

TRAINING KIT – LAND10

RICE MAPPING WITH SENTINEL-1 Case Study: Vietnam, 2018









Research and User Support for Sentinel Core Products

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The following training material has been prepared by Serco Italia S.p.A. within the RUS Copernicus project.

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1 Introduction to RUS

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 detect rice using a dense time-series of Sentinel-1 GRD products as input data over an area in Vietnam.

2 Rice mapping – background



According to the International Rice Research Institute (IRRI), rice, wheat, and maize are the three leading food crops in the world; together they directly supply more than 50% of all calories consumed by the entire human population. Wheat is the leader in area harvested each year with 214 million ha, followed by rice with 154 million ha and maize with 140 million ha. Human consumption accounts for 85% of total production for rice, compared with 72% for wheat and 19% for maize.

Rice fields in the south of Spain Ric

^{spain} Rice is also the most important crop to millions of small

farmers who grow it on millions of hectares throughout the region, and to the many landless workers who derive income from working on these farms.

A few years ago, the European Union (EU) started an ambitious program, Copernicus, which includes the launch of a new family of earth observation satellites known as Sentinels. Amongst other applications, this new generation of satellites will improve the identification, mapping, assessment, and monitoring of crops and their dynamics at a range of spatial and temporal resolutions.

3 Training

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

The Training Code for this tutorial is LAND10. If you wish to practice the exercise described below within the RUS Virtual Environment, register on the RUS portal and open a User Service request from Your RUS service > Your dashboard.

3.1 Data used

- 24 Sentinel-1A images acquired from March until December 2018 [downloadable at <u>https://scihub.copernicus.eu/</u> using the .meta4 file provided in the *Original* folder of this exercise]
- Pre-processed data stored locally @/shared/Training/LAND10_RiceMapping_Vietnam/AuxData/

3.2 Software in RUS environment

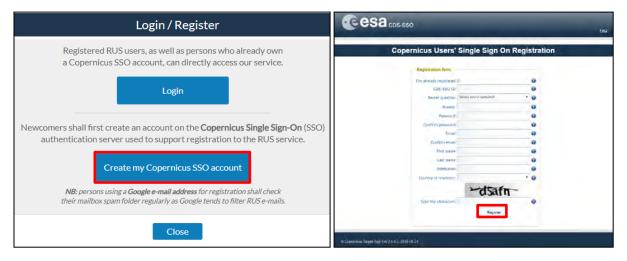
Internet browser, SNAP + GPT + S1 Toolbox + QGIS

4 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	🕼 🚜 💽 Login/Register s
The RUS Service * The RUS Offer * The RUS Library * The RUS Community *	
	Seath
	News from RUS
The second se	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
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 third enail sent by the Copernicus vervice. We advise you to consult this document and this page to facilitate your registration procedure. REGISTER COPERNICUS SSO account Users who already have a COPERNICUS SSO account can login here: Login Close	CDS-SSO ID Password Max Idle Time Max Session Time	half a day Until browser close Login Reset Eorgot your password?	¥ ¥	00000

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

	RUS Research and Gene User Support			Here Travil 🛔
(m)s n	e RUSService + The RUS C Do you	a want to subscribe for a new RUS acc	ount?	
	Your ESA-SSO sub	scription data:	You are for	ng Hand - Your D. Storten
* Your	RUS service Login			Q
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- You	corofile displays your person Last Name	The second se	US	
	Email	and the second se	Est Forirm - Strasb	ourg - 28 & 29 Nov.
- You	dashboard allows you'ld an Organization	and the second s	est-21 & 22 Nov.	ana l
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		Additional subscription information		
			vcier Velocity - 8 N	
	Please complete th	e following information:		76 Outobes 2018
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	RUS service? Select one or more h	colleagues tems newsletter	Hum - Pokind - 6.1	10.6.17 Nov. 2018
		conference	itton - Toulouse-	26-5-27 Oct. 2018
		social media other		
	Institution type	- Select one item	🗸 nda	
	Phone number Italy (IT):	+39	prestops	1 Star
	Title	- Select one item	×	

5 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** \rightarrow **Your Dashboard**.

CORRUS Research and User Support	~8 # B	
The RUS Service * The RUS Offer * The RUS Library * The RUS Con	nmunity Vour RUS servic	
Your RUS service	Your dashboard	ami Q
 This section gathers pages related to your RUS services: Your profile: displays your personal information linked to your ESA SSO and Your dashboard: Illows you to access your private dashboard, Your training: allows you to register to a training session you have been invited to your the private dashboard. 	d RUS accounts,	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 ^a AskRUS - Sentinel-1 ^a - 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	Helio, Miguel 😩
The RUS Service * The RUS Offer * The RUS Library * The RUS Community * 👯 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.

Step 1/3 Your experience	
Please help us learn more about your background by answering a few que information will be stored in your User Profile.	estions, Ti
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, please select yo (hold down CTRL key for multiple selections).	our choice
HAZA01 - Flood Mapping in Malawi	
HAZA02 - Burned Area Mapping in Portugal HYDR01 - Water Bodies Mapping over Northern Poland	- 1
LAND01 - Crop Mapping in Seville	
LAND04 - Land Monitoring in Cyprus OCEA01 - Ship Detection in Guif of Trieste	

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

'his is a collection of information selected 'ou can go back and edit this information		
General information on your request:		
Years of experience in Remote Sensing	5-10 years	
Downloaded Copernicus data? Handled/processed Copernicus data?	1	
Webinar codes	V HAZA02, LAND04	
About your RUS project:	hazadz, zarody	
Thematicarea	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	4	
S1 - Polarisation	a	
S1 - Orbit direction		
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	-4,6730	
Reference polygons	-2.7203	
Data acquisition date(s):		
None		
Additional data specifications		

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 Servie	ce					2	Chat with Support Desk
		Date of						
Project Name	ID	submission	Status		Actions		Virtual	Environment
S		1000		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.

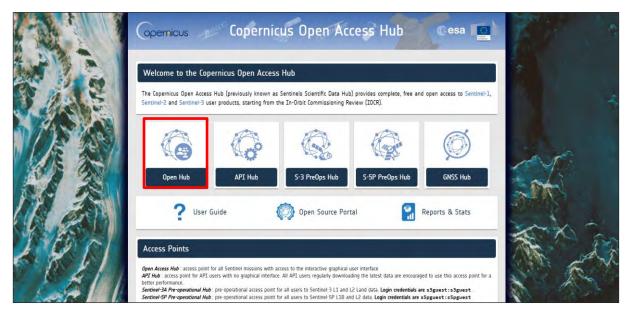


6 Step by step

6.1 Data download – ESA SciHUB

Before starting the exercise, make sure you are registered in the Copernicus Open Access Hub so that you can access the free data provided by the Sentinel satellites.

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



Go to *Open Hub*. If you do not have an account, sign up in the upper right corner, fill in the details and click register.

Copernicus Op	en Access Hub	
Register n	ew account	
Sentinel data access is free and open to all.		
On completion of the registration form below you will receive an e-mail with a link to valida Username field accepts only aphanumenic characters plus "", "s", "_a", and ".".	te your e-mail address. Following this you can start to download the data.	_
Firetrame.	Lasijiame	
Username		
Parsword	Confirm Password	
5-mai	Continn E-Inau	
Select Domain •		
Select Usage		
Select Country.		
By registering in this website you are deemed	to have accepted the T&C for Sentinei data use.	
		REGISTER

You will receive a confirmation email on the e-mail address you have specified: open the email and click on the link to finalize the registration.

Once your account is activated – or if you already have an account – log in.

6.2 Download data

In this exercise, we will analyze 24 Sentinel-1A images during 2018. The following table shows the date and reference of the images that will be used:

SATELLITE	DATE	IMAGE ID
	2018-03-07	S1A_IW_GRDH_1SDV_20180307T224528_20180307T224553_020915_023E2F_F92F
	2018-03-19	\$1A_IW_GRDH_1\$DV_20180319T224528_20180319T224553_021090_0243B4_2FEF
	2019-03-31	S1A_IW_GRDH_1SDV_20180331T224528_20180331T224553_021265_024942_546B
	2018-04-12	S1A_IW_GRDH_1SDV_20180412T224529_20180412T224554_021440_024EB3_0516
	2018-04-24	S1A_IW_GRDH_1SDV_20180424T224529_20180424T224554_021615_025428_1B32
	2018-05-06	S1A_IW_GRDH_1SDV_20180506T224530_20180506T224555_021790_0259B4_0789
	2018-05-18	\$1A_IW_GRDH_1\$DV_20180518T224530_20180518T224555_021965_025F45_05AD
	2018-05-30	S1A_IW_GRDH_1SDV_20180530T224531_20180530T224556_022140_0264E6_8978
	2018-06-11	S1A_IW_GRDH_1SDV_20180611T224532_20180611T224557_022315_026A59_BBF6
	2018-06-23	S1A_IW_GRDH_1SDV_20180623T224532_20180623T224557_022490_026F94_1CA0
	2018-07-05	S1A_IW_GRDH_1SDV_20180705T224533_20180705T224558_022665_0274AF_03A1
Sentinel-1A	2018-07-17	S1A_IW_GRDH_1SDV_20180717T224534_20180717T224559_022840_027A09_D025
Sentimeria	2018-08-10	S1A_IW_GRDH_1SDV_20180810T224535_20180810T224600_023190_02850C_4510
	2018-08-22	S1A_IW_GRDH_1SDV_20180822T224536_20180822T224601_023365_028AB2_F68E
	2018-09-03	S1A_IW_GRDH_1SDV_20180903T224537_20180903T224602_023540_029043_3D7A
	2018-09-15	S1A_IW_GRDH_1SDV_20180915T224537_20180915T224602_023715_0295DF_3261
	2018-09-27	S1A_IW_GRDH_1SDV_20180927T224537_20180927T224602_023890_029B8C_2691
	2018-10-09	S1A_IW_GRDH_1SDV_20181009T224538_20181009T224603_024065_02A150_C5FB
	2018-10-21	\$1A_IW_GRDH_1\$DV_20181021T224538_20181021T224603_024240_02A700_E03C
	2018-11-02	S1A_IW_GRDH_1SDV_20181102T224538_20181102T224603_024415_02ACCD_DD65
	2018-11-14	\$1A_IW_GRDH_1\$DV_20181114T224537_20181114T224602_024590_02B33B_A620
	2018-11-26	S1A_IW_GRDH_1SDV_20181126T224537_20181126T224602_024765_02B9AA_C6AC
	2018-12-08	S1A_IW_GRDH_1SDV_20181208T224536_20181208T224601_024940_02BF81_757D
	2018-12-20	S1A_IW_GRDH_1SDV_20181220T224536_20181220T224601_025115_02C5D5_0E2A

To improve the data acquisition process, we will use a download manager (See \square NOTE 1) that will take care of downloading all products that will be used. The metadata of the Sentinel products are saved in a *products.meta4* file created using the 'Cart' option of the Copernicus Open Access Hub.

NOTE 1: A download manager is a computer program dedicated to the task of downloading possibly unrelated stand-alone files from (and sometimes to) the Internet for storage. For this exercise, we will use aria2. Aria2 is a lightweight multi-protocol & multi-source command-line download utility. More info at: https://aria2.github.io/

The *products.meta4* file containing the links to the Sentinel-1 products to be downloaded can be created following the methodology explained in \square NOTE 2. Follow the instructions and create your cart file, download it and save it in the following path:

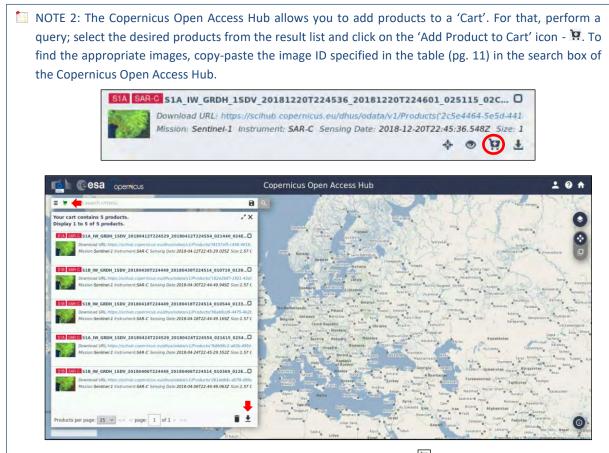
Path: /shared/Training/LAND10_RiceMapping_Vietnam/Original/

Before using the downloading manager and the .meta4 file, let's test if *aria2* is properly installed in the Virtual Machine. To do this, open the Command Line (in the bottom of your desktop window) and type the following and press *Enter*:

aria2c

If *aria2* is properly installed, the response should be as follows. If the response is '-bash aria2c: command not found' it means aria2 is not installed (See NOTE 3).





To view the products present in the cart just click anytime car icon - \square - on the top left corner of the screen. To download the cart click on "Download Cart" on the bottom right of the page. A download window will pop up, asking the user confirmation to save a .meta4 file named *'products.meta4'*. This file contains all the metalinks of the products.

NOTE 3: If (and only if) the response is '-bash aria2c: command not found', you need to install aria2. In the command line, type: sudo apt-get install aria2
 When requested, type: Y
 Once finished, test the installation as explained before.

Once *aria2* is ready to use, we can start the download process. For that, we need to navigate to the folder where the *products.meta4* file is stored. Type the following command in the terminal and run it (press *Enter*).

cd /shared/Training/LAND10_RiceMapping_Vietnam/Original/ Terminal - rus@front-usr-231: /shared/Training/LAND10_RiceMapping_Vietnam/Original Rice Edit View Terminal Tabs Help rus@front-usr-231:~\$ cd /shared/Training/LAND10_RiceMapping_Vietnam/Original/ rus@front-usr-231:/shared/Training/LAND10_RiceMapping_Vietnam/Original\$

Next, type the following command (in a single line) to run the download tool. Replace *username* and *password* (keep the quotation marks) with your login credentials for Copernicus Open Access Hub (COAH). Do not clear your cart in the COAH until the download process is finished.

```
aria2c --http-user='username' --http-passwd='password' --check-certificate=
false --max-concurrent-downloads=2 -M products.meta4
```

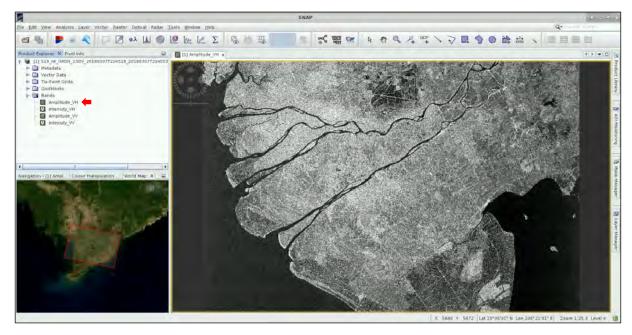
The Sentinel products will be saved in the same path where the *products.meta4* file is stored.

6.3 Sentinel-1 SNAP GPT Preprocessing

Once the Sentinel-1 images are downloaded, we need to run some pre-processing steps before they can be used for our final purpose. For this, we will use the SNAP software. In *Applications -> Processing* open **SNAP Desktop**; click **Open product** *(*, navigate to the following path and open the first S1 image (2018-03-07).

Path: /shared/Training/LAND10_RiceMapping_Vietnam/Original/

The opened product will appear in Product Explorer. Click + to expand the contents of the first image, then expand the *Bands* folder and double click on *Amplitude_VH* to visualize it. (See NOTE 4).



To process this and the other Sentinel-1 images, we will take advantage of the batch processing option available in SNAP GPT. In this way, we can define a specific processing chain and apply it to

several images in an automatic way. This allows reducing processing time and storage requirement since no intermediate steps are created. Only the final product is physically saved.

Before running batch processing, it is necessary to create a graph containing all the processing steps. Go to *Tools -> Graph Builder*. So far, the graph only has two operators: *Read* (to read the input) and *Write* (to write the output). By right-clicking on the white space at the top panel, you can add an operator while a corresponding tab is created and added at the bottom panel. To avoid confusion, right click on the *Write* operator and delete it.



6.3.1 Read

By default, Graph Builder will use the image we have previously opened in SNAP as the input image for the processing chain. Since we will be changing this parameter later in GPT, there is no need to change anything.

Read		
Source Product Name:		
[1] SIA_IW_GRD	H_1SDV_20180307T224528_20180307T224553_020915_023E2F_F92F	
Data Format	Any Format	

6.3.2 Apply orbit file

The first step of our Sentinel-1 pre-processing chain will update the orbit metadata (See NOTE 4) of the product to provide accurate satellite position and velocity information. To add the operator to our graph, right click and navigate to Add -> RADAR -> Apply-Orbit-File. 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. In the corresponding tab, check the option *Do not fail if new orbit file is not found*.

NOTE 4: The orbit state vectors provided in the metadata of a SAR product are generally not accurate and can be refined with the precise orbit files, which are available days-to-weeks after the generation of the product. 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. (*SNAP Help*)

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

6.3.3 Thermal Noise Removal

Next, we will remove the thermal noise (See NOTE 5). To add the operator to our graph, right click and navigate to Add -> RADAR -> Radiometric -> ThermalNoiseRemoval. In the corresponding tab, leave all the parameters for this operator as default. Connect the ThermalNoiseRemoval operator with the Apply-Orbit-File operator by clicking to the right side of the Apply-Orbit-File operator and dragging the red arrow towards the ThermalNoiseRemoval operator.

NOTE 5: Thermal noise in SAR imagery is the background energy that is generated by the receiver itself. (*SNAP Help*) It skews the radar reflectivity to towards higher values and hampers the precision of radar reflectivity estimates. Level-1 products provide a noise LUT for each measurement dataset, provided in linear power, which can be used to remove the noise from the product.

Read Apply-Orbit-File ThermalNoiseRemoval

Read	Apply-Orbit-File	ThermalNoiseRemoval
Polarisat	tions:	VH
		VV
Rem	ove Thermal Noise	
Re-In	troduce Thermal N	loise

6.3.4 Calibration

Now, we can perform the Radiometric calibration. The objective of SAR calibration is to provide imagery in which the pixel values can be directly related to the radar backscatter. Though uncalibrated SAR imagery is sufficient for qualitative use, calibrated SAR images are essential to quantitative use of SAR data (See NOTE 6). To add the operator to our graph, right click and navigate to Add -> RADAR -> Radiometric -> Calibration. In the corresponding tab, leave all the parameters for this operator as default. Connect the Calibration operator with the ThermalNoiseRemoval operator by clicking to the right side of the ThermalNoiseRemoval operator and dragging the red arrow towards the Calibration operator.

Read - Apply-Orbit-File - ThermalNoiseRemoval - Calibration

NOTE 6: Typical SAR data processing, which produces level-1 images, does not include radiometric corrections and significant radiometric bias remains. 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. (*SNAP Help*)

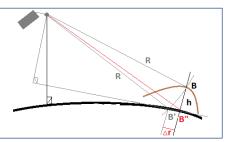
Read Apply-Orbit-File	ThermalNoiseRemoval Calibration
Polarisations:	VH VV
🗍 Save as complex putput	
🖌 Output sigma0 band	
Output gamma0 band	
Output beta0 band	

6.3.5 Terrain correction

Our data are still in radar geometry, moreover due to topographical variations of a scene and the tilt of the satellite sensor, the distances can be distorted in the SAR images. Therefore, we will apply terrain correction to compensate for the distortions and reproject the scene to geographic projection (See INOTE 7). To add the operator to our graph, right click and navigate to Add -> RADAR -> Speckle Filtering -> Speckle-Filter. In the corresponding tab, make sure you select UTM / WGS 84 (Automatic) as Map Projection. Uncheck the option Mask out areas without elevation (this option is only for visualization purposes). Connect the Terrain-Correction operator with the Calibration operator by clicking to the right side of the Calibration operator and dragging the red arrow towards the Terrain-Correction operator.

Read Apply-Orbit-File ThermalNoiseRemoval Calibration Terrain-Correction

NOTE 7: 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)



Source Bands:	Sigma0_VH Sigma0_VV				
Digital Elevation Model:	SRTM 3Sec (Auto Download)	-			
DEM Resampling Method:	BILINEAR_INTERPOLATION	-			
Image Resampling Method:	BILINEAR_INTERPOLATION	-			
Source GR Pixel Spacings (az x rg):	10.0(m) × 10.0(m)	(
Pixel Spacing (m):	10.0				
Pixel Spacing (deg):	8.983152841195215E-5				
Map Projection:	WGS84(DD)	-			
				Map Projection	
Mask out areas without elevatio	Output complex data				
Mask out areas without elevatio Output bands for:	Cutput complex data		Coordinate Reference System	m (CRS)	
Output bands for:	DEM Latitude & Longitude		Coordinate Reference System	m (CRS)	
Output bands for: Selected source band		e angle	Custom CRS	m (CRS)	
Output bands for: Selected source band Incidence angle from ellipsoid	DEM Latitude & Longitude	e angle	Custom CRS Geodetic datum		1
Output bands for; Selected source band Incidence angle from ellipsoid Apply radiometric normalization	DEM Latitude & Longitude	e angle	Custom CRS Geodetic datum	m (CRS) WGS B4 (Automatic)	
Output bands for: Selected source band Incidence angle from ellipsoid Apply radiometric normalization Save Sigma0 band	DEM Latitude & Longitude	e angle	Custom CRS Geodetic datum		Projectors Parametera,
Output bands for; Selected source band Incidence angle from ellipsoid Apply radiometric normalization	DEM Latitude & Longitude	e angle	Custom CRS Geodetic datum Projection: UTM /		
Output bands for: Selected source band Incidence angle from ellipsoid Apply radiometric normalization Save Sigma0 band	DEM Latitude & Longitude	e angle	Custom CRS Geodetic datum		Projection Parametera. Selad

6.3.6 Subset

To investigate the capabilities of the different polarizations to detect rice growth, we will save as independent files the VV and VH polarizations. In this way we will be able to analyse the temporal evolution of the backscatter coefficient for every channel independently. At the same time, we will reduce the original extent of the image. This will reduce the size of the product and processing time.

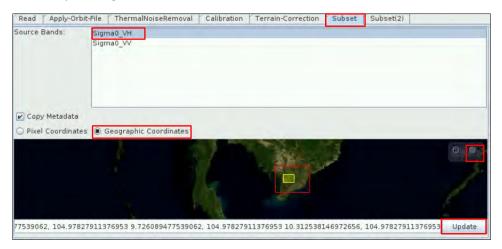
For this, add two *Subset* operators. Right click and navigate to *Add -> Raster -> Geometric -> Subset*. Next, connect the *Subset* and *Subset(2)* operators with the *Terrain-Correction* operator by clicking to the right side of the *Terrain-Correction* operator and dragging the red arrow towards the *Subset* operators.

Read Apply-Orbit-File ThermalNoiseRemoval Calibration Terrain-Correction Subset	

In the first *Subset* tab, select the band *Sigma0_VH* choose the option *Geographic Coordinates*. Paste the following Well-Known Text to define to subset area. Then, click *Update* and visualize the area (click on the zoom icon - ^{SSD}).

```
POLYGON ((104.97827895096175 10.312537866158335, 105.80329350853457 10.311540351754 259, 105.80185401875113 9.726089296805576, 104.97831787983566 9.727029083669775, 10 4.97827895096175 10.312537866158335))
```

In the second *Subset(2)* tab, select the band *Sigma0_VV* and choose the option *Geographic Coordinates*. Paste again the same Well-Known Text to define to subset area. Then, click *Update* and visualize the area by clicking on the zoom icon.



Read Apply-Or	rbit-File ThermalNoise	Removal Calibra	tion Terrain-Corr	ection Subset S	ubset(2)	
Source Bands:	Sigma0_VH					
	Sigma0 VV					
🖌 Copy Metadata						
O Pixel Coordinat	tes 🖲 Geographic Coor	dinates				
		100	68 L 107 4			Contraction of
			and the second second			and the
						27
1376953 9.726089	9477539062, 104.978279	11376953 10.3125	38146972656, 104.9	97827911376953 10.3	12538146972656))	Update

6.3.7 Write

Finally, add the *Write* operators. Right click and navigate to *Add -> Input-Output -> Write*. Add two *Write* operators. Although we will change the output name and output directory in GPT, to avoid confusion set the output directory to the following path.

Path: /shared/Training/LAND10_RiceMapping_Vietnam/

Read	Apply-Orbit-File	ThermalNoiseRemoval	Calibration	Terrain-Correction	Subset	Subset(2)	Write	Write(2)
	Product		1 constants	L verveni seti esteri	1		1	
Name:								
	SIA_IW_GRDH_IS	DV_20180307T224528_20	180307T22455	3_020915_023E2F_F9	2F_Orb_NR	Cal_TC		
Subset	t_S1A_IW_GRDH_1S s: BEAM-DIMAP	DV_20180307T224528_20	180307T22455	3_020915_023E2F_F9	2F_Orb_NR	_Cal_TC		
Subset			180307T22455	3_020915_023E2F_F9	2F_Orb_NR	_Cal_TC		

Once the graph is completed, click on the *Save* icon located on the lower part of the graph builder. Navigate to the following path and save the graph as *S1_Orb_Thm_Cal_TC_sub.xml*. After saving the graph, close the Graph Builder window and SNAP.

Path: /shared/Training/LAND10_RiceMapping_Vietnam/AuxData/

6.3.8 Graph Processing Tool | GPT

In this exercise, we will use the SNAP GPT command line interface (which can be found in the bin folder of the Sentinel Toolbox installation) to process our Sentinel-1 products. This tool is used to execute SNAP raster data operators in batch-mode. The operators can be used stand-alone or combined as a directed acyclic graph (DAG). Processing graphs are represented using XML files. Using the GPT provides a convenient way to use operators in a headless environment or in batch mode (See INOTE 8).

NOTE 8: To run an operator using the GPT, it is necessary to indicate the path to the source product(s), to the target product and to other operator-specific parameters which might be mandatory or specific. As for complex operators the call from the command line can easily become confusing, it is also possible to pass the required settings in form of a xml-encoded graph file. It will then suffice to just pass the graph as parameter to the GPT.

To access GPT, open a *Terminal* window by clicking on its icon - E - write the following text and press enter (See NOTE 9).

```
gpt
```

A CONTRACTOR OF THE OWNER	Terminal - rus@front-uir-231/ -	1.4 -
ite Edit View Terminal	Tairs timp	
IS@front-USF-231:- IFO: org.esa.snap, ernal tool adapter	core,gpf,operators.tooladapter,ToolAdapterIO:	Initializing ex
	bx.dataio.gdal.activator.GDALDistributionInst LIBRARY_PATH is not set. It must contain the	
	ile> [options] [<source:file-1> <source.file-< th=""><td>2>1</td></source.file-<></source:file-1>	2>1
operators can be (DAG). Processing	I to execute SNAP raster data operators in bat used stand-alone or combined as a directed ac graphs are represented using XML. More info s, the operator API, and the graph XML format mentation.	yclic graph about
rguments: <op> <graph-file> <source-file-i></source-file-i></graph-file></op>	Name of an operator. See below for the list Operator graph file (XML format). The <i>th source product file. The actual n file arguments is specified by <op>. May be</op></i>	umber of source

NOTE 9: Note that in the RUS Copernicus Virtual Machines, the gpt command is an environment variable and can be called directly from the terminal. If this is not your case, you will have to set it or specify the path to gpt to call the program.

To process our images in batch mode using GPT we need to change the input and output reference to specific input/output files by variables (See \square NOTE 10). Navigate to the following path, right click on the graph file (called *S1_Orb_Thm_Cal_TC_sub.xml*) and select *Open With -> Open with Mousepad*. Once the *xml* file is opened, click on *View -> Line Numbers*.

Path: /shared/Training/LAND10_RiceMapping_Vietnam/AuxData/

NOTE 10: The graph created in the *Graph Builder* tool in SNAP is an xml document that contains the different operators that have been added. The xml document is structured in a way that all the information of a specific operator is specified between the <node> and </node> tags.

In **line 7**, delete only the path to the input image highlighted in orange (do not remove *<file>* and *</file>*) and write *\$input1*. Line 7 should look like this (highlighted in green):

<file>\$input1</file>

1	S1_Orb_Thm_Cal_TC_sub.xml - Mousepad	(* _ 0 ×
File E	Edit Search View Document Help	
1 <g< td=""><td>raph id="Graph"></td><td>1</td></g<>	raph id="Graph">	1
2	<version>1.0</version>	
3 .	<node id="Read"></node>	
4	<operator>Read</operator>	
5	<sources></sources>	
6	<pre><pre><pre>com.bc.ceres.binding.dom.XppDomElement"></pre></pre></pre>	
7	<pre><file>/home/rus/shared/Training/LAND10 RiceMapping Vietnam/Original/</file></pre>	
51	A IW GRDH 1SDV 20180307T224528 20180307T224553 020915 023E2F F92F.zip	
8		
0		
9	ridge	
9	S1_Orb_Thm_Cal_TC_sub_GPT.xml - Mousepad	+ _ = ×
2		+ ± = ×
/ File E 1 <g< td=""><td>S1_Orb_Thm_Cal_TC_sub_GPT.xml - Mousepad Edit Search View Document Help raph id="Graph"></td><td>+ <u>+</u> = ×</td></g<>	S1_Orb_Thm_Cal_TC_sub_GPT.xml - Mousepad Edit Search View Document Help raph id="Graph">	+ <u>+</u> = ×
File E	S1_Orb_Thm_Cal_TC_sub_GPT.xml - Mousepad Edit Search View Document Help raph id="Graph"> <version>1.8</version>	+ = = ×
File E	S1_Orb_Thm_Cal_TC_sub_GPT.xml - Mousepad Edit Search View Document Help raph id="Graph">	+ _ = ×
File E	S1_Orb_Thm_Cal_TC_sub_GPT.xml - Mousepad Edit Search View Document Help raph id="Graph"> <version>1.0</version> <node id="Read"> <operatorsread< operator=""></operatorsread<></node>	+ <u>-</u> i ×
File E 1 < g 2 -	S1_Orb_Thm_Cal_TC_sub_GPT.xml - Mousepad Edit Search View Document Help raph id="Graph"> <version>1.0</version> <vdet id="Read"></vdet>	+ <u>-</u> = ×
File E 1 < g 2 3 4	S1_Orb_Thm_Cal_TC_sub_GPT.xml - Mousepad Edit Search View Document Help raph id="Graph"> <version>1.0</version> <node id="Read"> <operatorsread< operator=""></operatorsread<></node>	+ <u>-</u> - ×
File E 1 < g 2 4 5	S1_Orb_Thm_Cal_TC_sub_GPT.xml - Mousepad Edit Search View Document Help raph id="Graph"> <version>1.0</version> <node id="Read"> <operator>Read</operator> <sources></sources></node>	+ <u>-</u> = ×
File E 1 < g 2 4 5	S1_Orb_Thm_Cal_TC_sub_GPT.xml-Mousepad Edit Search View Document Help raph id="Graph"> <version>1.9</version> <node id="Read"> <operator>Read</operator> <sources></sources> <parameters class="com.bc.ceres.binding.dom.XppDomElement"></parameters></node>	+ ×

In **line 143**, delete only the path to the output image highlighted in orange (do not remove *<file>* and *</file>*) and write *\$output2*. Line 143 should look like this (highlighted in green):

<file>\$output2</file>

<file>\$output1</file>

1	S1_Orb_Thm_Cal_TC_sub.xml - Mousepad 🔷 🚊 🖻 🖄
File	Edit Search View Document Help
137	<pre><node id="Write(2)"></node></pre>
138	<pre><operator>Write</operator></pre>
139	<sources></sources>
140	<sourceproduct refid="Subset(2)"></sourceproduct>
141	
142	<pre><pre><pre><pre>class="com.bc.ceres.binding.dom.XppDomElement"></pre></pre></pre></pre>
143	<pre><file>/home/rus/shared/Training/LAND10 RiceMapping_Vietnam/Processing/</file></pre>
	Subset S1A IW GRDH 1SDV 20180307T224528 20180307T224553 020915 023E2F F92F Orb NR Cal TC.dim
144	<formatname>BEAM-DIMAP</formatname>
145	
146	
1	S1_Orb_Thm_Cai_TC_sub_GPT.xml - Mousepad 🛛 👘 🖃 🛪
LUG	Edit Search View Document Help
	Edit Search View Document Help <node id="Write(2)"></node>
137	<node id="Write(2)"></node>
File 137 138 139	
137 138 139	<node id="Write(2)"> <operator>Write</operator></node>
137 138 139 140 141	<node id="Write(2)"> <operator>Write</operator> <sources> <sourceproduct refid="Subset(2)"></sourceproduct> </sources></node>
137 138	<pre><node id="Write(2)"> <operator>Write</operator> <sources> <sourceproduct refid="Subset(2)"></sourceproduct></sources></node></pre>
137 138 139 140 141 142 143	<node id="Write(2)"> <operator>Write</operator> <sources> <sourceproduct refid="Subset(2)"></sourceproduct> </sources></node>
137 138 139 140 141 142	<node id="Write(2)"> <operator>Write</operator> <sources> <sourceproduct refid="Subset(2)"></sourceproduct> </sources> <parameters class="com.bc.ceres.binding.dom.XppDomElement"></parameters></node>
137 138 139 140 141 142 143	<pre><node id="Write(2)"> <operator>Write</operator> <sources> <operator>Write</operator> <sourceproduct refid="Subset(2)"></sourceproduct> </sources> <pre>carameters class="com.bc.ceres.binding.dom.XppDomElement"> <file>SoutputZ</file> </pre></node></pre>

In **line 153**, delete the path to the output image highlighted in orange (do not remove *<file>* and *</file>*) and write *\$output1*. Line 153 should look like this (highlighted in green):

1	51_Orb_Thm_Cal_TC_sub.xml - Mousepad	1 4 - 🗆
File	Edit Search View Document Help	
147	<node id="Write"></node>	
148	<operator>Write</operator>	
149	<sources></sources>	
150	<sourceproduct refid="Subset"></sourceproduct>	
151		
152	<pre><pre>cparameters class="com.bc.ceres.binding.dom.XppDomElement"></pre></pre>	
153	<pre><file>/home/rus/shared/Training/LAND10_RiceMapping_Vietnam/Processing/</file></pre>	
1.5	Subset S1A IW GRDH 1SDV 20180307T224528 20180307T224553 020915 023E2F F92F 0r	b_NR_Cal_TC.dim
154	<formatname>BEAM-DIMAP</formatname>	
155		
155	 	
156		+
156 File 147	S1_Orb_Thm_Cal_TC_sub_GPT.xml - Mousepad	
156 File 147 148	S1_Orb_Thm_Cal_TC_sub_GPT.xml - Mousepad Edit Search View Document Help	(*
156 File 147 148 149	S1_Orb_Thm_Cal_TC_sub_GPT.xml - Mousepad Edit Search View Document Help <node id="Write"> <operator>Write</operator> <sources> </sources></node>	+ _ = :
156 File 147 148 149 150	<pre>S1_Orb_Thm_Cal_TC_sub_GPT.xml - Mousepad Edit Search View Document Help <node id="Write"> <node id="Write"> <node id="Write"> <sourceproduct refid="Subset"></sourceproduct> <sourceproduct refid="Subset"></sourceproduct></node></node></node></pre>	+
156 File 147 148 149 150 151	S1_Orb_Thm_Cal_TC_sub_GPT.xml - Mousepad Edit Search View Document Help <node id="Write"> </node> </node> </node> </node> </node> </node> </node> <operator>Write</operator> <sources> <sourceproduct refid="Subset"></sourceproduct> </sources> <pre> <sources> <sources> </sources></sources></pre>	
156 File 147 148 149 150 151 152 153	S1_Orb_Thm_Cal_TC_sub_GPT.xml-Mousepad Edit Search View Document Help <pre>cnode_id="Write"></pre>	.+
156 File 147 148 149 150 151 152 153 154	<pre> S1_Orb_Thm_Cal_TC_sub_GPT.xml - Mousepad Edit Search View Document Help <pre></pre> <pre></pre></pre>	
156 File 147 148 149 150 151 152 153	S1_Orb_Thm_Cal_TC_sub_GPT.xml-Mousepad Edit Search View Document Help <pre>cnode_id="Write"></pre>	. * - 0 (

Once the input and output variables are defined, save the graph as a new xml file. Go to *File->Save* As. Navigate to the following path and save it as *S1_Orb_Thm_Cal_TC_sub_GPT.xml*.

Path: /shared/Training/LAND10_RiceMapping_Vietnam/AuxData/

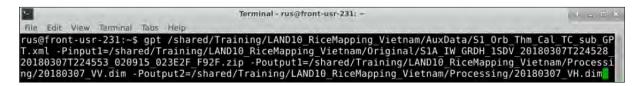
Now, the *\$input1*, *\$output1* and *\$output2* variables allow the graph to be used with different images. However, to run the graph, the value of the variables has to be properly set so that GPT knows which file to use as input and where to save the outputs. When running a graph with variables in GPT, we have to use the '-P' option followed by the name of the variables we have created. In an XML graph, all occurrences of $\{<nme>\}\}$ will be replaced with <value>.

To run a graph with variables in GPT, the following structure is used:

```
gpt /path/to/graph/ -Pinput1=/path/input/Sentinel/images/ -Poutput1=/path/o
utput1/directory/file.dim -Poutput2=/path/output2/directory/file.dim
```

For example:

```
gpt /shared/Training/LAND10_RiceMapping_Vietnam/AuxData/S1_Orb_Thm_Cal_TC_sub_GPT.x
ml -Pinput1=/shared/Training/LAND10_RiceMapping_Vietnam/Original/S1A_IW_GRDH_1SDV_2
0180307T224528_20180307T224553_020915_023E2F_F92F.zip -Poutput1=/shared/Training/LA
ND10_RiceMapping_Vietnam/Processing/20180307_VH.dim -Poutput2=/shared/Training/LAND
10_RiceMapping_Vietnam/Processing/20180307_VV.dim
```



6.3.9 Batch processing

Once the graph is modified with the *\$input1*, *\$output1* and *\$output2* variables, we are ready to process them in batch mode with GPT. For that, when an image is processed, the *\$input1*, *\$output1* and *\$output2* variables have to change with the appropriate name. There are several approaches to do so but, in this exercise, we will use a bash script (See \square NOTE 11).

NOTE 11: Bash is a Unix shell and command language written by Brian Fox for the GNU Project as a free software replacement for the Bourne shell. Bash is a command processor that typically runs in a text window where the user types commands that cause actions. Bash can also read and execute commands from a file, called a shell script. Like all Unix shells, it supports filename globbing (wildcard matching), piping, here documents, command substitution, variables, and control structures for condition-testing and iteration. The keywords, syntax and other basic features of the language are all copied from sh. Other features, e.g., history, are copied from csh and ksh. Bash is a POSIX-compliant shell, but with several extensions.

Go to the following path /shared/Training/LAND10_RiceMapping_Vietnam/AuxData/ and click on File -> Create document -> Empty file. Name it *Script_GPT.sh* and click *Create*. See NOTE 12 for some basic information regarding bash.

NOTE 12: The hash exclamation mark (#!) character sequence is referred to as the Shebang. Following it is the path to the interpreter (or program) that should be used to run (or interpret) the rest of the lines in the text file (for Bash scripts it will be the path to Bash, but there are many other types of scripts and they each have their own interpreter). The shebang must be on the very first line of the file. There must also be no spaces before the # or between the ! and the path to the interpreter. More information on bash scripting on: https://ryanstutorials.net/bash-scripting-tutorial/

The scrip that we will use first defines three variables that are used to set specific paths:

- *Path_S1*: path to folder containing the original Sentinel-1 products (Path_S1)
- Path_VH: path to folder where S1 processed images with VH polarization will be saved
- *Path_VV*: path to folder where S1 processed images with VV polarization will be saved

Next, the script defines three other variables:

- oldEnd: used to identify original products using the .zip pattern
- *VVpol*: used to define the name of the processed images in VV polarization
- VHpol: used to define the name of the processed images in VH polarization

Next, a *for* loop starts. All the Sentinel-1 images in the specify directory are identified and a list containing the names is created.

In each iteration (for each element of the list), the sensing time of the product is extracted from the file name and saved in the variable 'n'. Then, the element of the list is passed in to the *-Pinput1* variable and processed using the predefined graph. The *-Poutput1* variable is defined by adding:

- Path_VH → path of the output directory
- $n \rightarrow$ sensing time of the Sentinel-1 product
- VH_pol \rightarrow polarization

For example:

Path_VH + n + VH_pol /shared/Training/LAND10_RiceMapping_Vietnam/Processing/VH/ + 20180307 + _VH /shared/Training/LAND10_RiceMapping_Vietnam/Processing/VH/20180307_VH.dim

The same procedure is used to define the *-Poutput2* and the *-Poutput3* variables. The *date* command provides the starting and finish time of the gpt command.

Now that we have a better idea of what the bash script will do, right click on the *Script_GPT.sh* we have created and select *Open with Mousepad*. Copy-paste the following text and remember to save the file after pasting the script (*File -> Save*).

#!/bin/bash

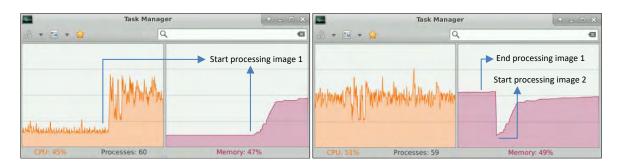
```
# 1- Define path variables
Path_S1=/shared/Training/LAND10_RiceMapping_Vietnam/Original/
Path_VH=/shared/Training/LAND10_RiceMapping_Vietnam/Processing/VH/
Path_VV=/shared/Training/LAND10_RiceMapping_Vietnam/Processing/VV/
# 2- Define name variables
oldEnd=.zip
VHpol=_VH
VVpol=_VV
# 3- Extract date & run GPT
for i in $(ls -d -1 $Path_S1$S1*.zip)
do
n=${i%.*}
n=${i%T*}
n=${n#"${n%_*}_"}
    date
    gpt /shared/Training/LAND10_RiceMapping_Vietnam/AuxData/S1_Orb_Thm_Cal_
TC_sub_GPT.xml -Pinput1=$i -Poutput1="$Path_VH$n$VHpol" -Poutput2="$Path_VV
$n$VVpol"
    date
done
```

Once the script is saved, we can run it. Open a new terminal window, copy-paste the following command and press enter to run it. If you get a *Permission denied* error, see NOTE 13. You can monitor the usage of RAM memory by opening the *Task Manager* (Applications -> System -> Task Manager). This process may take some time depending on the number of images to process, the processing steps applied and your IT environment.

/shared/Training/LAND10_RiceMapping_Vietnam/AuxData/Script_GPT.sh

1	NOTE 13: When running the <i>Script_GPT.sh</i> bash script, it can happen that the following error Terminal: <i>Permission denied</i>	appears in
ru	Terminal-rus@front-usr-231: - le Edit View Terminal Tabs Help us@front-usr-231:~\$ /shared/Training/LAND10_RiceMapping_Vietnam/AuxData/Script_GPT.sh ush: /shared/Training/LAND10_RiceMapping_Vietnam/AuxData/Script_GPT.sh: Permission de	+ - ⊡ × n enied
	It is cause by the lack of an execute permission bit for the file you want to run. To solve it, we specify that the file can be executed. For that, access the folder where the file is stored. Copy following code in Terminal and run it (Press Enter).	
	cd /shared/Training/LAND10_RiceMapping_Vietnam/AuxData/	
r	Terminal - rus@front-usr-231:/shared/Training/LAND10_RiceMapping_Vietnam/AuxData File Edit View Terminal Tabs Help us@front-usr-231:~\$ cd /shared/Training/LAND10_RiceMapping_Vietnam/AuxData us@front-usr-231:/shared/Training/LAND10_RiceMapping_Vietnam/AuxData\$	- = ×
	Next, copy-paste the following command to make the file executable and run it by pressing en	ter.
	chmod +x Script_GPT.sh	
ru	Terminal - rus@front-usr-231; /shared/Training/LAND10_RiceMapping_Vietnam/AuxData le Edit View Terminal Tabs Help us@front-usr-231:-\$ cd /shared/Training/LAND10_RiceMapping_Vietnam/AuxData/ us@front-usr-231:/shared/Training/LAND10_RiceMapping_Vietnam/AuxData\$ chmod +x Script_G	• = □ × PT.sh
File rus@	Terminal -rus@front-usr-231: - Edit View Terminal Tabs Heip front-usr-231:~\$ /shared/Training/LAND10_RiceMapping_Vietnam/AuxData/Script_	⊕ _ □ ×
	Terminal - rus@front-usr-231: ~ Edit View Terminal Tabs. Help	+ - = ×
Fri INFO ool SEVE aria Exec	Afront-usr-231:-\$ /shared/Training/LAND10_RiceMapping_Vietnam/AuxData/Script_ Apr 12 08:39:10 UTC 2019 0: org.esa.snap.core.gpf.operators.tooladapter.ToolAdapterI0: Initializing ex adapters RE: org.esa.s2tbx.dataio.gdal.activator.GDALDistributionInstaller: The envir bble LD_LIBRARY_PATH is not set. It must contain the current folder '.'. cuting processing graph 0: org.hsqldb.persist.Logger: dataFileCache open start	kternal t
	Terminal - rus@front-usr-231: ~	÷ = = *
rus@ Fri INFO ool	Edit View Terminal Tabs Help afront-usr-231:~\$ /shared/Training/LAND10_RiceMapping_Vietnam/AuxData/Script_ Apr 12 08:39:10 UTC 2019 b: org.esa.snap.core.gpf.operators.tooladapter.ToolAdapterIO: Initializing ex- adapters ERE: org.esa.s2tbx.dataio.gdal.activator.GDALDistributionInstaller: The envi	kternal t

SEVERE: org.esa.s2tbx.dataio.gdal.activator.GDALDistributionInstaller: The ariable LD_LIBRARY_PATH is not set. It must contain the current folder '.'. Executing processing graph INFO: org.hsqldb.persist.Logger: dataFileCache open start10%....20%....30%....40%....50%....60%....70%....80%....90% done. Fri Apr 12 08:40:37 UTC 2019



Once the script is finished and all the images have been processed, you will find them in the paths specified in the bash script. Navigate to the following paths and check the files have been created.

Path 1 \rightarrow /shared/Training/LAND10_RiceMapping_Vietnam/Processing/VH/

Path 2 \rightarrow /shared/Training/LAND10_RiceMapping_Vietnam/Processing/VV/

/LAND10_RiceMapping_Vietnam/Processing/VV/	C AND10_RiceMapping_Vietnam/Processing/VH/
20180307_VV.data 🕢 20180319_VV.dim	20180307_VH.data @ 20180319_VH.dim
20180319_VV.data / 20180331_VV.dim	20180319_VH.data 🕢 20180331_VH.dim
20180331_VV.data 📝 20180412_VV.dim	20180331_VH.data 20180412_VH.dim
20180412_VV.data 🕜 20180424_VV.dim	20180412_VH.data 🕢 20180424_VH.dim
20180424_VV.data 🔟 20180506_VV.dim	20180424_VH.data 🔤 20180506_VH.dim
20180506_VV.data 🔤 20180518_VV.dim	20180506_VH.data 20180518_VH.dim
20180518_VV.data 🔤 20180530_VV.dim	20180518_VH.data 🔡 20180530_VH.dim
20180530_VV.data 🔤 20180611_VV.dim	20180530_VH.data 🖉 20180611_VH.dim
20180611_VV.data 🕢 20180623_VV.dim	20180611_VH.data 💹 20180623_VH.dim
20180623_VV.data 🔤 20180705_VV.dim	20180623_VH.data 🙆 20180705_VH.dim
20180705_VV.data 🐻 20180717_VV.dim	20180705_VH.data 20180717_VH.dim
20180717_VV.data / 20180810_VV.dim	20180717_VH.data 20180810_VH.dim
20180810_VV.data 🔤 20180822_VV.dim	20180810_VH.data 🔤 20180822_VH.dim
20180822_VV.data 🔤 20180903_VV.dim	20180822_VH.data 🗾 20180903_VH.dim
20180903_VV.data 🛛 20180915_VV.dim	20180903_VH.data 🔤 20180915_VH.dim
20180915_VV.data 🕢 20180927_VV.dim	20180915_VH.data 🕢 20180927_VH.dim
20180927_VV.data 🔤 20181009_VV.dim	20180927_VH.data 20181009_VH.dim
20181009_VV.data 🔯 20181021_VV.dim	20181009_VH.data 🕢 20181021_VH.dim
20181021_VV.data 🕢 20181102_VV.dim	20181021_VH.data 📄 20181102_VH.dim
20181102_VV.data 🔤 20181114_VV.dim	20181102_VH.data 20181114_VH.dim
20181114_VV.data 🔤 20181126_VV.dim	20181114_VH.data 😸 20181126_VH.dim
20181126_VV.data 🕢 20181208_VV.dim	20181126_VH.data 🔤 20181208_VH.dim
20181208_VV.data 🕢 20181220_VV.dim	20181208_VH.data 🔤 20181220_VH.dim
20181220_VV.data 📃 VV.snap	20181220_VH.data 📃 VH.snap
20180307_VV.dim	20180307_VH.dim

6.3.10 Stack

After the images have been processed, we will stack them together according to their polarization to allow further processing.

To prevent errors when creating the stack, images have to be opened in chronological order. For convenience SNAP session files have been created in advanced and are located in the following paths (See NOTE 14). In SNAP go to File -> Session -> Open Session. Navigate to Path_1 and open the *VH_images.snap* file. Next, go to *RADAR* -> *Corregistration* -> *Stack Tools* -> *Create Stack*.

NOTE 14: Note that opening the SNAP session file will only work if Sentinel-1 images have been processed and stored in the appropriate path as explained in previous steps. If you run batch processing without errors, you should not face any issue. You can also manually load images in chronological order.

Path_1: /shared/Training/LAND10_RiceMapping_Vietnam/Processing/VH/

Path_2: /shared/Training/LAND10_RiceMapping_Vietnam/Processing/VV/

In the *1-ProductSet-Reader* click on the *Add Opened* icon - \square - and click on the *Refresh* - \square - icon to update the metadata information. In the *2-CreateStack* tab, select *NEAREST_NEIGHBOUR* resampling method, set the initial offset method to *Product Geolocation* and click on the *Find Optimal Master* button. In the *3-Write* tab, change the name to *S1_VH_Stack* and make sure to set the output directory to the *Path_1*. Click Run.

9		Create Stack			* E 8	e		Create Stack	÷ =
1-ProductSet-Reader	2-CreateStack	3-Write				1-ProductSet-Reader	2-CreateStack	3-Write	
File Name	Type	Acquisition	Track.	Orbit		Master:	20180717_VH		
0180307_VH	GRD	07Mar2018	18	20915	+	Resampling Type:	NEAREST_NEIG	HBOUR	3
HV_21E08101	GRD	19Mar2018	18	21090			The arear inches	indoon.	
0160331_VH	GRD	91Mar2018	18	21265		Initial Offset Method:	Product Geolo	cation	
0180412_VH	GRD	12Apr2018	18	21440		Output Extents:			
0180424_VH	GRD	24Apr2018	10	21615		o depart Enterneor	Master		1
0180506_VH	GRD	06May2018	18	21790	-	Find Optimal Master			
0180518_VH	GRD	18May2016	18	21965			_		
0180530_VH	GRD	30May2018	18	22140					
0180611_VH	GRD	11jun2618	18	22315					
0180623_VH	GRD	23jun2018	18	22490					
0188705_VH	GRD	05jui2018	18	22665					
0180717_VH	GRD	17jul2016	18	22840					
0180810_VH	GRD	10Aug2018	18	23190					
0180822_VH	GRD	22AUg2018	18	23365					
D180903_VH	GRD	035ep2018	18	23540					
0180915_VH	GRD	155ep2018	18	29715					
0180927 VH	GRD	275ep2018	18	23890	2				
0181009_VH	GRD	09Oct2018	18	24065					
0181021 VH	GRD	210ct2018	18	24240	63				
0181102 VH	GRD	02Nov2018	18	24415					
0181114_VH	GRD	14Nov2018	18	24590					
0181126 VH	GRD	26Nov2018	18	24765					
0181208 VH	GRD	08Det2018	10	24940					
0181220 VH	GRD	20Der2018	18	25115	24 Products				
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			Target Produ	ici.					
			Name						
			S1 VH Stack	c					
			Save as: BE		-				
			Directory						
			/home/n	s/shared/Training	/LAND10_RiceMag	pping_Vietnan/Processing/VHV		a second s	

Once finished, repeat the same procedure for the VV polarization images and save them with the appropriate names and in the appropriate directory: *S1_VV_Stack* and *Path_2* respectively.

6.3.11 Multi-temporal speckle filtering

Once the two different stacks have been created, we will reduce the effect of speckle noise in each of them. SAR images have inherent salt and pepper like texturing called speckles that degrade the quality of the image and make interpretation of features more difficult (See INOTE 15). To reduce the speckle effect, we will take advantage of the temporal dataset we are working with and apply a multi-temporal speckle filter. For this exercise, the default filter used in SNAP (Lee Sigma) will be used.

NOTE 15: Speckle is 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 by either spatial filtering or multilook processing. Multi-temporal filtering is one of the commonly used speckle noise reduction techniques. (*SNAP Help*)

Go to *RADAR -> Speckle Filtering -> Multi-temporal speckle filter*. First we will reduce the speckle for the *S1_VH_stack.dim* file that was created in the previous step. In the *I/O Parameters* tab click on the

icon go to *Path_1* and select the file. Make sure the output name is set to *S1_VH_Stack_Spk* and the output directory to the following path. In the *Processing Parameters* tab leave the default values.

Path_1: /shared/Training/LAND10_RiceMapping_Vietnam/Processing/VH/

🕑 Multi-temporal Speckle Filter 💮 🗉	x 💽 Mul	ti-temporal Speckle Filter	+ = ×
File Help	File Help		
I/O Parameters Processing Parameters	I/O Parameters	Processing Parameters	
Source Product source: S1_VH_Stack Target Product Name: S1_VH_Stack_Spk Save as: BEAM-DIMAP Directory: raining/LAND10_RiceMapping_Vietnam/Processing/Vietnam/VH COpen in SNAP	Source Bands: Filter: Number of Looks: Window Size: Sigma: Target Window Size	Sigma0_VH_db_slv16_27Sep2018 Sigma0_VH_db_slv17_09Oct2018 Sigma0_VH_db_slv18_21Oct2018 Sigma0_VH_db_slv20_14Nov2018 Sigma0_VH_db_slv20_14Nov2018 Sigma0_VH_db_slv21_26Nov2018 Sigma0_VH_db_slv23_20Dec2018 Lee Sigma 1 7x7 0.9	
<u>Bun</u> <u>C</u> lose		Bu	n <u>C</u> lose

Once finished, repeat the same procedure for the *S1_VV_Stack.dim* file. Make sure to save it with the appropriate name and in the appropriate directory: *S1_VV_Stack_Spk* and *Path_2* respectively. Once finished, close all the products in SNAP except for the two stacked files.

Path_2: /shared/Training/LAND10_RiceMapping_Vietnam/Processing/VV/

6.3.12 Decibel transformation

Due to the high dynamic range of SAR imagery, the decibel transformation is used to improve visualization and data analysis. The transformation will stretch the RADAR backscatter over a more usable range which has nearly a gaussian distribution. The RADAR backscatter coefficient (σ^0) is transformed into the decibel scale using the following equation:

$$\sigma^0 (dB) = 10 * \log 10\sigma^0$$

Go to *Raster -> Data Conversion -> Convert bands to/from dB*. In the *I/O Parameters* tab, make sure to select the *S1_VH_Stack_Spk* as input and set the output directory to the following path. Leave the default settings in the *Processing Parameters* tab.

Path: /shared/Training/LAND10_RiceMapping_Vietnam/Processing/VH/

	Converts bands to/from dB	* = × 🚺	Converts bands to/from d	IB I I I X
File Help		File	Help	
I/O Paran	neters Processing Parameters	1 10	O Parameters Processing Parameters	
Target Pr Name: S1 VH S Save Direct	H_Stack_Spk roduct tack_Spk_dB as: BEAM-DIMAP tory: d/Training/LAND10_RiceMapping_Vietnam/Proc		Purce Bands: Sigma0_VH_siv1_19Mar2018 Sigma0_VH_siv2_31Mar2018 Sigma0_VH_siv2_31Mar2018 Sigma0_VH_siv2_31Mar2018 Sigma0_VH_siv5_06May2018 Sigma0_VH_siv5_06May2018 Sigma0_VH_siv5_18May2018 Sigma0_VH_siv9_23Jun2018 Sigma0_VH_siv1_05Jul2018 Sigma0_VH_siv1_05Jul2018 Sigma0_VH_siv1_17Jul2018 Sigma0_VH_siv1_17Jul2018 Sigma0_VH_siv1_210Aug2018 Sigma0_VH_siv1_210Aug2018 Sigma0_VH_siv13_22A	
		Run <u>C</u> lose		<u>R</u> un <u>C</u> lose

Once finished, repeat the same procedure for the *S1_VV_Stack_Spk* file and save the output in the following path:

Path: /shared/Training/LAND10_RiceMapping_Vietnam/Processing/VV/

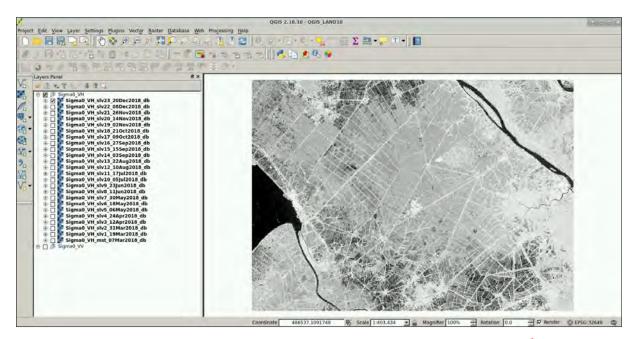
6.4 QGIS

6.4.1 Sigma Naught evolution

Once the conversion to the decibel scale is finished, close SNAP and open QGIS (*Applications -> Processing -> QGIS Desktop*). For convenience, a session containing the images we will use to analyse the temporal evolution of the backscatter coefficient has been created in advance. Go to *Project -> Open*, navigate to the following path and open the *QGIS_LAND10.qgs* file (See \square NOTE 16).

Path: /shared/Training/LAND10_RiceMapping_Vietnam/AuxData/

NOTE 16: The QGIS session file that is provided in this exercise will only work if you have saved the processed Sentinel-1 files with the same name and in the same path as specified in this tutorial. If not, you can always load the products to QGIS manually.



To analyse the evolution of the backscatter coefficient we will use the *Value Tool* (See NOTE 17), a specific plugin that allows to plot pixel values in different layers with the mouse position as reference.



Once installed, the tool will appear in the lower left corner (if not visible, right click on the Toolbar and select *Value Tool*). Activate the tool by clicking on *Enable*, go to the *Options* tab and click on the option *Plot values only when mouse is clicked*. Set the following parameters:

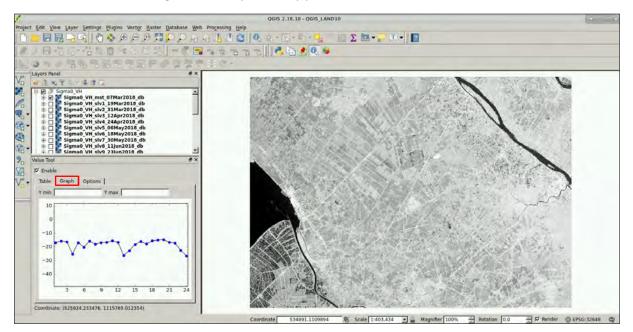
Show layers: Selected layers

Show bands: All bands

In the list of layers of the *Value Tool*, select all the VH (or VV) images (24 in total) to analyze the temporal profile.

alue	Tool			8×	Value Too	4			8
	nable ole Graph Options				I Enab Table	le Graph Options			
ঘ	Plot values only when mouse is clicke	đ			Plot	values only when mouse is clicke	d		
Sho	ow layers: Selected layers w bands: All bands				Show	ayers: Selected layers 💌 bands: All bands 💌 active layers and display options:			
					Junece				
Г	Layer	#	Bands	14		Layer	#	Bands	
1	Layer Sigma0_VH_mst_07Mar2018_db	#	Bands [1]	14	22	1	-	Bands [1]	-
1		-		J		Layer	#		
1 2 3	Sigma0_VH_mst_07Mar2018_db	#	(1)		23	Layer] Sigma0_VH_slv21_26Nov2018	# #	[1]	
1 2 3 4	Sigma0_VH_mst_07Mar2018_db	# #	(1) (1)	 	23 🗹 24 🗹	Layer 7 Sigma0_VH_slv21_26Nov2018 9 Sigma0_VH_slv22_08Dec2018	# # #	[1] [1]	

Once all the parameters are set, click on the *Graph* tab. Zoom in a specific area of the image, place your mouse over a field and click. The graph will then show the Sigma Naught (σ 0) evolution in all the Sentinel-1 VH (or VV) images we have previously processed.



6.4.2 QGIS Processing

In the last step we will take advantage of the large differences of backscatter produced by the different growing stages of rice to highlight the fields where this crop is been cultivated. Go to *Processing -> Toolbox.* In the search box, write *r.series* and open the tool.

Processing T	x B xodloc
r.series	đ
	used algorithms S GIS 7 commands [314 geoalgo r (r.*) r.series - Makes each output cel r.series.accumulate - Makes ea r.series.interp - Interpolates ras

In the *Input raster layer(s),* click on the icon, select all the VH bands and click OK.

Multiple selection	1 🕈 🔲
 Sigma0_VH_slv4_24Apr2018_db [EP5G:32648] Sigma0_VH_slv15_15Sep2018_db [EP5G:32648] 	Select all
Sigma0_VH_mst_07Mar2018_db [EPSG:32648] Sigma0_VH_mst_07Mar2018_db [EPSG:32648] Sigma0_VH_slv13_22Aug2018_db [EPSG:32648]	Clear selection
Sigma0_VV_slv9_23Jun2018_db [EPSG:32648] Sigma0_VV_slv11_17Jul2018_db [EPSG:32648]	Toggle selection
✓ Sigma0_VH_slv21_26Nov2018_db [EPSG:32648] Sigma0_VV_slv20_14Nov2018_db [EPSG:32648]	ОК
 Sigma0_VH_slv20_14Nov2018_db [EPSG:32648] Sigma0_VH_slv19_02Nov2018_db [EPSG:32648] Sigma0_VV_slv18_21Oct2018_db [EPSG:32648] 	Cancel
Sigma0_VV_mst_07Mar2018_db [EPSG:32648]	
☐ Sigma0_VV slv6_18May2018_db [EPSG:32648] ☐ Sigma0_VV slv13_22Aug2018_db [EPSG:32648]	
Sigma0_VH_slv9_23Jun2018_db [EPSG:32648] Sigma0_VV_slv7_30May2018_db [EPSG:32648]	
Sigma0_VV_slv17_09Oct2018_db [EPSG:32648] Sigma0_VH_slv7_30May2018_db [EPSG:32648]	
Sigma0 VH slv5 06May2018 db [EPSG:32648]	-1

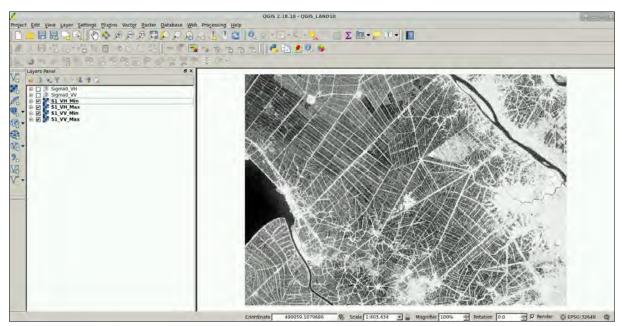
In the *Aggregate operation* tab, select *minimum*. Leave the remaining parameters as default and save the output as *S1_VH_Min* in the following path. Then, click *Run*. Once finished, change the *Aggregate operation* to *maximum* and save the output as *S1_VH_Max* in the same directory as before.

Path: /shared/Training/LAND10_RiceMapping_Vietnam/Processing/VH/

rseries - Makes each output call value a function of the values assigned to t	he corresponding ce 👴 🗟 💵	📝 r.series - Makes each output cell value a function of the values assigned to t	the corresponding co 🙃 🗟 🕃
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Advanced parameters		Advanced parameters	
Aggregated		Aggregated	
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IF Open output file after running algorithm		Den output file after running algorithm	
	0%		0%
	Run Close		Run Close

Once the minimum and maximum value for each pixel has been derived for the Sentinel-1 VH images, do the same for the VV layers. Change the *input raster layer(s)* and derive the same statistics. Name them *S1_VV_Min* and *S1_VV_Max* and save them in the following path:

Path: /shared/Training/LAND10_RiceMapping_Vietnam/Processing/VV/



Next, we will derive the difference between the minimum and maximum value for both polarizations. Go to *Raster -> Raster Calculator*. Set the output name as *Difference_VH* and save it in the following path.

Path: /shared/Training/LAND10_RiceMapping_Vietnam/Processing/VH/

Leave the remaining parameters as default and copy-paste the following expression under the *Raster calculator expression*. Then, click Ok.

```
"S1_VH_Max@1" - "S1_VH_Min@1"
```

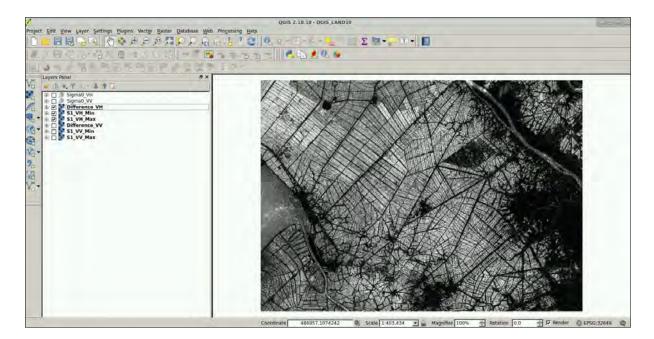
aster bar			Result	layer	-						
S1 VH_Max@1 S1 VH_Min@1			- Output	Output layer cessing/VH/Difference_VH						l.tif	
51 VV Max@1 51 VV Min@1			Output	Output format GeoTIFF			_		- 3		
Sigma0_VH_mst_07Mar2018_db@1 Sigma0_VH_slv10_05Jul2018_db@1			Curren	Current layer extent							
Sigma0_VH	H_slv11_17jul2 H_slv12_10Au	2018_db@1	X min	497614.4	43535	÷	XMax	587964	4.43535		
Sigma0 VI	H slv13 22Au H slv14 03Ser	2018 db@1	Y min	1075119	.26588	÷	Y max	11400	79.26588	-	
Sigma0 VI	H_slv15_15Sep H_slv16_27Sep	2018 db@1	Column	s 9035		÷	Rows	6496	-	-	
	H slv18 210ct H slv19 02Nov		+ I I Add	result to pro	ject						
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Operato + - < aster cal	rs 	sqrt 		sin asin	atan		in		() OR		

Once finished, repeat the same procedure to derive the difference between the *S1_VV_Max* and *S1_VV_Min* layers. Set the output name as *Difference_VV* and save it in the following path. Leave the remaining parameters as default and copy-paste the following expression. Then, click OK.

Path: /shared/Training/LAND10_RiceMapping_Vietnam/Processing/VV/

```
"S1_VV_Max@1" - "S1_VV_Min@1"
```

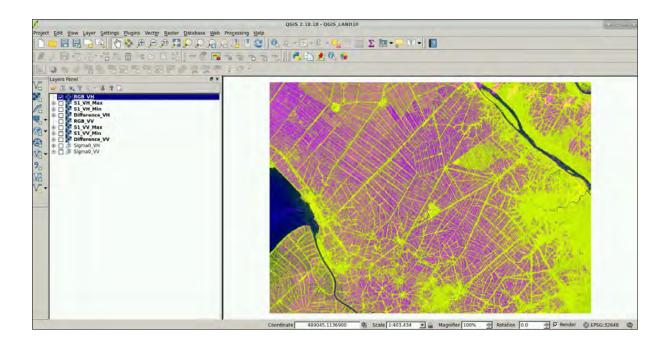
Finally, we will create a false-colour RGB composition to better visualize the crop patterns. In the *Layers Panel*, select only the *Difference_VH*, *S1_VH_Max* and *S1_VH_Min* layers. Next, go to *Raster -> Miscellaneous -> Build Virtual Raster*



Select the option *Use visible raster layers for input*, save the output file as *RGB_VH* in the following path and check the option *Separate*. Then, click Ok. Repeat the same procedure for the *Difference_VV*, *S1_VV_Max* and *S1_VV_Min* layers and save it as *RGB_VV* in the corresponding folder. (You may have different color patterns depending on how the layers have been assigned to the RGB channels).

Path: /shared/Training/LAND10_RiceMapping_Vietnam/Processing/VH/

Input files	rectory instead of files	Select .
Output file	/Processing/VH/RGB_VH	Select
F Resolution	Average	2
Source No Data	Į0	
Target SRS	Γ	Select
Separate		
F Allow projection	difference	
Load into canvas	when finished	
gdalbuildvrt -separa	ato	- 1



THANK YOU FOR FOLLOWING THE EXERCISE!

Further reading and resources 7

Sentinel-1 User Guide

https://sentinel.esa.int/web/sentinel/user-guides/sentinel-1-sar

Sentinel-1 Technical Guide

https://sentinel.esa.int/web/sentinel/technical-guides/sentinel-1-sar

SNAP GPT Guide

https://senbox.atlassian.net/wiki/spaces/SNAP/overview

Bash and Linux Tutorial

https://ryanstutorials.net/bash-scripting-tutorial/

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