Generate Inundation Map using Sentinel-1 GRD with S1TBX

Adapted from the United Nations Platform for Disaster Management and Emergency Response - [UN-SPIDER](#) program

In this document you will find:

A. System Requirements
B. Background
C. Materials List
D. Steps to Generate Inundation Map
E. Sample Image

A) System Requirements

Many of the steps within this data recipe will take some time to process. We recommend the following:

- At least 16GB memory (RAM)
- Close other applications if possible while using S1TBX
- Do not use the computer during processing to avoid crashes

B) Background

The Sentinel-1 system consists of two satellites: Sentinel-1A and Sentinel-1B, each carrying C-band synthetic aperture radar (SAR) sensors. Sentinel-1A was launched on 3, April 2014 and Sentinel-1B on 25, April 2016. They orbit 180° apart, together imaging the entire Earth every six days. In addition, this radar imagery is sensitive to standing water, making it an ideal tool for mapping the extent of floodwater covering an area.

Sentinel-1A passed over Houston, Texas on August 29th, making it possible to create a map that highlights water and flood inundation on the surface. Harvey's extreme slow movement Aug. 26-30 kept an onslaught of moisture in southeast Texas and Louisiana for days, resulting in catastrophic flooding.

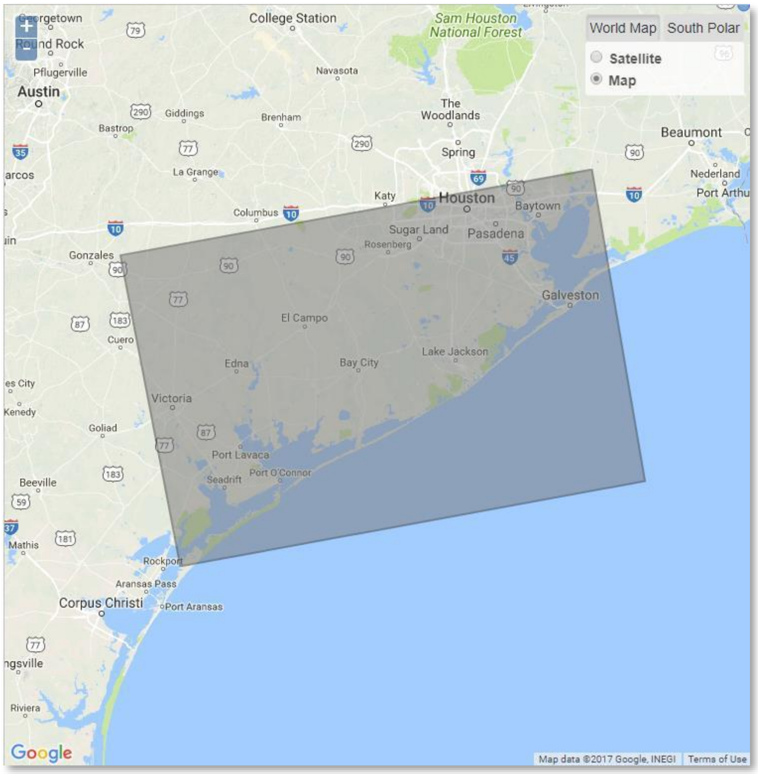

Figure 1: Footprint of Sentinel-1 GRD Product

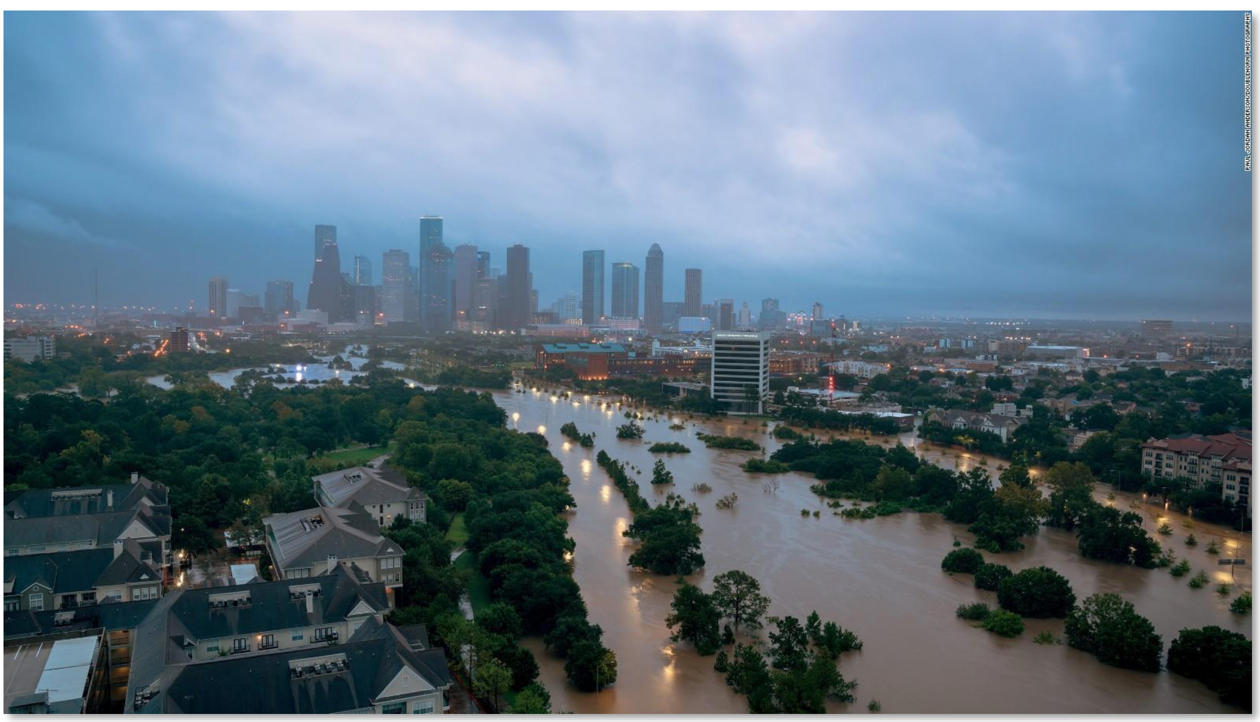

Figure 2: Houston flooding as a result of Hurricane Harvey; Credit: CNN

C) Materials List

- Windows, OS X, Unix
- Sentinel-1 GRD product downloaded from Vertex or use this sample granule:
  - S1A_IW_GRDH_1SDV_20170829T002620_20170829T002645_018131_01E74D_D734
- Sentinel-1 Toolbox (latest version)

D) Steps to Generate Inundation Map

Step 1: Data preparation

A. Download the sample granule from *Section C* or download your own granule using *Vertex* (Do not unzip)

B. Open the Sentinel-1 Toolbox (S1TBX)

C. In S1TBX, use the **Open Product** button to add your Sentinel-1 GRD product

D. Navigate to the Sentinel-1 GRD product, select the *.zip* file, and click **Open**

E. In the *Product Explorer* window on the left, double-click on the Product to expand its information, which includes *Metadata*, *Tie-points grid*, and *Bands*.

F. View a band by expanding the *Bands* folder (Figure 3). For each polarization recorded, there are two bands: *Amplitude* and *Intensity*. (The Intensity band is a virtual one. It is the square of the amplitude). Double-click on either the Amplitude or Intensity to view the image.

G. In the bottom left corner, the *World View* shows the footprint of the selected scene (Figure 4).

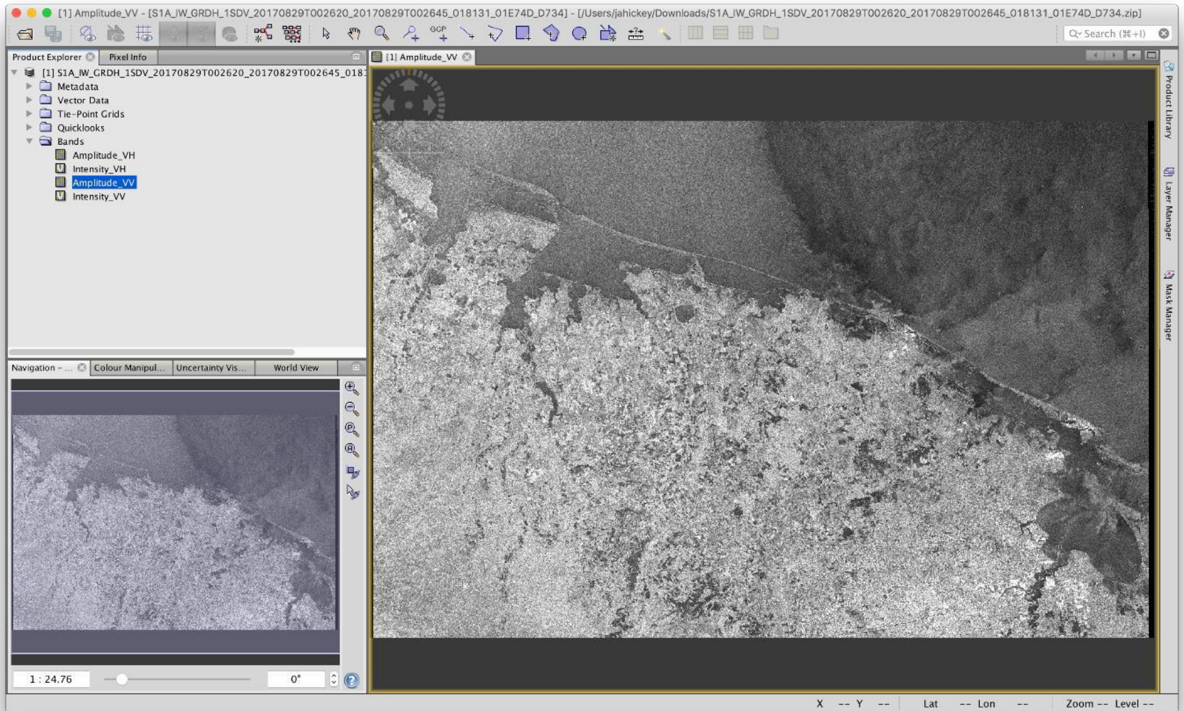

Figure 3: Amplitude band of Sentinel-1 GRD Product

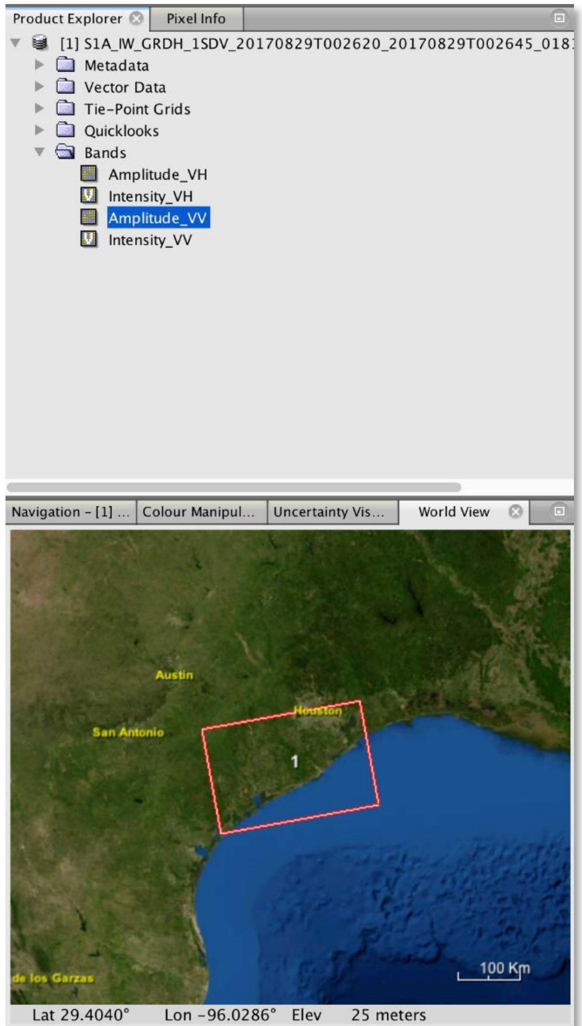

Figure 4: Footprint of GRD product in S1TBX World View

H. View *Product Properties* by right-clicking on the Product, which includes information on mission, acquisition date, pass, etc.

Optional: Create a Subset

A. Open the product phase band and zoom-in on your area of interest using the scroll wheel on your mouse.
B. Right-click on the image when you are satisfied and select **Create Subset from View…** in the pop-up menu
C. When the **Specify Product Subset** dialog appears (Figure 5), double-check your Subset scene and click <**OK**> to create subset
D. The created subset is added as a new product, which is also shown in the *World View* (Figure 6).

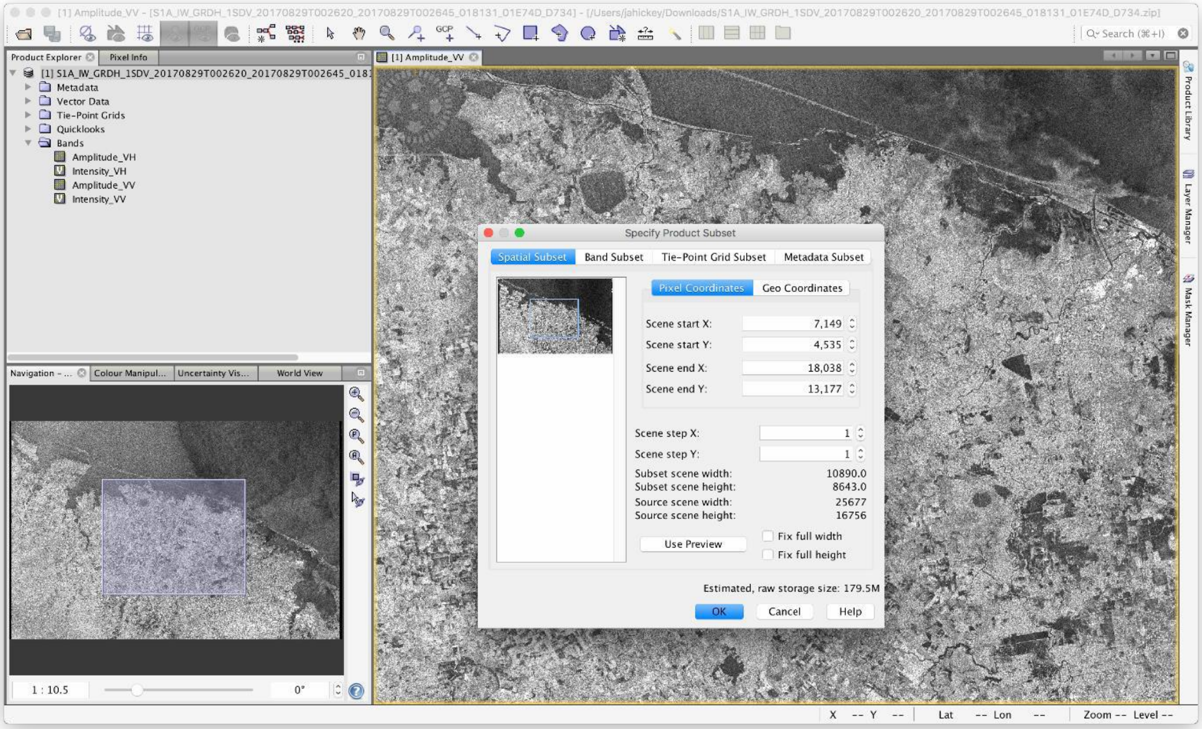

Figure 5: Specify Product Subset dialog

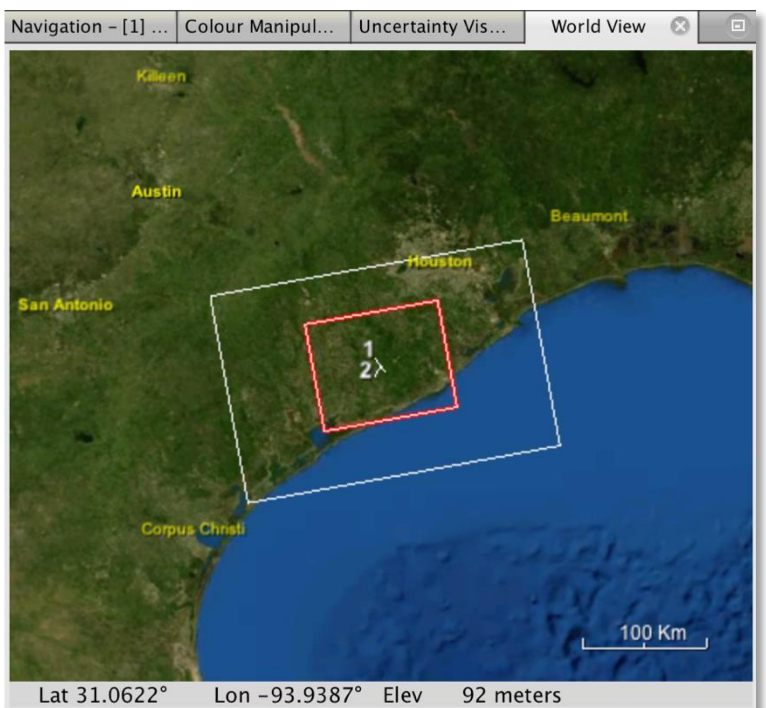

Figure 6: Subset footprint in S1TBX World View

Step 2: Pre-processing – Calibration

1. In S1TBX, select the Sentinel-1 GRD product in the Product Explorer. If you created a subset, select the subset, instead.
2. Navigate to *Radar* > *Radiometric* > *Calibrate* from the Menu panel
3. A Calibration window will open (Figure 7). In the **I/O Parameters** tab, specify Target Product name and output directory. By default, the Target Product name will be appended with "_*Cal*" if you do not create a custom file name.

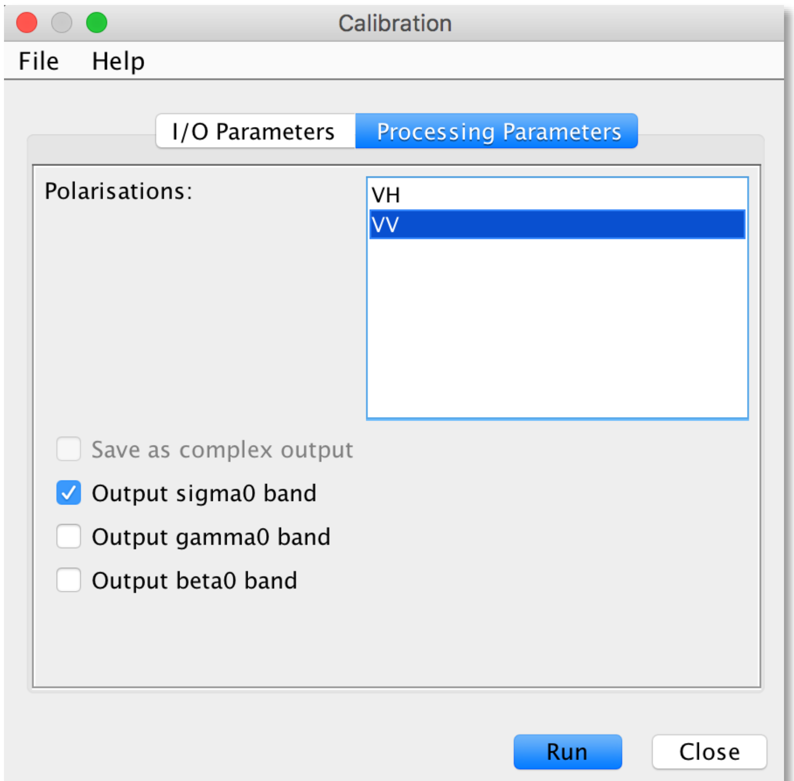

Figure 7: Calibration dialog with VV selected

4. In the **Processing Parameters** tab, select the "**VV**" polarization. This will create a new product with calibrated values of the backscatter coefficient.
5. Leave all other parameters as default and click <**Run**> to calibrate.

Step 3: Pre-processing – Speckle filtering

In this step, we will filter out the speckle noise that exists in SAR imagery due to random interference between returns and the scatterers present on a surface. Speckle noise is a critical pre-processing step for detection/classification optimization. In this example, we will be using a standard "Lee" speckle filter; however, you may experiment with the other speckle filters within S1TBX.

1. In S1TBX, select the calibrated product in the Product Explorer
2. Navigate to *Radar > Speckle Filtering > Single Product Speckle Filter* from the Menu panel
3. The **Single Product Speckle Filter** dialog will appear (Figure 8). Specify Target Product name and output directory. By default, the Target Product name will be appended with "*_Spk*" if you do not create a custom file name.

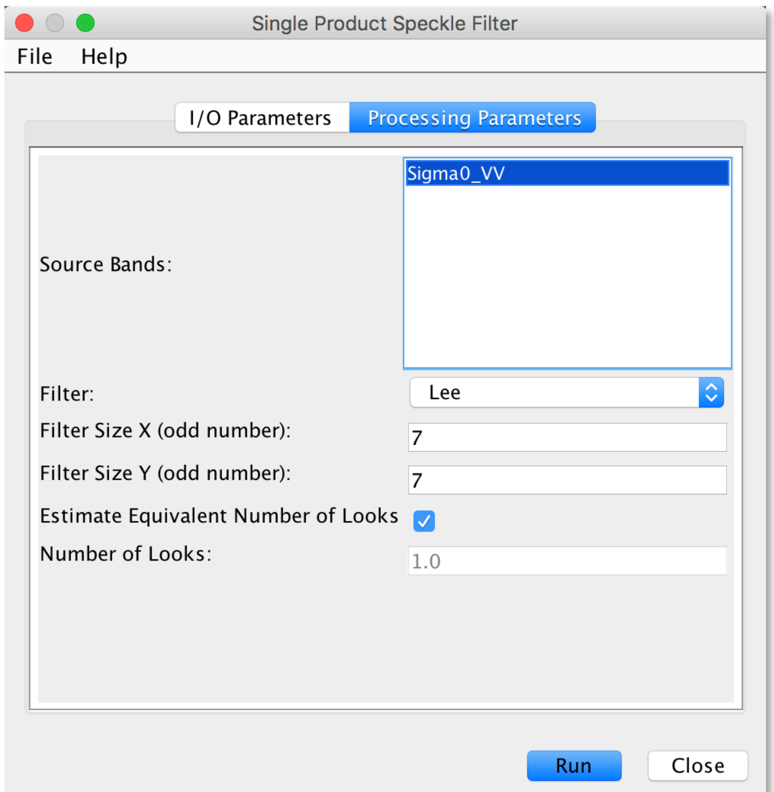

Figure 8: Single Product Speckle Filter dialog with 7x7 filter

4. In the **Processing Parameters** tab, choose "*Lee*" for the filter
5. Change the Filter Size X and Filter Size Y to "*7*"
6. Click <*Run*> to begin image filtration
7. A new product will be created in the Product Explorer. Open the band in the newly created product to compare the non-filtered and filtered version (Figure 9)

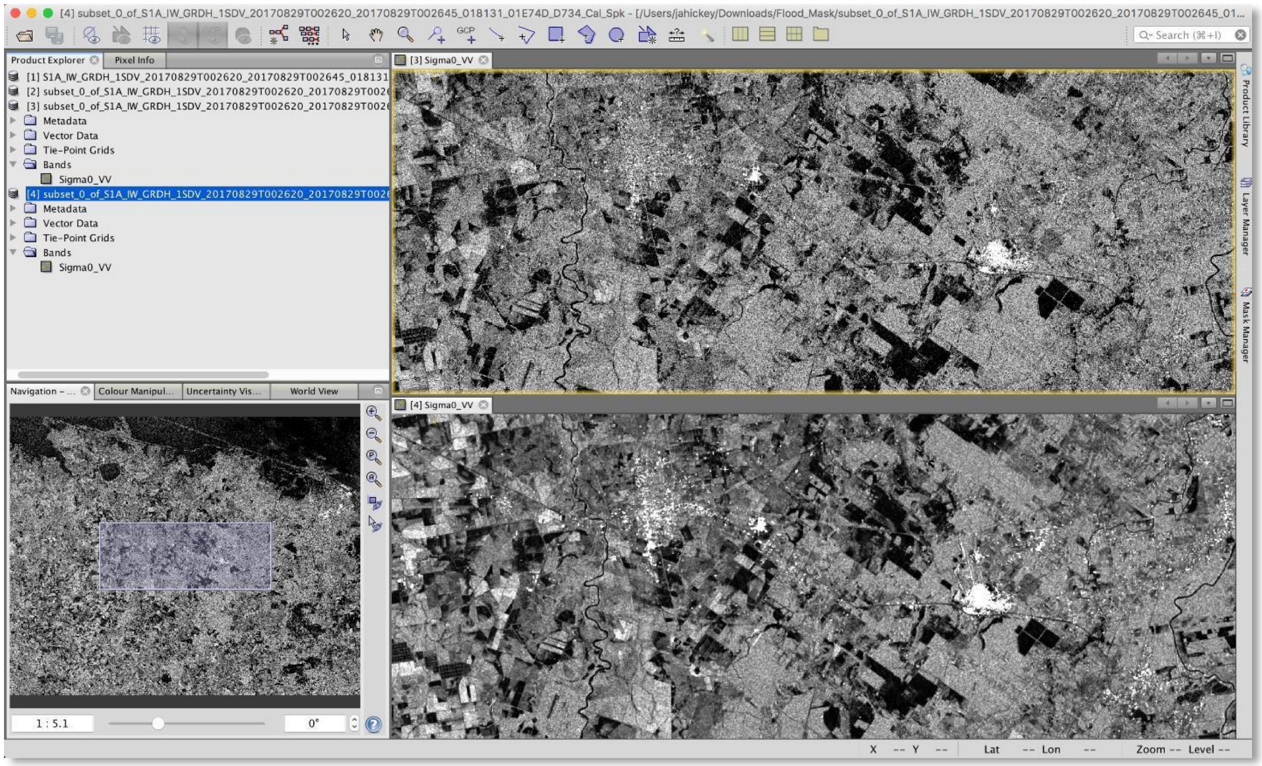

Figure 9: Juxtaposition of speckle and non-speckle filtered images

Step 4: Determine Threshold

To separate water from non-water, a threshold can be applied. For this, we will analyze the histogram of the filtered backscatter coefficient.

1. Select the speckle-filtered product you created in Step 3
2. Open the "*Sigma0_VV*" band in the Product Explorer
3. On the left side panel, select the **Color Manipulation** tab
4. The histogram of the image will show up. Select the *logarithmic display* button (*Log10*).
5. The histogram will show one or more peaks of different magnitude depending on the data (Figure 10). Low values of the backscatter will correspond to water, and high values will correspond to non-water classes.
6. To separate water from the rest of the image, pick a threshold at or near the minimum between the two modes of the distribution, assuming you have a bimodal data distribution (e.g., at 4.2E-2). Drag the sliders within the histogram for reference. Keep a note of this threshold, as you will use it in later steps.

Note: This step assumes that your images have a bimodal distribution of pixel values in the image. If you are using different data, the class values will vary and it may take several iterations to determine the appropriate thresholds. For the process of determining the appropriate thresholds, it is good practice to consider one image representing the maximum flooding and another image representing minimum flooding. Knowledge of the geographical coverage of seasonal flooding helps confirm whether the results are correct.

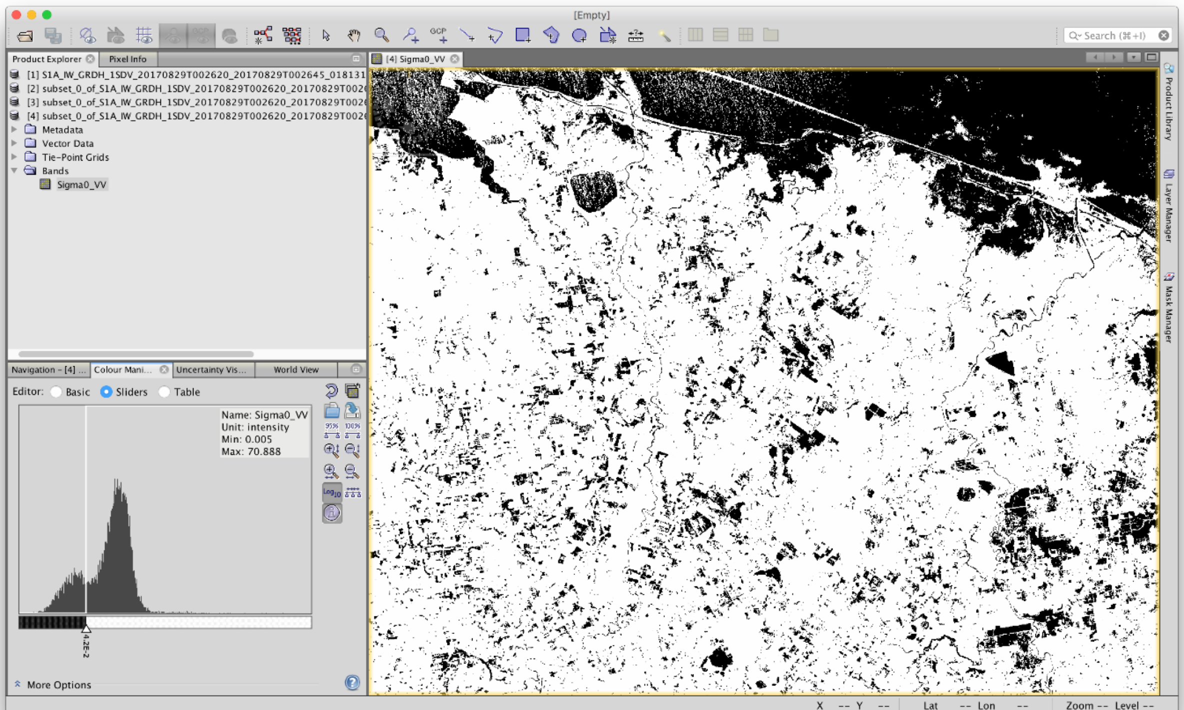

Figure 10: Histogram of GRD product with threshold selected

Step 5: Geometric correction

Before creating the water mask, we will terrain correct the image, which will in turn, reproject the image into latitude and longitude as well as mask out areas with no elevation.

1. Select the speckle-filtered product you created in Step 3
2. Navigate to *Radar* > *Geometric* > *Terrain Correction* > *Range-Doppler Terrain Correction* from the Menu bar
3. In the **I/O Parameters** tab (Figure 11), specify the output name and directory. By default, the name will be appended with "*_TC*" if you do not create a custom file name.

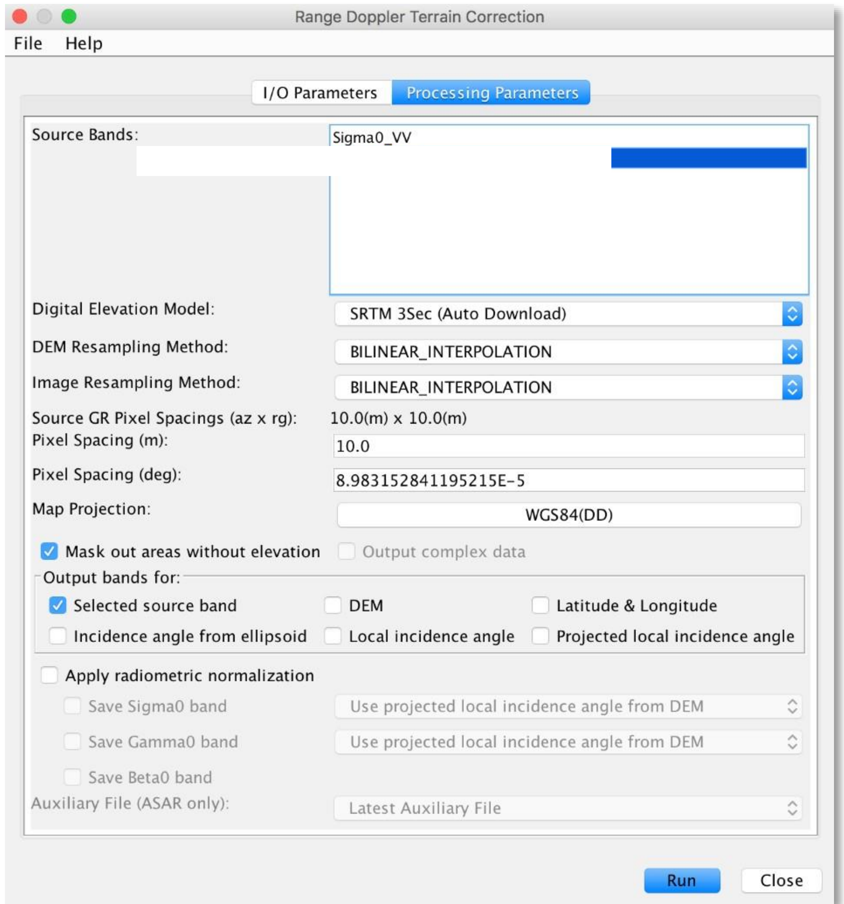

Figure 11: Range-Doppler Terrain Correction dialog

4. In the **Processing Parameters** tab leave the default settings and click <**Run**> to begin correction.
5. A new product will be created and will appear in the Product Explorer

Step 6: Binarization

1. Select the terrain corrected image created in Step 5 and open the band
2. Using the determined binary threshold in Step 4, right-click on the band and select "**Band Maths…"** from the pop-up menu
3. The *Band Maths* window will open. Type a name for the new band, for example, "**Water Mask**".
4. Uncheck the *Virtual Band* option
5. In the Band Maths Expression box, enter the following formula (Figure 12):

if Sigma0_VV<4.22E-2 then 1 else NaN

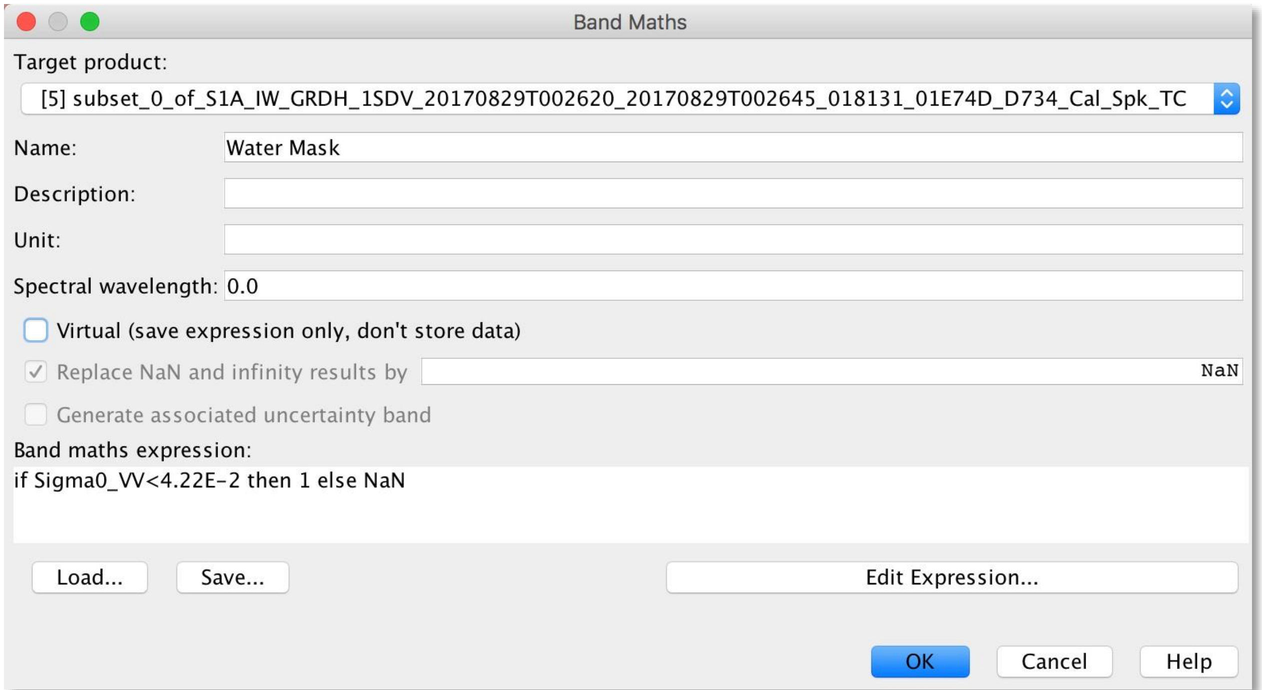

Figure 12: Band Maths dialog with water mask expression

6. Click <**OK**> to create your water mask

Step 7: Visualization in Google Earth

1. Open the band you created in Step 6
2. On the left side panel, select the **Color Manipulation** tab
3. Within the Color Manipulation tab, select "**Table**" (Figure 13)

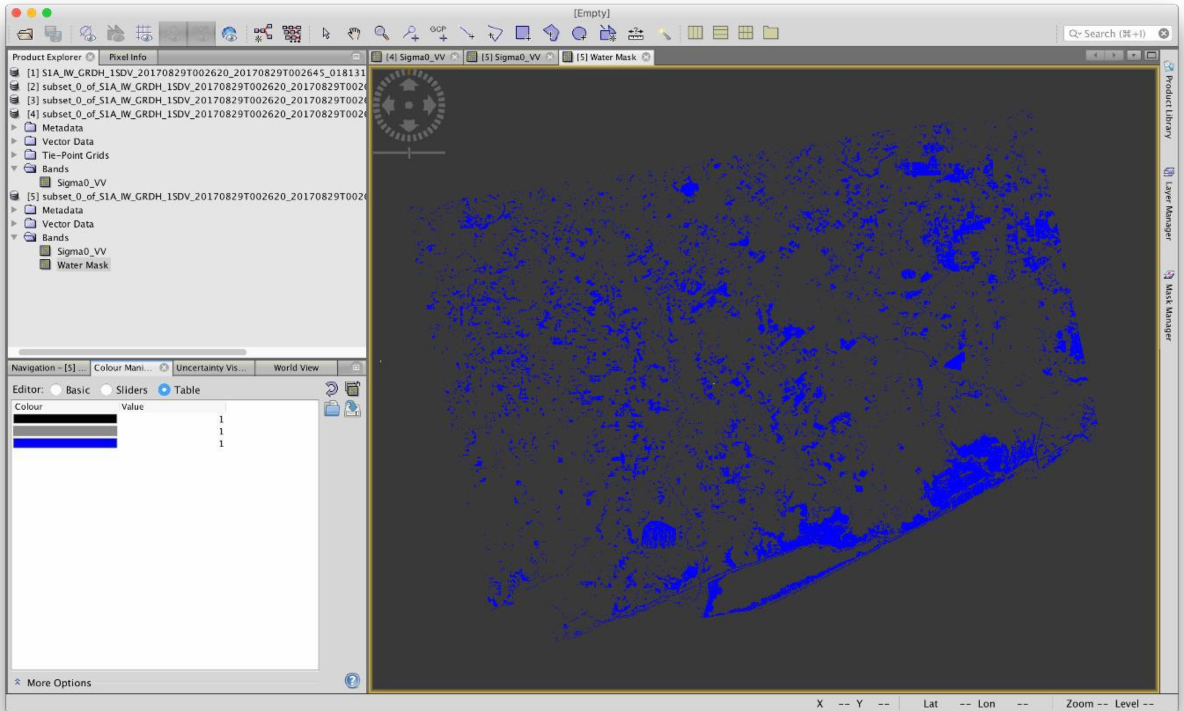

Figure 13: Water mask with Color Manipulation: Table adjusted to blue

4. Click on the third Color box and change to a color of your choice (e.g., blue)
5. In the Product View, right-click on the image and select “**Export View as Google Earth KMZ**”
6. In the **Export** dialog, specify a name and directory to output your KMZ file
7. Once saved, open your new image in Google Earth for visualization (Figure 14)

D)Sample Image

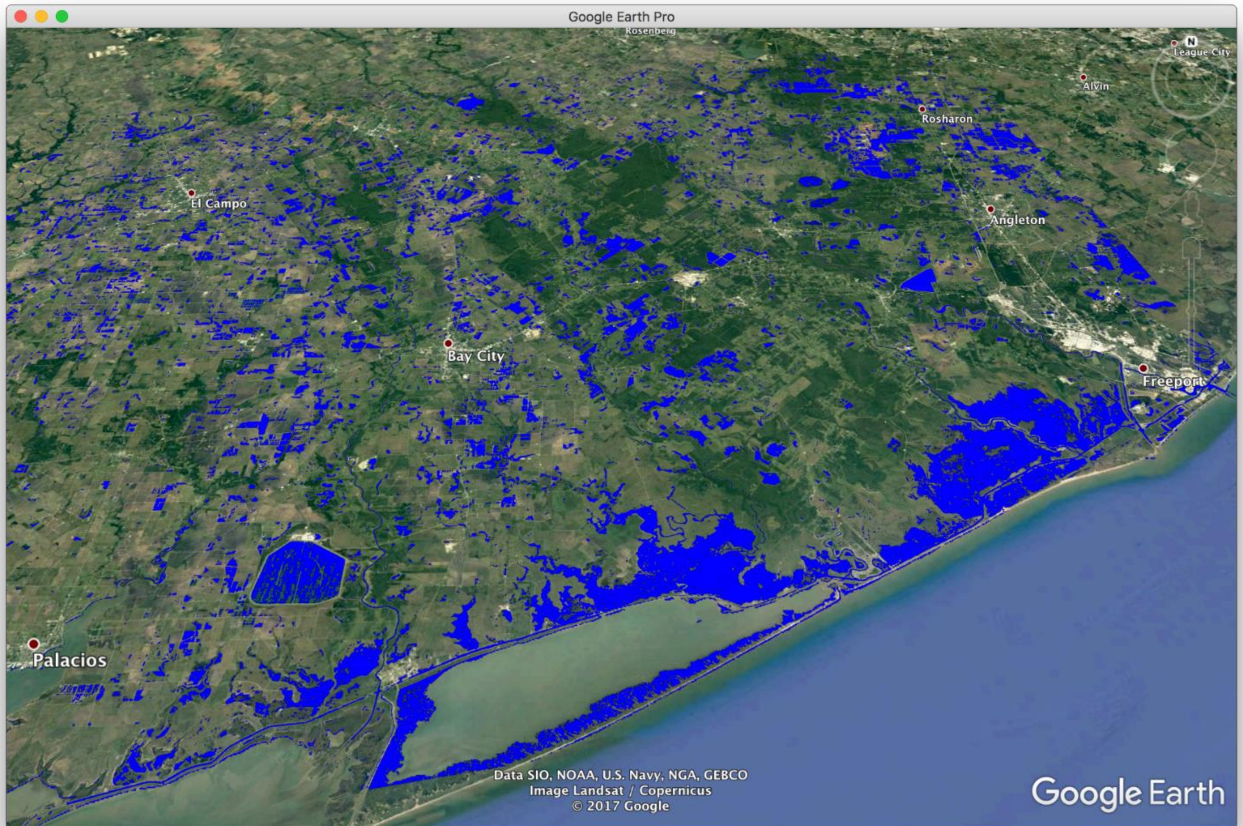

Figure 14: Water mask of the Houston area overlain in Google Earth; Contains modified Copernicus Sentinel data 2017; processed by ESA