MULTITEMPORAL CHANGE DETECTION USING SENTINEL-2 AND LANDSAT 8

EXERCISE OVERVIEW

The study area is in the Tatra Mountains of Slovakia.

We will prepare NDVI time series from Landsat-8 and Sentinel-2, and analyse them with a change detection algorithm to map areas that could show damage due to the bark beetle.

The first part will be done in SNAP, and the rest will be done in Rstudio.

DATA & BACKGROUND INFORMATION

The time series covers spring and summer (May to September) of the years 2013 – 2018.

Sentinel-2: subsets of atmospherically corrected Level 2A data. For instructions on how to produce them using Level 1C data, see Annex A. Level 2A products contain a cloud mask, showing the likelihood for a pixel to be cloudy (%).

FYI, the S2 subsets already created have the following coordinates:

Lat / Long (decimal) (for SNAP)		UTM coordinate system (for the Rstudio scripts)	
North Latitude Bound	49.168	xmin	404640
West Longitude Bound	19.692	xmax	417420
South Latitude Bound	49.086	ymin	5437590
East Longitude Bound	19.869	ymax	5446950

Landsat-8: NDVI products are part of Landsat Level-2 Science Products, and can be simply ordered following the instructions at https://landsat.usgs.gov/landsat-data-access.

The file Landsat_image_IDs.txt, saved in the inputs folder, is an example of the text file that can be submitted to download several images at once. NDVI products come along with a Quality Band (more info at https://landsat.usgs.gov/qualityband).

Landsat NDVI products are saved at *output>Step5_NDVI*, for simplicity regarding the Rstudio part.

Rstudio and the BFASTmonitor algorithm:

To expand your knowledge of Rstudio, explore https://www.rstudio.com/ and http://rspatial.org/index.html. There are a lot of resources and blogs on the internet. If you are working on your own and have doubts, don't hesitate to google your problem, because many forums or blogs will show answers that could guide you. One of them is Stack Overflow (https://stackoverflow.com/), where you can create a profile and post your own questions.

The Rstudio part of this exercise uses the 'raster' package. It is accessible at https://r-forge.r-project.org/R/?group_id=294. It's documentation contains numerous examples on how to use the available functions https://cran.r-project.org/web/packages/raster/vignettes/Raster.pdf.

The exercise also monitors disturbances in a forest, using a method that distinguishes between normal and abnormal changes in near real time, and it is based on the Breaks For Additive Season and Trend (BFAST) concept. The method is robust and can be applied to different sorts of data. It is publicly available in the 'bfast' package of Rstudio, in the *bfastmonitor* function(1).
Read more about it and about the BFAST project and algorithms at http://bfast.r-forge.r-project.org/. The 'bfast' Rstudio package is documented at https://cran.r-project.org/web/packages/bfast/bfast.pdf.

For the Rstudio part, we will present two alternatives to create and work with the scripts:
- with the script as an .R file
- with the script as an R Notebook (.RNotebook)

The script in both files is the same. There is only one difference (in Step 9), where the Step9_TimeSeries.R file contains an additional step.
To learn more about R Notebooks, visit https://rmarkdown.rstudio.com/r_notebooks

(1) Verbesselt, J., Zeileis, A., & Herold, M. (2013). Near real-time disturbance detection using satellite image time series, Remote Sensing of Environment. DOI: 10.1016/j.rse.2012.02.022.

PART A (ON SNAP): REMOVE CLOUDS FROM SENTINEL-2 AND CALCULATE NDVI

1. Load images into SNAP

   S2 subsets are saved in **Inputs > S2**. Drag the .dim files into SNAP and open the bands. The “quality_cloud_confidence” band (in Bands>Quality folder) is an output of the atmospheric correction done prior to this course.

2. Create a graph to mask clouds

   We will mask pixels where the cloud probability is higher than 40%, and preserve the others.

   2.1. Go to Tools>GraphBuilder. Right click and add the steps below, in the order shown:

   2.1.1. The first tool is Read.

   2.1.2. To mask the Red Band (B4): Add>Raster>Band Maths. Name it “***Red_cloudmask***”. Enter the following equation in the equation field:

   if quality_cloud_confidence > 40 then NaN else B4

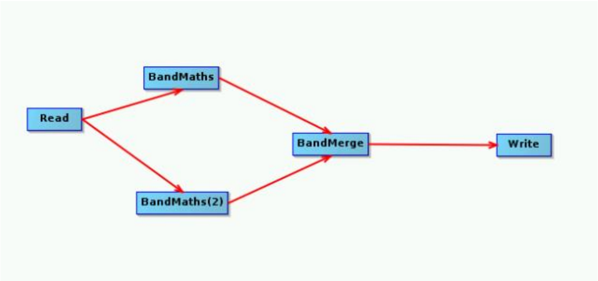
   2.1.3. To mask the NIR Band (B8A): Add>Raster>Band Maths. Name it “***NIR_cloudmask***” Enter the following equation in the equation field:

   if quality_cloud_confidence > 40 then NaN else B8A

   2.1.4. To join both cloud masks into a single product, Add>Raster>BandMerge. Connect the different operators, and then the cloud masks will appear in the BandMerge tool. Highlight both cloud masks.

   2.1.5. The last tool is Write

   2.1.6. File>Save Graph (Step2_S2_cloudmask_graph.xml)



3. Apply the Cloud Masking graphs with batch processing:

   3.1. Tools>Batch Processing, or click the Batch Processing tool in the toolbar

   3.2. Click on Add Opened

   3.3. Load Graph>select the cloud mask graph from Step 2

   3.4. Select an output folder different from the one where your originals are saved. This will prevent them to be overwritten, because the Batch Processing does not allow to change the output name. (e.g. outputs>Step4_S2_cloudmasked)

3.5. Click Run. Close the first 7 S2 images of your Product Explorer window.

4. Create a graph to calculate the NDVI

The NDVI is defined as: NDVI = (NIR band – red band) / (NIR band + red band) and is used to measure the health of vegetation. For Sentinel-2 we use the narrow near infrared band (band 8A) which is closer to the Landsat NIR band in terms of central wavelength than band 8.

4.1. Go to Tools>GraphBuilder. Right click and add the steps below, in the order shown:

4.1.1. The first tool is Read

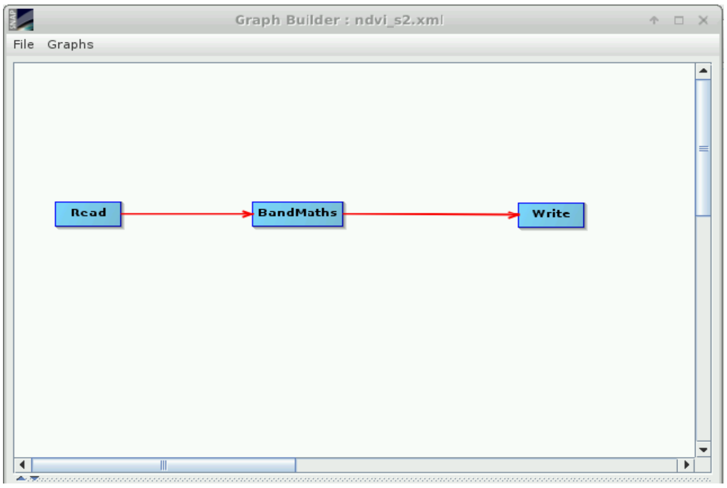
4.1.2. Add>Raster>Band Maths, name the band as NDVI

4.1.3. In Edit Expression, enter

(NIR_cloudmask – Red_cloudmask)/(NIR_cloudmask + Red_cloudmask)

4.1.4. The last tool is Write. Select GTIFF as the output format

4.1.5. As before, connect each tool. File>Save Graph (Step3_NDVI_graph.xml)



5. Apply the graph that calculates NDVI with batch processing

5.1. As above, load the NDVI graph. Select GTIFF as the output format (in Target Folder: Save As), and adjust the output folder (outputs>Step5_NDVI).

5.2. Close the first 7 S2 products of your Product Explorer window.

For the next step it is easier to have all the NDVI files (from both L8 and S2 in one single folder). That is why the L8 NDVI images have been saved in outputs/Step5_NDVI, and not in the inputs folder.

PART B (IN RSTUDIO): DETECT CHANGES IN THE PIXEL TIME SERIES OF AN NDVI STACK OF S2 AND L8 DATA

Overview and comparison of the R scripts and the R Notebooks:

- Open the Step6_L8_cloudmask.R script by double clicking on it. They are saved in "Rstudio scripts"
- Open as well the Step6_Rnotebok.Rmd by double clicking on it. They are saved in Step5_NDVI for simplicity

Both will be now open in Rstudio. Observe the commands are identical in both, but the presentation is different and in the RNotebook we have included more detailed explanations.

During this course, we will use the R Notebook files. Only at the end of Step 9 we will do an additional step in the corresponding .R file.

Description of each step:

Open the R Notebooks below, in the order indicated, and follow their precise instructions:

- Step 6: Mask clouds from L8 NDVI products and crop them to the extent of S2 images
- Step 7: Create a data frame of L8 and S2 data orderedchronologically
-Step 8: Use that dataframe to create a stack of L8 and S2 data ordered chronologically
-Step 9: Explore time series of different pixels. At the end of this, open and run the Step 9 .R file, and perform the additional step shown at the end.
-Step 10: Monitor changes in the area in near real time

Brief discussion:

1- In Step 6, you noticed we need to use a 'for' loop to iterate through the list of files in our folder, and create a raster for each, and progressively build our raster stack. Try to understand why we did not use directly the stack() function with the list of files.

Hint: investigate the inputs accepted by the stack and crop functions, and read well any errors if you attempt to run them using our list.

1- Solution: in your Rstudio console, type:

?stack

Observe the inputs this function accepts. It accepts a list! However, as you have seen, we did not use our list as an input...
Try to use it and see what happens. In your Rstudio console, type:

stack(list)

(Note you will need to create the list before, as we have done in in Step 6)
It does not work….do you understand the error message?

It has to do with the extents of the Landsat-8 images. They do not all have the same extent, therefore cannot be stacked so easily. This could be corrected, if you resampled them. Type:

?resample

However, the L8 are big and this function would take really long. You could crop your L8 files, to reduce computing time. Type:

?crop

Which inputs does this function need? It only accepts a raster as input.

Therefore, we have two options:
- Either use the 'for' loop as we have done
- Or try resampling the full L8 scenes (which would be very slow), and then create a list of resampled files and crop/stack them.

ANNEX-A: Atmospheric correction of Sentinel 2 data (from Level 1C to Level 2A):

Sentinel 2 Level 1C products do not have atmospheric correction. Sentinel 2 Level 2A products are atmospherically corrected, but are not always available for direct download in the Copernicus Open Access Hub, especially for older acquisitions.

To do the atmospheric correction with Sentinel, we used the SNAP plugin sen2cor.

When using sen2cor, the image has to be imported (not opened with the open button) by going to

File->Import->Optical Sensors->Sentinel-2->S2-MSI-L1C

Navigate to the .safe folder of the product and open the .xml file in the main folder. Now start sen2cor, using the default parameters. Only change the pixel size to 20 meter and set the cirrus correction field to 1 (or True). The processing might take a while.

After performing the atmospheric correction with sen2cor, a new band named 'quality_cloud_confidence' has been added to the Sentinel images in a subfolder called 'quality' under the bands tab. This band contains the cloud probabilities.

When subsetting the Sentinel scenes, the cloud band disappears. Therefore, we went back to the original datasets and saved the cloud band as a separate image which we then subsetted to the same size. Then we used the collocation tool to add the band to the subset