

Morphology Change Procedure using Satellite Derived Bathymetry

Brian Madore

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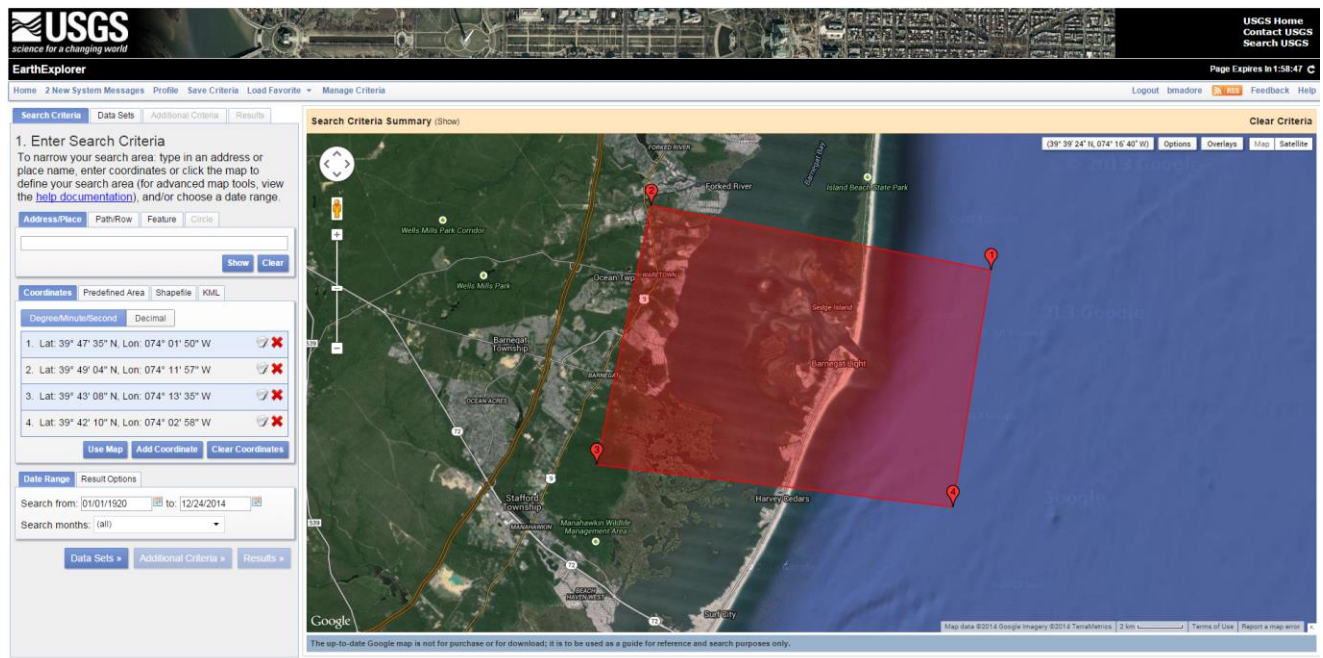
To monitor the morphology of a region it is important to have imagery which is taken consistently and can cover large areas. Due to these factors, satellite imagery has been used to create a process to monitor changes in the shallow water bathymetry of coastal areas. Producing morphological maps prior to a storm event provides a background on the area, showing how the region changes seasonally or annually. After a storm event the morphology products can be used to distinguish changes and to monitor the changes into the future.

Based on the research for using satellite imagery to monitor morphological changes, Landsat 8 gives large area of coverage and consistent acquisition of imagery. Other satellite imagery can be used for this procedure, however this procedure will focus primarily on Landsat 8. Proceed to part B if other satellite imagery is being used, however make sure to know which bands are the blue, green, and IR bands if not using Landsat 8 imagery.

A. Obtaining Landsat 8 Imagery

A.1. Landsat 8 imagery can be downloaded from <http://earthexplorer.usgs.gov/>. A login is required, however registration is free and easy to obtain.

A.2. Once logged in zoom to the place of interest on the map. Create a polygon around the area of interest by clicking on the map to create the vertices of the polygon.



A.3. If there are any date constraints that need to be used input those under the Search Criteria tab.

A.4. Select **Data Sets**.

A.5. Open the **Landsat Archive** section and select **L8 OLI/TIRS**.

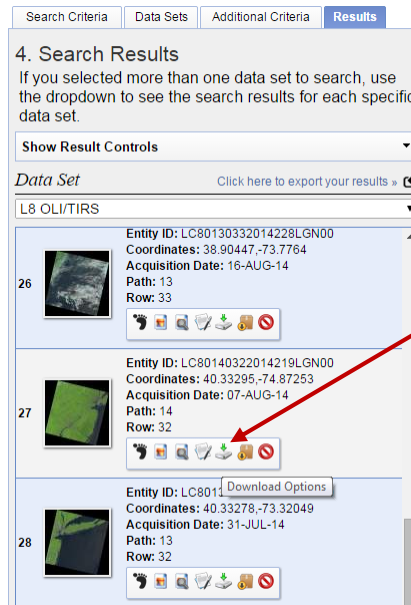
The screenshot shows the 'Data Sets' tab of a web application. At the top, there are four tabs: 'Search Criteria', 'Data Sets' (selected), 'Additional Criteria', and 'Results'. Below the tabs, the heading '2. Select Your Data Set(s)' is followed by instructions: 'Check the boxes for the data set(s) you want to search. When done selecting data set(s), click the *Additional Criteria* or *Results* buttons below. Click the plus sign next to the category name to show a list of data sets.'

Below the instructions is a checkbox labeled 'Use Data Set Prefilter' with a link '(What's This?)'. Underneath is a 'Data Set Search:' text input field.

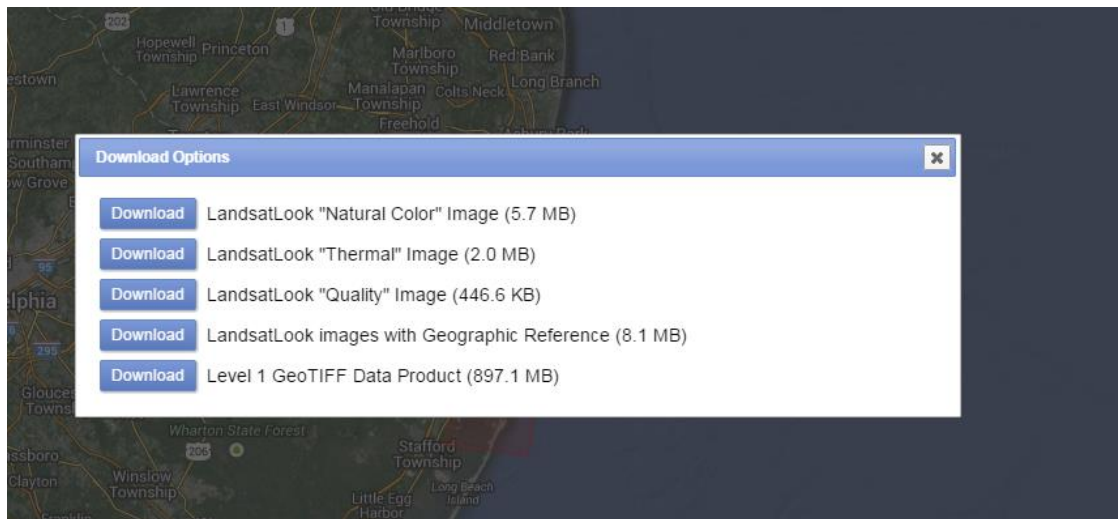
The main area is a scrollable list of data categories, each with a plus icon to its left. The categories are: Aerial Imagery, AVHRR, Cal/Val Reference Sites, Commercial, Declassified Data, Digital Elevation (with a small orange icon), Digital Line Graphs, Digital Maps (with a small orange icon), EO-1, GEOGLAM, Global Fiducials, Global Forest Observations Initiative, Global Land Survey, HCMM, JECAM Sites, LIDAR, Land Cover, and Landsat Archive (with a small orange icon). The 'Landsat Archive' category is expanded, showing a list of data sets with checkboxes and information icons:

- ☒ L8 OLI/TIRS
- ☐ L8 OLI/TIRS Pre-WRS-2
- ☐ L7 ETM+ SLC-off (2003-present)
- ☐ L7 ETM+ SLC-on (1999-2003)
- ☐ L7 ETM+ Intl Ground Stations (Search Only)

A.6. Open the **Results** tab and search for the image desired for download. Select **Download Options** on the desired image.



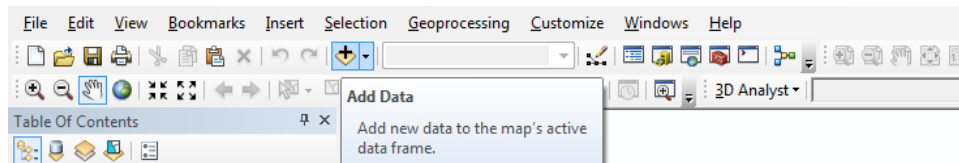
A.7. Select **Level 1 GeoTIFF Data Product** for download.



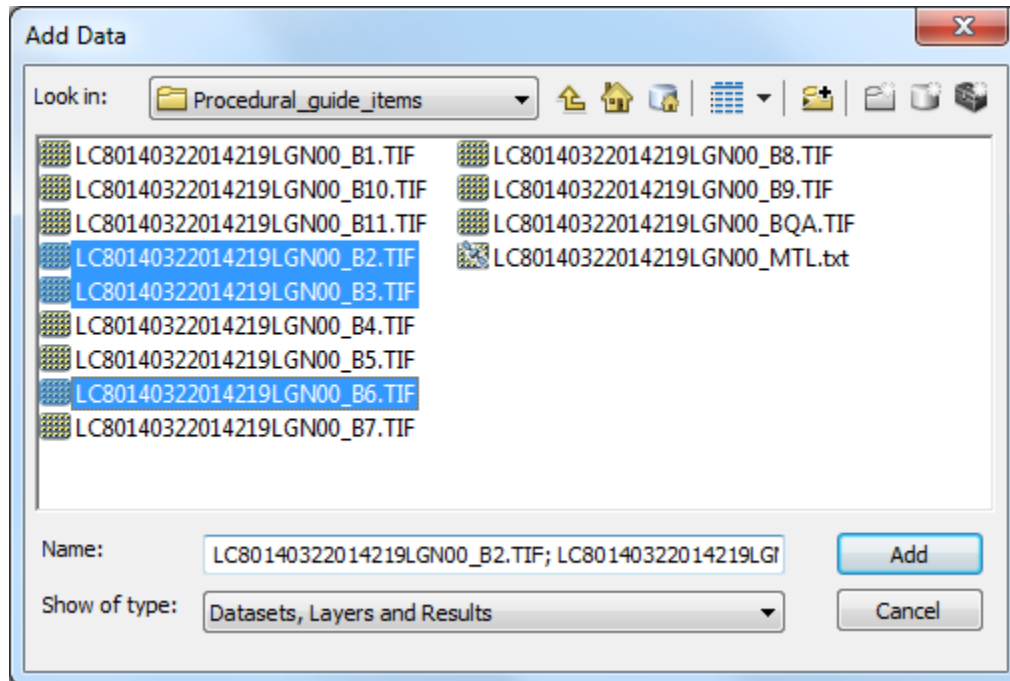
A.8. Once downloaded unzip the file and save the data to a desired folder. It is recommended that the folder the unzip files are saved in be created with the date of the satellite imagery's acquisition date.

B. Creating Satellite Derived Bathymetry

B.1. In ArcMap select **Add Data**.

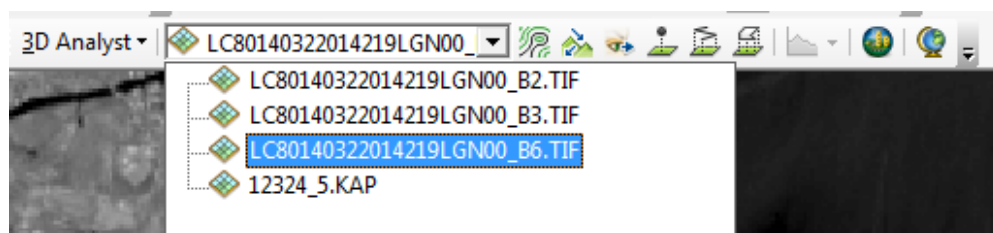


B.2. Add bands 2, 3, and 6 to the data frame. If it asks to create pyramids, select yes.



B.3. Using band 6, which is the IR band, the threshold between the land and water surfaces will need to be distinguished. Because water absorbs IR radiation this difference in the IR values for land and water surfaces will be used to mask out all of the land features. There are a couple of ways of determining the threshold.

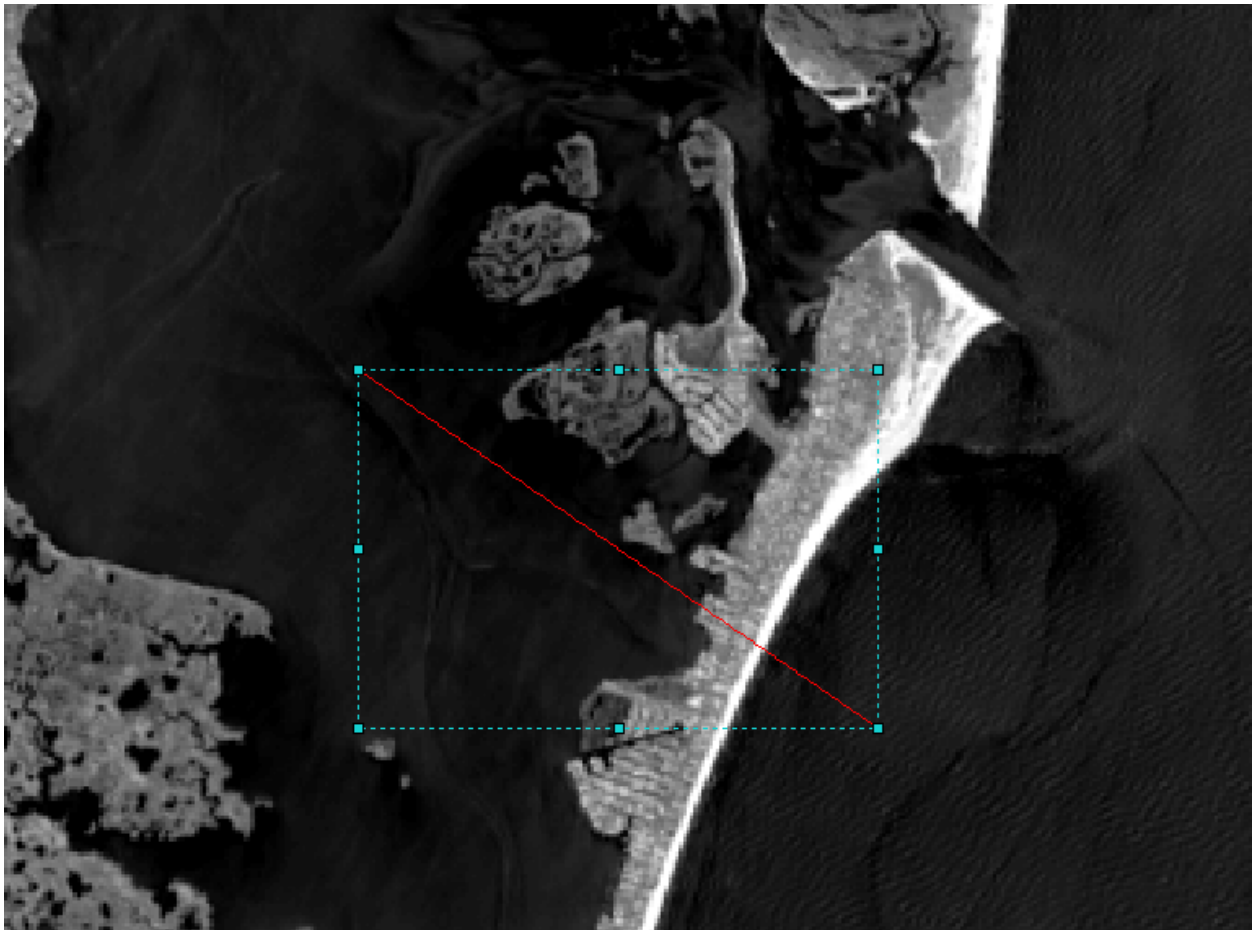
B.4. If possible, using the 3D analyst tool is the easiest way to determine the value between the land/water threshold. Go to **Customize>Toolbars** and select the 3D Analyst toolbar. In the toolbar there is a dropdown box which can be used to select different layers. Select the band 6 layer.



B.5. Select **Interpolate Line** on the toolbar.



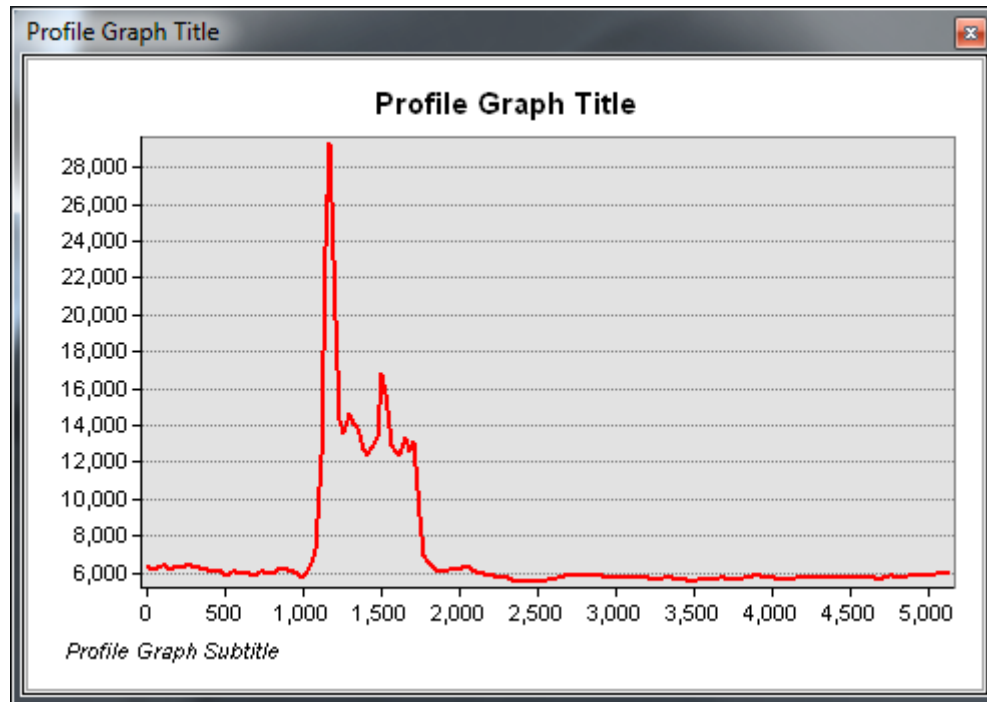
B.6. Draw a line that goes over both land and water.



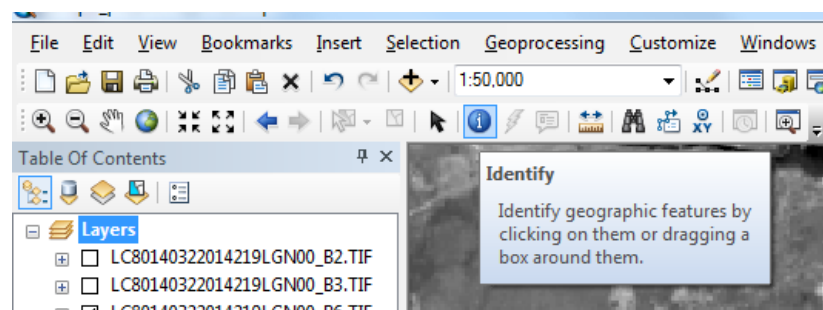
B.7. Select **Profile Graph** on the 3D Analyst toolbar.



B.8. The profile graph will show the values of the IR band over the red line extent. The land IR values will be higher values and the water values will be a consistent lower value. The graph below shows the IR values for this example. All of the water values are below the value of 7000, and the land values are all much higher. Therefore the value of 7000 will be the threshold for this specific image. **Important:** each satellite image, even if collected from the same satellite, will have a different threshold value.



B.9. If the 3D Analyst toolbar cannot be used, the other way to determine the threshold difference is to use the identify tool on the band 6 layer.



B.10. Select multiple points in the water, on land, and near the water/land boundary to determine what the typical values for the IR band are. A threshold value then should be

selected where all values below the threshold value are water and all values above the threshold are land values.

B.11. In the **ArcToolbox** select **Spatial Analyst Tools>Conditional>Set Null**.

B.12. For the **input conditional raster** select the Landsat 8 band 6 (IR band). For the

Expression use “**Value**” > (threshold value) **OR** “**Value**” = 0

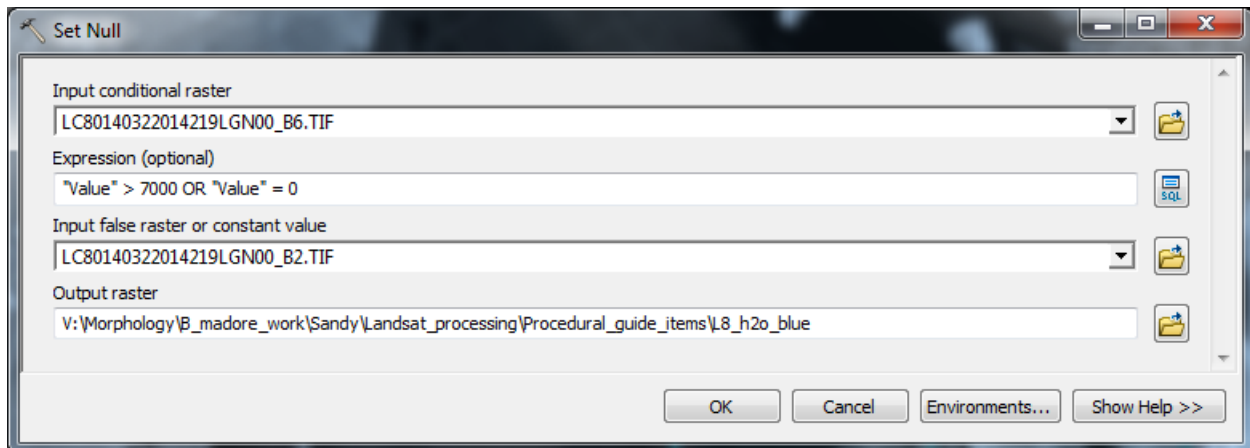
IMPORTANT: Make sure the expression is used correctly, see the below expression as an example, but make sure to input the correct threshold value for the image being examined, instead of the 7000 which is the value for the image in this procedure.

Select the band 2 (blue band) for the **false raster**. Select the folder icon next to **Output**

Raster to designate a location to save the layer being created. Name the layer

L8_h2o_blue (or similar). This layer being created is using the IR band to mask out all

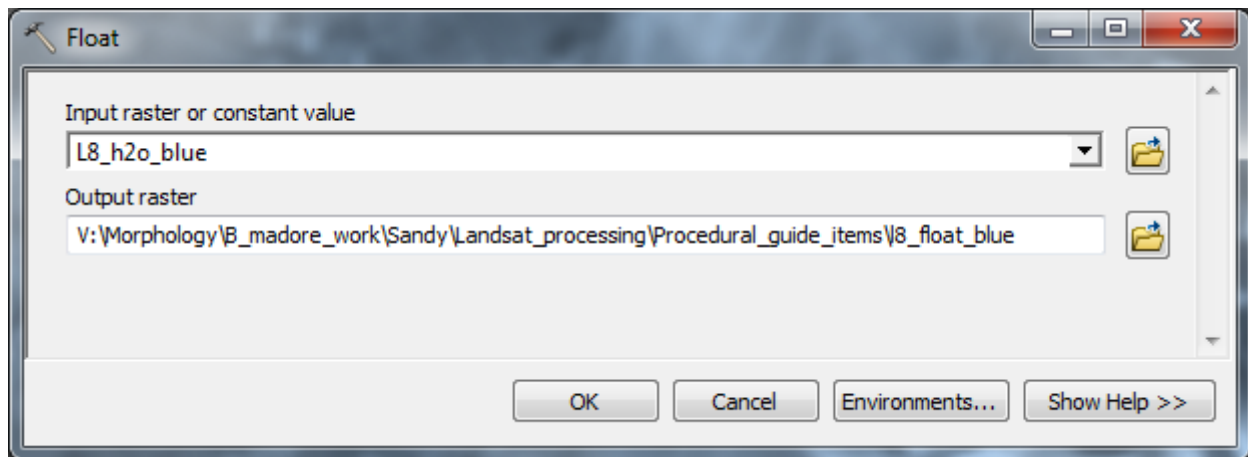
values from the IR band that are considered land by the threshold value on the blue band.



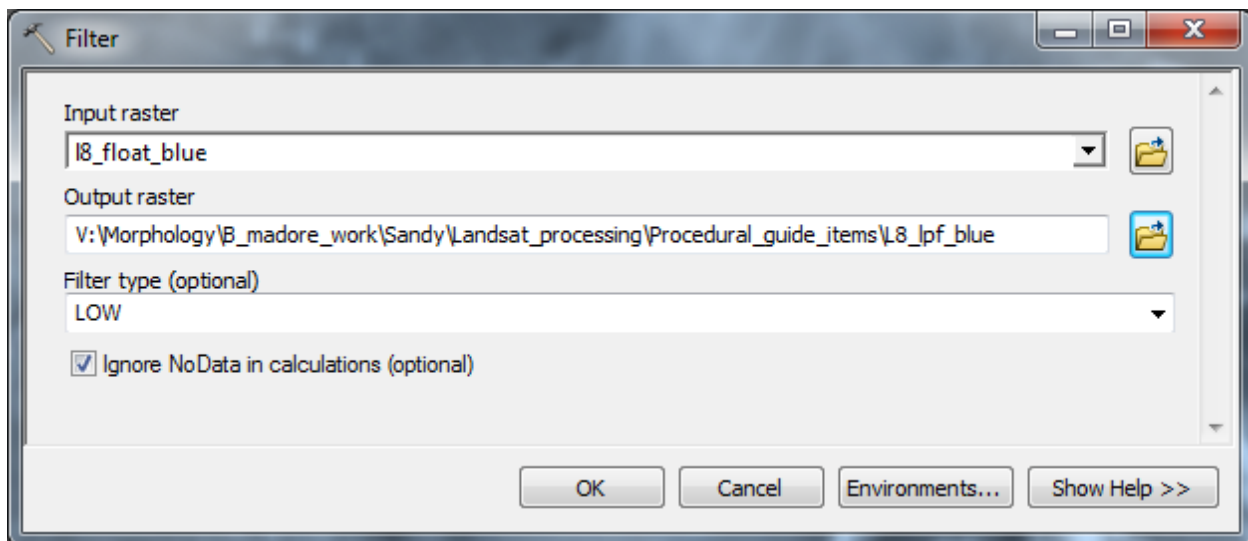
B.13. Repeat step B.11. and B.12. using band 3 as the **false raster** and saving the layer as L8_h2o_green (or similar).

B.14. In the **ArcToolbox** select **Spatial Analyst Tools>Math>Float**.

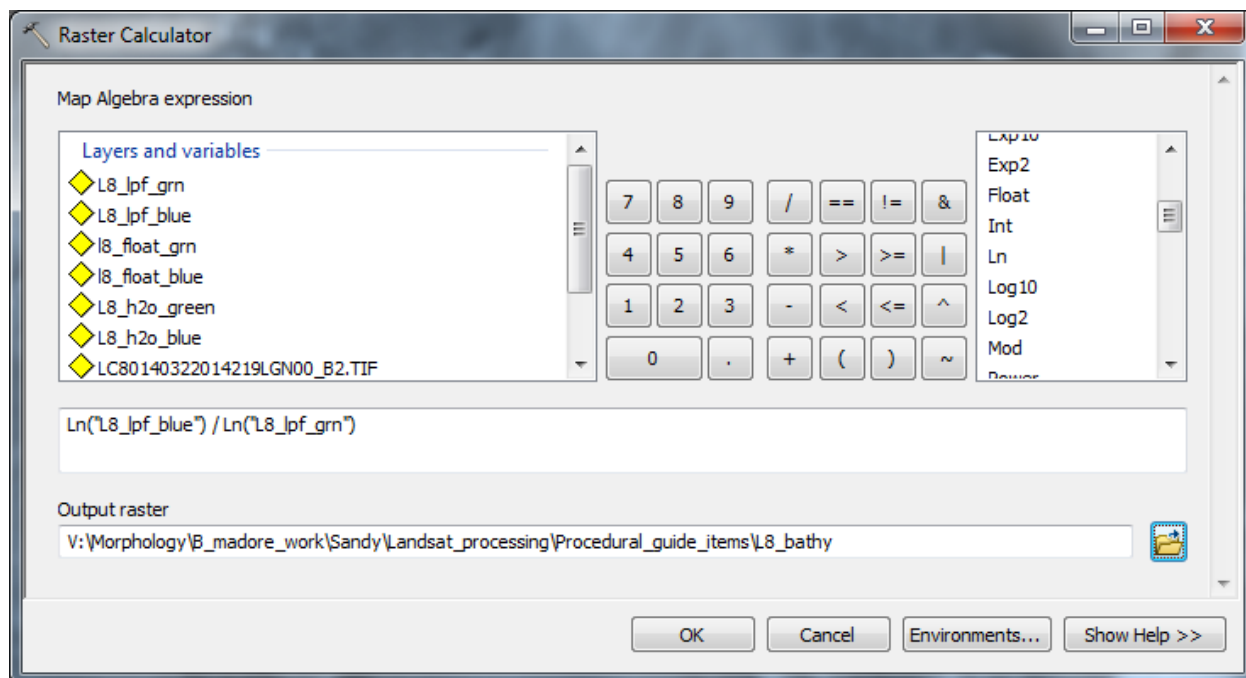
B.15. For the **input raster** select L8_h2o_blue. Select a destination to save the **output raster** and name the layer L8_float_blue (or something similar).



- B.16. Repeat steps B.14. and B.15. using the L8_h2o_green for the **input raster** and saving the **output raster** as L8_float_green (or similar).
- B.17. In the **ArcToolbox** select **Spatial Analyst Tools>Neighborhood>Filter**.
- B.18. Select L8_float_blue for the **input raster**. Save the output raster as L8_lpf_blue (or similar). **Filter type** should be set to LOW.



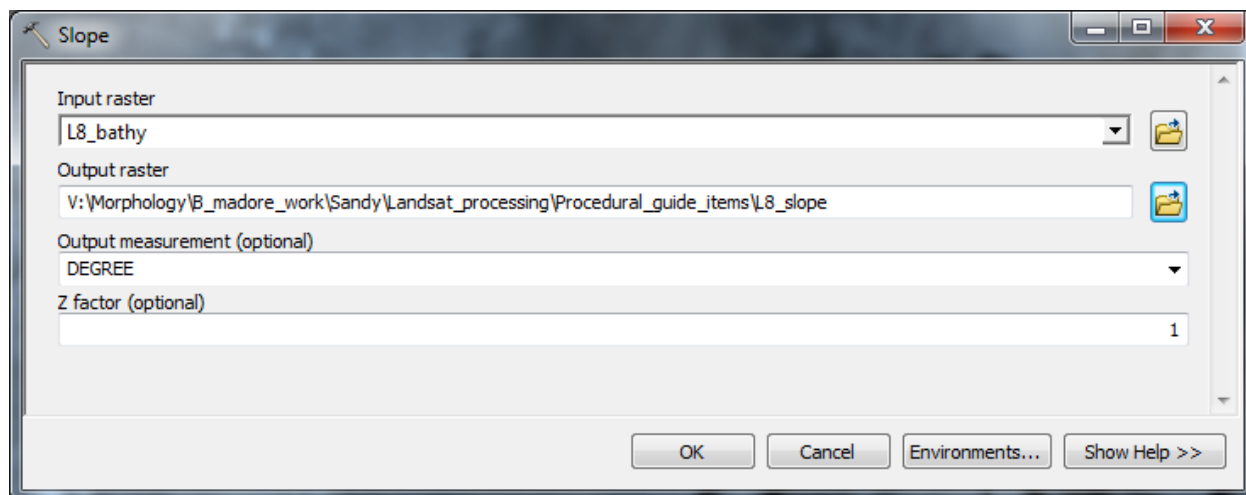
- B.19. Repeat steps B.17. and B.18 using L8_float_green for the **input raster** and saving the **output raster** as L8_lpf_green (or similar).
- B.20. In the **ArcToolbox** select **Spatial Analyst Tools>Map Algebra>Raster Calculator**.
- B.21. Input the equation $\text{Ln}(\text{"L8_lpf_blue"})/\text{Ln}(\text{"L8_lpf_green"})$.
See the following figure for reference. Save the **output raster** as L8_bathy.



C. Creating Slope Maps

C.1. In the **ArcToolbox** select **Spatial Analyst Tools>Surface>Slope**.

C.2. For the **input raster** select L8_bathy and save the **output raster** as L8_slope (or similar). Leave the Z factor as 1.

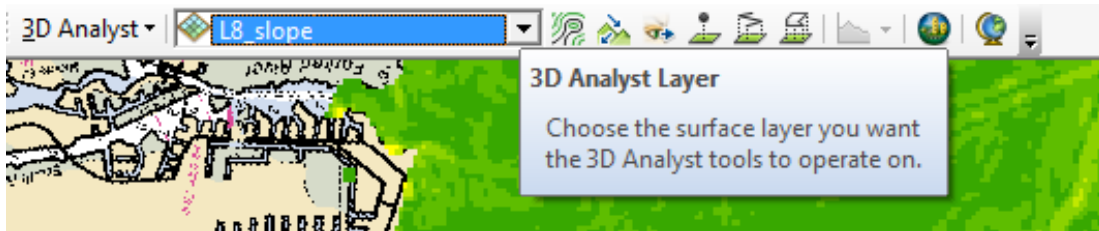


C.3. The resulting layer shows the low slope areas as green and high slopes areas as red.

Bathymetric areas that are near shallow areas, such as shoals, channels, sandbars, etc... will be displayed as red, as those areas have changing bathymetry over a short distance.

C.4. Using a similar method as determining the IR threshold value between land and water in steps B.4. to B.8. the 3D Analyst toolbar and the **interpolate line** feature will be used to determine the threshold between low slope and high slope areas. The identify tool could also be used to do this by selecting areas near the boundary between low and high slope areas. The threshold value is going to be used to extract only the high areas of slope.

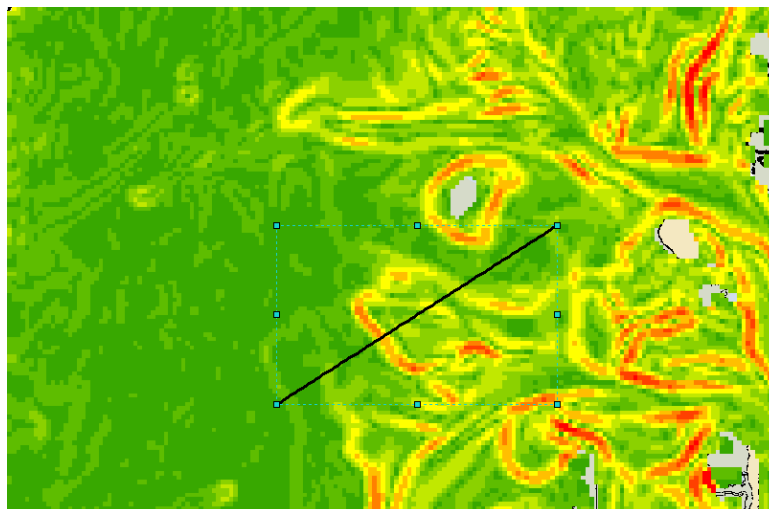
C.5. In the 3D Analyst toolbar select L8_slope in the drop down area.



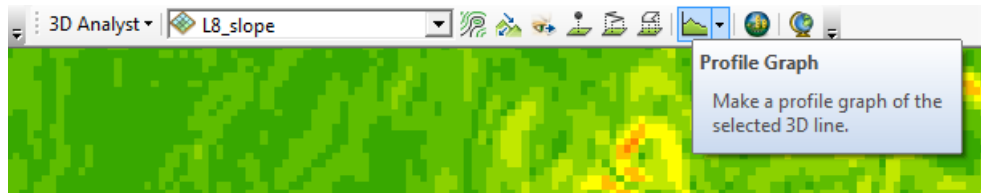
C.6. Select **interpolate line**.



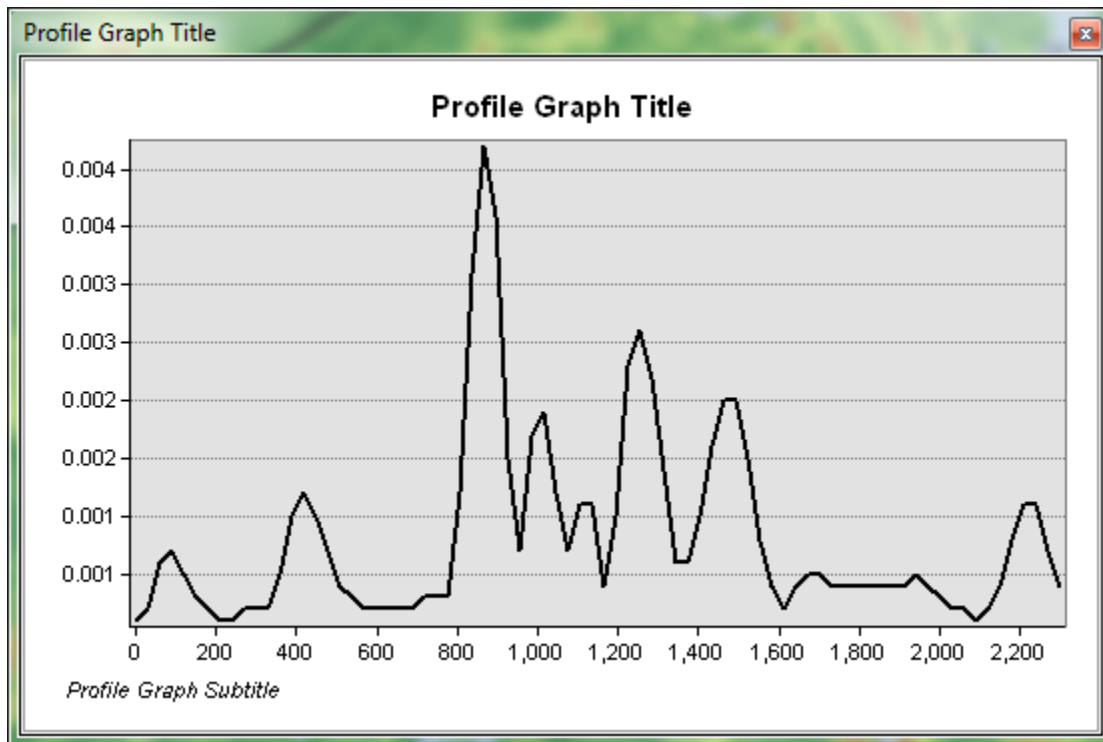
C.7. Draw a line that goes over both high and low slope areas.



C.8. Select **Profile Graph** in the 3D Analyst toolbar.



C.9. Use the resulting graph to determine the threshold which will be used to mask all values lower than the threshold value. For this slope layer the value appears to be .0035. If when the threshold value is used and either too much or too little is masked, repeat the step and adjust the threshold value.

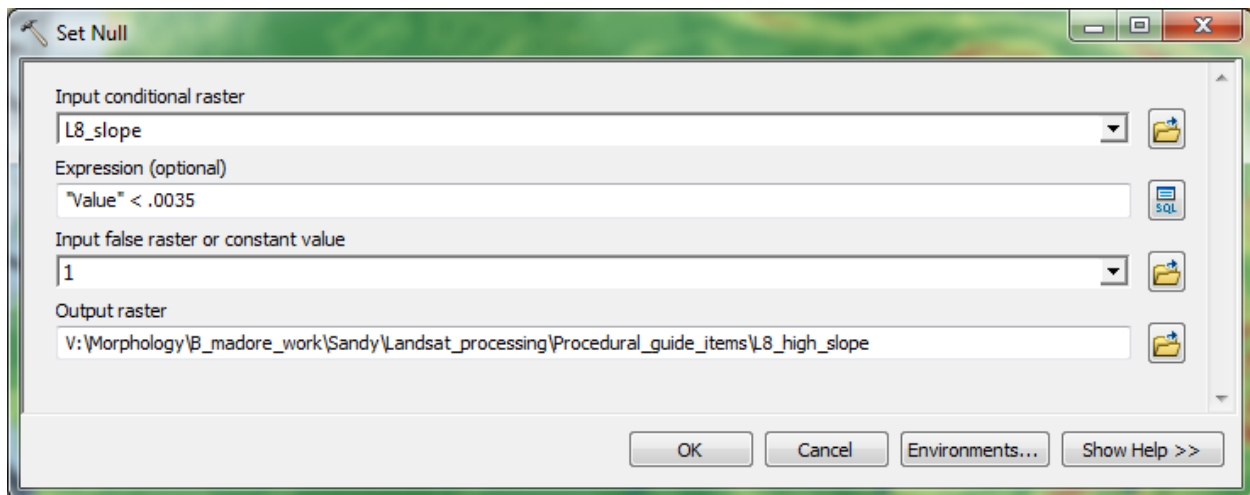


- C.10. In the **ArcToolbox** select **Spatial Analyst Tools>Conditional>Set Null**.
 C.11. Select L8_slope for the **input raster**.

For the **Expression** use “**Value**” < (threshold value)

For this example that would be “**Value**” < .0035

Use 1 for the **false raster or constant value** and save the **output raster** as L8_high_slope (or similar).



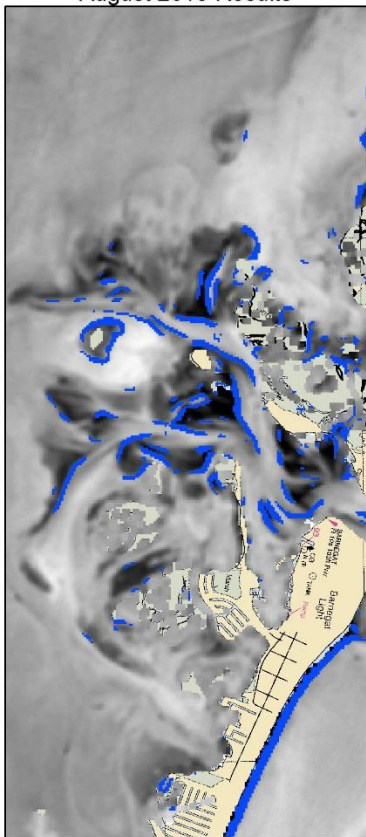
C.12. The resulting layer shows only the high slope areas, which correlate to the channels, sand bars, shoals, and other potentially navigation hazardous locations.

D. Analysis

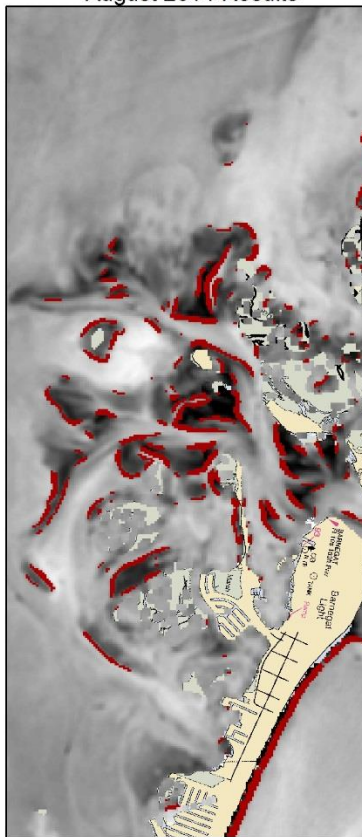
D.1. By creating the high slope area for various different satellite imagery from before and after the storm event it is possible to monitor and determine stable and dynamic areas. Once these areas have been identified they can be continued to be monitored for additional changes, to determine if a new equilibrium post-storm has been achieved, or perhaps if the areas are reverting to the pre-storm scenario.

D.2. The following image shows a comparison using two different satellite images, one from 2013 and one from 2014. For the most part all of the areas in this image are seen to be stable as there are no major differences when looking at the comparison image. These two images are both from after the storm event and would suggest a stable environment has been reached, but comparison with other images taken monthly (if possible) would also be assessed.

August 2013 Results



August 2014 Results



Comparison of High Slope Areas

