Flood Mapping using SAR images

VICCS Spring School 2015

Fabio Cian
PhD Programme in Science and Management of Climate Change
Contents

• Satellite missions, acquisitions and Synthetic Aperture Radar
• Exercise introduction
  • Case study: Veneto 2010
  • Data overview
  • Flood Mapping
  • Depth estimation
• Flood Mapping using NEST
  • Basic theory for flood mapping
• Flood depth using QGIS
Satellite mission, acquisitions and Synthetic Aperture Radar
Disaster Management and Satellites
Rapid Mapping of Flooding

Floods in Central Europe have caused widespread damage. Such events are likely to increase. Maps based on satellite data help national emergency services to plan their response.
NASA Earth Observation Satellites
Landsat-8 Orbit
ESA Sentinel-1 Constellation
Satellite images?
Satellite Images - Optical
Satellite Images – Synthetic Aperture Radar
Oil slick in the Gulf of Mexico
Satellite Images - SAR
Satellite Images - SAR

The Pyramids of Giza, Egypt
Satellite Images - SAR

Guelb er Richat, Mauritania
Satellite Images - SAR

Nördlinger Ries in the Swabian Jura, Germany
Flood In Gloucester and Cheltenham, England
http://www.geos.ed.ac.uk/~ihw/hype/radar/intro2radar.html
Synthetic Aperture Radar Image
Exercise Introduction
PhD Programme in Science and Management of Climate Change

Full Resolution – 3 meters
Flood in Veneto 2010
Flood in Veneto November 2010
Flood in Veneto November 2010
Flood in Veneto November 2010
Flood extent – Saletto Area
Flood – SAR Image – Saletto Aerea
Dataset
Dataset – COSMO-SkyMed

- Constellation of small Satellites for Mediterranean basin Observation
  - Military and civilian operations
  - Synthetic Aperture Radar X-Band (~3cm)
  - Italian Space Agency and Ministry of Defense

- Stripmap Himage: 3 to 5 meters resolution
  - Flood: 6th November 2010
  - Archive: 31st October 2008

- Preprocessed data
  - Terrain Correction
  - Calibration

- Useful for: flood extent
Dataset – COSMO-SkyMed

31st October 2008

6th November 2010
Dataset – COSMO-SkyMed

31st October 2008 6th November 2010
Dataset – Digital Elevation Model

- Digital Elevation Model – Regione Veneto Database
  - 5 meters resolution

- Useful for: compute flood depth
Dataset – Digital Elevation Model
Flood Mapping
Flood Mapping using SAR – Basic Theory

Reflectance
Dataset – COSMO-SkyMed

31st October 2008  6th November 2010
How to distinguish land from water?
Surface roughness

**Water:** smooth surface --> specular reflection --> low reflection to radar sensor

**Land:** rough surface --> diffuse indirect reflection
  --> sharp edge reflection
  --> double bounce effect
Dataset – COSMO-SkyMed

31\textsuperscript{st} October 2008

6\textsuperscript{th} November 2010
Problems in detecting water surface:

- Rough water surface:
  - Presence of wind increases roughness
  - Increase backscatter
  - Possible confusion with land

Object with low backscatter:
- Airstrips, dunes, radar shadow,
Flood Mapping – Basic Theory

Flood under vegetation

**Double bounce effect** --> increase of backscatter
Flood under vegetation
Flood under vegetation
Permanent water bodies

Image of the flood compared to a reference image

• Both images need to have been acquired from the same sensor geometry!
  
  (Radar return depends on the angle and direction of the incident radar pulse)
Flooded areas have **low backscatter values**

**Change Detection - - > Thresholding on intensity difference**
Flooded areas have **low backscatter values**

**Change Detection** - - > **Thresholding on intensity difference**

Image Difference
Flooded areas have low backscatter values

Change Detection - - > Thresholding on intensity difference

Normalized Difference
Extract Flood Extent with NEST
Processing of SAR data from ESA and third party Mission

https://earth.esa.int/web/nest/home
Flood Mapping - Overview

• Objective: flood map

• Pre-processing 0: calibration and terrain correction
  • Pre-processing 1: map projection

• Step 1: band math --> obtain image difference and normalize
• Step 2: decide a threshold
• Step 3: apply the threshold
• Step 4: apply filters to “clean” the extracted flood map
Open the data

Files are in **ENVI format**

File --> Import Raster Data --> Common File Formats --> ENVI --> C:\Users\cian\Dropbox\Spring Scool\FirstSecond-Day\Data\COSMO-SkyMed\20101106_20081031_saletto.hdr
Visualize the data

Expand Bands --> double click on one of the two bands
Visualize the data

Colour Manipulation Tab --> 95% --> Slider
Reproject the data

Geometry --> Reprojection...
Reproject the data

Geometry --> Reprojection...
Write name, Save as BIM-DIMAP
Reproject the data

Geometry --> Reprojection...
Set projection --> UTM / WGS84 (Automatic)
Visualize the projected data
Band Math – Normalized Difference Flood Index

Utilities --> Band Math
Band Math – Normalized Difference Flood Index

Name: NDFI
Edit Expression --> (Flood – Reference) / (Flood + Reference)
Band Math – Normalized Difference Flood Index
Thresholding – Normalized Difference Flood Index

Select flood area to analyze NDFI statistic --> Polygon drawing tool --> Draw polygon
Thresholding – Normalized Difference Flood Index

Analyze NDFI statistic --> Analysis --> Statistic
Thresholding – Normalized Difference Flood Index

Analyze NDFI statistic --> Analysis --> Statistic
Choose the 75th percentile
Thresholding – Normalized Difference Flood Index

Apply threshold: Utilities --> Band Math --> Edit expression
NDFI < 75th Percentile
Thresholding – Normalized Difference Flood Index

Flood Map looks “dirty”
Flood Map filtering

Utilities --> Image Filtering
Flood Map filtering

Utilities --> Image Filtering
Set source products, type name
Flood Map filtering

Utilities --> Image Filtering
Set source band, select Median Filter 5x5
Flood Map filtering

Map appear “cleaner”
Apply filter a second time: Pay attention to source products and name of output
Flood Map filtering

Map appear “cleaner”
Apply filter a second time: Pay attention to source products and name of output
Flood Map

Flood map is now ready to be used in a GIS.

Check in the data folder:
- Folder with the name you gave + .dim file
- Open the folder: .img file --> the file we need!
Extract Flood Depth with QGIS
Flood Depth

Water surface is a **plane**

If flood map is accurate, the **elevation along the contour** of each flooded area **must be the same**

Detect the **maximum elevation** along the contour to compute flood depth
Flood Depth

Water surface is a **plane**

If flood map is accurate, the *elevation along the contour* of each flooded area *must be the same*

Detect the **maximum elevation** along the contour to compute flood depth
Flood Depth
Flood Depth
Flood Mapping - Overview

- Objective: flood depth

- Pre-processing 0: convert from raster to shapefile (polygons)
- Pre-processing 1: delete polygons (flooded areas) smaller than 300 m²
- Pre-processing 2: create polylines file

- Step 1: Inspect elevation along flood contours
- Step 2: Create a raster with water elevation
- Step 3: Calculate flood depth
QGIS – Open data

• Drag and drop flood_map.img into layers panel
QGIS – Pre-Processing 0 - Convert raster to shapefile

- Raster --> Extraction --> Clipper
- Write output name and select an area within the flood map extent
- Check No Data Value
QGIS – Pre-Processing 0 - Convert raster to shapefile

• (We got rid of the borders) and assigned NaN to no value pixels
QGIS – Pre-Processing 0 - Convert raster to shapefile

- Raster --> Conversion --> Polygonize
QGIS – Preprocessing 1 – Delete small polygons

- Right click on flood_map_shape --> Toggle editing
QGIS – Preprocessing 1 – Delete small polygons

Select the outer polygon
View --> Select --> Select features --> Select outer polygon(s)
QGIS – Preprocessing 1 – Delete small polygons

Edit --> Delete selected
Right click on flood_map_shape --> Toggle editing --> Save
QGIS – Preprocessing 1 – Delete small polygons
• Open attribute table
• Open field calculator
  • Create new field, name ID
  • Record $id$
QGIS – Delete small polygons – Calculate Area

- Right click on flood_map_shape --> Open Attribute table
- Field Calculator --> Geometry --> Area
- Select field type: decimal, precision 3
QGIS – Delete small polygons

• Select features using an expression
• Area < 300 m²
• Delete selected and save edits
QGIS – Final shapefile
QGIS/GRASS – New Mapset

• Click on Plugins → GRASS → New Mapset
QGIS/GRASS – New Mapset

• Select a path to a folder to save the new GRASS Mapset
Define the name of the Location (e.g. Veneto)
QGIS/GRASS – New Mapset

• Define the projection (i.e. EPSG: 32632)
• Define the Mapset name (e.g. Veneto)
• Review and save the Mapset
QGIS/GRASS – Import QGIS Data

• Click on Plugins → GRASS → Open GRASS Tools
QGIS/GRASS – Import QGIS Data

• Go to Module Tree → File management → Import into GRASS → Import raster into GRASS → Import raster into GRASS from QGIS view → \texttt{r.in.gdal.qgis}
QGIS/GRASS – Import QGIS Data

• Select the DTM raster file from the drop menu.
• Name the new raster GRASS file (e.g. DTM_GRASS) and hit Run
QGIS/GRASS – Import QGIS Data

• Go to Module Tree → File management → Import into GRASS → Import vector into GRASS → v.in.ogr.qgis
QGIS/GRASS – Import QGIS Data

• Select the vector file from the drop menu.
• Name the new GRASS vector file (e.g. FloodExtension_GRASS) and hit Run
QGIS/GRASS – Import QGIS Data

- Go to Browser tab and click on the **Refresh** button.
Click over the raster file to select it and click on the **Set current region to selected map** button.
QGIS/GRASS – Import QGIS Data

• Add the selected **raster** file to the QGIS environment, and...
QGIS/GRASS – Import QGIS Data

•... do the same for the GRASS vector file.
You now should have something similar to this:

Observation: Note that there may be two "shapefiles". This happens due to the GRASS conversion. Evaluate which is the right one for the next steps!
QGIS/GRASS – Calculate the Statistics

• Go to Module Tree → Vector → Vector update by other maps → v.rast.stats
QGIS/GRASS – Calculate the Statistics

• Select both the **raster** and the **vector** files from their respective drop down menu;
• Fill-up the column prefix field with a **small string** (i.e. “S”) and hit Run.
QGIS/GRASS – Export GRASS Data

- Remove the old vector files, and...
QGIS/GRASS – Export GRASS Data

• Add the new vector files to the QGIS environment.
QGIS/GRASS – Results

- Finally, check if everything is ok.
- If certain polygons have Null value under $S_{\text{Max}}$, select all of them and delete them.
QGIS – Clip DTM to flood extent

- Raster --> extraction --> Clipper
- Select DTM, Mask layer: shapefile, check No_Data_Value
QGIS – Create raster DTM with same flood extent and value of maximum elevation

- Raster --> Conversion --> Rasterize
- Input: shapefile  Attribute: Max
QGIS – Compute flood depth

- Raster --> Raster calculator --> DTM_max_el – DTM_clip
QGIS – Flood depth
Thank you for your attention!

Fabio Cian

PhD candidate in Science and Management of Climate Change

Tel.: +39 340 61 06 064
Skype: cianfabio

fabio.cian@unive.it

University Ca' Foscari Venice

Department of Economics
Fondamenta San Giobbe | Cannaregio 873 | 30121
Venice | Italy

www.unive.it