Processing of Sentinel-1 SAR images Application to flood monitoring

L. Ferro-Famil[1,2], M. Planells[3,2], Y. Huang[4,2]

2021

(1) ISAE-SUPAERO, University of Toulouse, France, laurent.ferro-famil@isae-supaero.fr
(2) CESBIO, University of Toulouse, France.
(3) CNES, French Space Agency, Toulouse, France.
(4) University of Rennes 1, Rennes, France.

Summary: This practical session is an introduction to processing and analysis of SAR images using the ORFEO Toolbox (OTB). Note that other open sources processing tools, able to handle SAR images, exist and may be used in combination with OTB.
In this computer exercise, Sentinel-1 (S1) images are used to monitor a flooded region in South-West France. The flooding occurred during the night of October 14, 2018, and was a consequence of the Leslie storm. Due to densely cloudy weather conditions during that period of time, the first Sentinel-2 optical image that could be used to observe the region was acquired on October 25, 2018, and S1 data revealed very useful to observe the extent of this natural disaster from space. S1 images acquired at the closest dates before and after the flooding, i,e, on October 04 and 16, 2018, will be used to discriminate flooded areas.

1 General information and software handling

1.1 Main features of Sentinel 1 SAR images

The Sentinel-1 images are stored in the folders

```
TP_S1/InputData/S1B_IW_GRDH_1SDV_20181004T060051_20181004T060116_023982_029EA5_0956.S
AFE/measurement/
TP_S1/InputData/S1A_IW_GRDH_1SDV_20181016T060051_20181016T060116_024157_02A459_BFCA.
SAFE/measurement/
```

Action

Using specific websites, identify some essential features of the S1 data sets used in this exercise:

- Data type, image resolution, polarisation channel, acquisition date and time
- Carrier frequency and incidence angle

1.2 Software installation & settings

1.2.1 Software description

The different processing functions provided by the OTB may be launched through various interfaces. Four solutions are shown in this practical, using

- The Monteverdi visualization interface, included in the OTB
- Qgis, a geographic information system application
- A Jupyter-notebook code
- the command line, i.e. a shell interface, from which OTB programs and arguments can be launched. The exact syntax and parameter values can be read from the Jupyter-notebook code.

OTB can be downloaded from the Orfeo Toolbox web site, and easily installed. It is highly recommended to run the self-testing program located in the `tool` directory of the OTB, and to fix any issue, in particular those related to the currently installed version of Python.

Qgis can be easily installed (from the list of programs of most Linux distributions), and it is recommended to install Jupyter-notebook with conda.

1.2.2 A glance at Monteverdi

Action

Using Monteverdi, open the VV image of the first date (2018-10-04).

The pixel values, related to intensity, are in DN (Digital Numbers) format, i.e. the magnitude has been quantized and stored under the form of discrete values, Digital Number.

As seen during the lecture, the received signal intensity is proportional to the backscattering coefficient, up to a multiplicative factor that depends on the satellite design. The conversion of DN values to backscattering coefficients is called "radiometric calibration". The relationship between DN and the backscattering coefficient for Sentinel-1 is given by:

$$\sigma^0 = \frac{DN^2}{A_\sigma^2} \quad \text{and} \quad A_\sigma^2 = \sqrt{\frac{A_{dn}^2 K}{\sin\alpha}}$$

with α, the local incidence angle, and A_{dn}, the scaling factor from internal SLC to final SLC or GRD image product, given in the metadata folder.

Action

Tick the `View/OTB-Applications browser` option and convert the quantized imaged

into σ_0 values using the `SAR calibration` OTB program, which automatically computes backscattering coefficients.
The whole practical could be realized using Monteverdi, but Qgis will be used in the following.

1.2.3 Qgis set up

Open the Qgis application.
Action

- In `Processing/Toolbox/options/Providers/OTB`
  - Tick the `Activate` option
  - Set `OTB Application folder` to the `lib` directory of the OTB program set
  - Set `OTB folder` to the `OTBxxx64` directory containing the `bin`,`lib` ... directories of the OTB toolbox.
- Display a SAR image
  - In `Layer/Add Layer/Add Raster Layer`, read the S1 VV SAR image of the first date.
  - In the `Layer` frame, check the `Information` (size, location, ...) of the image, and adjust its min-max display values using the data histogram.
  - Install source of external data. In `Plugins/Manage and Install Plugins` search for and install the `QuickMapServices` plugin. In `Web/QuickmapServices/Settings/More` click `Get contributed pack`, then `Save`.
  - Visualize external data. Select `Web/QuickmapServices/Google/Google Labels`. In the `Layer` frame, move the `Google Labels` layer to the top, and identify the region observed by S1.

Perform the Radiometric Calibration of the VV image.

2 Basic processing steps using Qgis

The different processing steps to be performed during this exercise are

1. SAR image import
2. Radiometric calibration
3. Sub-image selection
4. Speckle filtering
5. Geometrical corrections
6. Multi sensor data superposition and analysis (S1 and S2)

7. Flooded area mapping using S1 image multi-date analysis

Steps 1 to 4 will be implemented manually using Qgis and its OTB plugin. Parameter values for the different OTB functions can be checked in the Jupyter-notebook file named `TP_S1.ipynb`.

2.1 Radiometric calibration

Action

- Import the VV image of the first S1 acquisition and calibrate it to σ_0 Radar Cross Section (calibrated reflectivity values). Call `OutputImage/VV1.tiff` the resulting image. Check and adjust the dynamic range of the image.
- SAR images are generally represented in dB (log-scale). Create a dB-valued image, named `VV1_dB.tiff`, using `Raster/Raster Calculator` and the expression `10*log10(max(XX,0))`, where `XX` stands for the image name and specifying the output image name too. Adapt the dynamic range of the dB-valued image and comment its content.

2.2 Image clipping

Action

Clip, i.e. select a sub-part of, the calibrated **linear** image, **not the one expressed in dB** using the `Extract ROI` function and the parameters specified in the Jupyter-notebook file. Set `OutputImage/VV1_Clip.tiff` as the output file.

2.3 Speckle filtering

Action

- Using the `Despeckle` function, apply a Lee filter with radius 3, 5 and 7, calling the output image `OutputImage/VV1_Clip_LeeX.tiff`
- Create dB-valued images of the non-filtered and filtered images
- Evaluate the characteristics of each image, in terms
  - Dynamic range
  - Blurring
  - Variability, i.e. random aspect
- Apply the same processing, i.e. import, calibration, clipping, filtering (with the filtering parameters considered as those most adapted to the analyzed image) to the S1 HV image acquired at the first date. Compare VV and HV filtered images and provide interpretations.

3 Batch processing using Jupyter-notebook

3.1 Settings

Action

Launch `Jupyter-notebook` and make sure the OTB program locations are in the path. This can be done through the `otbenv.profile` script provided with the OTB toolbox. Linux users may run `source PATH_TO_OTB_FOLDER/otbenv.profile` before launching the Jupiter-notebook.

The Notebook contains two main sections, devoted to the automatic processing of the S1 VV image acquired at the first date, and to the batch processing of all 4 S1 images, i.e. 2 polarizations and two dates.

Action

- The **first part** is left as an illustration and shall not be launched
- Run the items of the **second part**

The batch process runs the different steps mentioned before and uses an the orthorectification application to perform geometrical corrections using the S1 metadata of the GRD product. The speckle filter apply here correpond to the Frost algorithm, characterized by a radius of 3 and a damping factor of 0.2.

Action

Explain what these parameters correspond to.

The last step of the batch process consists in superimposing a S2 optical image onto the selected S1 processing results, i.e. clipping and resampling the S2 image to the S1 orthorectified coordinates.

4 Analysis

Action

- Load, and display in dB the VV and HV images at both acquisition dates
- Observe temporal variations on the VV channel, superimpose Google labels and localize flooded areas. Looking for the translation of the French word "écluse" might reveal worthy.
- Provide an interpretation of the change of reflectivity due to flooding. A comparison with other, non flooded, areas of the image having a similar reflectivity could give a clue.
- Determine which polarization channel, VV or HV, is better adapted to flood mapping
- Provide a map of the flooded area using a multi-temporal color-coded image of your favorite polarization channel