

1. Heading and logos

Practice on **SAR flood mapping** recommended by **SRI NASU-SSAU and UN-SPIDER RSO in Ukraine**.

2. Contact details

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3. Workflow

See the file SAR-floodmapping-Worfklow.ppt.

General description of the workflow:

- (1) SAR image acquisition.
- (2) Radiometric correction (calibration), filtering (de-speckling).
- (3) Processing of SAR image (segmentation and classification), e.g. threshold or more advanced statistic or machine learning techniques. Here we will focus on a simple threshold image segmentation method.
- (4) Geometric (ortho-rectification) of the processed image using digital elevation model (DEM).
- (5) Generation of a map and visualization in GIS.

4. Explanations and recommendations

Abstract on the recommended practice

Efficient monitoring and prediction of floods and risk management for large river is quasi-impossible without the use of Earth Observation (EO) data from space. As a matter of fact, one of the most important problems associated with flood monitoring is the difficulty to determine the extent of the flood area as even a dense network of observations cannot provide such information. The flood extent information is used for damage assessment and risk management, and benefits to rescuers during flooding; it is also very important for calibration and validation of hydraulic models to reconstruct what happened during the flood and determine what caused the water to go where it did.

The use of optical imagery for flood monitoring is limited by severe weather conditions, in particular presence of clouds. In turn, SAR (synthetic aperture radar) measurements from space are independent of daytime and weather conditions and can provide valuable information to monitoring of flood events. This is mainly due to the fact that smooth water surface provides no return to antenna in microwave spectrum and appears black in SAR imagery.

This recommended practice focuses on a simple threshold method for deriving flood extent from SAR imagery.

Requirements

The following are required for the recommended practice:

- Data requirements: SAR images (current and possible archived) in Level1, and DEM for ortho-rectification. (SRTM DEM is automatically downloaded in NEST within ortho-rectification procedure) Also, archived optical imagery, land cover / land use maps with vector data on infrastructure objects are beneficial.
- For SAR image processing, NEST software version 5.0.16 is required. Both 32 and 64 bit versions are freely available from <http://nest.array.ca> (registration required). For visualization and creation of maps, we will use Quantum GIS version 2.0 Dufour which can be freely downloaded from <http://www.qgis.org>.
- Skills requirements: basic to intermediate knowledge of image processing; basic knowledge of SAR theory.
- Hardware requirements: for processing real SAR images, it is advisable to have minimum 2 Gb of RAM. Use of multi-core processors (with hyperthreading) is beneficial since NEST is parallelised.

Applications

The applications of flood extent include:

- Operational estimation and detection of flooded areas (within 6-12 h after data acquisition).
- Damage assessment of flooded objects.
- Calibration of hydrometeorological models.
- Detection of water levels using high-resolution DEM.
- Spatial extent: from villages to global scale.
- Can be used for all stages: risk assessment, operational mapping and response, recovery.
- Spatial resolution: from 1 m to 150 m.

Advantages and limitations

The use of threshold method for SAR has the following advantages:

- Cloud independent SAR images.
- High revisit time.
- Easy detection of smooth water.

Accuracy: up to 95% (depending on the landscape and area).

Limitations:

- Potential false alarm from shadows (variable terrain), smooth objects (like roads) and sand.
- Difficulties in detection floods in urban areas.
- Difficulties in detecting flooded vegetation. (For flooded vegetation detection from SAR usually two multi-temporal images are required.)

Bibliography

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5. Step-by-step procedures using NEST and QGIS

Follow the presentation with the screenshots, The processing are numbered, and these numbers corresponds to the numbers in the presentation.

Data access

Currently, there is no freely available SAR imagery. These include: Radarsat-2, Terra-SAR/X, and Cosmo-SkyMed. But archived SAR images from past missions can be freely obtained. For example, SAR images from Envisat/ASAR can be obtained from the ESA Category-1 programme (<http://eopi.esa.int/>). Also, for commercial images (Radarsat-2, Terra-SAR/X, and Cosmo-SkyMed) there are opportunities for scientific use of data for free or reduced rates. The data from the new Sentinel-1/SAR mission from ESA (to be launched in spring 2014) will be free as well.

Data preparation / Pre-processing

NEST supports all major data formats that are used to store SAR images.

1. Data preparation:

- 1.1. To read the date set point to **File → Import Raster Data → RADARSAT-2**.
- 1.2. Select file **product.xml**. This is a file that contains metadata concerning the Radarsat-2 image.
- 1.3. If you need a subset click on the **Subset** button on right of the **Import Radarsat-2 Product window**. Specify parameters of the region of interest and click OK button. NEST will open the product with all metadata relevant to the subset.
- 1.4. On the left panel, **Product View**, relevant information on the product is shown. This includes: **Identification** (mission, acquisition date, pass, etc); **Metadata** (different SAR parameters on the orbit and image); **Tie-points grid** (interpolated latitude, longitude, incident angle and slant range time values); **Bands** (actual image bands).
- 1.5. For a single polarisation product (as in our case) there are actually two bands: **Amplitude** and **Intensity**. (The Intensity band is just a virtual one, created on the fly, and it is not part of the product. It is the square of the amplitude). Double click on the **Amplitude** to view the image.

2. Pre-processing:

- 2.1. Calibration: select on the Menu panel **SAR Tools → Radiometric correction → Calibrate**.
- 2.2. A **Calibrate** window will open. Select the tab: **Processing Parameters**. Select **Intensity_HH** and check **Save in dB**. This will create a new product with calibrated values of the backscatter coefficient in dB.
- 2.3. Next step is filtration. Select **SAR Tools → Speckle Filtering → Single Product Speckle Filter**.
- 2.4. A **Speckle filtering window** will appear. Select the tab: **Processing Parameters**. Select **Sigma0_HH_dB** and select **Lee filter** with window size **7 by 7**. Click **Run** button.
- 2.5. A new product will be created in the **Product View**. Open the band in the newly created product.
- 2.6. Compare the non-filtered and filtered versions.

Processing steps

3. Segmentation:

- 3.1. To separate water from non-water a threshold should be selected. For this, we will analyse the histogram of the filtered backscatter coefficient. On the left side panel select **Colour manipulation** tab. The **histogram** of the backscatter coefficient will show up. The histogram will be in the form of two peaks of different magnitude. Low values of the backscatter will correspond to the water, and high values will correspond to the non-water class. We need to select the value that will separate these two peaks. In our case, the threshold value will be **-17.5 dB**.
- 3.2. To segment the image we will apply band arithmetic. For this, go to **Utilities → Band Math**.
- 3.3. A window will open. Type name, for example, **Water** in the **Name** parameter. Remove checkbox from virtual band (virtual band is in the memory but not physically on the disc). Click **Edit expression...** button. The band math utility allows one to make any sorts of mathematical and logical expressions on the bands available in the product. Our goal is to create a new image which will be, for example 255, for water

objects (for backscatter lower our threshold of **-17.5 dB**), and 0 for higher values. To do this, enter into the **Expression field** the following expression:

255*(Sigma0_HH_dB<-17.5). The expression (**Sigma0_HH_dB<-17.5**) will return the logical value: true (or 1) for values less than **-17.5**, and false (or 0) for higher values. Then we just multiply by 255. Click **OK** button.

- 3.4. A new band named **water** will be added to the product. Double click this band to view the image.

4. Post-processing:

- 4.1. The obtained image is in the geometry of the sensor. We need to reproject it to the geographic projection. To do this, select **Geometry → Terrain Correction → Range-Doppler Terrain Correction**.
- 4.2. A window with parameters will open. Select the **Processing Parameters** tab. In the **Source Bands** select only **water**; **Digital Elevation Model – SRTM3Sec (Auto Download)**, the DEM over the region that SAR image covers will be automatically downloaded; **DEM Resampling Method – BILINEAR_INTERPOLATION**; **Image Resampling Method – NEAREST_NEIGHBOUR**; **Pixel Spacing – 3 m**; **Map projection – UTM/WGS84 (Automatic)**, we select the UTM and the NEST will automatically selects the zones. Click **OK** button.
- 4.3. A new product will be created and appear in the **Product View**. The product will be created in the DIM format and the image will be in img format. Double click the band in the newly created product. Notice that the geometry of the image became in the geographic projection. We can now open this file in the QGIS to visualize and create the map.

5. Map creation:

- 5.1. The product that we created in step 4.3 will have a dim file (e.g. **subset_1_RS2-SGF-U13-DES-14-Feb-2009_20_Calib_Spk_TC.dim**) and a folder containing the image (e.g. **subset_1_RS2-SGF-U13-DES-14-Feb-2009_20_Calib_Spk_TC.data**).
- 5.2. Run QGIS. On the left panel find the button **Add Raster Layer** and click on it. Go to the folder that contains the **water_HH.img** file.
- 5.3. A raster image with our segmented image will be added. Notice that this is a geo-referenced image in the UTM projection, and may be imported to any GIS and remote sensing software.
- 5.4. Then we would like to show water with a blue colour and non-water class to be transparent. For this, double click on the opened layer in the **Layers** window. A **Layer Properties** window will open.
- 5.5. In the **Render Type** select **Singleband pseudocolor**. Set **Color Interpolation** to **Discrete**. Click on the **Green Plus** button to manually add a color interpretation. Set value to 255 and change the color to blue. Click once again and set up the color for the value 0. Click **OK** button.
- 5.6. The water will appear in blue and the non-water will appear in white.

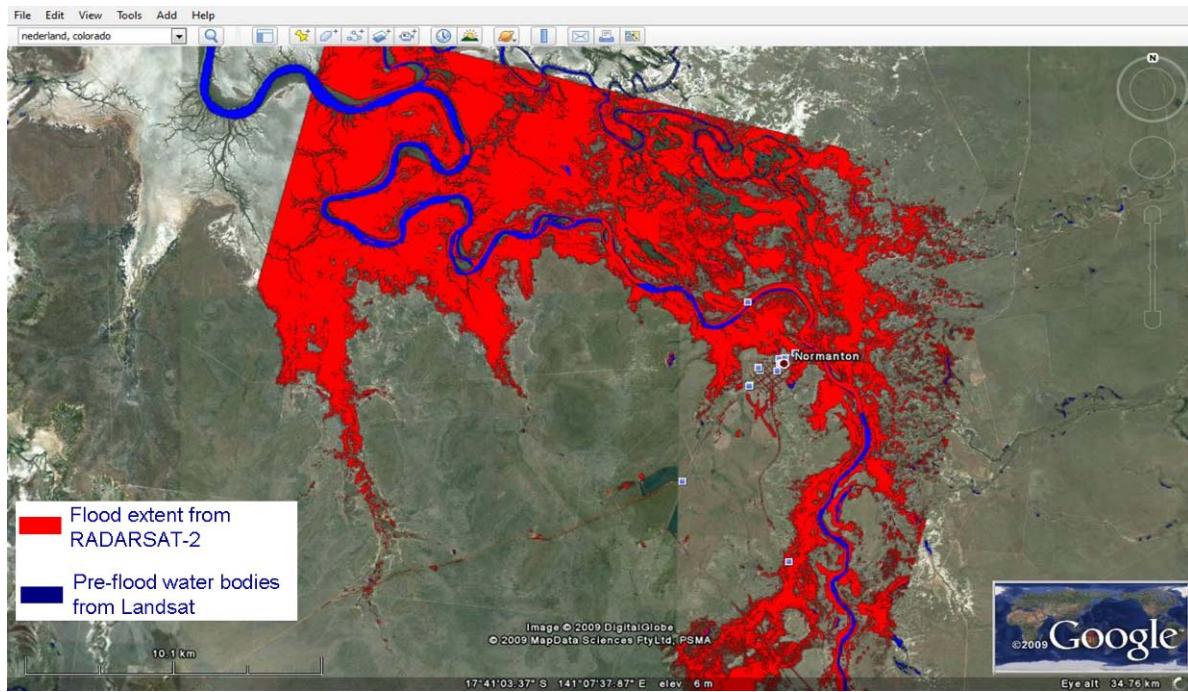
You may want to add any other relevant data to the GIS to make any further analysis. It is possible to convert the obtained map into GeoTiff, KML rasters using NEST, or this raster can be vectorized in the QGIS.

Assessment of the resulting product

The accuracy can be assessed visually and by comparing to archived SAR and optical images.

6. Example of the resulting product (e.g. map)

The example of the resulting map is also given in the accompanied presentation.



7. Real life example (optional)

The example of the resulting map presents the real example of application of SAR imagery to flood mapping. The case was for the 2009 Australia flood in Normanton, Queensland.