





# TRAINING KIT – HAZA02

BURNED AREA MAPPING WITH SENTINEL-2 (SNAP) JUNE 2017, PORTUGAL









Research and User Support for Sentinel Core Products

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

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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.



Portugal wildfires June 2017 Credits: www.theguardian.com [June 18, 2017]

A series of four initial deadly wildfires erupted across central Portugal in the afternoon of 17 June 2017 within minutes of each other, resulting in at least 64 deaths and 204 injured. An intense heat wave preceded the fires, with many areas of Portugal, seeing temperatures in excess of 40 °C (104 °F).

During the night of 17–18 June, a total of 156 fires erupted across the country, particularly in mountainous areas 200 km (120 mi) north-northeast of Lisbon. The fires began in the Pedrógão Grande municipality before

spreading to others and causing a firestorm. A total of 44,969 hectares of land was burned by the fires as of 20 June, 29,693 hectares (73,370 acres) of which, was in the Pedrógão Grande area.

## 2 Training

Approximate duration of this training session is two hours.

The Training Code for this tutorial is HAZA02. If you wish to practice the exercise described below within the RUS Virtual Environment, register on the <u>RUS portal (rus-copernicus.eu)</u> and open a User Service request from Your RUS service  $\rightarrow$  Your dashboard.

#### 2.1 Data used

Two Sentinel-2A Level 2A tiles (Tile ID: T29TNE) acquired between on June 4, 2017 (before the main event) and July 4, 2017 (after the main event).
 [downloadable @ <u>https://scihub.copernicus.eu/</u>]

S2A\_MSIL2A\_ 20170604T112121\_N0205\_R037\_T29TNE\_20170604T112755.zip S2A\_MSIL2A\_ 20170704T112111\_N0205\_R037\_T29TNE\_20170604T112431.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	Ÿ Ÿ	000
Close		Forgot your password?		

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

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+ Your RUS service	Login			9
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	RUS service?	colleagues	mpn Politini - 5, 9, 10 & 13 Nov.	1000 No. 1000
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		other		
	Institution type	Select one item	∽ nda	
	Phone number Italy (IT):	+39	arkainare -	100
	Title	Select one item	~	L VILLAN

## 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 RUS service *
	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.

ease help us learn more about your background by answering a few question formation will be stored in your User Profile. ow many years of experience in Remote Sensing do you have? Choose one Item ave you already downloaded Copernicus data via the Copernicus Open access hubs? Yes No ave you already handled/processed Copernicus data? Yes No o you wish to practice a tutorial exercise shown in a RUS webinar? If yes, please select your of	nns. Th
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IAZA01 - Flood Mapping in Malawi	
IAZA02 - Burned Area Mapping in Portugal IYDR01 - Water Bodies Mapping over Northern Poland	- 11
AND01 - Crop Mapping in Seville	- 11
AND04 - Land Monitoring in Cyprus ICEA01 - Ship Detection in Gulf of Trieste	*
you wish to request another tutorial exercise that doesn't appear in the above list, please typ s name or code. Note that you can request multiple tutorial exercises.	pe here
	- Harde

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

Summary information on your request:		
This is a collection of information selected		
You can go back and edit this information	if necessary.	
General information on your request:		
Years of experience in Remote Sensing	5-10 years	
Downloaded Copernicus data?	1	
Handled/processed Copernicus data?	1	
Webinar codes	HAZA02, LAND04	
About your RUS project:		
Thematic area	Cryosphere (ice and snow)	
Operations to perform on RUS	Algorithm development	
Preference for downloading process	Self-downloading	
Foreseen activities and support needs	Develop a land cover classification	
Project name	RUS_Project1	
Earth Observation Data information:		
Type of Earth Observation Data:		
Sentinel-1	1	
	S1-Product 1	
S1 - Product type	GRD	
S1 - Sensor mode	4	
S1 - Polarisation	a	
S1 - Orbit direction	-	
Sentinel-2	x	
Sentinel-3	×	
Other	x	
I don't know	×	
Region of Interest: Min Latitude	39.3303	
Max Latitude	40.5877	
Min Longitude	-4.6736	
Max Longitude	-2.7205	
Reference polygons		
Data acquisition date(s):		
None		
Additional data specifications		
I have read and agree to the Terms and	conditions of RUS Service.	

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

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

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



This is the remote desktop of your Virtual Machine.

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## 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.

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		Register ne	w account	
	the data.		nk to validate your e-mail address. Following this you can sty, to do	ownload
	Bistname		Lasiname	
	Üsername			
	Passward		Confirm Password	
	6-mail		Çonûrm E-mail	
	Select Domain			
	Select Usage			
	Select Country	•		

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".



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 (See 💗 TIP 1):

Sensing period: From 2017/06/04 to 2017/07/04 Check Mission: Sentinel-2 Product Type: S2MSI2Ap

TIP 1: For the Level 2A products that 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**). Atmospheric correction using Sen2Cor algorithm is a computationally heavy process and takes approximately 30 minutes per image to be completed depending on your machine. However, since April 2017 the Level-2A products have already been generated and are available to download for acquisitions over Europe (such as this case). If you want to try to run the atmospheric correction (section **4.1**) nevertheless, you can change:

Product Type: S2MSIL1





In our case the search returns 13 results depending on the exact search area defined. Download the scenes (pay attention to the tile ID, below in red):

S2A\_MSIL2A\_ 20170604T112121\_N0205\_R037\_T29TNE\_20170604T112755 S2A\_MSIL2A\_ 20170704T112111\_N0205\_R037\_T29TNE\_20170704T112431

Data will be downloaded to */home/rus/Downloads* as ZIP archives. Move the archives to: */shared/Training/HAZA02\_BurnedArea\_Portugal\_TutorialKit/Original* 

#### 5.2 SNAP – open and explore data

Launch SNAP (icon on desktop ......). When the SNAP window opens click Open product and navigate to /shared/Training/HAZA02\_BurnedArea\_Portugal\_TutorialKit/Original

Select both downloaded products and click **Open.** At the end you will have both products opened in the **Product Explorer** window on the left.

Now, we will look at the products. We could visualize them in true (natural) colours but for distinguishing the burned areas it is better to use the Near InfraRed (NIR) and Short-Wave InfraRed (SWIR) bands as these provide the best separability (for more explanation, check the graph in  $\square$  NOTE 2).

Right click the pre-fire product from 4 June and click **Open RGB image window**, a new window will open.

2 MSI Natural Colors (modified)	
\$1.B12	-
\$1.B11	<b>•</b>
\$1.B8A	
	\$1.B12 \$1.B11

Set: Red: B12 Green: B11 Blue: B8A

Then click **OK**. The RGB image will be created at the View window.

Do the same for the post fire product from 4 July. Now we will have 2 windows opened.



Now go to Navigation pane in the lower left and make sure the cursor  $\searrow$  and the views  $\bowtie$  are both checked, so that they are linked. Then, go to **Window**  $\rightarrow$  **Tile Horizontally**. The image appears in the upper left corner of the view window. Click on the Pan mode on View [2] and zoom in to the burned area – orange-brown colour. (See  $\frown$  NOTE 1).

NOTE 1: The input product contains 13 spectral bands 3 different spatial in 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.





#### 5.3 Creating a cloud mask band

The Sentinel-2 L2-A product conveniently contains vector cloud and cirrus masks, which are created as a product of the atmospheric correction, however, applying the mask on all bands and full scene takes some time. We can subset the product, but the vector products are lost by that operation. So, in our case to preserve the information we will create a new band containing a cloud mask. This is currently not possible to do using Batch Processing, so we need to add the *cloud\_mask* band to each product separately.

Right-click on the first product from 4 June [1] and click on "Band Maths...". A new window will open.

Set **Name** to: "cloud\_mask" (the name must be the same in both products!!!) and deselect "Virtual (safe expression only, don't store data)"

Then click "Edit Expression..." and enter the following statement:

2	B	and Maths		- • ×	
Target product:					
[1] S2A_MSIL2A	_20170604T112121_N0205_N	R037_T29TNE_20170604	T112755	-	
Name:	cloud mask			l	
Description:					
Unit:					
Spectral wavele	ngth: 0.0				
/irtual (save	e expression only, don't stor	e data)			
Replace Nak	and infinity results by			NaN	
Generate as	sociated uncertaint, hand				
Band maths exp	pression:				
if (\$1.scl_cloud_	medium_proba+ \$1.scl_clou	d_high_proba+ \$1.scl_t	hin_cirrus) > 255 then 0	else 1	
Load	Save		Edit Expression		

8	Band	Maths Expression	Edito	r	↑ □ ×			
Product: [1] S2A_MSIL2A_20170	604T112121_N02	205_R037_T29TNE_20	170604	4T112755	-			
Data sources:				Expression:				
\$1.B1	•	0+0		if (scl_cloud_medium_proba +	Sec. 19.			
\$1.82	1			- scl_cloud_high_proba + scl_thin_cirru				
\$1.B3		6 - 6	_	< 255 then 0 else 1				
\$1.B4		6 + 6						
\$1.85		0/0		1				
\$1,B6			-	4				
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\$1.88		Constants						
🖌 Show bands		Operators	-	1				
🖌 Show masks		Functions	-					
Show tie-point ger			_					
Show ingle flags				書簡フ記	Ok, no errors			
				QK. <u>C</u> ancel	Help			

Click **OK** in both windows and the new band will automatically open in a new view; we can click at the name of the "cloud\_mask" tab and drag this view window next to the corresponding RGB view. In **Navigation tab** click Zoom All<sup>®</sup>.

Right-click on the second open product from 4 July [2] (post-fire product) and apply the same steps.



#### 5.4 Pre-processing

As we have seen in the previous step, processing the data one by one would be very time consuming and inconvenient. However, we can 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. Another advantage of the **GraphBuilder** is that only the final product will be physically saved, and we save valuable disk space.

So, let's build our graph. Go to **Tools → GraphBuilder**.

[2] Sentinel 2 MSI Natural Colors RGB - S2A MSIL2A 201707047112111 N0205	R037_T29TNE_20170704T112431 - /root/Tutorials/Portugal_file_2017_tutorial_bas	sic/Original/52	A MSIL	2A_20170	704711211.	N0205	R037_T2	TNE_2	d 8
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At the moment, the graph only has two operators: **Read** (to read the input) and **Write** (to write the output).

The 13 bands in Sentinel-2 products do not all have same resolution (therefore size) as mentioned in NOTE 1. Many operators do not support products with bands of different sizes so first we need to resample the bands to equal resolution.

To add the appropriate operator, right-click the white space between existing operators and go to Add  $\rightarrow$  Raster  $\rightarrow$  Geometric  $\rightarrow$  Resample

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



Next step will be to subset the images to the area of interest, we do this by right-clicking the white space somewhere right of the resample operator and going to Add  $\rightarrow$  Raster  $\rightarrow$  Geometric  $\rightarrow$  Subset. Connect the Subset operator with the Resample operator.

Now, we will add the BandMath operator from Add  $\rightarrow$  Raster  $\rightarrow$  BandMaths and then connect it to the Subset operator. Last, we add BandMerge operator from Add  $\rightarrow$  Raster  $\rightarrow$  BandMerge. Connect both, the Subset operator and the BandMaths operator, to the BandMerge operator. Finally, connect the BandMerge operator to the Write operator.



At the moment, do not change anything in the parameter tabs, save the graph as *Graph\_process.xml* under */shared/Training/HAZA02\_BurnedArea\_Portugal\_TutorialKit/Processing* path by clicking **Save** at the bottom of the window and then close the **GraphBuilder** window.

In the **Product Explorer**, we select (highlight) the product [1] (4 June 2017). Now we can open the Batch Processing tool at **Tools**  $\rightarrow$  **Batch Processing**.

Now, we will add both opened products. In the **I/O Parameters** tab, click **Add Opened** on the upper right (second from top) and click **Refresh**. Deselect the **Keep source product name**. Then 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.

	ple Subset	BandMaths	BandMerge	Write		
File Name	Type	Acquisition	Track	Orbit	4-	
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Now, let's set the parameters. In **Resample** tab we set:

Under **Define size of resampled product**: Select the "**By reference band from source product**" and choose the **B2** band (we will resample all the bands to 10m resolution). And at the bottom set, choose as **Upsampling method**: **Bilinear** 

myGraph.xml	- E			
dMaths BandMerge	Write			
(B2)				
Resulting target width:	10980			
Resulting target height:	10980			
Tanget width	10,980			
Target bright	11.980			
Width J height ratio.	1.00000			
	00			
Resulting target width: 1850				
Resulting target height:	1830			
Bilinéar				
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First				
	1ED			
	B2 Resulting target width: Resulting target height: Target width Target beight Width J theight ratio. Resulting target width: Resulting target height Bilinear First			

In the Subset tab we select bands: B3, B8, B12 and cloud\_mask (to select multiple hold Ctrl). And set:

Pixel coordinates to:	X: 5400	Y: 4800	
	Width: 5580	Height: 6180	
	a second second	providence and the second	_

I/O Parameters	Resample Sub	set BandMaths BandMa	ths BandMerge W	rite
Source Bands:	B1			1
	B2			
	B3			
	B4			
	B5			
	B6			
	B7			
	B8			1
Copy Metadata				
	22 11	Coordinates		
Pixel Coordinat	es 🔾 Geographic	coordinates		
Pixel Coordinat	5400	Y:	4800	_
			4800 6180	

Next, we set the expression for the calculation of **Normalized Burn Ratio** (NBR). (See  $\square$  NOTE 2) In the **BandMaths** tab set:

#### Target band: "NBR"

No-Data Value: NaN

**Expression:** (B8 - B12)/(B8 + B12)

Ba	tch Processing - Graph_process.cml 👘 🗧 🗉 🛪	Arithr	netic E	expression Editor		★ ■ ×
File Graphs		Data sources:				Expression:
/ I/O Parameters	Resample Subset BandMaths BandMerge Write	B2	-	6 + 6		(B8 - B12) / (B8 + B12)
Target Band:	NBR	B8 B12		0 - 0		
Target Band Type:		cloud mask		6 * 6		
Band Unit:		detector_footprint-B01-02		0/0		
No-Data Value:	NaN	detector_footprint-B01-03	_	(6)		
Expression:		detector_footprint-B01-04 detector_footprint-B01-05	-	Constants	-	
		Show bands		Operators	-	
		🗹 Show masks		Functions	-	
	Edit Expression Load Graph Run <u>C</u> lose <u>H</u> elp	⊡ Shaw lie onint ands □ Shaw kingle flags				K Cancel Help

Click **OK** to close the "Arithmetic Expression Editor" window.

NOTE 2: The most commonly used metrics for burned area and burn severity mapping, derived from satellite data, is the normalized burn ratio (NBR).

$$NBR = \frac{NIR - SWIR}{NIR + SWIR}$$

Healthy vegetation has very high near-infrared reflectance and low reflectance in the shortwave infrared portion of the spectrum. Burned areas on the other hand have relatively low reflectance in the near-infrared and high reflectance in the shortwave infrared band. A high NBR value generally indicates healthy vegetation while a low value indicates bare ground and recently burned areas.



In the **BandMerge** tab, keep the default parameters.

le Graphs		
I/O Paramete	ers Resample Subset BandMaths BandMerge Write	3
Source Bands:	NBR::Subset_S2A_MSIL2A_20170604T112121_N0205_R037_T29 B3::Subset_S2A_MSIL2A_20170604T112121_N0205_R037_T29T B8::Subset_S2A_MSIL2A_20170604T112121_N0205_R037_T29T B12::Subset_S2A_MSIL2A_20170604T112121_N0205_R037_T29 cloud_mask::Subset_S2A_MSIL2A_20170604T112121_N0205_R0	NE_20170604T11 NE_20170604T11 TNE_20170604T1
	Load Graph Run	Close Help

In the **Write** tab check that the name contains **20170604** but do not change anything. Set the output directory: */shared/Training/HAZA02\_BurnedArea\_Portugal\_TutorialKit/Processing* 

	Batch Pre	ocessing	: Graph_Pro	cessing.x	ml		• Ξ ×
ile Graphs							-
I/O Parameters	Resample	Subset	BandMaths	BandMer	ge Write		
Target Product Name: Subset S2A_MSI		T112121_	N0205_R037_T	29TNE_201	70604T1127	55_resample	ed )
Save as: BEAM-D	DIMAP						
/home/rus/sh	nared/Training/	HAZA02_E	BurnedArea_Po	rtugal_Tuto	rialKit/Proce	essing	
			Loa	ad Graph	Run	Close	Help

And let's click **Run.** This might take approximately 3 minutes depending on your machine.

Now, you should have two new products in the **Product Explorer** window. Let's have a look at the subset products. For that, close all the previous view windows and expand product [3]. In **Bands** 

folder, double click the NBR band. Now do the same for product [4]. Go to **Window**  $\rightarrow$  **Tile Horizontally** and then in Navigation tab at the lower left, click Zoom All  $\bigcirc$ .



Close all view windows.

#### 5.5 Collocation

Now we will merge the two pre-processed products, so we can easily calculate the change in the preand post-fire NBR values. Go to **Raster**  $\rightarrow$  **Geometric Operations**  $\rightarrow$  **Collocation.** 

In Source Products set product [3] as Master and product [4] as Slave.

#### In Target Products set Name: S2A\_20170604\_20170704

Collocation	⊕ Ξ ×.	∽ 🛢 [1] 52A_MSIL2A_20170604T1121	21_
File Help		►	11_
Source Products	1	[3] Subset_S2A_MSIL2A_2017060	)4T
Master (pixel values are conserved):		- 8 [4] Subset S2A MSIL2A 2017070	)4T
[3] Subset_S2A_MSIL2A_20170604T112121_N0205_R037_T29TN	E_20170604T 🔻	9 🗃 [5] S2A 20170604_20170704	
Slave (pixel values are resampled onto the master grid):		🗢 🛅 Metadata	
[4] Subset_S2A_MSIL2A_20170704T112111_N0205_R037_T29TN	E_20170704T 🔻	- G Flag Codings	
Target Product		- 🔁 Vector Data	
Name:		9 🖼 Bands	
S2A_20170604_20170704		NBR June	
Save as: BEAM-DIMAP		- B3 June (560 nm)	
Directory:		B8 June (842 nm)	
/root/Tutorials/Portugal_fire_2017_tutorial_basic/Processing			
P Open in SNAP		B12 June (2190 nm)	
Renaming of Source Product Components		- cloud_mask_lune	
Rename master components: \${ORIGINAL_NAME}_June		NBR July	
Rename slave components: \${ORIGINAL NAME} July		B3_July (560 nm)	
Resampling		- 🔲 88_July (842 nm)	
Method: Nearest neighbour resampling		B12_July (2190 nm)	
reares heares reguest readinging		- Cloud_mask_July	
	<u>Run</u> <u>C</u> lose	collocation_flags	

In **Renaming of Source Product Components** change: Rename master components: "*\${ORIGINAL\_NAME}\_June*" Rename slave components: "*\${ORIGINAL\_NAME}\_July*". Set output directory to */shared/Training/HAZA02\_BurnedArea\_Portugal\_TutorialKit/Processing*. Click **Run**. A new product [5] has been created in **Product Explorer** window.

#### 5.6 Water and cloud mask

Water bodies can show similar NBR difference in certain circumstances, therefore, it is necessary to mask them out. We also need to mask out clouds occurring in either input image. For this purpose, we will create a single combined water and cloud mask. To detect the water bodies we will use the Normalized Difference Water Index - NDWI (See INOTE 3).



Right click on the newly created stacked product [5], select **BandMaths** and set:

#### Name: "cloud\_water\_mask"

**Deselect** the "Virtual (save expression only, don't store data)" option - we want to store the band. Click on "**Edit Expression**" and set as **Expression**:



Band Maths	Ban	nd M	aths Expression E	ditor	* = ×	
Target product:	Product: [5] S2A_20170604_201	7070	04			
[5] S2A_20170604_20170704	Data sources:				Expression:	
lame: cloud_water_mask	\$5.NBR_June	0+0		if (cloud_mask_June > 0		
Description:	\$5.83_June @ - @ \$5.88_June @ * @	6 - 6		or cloud_mask_July > 0 or ((B3_June - B8_June)		
Unit:		-	(B3 June + B8 June))>⊨			
Spectral wavelength: 0.0	\$5.cloud mask_June		0/0		0.0) then 1 else 0	
/irtual (save expression only, don't store data)	\$5.NBR_July	1	-			
Replace NaN and infinity results by NaN	\$5.B3_July		(@)	-		
Generate associated uncertainty band	\$5.88_July		Constants			
Band maths expression:	\$5.B12_July \$5.cloud mask July	-	Operators	-		
	Show bands		Functions	-		
	Show masks			-		
Load Save Edit Expression	Show tie-point grids					
	Show single flags				1 1 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	
<u>Q</u> K <u>C</u> ancel <u>H</u> elp					<u>QK</u> <u>Cancel</u> <u>H</u> elp	

Click **OK** in both windows to create the band.



#### 5.7 Burned areas and burn severity

To identify recently burned areas and differentiate them from bare soil and other non-vegetated areas the difference between pre-fire and post-fire NBR, the delta Normalized Burn Ratio (dNBR) is frequently used.

$$dNBR = NBR_{pre-fire} - NBR_{post-fire}$$

However, the dNBR is an absolute difference which can present problems in areas with low pre-fire vegetation cover, where the absolute change between pre-fire and post-fire NBR will be small. In such cases the relativized version of burn severity is advantageous. In this tutorial we will use the Relativized Burn Ratio (RBR)<sup>3</sup>.

$$RBR = \left(\frac{dNBR}{\left(NBR_{pre-fire} + 1.001\right)}\right) = \left(\frac{NBR_{pre-fire} - NBR_{post-fire}}{\left(NBR_{pre-fire} + 1.001\right)}\right)$$

In this step we will also apply the cloud and water mask we have created. Again, we will create new band by going to **BandMaths** in product [5] and we set:

#### Name: "RBR"

**Deselect** the "*Virtual (save expression only, don't store data)*" option - we want to store the band. Click on "**Edit Expression**" and set as **Expression**:

if cloud\_water\_mask == 0 then ((NBR\_June - NBR\_July)/(NBR\_June + 1.001))
else NaN

Band Maths		Ba	nd Maths Expression	Ed	itor 💿 🗴
Target product:	Product: [5] S2A_2017	0604_	20170704		-
[5] S2A_20170604_20170704	Data sources:				Expression:
Name: RBR	\$5.NBR_June	-	0+0		if cloud_water_mask == 0 then
Description:	\$5.B3_June		0 - 0	-	((NBR_June - NBR_July)/(NBR_June + 1.001)) else NaN
Unit	\$5.88_June			_	
Spectral wavelength: 0.0	\$5.B12_June		0 * 0	_	
Virtual (save expression only, don't store data)	\$5.cloud_mask_June		0 / 0		
✓	\$5.NBR_July \$5.B3 July	-	(@)		
Replace NaN and infinity results by	IaN \$5.83_JULY \$5.88 July	-	Constants	Ŧ	
Generate associated inicertainty band	\$5.812 July			-	
Band maths expression:	\$5.cloud mask July	-	Operators	*	
	Show bands		Functions	*	
	Show masks				
Load Edit Expression	Show tie-point grid:				
QK <u>C</u> ancel <u>H</u> elp					<u>O</u> K <u>C</u> ancel <u>H</u> elp

Click **OK** in both windows to create the band.



The burned pixels appear much brighter as the change in between pre- and post-fire values is much higher. Now let's create another new band that will only contain burned areas. We will set the threshold for pixel to be classified as burned to > 0.27 (threshold derived from literature).

Right click product [5] and for to **BandMaths** again. Set:

Name: "RBR\_"

**Deselect** the "Virtual (save expression only, don't store data)" option - we want to store the band. Click on "Edit Expression" and set as Expression: if RBR > 0.27 then RBR else NaN

Band Maths + O	Ban	d Maths Expression Edi	tor 🖉 🔿 🖂 😒
Target product:	Product: [5] S2A_20170604	20170704	-
[5] S2A_20170604_20170704	Data sources:		Expression:
Name: RBR	\$5.NBR_June	0+0	if RBR > 0.27 then RBR
Description:	\$5.B3_June	0 - 0	⊣else NaN
Unit:	\$5.B8_June		4
Spectral wavelength: 0.0	\$5.B12_June	6 * 6	
Virtual (save expression only, don't store data)	\$5.cloud_mask_June	0/0	
-	\$5.NBR_July aN \$5.B3_July	(@)	
	\$5.B8_July	Constants	
Generate associated uncertainty bend     Band maths expression:	\$5.B12_July	Operators,	
Conto motifa copi casion.	\$5.cloud mask July  Show bands	Functions	-
	Show masks		
Load Save Edit Expression	Show tie-point grids		
	Show single flags		
QK Cancel Help			<u>QK</u> <u>Cancel</u> <u>H</u> elp

Click **OK** in both windows to create the band.



#### 5.8 Export as GeoTIFF

Close all view windows.

In **Product Explorer** tab, select (highlight) product [5], go to **File**  $\rightarrow$  **Export**  $\rightarrow$  **GeoTiff** (NOT! Geotiff/Big Tiff).

In the dialog that opens click on **Subset**, go to the **Band Subset** tab (second tab) and **select only bands RBR and RBR\_.** 

Click **OK** and in the dialog that appears (No Flag Dataset Selected) click **No**.

Save the product to the */shared/Training/HAZA02\_BurnedArea\_Portugal\_TutorialKit/Processing* folder with **File Name**: *"S2A\_20170604\_2017\_0704\_RBR.tif"* by clicking **Export Product**.

	SNAP - Export Pro	duci	POE X	Specify P	roduct Subset	× 🗆 🔨
Save in:	Processing				tadata Subset Spatial Subset	
Subset_S2	0504_20170704.data 2A_MSIL2A_20170604T112121_N0205 2A_MSIL2A_20170704T112111_N0205		Subset	B3_July B8_July B12_July cloud_mask_July collocation_flags doud_water_mas	Reflectance in band 83 Reflectance in band 88 Reflectance in band 812 k	
4		•		RBR		
File <u>N</u> ame:	S2A_20170604_20170704_RBR.tif				Select none	
Files of Type:	GeoTIFF product (*.tif.*.tiff)		-			
		Export Product	Cancel	E	Estimated, raw storage siz	te: 65.8М <u>H</u> elp

Now we can import the image to another GIS/ Remote sensing software for further processing or map creation. In this tutorial we will use QGIS. Keep SNAP opened for now.

#### 5.9 Visualization

Go to *Application* → *Processing* → *QGIS Desktop* (or use the desktop icon). Click on the Add Raster Layer button located in the left panel (ﷺ), navigate to: /shared/Training/HAZA02\_BurnedArea\_Portugal\_TutorialKit/Processing select the S2A\_20170604\_2017\_0704\_RBR.tif and click Open.



We can change the colour scheme to classes proposed by the United States Geological Survey (USGS) to interpret the burn severity (See 📜 NOTE 4).

NOTE 4: The United States Geological Survey (USGS) proposed a classification table to interpret the burn severity, which can be seen in the table below<sup>4</sup>. In our data the lowest value is -0.08, demonstrating that there were no values related to detectable regrowth. The large number of ambiguous pixels (yellow) is caused by the one-month difference between our pre- and post-fire images. Due to the severe drought the vegetation likely degraded significantly between these two dates producing similar NBR difference as low severity burn.

Severity Level	dNBR range (scaled by 10 <sup>3</sup> )	dNBR range (not scaled)
Enhanced Regrowth, high (post-fire)	-500 to -251	-0.500 to -0.251
Enhanced Regrowth, low (post-fire)	-250 to -101	-0.250 to -0.101
Unburned	-100 to +99	-0.100 to +0.099
Low Severity	+100 to +269	+0.100 to +0.269
Moderate-low Severity	+270 to +439	+0.270 to +0.439
Moderate-high Severity	+440 to +659	+0.440 to +0.659
High Severity	+660 to +1300	+0.660 to +1.300

We will use a predefined file to import the colour palette.

Right-click on the opened raster-layer in the Layers Panel (lower left) and go to Properties. In the Style tab set:

Render type: Singleband pseudocolor Interpolation: Discrete Band: Band 1 (BRB)

Then click 📁 Load colour map from file to import predefined colour map.

Navigate to the *Auxdata* folder and open *Colour\_palete\_RBR.txt*. Click OK.

	0.0	Layer Pro	perties - S2	A_20170604_20170	704_RBR   Style		4 10
General	Render type	Singleba	and pseudoc	olor 🔻			
Style	Band	Band 1 (		-0.0849289	Max	0.621621	-
Pyramids	Load min		-				
Histogram	Interpolation Color	Discrete	Spectral	-	Edit	□ Invert	-
Metadata Legend	Label unit suffix Min / max origin:	Estimated	d cumulative	e cut of full extent.			
	Value <= -0.5 -0.25 -0.1 0.1 0.27	Color	Label None High regrow Low regrow Unburned Low severit	/th			



To visualize only the "Moderate to High severity areas" go to **Properties** again and in **Style** tab set band to **Band 2**. You will have to import the colour map again the same way as we have done for Band 1. Click **OK**.

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  $\frown$  NOTE 5). In case Google Satellite is not available for any reason, use a different layer, e.g. **Bing**  $\rightarrow$  **Bing Aerial**. Then in the "Layer Panel" click on the Google Satellite layer and drag it below our raster layer.



To download the results to your local computer, see section **6.2 Downloading the outputs from VM**.

THANK YOU FOR FOLLOWING THE EXERCISE!

## 6 Extra steps

#### 6.1 Atmospheric correction (\* TIP 1)

For the Level 2A products that we have downloaded, the atmospheric correction has already been applied (pre-processing of Level-1C product to a Level-2A is described in section 4.1). Atmospheric correction using Sen2Cor algorithm is a computationally heavy process and takes approximately 30 minutes per image to be completed depending on your machine. However, since April 2017 the Level-2A products have already been generated and are available to download for acquisitions over Europe (such as this case). If you want to try to run the atmospheric correction (section 4.1) or you want to apply this method to products for which Level-2 data are not available (MSIL1C), follow the steps below.

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 6) 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).



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.

First, download your desired Level-1 products and move them to:

#### /shared/Training/HAZA02\_BurnedArea\_Portugal\_TutorialKit/Original

Then right click each archive and use "*Extract Here*" to unzip the folders. In SNAP window, click **Open product** and navigate to /*Original* folder an in each extracted folder select *MTD\_MSIL1C.xml*. Then go to **Optical**  $\rightarrow$  **Thematic Land Processing**  $\rightarrow$  **Sen2cor** 

In the I/O Parameters tab, select your product.

In the **Processing Parameters** tab, change the resolution to 10 m, **select** the "Display execution output" and keep the rest parameters as by default.

	SEN2COR	* = ×
File Help		
VO Parameters Processing Pa	arameters	
Source Product		
Source product:		
[1] S2A_MSIL1C_20170604T1121	121_N0205_R037_T29TNE_20170604T112755	<b>Z</b>
	SEN2CON.	* 2 ×
File Help		
I/O Parameters Processing Pa	arametera	
Display execution output		
Scene only		*
Resolution: 10		-
Cr only		-
L2A_GIPP file		
(If a file is selected, the parameters below		
will not be used)		
Nb processes:		1
Median filter:		0
operation mode windertesat to roo LB	and and and and and	
Sentinel-2 Level 2A Processor (Sen2Co	or). Version: 2.5.5, created: 2018,03.19, supporting Level	-1C product version <= 🚔
14.5 started Product version: 14.2. Operation mode	: TOOLBOX. Processing baseline: 02.05.	_
Selected resolution: 10 m.	esolution must be processed first, elapsed time[s]: 0.428	http:// 0.00.02.786705
Progress[%]: 0.03 : PID-17663, L2A_P	rocessTile: processing with resolution 20 m, elapsed time[	
		. total: 0:00:03.126942 205473 👻

Click Run. Repeat the process for the other product [2] as well.

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

The process creates two new Level 2-A product in the **\*.SAFE** format in the /shared/Training/HAZA02\_BurnedArea\_Portugal\_TutorialKit/Original

## 6.2 Downloading the outputs from VM

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



### 6.3 Export as KMZ (Google Earth)

If we want to view the product for example in Google Earth, unfortunately we must first reproject it to WGS 84 Lat/Lon coordinate system (EPSG 4326), as the KMZ format does not accept other projections, set colour scheme, export to KMZ format readable by Google Earth and then download results to our local PC for visualization as the RUS VM does not support Google Earth installation.

It is time consuming and unnecessary to reproject the whole product [5] therefore we will first apply **band subset**. Click on product [5] so it is highlighted and then go to **Raster**  $\rightarrow$  **Subset**. Do not change anything in the **Spatial Subset** tab and go to the **Band Subset** tab. **Deselect** all the bands **except RBR and RBR\_**. Click **OK**.

In the "No Flag dataset selected" dialog click "No".

	Specify Product S	subset	+ = ×	
Spatial Subset B	and Subset   Metadata S	Subset		
			-	
B3_lune	Reflectance in band B3			
BB_June	Reflectance in band 88			
B12_une	Reflectance in band B12			
cloud_mask_lune				
NBR_July				
B3_July	Reflectance in band 83			
BE_July	Reflectance in band 88		=	
B12 July	Reflectance in band B12			
cloud_mask_july				
collocation_flags				
cloud_water_mask				No Flag Dataset Selected
RBR.				2 No flag dataset selected.
RBR_	lexpression was 'if \$5.RBR >	0.27 then \$5.RBR else NaN'I	-	If you do not include a flag dataset in the subset.
Select all	elect none			you will not be able to create bitmask overlays.
		Estimated, raw stor	and size SE OM	Do you wish to include the available flag dataset(s in the current subset?
		Loundled, Taw stor		
		<u>O</u> K <u>C</u> ance	el <u>H</u> elp	Yes No Cancel

Product [6] was created containing only the two selected bands. To reproject from the default UTM33 projection to Lat/Long we go to **Raster**  $\rightarrow$  **Geometric Operations**  $\rightarrow$  **Reproject**.

Check that the new subset [6] is selected as input and the **Processing** folder is set as the target directory.

In the **Projection Parameters** tab, make sure the Projection is set to "Geographic Lat/Lon (WGS84)" and click **Run**.

Reprojection	* = × 🚺	Reprojection	-* = ×
ile Help	File Help		
I/O Parameters Reprojection Parameters	VO Parameters	Reprojection Parameters	
Source Product Name:	Custom CP	ference System (CRS) RS	
[6] subset_0_of_S2A_20170504_20170704	Geodetic o	datum:	
Target Product	Projection	Geographic Lat/Lon (WGS 84)	
Name: subset 0 of S2A 20170604 20170704 reprojected			Projection Parameters
Save as: BEAM-DIMAP	O Predefined		Select.
/home/rus/shared/Training/HAZA02 BurnedArea Portugal T	TutorialKit/Processing Output Setting		grids
	Cutput /	Parameters No-data value: N	laN
	Add delta l	at/lon bands Resampling method:	learest 💌
	Output Informa Scene width: Scene height CRS:	8308 pixel Center longitude	
	<u>Run</u> <u>C</u> lose		<u>R</u> un <u>C</u> lose

Go to **Colour Manipulation** Tab in the lower left corner at the "Editor: **Sliders**" and right click the colour bar between existing sliders – add 2 new sliders.

Then go to the "Editor: **Table**" and set colours and values as in the table in 1 NOTE 5.

To export the KMZ layer, click on the RBR View to activate it and go to File  $\rightarrow$  Export  $\rightarrow$  Other  $\rightarrow$  View as Google Earth KMZ (only the active band open in the view window will be saved).

Save to the **Processing** folder as: *Burn\_severity\_20170704.kmz*.

Now open or activate the BRB\_ layer and export it as well (Burned\_area\_20170704.kmz)

Download the KMZ files to your laptop following instructions in section 6.2.

Open Google Earth (Applications  $\rightarrow$  Internet  $\rightarrow$  Google Earth) if you have it installed.

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



## 7 Further reading and resources

The European Forest Fire Information System (EFFIS) – <u>link</u> Normalized Burn Ratio by Humbold State University – <u>link</u> UN-SPYDER Knowledge Portal – Normalized Burn Ratio – <u>link</u>

## 8 References

- 1. Mousivand, A., Verhoef, W., Menenti, M. & Gorte, B. Modeling Top of Atmosphere Radiance over Heterogeneous Non-Lambertian Rugged Terrain. *Remote Sens.* **7**, 8019–8044 (2015).
- Du, Y. *et al.* Water Bodies' Mapping from Sentinel-2 Imagery with Modified Normalized Difference Water Index at 10-m Spatial Resolution Produced by Sharpening the SWIR Band. *Remote Sens.* 8, 354 (2016).
- 3. Parks, S. A., Dillon, G. K. & Miller, C. A New Metric for Quantifying Burn Severity: The Relativized Burn Ratio. *Remote Sens.* **6**, 1827–1844 (2014).
- 4. Keeley, J. E. Fire intensity, fire severity and burn severity: a brief review and suggested usage. *Int. J. Wildland Fire* **18**, 116–126 (2009).

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