Mapping Regional Inundation with Spaceborne L-band SAR

Sources: Bruce Chapman [1], and Rick Guritz [2]

[1] *Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109 USA*
[2] *Alaska Satellite Facility, University of Alaska, Fairbanks, AK 99775 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) Colorized inundation map
   b) Inundation animation

In this document you will find:
   A. Background
   B. Materials List 1
   C. Steps for Generating Inundation Animation
   D. Sample Inundation Animation
   E. Sample Granules
   F. Materials List 2
   G. Steps for Generating Colorized Inundation Map
   H. Sample Colorized Map

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 recent 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) now 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 16 PALSAR RTC products and (b) produce an inundation map that quantifies the number of flooding events from the given set of data.

B) Materials for generating inundation animation
- ALOS-1 PALSAR RTC products
  - o For this exercise, you may use the sample granules in Section E
- ArcMap (version 10.3 used in this recipe)
  Adobe Photoshop (CS6 used in this recipe)

C) PART 1: Processing steps to generate inundation animation

Download and Organize Data
1. Download data either by clicking the links to the sample data below in Part E or by bulk downloading using the Vertex data portal.
   a) For help using Vertex to search for and download data, please refer to the Vertex Getting Started User Guide
2. Organize data
   a) Extract data from the downloaded .zip files and copy the HH image from each granule into a single HH frame folder

Convert Images to decibels

1. Convert the RTC images from linear power to db
   a) In ArcMap, load all of the RTC HH GeoTIFF images from the folder. If prompted to create pyramids for an image layer, click <No>
   b) Start the Raster Calculator tool (Spatial Analysis Tools > Map Algebra)
      Note: Raster Calculator is part of the Spatial Analyst toolbox, which requires the Spatial Analyst license
   c) Create output folder HH_db, and specify output filename as Rnnnnn_db.tif where nnnnn is orbit number.
   d) Compute db = 10. * Log10 ("RTC_HH_granule") *(Figure 1)*
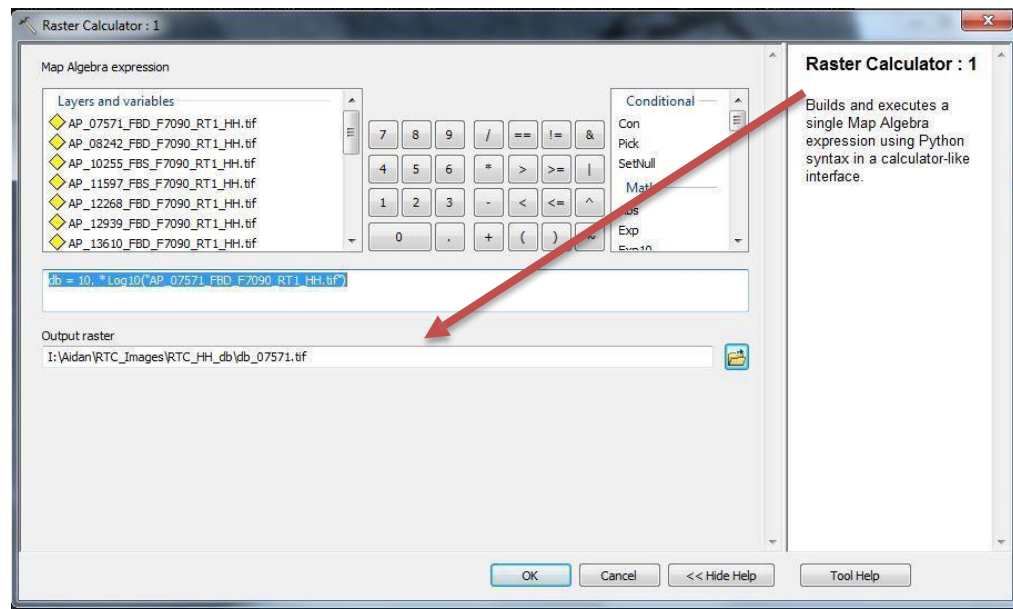   e) Repeat process for all RTC granules.

Figure 1: Raster Calculator set-up for one sample granule

Process and Classify Images

1. Filter Images to reduce speckle
    a) In the ArcMap top menu, go to Windows > Image Analysis
    b) Select the first image.
    c) Under "Processing," click on "Add Function" (*Figure 2).*
    d) In the "Function Template Editor," right-click on "Identity Function," mouse-over "Insert Function," and select "Speckle Function" from the menu.
    e) In the parameters menu that appears, change the "Filter Type" setting from "Lee" to "Enhanced Lee" and keep the rest of the parameters set to their defaults.
    f) The files that result from this are temporary. To save them permanently to the hard drive as a GeoTIFF, use the Copy Raster (Data
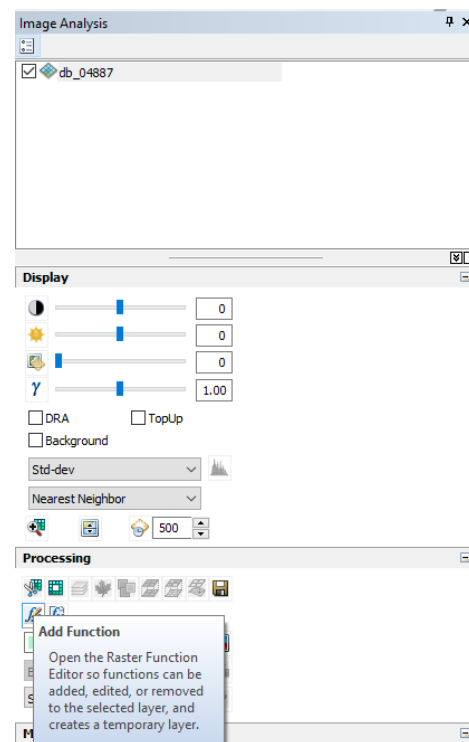

Figure 2: Location of the Add Function tool in the Image Analysis

Management Tools > Raster > Raster Dataset) tool, with the Output Raster Dataset field set to a directory and filename (ending in .tif) of your choice, and all other fields blank.

   g) Repeat Steps b through f for all images.

2. Require calculation of statistics
   a) In ArcMap, display all filtered db images created by the Copy Raster tool.
   b) Open Batch Calculate Statistics (Data Management Tools > Raster > Raster Properties).
   c) Drag and drop all images in to the input and click OK to calculate statistics for all of the images.

3. Display images
   a) Right-click on a feature layer and select Properties. Then click on the <Symbology> tab. Under "Show:" select "Classified." Then, under "Classification," set Classes to "2."
   b) Click the <Classify> button, and a histogram will display.
   c) By default, "Classification Method" is "Natural Breaks (Jenks)." Two vertical blue lines appear on the graph, and you should notice a small peak and a large peak indicating a bimodal distribution.
   d) Set "Classification Method" to "Manual," and specify a starting break point, such as "-14." Click <OK> (*Figure 3*).
   e) Under "Color Ramp," double click on the first class Color box and select a blue color.
   f) Double click on the second class Color box, select black, and click <OK>. The feature layer will be displayed with open water as blue and land as black. *Notes: The values for the break points can change significantly between locations and datasets, and will generally require several iterations to determine.*

4. Refine the breakpoint value until water is mostly contained within river channels, and very small number of blue dots show on land outside river channels.
   a) Right-click the image layer, and select "Properties."
   b) Click on the <Symbology> tab; then click on "Classify…"
   c) Change the value of the breakpoint, increasing it by one each time (so "-13" is the first increased value).
   d) Click <OK>.
   e) Again specify the two colors for the two classes as blue and black; then click <OK>

   Notes: We found "-11" to be the best value for minimizing water speckle over land.

5. Further refine breakpoint values
   a) Determine a second breakpoint for areas in the image that are brighter due to double bounce of flooded forests. Here you will determine a breakpoint on the other side of the large peak.
   b) Start with a higher value such as "0."

c) Set the first class color box to black and the second class color box to yellow, for values greater than the breakpoint. Look for yellow in the image and notice how much speckle noise you have away from the bright feature areas.
d) Decrease the breakpoint value by one until the amount of speckle is close to what was observed for the blue class.

Notes: We found "-4" to be a good value for the second class

e) Select number of classes to be "3," and enter both breakpoint values. Set the first class Color to blue, second class Color to black, and third class Color to yellow. You should see the image classified with water channels as blue and double bounce areas as yellow.

Notes: We found it useful to pick a minimum flood and maximum flood image to verify that the breakpoints work as desired. Some knowledge of the extent of seasonal flooding is useful to confirm that the results are correct.
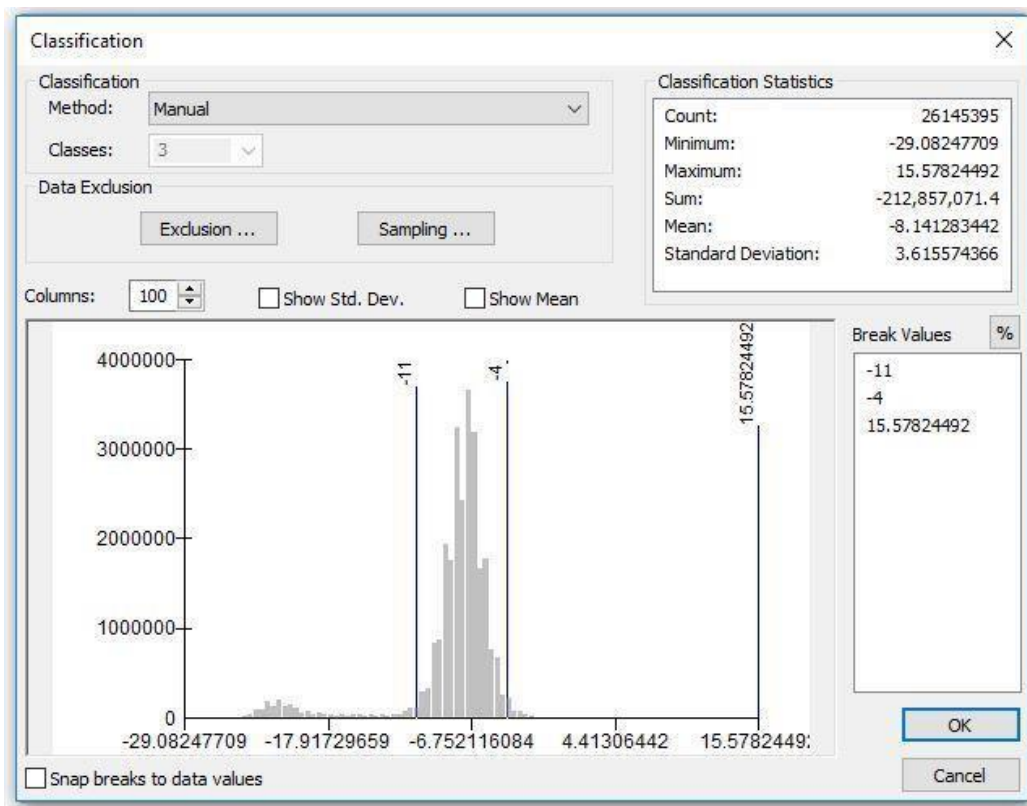

Figure 3: Final results of steps a-e with the suggested breaks.

6. Save a colorized raster dataset for each classified image for creating an animation.
    a) Use the Apply Symbology From Layer tool (Data Management Tools > Layers and Tables Views) to set the symbology of the remaining greyscale images, with the "Symbology Layer" field set to any correctly colored image.
    b) When each image is colored correctly, right click on the image and select "Data -> Export Data..." This will display the "Export Raster Data" window.
    c) Set "Extent" to "Data Frame (Current)."
    d) Set "Output Raster" to "Use Renderer" and "Force RGB."
    e) Specify an output directory by clicking the folder button; then browse to the desired output directory.
    f) In the "Name:" field, specify the output filename, such as class_xxxxx_db.tif, and "Format:" "TIFF.
    g) Click the <Save> button.

_____

Generate and View Animated GIF

1. **Generate animated GIF** to show the sequence of classified images showing inundation
    a. Open Adobe Photoshop
    b. Select "File -> Scripts -> Load Files into Stack…" to load the color classified imagery.
    c. Use the <Browse> button to navigate to the directory you used for the "Export_Data" step in ArcMap (step 6). Select all input files. The data files will load in the layers control panel.
    d. Once the data are all loaded, click on the Create Frame Animation button in the <Timeline> tap section located below the image. This will create a single frame instance.
    e. In the bottom right corner of the image display window, click on the menu button that looks like an arrowhead next to four horizontal lines. A timeline menu is displayed (*Figure 4).
    f. In the timeline menu, select "Make Frames From Layers" to populate the timeline with all image frames. The frames are numbered 1 through 16. There is a delay setting below each frame.
    g.
        Notes: It is preferred to set the delay to increments of 0.5 seconds per cycle of PALSAR data. Each cycle is 671 orbits; if there are gaps in the temporal coverage, then a longer delay can be set as a multiple of 0.5 seconds. In our case, we set delays of 0.5, 0.5, 1.5, 1.0, 0.5, 0.5, 0.5, 1.5, 2.0, 0.5 1.5, 1.0 0.5, 0.5, and 0.5

        respectively. The delay of 1.0 was when one cycle was skipped, 1.5 for when two cycles were skipped, etc.
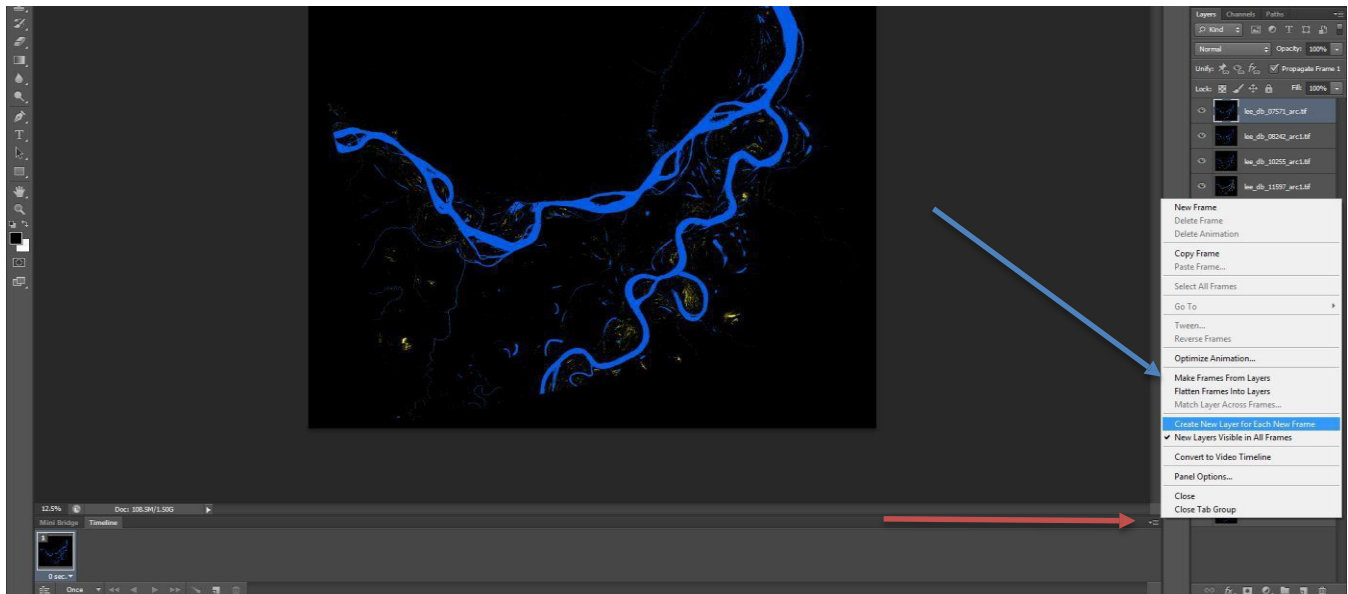
Figure 4: Location of the timeline menu (red arrow) and "Make Frames From Layer" (blue arrow) in Photoshop

    h. Click on the "0 sec." dropdown menu under each frame, which offers a choice of delay settings. If the specific delay you want is not listed, select "Other" and enter the delay.

    i. If you want the animation to loop more than once, click on the <Once> button located below the timeline images and select "3 times," for example .

    j. To save this animation, select "File -> Save For Web."

    Notes: A warning may be displayed due to the size of the images; click yes if it does. In the image size section, type 15% to reduce the image size of the output.

    k. Click the <Save> button, specify the output filename, and click save again to save the animated GIF image.

2. Using your file browser, navigate to the output directory containing animated GIF. Double click on file to execute. Your animation should be displayed.

D) Output Example of Inundation Animation

Click the following link to see the resulting gif in your browser:
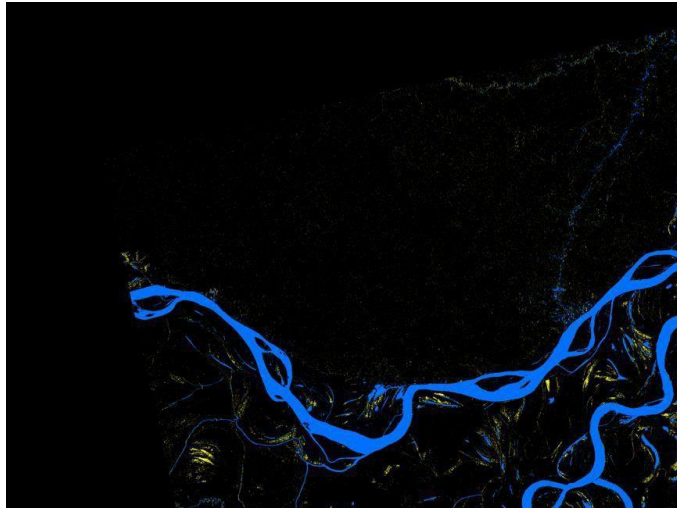https://www-dev.asf.alaska.edu/data-tools/data-recipes/how-to-map-inundation/

Figure 5: Frame from animation of inundation in Amazon rain forest. Credit: Chapman, Guritz 2016; RTC: ASF 2015; Includes Material © JAXA/METI 2007.

E) Links to Sample RTC Products

Click on product names to download each granule individually, or copy the list of granule names and paste them in Vertex to bulk download them. See Part One for more detailed instructions on using Vertex.

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

F) Materials List to Generate a Colorized Inundation Map

- [ArcMap](#)
- lee filtered db images from generating an inundation animation (see above)

G) PART 2: Processing Steps to Generate a Colorized Inundation Map

Classify Images

1. Classify each image to water (1) or land (0)
   a) In ArcMap, load each of the lee filtered db images. Then Reclassify the floating point data of each image, mapping all water areas to 1 and all non-water areas to 0. Select the Input Raster as one of the displayed images. This will populate the reclass table. There are nine data ranges, plus NoDATA. First, select ranges 2 through 7, and delete them. Then change the remaining (*Figure 6*)

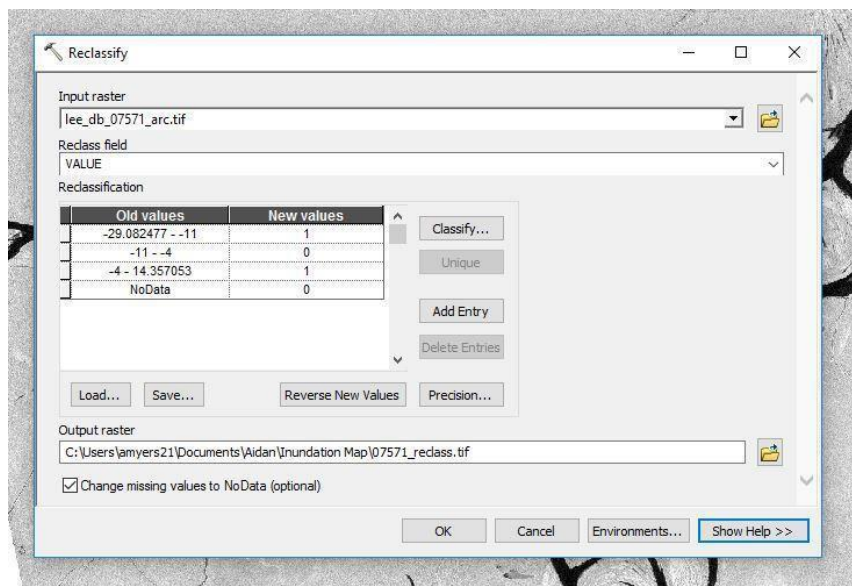|	Old Values:	New Value:
i.	Old Values:	New Value:
ii.	-29.082478 - -11.0	1
iii.	-11.0 - -4.0	0
iv.	-4.0 – 15.578245	1
v.	NoData	0

Figure 6: Reclassify set-up in ArcGIS for one sample granule, shows i-v above.

b) Also specify the output filename and check the box to set data outside data range to NoData. The result should be an image with two values: 0 and 1.

   Notes: Values in this table can be tricky; once you have set all new values, click on an unchanged value to ensure that all values are entered.

c) Repeat this for all images. Then right click on each input image, and select remove to leave just the classified images.

Create the Final Product

1. Add up all these images**.**
   a) Bring up Raster Calculator, and notice the list of images on the left.
   b) In the equation box, type in **count =**
   c) Double click on the first image name; then click on the + button.
   d) Continue adding filenames with the symbol **+** between each until all image names are used.
   e) Specify the path and filename of the output raster you will create.
   f) Click the ok button to execute the command.

   Notes: The combined image will display with random colors assigned. It is a good idea to set the color for 0 and 1 to black. Usually values of one are due to remaining speckle in the data after filtering. You can change colors by right-clicking on a color in the layers panel, which brings up a matrix of standard colors. Select colors that are easily distinguished and in some logical order.

   g) When you are happy with the color settings, right click on the filename and select Data/Export Data. An export raster data panel will display.
   h) Set Data Frame (current) for Extent.
   i) Click check box for Use Renderer, and Force RGB.
   j) Specify an output directory, click the folder button, and browse to the output directory for this classified image.
   k) Also specify the output filename, such as overlap_count.tif, and format: TIFF.
   l) Click the save button.

   Notes: This creates a full resolution image of inundation. You should also use the snipping tool to grab a low-resolution version of the overlap count image and the color key to be used with either image.

H) Output Example of Colorized Inundation Map
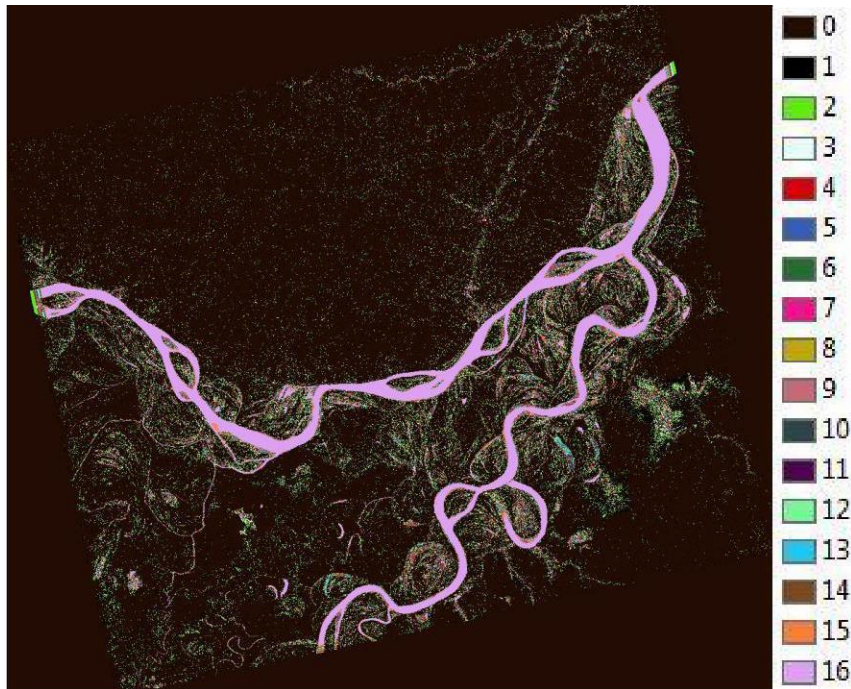
Figure 7: Map of inundation in Amazon rain forest. The color key provides the color for the number of times an area was flooded in 16 granules, and 16 (pink) represents constant river. Numbers less than 16 are the number of times an area floods.
Credit: Chapman, Guritz 2016; RTC: ASF 2015; Includes Material © JAXA/METI 2007.