FYS-3023 Assignment SAR

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Introduction

Forest fires have ravaged both southern Europe as well as Canada in the spring and summer of 2023. To monitor such fires satellite images can be a key source of information. NASA has described some of how they work with forest fires here: `https://www.nasa.gov/mission_pages/fires/main/missions/index.html`.

Satellites can be used to monitor progress and change in direction of the fires as well as to provide information about which roads are still passable. Different types of satellite images can contribute with different information, and here you'll be working with both synthetic aperture radar (SAR) images as well as optical images.

The area of choice is Canada as it was observable as far away as the Arctic ocean between Svalbard and Greenland at the time. Open access images from the ESA Sentinel-1 and Sentinel-2 will be used in the exercise. The reason behind the exercise is to see how different satellite sensors can contribute towards an overall improved knowledge of a phenomena on Earth, and for you to be better acquainted with the pros and cons each type of satellite sensors. By using open access images this also means that you are familiar with how to work with the data and can easily perform additional analysis on other images on your own afterwards. Each step in the assignment is there to help you build and overall understanding about how the satellite images can be combined and to learn the basics about how to prepare the images for an analysis.

You'll be working with in total 4 images, 2 SAR images and 2 optical images. One pre- and post-fire for each one. The images are real life examples and may not have as clear an answer as you may be used to from earlier courses.

More information about the Normalised difference burnt radio (optical) and the log-ratio (SAR) can be found in a paper lead by Yifang Ban that can be found here: `https://www.nature.com/articles/s41598-019-56967-x`.

Recent images of forest fires can be found here: `https://www.esa.int/ESA_Multimedia/Images/2023/07/Rhodes_wildfire_forces_thousands_to_flee`

The images can be found in the folder */Files/Assignments/Assignment 1/data/*. You will be working in SNAP and a programming language of choice.

Task 1

a)

Display the VV-channel of the pre-fire S1 file:
S1A_IW_GRDH_1SDV_20230529T225334_20230529T225359_048755_05DD08_4D82 in decibel scale using a programming language of your choice. The VH- and VV-channels are located in the *measurement* folder. Can you identify any features in the image? Are there any SAR ambiguities present?

b)

Open the pre-fire S1 scene in SNAP. What is the acquisition time, geographical extent and spatial resolution of the scene? Hint: the information can be found in the metadata. You should from the lectures be familiar with these concepts.

c)

Using SNAP (or any other software of your choice), perform a set of basic pre-processing of the pre-fire S1 scene. These are relatively standard procedures when working with SAR images, though order may wary and not all steps are always needed.

The pre-processing should include

1. Subsetting
2. Thermal noise removal
3. Calibration
4. Radiometric terrain flattening
5. Speckle filtering
6. Multilooking
7. Range-Doppler terrain correction

The subset boundary should be

$$\text{North} = 48.7 \quad \text{West} = -76.3 \quad \text{South} = 49.6 \quad \text{East} = -75$$

Subsetting is often used to speed up computation time and focus the study on the area of choice. The SAR images can cover up tp 450 km and if the area of interest is only 50x50 km subsetting is advantageous. Note that in "Geo Coordinates" (north and south are reversed as an unprojected SAR image is sometimes "upside down"). This depends on if the image is an ascending or a descending image. Which type of image are you working with here?

What is thermal noise removal? Why do we use it?

Calibrate the scene to *beta0* level. Why would one use *beta0*? What is the advantage over using, e.g., *sigma0*?

Use parameters of your choice for speckle filtering and multi-looking, but provide some reasoning for your choices.

For terrain correction and geocoding use the SRTM dem provided in SNAP. Choose EPSG:4326 as the coordinate reference system. Briefly explain the purpose of all the preprocessing steps. Note that the processing may take a while depending on your hardware. What is the difference between the geo and the image coordinates? When might one or the other be more useful to work with? Here you are given a specific coordinate system, what is the advantage of picking a specific system?

Export the preprocessed image in *GeoTIFF* format by selecting GeoTIFF in the "Save as" menu in the Range-Doppler terrain correction module. Use a programming language of your choice (Python, MATLAB, etc.) to open the image, and display the VV channel on decibel scale. How does this compare to the image in 1a)?

d)

Repeat task c) for the post-fire S1 image:
S1A_IW_GRDH_1SDV_20230622T225335_20230622T225400_049105_05E7A2_5922

For the remaining tasks, you will work in Python/MATLAB etc.

To ensure that the images have a common extent, crop them to match the outline of the pre-fire S2 image provided:
S2A_MSIL2A_20230531T160901_N0509_R140_T18UVV_20230601T000958.SAFE

Use one of the S2 bands for this. The 10m bands are located in
path_to_S2/ GRANULE/ *file id*/ IMG_R/R10m/. Choose one of the bands as a geographical reference.

Cropping the preprocessed S1 images can be done by opening the S2 image through GDAL, and extracting its geotransform which is then used as boundaries for the S1 images. In Python, this could look like the following:

```
from osgeo import gdal
import os

# opening the Sentinel-2 band
s2 = gdal.Open(path_to_S2_file.jp2)
```

```
# obtaining the geotransform
geoTransform = s2.GetGeoTransform()

# extracting corner coordinates
minx = geoTransform[0]
maxy = geoTransform[3]
maxx = minx + geoTransform[1] * s2.RasterXSize
miny = maxy + geoTransform[5] * s2.RasterYSize

# cropping the Sentinel-1 data to the extent of the Sentinel-2 data
os.system(f'gdalwarp -overwrite -s_srs EPSG:4326 -t_srs EPSG:32618
-te {minx} {miny} {maxx} {maxy} {original_file.tif} {cropped_file.tif}')
```

where *original_file.tif* is the path of the input file and *cropped_file.tif* is the path of the output file (which you decide yourself).

For both channels, VH and VV, calculate the log-ratio of the pre- and post-fire image. The log ratio is defined as

$$\Delta\gamma^0_{XY} = 10\log_{10}(\gamma^0_{XY-pre}) - 10\log_{10}(\gamma^0_{XY-post})$$

and create a false color composite with the following channels

$$\begin{aligned} \text{Red} &: \Delta\gamma^0_{VH} \\ \text{Green} &: \Delta\gamma^0_{VV} \\ \text{Blue} &: \Delta\gamma^0_{VH} \end{aligned}$$

Explain why the difference of two images on decibel scale is equivalent to a ratio.

e)

Display the false color composite from 1d as an RGB image. Feel free to use the illustrations in the paper by Yifang Ban when you decide on how you put together your RGB image.

f)

The normalized difference burn ration (dNBR) is an established method for detecting forest fires from optical images, and is defined as

$$\text{NBR} = \frac{\text{NIR} - \text{SWIR}}{\text{NIR} + \text{SWIR}}$$
$$\text{dNBR} = \text{NBR}_{\text{pre-fire}} - \text{NBR}_{\text{post-fire}}$$

Calculate the dNBR from the pre- and post-fire Sentinel-2 images (S2A_MSIL2A_20230531T160901_N0509_R140_T18UVV_20230601T000958 and S2A_MSIL2A_20230620T160901_N0509_R140_T18UVV_20230620T234755). Display the dNBR image with a suitable colormap.

g)

With the Sentinel-2 images as reference, try to identify regions affected by forest fire in the Sentinel-1 RGB image. Based on this, give an interpretation as to why changes appear as they do in the false color composite. Discuss advantages and disadvantages with both methods (log-ratio and dNBR).

h)

Describe how you would develop a long-term fire monitoring program from space, and explain why and in what situations certain sensors are better for mapping forest fire burn scars than others? There is no right answer we are looking for creativity and reasoning behind your solution. Feel free to google existing systems and how they are put together, but don't copy text straight from the web.