esa
IV ESA EARSEL CNR School
Remote Sensing for Forest Fires:
Burned area mapping with Sentinel-1
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30/09/2019
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European Space Agency

Learning outcomes

- Interpretation of S1 results
- S1 data download
- SNAP:
  - Basic S1 pre-processing
  - Graphs and Batch processing
  - Mask generation
  - Export product
  - Help & Forum

Summary

1. Wildfires in Republic of Congo (2016):
    1. Background info
    2. Scientific publication by Verheggen et al (2016)
2. SNAP Exercise with discussion
    1. Open data & Help function
    2. Build pre-processing graph
    3. Apply Batch processing
    4. Create stack
    5. Band Maths:
        - 5.1. Create average backscatter
        - 5.2. Post-fire minus Pre-fire
        - 5.3. Extract burned areas
    6. Export to KML
    7. Forum

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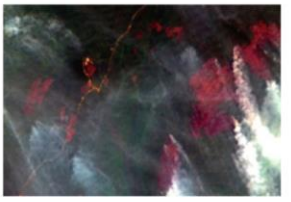
1- Wildfires in Republic of Congo (2016):

- Very strong **El Niño** event in 2016 – severe drought
- Fire alerts rose in Congo from **28 January to 4 February**
- >15 000 ha destroyed
- Possible anthropogenic origin



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Amalia Castro Gómez| 30/09 – 01/10/2019 | Slide 5

European Space Agency

The Congo Basin's rainforest is second in size to the Amazon and is home to endangered wildlife.

Wildfires are not common in rainforests, which are usually perpetually moist. This also means that rainforests have not evolved in concert with wildfires. Fires threaten commercial extraction of wood as well as the regeneration of the forest and its biodiversity.

In the northern parts of Congo, soil is porous and the forest depends on regular and frequent rainfall.

The period 2015-2016 is considered an El Niño year – an especially severe one.

Africa in particular was affected by dramatic droughts in the southern portion of the continent.

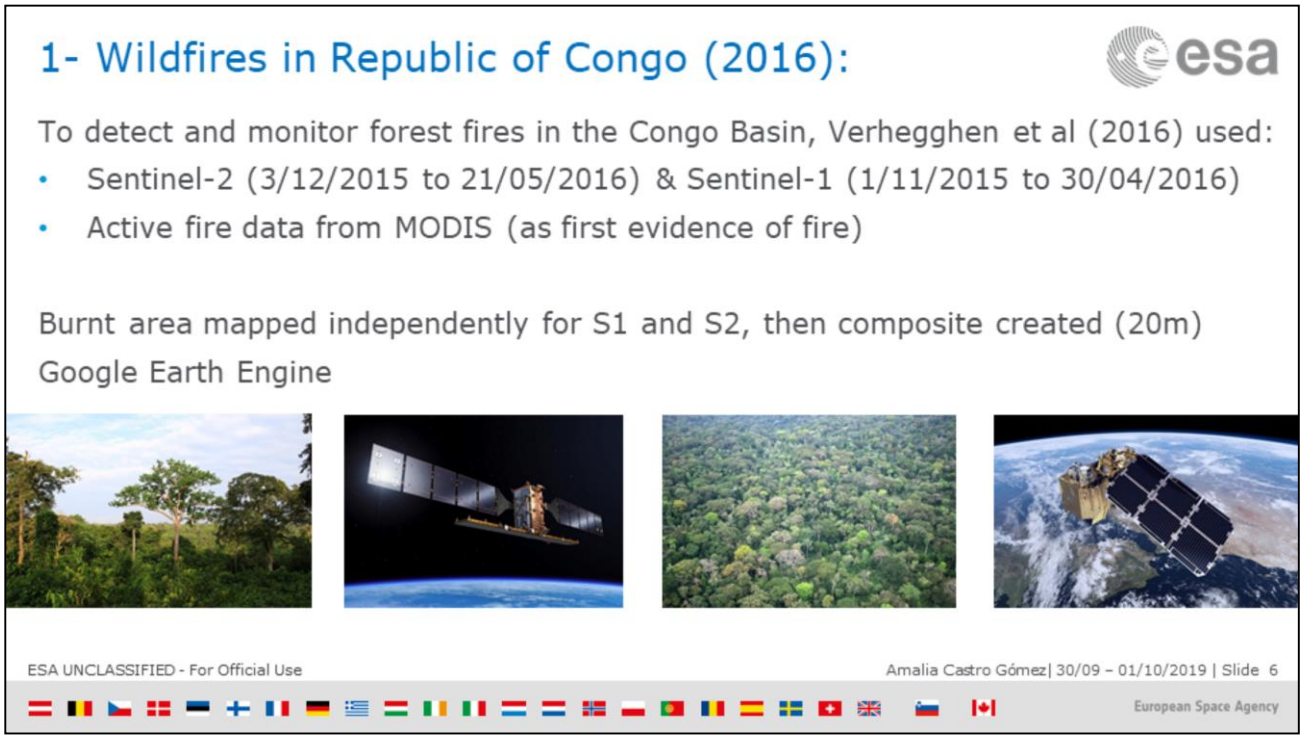
It is in this context that one of the largest fires in Central Africa broke out: lasting from late January until March/April 2016, it destroyed more than 15 000 ha of intact rainforest. Data from NASA show a starting date on January 28th and a rapid spread until around February 4th.

More information about the Congo wildfires in early 2016:
https://news.mongabay.com/2016/03/massive-wildfire-rips-through-congo-rainforest-is-logging-to-blame/

El Niño Southern Oscillation cycle describes the temperature fluctuations between ocean and atmosphere in the east-central Equatorial Pacific. It has two opposite phases, known as El Niño (warm phase) and La Niña (cold phase). These deviations from normal surface temperatures can have large-scale impacts on ocean processes, global weather and climate.

More info: https://oceanservice.noaa.gov/facts/ninonina.html

Images taken from https://www.worldwildlife.org/places/congo-basin and https://www.greenpeace.org.uk/what-we-do/forests/congo/



The scientific paper we will reproduce in a simplified way is authored by Verhegghen et al and titled "The Potential of Sentinel Satellites for Burnt Area Mapping and Monitoring in the Congo Basin Forests". It was published in the Remote Sensing Journal in 2016, and can be found at https://www.researchgate.net/publication/311202039_The_Potential_of_Sentinel_Satellites_for_Burnt_Area_Mapping_and_Monitoring_in_the_Congo_Basin_Forests

As detailed in their paper, fires occurred mainly in Marantaceae forests, characterized by open tree canopy cover and an extensive tall herbaceous layer.

Remote sensing is widely used to monitor active fires and burnt areas, with sensors such as AVHRR, VGT, MODIS (1km) and MERIS. Their daily revisit is useful to detect active fires or burn scars. Their spatial resolution, which ranges between 300m and 1km, is relatively coarse and can cause underestimations if areas burnt have smaller extents. Furthermore, it is difficult to assign the correct vegetation class (important for estimating emissions & evaluating ecological impact).

Fusion between sensors of different spatial resolutions is possible, but the

challenge of cloud cover over tropical forests remains. SAR sensors can be used to overcome this issue. Sentinel-1 provides time series that can be used to monitor tropical forests.

As the authors explain, ”the basic assumption of this study is that most of the C-band radar backscatter of intact forests comes from surface, volume and multiple volume-surface scattering. After a fire, the surface scattering becomes the major contributor to the return signal. At this stage, the difference between radar backscatter before and after the fire can be used to delineate the fire-affected area from its surroundings. However, changes in the ground moisture can also contribute to the SAR backscatter signal. Hence limitations in the use of SAR are the soil moisture changes and the fact that the vegetation structure must be severely modified in order for a fire to be detected.”

S1 and S2 can be complementary, and Verhegghen et al (2016) evaluate the potential of their joint use to monitor burnt areas in tropical forests. Active fires detected by MODIS on Aqua and Terra satellites are used as a first evidence of the location and timing of this event. S1 and S2 time series are used to map the location, extent and speed of these fires.

Some of the main issues of using radar satellites to monitor wildfires are:

1- Radar is sensitive to changes in the forest structure, it is therefore only suitable for severe fires which remove vegetation parts (such as tree trunks or branches).

2- Changes in backscatter can also stem from changes in soil moisture.

The method proposed by Verhegghen et al. (2016) includes aggregating the Sentinel-1 scenes over several months (before and after the fire event) and then calculating the difference in backscatter between the different aggregates. Finally, a threshold is applied to extract the burned areas from the difference image.

Pictures of a tropical Marantaceae rainforest (Odzala National Park, Congo) from https://www.flickr.com/photos/revillaeloy/39172787942

1- Wildfires in Republic of Congo (2016):

- Study area in Sangha department (north of Republic of Congo)
- Tropical humid climate, 2 dry seasons (June-August and December-February)
- Majority of area covered by open or very open Marantaceae forests

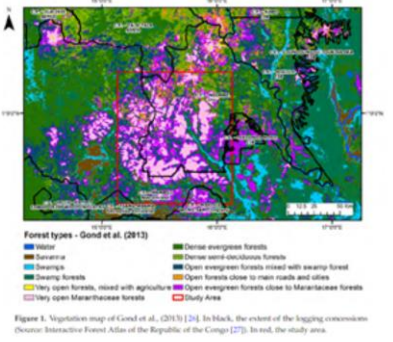


Figure 1. Vegetation map of Gond et al., (2013) [24]. In black, the extent of the logging concessions (Source: Interactive Forest Atlas of the Republic of the Congo [27]). In red, the study area.

Pictures of a tropical Marantaceae rainforest (Odzala National Park, Congo) from https://www.flickr.com/photos/revillaeloy/39172787942

Figure from https://www.researchgate.net/publication/311202039_The_Potential_of_Sentinel_Satellites_for_Burnt_Area_Mapping_and_Monitoring_in_the_Congo_Basin_Forests

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    7. **Forum**

2- SNAP Exercise

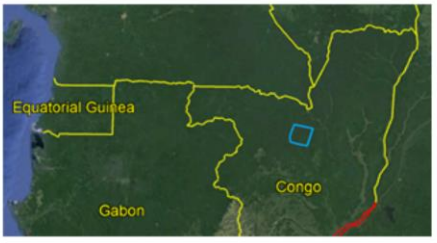
We will use a total of 10 S1 images in this simplified version of the methodology:
S1A, IW GRD, Relative Orbit: 7, **VV** + VH, 25m spatial resolution

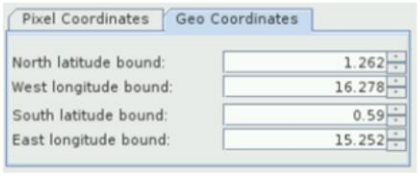
Before the fires:

- 18 November 2015
- 12 December 2015
- 24 December 2015

During & After the fires:

- 29 January 2016
- 10 February 2016
- 05 March 2016
- 17 March 2016
- 29 March 2016
- 10 April 2016
- 22 April 2016



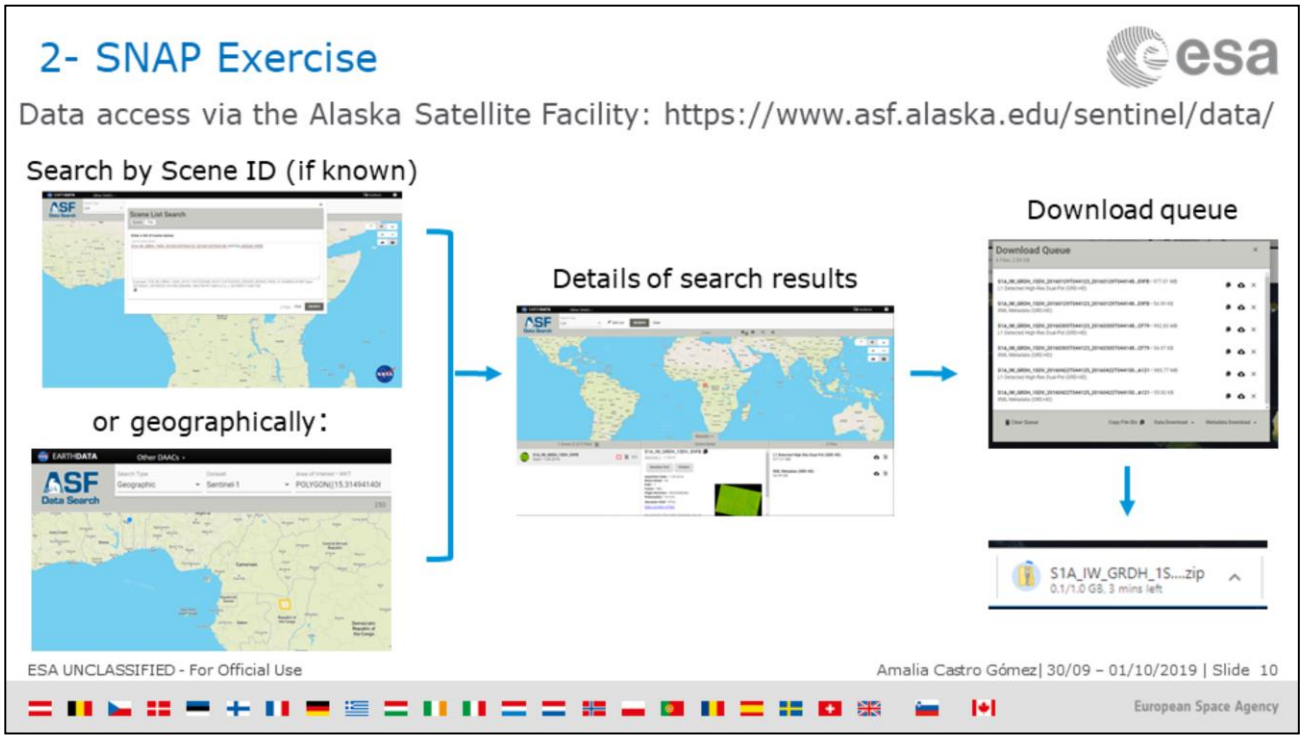


In the exercise we will do together, we will look at the processing of S1 images in SNAP (not in Google Earth Engine)

Here is the list of inputs we will use: it is all the images captured by S1 over the area with relative orbit= 7.

Note that Verhegghen et al (2016) used a total of 24 S1 images.

The paper explains that only VV shows results coherent with S2 results. We will work with both and have a look at results.



In the previous exercise, done by RUS “Burned area mapping with S2 ”, you were shown how to use the Copernicus Open Access Hub to access data.

As an alternative, here we will quickly look at how to access them from the Alaska Satellite Facility: NASA provides the complete ESA S-1 archive through this facility, thanks to an agreement between the US State Department and the European Commission.

https://www.asf.alaska.edu/sentinel/data/

In Vertex, you can search by Scene (if you already know the ID of the image(s) you would like to have), or Geographically (drawing an AOI, and specifying the period and path)

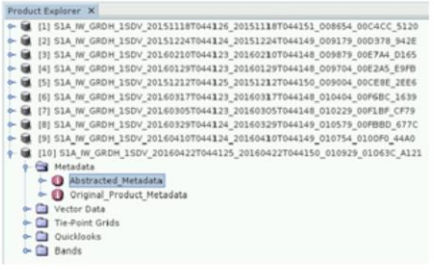
You can see the details of a search result, and add it to the cart if you wish.

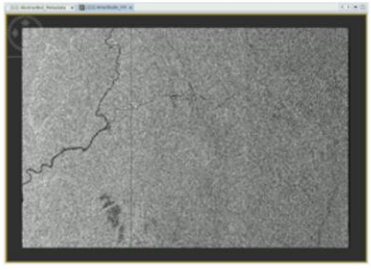
The images you order are added to your cart, from where you can download them.

2- SNAP Exercise: (1) Open data

"Training" folder in your RUS VM

1. Open SNAP
2. Go to **File/Open Product**, navigate to **shared/Training/Burned_area_S1/inputs**
3. Select all images (10 in total) and click Open
4. Explore their metadata and display one of the bands

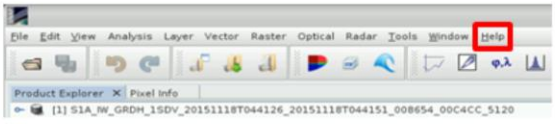




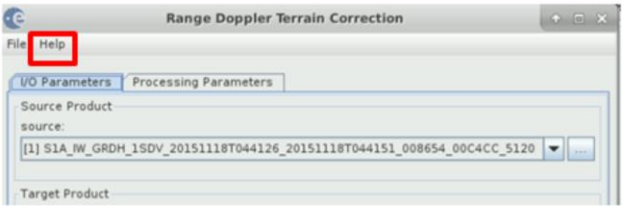
In your RUS VM, the **shared/Training/Burned_area_S1** folder that is in your desktop contains the datasets you will need. It also contains an outputs_backup folder, with results already produced in case you need them.

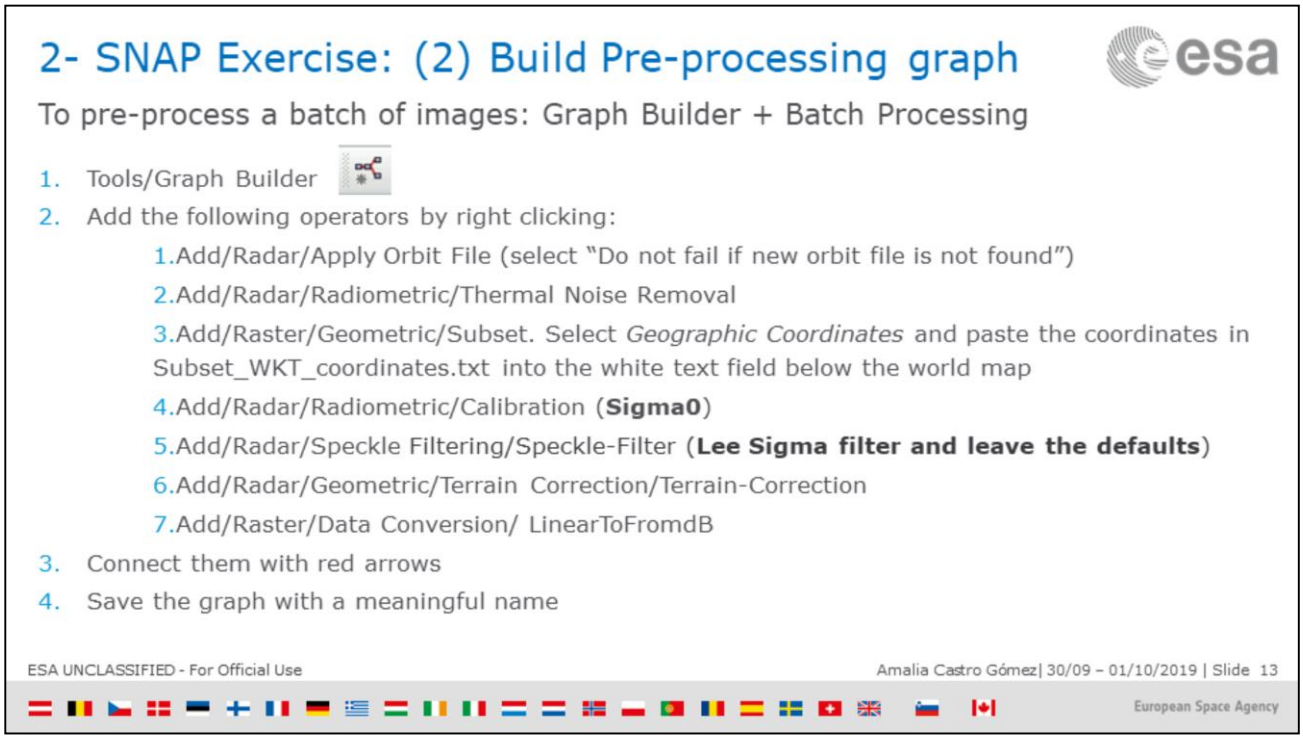
2- SNAP Exercise: (1) Help function

The "Help" function allows you to find more information on how to use a tool or the algorithms behind it



It is also available from inside a tool:





To apply easily the same pre-processing to all images, we will create a workflow using the Graph Builder, and apply the workflow to all images using Batch Processing. You have already seen this approach in the previous exercise, done by RUS and called "Burned area mapping with S2 ".

Apply Orbit File: A product contains Orbit State Vectors which are downloaded with the image but are not the most accurate ones available about the satellite position and velocity. The Precise Orbit File becomes available a few days after the acquisition, and therefore it is good practice to update it in the product. They can be found at https://qc.sentinel1.eo.esa.int/ (AUX_POEORB)

Thermal Noise Removal: corrects for the background energy that is created by the receiver itself. This is noise generated at the level of the sensor, and it is good practice to correct for it.

Radiometric Calibration: the SNAP tool adapts for different SAR sensors (e.g. ALOS-1). Calibration relates the pixel value to the radar backscatter on the ground, and is necessary for comparing SAR images acquired with the same sensor at different times, or with different sensors.

Speckle Filtering: the salt and pepper effect is random noise coming from the different scatterers that are within one cell. The filter can be chosen, based on your objectives. In this example we can keep the default (**Lee Sigma**) but ideally you would research which types of filter suit better your study area, and you would experiment with the window size. For example, for agricultural areas where we want to preserve the edges of agricultural fields, we could use the Lee filter. This is an intelligent filter that recognises which areas are homogeneous and applies the filter there without smoothing borders.

Terrain Correction: Because of the side-looking geometry of SAR, targets are mapped in the slant-range domain, **not in ground range geometry**. In other words, radar geometry is not orthogonal, images are acquired in a squinted way. Besides, SAR images can contain geometric distortions (layover, foreshortening, shadows). Terrain Correction uses a digital elevation model and projects the image into the ground, in a defined cartographic system.

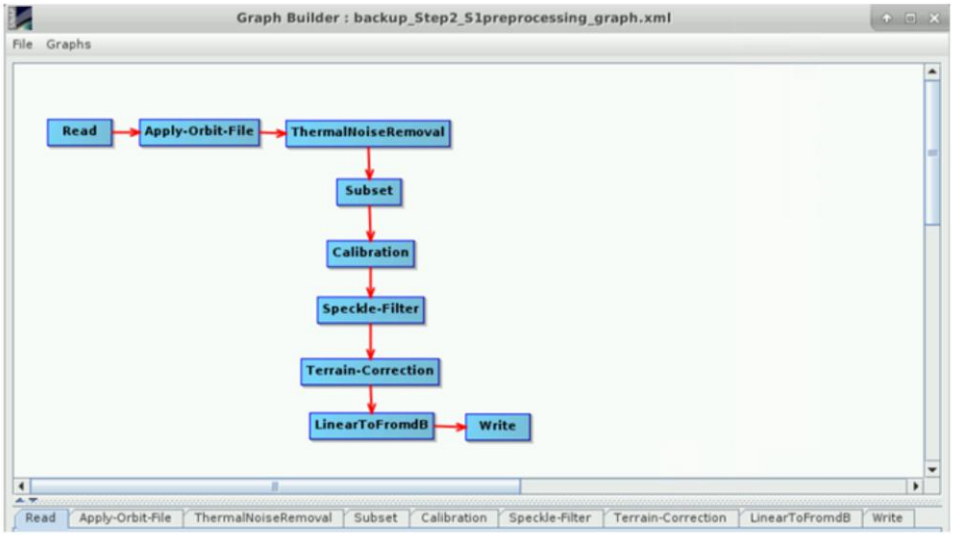
LinearToFromdB: this step just aims to improve the visualisation of the radar image

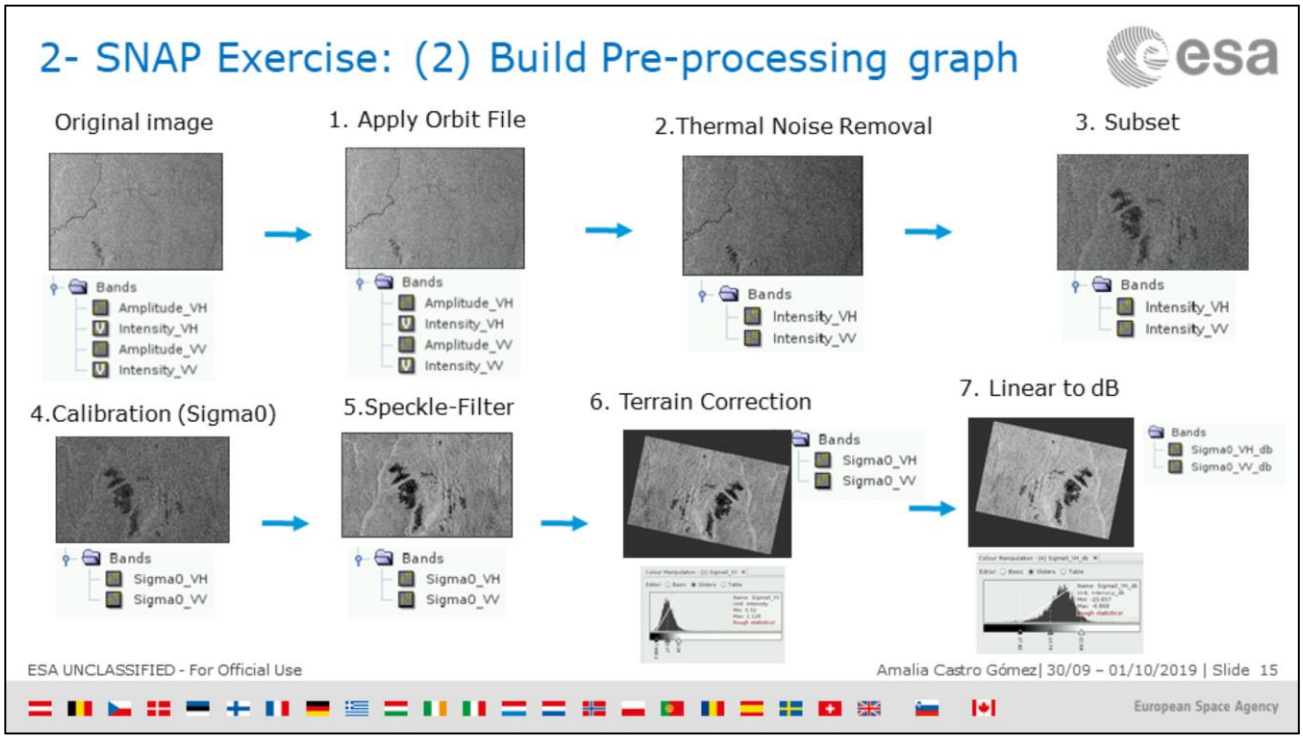
Note that in the Abstracted Metadata it is possible to see which corrections have been applied to the image (e.g. Thermal Noise Removal, or Terrain Correction): a value of 1 means the specific correction was applied, a value of 0 means it was not applied.

<u>Getting coordinates in WKT format from SNAP:</u>

In SNAP, to use the subset tool as part of a workflow and then run it for several files with batch processing, you need to provide the coordinates of your subset in WKT format. An easy way to do this is to draw a polygon along the perimeter of the area that will be your subset, then double clicking on it so it becomes highlighted in yellow, and finally right clicking and selecting WKT from Geometry. The coordinates in WKT format will then appear in a pop-up window for you. You can easily copy them, and insert them in the Subset tool of your graph.

2- SNAP Exercise: (2) Build Pre-processing graph

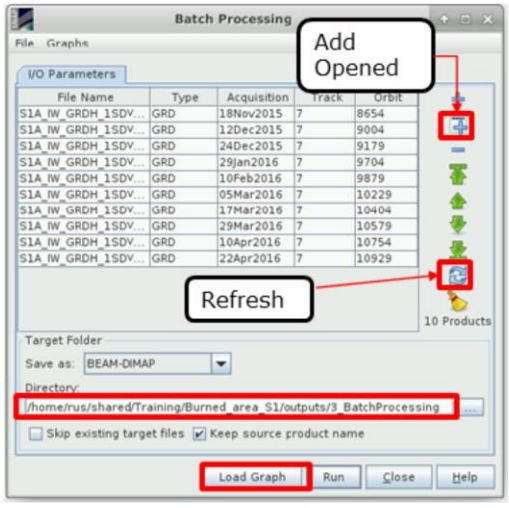




For clarity, in this slide we visualize the intermediate results of each step, for a single image.

The image used for this visualization is from 29 March 2016

2- SNAP Exercise: (3) Apply Batch Processing



- Tools/Batch Processing
- Add Opened & Click Refresh
- Load Graph (created previously)
- Specify output folder to shared/Training/Burned_area_S1/Outputs/3_BatchProcessing
- Check different operators

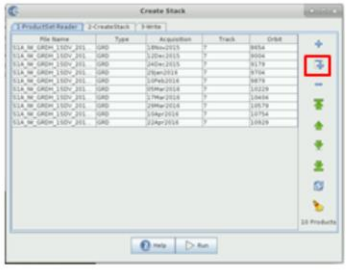
Do not Run! Instead, open the outputs prepared for you before the course (**outputs/3_BatchProcessing**)

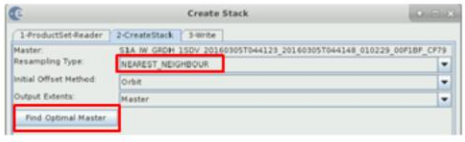
- Click Run (45 min for 10 images)
- For clarity, after it has run, close the first 10 products from the Product Explorer!

This slide shows how to use the Batch Processing. However, running the graph we have created for the 10 input images would take around 45 min.

The outputs have been created in advance for you, and they are saved in outputs/3_BatchProcessing, so you do not need to run the batch processing yourself.

2- SNAP Exercise: (4) Create Stack





To do calculations on the different S1 scenes, we need an image stack containing all the scenes:

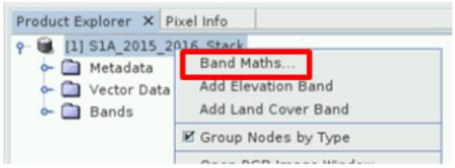
- Radar/Coregistration/Stack Tools/Create Stack
- Add the 10 results of the Batch Processing
- Tip: order them chronologically
- In the "2-Create Stack" tab, click on Find Optimal Master and select Resampling Type: Nearest Neighbour
- Adjust name
- Specify output folder to

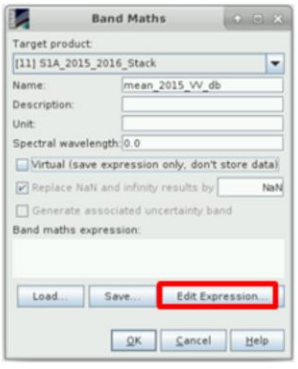
  shared/Training/Burned_area_S1/Outputs/4_Stack

Do not Run! Instead, open the output prepared for you before the course (outputs/4_Stack)

- Run (takes 40min)
- Close the 10 inputs from Product Explorer

2- SNAP Exercise: (5.1) Create average backscatter





We will:

1. Create average backscatter images (for before & for after the fire) for one polarisation (**VV** or VH)
2. Post-fire average minus Pre-fire average
3. Threshold on the difference image, to extract burned areas

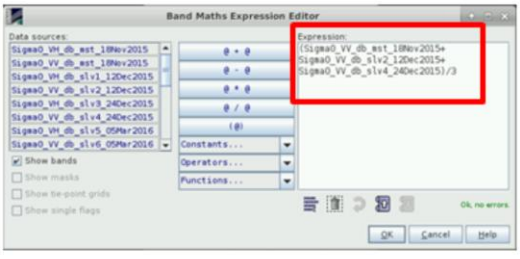
- Display bands of the stack
- Right click/Band Maths
- Name: **mean_2015_VV**
- Remove the tick next to Virtual
- Click on Edit Expression…

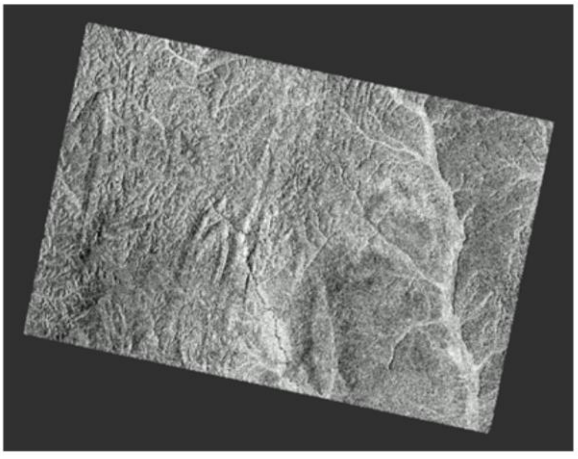
2- SNAP Exercise: (5.1) Create average backscatter

Average the bands from **2015** with the same polarisation (**VV** in this example):

Before the fires:

- 18 November 2015
- 12 December 2015
- 24 December 2015





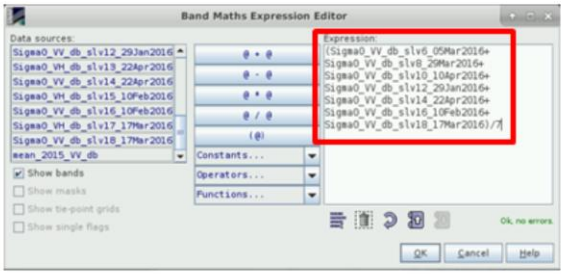
Tip: Save the expression as .txt file via "Save..."

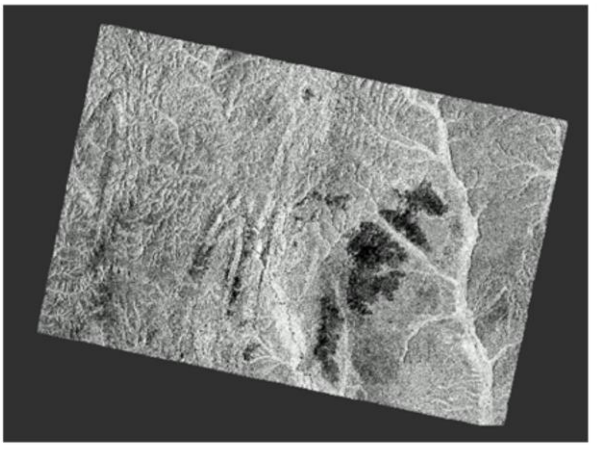
2- SNAP Exercise: (5.1) Create average backscatter

Repeat for **2016** with the same polarisation (**VV**)
Then save the stack

During & After the fires:

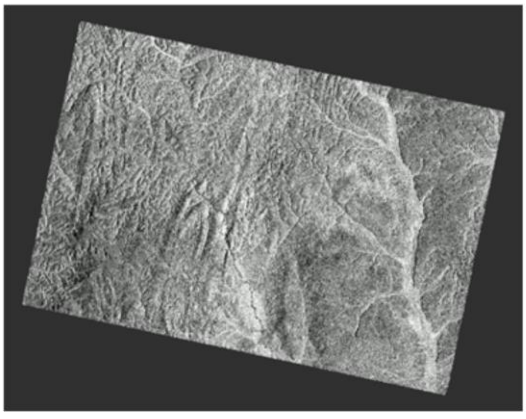
- 29 January 2016
- 10 February 2016
- 05 March 2016
- 17 March 2016
- 29 March 2016
- 10 April 2016
- 22 April 2016

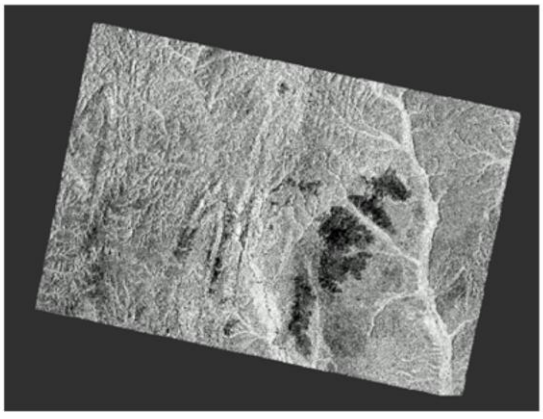




2- SNAP Exercise: (5.1) Create average backscatter

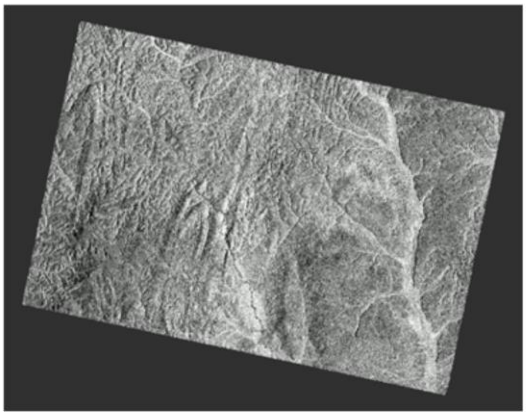
Average for **VV** polarisation (left: 2015, right: 2016)
Display both and use Pixel Info to understand the range of values in burned areas

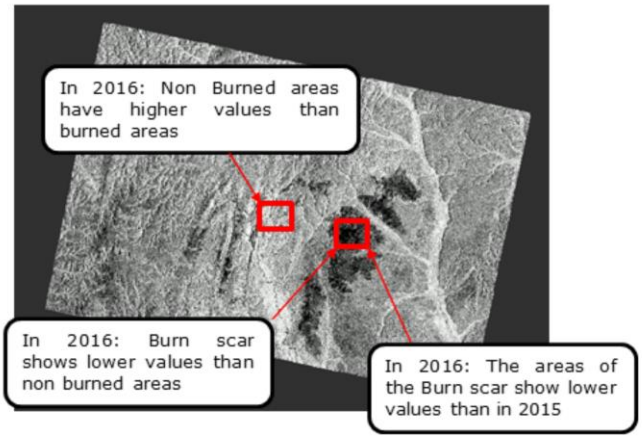




2- SNAP Exercise: (5.1) Create average backscatter

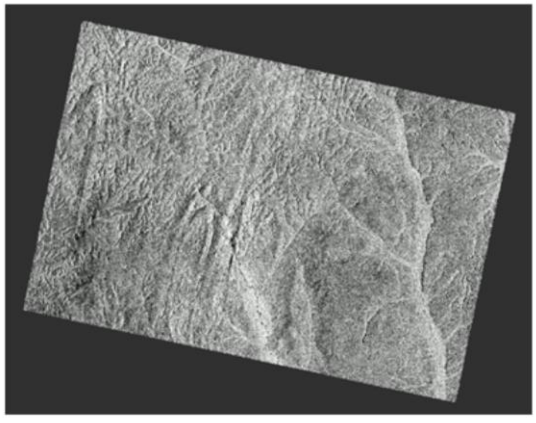
Average for **VV** polarisation (left: 2015, right: 2016)
Display both and use Pixel Info to understand the range of values in burned areas

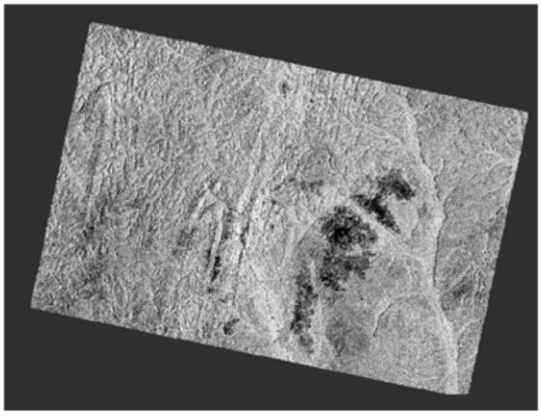




2- SNAP Exercise: (5.1) Create average backscatter

Average for **VH** polarisation (left: 2015, right: 2016)
Display both and use Pixel Info to understand the range of values in burned areas





2- SNAP Exercise: (5.1) Create average backscatter

How can we explain the fact that the burn scar is more visible in VV than in VH?

Two images of Maranthaceae forests in Congo

Changes appear more obviously when we use VV polarisation instead of VH.

We know from the authors that the area is covered by open or very open Maranthaceae forests.

This means the forest does not have a dense/closed tree canopy, and trees are relatively sparse with thick vegetation on the lower levels.

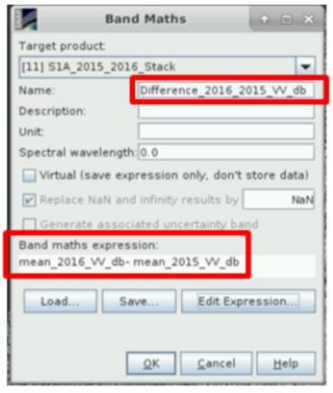
When the forest is burnt, the tree trunks disappear therefore the vertical component of the backscatter is not so strong compared to the horizontal component.

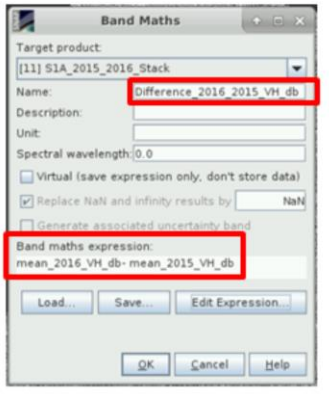
That horizontal component, especially for C-band can come from debris on the ground (tree trunks that fell, branches). Before the fire, the horizontal component was coming from tree canopy and from shrubs (in those areas where trees were not present). And after the fire, it comes from such debris. The horizontal component has decreased after the fire, but it is still higher than the Vertical component after the fire.

2- SNAP Exercise: (5.2) Post-fire minus Pre-fire

Generate a difference image:

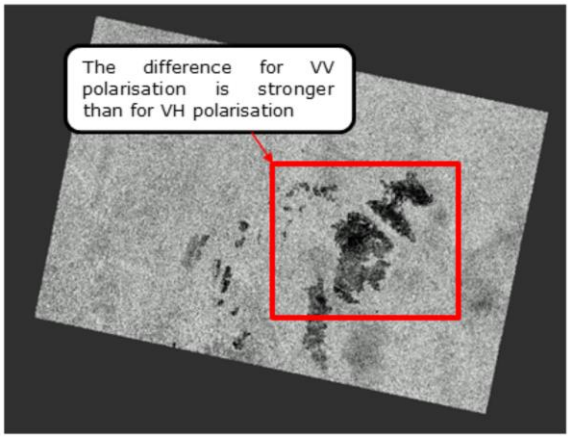
With Band Maths, for a certain polarisation calculate the difference between the means of 2016 and 2015



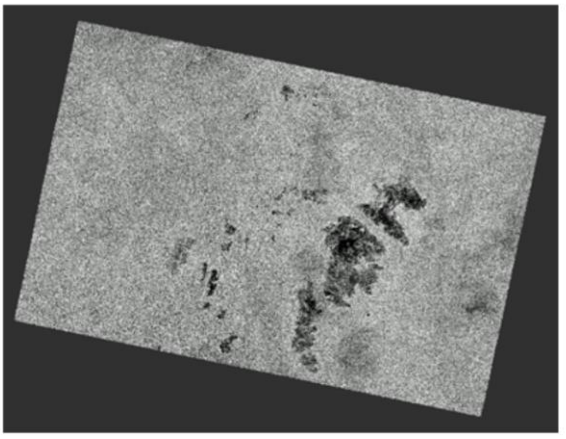


2- SNAP Exercise: (5.2) Post-fire minus Pre-fire

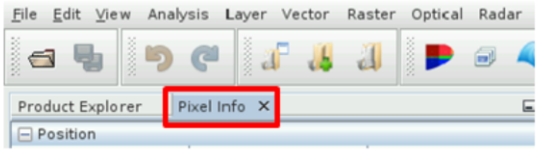
Left: Difference image for **VV_db**



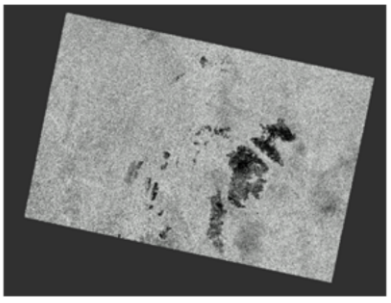
Right: Difference image for **VH_db**



2- SNAP Exercise: (5.3) Extract burned areas



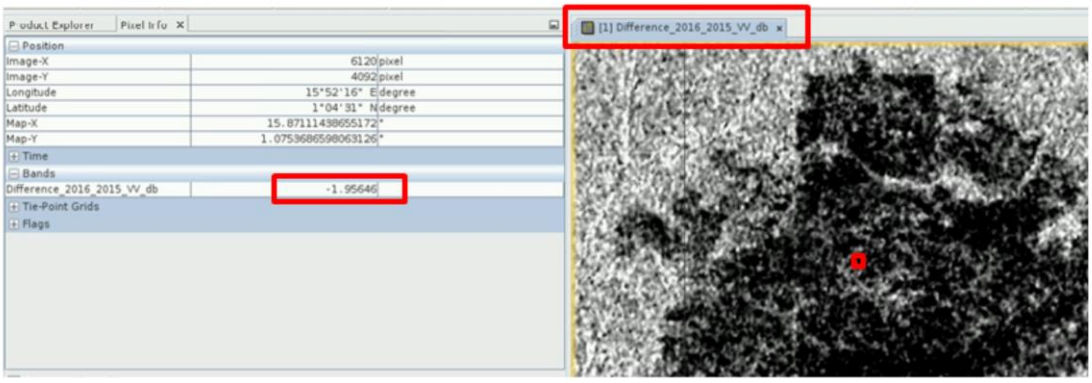
We will create an image where only those pixels belonging to the Burned Area contain values.



- Display the **Difference image for VV_db**
- Using Pixel Info, move the mouse over the burn scar
- Estimate what is the highest a pixel value can be inside the scar

Areas below that value (threshold) will be considered as Burned

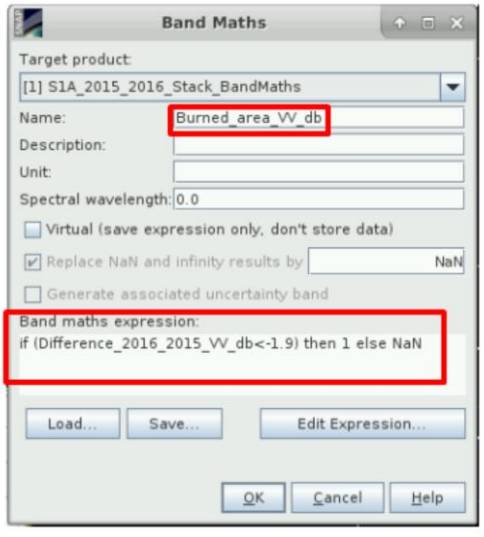
2- SNAP Exercise: (5.3) Extract burned areas



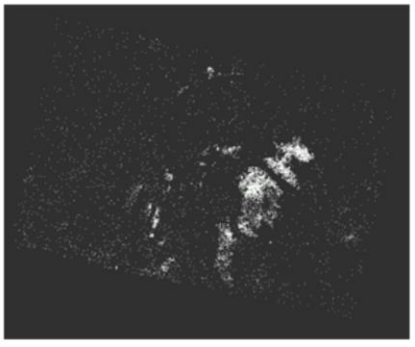
We propose **-1.9** as threshold

- Lower values = Burned
- Higher values = Non Burned

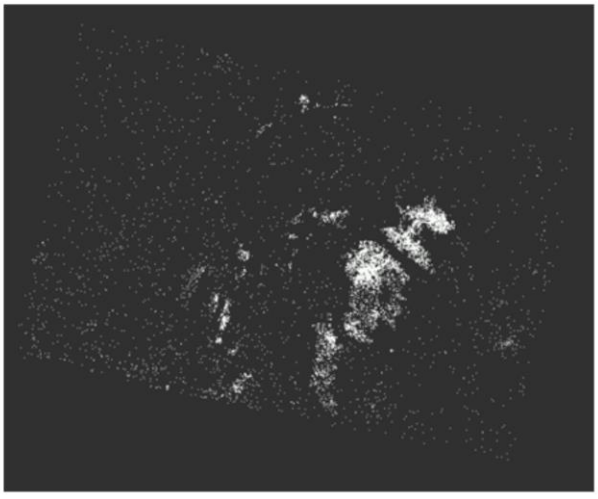
2- SNAP Exercise: (5.3) Extract burned areas



- Open Band Maths
- Name the band Burned_Area_VV_db
- Enter the expression
- Click OK



2- SNAP Exercise: (5.3) Extract burned areas



- White areas: Burned (value = 1)
  Note: isolated pixels are noise.
- Grey areas: Non burned (value = NaN)

- NaN pixels will show transparent when we export the product (e.g. as KML)

2- SNAP Exercise: (5.3) Extract burned areas

Burned_Area_VV_db

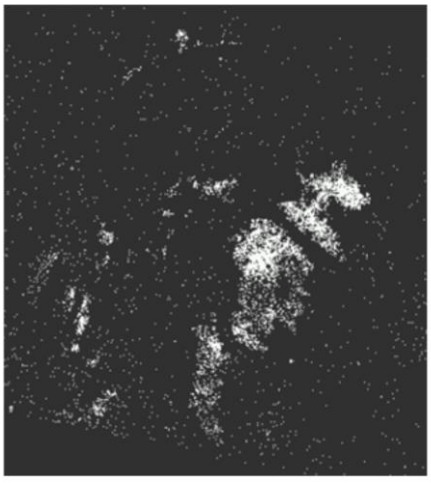
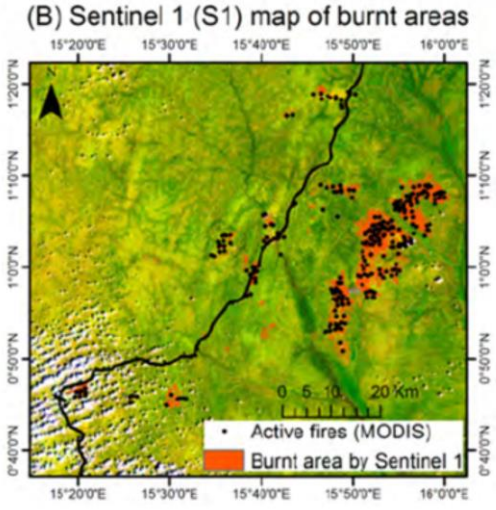


Figure from Verheggen et al (2016)



2- SNAP Exercise: (5.3) Extract burned areas

Burned_Area_VV_db

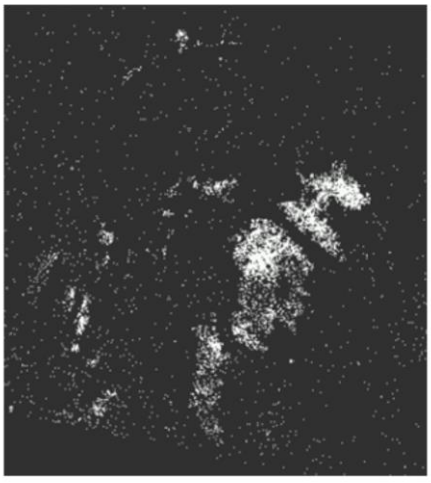
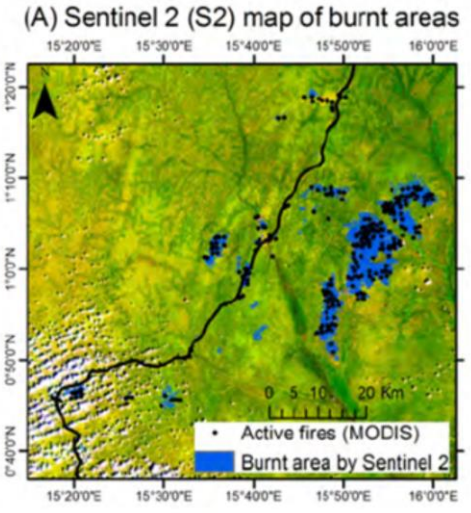


Figure from Verheggen et al (2016)



2- SNAP Exercise: (5.3) Extract burned areas

Burned_Area_VV_db

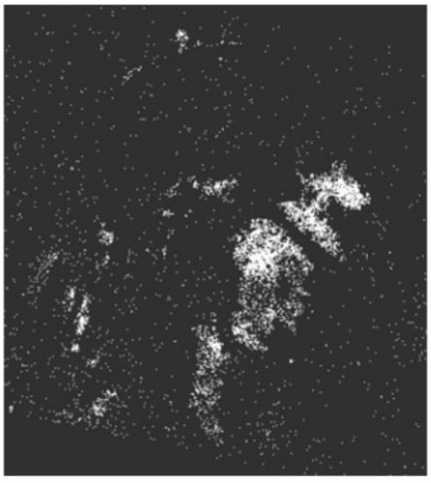
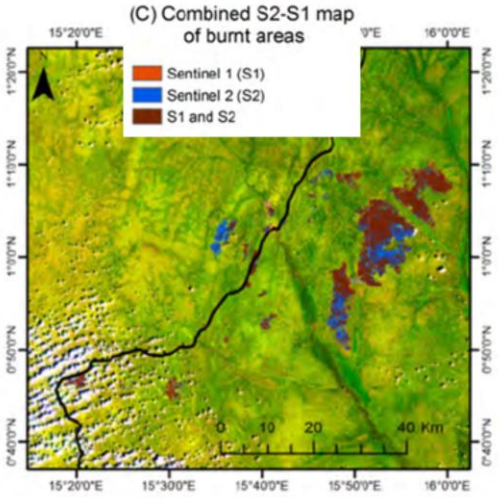
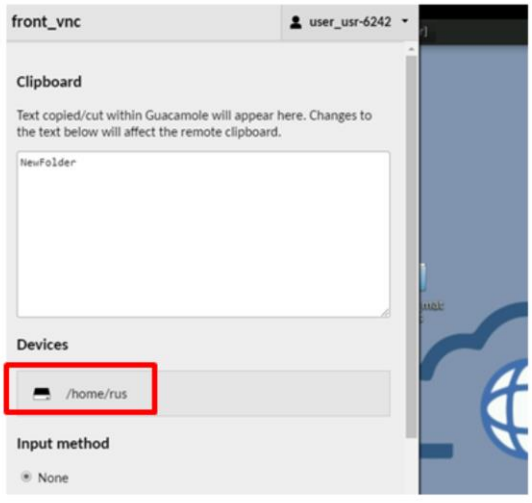


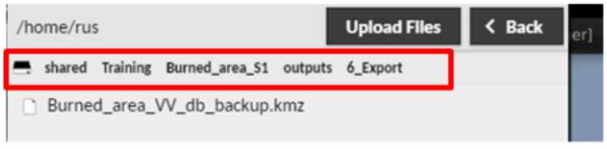
Figure from Verheggen et al (2016)



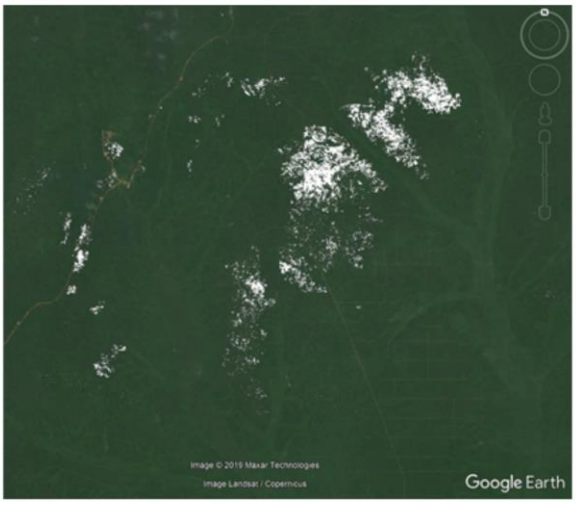
2- SNAP Exercise: (6) Export to KML



- File/Export/Other/View as Google Earth KMZ
- Download the KMZ to your local computer:
  - Ctrl + ALT+ Shift
  - Click under "Devices"
  - Navigate to output folder:
  - Double click on file and it will download

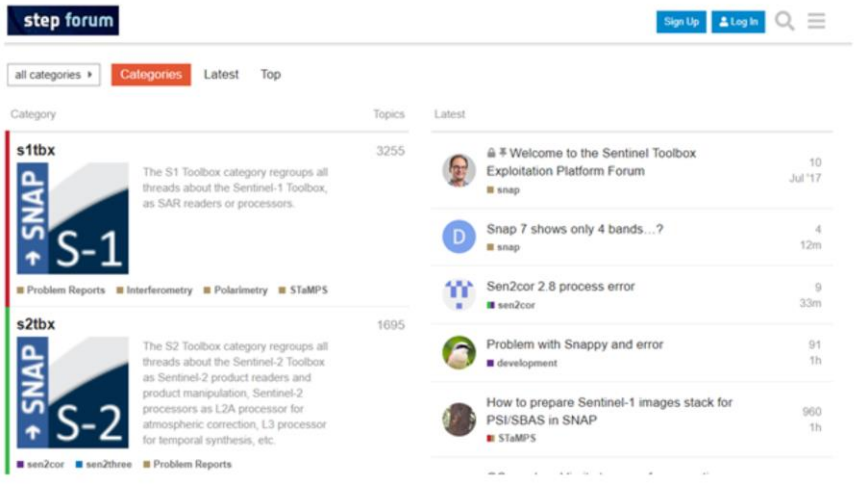


2- SNAP Exercise: (6) Export



7. SNAP Forum

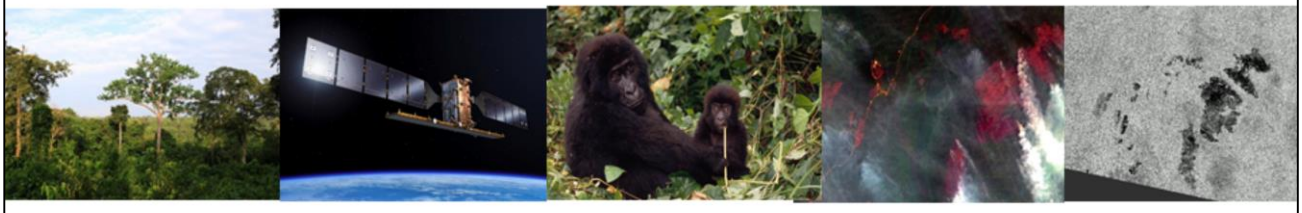
https://forum.step.esa.int/



Learning outcomes

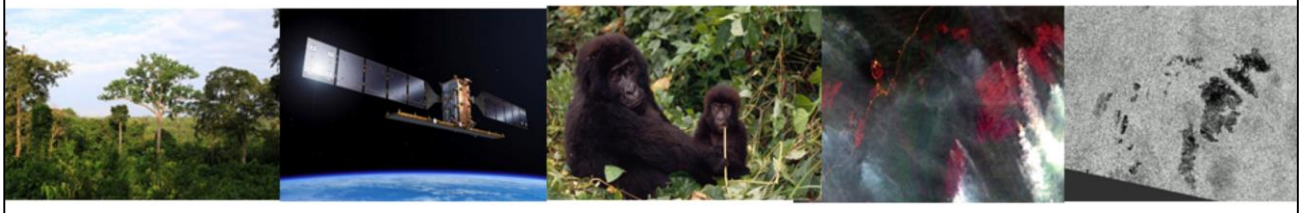
- Interpretation of S1 results
- S1 data download
- SNAP:
  - Basic S1 pre-processing
  - Graphs and Batch processing
  - Mask generation
  - Export product
  - Help & Forum

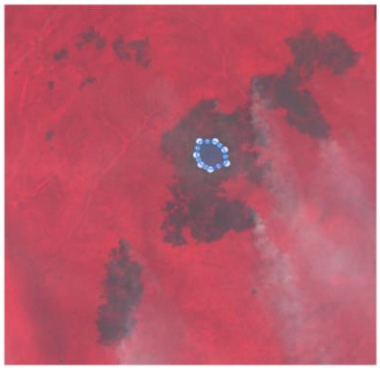
Thank you!
Any Questions?



References

Verhegghen, Astrid & Eva, Hugh & Ceccherini, Guido & Frédéric, Achard & Gond, Valéry & Gourlet-Fleury, Sylvie & Cerutti, Paolo. (2016). The Potential of Sentinel Satellites for Burnt Area Mapping and Monitoring in the Congo Basin Forests. Remote Sensing. 8. 986. 10.3390/rs8120986.



Extra:
NDVI time series of an area that was burned (extracted using EO Browser), image of February 1st 2016, and two timelapses showing evolution

More about EO Browser during tomorrow's session