Mapping Regional Inundation with Spaceborne L-band SAR

Using open-source software such as QGIS and GIMP

Adapted from Bruce Chapman[1], Rick Guritz[2], and Eric Anderson[3]

[1]*Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109 USA*
[2]*Alaska Satellite Facility, University of Alaska, Fairbanks, AK 99775 USA*
[3] *Earth System Science Center, University of Alabama in Huntsville, Huntsville, AL 35805 USA*

This two-part data recipe is for users who wish to map regional inundation with spaceborne L-band synthetic aperture radar (SAR). Users will create:

a) Inundation animation
b) Colorized inundation map

In this document you will find

A) Background

The all-weather ability of synthetic aperture radar (SAR) to penetrate cloud cover and low-light conditions to acquire imagery of the Earth's surface is well known. Given the availability of high-resolution terrain models at 30 meters from the Shuttle Radar Topography Mission (SRTM) and an interest to make SAR data easier to use, the Alaska Satellite Facility (ASF) offers radiometric terrain corrected (RTC) L-band image products from ALOS PALSAR data.

At longer wavelengths such as L-band, SAR can penetrate surface vegetation including the Amazon rain forest, and flooding events can be mapped very accurately at high resolution. With the availability of RTC data, it is now relatively easy to do accurate flood mapping using PALSAR data. In this recipe, we describe methods used to (a) create an inundation image animation from 18 PALSAR RTC products and (b) produce an inundation map that quantifies the number of flooding events from the given set of data.

B) Materials List for Generating Animation

- Windows, Mac OS X
- ALOS-1 Palsar RTC products
    - For this tutorial you may use the sample granule list below, or download your own RTC products using Vertex
    - For help using Vertex, refer to the Vertex Getting Started User Guide
- QGIS (version 2.18.12 used in this recipe) with Orfeo Toolbox (Windows users see Section I)
- GIMP (version 2.8 used in this recipe)

C) Sample Granule List

Click on the product names to download each granule individually

Granule Name	Product Name
ALPSRP048877090	AP_04887_FBS_F7090_RT1.zip
ALPSRP075717090	AP_07571_FBD_F7090_RT1.zip
ALPSRP082427090	AP_08242_FBD_F7090_RT1.zip
ALPSRP102557090	AP_10255_FBS_F7090_RT1.zip
ALPSRP115977090	AP_11597_FBS_F7090_RT1.zip
ALPSRP122687090	AP_12268_FBD_F7090_RT1.zip
ALPSRP129397090	AP_12939_FBD_F7090_RT1.zip
ALPSRP136107090	AP_13610_FBD_F7090_RT1.zip
ALPSRP156237090	AP_15623_FBS_F7090_RT1.zip
ALPSRP183077090	AP_18307_FBD_F7090_RT1.zip
ALPSRP189787090	AP_18978_FBD_F7090_RT1.zip
ALPSRP209917090	AP_20991_FBS_F7090_RT1.zip
ALPSRP223337090	AP_22333_FBS_F7090_RT1.zip
ALPSRP230047090	AP_23004_FBD_F7090_RT1.zip
ALPSRP236757090	AP_23675_FBD_F7090_RT1.zip
ALPSRP243467090	AP_24346_FBD_F7090_RT1.zip
ALPSRP263597090	AP_26359_FBS_F7090_RT1.zip
ALPSRP270307090	AP_27030_FBS_F7090_RT1.zip

D) Part 1: Steps for Generating Inundation Animation

Step 1: Download and Organize the Data

1. Download the granules from Section C
2. Extract data from the downloaded .zip files and copy the HH image from each granule into a new folder (e.g., HH)

Step 2: Convert Images to Decibels in QGIS

1. Create a new directory to place your output images (e.g., db_HH)
2. Open QGIS and use the Open Raster  button to load the HH images from the folder you created in Step 1
3. Ensure that your HH images are open in the *Layers Panel* (there should be 18 of them)
4. Ensure that your *Processing Toolbox* is open and ready *(Processing menu>Toolbox)*
5. Within the *Processing Toolbox* search for “raster calculator”

6. Right-click on Raster calculator (GDAL) and execute as batch process (Figure 1)

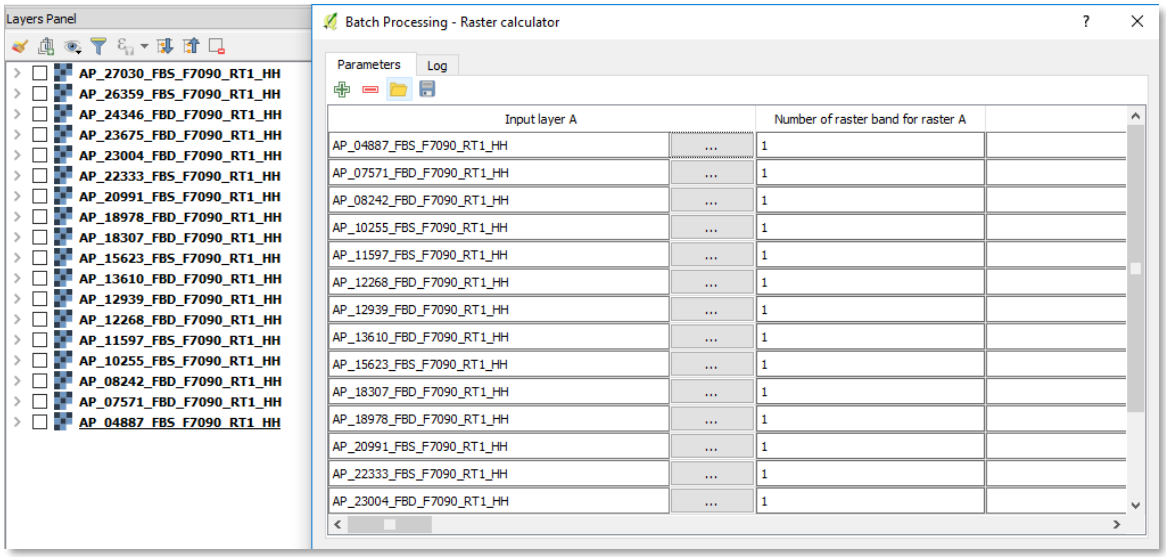

Figure 1: GDAL Raster Calculator with batch processing

7. In the *Parameters* tab, click on "**…**" next to the first box within "*Input Layer A*"
8. Select from open layers and click "*Select All*"
9. Click *OK* to add all image layers to *Input Layer A*
10. Drag the navigation bar over until you see "*Calculation in gdalnumeric syntax…"*
11. In the first box, enter "*10*log10(A)"*
12. *Double-click* on the title above where you just entered your formula
13. To the right of the "*Calculation" header, find "Output raster type"*
14. Under *Output raster type*, change the selection from *Byte* to *Float32*
15. *Double-click* on "Output raster type " to apply to all
16. To the right of *Output raster type*, find "*Calculated*"
17. Click on "**…**" next to the first box within "Calculated"
18. Navigate to the directory/folder you created and enter "db_" and click Save
19. When prompted select "Fill with parameter values" and click OK
20. To the right of "Calculated" find "Load in QGIS"
21. Change the first "Yes" to "No" and double-click on "Load in QGIS"
22. Click Run to begin batch processing
23. Close Batch Processing dialog window once complete
24. Close all images in QGIS using the Layers Panel close button

Step 3: Apply Despeckling to dB Converted Images

1. Create a new directory to place your output images (e.g., sf_db_HH)
2. In QGIS, use the Open Raster button to load the decibel-converted images you created in Step 2
3. Within the *Processing Toolbox,* search for "Despeckle"
4. Right-click on Despeckle (lee) (Orfeo) and execute as batch process (Figure 2)

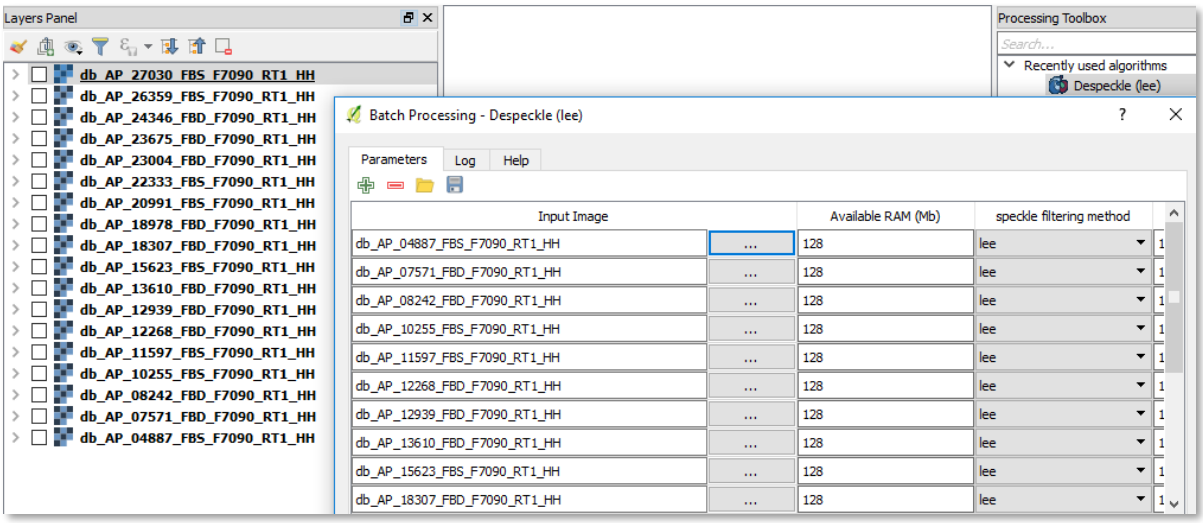

Figure 2: Despeckle (lee) tool with batch processing

5. Under "Input Image", click the "**…**" and select from open Layers
6. Click "Select All" and click OK to add all images
7. Scroll right until you find "Output Image" and select "**…**"
8. Navigate to the directory/folder you created and enter "sf_" and click Save
9. When prompted select "Fill with parameter values" and click OK
10. To the right of "Fill with parameters values" find "Load in QGIS"
11. Select "No" and double-click on "Load in QGIS" to apply to all
12. Click Run to begin batch processing
13. Close Batch Processing dialog window once complete
14. Close all images in QGIS using the Layers Panel close button

Step 4: Exclude Erroneous Pixels at the Edge of Your Images

The Despeckle tool leaves a strip of extra pixels with very negative values to the edge of the images, which must be removed before the following analysis. When you open the despeckle images you will find that the images are not correctly rendering due to these negative values.

1. Create a new directory to place your output images (e.g., xsf_db_HH)
2. In QGIS, use the Open Raster button to load the images created in Step 3
3. Within the *Processing Toolbox* search for “raster calculator”
4. Right-click on Raster calculator (GDAL) and execute as batch process
5. In the Parameters tab click on “…” next to the first box within “Input Layer A”
6. Select from open layers and click “Select All”
7. Click OK to add all image layers to Input Layer A
8. Drag the window bar over until you see “Calculation in gdalnumeric syntax…”
9. In the first box (Figure 3), enter “(A>-9999)*A”

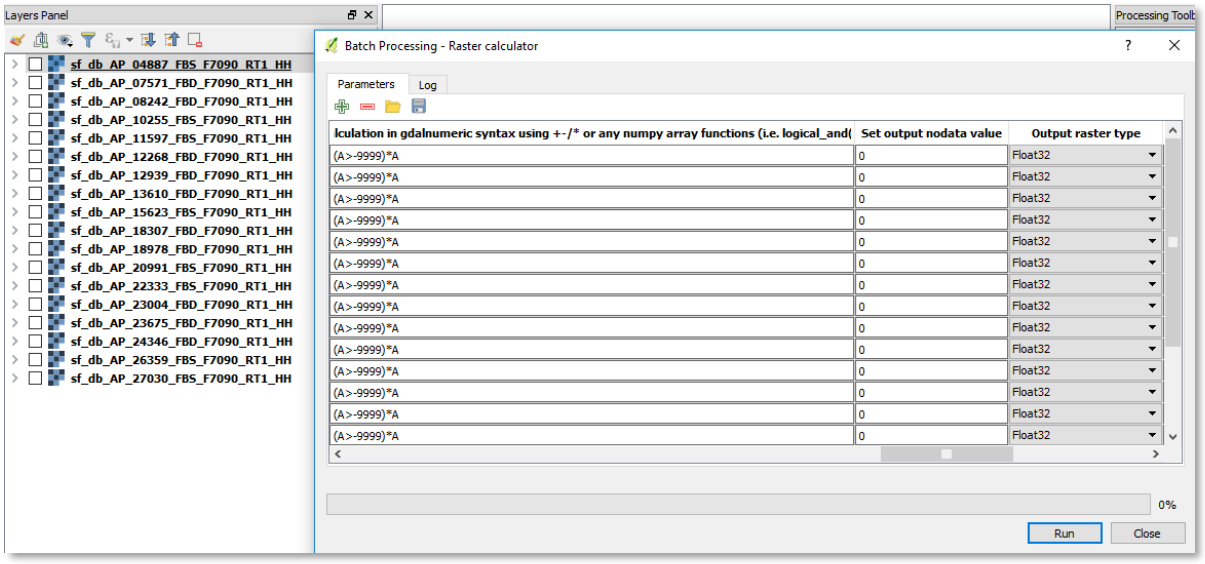

Figure 3: Raster Calculator with batch processing showing correct formula

10. Double click on ““Calculation in gdalnumeric syntax…” to apply to all
11. To the right of “Calculation”, find “Set output nodata value”
12. Enter “0” in the first box and double-click on “Set output nodata value”
13. To the right of the “Calculation”, find “Output raster type”
14. Under “Output raster type”, change the selection from Byte to Float32
15. Double-click on “Output raster type” to apply to all
16. To the right of “Output raster type”, find “Calculated”
17. Click on “…” next to the first box within “Calculated”
18. Navigate to the directory/folder you created and enter “x” and click Save
19. When prompted select “Fill with parameter values” and click OK
20. To the right of “Calculated” find “Load in QGIS”
21. Change the first “Yes” to “No” and double-click on “Load in QGIS”
22. Click Run to begin batch processing
23. Close Batch Processing dialog window once complete
24. Close all images in QGIS using the Layers Panel close button

Step 5: Classify the Images using a Threshold

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.

1. In QGIS, use the Open Raster button to load the images created in Step 4
2. Right-click on the first image in the Layers Panel and choose “Properties”
3. In the Style menu change the Render type to “Singleband pseudocolor”
4. Click on the Histogram tab from the Layer Properties window you have open
5. View the histogram to interpret the distribute of pixel values in the image

   Note: You should see a clearly bi-modal histogram (Figure 4) with water pixels appearing significantly darker than the main image data
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 (e,g., -13)

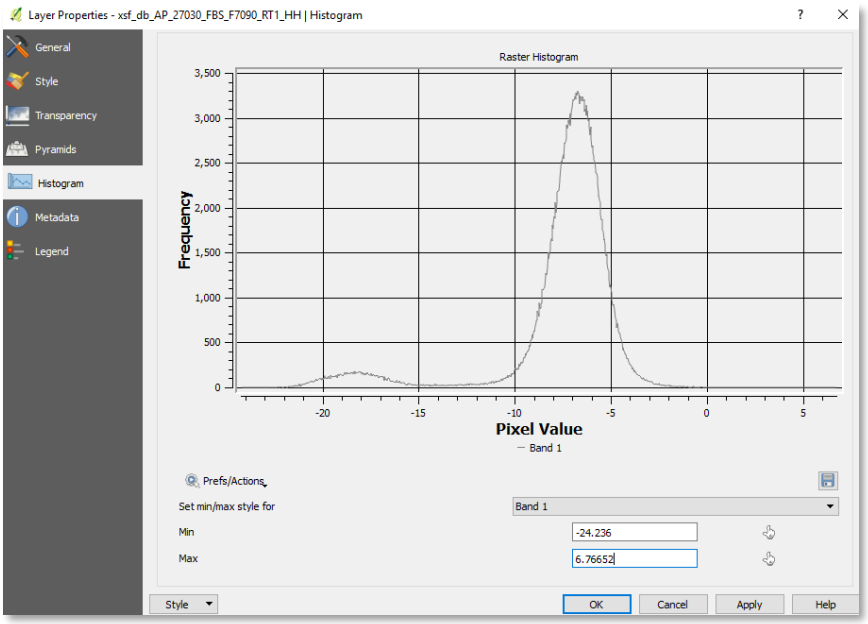

Figure 4: Histogram showing bimodal distribution of pixel values

7. Return to the Style tab of the Layer Properties window and change the Interpolation to “Discrete” (Figure 5)
8. Next to “Classify” click on three times to add your class value

9. Change the value of the classes to the following: “-13”;”-2”;”inf”
10. Double-click on the Color to change the class colors
11. Set “-13” to blue to represent the main channels of water. Refine the breakpoint values until water is mostly contained within river channels and a very small number of blue dots show on land outside river channels.
12. Set “-2” to black to represent land
13. Set “inf” to yellow to represent brighter areas because of double-bounce, which indicates flooded vegetation. To increase the prominence of double-bounce, you must adjust “-2” to a lower value, which adjusts the breakpoint of your second threshold value.

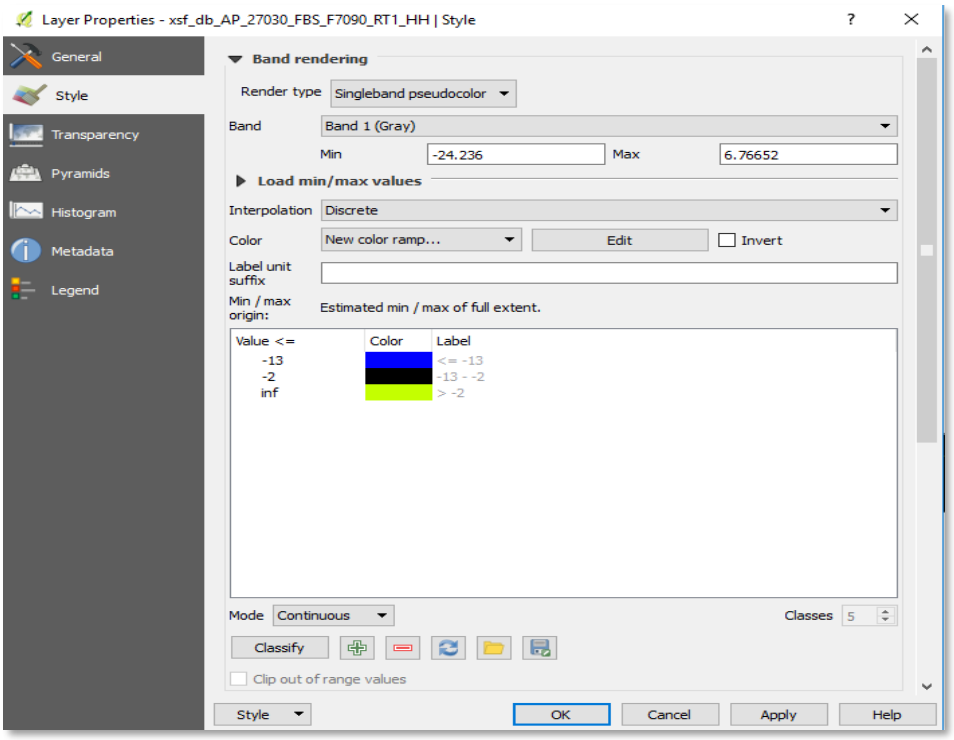

Figure 5: Classification of the image with determined thresholds

14. Adjust the following values until you are satisfied. The class values will be determined by the pixel values in the image.
15. Optional: You may adjust Resampling in the Style menu to smooth rendered pixels
16. Apply the same Style properties to all images by right-clicking on the image with the desired classification and select “Styles>Copy Style”
17. Click the button in the Layers Panel to collapse all layers and select all other layers (using Shift)

18. Right-click on any of the selected images and click on “Paste Style”

Step 6: Export Classified Images as PNG Image Files

1. Create a new directory to save your exported images (e.g., Flood_PNG)
2. In QGIS, ensure that all of your images are still open in the *Layers Panel*
3. After applying the correct thresholds and colors to all images, turn off visibility of all layers except the first one (xsf_db_AP_27030_FBS_F7090_RT1_HH) by clicking on the checkbox next to the raster layer’s name
4. Use  in the Map Navigation toolbar to center your image to prepare for PNG exporting (Figure 6)

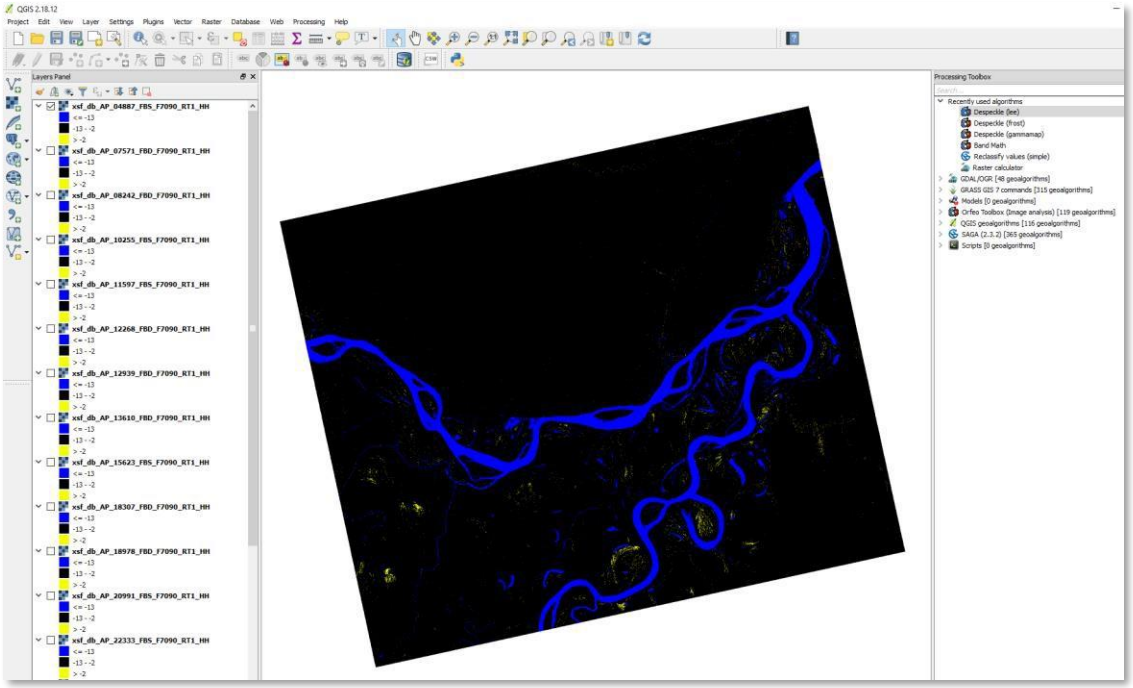

Figure 6: All of the images with the same symbology

5. Navigate to *Project* > *Save as Image…*

   Tip: *These steps can be cumbersome if you manually type in each file name. To speed up the process, right-click on each image and select “Rename”. Once highlighted you can copy the name of the file before saving your image and simply paste the file name in box, then add a “.png” file extension*

6. Save the as “xsf_db_AP_27030_FBS_F7090_RT1_HH.png” and click OK
7. Turn off the first image and select the next image
8. Repeat Steps 1-5 for all images until you have 18 PNG image files
9.

Step 7: Generate and Display Animated GIF with GIMP

1. Select or create a directory to save your animated GIF file
2. Open GIMP 2 and select “File > Open as Layers…”
3. Navigate to the directory where your image files are located and select all
4. Once all images are loaded, select “File > Export As…”
5. Select the directory you chose to save your animation and save the animation as “Flood_Animation.gif” and an Export GIF dialog window will appear (Figure 7)

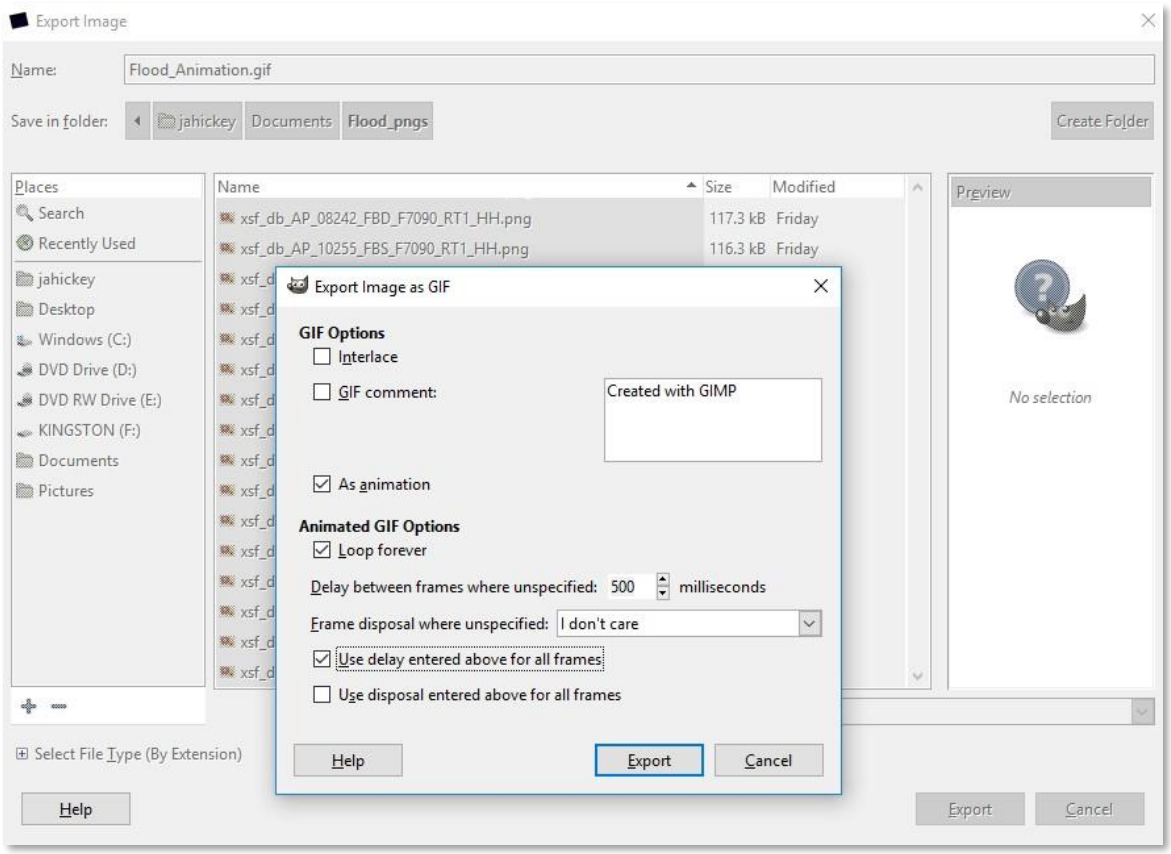

Figure 7: GIMP Export Image as GIF dialog

6. Check the “As animation” box and set “Delay between frames” to “500”
7. Check “Use delay entered above for all frames” and click “Export”
8. Navigate to the “Flood_Animation.gif” file and open the animation in a browser by using right-click “Open as ”

E) Sample Inundation Animation

Click on the following link to see the resulting gif:

https://media.asf.alaska.edu/uploads/Data%20Recipes/palsar_inundation_bigger.gif

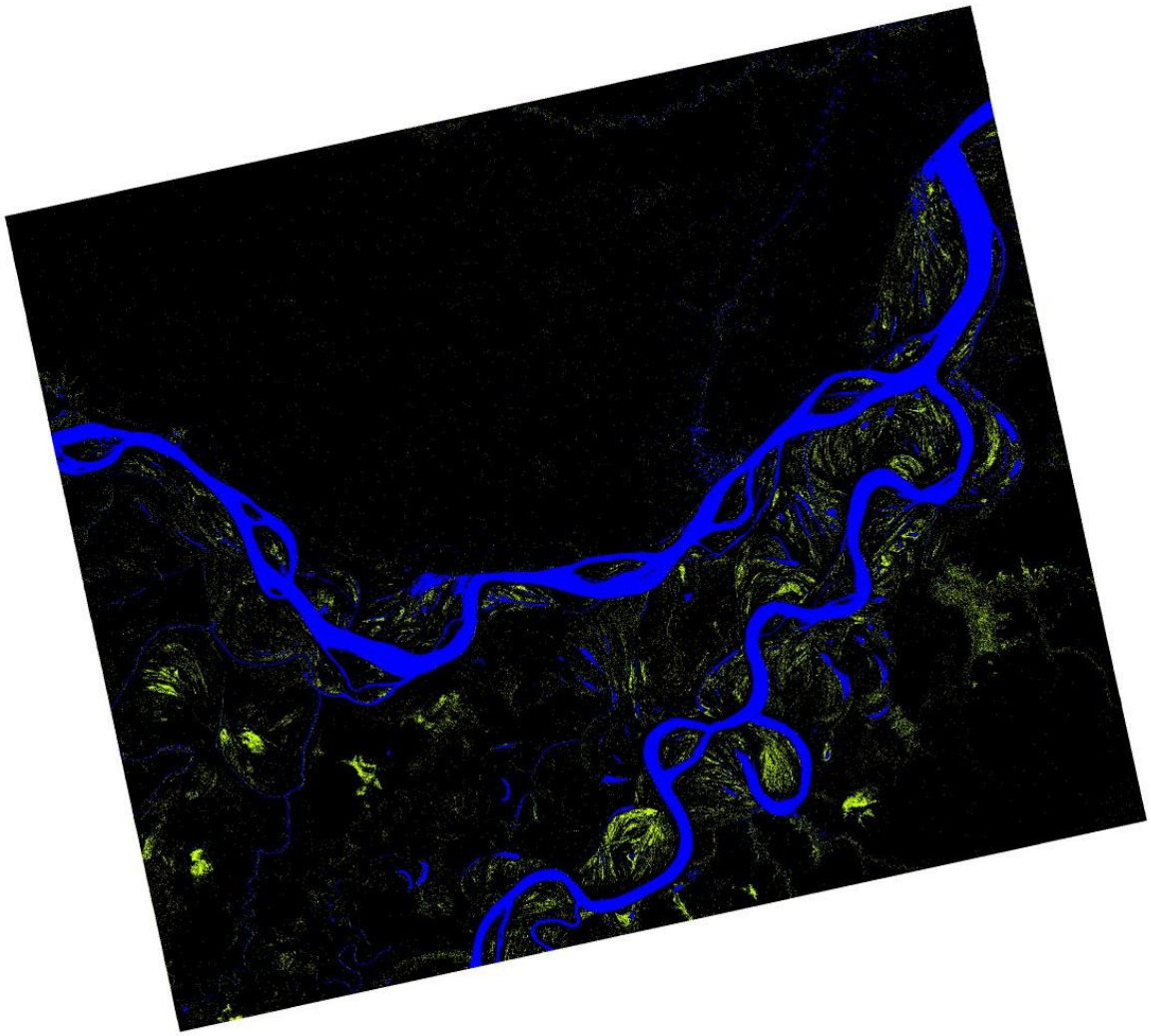

Figure 8: Frame from animation of inundation in Amazon rain forest. Credit: Chapman, Guritz 2016; RTC: ASF 2015; Includes Material © JAXA/METI 2007.

F) Materials List for Generating Colorized Map

- Filtered PALSAR images that were previously generated in Step 4 of Part 1
- QGIS 2.18.12

G) Part 2: Steps for Generating Colorized Inundation Map

Step 1: Classify the Images Using a Threshold In QGIS

Classify each image to separate water (1) from land (0).

1. Create a new directory to save your output files (e.g., Reclass_HH)
2. In QGIS, use the Open Raster button to load the images created in Step 4 (e.g., xsf_db_AP_10255_FBS_F7090_RT1_HH)
3. Within the *Processing Toolbox* search for "reclassify"
4. Right-click on Reclassify values (simple) (SAGA) and run as batch process (Figure 9)

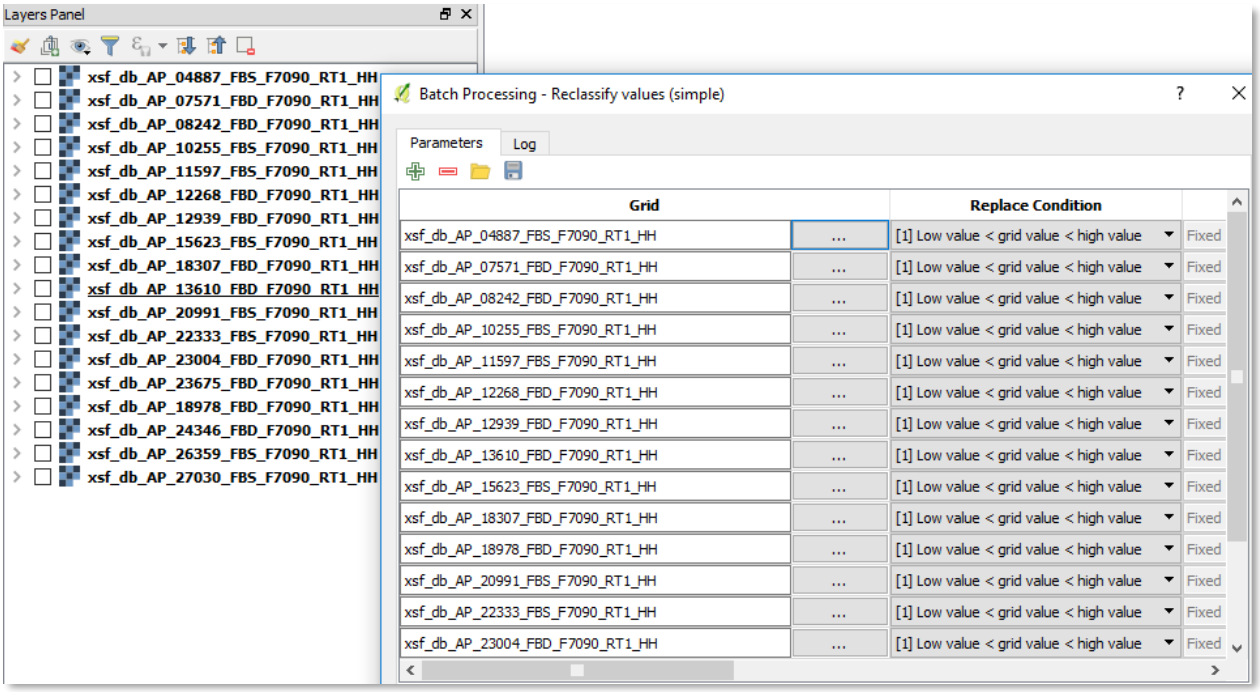

Figure 9: Reclassify values (simple) with batch processing

5. Click on "…" next to the first box within "Grid"
6. Select from open layers and click "Select All"
7. Click OK to add all image layers to Grid
8. To the right of "Grid" find "Replace Condition"
9. Change the condition to "(1) Low value < grid value < high value"
10. Double-click on "Replace Condition" to apply to all

11. To the right of “Replace Condition” find “Lookup Table”
12. Click on “…” to the right of the first box within Lookup Table
13. In the Fixed table window assign the following values seen in Figure 10 below

	Low Value	High Value	Replace with
1	-30	-11	1
2	-11	-4	0
3	-4	15	1

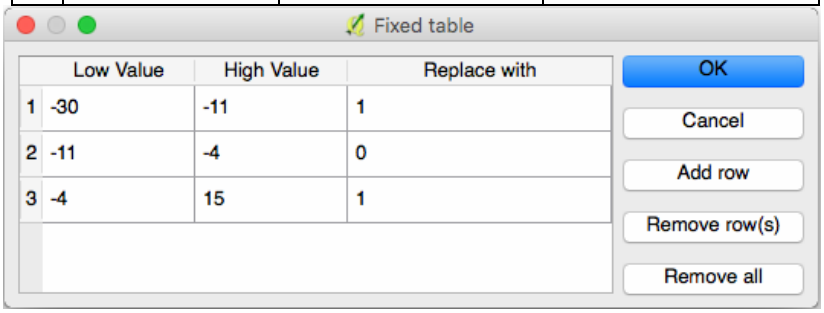

Figure 10: Table to reclassify the values

15. Repeat for all images (batch process won’t allow to apply to all)
16. To the right of “Lookup Table” find “Changed Grid”
17. Click on “…” next to the first box within “Changed Grid”
18. Navigate to the directory you created and enter “r_” and click Save
19. When prompted, fill with parameter values and click OK
20. To the right of “Changed Grid” find “Load in QGIS”
21. Change the first option to “No” and double-click “Load in QGIS” to apply to all
25. Click Run to begin batch processing
26. Close Batch Processing dialog window once complete
22. Close all images in QGIS using the Layers Panel close button

Step 2: Create the Final Product

1. Choose a directory to save your colorized inundation map
2. In QGIS, use the Open Raster button to load your reclassified images created in Step 1 of Part 2
3. Open the Raster Calculator by navigating to *Raster > Raster Calculator*
4. Double-click on the first image and click on the “+” operator (Figure 11)
5. Continue adding each image and symbol until all images are in the equation

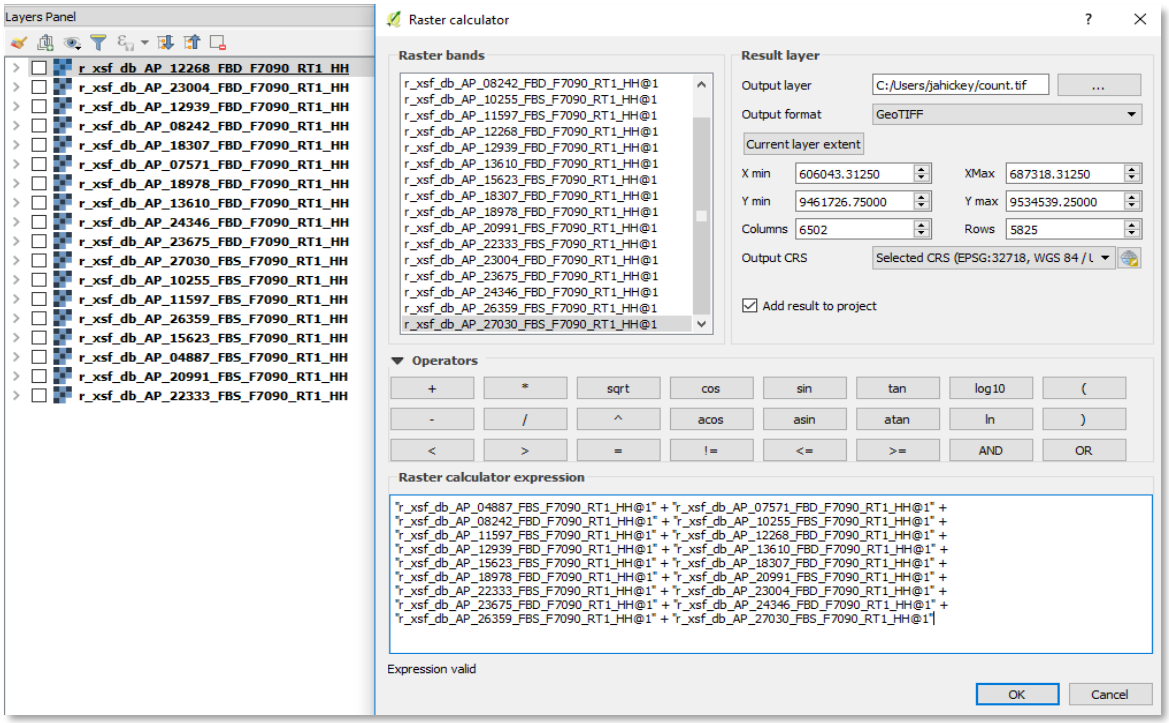

Figure 11: Raster Calculator with correct setup

6. Set the Output Layer to a name and directory of your choosing (e.g., count.tif)
7. Click OK to run the Raster Calculator

   Note: the combined image will display as range of gray values. To change this, you may classify the pixel values of the image for analysis. It is good to assign values 0 and 1 to black because these values are usually a result of speckling that remained after filtering. It helps to choose colors that are distinguishable and have logic in terms of the combined image (higher values indicate more frequent flooding).

8. Right-click on the image and click on Properties
9. In the Style tab change render type to “singleband pseudocolor”
10. Under Color options, select a color ramp from the list or choose random colors
11. Change classification method to “Equal Interval”
12. Change the number of classes to “19”
13. Optional: adjust resampling type to smooth the rendered image
14. When you are satisfied click Okay to see the results (Figure 12)

H) Sample Colorized Inundation Maps

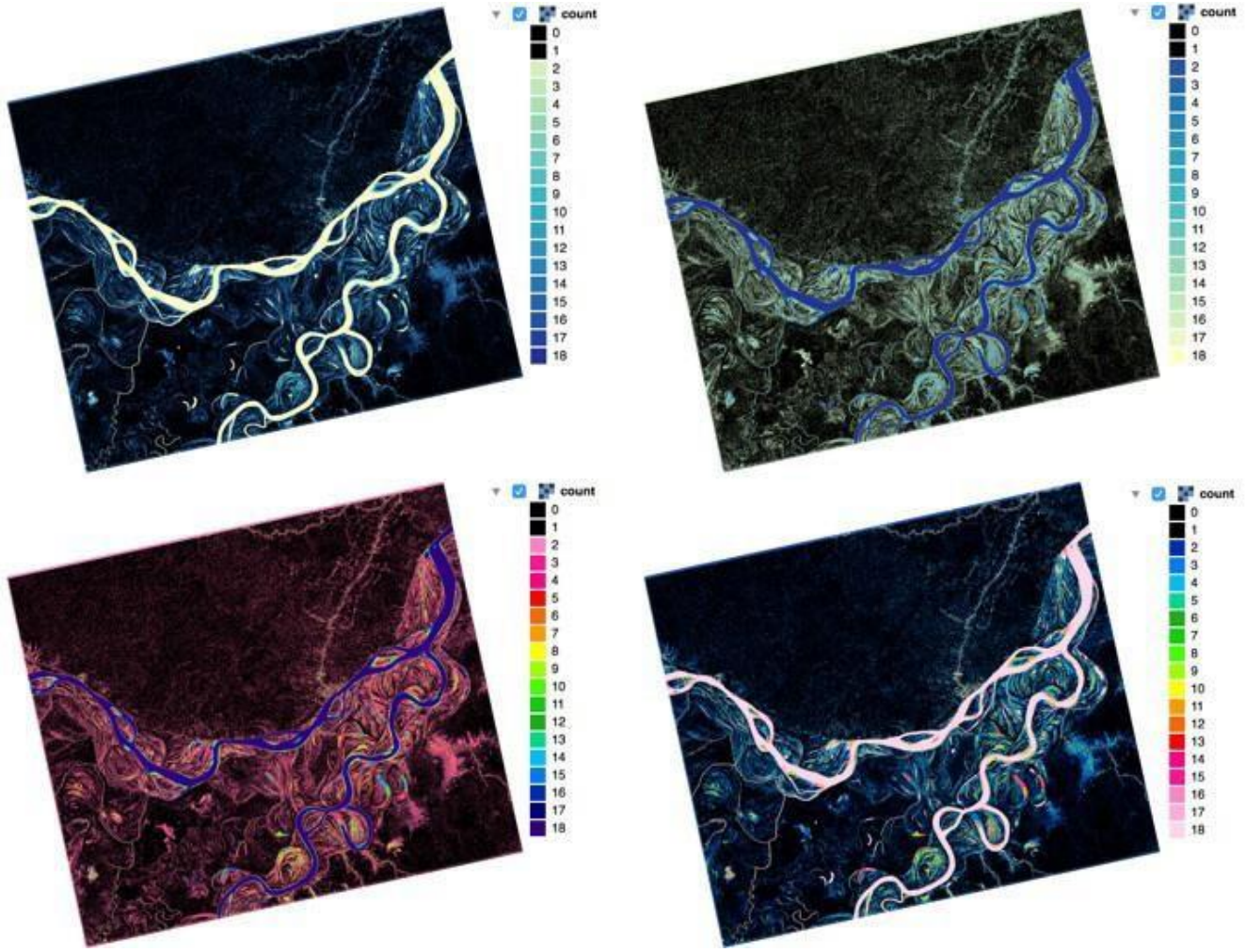

Figure 12: Map of inundation in Amazon rain forest. The color key provides the color for the number of times an area was flooded, and 18 represents constant river. Numbers less than 18 are the number of times an area floods. Credit: Anderson 2017; RTC: ASF 2015; Includes Material © JAXA/METI 2007

I) How to Access Orfeo Toolbox (Windows)

To use the despeckle tool you must have access to the Orfeo Toolbox, which is not included with the Windows standalone version of QGIS 2.18.12. To add the toolbox to you must download the toolbox using the OSGeo4W installer.

Note: For these steps to work properly, you must have QGIS pre-installed.

1. Navigate to QGIS.org
2. Select “Download Now”
3. Under Advanced Users download OSGeo4W (64 bit)
4. Open OSGeo4W setup (Fig. 13)
5. From the dialog window select Advanced Install and click Next >
6. Select Install from Internet and click Next >
7. Select Root Install Directory (e.g., C:\OSGeo4W) and click Next >
8. Select Local Package Directory (default works fine) and click Next >
9. Select Direct Connection and click Next >
10. Click on ‘http://download.osgeo.org’ to select and click Next >
11. In Select Packages menu type in “otb” in the search box
12. Click on “Libs” to expand
13. Under “Libs” click on each “Skip” once and click Next >
14. Leave all defaults and Click Next >
15. Click on the checkbox and click Next >
16. Your download will begin
17. Click finish once installation completes
18. Open QGIS 2.18.12
19. Select ‘Processing’ from the main menu bar
20. Click on ‘Options…’

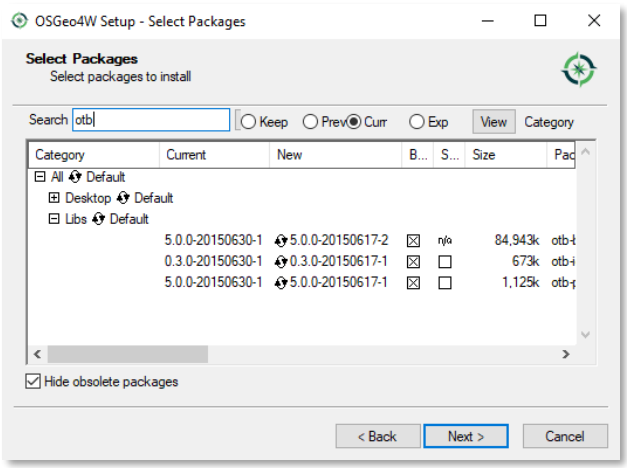

Figure 13: OSGeo4W Setup

21. Click on ‘Providers’ to expand (Figure 14)

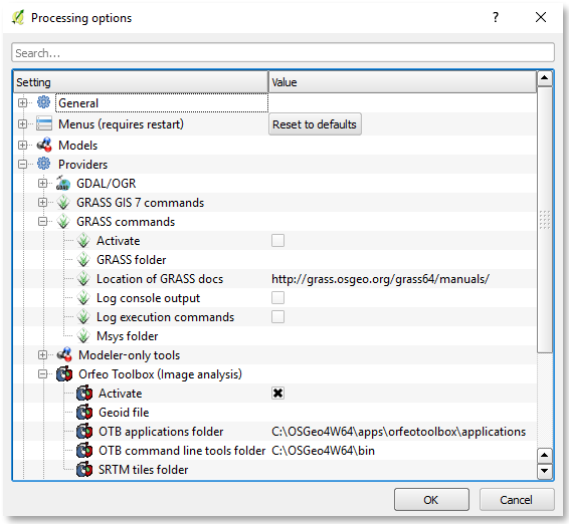

Figure 14: Processing Options: Providers

22. Click on ‘GRASS commands’ to expand
23. Double-click in blank space to the right of “Msys folder”
24. Delete the existing path for “Msys folder”
25. Click on ‘Orfeo Toolbox’ to expand
26. Ensure ‘Activate’ is checked
27. Double-click in blank space to the right of “OTB applications folder”
28. Enter the path of your OTB applications folder in the box (e.g., “C:\OSGeo4W\apps\orfeotoolbox\applications”)
29. Double-click in blank space to the right of “OTB command line tools folder”
30. Enter the path of the OSGeo4W64 bin folder in the box (e.g.,“C:\OSGeo4W64\bin”)
31. Exit QGIS and restart the application
32. In the Toolbox menu on the right the Orfeo Toolbox will now appear
33. Click here to return to Section B