_0_of_Subset_S1A_IW_GRDH_1SDV_20190908_Orb_NR_Cal_GLCM_Spk_TC** product, will appear at the **Product Explorer** window. Right click on it, select **Save Product**, then click **Yes** on the window that appears.

Navigate to */shared/Training/GEOL01_LithologicalClassification_Morocco_TutorialKit/Processing* path and **Save** it with the **File Name**:

Final_Subset_S1A_IW_GRDH_1SDV_20190908_Orb_NR_Cal_GLCM_Spk_TC

Then go to the subset at the **Product Explorer** window, right click on it, select **Close Product**, click no if a window pops up and then load in SNAP the Final saved subset. Open the following bands:



Sigma0_VH_Contrast Sigma0_VH_Homogeneity Sigma0_VH_GLCMMean Sigma0_VV_Contrast Sigma0_VV_Homogeneity Sigma0_VV_GLCMMean

Go to Window → Tile Evenly

These are the bands that will initially be used for the Unsupervised lithological Classification based on their results.

Additionally, **Sigma0_VV_Homogeneity** band has been chosen to be used for a second Unsupervised Classification to see if the results will be improved. This band will also be the one that will be used for the Supervised Classification. Explore more bands and select any that you consider more appropriate.

5.4.10 Unsupervised Classification

Go to Raster \rightarrow Classification \rightarrow Unsupervised Classification \rightarrow K-Means Cluster Analysis.

In the I/O Parameters tab set as:

Source Product: Final_Subset_S1A_IW_GRDH_1SDV_20190908_Orb_NR_Cal_GLCM_Spk_TC **Target Product Name:** Final_Subset_S1A_IW_GRDH_1SDV_20190908_Orb_NR_Cal_GLCM_Spk_TC_kmeans **Directory:** /shared/Training/GEOL01_LithologicalClassification_Morocco_TutorialKit/Processing

In the **Processing Parameters** tab, keep the **Number of clusters**, **Number of iterations** and **Random seed** as <u>by default</u>, and at the **Source bands names**, press Ctrl and <u>select only</u> the Sigma0_VH_Contrast, Sigma0_VH_Homogeneity, Sigma0_VH_GLCMMean, Sigma0_VV_Contrast, Sigma0_VV_Homogeneity and Sigma0_VV_GLCMMean bands, that have been mentioned before.

K-Means Cluster Analysis 🔹 💿 🗙	K-Mean:	s Cluster Analysis	1 + E ×
File Help	File Help		
VO Parameters Processing Parameters	I/O Parameters Pr	ocessing Parameters	
Source Product	Number of clusters:		14
Source product:	Number of iterations:		30
[3] Final_Subset_SIA_IW_GRDH_ISDV_20190908	Random seed:		31415
Target Product Name: GRDH_1SDV_20190908_Orb_NR_Cal_GLCM_Spk_TC_kmeans Save as: BEAM-DIMAP Directory: ogicalClassification_Morocco_TutorialKit/Processing	Source band names:	Sigma0_VV_Contrast Sigma0_VV_Dissimilarity Sigma0_VV_ASM Sigma0_VV_ASM Sigma0_VV_Energy Sigma0_VV_MAX Sigma0_VV_Entropy Sigma0_VV_Entropy	
☑ Open in SNAP	ROI-mask:		-
<u>B</u> un <u>C</u> lose		Run	<u>C</u> lose

Click Run. The new product will appear at the Product Explorer window. Close the previous views.

Now go to the **Final_Subset_S1A_IW_GRDH_1SDV_20190908_Orb_NR_Cal_GLCM_Spk_TC_kmeans** product at the **Product Explorer** window, expand it, then expand the **Bands** folder and double click on the **class_indices** band to visualize it.



Repeat the **K-Means Cluster Analysis Unsupervised Classification**. <u>Keep ALL parameters the same</u> as previously, <u>apart from the following</u>:

In the I/O Parameters tab change only the Target Product Name to:

Final_Subset_S1A_IW_GRDH_1SDV_20190908_Orb_NR_Cal_GLCM_Spk_TC_kmeans_VV_Hom

In the **Processing Parameters** tab <u>select only</u> the **Sigma0_VV_Homogeneity** band.

K-Means Cluster Analysis	÷ ×	K-Means	Cluster Analysis 🛛 🔶 🗉 🗙
File Help	File	Help	
1/O Parameters Processing Parameters	1 1/0	Parameters Pr	ocessing Parameters
Source Product	Nu	mber of clusters:	14
[3] Final_Subset_S1A_IW_GRDH_1SDV_2019	909 👻 Nu Rai	mber of iterations: ndom seed:	30
Target Product Name:			Sigma0_VH_GLCMCorrelation Sigma0_VV_Contrast Sigma0_VV_Dissimilarity
20190908_Orb_NR_Cal_GLCM_Spk_TC_km Save as: BEAM-DIMAP Directory:	neans_VV_Hom So	urce band names:	Sigma0_W_Homogeneity Sigma0_VV_ASM Sigma0_VV_Energy Sigma0_VV_MAX
calClassification_Morocco_TutorialKit/Pr	rocessing RO	I-mask:	Sigma0_W_Entropy
B	un <u>C</u> lose		<u>R</u> un <u>C</u> lose

Click **Run**. The new product will appear at the **Product Explorer** window.

Go to the new classified product Final_Subset_S1A_IW_GRDH_1SDV_20190908_Orb_NR_Cal_GLCM _Spk_TC_kmeans_VV_Hom product at the Product Explorer window, expand it, then expand the Bands folder and double click on the class_indices band to visualize it.

Go to **Window** \rightarrow **Tile Horizontally** and compare the results of the two classifications. We can see that when we classify our product based only on **Sigma0_VV_Homogeneity** band, the results look better and more precise, for this reason we use only this band for the supervised classification that follows.



5.4.11 Supervised Classification

Let's continue now to the supervised classification by importing the shapefiles with the geology of the area and the training data for each different lithology, as mentioned in *5.3.5 Supervised Classification* chapter. The shapefiles will be loaded on the **Final_Subset_S1A_IW_GRDH_1SDV_20190908_Orb_NR** _**Cal_GLCM_Spk_TC** product. Close the previously opened views.

Select the Final_Subset_S1A_IW_GRDH_1SDV_20190908_Orb_NR_Cal_GLCM_Spk_TC product at the Product Explorer window and import the shapefiles and the training data from */shared/Training/GEOL01_LithologicalClassification_Morocco_TutorialKit/AuxData* folder, as mentioned before in the *5.3.5 Supervised Classification* chapter.

Go to the **Final_Subset_S1A_IW_GRDH_1SDV_20190908_Orb_NR_Cal_GLCM_Spk_TC** product and expand the **Vector Data** folder. You will see that all the shapefiles we have imported are now in that folder as in the following image. **Right click** on the product and select **Save Product**, to save the imported data. Double-click on **Sigma0_VV_Homogeneity** band to open it in a View window.



The classifier we will use is again **Random Forest** Classifier.

Go to Raster \rightarrow Classification \rightarrow Supervised Classification \rightarrow Random Forest Classifier.

In the **ProductSet-Reader** tab, click on Analysis to **/shared/Training/GEOL01_LithologicalClassifi** cation_Morocco_TutorialKit/Processing and add this product: Final_Subset_S1A_IW_GRDH_1SDV_ 20190908_Orb_NR_Cal_GLCM_Spk_TC

In the Random-Forest-Classifier tab set as:

Select Train and apply classifier: newClassifier_S1 Keep Train on Vectors and Evaluate classifier selected



Keep Number of training samples and Number of trees as by default

In the Training vectors select all "geometry_xx_Polygon"

In the **Feature bands** <u>select only</u> Sigma0_VV_Homogeneity band.

In the **Write** tab set as:

Name: Final_Subset_S1A_IW_GRDH_1SDV_20190908_Orb_NR_Cal_GLCM_Spk_TC_RF_VV_Hom **Directory**: /shared/Training/GEOL01_LithologicalClassification_Morocco_TutorialKit/Processing

Click **Run**. The new product will appear at the **Product Explorer** window.

9	Random Forest Classifier	▼ Ξ ×	Random Forest Classifier
ProductSet-Reader Ran	dom-Forest-Classifier Write		ProductSet-Reader Random-Forest-Classifier Write
Classifier Train and apply classif	ier newClassifier_S1		Target Product
C Load and apply classif	ier	+ *	
Evaluate classifier Evaluate Feature Power Se	C Train on Raster Train on Vectors		
Number of training sample	Min Power Set Size: Max Power Set Size: 5000		
Vector Training Training vectors: geom geom geom geom	isty_10_Polygon isty_10_Polygon isty_12_Polygon isty_12_Polygon isty_14_Polygon isty_14_Polygon isty_2_Polygon isty_2_Polygon	-	Name: Pinal Subset SIA IN GROM ISOV 20190908 Orb NR. Cal. GLCM. Spk. TC. RF. VV. Hom Save as IREAM-DIMAP Directory: /shared/Training/GEDLD1_LthologicalClassification_Morocco_TutorialKit/Processing
Peature Selection Feature bands Sigm Sigm Sigm Sigm Sigm	a0 VH_GLCMCorrelation a0 VH_GLCMCorrelation a0 VM_Determination a0 VM. Homogeneity- a0 VM_Ant a0 VM_ANT a0 VM_ANT a0 VM_ANT a0 VM_Entropy		
	🕑 Help 🕞 Run		😢 Helo 🔃 Pum

Go to the **Final_Subset_S1A_IW_GRDH_1SDV_20190908_Orb_NR_Cal_GLCM_Spk_TC_RF_VV_Hom** product at the **Product Explorer** window, expand it, then expand the **Bands** folder and double click on the **LabelledClasses** band to visualize it. In case you see the shapefiles imported initially, go to *Vector Data* folder, select them, right-click and **Delete** them.



Open the class_indices band from Final_Subset_S1A_IW_GRDH_1SDV_20190908_Orb_NR_Cal_ GLCM_Spk_TC_kmeans_VV_Hom product as well, go to Window \rightarrow Tile Horizontally and compare the results of the two different classifications. You can zoom in to selected areas and see differences between the two outputs.



We see that the results from the Unsupervised Classification based on the *Sigma0_VV_Homogeneity* band, look better than those from the Supervised Classification. This happens because the training data we used, were the same as in the optical image. Since in this case the *Sigma0_VV_Homogeneity* band is more appropriate for lithological classification, we can create new training data based on this band and apply again the Random Forest Classification. The results will be much more accurate. The same can be done for Sentinel-2 products as well, if there are not auxiliary geological data of the area.

Now load in SNAP the following products, so that you can make comparisons for the classification results between Sentinel-1 and Sentinel-2 data and have them ready for exporting those you want to *.tif* and *.kmz* formats:

Subset_S2B_20190914_s2resampled_reprojected_kmeans Subset_S2B_20190914_s2resampled_reprojected_RF Subset_S2B_20190914_s2resampled_reprojected

5.5 Export products

Let's export the bands we want to visualise in **QGIS**. Select the appropriate band from the products at the **Product Explorer** window. Go to **File** \rightarrow **Export** \rightarrow **GeoTIFF**.

To all of them set in **Save In:** */shared/Training/GEOL01_LithologicalClassification_Morocco_Tutorial Kit/Processing* path. For the classified products, write at the **File Name** the full name of the product:

Subset_S2B_20190914_s2resampled_reprojected_kmeans Subset_S2B_20190914_s2resampled_reprojected_RF Final_Subset_S1A_IW_GRDH_1SDV_20190908_Orb_NR_Cal_GLCM_Spk_TC_kmeans Final_Subset_S1A_IW_GRDH_1SDV_20190908_Orb_NR_Cal_GLCM_Spk_TC_kmeans_VV_Hom Final_Subset_S1A_IW_GRDH_1SDV_20190908_Orb_NR_Cal_GLCM_Spk_TC_RF_VV_Hom

Then click Export Product.

For the **Subset_S2B_20190914_s2resampled_Reprojected** product, we only need to export the bands B4, B3 and B2 to have an RGB image in Natural Colours. For this, go to **File** → **Export** → **GeoTIFF**, click on **Subset**, go to **Band Subset** and <u>select only</u> B2, B3 and B4. Click **OK**, set the name of the output as **Subset_S2B_20190914_s2resampled_reprojected_B4_B3_B2** and click **Export Product**.

SNAP - Exp	ort Product	+ = ×		Specify Product Subset	, * 🗆 x
			Spatial Subset Ba	nd Subset Metadata Subset	
Save In: Processing	· @		() H1	Reflectance in band 81	1
Teres 1	er 14 110 1		N BZ	Reflectance in band 82	
Name	SizeModified	Subset	¥ B3	Reflectance in band B3	1
Final_Subset_S1A_IW_GRDH_1S	1/26/20 7:54 PM		₩ B4	Reflectance in band B4	
Final_Subset_S1A_IW_GRDH_1S	1/26/20 9:44 PM		85	Reflectance in band 85	
Final_Subset_S1A_IW_GRDH_1S	1/27/20 8:25 AM		0 B6	Reflectance in band B5	
Final_Subset_S1A_IW_GRDH_1S	1/27/20 9:42 AM		87	Reflectance in band B7	
S2B_20190914_s2resampled.d	1/26/20 1:58 PM		D BB	Reflectance in band BS	
S2B_20190914_s2resampled_2	1/31/20 3:04 PM		BBA	Reflectance in band BBA	
52B_MSIL2A_20190914_s2resa	1/28/20 7:26 AM		89	Reflectance in band 89	
Subset_SIA_IW_GRDH_1SDV_20	1/26/20 6:25 PM		811	Reflectance in band B11	
Subset_S2B_20190914_s2resa	1/26/20 2:39 PM		812	Reflectance in band 812	
	10000 200 000		auality ant	Aerosol Optical Thickness	
	1.1.1	1	ausity wwp	Water Vapour	
File Name: Subset S2B 20190914 s2	resampled reprojected B4 B3 E	32.tif	aulty cloud confd	Inca Cloud Confidence	Ŧ
Files of Type GenTIFE product (* tif * tiff			Select all Sel	ect none	
There of Take. Teccult bigman is the state of				Estim	ated, raw storage size: 93 0M
	Export Broduct	Cancel			
	Export Product	Carret		1	QK <u>Cancel</u> <u>H</u> elp

In order to export the views you need for visualization in Google Earth, just **right click** on the opened View window in SNAP and select **Export View as Google Earth KMZ**. Define the name and the path as mentioned above.

Then close SNAP. If a window appears asking to save the changes, click No.

6 Visualization in QGIS

Open QGIS Desktop application. First go to Web \rightarrow OpenLayers plugin \rightarrow Bing Maps \rightarrow Bing Aerial to add a basemap (See $\stackrel{\frown}{=}$ NOTE 13).

Then navigate to */shared/Training/GEOL01_LithologicalClassification_Morocco_TutorialKit/Pro cessing* folder by opening a folder window, and drag and drop one by one the following .*tif* files you have exported before:

Subset_S2B_20190914_s2resampled_reprojected_B4_B3_B2.tif Subset_S2B_20190914_s2resampled_reprojected_kmeans.tif Subset_S2B_20190914_s2resampled_reprojected_RF.tif Final_Subset_S1A_IW_GRDH_1SDV_20190908_Orb_NR_Cal_GLCM_Spk_TC_kmeans.tif Final_Subset_S1A_IW_GRDH_1SDV_20190908_Orb_NR_Cal_GLCM_Spk_TC_kmeans_VV_Hom.tif Final_Subset_S1A_IW_GRDH_1SDV_20190908_Orb_NR_Cal_GLCM_Spk_TC_RF_VV_Hom.tif

NOTE 13: In case the **OpenLayers** plugin is not installed, click on **Plugins** → **Manage and Install Plugins.** Select the *"All"* tab on the left-side panel and write "**OpenLayers plugin**" on the search box. Select the plugin on the list and click "Install Plugin". Restart QGIS to finalize the installation.

Deselect them all, apart from the **Subset_S2B_20190914_s2resampled_reprojected_B4_B3_B2.tif** and the **Bing Aerial**. Right-click on the selected product and click on **Zoom to Layer**.

Navigate to */shared/Training/GEOL01_LithologicalClassification_Morocco_TutorialKit/Auxdata/ Geology_Morocco* folder and load in QGIS the **FINAL_GEOLOGY.shp**. Move it on the top of all layers.

1		Layer Properties - FINAL_GEOLOGY Style					
X General	Categoria	zed		2			
💐 Style	Column	abe CODE_DE	S_1			3 •	
abs Labels	Symbol				Change		
Fields	Color ramp	Random colo	ors			×	Edit
 Rendering Display Actions Joins Joins Diagrams Metadata Variables 	Symbol 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9	✓ Value Legend SEDIME SEDIMENTARY ROCKS PROTEROZOIC UPPER SEDIME SEDIMENTARY ROCKS CAMBRIAN LOWER SEDIME SEDIMENTARY ROCKS CAMBRIAN MIDDLE SEDIME SEDIMENTARY ROCKS DEVONIAN LOWER SEDIME SEDIMENTARY ROCKS DEVONIAN LOWER SEDIME SEDIMENTARY ROCKS FOCUNIAN MIDDLE - UPPER SEDIME SEDIMENTARY ROCKS HOLOCENE FLUVIATILE SEDIME SEDIMENTARY ROCKS ORDOVICIAN UPPER SEDIME SEDIMENTARY ROCKS ORDOVICIAN UPPER SEDIME SEDIMENTARY ROCKS PLEISTOCENE Continental SEDIME SEDIMENTARY ROCKS PLEISTOCENE Continental				Advanced •	
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	Layer blendir Feature blend I Draw effer Control fe Style	ng mode ding mode cts ature renderin	Normal Normal	1	ок	Cancel An	oly Help

Right-click on the selected Sentinel-2 product and go to **Properties**.

At the Style tab select Categorized

At the Column: CODE_DES_1

Click on Classify.

Set the Layer transparency to 50

Finally click OK.

You can select and deselect the layers, set them under certain Transparency, see the classification results and compare it with the geological maps or other auxiliary data.



7 Extra Steps

7.1 Visualization in Google Earth

Google Earth is not pre-installed in RUS VMs and if you want to visualise the results, you need to download them to your local computer. We have already exported the results to **KMZ** format. Download the following products and then load them in Google Earth:

Subset_S2B_20190914_s2resampled_reprojected_B4_B3_B2.kmz Subset_S2B_20190914_s2resampled_reprojected_kmeans.kmz Subset_S2B_20190914_s2resampled_reprojected_RF.kmz Final_Subset_S1A_IW_GRDH_1SDV_20190908_Orb_NR_Cal_GLCM_Spk_TC_kmeans.kmz Final_Subset_S1A_IW_GRDH_1SDV_20190908_Orb_NR_Cal_GLCM_Spk_TC_kmeans_VV_Hom.kmz Final_Subset_S1A_IW_GRDH_1SDV_20190908_Orb_NR_Cal_GLCM_Spk_TC_RF_VV_Hom.kmz



Example of Subset_S2B_20190914_s2resampled_reprojected_kmeans.kmz image in Google Earth.

7.2 Download files from VM

In your VM, press Ctrl+Alt+Shift.

A pop-up window will appear on the left side of the screen. Click on the bar below **Devices**, navigate to the folders you have saved the files you want to download and **double click** on them. The downloading process to your local computer will start automatically.

Once the KMZ files have been downloaded, you can load and visualize them in **Google Earth**.



THANK YOU FOR FOLLOWING THE EXERCISE!

8 Further reading and resources

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- FAL, S., MAANAN, M., BAIDDER, L., Rhinane, H., 2019. "The contribution of Sentinel-2 satellite images for geological mapping in the south of Tafilalet basin (Eastern Anti-Atlas, Morocco)" The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XLII-4/W12, 2019 <u>https://doi.org/10.5194/isprs-archives-XLII-4-W12-75-2019</u>
- Soulaimani A. & Burkhard M. 2008. Geological Society, London, Special Publications, 297, 433-452, 1 January 2008 <u>https://doi.org/10.1144/SP297.20</u>
- <u>https://sentinel.esa.int/web/sentinel/missions/sentinel-1</u> Sentinel-1 Mission
- <u>https://sentinel.esa.int/web/sentinel/missions/sentinel-2</u> Sentinel-2 Mission
- <u>http://antimonyworld.com/index/documents</u> Geological Map of Morocco

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