





TRAINING KIT – HYDR01

WATER BODIES MAPPING FROM SPACE JUNE – NOVEMBER 2017, NORTHERN POLAND









Research and User Support for Sentinel Core Products

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1 Introduction

The Research and User Support for Sentinel core products (RUS) service provides a free and open scalable platform in a powerful computing environment, hosting a suite of open source toolboxes pre-installed on virtual machines, to handle and process data derived from the Copernicus Sentinel satellites constellation.



Flims, Switzerland Credits: Photo by Stephen Leonardi on Unsplash.

Water surfaces, whether they are lakes, rivers, dams or ponds are crucial part of our landscapes. Timely monitoring of surface water and delivering data on the dynamics of surface waters are essential for policy and decisionmaking processes.

Number of different methods has been developed for the extraction/delineation of waterbodies in remotely sensed data. Generally, we can split the basic methods to three categories: single band thresholding, band ratio indexes, more sophisticated methods (machine learning, etc.).

In this webinar, we will have look at the two first approaches. First, we will use Sentinel-2 optical data to calculate the Normalized Difference Water Index (NDWI). Then we will use the thresholding method with averaged stack of Sentinel-1 SAR data and see the advantages and disadvantages of each method.

2 Training

Approximate duration of this training session is two hours.

2.1 Data used

 One cloud-free Sentinel-2A Level 2A tile (Tile ID: T34UEE) acquired on August 16, 2017 [downloadable @ <u>https://scihub.copernicus.eu/</u>]

S2A_MSIL2A_20170816T095031_N0205_R079_T34UEE_20170816T095031.zip

 Five Sentinel-1A IW GRDH products acquired in July and August 2017 [downloadable @ https://scihub.copernicus.eu/]

S1A_IW_GRDH_1SDV_20170711T161931_20170711T161956_017426_01D1DE_4164.zip S1A_IW_GRDH_1SDV_20170723T161931_20170723T161956_017601_01D729_290F.zip S1A_IW_GRDH_1SDV_20170804T161932_20170804T161957_017776_01DC8A_4628.zip S1A_IW_GRDH_1SDV_20170816T161933_20170816T161958_017951_01E1D7_0173.zip S1A_IW_GRDH_1SDV_20170828T161933_20170828T161958_018126_01E722_FB07.zip

2.2 Software in RUS environment

Internet browser, SNAP + Sentinel-2 Toolbox, QGIS, (Extra steps: Sen2Cor, 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	
The RUS Service * The RUS Offer * The RUS Library * The RUS Community *	
	Senth
	News from RUS
	One year on!
	Copernicus Info Session - Reykjavik - 19 September 2018
	SPIE Remote Sensing 2018 – Berlin (Germany) – 11-12 September 2018
	SIWI World Water Week 2018 – Stockholm – 26-31 August 2018
	MedRIN Kick-off Meeting - Chania - 13 & 14 July 2018
	RUS Webinar – Special edition "AskRUS – Sentinel-1" – 12 July 2018
Welcome to Research and User Support	RUS Training Session - Valencia - 22 July 2018
	IGAR55 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 email sent by the Copernicus service. 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	CDS-SSO ID Password Max Idle Time Max Session Time	half a day Until browser close Login Reset Forgot your password?	*	000000000000000000000000000000000000000

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

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	Select one or more items	newsletter	then - Paliting - 5, 9, 40, 5, 13 Nov. 201	
		conference social media	than - Foojoung - 26% 27 Oct. 2018	
		other		
	Institution type	Select one item	~ nda	
	Phone number Italy (IT):	+39	or las regros	1.000
	Title	Select one item	~	I STREET

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** \rightarrow **Your Dashboard**.

The RUS Service • The RUS Offer • The RUS Library •	Helto, Miguel
Your RUS service	Your profile You are here: Home > Your RUS ser Your dashboard
This section gathers pages related to your RUS services: • Your profile: displays your personal information linked to you	Your training Your training News from RUS
Your dashboard: Illows you to access your private dashboard	One year on! Copernicus Info Session – Reykjavik – 19 September 2018
Your training: allows you to register to a training session you	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
	RUS Webmar - special edition AskRUS - sentine: 1 - 12 July 2018 RUS Training Session - Valencia - 22 July 2018 IGARSS 2018 - Valencia - 22-27 July 2018

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

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The RUS Service * The RUS Offer * The RUS Library * The RUS Community *	Construction Page Your RUSservice •
	You are here: Home > Your RUS service > Your dashboard
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 f	ew 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 I	hubs?
Yes	
© No	
Have you already handled/processed Copernicus data?	
W Yes	
© No	
Do you wish to practice a tutorial exercise shown in a RUS webinar? If yes, please (hold down CTRL key for multiple selections).	select your choice
HAZA01 - Flood Mapping in Malawi	
HAZA02 - Burned Area Mapping in Portugal HYDR01 - Water Bodies Mapping over Northern Poland	
LAND01 - Crop Mapping in Seville	
LAND04 - Land Monitoring in Cyprus	
OCEA01 - Ship Detection in Gulf of Trieste	
If you wish to request another tutorial exercise that doesn't appear in the above I	ist, 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.

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This is a collection of information selected You can go back and edit this information		
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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:		
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		
S1 - Polarisation		
S1 - Orbit direction		
Sentinel-2	X	
Sentinel-3	X	
Other	x	
I don't know	X	
Region of Interest: Min Latitude	39.3303	
MaxLatitude	40.5877	
Min Longitude	-4.6736	
Max Longitude	-2.7205	
Reference polygons	2.7.203	
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**.

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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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5 Step by step

5.1 Data download – ESA SciHUB

In this step we will download a Sentinel-2 scene from the Copernicus Open Access Hub using the online interface (Applications \rightarrow Network \rightarrow 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.

ē P	esa opernicus	Copernicus Open Access Hub	
		Register new account	
	Sentinel data access is free ar	nd open to all.	
	the data.	form below you will receive an e-mail with a link to validate your e-mail address. Following this yo nanumeric characteric plus γ^{a} , γ^{a} , γ^{a} and γ^{a} .	su can ax up download
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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".

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Switch the rectangle-drawing mode to pan mode by clicking on the "**Pan**" icon in the lower left corner of the map (**Green arrow**) and navigate over Portugal (approximate area – blue rectangle).



Switch to drawing mode and draw a search rectangle approximately as indicated below. Open the search menu (red arrow) and specify the following parameters:

Sensing period:	From 2017/07/01 to 2017/08/31
Check Mission:	Sentinel-1
Satellite Platform:	S1A*
Product Type:	GRD
Sensor Mode:	IW
Relative Orbit:	29

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4.0052, 51.9755 Pan Box	Polygon Clear	Poland Poland	

Press "Search" (red arrow below).



In our case, the search returns five results depending on the exact search area defined. Using the 🐖 icon, import all six products to Cart.

Then open the search menu again and reset the parameters as defined below, **do not forget to deselect Mission: Sentinel-1** as this time we will search for Sentinel-2 data (See * TIP 1):

Sensing period:	From 2017/08/16 to 2017/08/16
Check Mission:	Sentinel-2
Product Type:	S2MSI2Ap

TIP 1: For the Level 2A products we are downloading, the atmospheric correction has already been applied (pre-processing of Level-1C product to a Level-2A is described in section **4.1**). Since April 2017, the Level-2A products available to download for acquisitions over Europe (such as this case). Global coverage of Level 2A products is available as of December 2018.



In our case, the search returns four results depending on the exact search area defined. Using the 🔛 icon, import only the following product to **Cart**:

S2A_MSIL2A_20170921T101021_N0205_R022_T32TQQ_20170921T101436

Then click on the Profile icon in the upper left corner (marked with **green circle** above) and go to **Cart**. You should now have six products in your cart. Click **Download Cart**.

	Copernicus Open Access Hub	🖲 🛛 🕇
	Your cart contains 6 products. Display 1 to 6 of 6 products.	團
SIA MRC SIA_IW_GRDH_ISDV_201708167161933_2017	108161161958_017951_01E1D7_0173 tax/1/Products/c07c311-c2h3-4e0b-6m/h-3dmbbc15129b1/svmlum	
Mission: Sentinel-1 Instrument: SAR-C Sensing Date		
SIA SARCE SIA IW GRDH 15DV 20170711T161931 2017		
Download URL: https://icihiub.copernicue.es/dhus/oda Mission: Sentinel-1 Instrument: SAR-C Sensing Date:	lah/1/Productsi'e4345720-0e22-4180-4546-7c13e6346-7b4://Leitum 2017-07-11716-19:31.165Z Size: 1.65-68	
A MU SZA_MSILZA_201708167095031_N0205_R079_T		
Download URL: https://pcihlub.copernicus.eu/ohuvoda Mission: Sentinel-2: Instrument: MSI: Sensing Date: 20	fay/1/Produch(/0960/e85-1274-488/-aedo.156/6-8d444a1/)/Svalue 117-08-18709-50-31.0262 Size: 1.02.08	
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SIA MAR-0 SIA_IW_GRDH_15DV_20170826T161933_2017	70828T161958_018126_01E722_F807	
Download URL: https://scinub.capernicus.eu/dhur/pila Mission: Sentinel-1_Instrument: SAR-C_Sensing Date	fav/LPmiluethf34e42407-4ca8-4act-a3ac.3551902445357Avalue 2017-08-28716:19-33.7822 Size 1.65 G8	
Products per page: 25 - Page#:] of 1 -		DOWNLOAD CART CLEAR CART

A *products.meta4* file will be downloaded to your */home/rus* folder. To download our data, we will use **aria2** tool. To use the tool, we first need to place the **products.meta4** file to the folder where we wish our data to be downloaded to: */shared/Training/HYDR01_WaterBodies_TrainingKit/Original*

First let's test our aria2 installation. To do this we open the Command Line 🛅 (in the bottom of your desktop window) and type:

aria2c

The correct response should be as follows:



If the response is "-bash aria2c: command not found" (see 🛄 NOTE 1).

NOTE 1: If (and only if) the response is "-bash aria2c: command not found". Then we have to install the tool, to do this in command line type: sudo apt-get install aria2 When requested type: Y Then you can test your installation again.

If you have received the correct response, then we can run the tool by typing following commands in the command line (replace **<username>** and **<password>** with your login credentials for Copernicus Open Access Hub):

```
cd /shared/Training/HYDR01_WaterBodies_TrainingKit/Original
aria2c --http-user='<username>' --http-passwd='<password>' --check-
certificate=false --max-concurrent-downloads=2 -M products.meta4
```

The first line changes our directory to the target directory. The second line runs the download tool (Type the red text all in single line). All six products will be downloaded to the *Original* folder two products in parallel automatically

(**Note** that the constraint of maximum 2 parallel downloads at a time is imposed by the Copernicus Access Hub, if you increase the number, your download will fail). This might take some time.

5.2 Optical data – Sentinel-2

5.2.1 SNAP – open and explore data

Launch SNAP (icon on desktop). When the SNAP window opens click **Open product** and navigate to: /shared/Training/HYDR01_WaterBodies_TrainingKit/Original

Open the S2 product. Now, we will look at the product. We could visualize it in true (natural) colours but for distinguishing water surfaces, it is better to use the false colour. **Right-click** the product and click **Open RGB image window**, a new window will open. From the drop-down menu select:

Profile: Sentinel 2 MSI False-colour-Infrared

Click OK.



Now, let's investigate the **cloud cover** and **water mask** bands that are the result of atmospheric correction applied to the level 2 products.

Expand the product in the **Product Explorer** window and go to **Masks** \rightarrow **scl**. Open masks **scl_cloud_high_proba** (Cloud high probability), **scl_water** (Water) and **scl_thin_cirrus** (Thin cirrus). Pixels with detected clouds/cirus/water will appear white in the respective masks.

Now you should have four bands open in your **View** window. Go to **Window** \rightarrow **Tile Evenly** and then go to the **Navigation** tab, click **Zoom All**.



We can see that as expected our image is cloudless. The default water mask distributed with the Level-2 product, however, does not look very accurate.

5.2.2 Resample

The 13 bands in Sentinel-2 products do not all have same resolution (therefore size, see \square NOTE 2). Many operators in SNAP toolbox do not support products with bands of different sizes so first we need to resample the bands to equal resolution.

Go to **Raster** \rightarrow **Geometric Operations** \rightarrow **Resampling** (See $\stackrel{\frown}{=}$ NOTE 3).

Do not change anything in the **I/O Parameters** tab.

In the **Resampling Parameters** tab under "**Define size of resampled product**", choose: **By reference band from source product: B2**

	Resampling	+ = ×		Resam	pling		* = X
File Help			File Help				
VO Parameters Res	ampling Parameters		VO Parameters	Resampling Parameters			
Source Product Name: [1] S2A_MSIL2A_20170	816T095031_N0205_R079_T34UEE_20170816T095031			esampled product. e band from source product:	B2 Resulting target width	10000	•
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Directory:	Wite Victory StenaFragratesea/Fracti		😡 By pixel res	olution (in m):	Resulting target widt Resulting target heigt	r 1830	10
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			Downsampling m	ethod:	First		-
			Flag downsamplin	ng method:	First		-
			Resample on	pyramid levels (for faster in	taging)		
		<u>R</u> un <u>C</u> lose				B	un <u>C</u> lose

Click Run.

After the process is completed, if a window appears, click Yes.

NOTE 2: The input product contains 13 spectral bands in three different spatial resolutions (The surface area measured on the ground and represented by an individual pixel). When we open the RGB view all our input bands have 20 m resolution, however, the view is displayed in the full 10 m resolution.



间 NOTE 3: The resampling product appears in the Product Explorer window but it is not physically saved. Therefore, it will be lost if you close it or if you close the source product.

A new product [2] appeared in the Product Explorer tab. Now we will have a look at the product. Close all the views we have open and expand the product structure by clicking the + sign on the left of the product name, then expand the Band folder and double click B8 (842nm) - (NIR).

5.2.3 Subset

In the next step, we will subset the image to our area of interest. Click on the resampled product in the **Product Explorer** tab, to highlight it. Then go to **Raster** \rightarrow **Subset** and in the **Spatial Subset** tab, set **Pixel coordinates** to:

Sp	ecify Product Subset	• m ×:	Scene star
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	-		
	Estimat	ed, raw storage size: 1785.7M	
		OK Cancel Help	

X: 200 **Y**: 0 7300 (: **'**: 6850

Keep the other Subset tabs as by default. Click **OK**.

A new product will appear in the **Product Explorer** tab [3]. Right-click the new product and click **Save** Product. In the pop-up window click Yes, in the next window navigate to /shared/Training/HYDR01_WaterBodies_TrainingKit/S2_Processing and save the subset data.

Right-click the product [3] and click **Open RGB image window** and from the dropdown menu select:

Profile: Sentinel 2 MSI Land/Water

Click OK.



5.2.4 NDWI

To detect the water bodies, we will use the Normalized Difference Water Index – NDWI. It was proposed by $McFeeters^2$ and it is designed to:

- i) maximize the reflectance of the water body in the green band;
- ii) minimize the reflectance of water body in the NIR band. McFeeters's NDWI is calculated as:

$$NDWI = \frac{Green - NIR}{Green + NIR} = \frac{B3 - B8}{B3 + B8}$$



Right-click on the newly created subset product [3], select **BandMaths** and set:

Name: NDWI

Deselect "Virtual (save expression only, don't store data)" - we want the band to be stored!

Click on "Edit Expression" and set as Expression: (B3 - B8)/(B3 + B8)

Click **OK** in both windows.



The open water pixels appear much brighter than other surfaces. Now, let's create another new band that will only contain water surfaces.

We will set the **threshold** for pixel to be classified as water to >= **0**.

Right click the product [3] and go to **BandMaths** again. Set:

Name: NDWI_mask

Deselect "Virtual (save expression only, don't store data)" - we want the band to be stored!

Click on "Edit Expression" and set as Expression: if NDWI >= 0 then 1 else 0

Click **OK** in both windows.

You can also go to **Window** \rightarrow **Tile Horizontally** to see the difference between the *NDWI* and the *NDWI_mask* bands.



Finally, right click on product [3] and go to **Save Product**. If a window appears click **Yes** and navigate to: */shared/Training/HYDR01_WaterBodies_TrainingKit/S2_Processing* to save it. If another window appears, click **Yes** as well.

Then go to File → Export → GeoTIFF.

Click on **Subset** and go to **Band Subset** tab; select only **NDWI_mask** band and click **OK**. Save as **File name**: *S2_watermasks.tiff*.

Finally click Export Product.

SNAP - Export Product 🔹 🗉	Specify Product Subset
	Spatial Subset Band Subset Metadata Subset
Save In: S2 Processing	view_zenith_BB Viewing incidence zenith angle
Name Size Modified Subset	view zenth BBA Viewing incidence zenith angle
subset 0 of S2A 1/18/19 10	view_azimuth_B8A Viewing incidence azimuth angle
	view_zenith_B9 Viewing incidence zenith angle
	view_azimuth_89 Viewing incidence azimuth angle
	view_zenith_B10 Viewing incidence zenith angle
	view_azimuth_B10 Viewing incidence azimuth angle
	view_zenith_B11 Viewing incidence zenith angle
	view_azimuth_Bll Viewing incidence azimuth angle
	view_zenith_B12 Viewing incidence zenith angle
	view_azimuth_B12 Viewing incidence azimuth angle
	NDW
ile Name: S2 watermasks.tiff	NDW_mask
iles of Type: GeoTIFF product (* tif, * tiff)	Select all Select none
	Estimated, raw storage size: 46.
Export Product Cancel	
Laport rivadet cancer	QK Cancel Help

Our first water mask is ready. Take some time to compare it to the RGB image. Now, let's derive the water mask from SAR data so we can compare.

Close the SNAP window. Any dialog windows that might appear asking you to save the data, click Yes.

5.3 SAR data – Sentinel-1

5.3.1 SNAP – open and explore data

Launch SNAP (icon on desktop). When the SNAP window opens click **Open Product** , navigate to **/shared/Training/HYDR01_WaterBodies_TrainingKit/Original** and open the five S1 products. Right-click each product and expand the **Bands** folder. Then double click the **Intensity_VH** band.



5.3.2 Build step-by step processing chain

We will now need to pre-process all five images but doing this one by one would be quite time consuming so let's use the **Batch Processing** tool available in SNAP to process all images at the same time.

To use the tool, we first need to define the process we want to apply and all its steps. We can do this using the **GraphBuilder** tool. The nice thing about the **GraphBuilder** is also that no intermediate product will be physically saved, only the end-product, which saves valuable disk space.

Go to **Tools** → **GraphBuilder**.

At the moment, the graph only has two operators: **Read** (to read the input) and **Write** (to write the output).

	rr (61466 0)760) (010779,2007) - Laborentireadorendiy D601 (yarordenios: Forecador (Vigieri)))	i ya jiy	GRDH VI	DY 201	0721111	1991.2		10590.0	
Ele Ede Yess Analysis Layer Vector Raster Optical Radar India Wind	Graph Builder	-	-	_	_	_	q.	1.1	-
a 1 9 0 4 4 1 9 3 4 12	nie Graphs	4	10 9	4	2º /	21	19:	1 4	1
Wodurt Explore: Pinel Info • (11) 132, 16, 0600, 13000, 201707337361353, 201 • (11) 132, 16, 0600, 13000, 201707337361353, 201 • (11) 132, 16, 1030, 201707337361353, 201 • (11) 132, 16, 1030, 201701307361353, 201 • (11) 132, 160, 1030, 2017013017361353, 201 • (11) 134, 160, 1040, 2017081671613953, 201 • (11) 134, 160, 1040, 2017081671613953, 201 • (11) 134, 160, 1040, 1300, 2017081671613953, 201 • (12) 134, 160, 1040, 1300, 2017081671613953, 201 • (12) 134, 160, 1040, 1300, 2017081671613953, 201 • (12) 134, 160, 1040, 1300, 2017081671613953, 201 • (12) 134, 160, 1040, 1300, 2017081671613953, 201 • (13) 134, 100, 1040, 1300, 2017081671613953, 201	Read Right click here to add an operator								A Hast Manager
Terepati Cator Uncertat work * 2									

Since our Area of Interest (AOI) is quite small and there is no need to process the whole image, we start by adding a **Subset** operator. To add the operator right-click the white space in the graph builder and go to Add \rightarrow Raster \rightarrow Geometric \rightarrow Subset.

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



In the next step, we will update the orbit metadata (See \square NOTE 4). To add the operator, right-click the white space between existing operators and go to Add \rightarrow Radar \rightarrow Apply-Orbit-File. Connect the new Apply-Orbit-File operator with the Subset operator.



Read Subset Apply-Orbit-File	Write
------------------------------	-------

The next step will remove the thermal noise (See \square NOTE 5). We add this operator by right-clicking the white space somewhere left of the resample operator and going to Add \rightarrow Radar \rightarrow Radiometric \rightarrow ThermalNoiseRemoval. Connect the ThermalNoiseRemoval operator with the Apply-Orbit-File 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.

Now, we can add the **Calibration** operator. 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 1 NOTE 6).

To add the operator go to $Add \rightarrow Radar \rightarrow Radiometric \rightarrow Calibration$. Connect the **ThermalNoiseRemoval** operator to the **Calibration** operator.

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 Subset Apply-Orbit-File ThermalNoiseRemoval Calibration	Write
--	-------

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, as the last step of our preprocessing, we will apply terrain correction to compensate for the distortions and reproject the scene to geographic projection (See \sum NOTE 7).

To add the operator, go to Radar \rightarrow Geometric \rightarrow Terrain Correction \rightarrow Terrain-Correction then connect the Calibration operator to it.



At the moment, do not change anything in the parameter tabs and save the graph by clicking **Save** at the bottom of the window.

Navigate to:

/shared/Training/HYDR01_WaterBodies_TrainingKit/S1_Processing and save the graph with the File Name: Graph_preprocess.xml.

Close the **GraphBuilder** window.

5.3.3 Batch processing

In the **Product Explorer** window, we select (highlight) the product [1] (11 July 2017). Now we can open the Batch Processing tool (**Tools** \rightarrow **Batch Processing**).

We will add the opened products by clicking **Add Opened** on the upper right (second icon from the top) and click **Refresh**. Then, we click **Load Graph** at the bottom of the window, navigate to our saved graph, and open it. We see that new tabs have appeared at the top of window corresponding to our operators with the exception of **Write**; this is correct, as these parameters will be set in the **I/O Parameters** tab.

In the **I/O Parameters** tab set the directory to: */shared/Training/HYDR01_WaterBodies_TrainingKit /S1_Processing* and then **deselect** the "Keep source product name".

ThermalNoiseRemoval	Calibration	Terrain-Correct	ion			
I/O Paramete	rs	Subset		Apply-Orbit-Fil	e	
File Name	Туре	Acquisition	Track	Orbit	4	
SIA IW GRDH 1SDV 20	GRD	11Jul2017	29	17426	+ 	
SIA W GRDH ISDV 20.	GRD	23Jul2017	29	17601		Add opene
SIA IW GRDH 1SDV 20.	GRD	04Aug2017	29	17776	-	
SIA IW GRDH 1SDV 20.	GRD	16Aug2017	29	17951		
SIA_W_GRDH_1SDV_20	GRD	28Aug2017	29	18126		
	GRD	28Aug2017	29	18126		
SIA_W_GRDH_1SDV_20 Target Folder	GRD	28Aug2017	29	18126	* ₩₩ *	
	GRD	28Aug2017	29	18126	* ₩₩ *	
Target Folder		28Aug2017	29	18126	* ₩₩ *	
Target Folder	-				* ₩₩ *	

In the **Subset** tab press **Ctrl** and select bands **Amplitude_VH** and **Intensity_VH** 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 ((21.03027778 54.14805556, 22.11722222 54.14833333, 22.10111111 53.52722222, 21.03000000 53.53250000, 21.03027778 54.14805556))
```

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

ThermalNoiseRei	moval Calibration	Terrain-Correction			
Contraction of the state of the second state of the	rameters	Subset	Apply-Orbit-File		
Source Bands: Copy Metadata	-				
Pixel Coordinat	tes 💿 Seographic Ci	Sordinates		<u>e e</u> ¢	<u> </u>

In the Apply-Orbit-File tab we can accept the default settings.

Batch Processing : Graph_Preprocess.xml					• = *
File Graphs					
ThermalNoiseRem			Terrain-Correction	1	
I/O Para	meters	5	Subset	Apply-Orbit-File	
Orbit State Vectors:	Senti	nel Precise (Al	uto Downloadi		-
Polynomial Degree:	3				1
	Do	not fail if nev	v orbit file is not foun	d	

In the **ThermalNoiseRemoval** tab select **VH** polarization and make sure that "**Remove Thermal Noise**" option is selected.

Batch Processing : Graph_preprocess1.xml					
File Graphs					
ThermalNoiseRemoval	Calibration	Terrain-Correction	1		
I/O Parameters		Subset	Apply-Orb	it-File	
Polarisations:	VH				
	W				
Remove Thermal Nois	e				
Re-Introduce Thermal	Noise				

In the **Calibration** tab we will also accept all default settings.

Ba	tch Processi	ng : Graph_prepro	cess1.xml	
File Graphs				
ThermalNoiseRemoval	Calibration	Terrain-Correction		
I/O Paramete	rs	Subset	Apply-Orbit-File	
Polarisations:	VH			
Save as complex outp	out:			
🕑 Output sigma0 band				
🔲 Output gamma0 band				
Output beta0 band				

In the **Terrain-Correction** tab: **Map Projection -> Predefined CRS**. Click on "**Select**" and choose: **AUTO: 42001 – WGS 84 / Auto UTM**. Leave all the other default settings.

C4.	ing : Graph_preprocess1.xml	1 1 2	Map Projecti	
File Graphs			Coordinate Reference System	(CRS)
ThermalNoiseRemoval Calibratio	on Terrain-Correction		Custom CRS	
VO Parameters	Subset Apply-Orbit-File		Geodetic datum:	in the second se
Source Bands:	Sigma0_VH	*		
			Projection	
			- Er	rojection Parameters
			Predefined CRS	Select
			2	K <u>Ç</u> ancel <u>H</u> elp
Digital Elevation Model:	SRTM 3Sec (Auto Download)	1-		
DEM Resampling Method:	BILINEAR_INTERPOLATION		Select Coordinate Refe	rence System 👔 🕤 🤉
Image Resampling Method:	BILINEAR_INTERPOLATION		Filter Type here to f Well-Know	n Text (WKT)
Source GR Pixel Spacings (az x rg):	10.0(m) × 10.0(m)		AUTO:42001 - WGS - AUTO:420	101 - WGS 84 / Auto UTM
Pixel Spacing (m):	10.0		AUTO:42002 - WGS	
Pixel Spacing (deg):	8.983152841195215E-5		AUTO:42004 - WGS	
Map Projection:	WGS84(DD)	-	AUTO:97001 - WGS	=
Mask out areas without elevation	Output complex date		AUTO: 97002 - WGS EPSG: 2000 - Angui	
Output bands for:			EPSG 20004 - Pulk	
Selected source band	DEM Latitude & Longitude		EPSG: 20005 - Pulka	
Incidence angle from ellipsoid	Local incidence angle Projected local incide	nce angle	EPSG: 20006 - Pulk	-
1			4 M P 4	

Click **OK** in both windows and finally click **Run** to pre-process our images.

Approximate processing time: 10 minutes depending on machine

Close the **Batch Processing** window. Now you should have five new products in the **Product Explorer** tab. Select the original products [1-5], right-click on them and click **Close 5 Products**.

5.3.4 Coregister and average

Now, we need to add all our pre-processed products to a single coregistered stack, so we can calculate the 2-month mean. Unfortunately, coregistration is rather heavy and time consuming, so be patient. Averaging the observations will greatly decrease the speckle and make the delineation of water bodies much more accurate.

Go to Radar \rightarrow Coregistration \rightarrow Coregistration.

In the **ProductSet-Reader** tab, we will add the opened products by clicking **Add Opened** on the upper right (second icon from the top) and then click **Refresh**.

				Warp Write	relation	ProductSet-Reader CreateStack Cross-Corr
	4	Orbit	Track	Acquisition	Туре	File Name
	-15-	17426	29	11jul2017	GRD	SIA_IW_GRDH_1SDV_20170711T161931_201707
 .		17601	29	23Jul2017	GRD	SIA_IW_GRDH_1SDV_20170723T161931_201707
Add opened	同会	17776	29	04Aug2017	GRD	SIA_IW_GRDH_1SDV_20170804T161932_201708
		17951	29	16Aug2017	GRD	SIA_IW_GRDH_1SDV_20170816T161933_201708
	-	18126	29	28Aug2017	GRD	SIA_IW_GRDH_1SDV_20170828T161933_201708
Refresh						

In the CreateStack tab, set Resampling Type: "Nearest Neighbour" and click Find Optimal Master.

e		Coregistration		(* E >		
ProductSet-Reader	CreateStack	Cross-Correlation	Warp	Write		
Master:	SIA W GRE	H_1SDV_20170804T	161932	20170804T161957_	017776_01DC8A_4628	
Resampling Type:	NEAREST_N	NEAREST_NEIGHBOUR				
Initial Offset Method:	Orbit	Orbit				
Output Extents:	Master					
Find Optimal Master	4					

In the Cross-Correlation tab, leave the defaults.

C		Co	registration 🔹 🗉 👌
ProductSet-Reader CreateS	tack C	ross	-Correlation Warp Write
Number of GCPs:			2000
Test GCPs are on land			Apply Fine Registration for SLCs
Coarse Registration			Fine Registration
Estimate Initial Coarse Offs Coarse Window Width:	128	-	Fine Window Height
Coarse Window Height	128	-	Coherence Threshold:
Row Interpolation Factor:	4	-	O Cross-Correlation based registration
Column Interpolation Factor:	4	-	Fine Accuracy in Azimuth:
Max Iterations:	10	-	Fine Accuracy in Range:
GCP Tolerance:	0.25		Fine Window oversampling factor:
			Coherence based registration
			Use Coherence Sliding Window
			Coherence Window Size:

In the **Warp** tab, leave the defaults.

C		Coregistration	* = ×
ProductSet-Reader	CreateStack (Cross-Correlation Warp Write	
RMS Threshold (pixel	ccuracy): 0.05		-
Warp Polynomial Orde	1		Ŧ
Interpolation Method:	Cubic co	onvalution (6 paints)	-
Show Residuals			

In the **Write** tab, change the name to **S1A_IW_summerStack** make sure that the output directory is: /shared/Training/HYDR01_WaterBodies_TrainingKit/S1_Processing

e.	Coregistration	(+ = x
ProductSet-Reader	CreateStack Cross-Correlation Warp	Write
Target Product =		
Name:		
SIA_IW_summerStan Save as: BEAM-DIMA Directory:		
	d/Training/HYDR01_WaterBodies_TrainingKit	S1_Processing
	1	-
	🕐 Help 🕞 Rur	• • • • • • • • • • • • • • • • • • •

Click **Run**. Approximate processing time: 20 minutes depending on machine

Close the **Coregistration** window. A new product [11] has appeared in the **Product Explorer** window. Expand it and have a look at the contents of the **Bands** folder. It contains five bands, each corresponding to one acquisition date. Double click the first band to open it in **View** window.



We can see the extent of the image is larger than that of our S2 subset (marked in red above) 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 can correct this by using a simple subset again. Go to **Raster** \rightarrow **Subset**.

In the Spatial Subset tab click on the Geo Coordinates and set:



North latitude bound: 54.148 West longitude bound: 21.030 South latitude bound: 53.527 East longitude bound: 22.101 Click OK.

New product [12] has appeared in the **Product Explorer** tab.

Right-click the product and go to **Open RGB Image Window**.



This we do just out of interest, by creating the multi-temporal RGB combination we can see the changes that have occurred between the acquisitions. These will mostly be related to harvested fields. We will not see many changes in the water bodies unless for example, the water level changed significantly, or an area was flooded. Now, let's calculate the average backscatter.

Go to Radar \rightarrow Coregistration \rightarrow Stack Tools \rightarrow Stack Averaging. In the I/O Parameters tab make sure that the directory is: /shared/Training/HYDR01_WaterBodies_TrainingKit/S1_Processing.

In the Processing Parameters tab, set Statistics: Mean Average.

Click Run.

e	Stack Averaging	* = × 👌	ġ.	Stack Averaging	+ E X
File Help		F	ile Help		
1/0 Parame	ters Processing Parameters	1	1/O Parameters	Processing Parameters	
Source Pro Source pro			Statistic: Mean A	verage	
[12] subse	t_0_of_S1A_IW_summerStack				
Target Proc	duct				
subset_0_c	of_S1A_IW_summerStack_avg				
	S: BEAM-DIMAP				
Director	ry: aining/HYDR01_WaterBodies_TrainingKit/S	1_Processing			
Ø Open in	SNAP				
		<u>R</u> un <u>C</u> lose			Run Close

A new product [13] was created; the **Bands** folder contains a single band with averaged values.



If we open all the bands of the stacked product and the averaged band and use the **Window** \rightarrow **Tile Evenly** tool, then we can see that the averaged image appears much smoother.

5.3.5 Binarization

To separate water from non-water on an image we need to have enough separability between the two classes. Let's close all views except for the averaged band.

Then go to the **Product Explorer** window and **right-click** on the averaged band "Sigma0_VH".

Go to **Linear from/to dB** and click yes to add the dB band as new virtual band. This operation transforms the histogram to logarithmic scale and helps us to better distinguish between water and other surfaces.



Let's inspect the histogram to find a good threshold value. In addition, we can also draw some polygons over water surfaces and extract statistics...



Then we can go to **Analysis** \rightarrow **Statistics**.

Statistics × Sigma0_VH_db with ROI-mask geometry C #Pixels to... |371952 0 ☑ Use <u>R</u>OI mask(s): 3.250 Minimum: -89.7614 -10 3,000 5 Maximum: -19.4694 Filter: Mean -34.9373 2,750 -20 **i**geometry 4.4150 Sigma: 2,500 Median: -34.1605 Value Threshold -30 2,250 -0.1264 Coef Varia. 2,000 62.6210 ENL -40 #Pixels P75 thres... -31.9814 1,750 -50 -31.5597 -30.9973 P80 thres. 1,500 P85 thres. 1,250 -60 P90 thres... -30.4350 1,000 Max error: 0.0703 🖌 Select all 🛛 🔲 Select none -70 750 500 -80 Histogram accuracy 250 -90 Auto accuracy 0 Histogram accuracy -90 -80 -70 -60 -50 -40 -30 -20 Ó 25 50 75 100 Percentile (%) Value 0 窗

Tick the "Use ROI mask" option, select geometry and then click Refresh.

In our case, just by visual analysis we will select value -25 as our threshold. Go to **Product Explorer** tab and **right-click** the *Sigma0_VH_dB* band.

Select **Band Maths...** and set as **Name**: "*water_mask*". Deselect the **Virtual** option. Then click on **Edit Expression ...** and type:

if $13.Sigma0_VH_db < -25.0$ then 1 else 0

	Band Maths = = x	Bai	nd Maths Expression Ed	itor 🔶 🗉 🗙
Target product		Product: [13] subset_1_	of_S1A_IW_summerStack_av	· 0
[13] subset_1_c	of_S1A_IW_summerStack_avg	Data sources:		Expression:
Name: water_mask		\$13.SigmaO_VH	0+0	if \$13.Sigma0_VH_db < -25
Description:		\$13.SigmaO_VH_db	0 - 0	- then 1 else 0
Unit:		\$13.geometry		4
Spectral wavele	ngth: 0.0		6 * 6	
	expression only, don't store data)		0/0	
E	and infinity results by NaN		(@)	
-			Constants 💌	
Band maths exp	sociated uncertainty band		Operators 👻	
Dalia mabis exp	n 6551011.	Show bands	Functions 👻	
		Show masks		
Load	Save Edit Expression	Shew the point grids		
		Shaw single flags		
	QK <u>C</u> ancel <u>H</u> elp		0	<u>OK</u> <u>Cancel</u> <u>H</u> elp

Click **OK** in both windows.



Finally, right click on product [13] and go to Save Product.

Then go to File \rightarrow Export \rightarrow GeoTIFF. Click on Subset and go to Band Subset tab; select only "water_mask" band and save as S1_watermask.tiff at:

/shared/Training/HYDR01_WaterBodies_TrainingKit/S1_Processing and click on Export Product.

SNAP - Export Product	+ = X	Specify Product Subset		• = ×
Save In: S1_Processing	Spatial Sign	a0_VH Sigma0_VH average intensity a0_VH_db Sigma0_VH average intensity		
File Name: S1_watermask.tiff Files of Type: GeoTIFF product (*.tif,*.tiff) Export Product Can		ct gll 🔲 Select none Estimated QK	. raw storage	size: 46.4M

5.4 Visualization (QGIS) and comparison

Let's compare the 2 masks we have produced. To be able to do so, we will open the saved masks (GeoTIFF) in QGIS.

Go to *Application* \rightarrow *Processing* \rightarrow *QGIS Desktop*. Click on the Add Raster Layer button located in the left panel (\blacksquare), navigate to: */shared/Training/HYDR01_WaterBodies_TrainingKit/S2_Processing* select the saved *S2_watermask.tiff* and click **Open**.

Load also the **S1_watermask.tiff** from the **S1_Processing** folder.

Right click the *S1_watermask* in the Layers Panel and go to Properties. In the Transparency tab set: Global transparency: 50 %

Additional no data value: 0

X	Layer Properties - 51_watermask Style	• ÷ • •	<u>/</u>	Layer Properties - 51_watermask Transparency	10.00
🥳 General 🎻 Style	Band rendering Hender type Singleband pseudocolor	-	🧏 General 🂕 Style	Global transparency Sono data value Mone 50% Full Additional no data value	_
Varosparency	Band Band 2 (Gray) Min 0 Max 0.999 Load minimax values Interpolation Linear Color Careys Edit 1" Inven Label unit Suffix Min / max Estimated cumulative cut of full extent. Value Color Label		Transparency Pyramids Hestogram Metallata Legend	None 30% Full Additional no data value 0 * Castom transparency options Transparency band None Transparent pixel list From To Percent Transporent	

Then, go to **Style** tab and set Render type to **Singleband pseudocolor**, scroll down and click to add a value to the colour table. Click the value 0 and change it to 1. Then double-click the Colour field and change the colour to **blue**. Click **OK**.

Now do the same for the S2_watermask but change the colour to **red** and leave the transparency at 0%.

Finally, we can add a base-map to link our water masks to GIS data. Click on Web \rightarrow OpenLayers plugin \rightarrow Google Maps \rightarrow Google Satellite (See $\stackrel{\frown}{=}$ NOTE 8). Then in the Layer Panel click on the Google Satellite layer and drag it below our raster layers.

In case Google Satellite is not available for any reason, use a different layer, e.g. **Bing** \rightarrow **Bing** Aerial.

NOTE 8: 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.



THANK YOU FOR FOLLOWING THE EXERCISE!

6 Extra steps

6.1 Atmospheric correction for S2

Solar radiation reflected by the Earth's surface to satellite sensors is affected by its interaction with the atmosphere. The objective of applying an atmospheric correction is to determine true surface (Bottom-Of-Atmosphere, BOA) reflectance values from the Top-Of-Atmosphere (TOA) reflectance values, by removing atmospheric effects. (See INOTE E1) Atmospheric correction is especially important in cases where multi-temporal images are compared and analysed as it is in our case (pre-fire and post-fire images).



In this tutorial, we will use the Sen2Cor processor. Sen2Cor is a processor for Sentinel-2 Level 2A product generation and formatting; it performs the atmospheric, terrain and cirrus correction of Top-Of-Atmosphere Level 1C input data. Sen2Cor creates Bottom-Of-Atmosphere, optionally terrain and cirrus corrected reflectance images; additional, Aerosol Optical Thickness, Water Vapour, Scene Classification Maps and Quality Indicators for cloud and snow probabilities.

To run the atmospheric correction, we first need to go out of SNAP and in File Manager navigate to the folder where our data are saved: */shared/Training/HYDR01_WaterBodies_TrainingKit/Original* and unzip the product by right-clicking each and going to *"Extract Here"*. This will create a folder with suffix *".SAFE"*.



Then go back to SNAP and go to **Optical** \rightarrow **Thematic Land Processing** \rightarrow **Sen2Cor**.

In the I/O Parameters we need to click on ... next to the product name and navigate inside of the first product folder (".*SAFE"* suffix). Then, open the *MTD_MSIL1C.xml* file. In the **Processing Parameters** tab change the resolution to "*ALL"* and select "*Display execution output"*. Click **Run**.

	SEN2COR	* = ×		SENZCOR		1.0		
File Help			File Help					
I/O Parameters	Processing Parameters		I/O Parameters P	rocessing Parameters				
Source Product Source product S2A_MSILIC_20160813T141052_N0204_R110_T20KQB_20160813T141049 Select Source Product Select Source Product AUX_DATA INSPIRE.xml AUX_DATA INSPIRE.xml AUX_DATA INSPIRE.xml AUX_DATA INSPIRE.xml I			Display execution output					
			Cr only L2A_GIPP file Iff a file is selected, the parameters below will not be used) Nb processes. Median filter.] ar 1 0			
			GRANULE GRANULE File Name: MTD Files of Type: All File	MTD_MSILIC.xml MTD_MSILIC.xml II Files		Ilo resolution specified, will process all resolutions. Progress (%): 001: PID-29105, L2A_ProcessTile: processing with resolution 60 m, elapsed time[s]: 0.418, total: 0.0327,829522 Progress (%): 001: PID-29105, L2A_ProcessTile: start of pre processing, elapsed time[s]: 0.000, total: 0.0327,929530 Progress (%): 001: PID-29105, L2A_Tables: start import, elapsed time[s]: 0.095, total: 0.0327,925560 Progress (%): 005: PID-29105, L2A_Tables: start import, elapsed time[s]: 0.158, total: 0.0329,064231 Progress (%): 0.05: PID-29105, L2A_Tables: band 802 imported, elapsed time[s]: 26,699, total: 0.0355, 98042		
		Select Cancel	1		Bun <u>C</u> lose <u>H</u>	elp		

This is rather a time demanding process and requires approximately 30 minutes per image (with 8GB RAM).

The process creates a new Level 2-A product in the *.SAFE* format in the original folder. Now let's load the result to SNAP.

Click Open product , navigate to: /shared/Training/HYDR01_WaterBodies_TrainingKit/Original then open the Level-2A product folder for 2016: *S2*_MSIL2A_*.SAFE* And open the *MTD_MSIL2A.xml*

6.2 Downloading the outputs from VM

On your keyboard, press **Ctrl+Alt+Shift.** A pop-up window will appear on the left side of the screen. Click on the bar below **Devices**, the folder structure of your VM will appear. Navigate to your Processing folder and **double click any file you want to download.**



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