

Jet Propulsion Laboratory
California Institute of Technology

Classifying inundation from UAVSAR polarimetric data

Bruce Chapman, Jet Propulsion Laboratory, California Institute of Technology

Bruce.chapman@jpl.nasa.gov

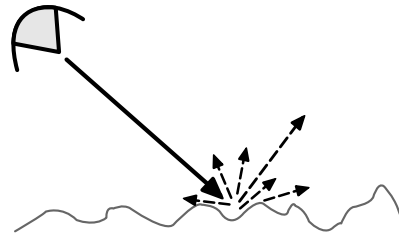


How can we identify inundation in L-band quad-pol UAVSAR data?

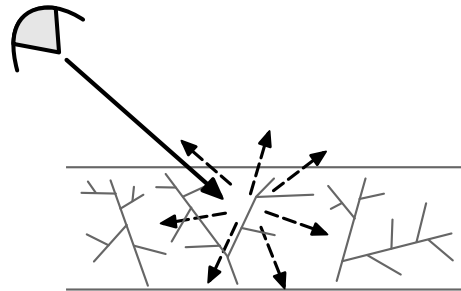
- We can use the freely available PolSARpro software to identify the scattering mechanisms
- Then, we can classify the scattering mechanisms as inundated vegetation, open water, or other.

Scattering mechanisms

- Open water will result in surface scattering and be radar dark.

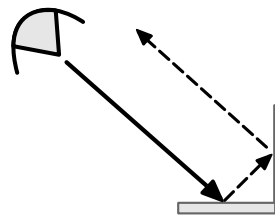


Surface scatter
("odd" bounce)



Volume scatter

- At L-band, woody trees standing in water will typically result in double bounce reflections and will be radar bright



Double bounce
scatter

PolsarPro

- PolSARpro is open source software available from ESA
- It can ingest UAVSAR data, and perform various polarimetric decompositions
- We will utilize the “Freeman-Durden” decomposition, since its output files are exactly what we want: the fraction of the radar power that is the result of these three scattering mechanisms.

esa

→ POLSARPRO V. 5.0

The Polarimetric SAR Data Processing and Educational Tool

ENTER

EXIT

<http://earth.esa.int/polsarpro>

www.esa.int

European Space Agency

PoSARPro

- PoSARpro is described as supporting both 64 bit Windows and 32bit linux computers, but I will also show you how you can execute the software on a Mac.
- Download with installation instructions at
- <https://earth.esa.int/web/polsarpro/download/version-5.0>

The screenshot shows a web browser window displaying the PoSARpro 5.0 download page. The address bar shows the URL <https://earth.esa.int/web/polsarpro/download/version-5.0>. The browser's address bar contains several bookmarks, including NBS Website, Gmail - Inbox, AIRSAR, UAVSAR, Inside JPL, My Yahoo!, NASA Watch, old Bookmarks, ALOS KC, TinyURL!, and Large File Transfer. The page header features the ESA logo and the text "esa PoSARpro The Polarimetric SAR Data Processing and Educational Tool". There are "Login" and "Register" buttons in the top right corner. The main navigation menu includes "Data Sources", "Overview", "Download and Installation", "Documentation", and "Results & News". The "Download and Installation" menu item is highlighted. Below the navigation menu, the breadcrumb trail reads "You are here Home > Download and Installation > PoSARpro 5.0 Downloads". There are social media sharing icons for Facebook, Twitter, Email, and Print. The main content area has a dark blue header with the text "- PoSARpro 5.0 Downloads". Below this header, there are two links: "Installer (64Bit) for Windows (MD5: db469a9e4d6021d44834bf2b0fe074ef)" and "Installer (32Bit) for Linux (MD5: 99ad2b0165eb36fed82cb88361fd2161)". The word "Installation" is partially visible at the bottom left. On the right side, there is a sidebar with the heading "Download and Installation" and a list of links: "Download and Installation Home", "PoSARpro 5.0 Downloads", and "Release Notes".

PolSARPro

- For Windows and linux computers, follow the instructions for installation. The download also includes packages such as gimp and tcl-tk that are used for the graphical user interface.
- For Mac OSX, download the linux software, and then just execute the .bat file to compile the software as described in the linux instructions. We will not use the GUI.
- Once the software is installed, we have to ingest the UAVSAR data files and convert to the format expected by PolSARpro. Then we perform the Freeman-Durden polarimetric decomposition. Separately from PolSARpro, we then classify the binary output files.

PoISARPro

UAVSAR data can be downloaded from [UAVSAR.jpl.nasa.gov](https://uavsar.jpl.nasa.gov) or from ASF at <https://vertex.daac.asf.alaska.edu>

You can choose to download data in radar slant range coordinates (MLC) or geographic coordinates (GRD). Both can be used in PolsarPro, but I will use the orthorectified data in this tutorial.

Metadata	Text Annotation File
Slant Range Products	ShhShh* (0.2191 Gbytes) ShvShv* (0.2191 Gbytes) SvvSvv* (0.2191 Gbytes) ShhShv* (0.4382 Gbytes) ShhSvv* (0.4382 Gbytes) ShvSvv* (0.4382 Gbytes) Compressed Stokes Matrix (AIRSAR format) (0.5479 Gbytes)
Orthorectified Products (geographic projection)	ShhShh* (1.4095 Gbytes) ShvShv* (1.4095 Gbytes) SvvSvv* (1.4095 Gbytes) ShhShv* (2.8190 Gbytes) ShhSvv* (2.8190 Gbytes) ShvSvv* (2.8190 Gbytes) High Resolution KMZ file (0.3706 Gbytes)
SRTM DEM	Incidence Angle File (1.4095 Gbytes) SLOPE File (2.8190 Gbytes) DEM used in projection (1.4095 Gbytes)

PoISARPro

Input UAVSAR data format

Convert to PoISARpro format

Separate floating point files for

$$S_{hh} S_{hh}^*, S_{hv} S_{hv}^*, S_{vv} S_{vv}^*$$

and the complex floating point files for

$$S_{hh} S_{hv}^*, S_{hh} S_{vv}^*, S_{hv} S_{vv}^*$$

Either the covariance matrix - C3

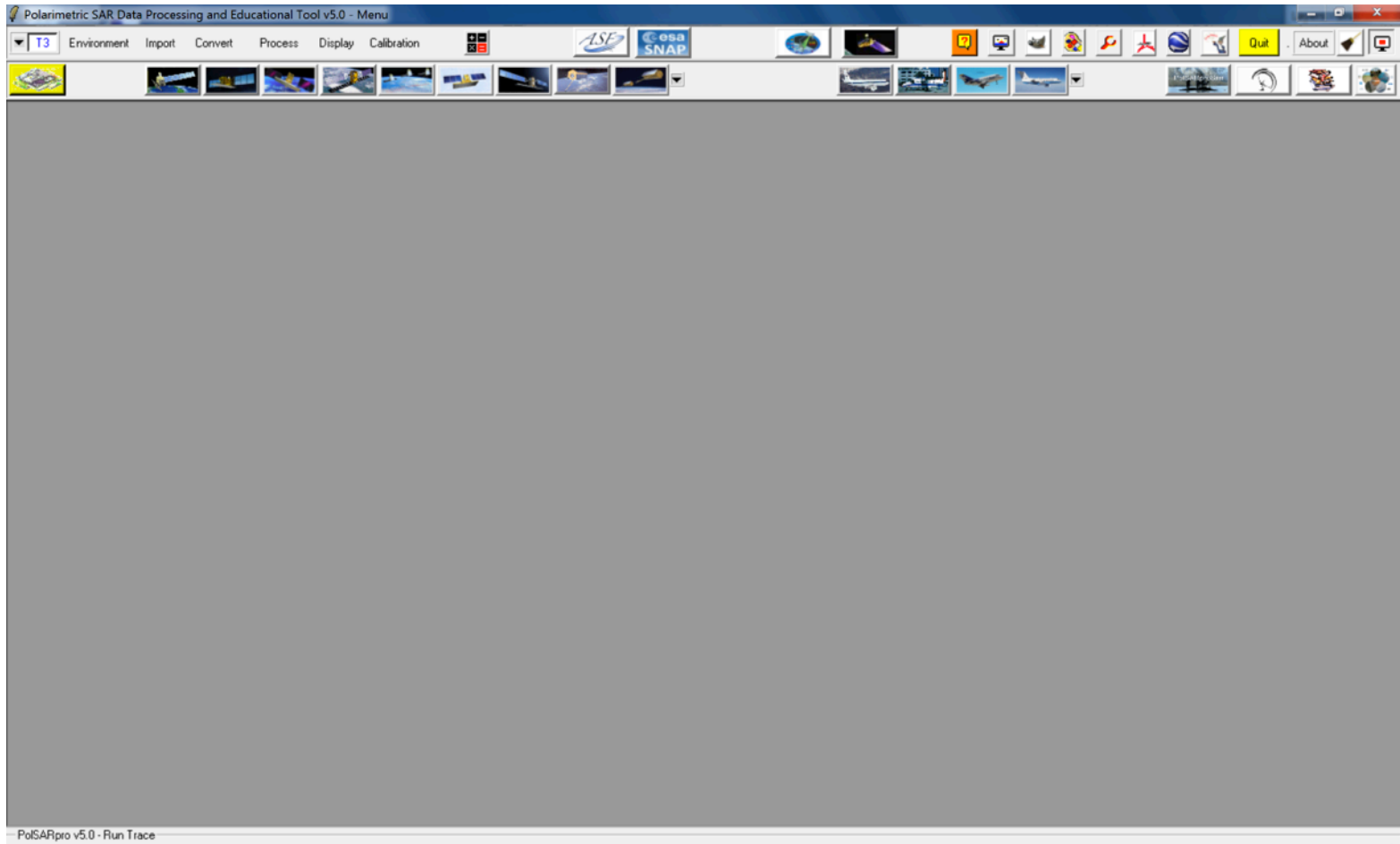
$$\begin{bmatrix} \langle |S_{HH}|^2 \rangle & \sqrt{2} \langle S_{HH} S_{HV}^* \rangle & \langle S_{HH} S_{VV}^* \rangle \\ \sqrt{2} \langle S_{HV} S_{HH}^* \rangle & 2 \langle |S_{HV}|^2 \rangle & \sqrt{2} \langle S_{HV} S_{VV}^* \rangle \\ \langle S_{VV} S_{HH}^* \rangle & \sqrt{2} \langle S_{VV} S_{HV}^* \rangle & \langle |S_{VV}|^2 \rangle \end{bmatrix}$$

Or the coherency matrix - T3

$$\frac{1}{2} \begin{bmatrix} \langle |S_{HH} + S_{VV}|^2 \rangle & \langle (S_{HH} + S_{VV})(S_{HH} - S_{VV})^* \rangle & 2 \langle (S_{HH} + S_{VV}) S_{HV}^* \rangle \\ \langle (S_{HH} - S_{VV})(S_{HH} + S_{VV})^* \rangle & \langle |S_{HH} - S_{VV}|^2 \rangle & 2 \langle (S_{HH} - S_{VV}) S_{HV}^* \rangle \\ 2 \langle S_{HV} (S_{HH} + S_{VV})^* \rangle & 2 \langle S_{HV} (S_{HH} - S_{VV})^* \rangle & 4 \langle |S_{HV}|^2 \rangle \end{bmatrix}$$

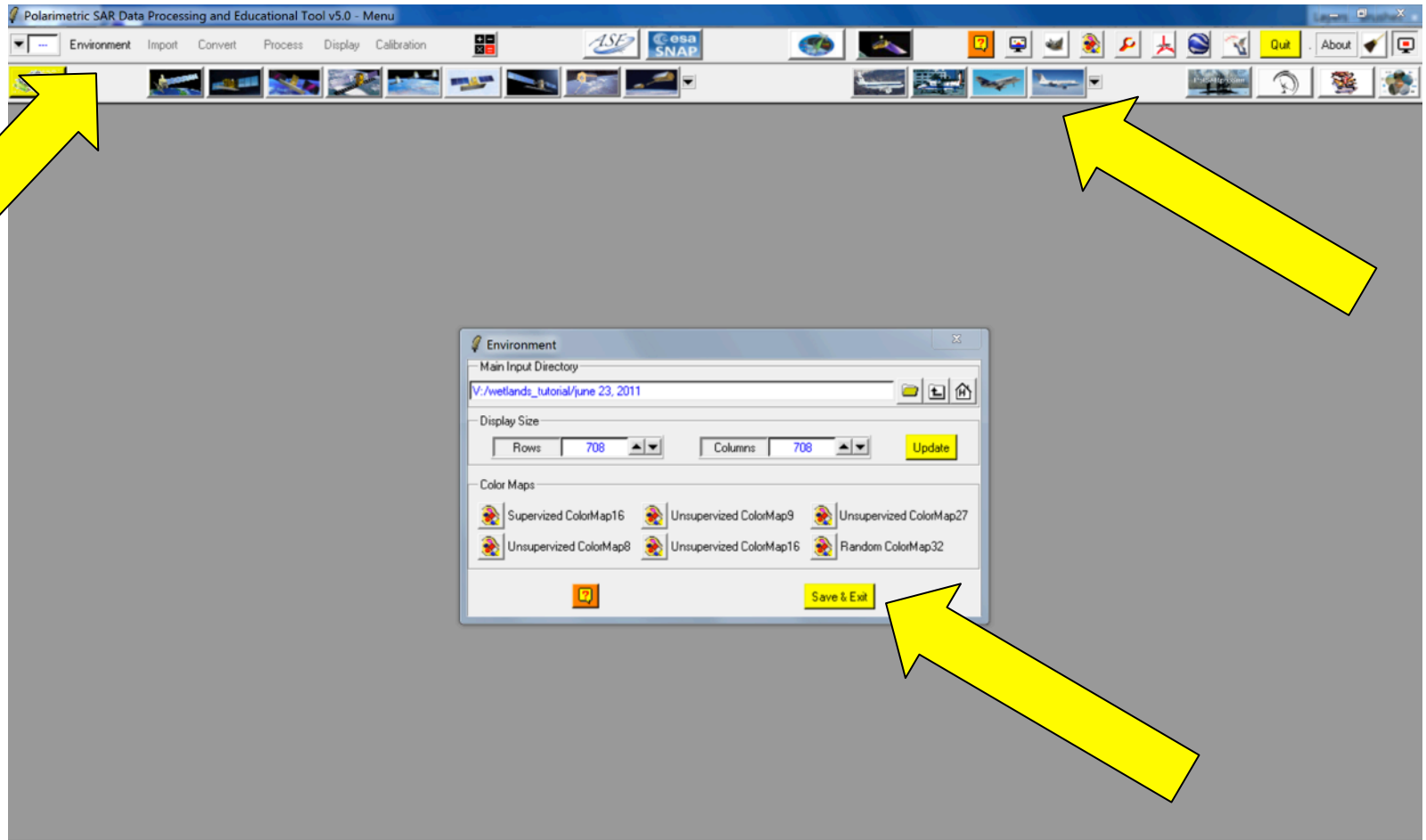
PoISARPro - Windows

After you launch the software, it will look like this:



PoISARPro - Windows

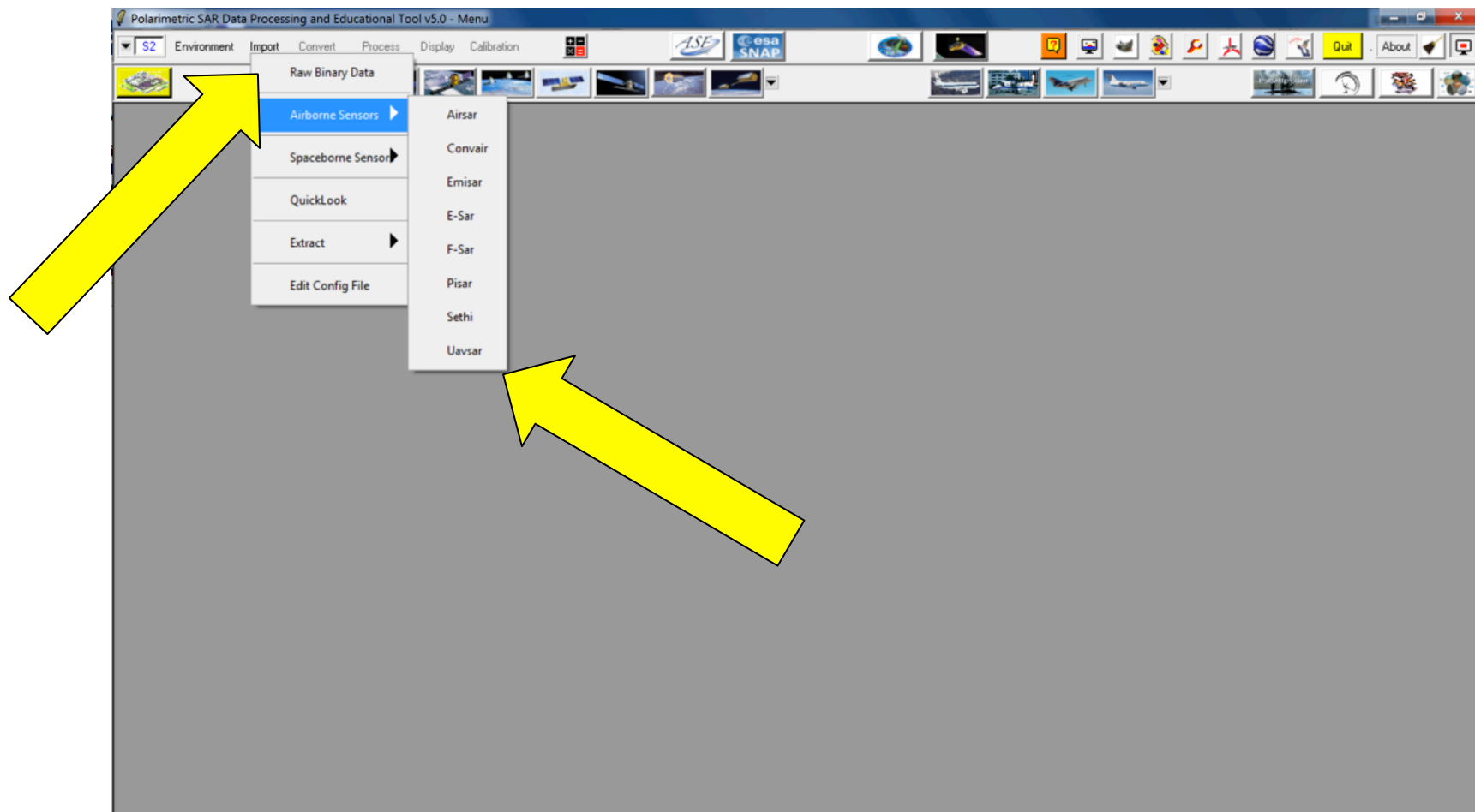
Click on the small UAVSAR G-III image, and then click on “environment”



Then, locate your directory with your UAVSAR data, and click “Save and Exit”

PoISARPro - Windows

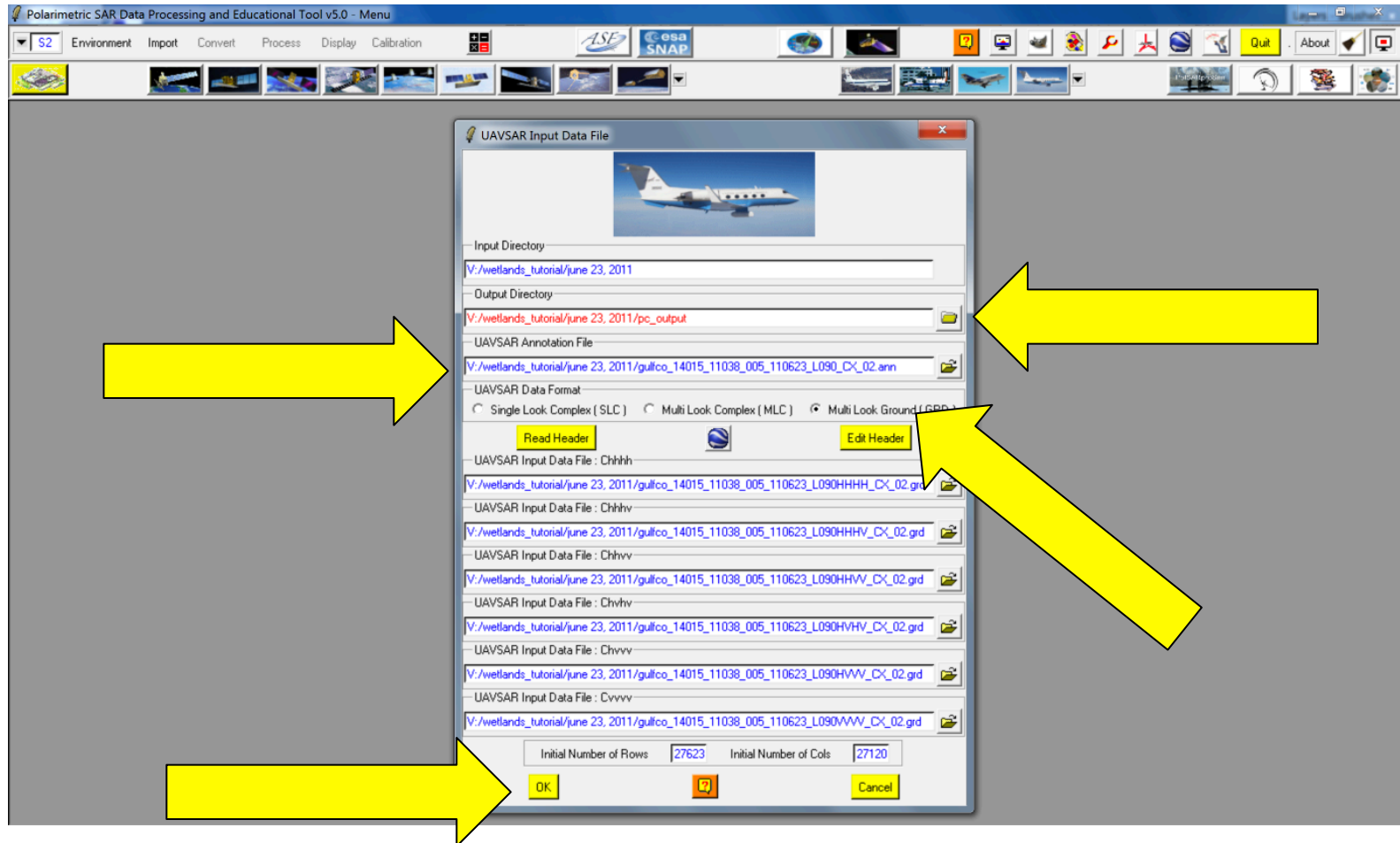
Now import the UAVSAR data by pulling down the import menu and selecting UAVSAR which is listed under the “Airborne sensors”.



PoISARPro - Windows

Identify the output directory, select “Multi Look Ground”

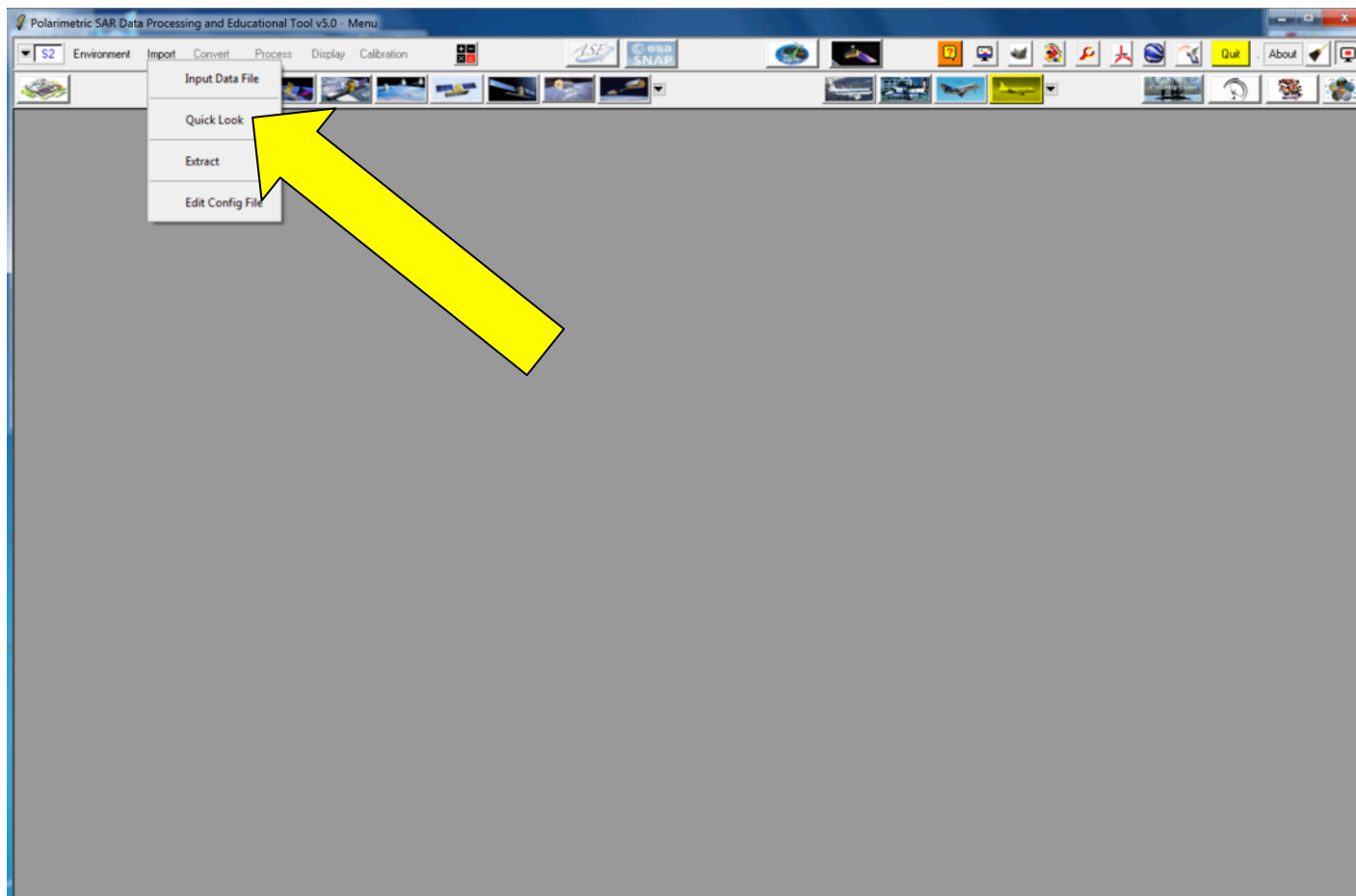
Find the annotation file from the UAVSAR data download page, and click “Read Header”



Then, click ok.

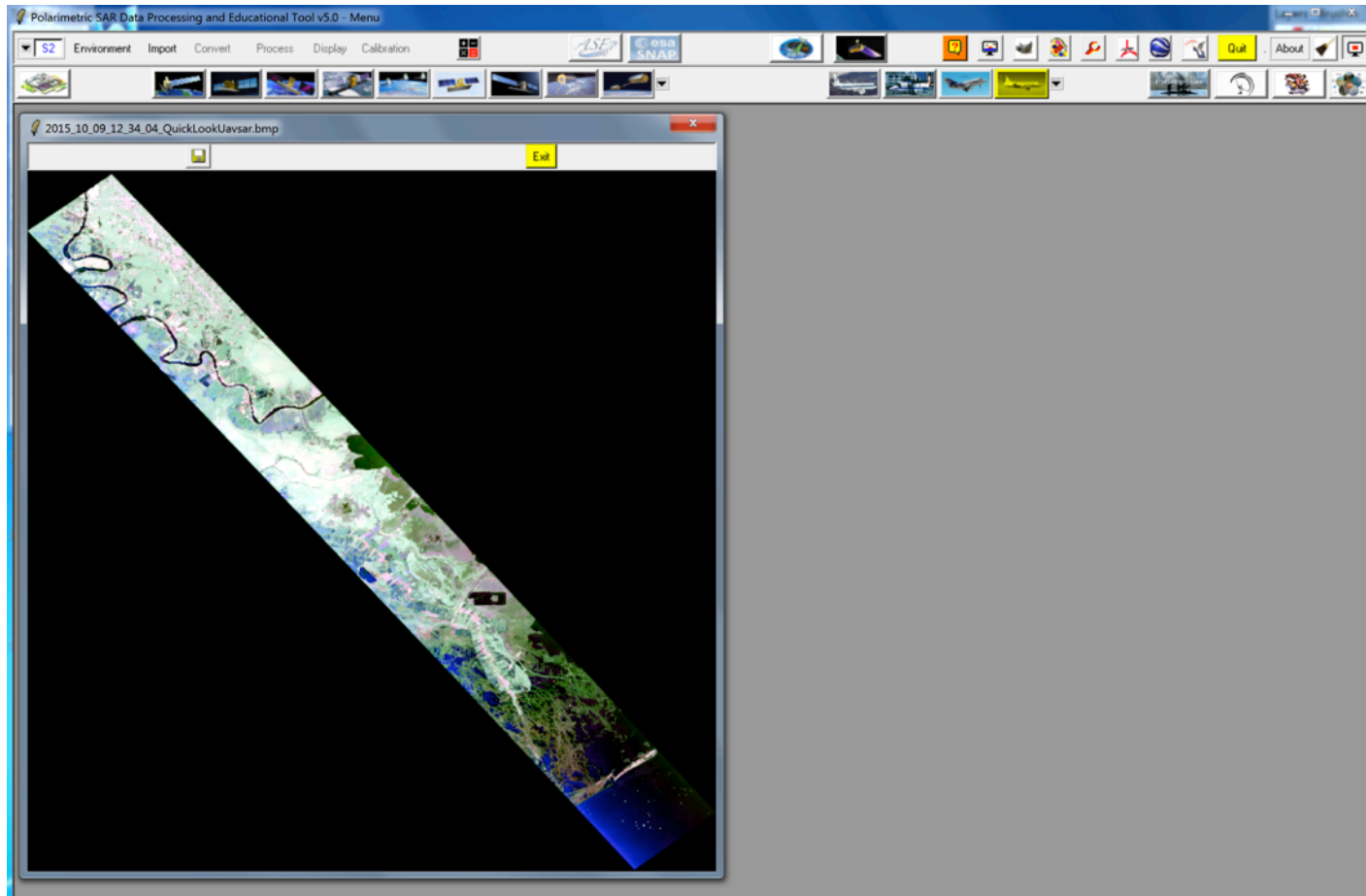
PoISARPro - Windows

Now, make a quick look image. This will be useful if you want to extract just a portion of the image.



PoISARPro - Windows

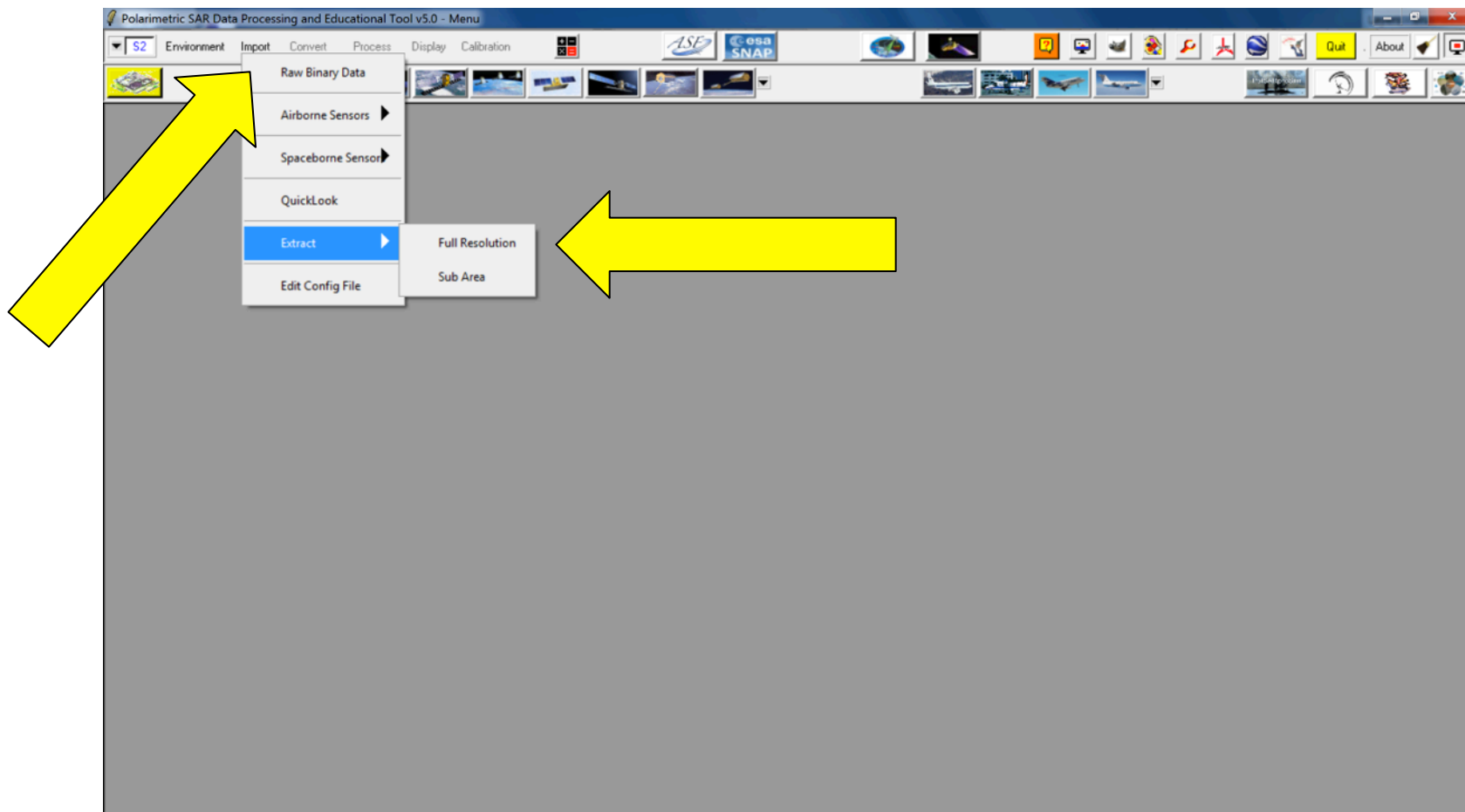
After awhile, PoISARpro will open gimp and display a quick-look image.



You can use this image to decide if you just want to analyze a subset of the data, and if so, which pixel coordinates to select.

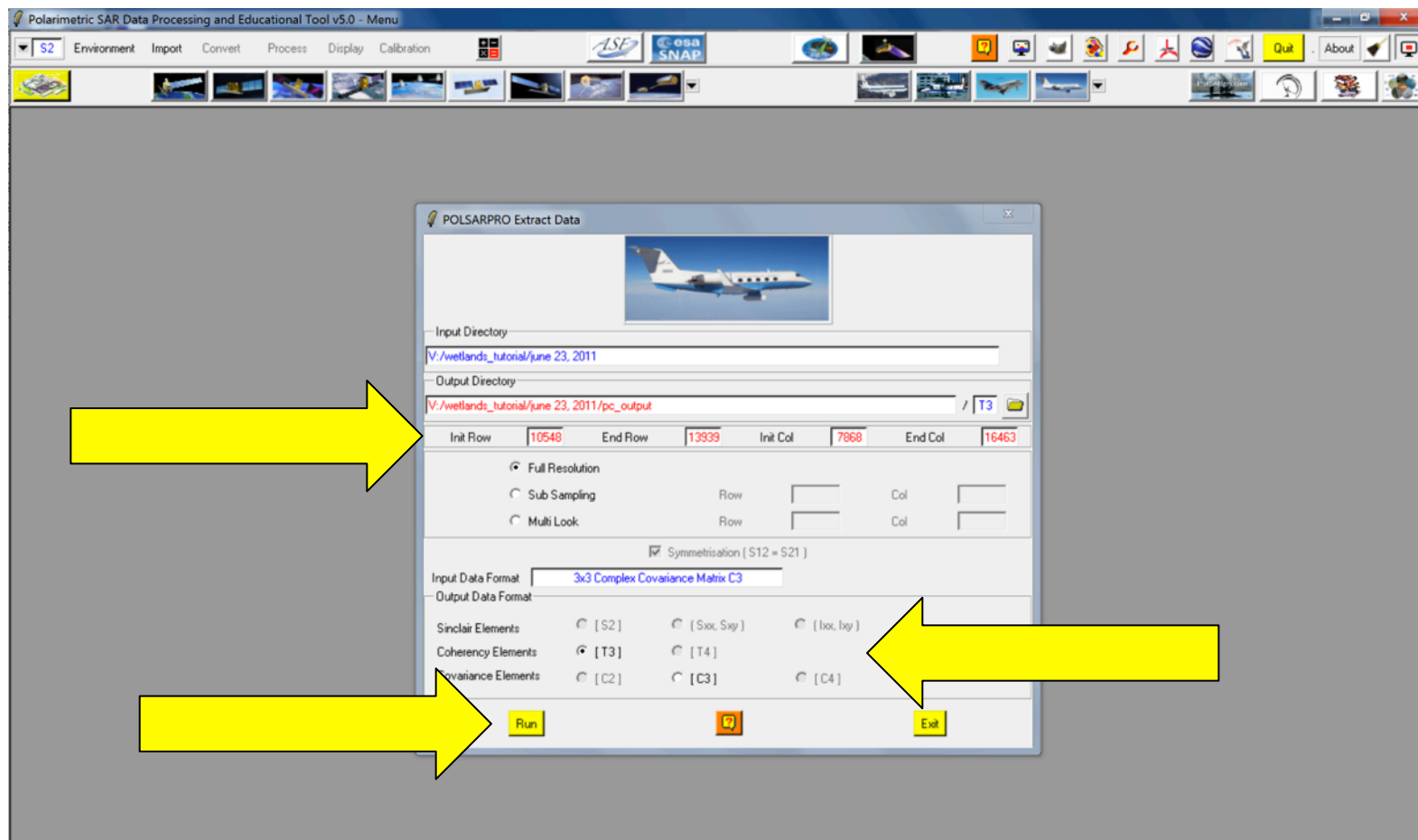
PoISARPro - Windows

Pull down the import menu again, select extract, then select full resolution



PoISARPro - Windows

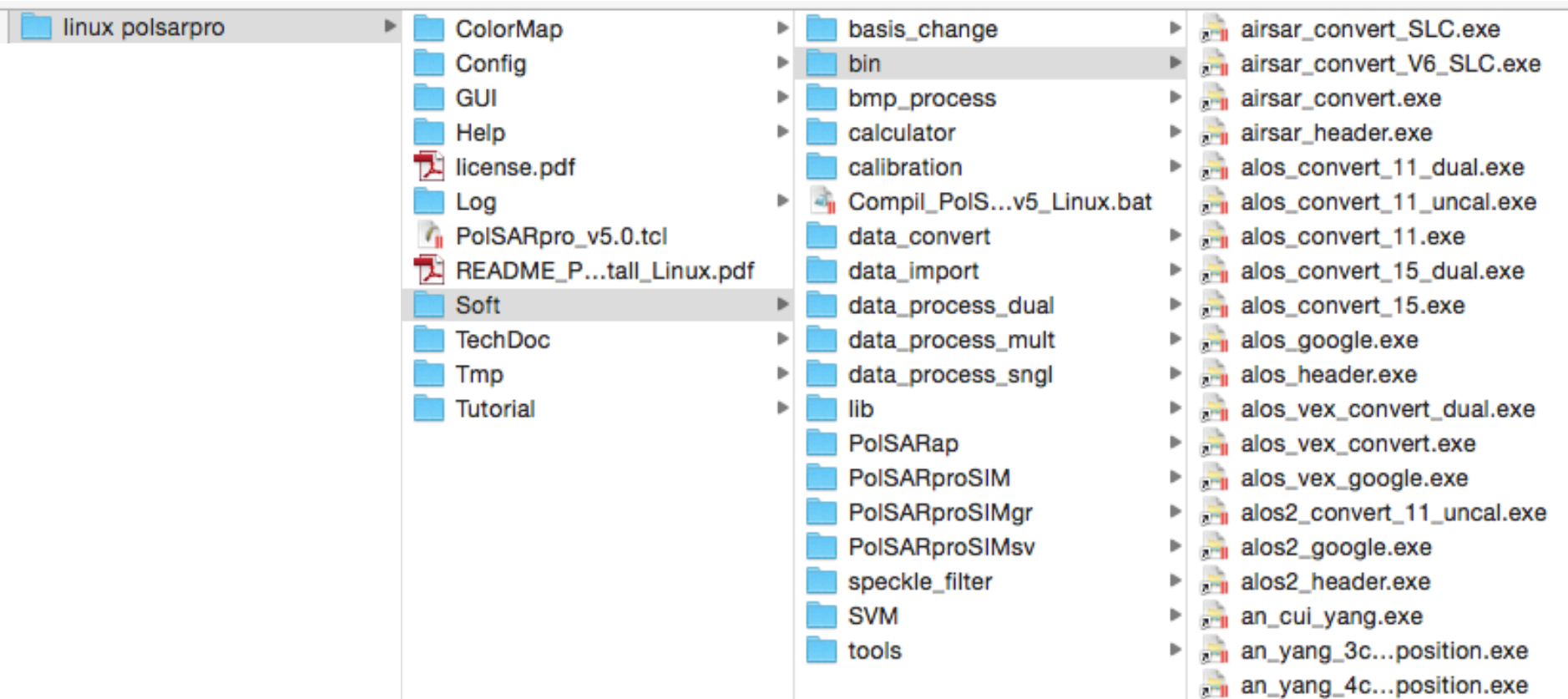
Now select how much of the image you want to extract, or just leave the existing values and process the entire image.



Change the values of init row, end row, init col, and end col if desired, Select T3 or C3, and then click 'run'

PoISARPro – Mac or linux

In the Soft directory are directories containing executable code. I made symbolic links to all of them in a new directory I called “bin”.



PoISARPro – Mac or linux

You can execute the routines on the command line in the terminal window.

This creates a bitmap file, in case you want to look at the data before subsetting it:

```
create_bmp_file.exe -if SMAP13_13500_14112_012_140814_L090HHHH_CX_01.grd  
-of smap13.bmp -ift float -oft real -clm gray -nc 20970 -ofr 0 -ofc 0 -fnr 16804 -fnc 20970 -mm 0 -min 0 -max .3
```

This makes data files containing the elements of the T3 coherency matrix (and subset if desired):

```
uavsar_convert_MLC.exe -hf SMAP13_13500_14112_012_140814_L090_CX_01.ann  
-if1 SMAP13_13500_14112_012_140814_L090HHHH_CX_01.grd  
-if2 SMAP13_13500_14112_012_140814_L090HHHV_CX_01.grd  
-if3 SMAP13_13500_14112_012_140814_L090HHVV_CX_01.grd  
-if4 SMAP13_13500_14112_012_140814_L090HVHV_CX_01.grd  
-if5 SMAP13_13500_14112_012_140814_L090HVVV_CX_01.grd  
-if6 SMAP13_13500_14112_012_140814_L090VVVV_CX_01.grd  
-od ./ -odf T3 -inr 16804 -inc 20970 -ofr 0 -ofc 0 -fnr 16804 -fnc 20970 -nlr 1 -nlc 1 -ssr 1 -ssc 1
```

This subsets the incidence angle or hgt (not sure how to do this in Windows version), but it always calls the output dem.bin:

```
uavsar_convert_dem.exe -hf SMAP13_13500_14112_012_140814_L090_CX_01.ann  
-if SMAP13_13500_14112_012_140814_L090_CX_01.inc  
-od ./ -inr 16804 -inc 20970 -ofr 0 -ofc 0 -fnr 16804 -fnc 20970 -nlr 1 -nlc 1 -ssr 1 -ssc 1
```

PoISARPro

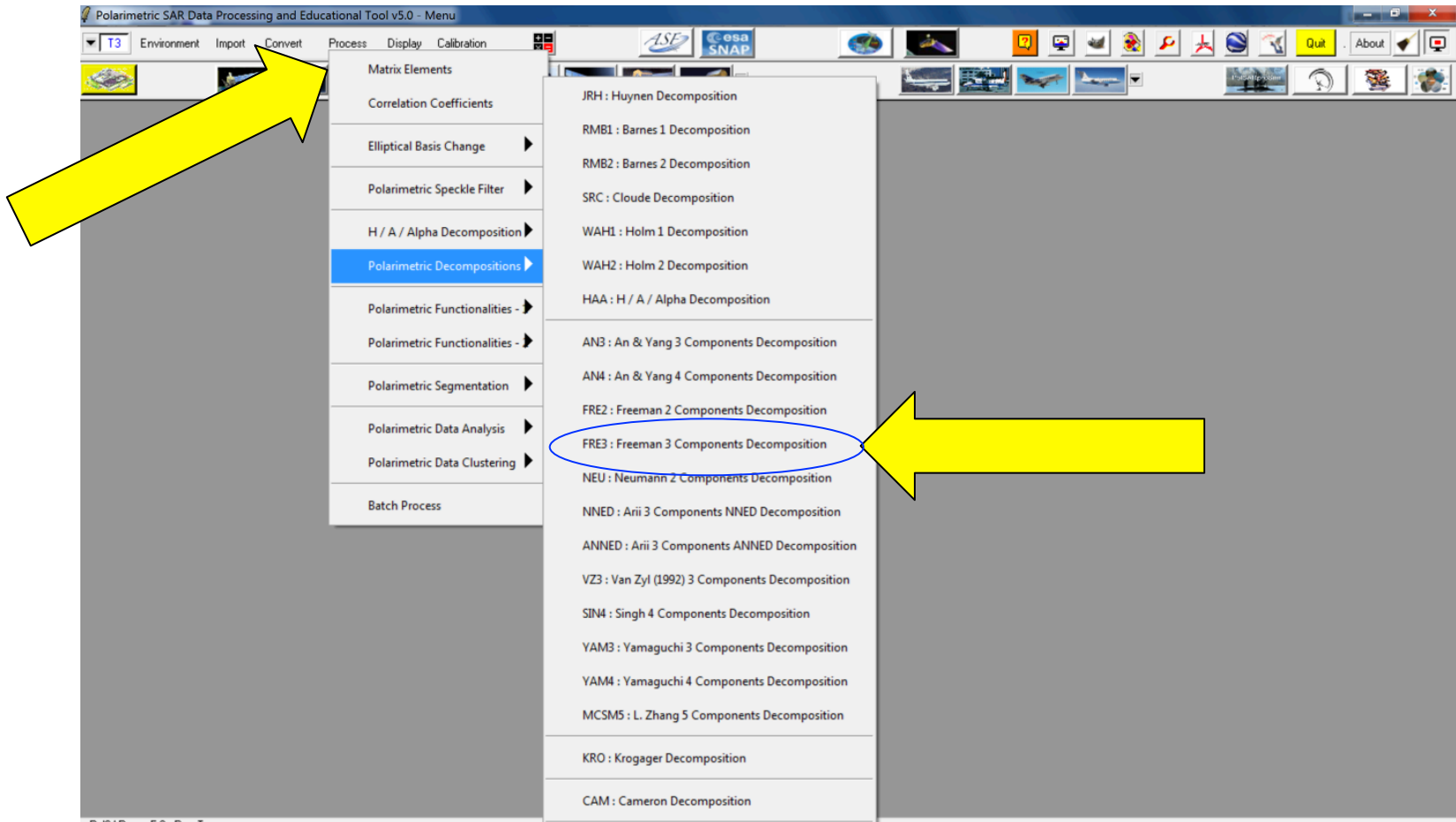
The files that are created (for the coherency matrix [T3] case):

T11.bin
T12_imag.bin
T12_real.bin
T13_imag.bin
T13_real.bin
T22.bin
T23_imag.bin
T23_real.bin
T33.bin

These floating-point binary files represent the elements of the coherency matrix determined from the input UAVSAR data files. The number of lines and samples depends on the sub-setting of the data (or are the same as the original input data if no sub-setting was desired).

PoISARPro - Windows

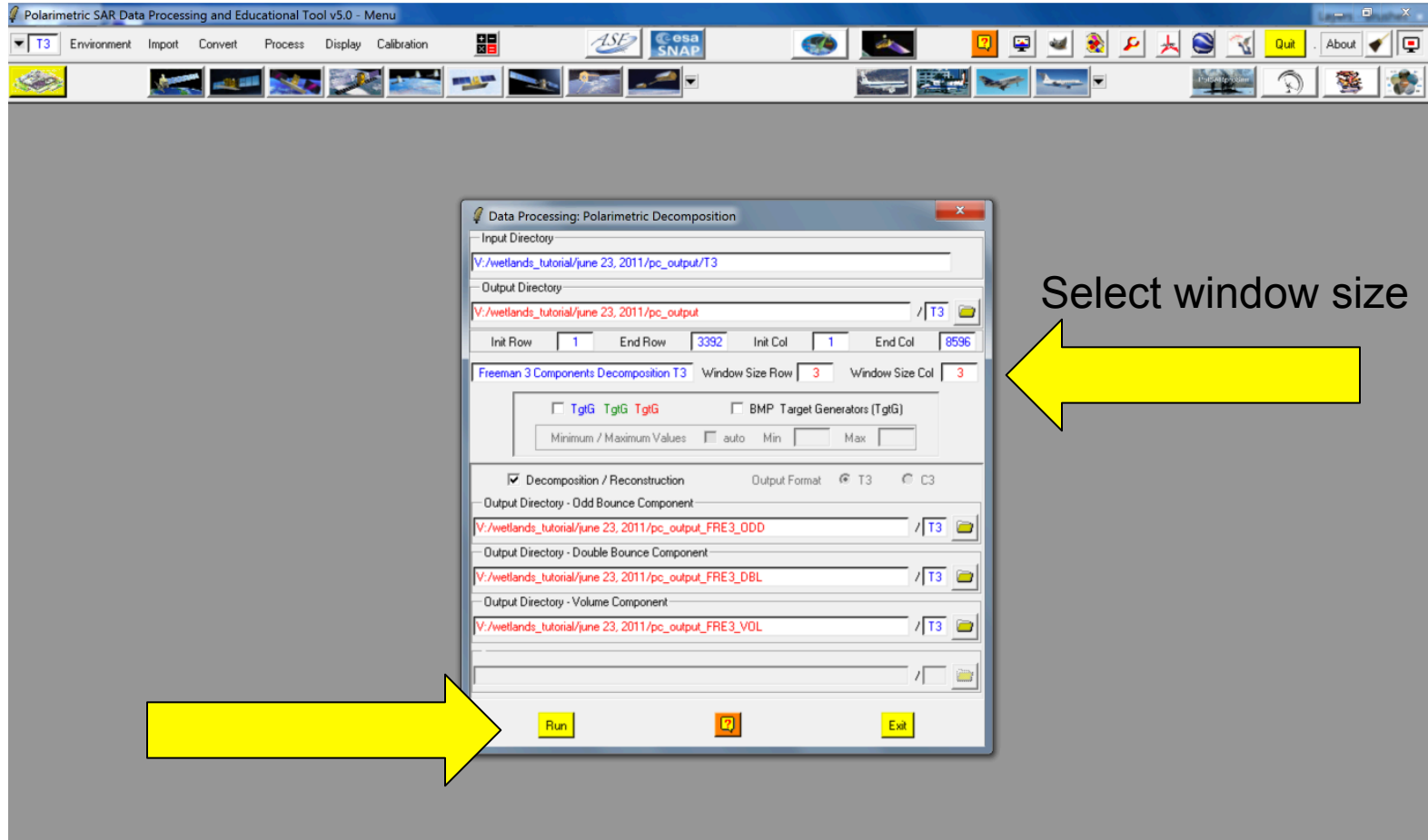
Now process the Freeman-Durden 3 components decomposition



Pull down the “process” menu, select “Polarimetric Decompositions”, then select “FRE3: Freeman 3 Components Decomposition”

PoISARPro - Windows

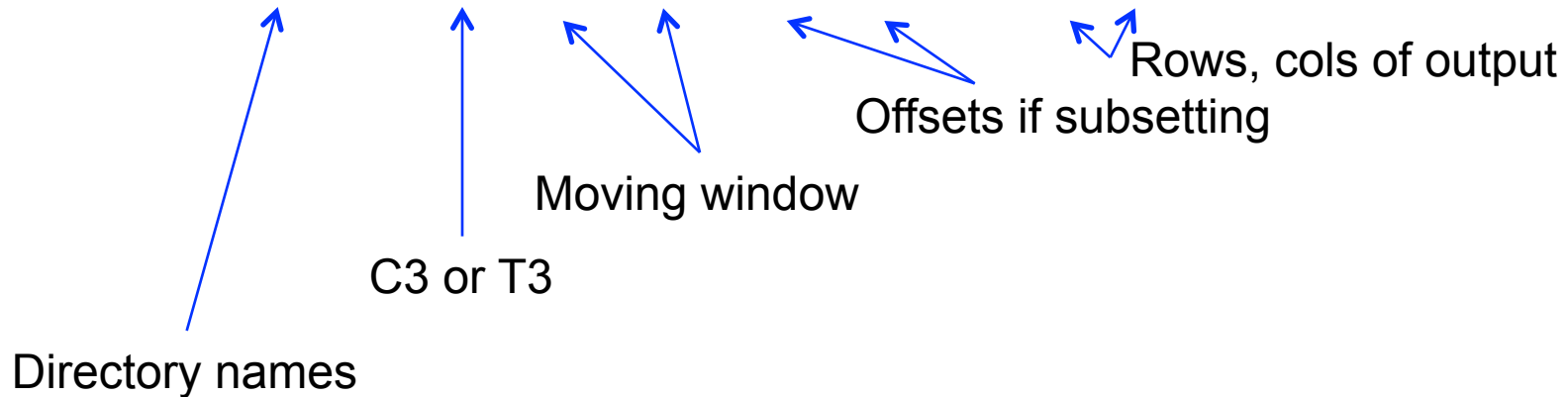
Click run to generate the results



PoISARPro – Mac or linux

On Mac on linux computers, the command line tool automatically finds the T3 or C3 binary files if you provide the directory

```
freeman_decomposition.exe -id ./ -od ./ -iodf T3 -nwr 5 -nwc 5 -ofr 1 -ofc 1 -fnr 16804 -fnc 20970
```



PoSARPro

The files created are: Freeman_Dbl.bin, Freeman_Odd.bin, and Freeman_Vol.bin

The .hdr file are envi header files with the correct number of lines and samples, but with the corner lat,lon for the original image (even if you have subset the data). These envi header files are generated by the windows version, but I am not sure how to generate them with the code library.

```
bash-3.2$ ls
Freeman_Dbl.bin          T12_imag.bin.hdr      T23_imag.bin.hdr
Freeman_Dbl.bin.hdr     T12_real.bin         T23_real.bin
Freeman_Odd.bin         T12_real.bin.hdr     T23_real.bin.hdr
Freeman_Odd.bin.hdr    T13_imag.bin         T33.bin
Freeman_Vol.bin        T13_imag.bin.hdr     T33.bin.hdr
Freeman_Vol.bin.hdr    T13_real.bin         config.txt
PauliRGB.bmp          T13_real.bin.hdr     config_mapinfo.txt
T11.bin               T22.bin              mask_valid_pixels.bin
T11.bin.hdr           T22.bin.hdr          mask_valid_pixels.bin.hdr
T12_imag.bin          T23_imag.bin         mask_valid_pixels.bmp
```

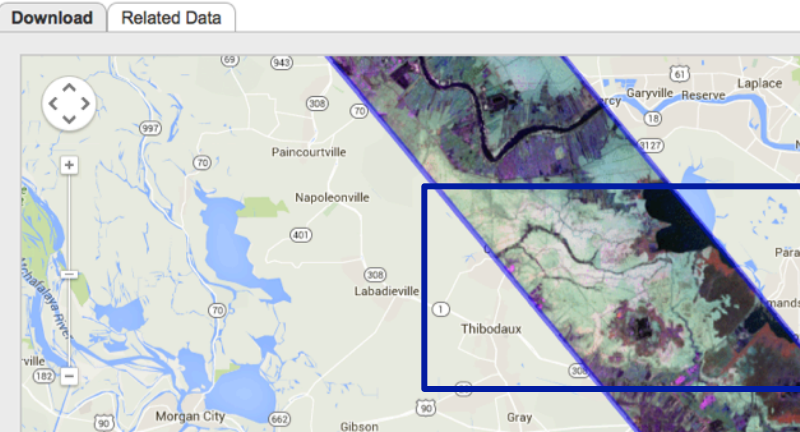
The .bin files are all floating point binary files that may be displayed.

Freeman_Dbl corresponds to P_d , Freeman_Odd.bin to P_s , and Freeman_Vol.bin to P_v where:

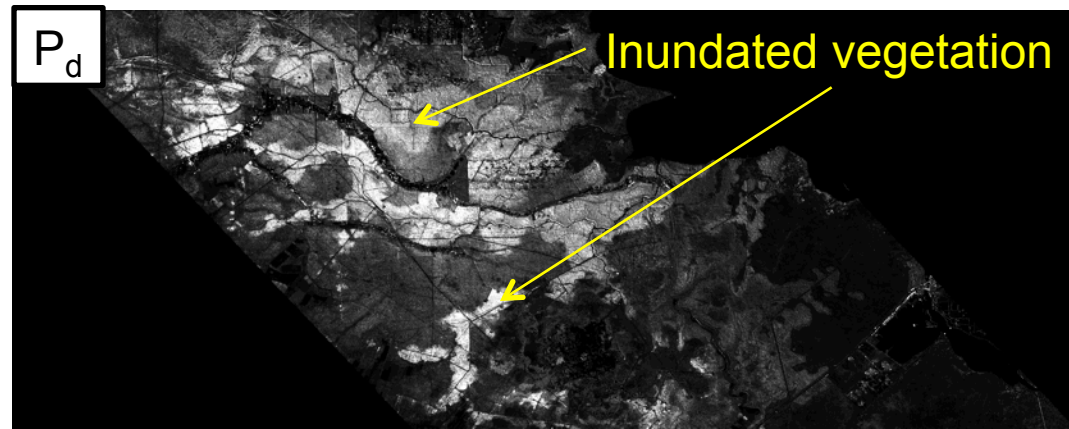
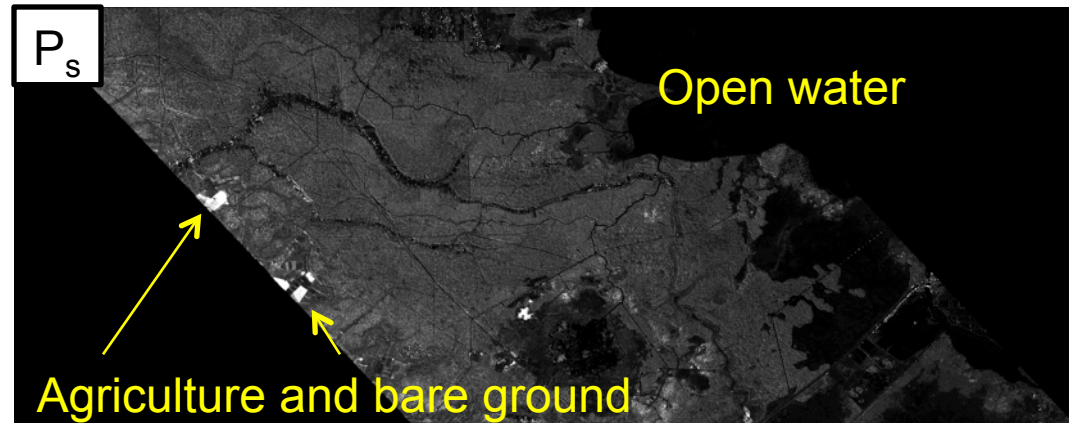
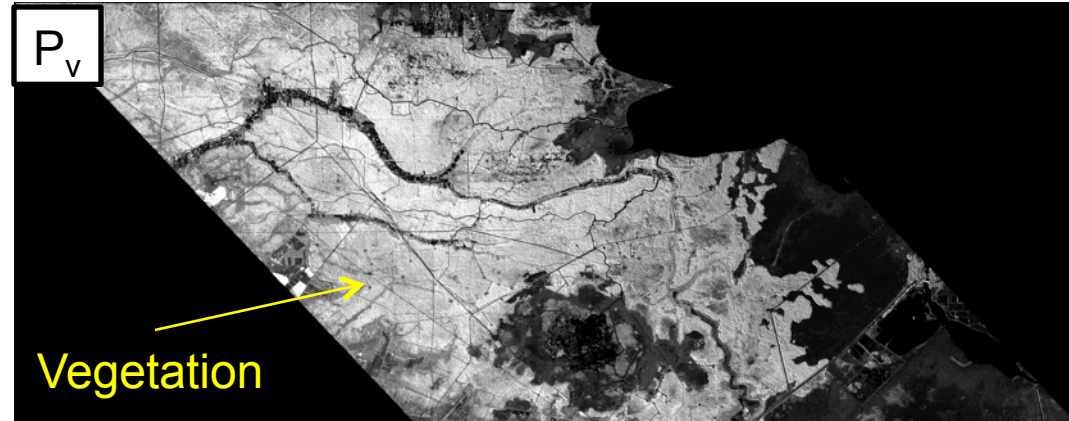
$$SPAN = |S_{hh}|^2 + |S_{vv}|^2 + 2|S_{hv}|^2 = P_v + P_d + P_s$$

Examples- UAVSAR data collected over the Louisiana coast

June 2011



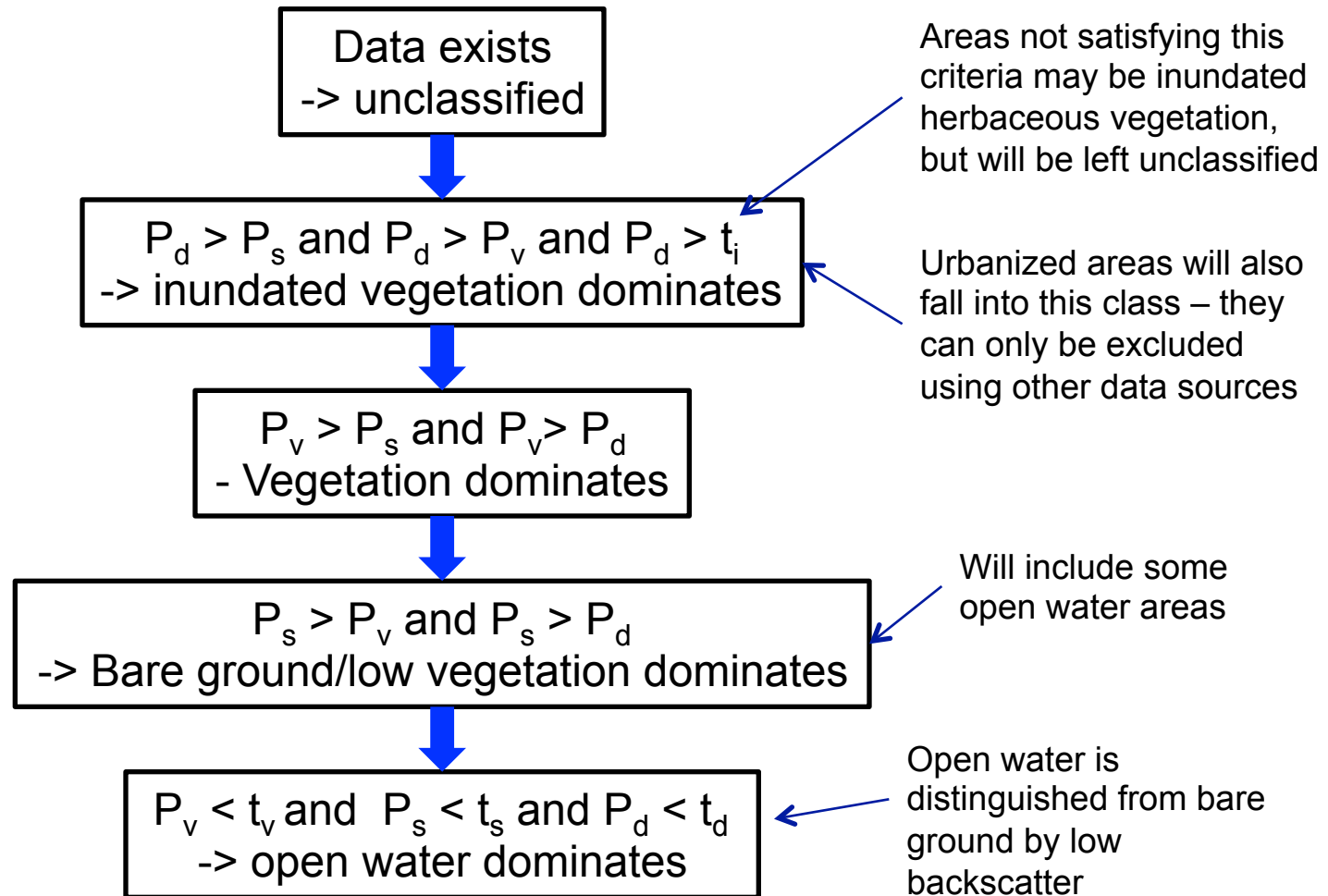
Low res KML from download page
Color composite (HH-red, HV-green, VV-blue)



Pixel values ranging from 0 to 0.5

Classification

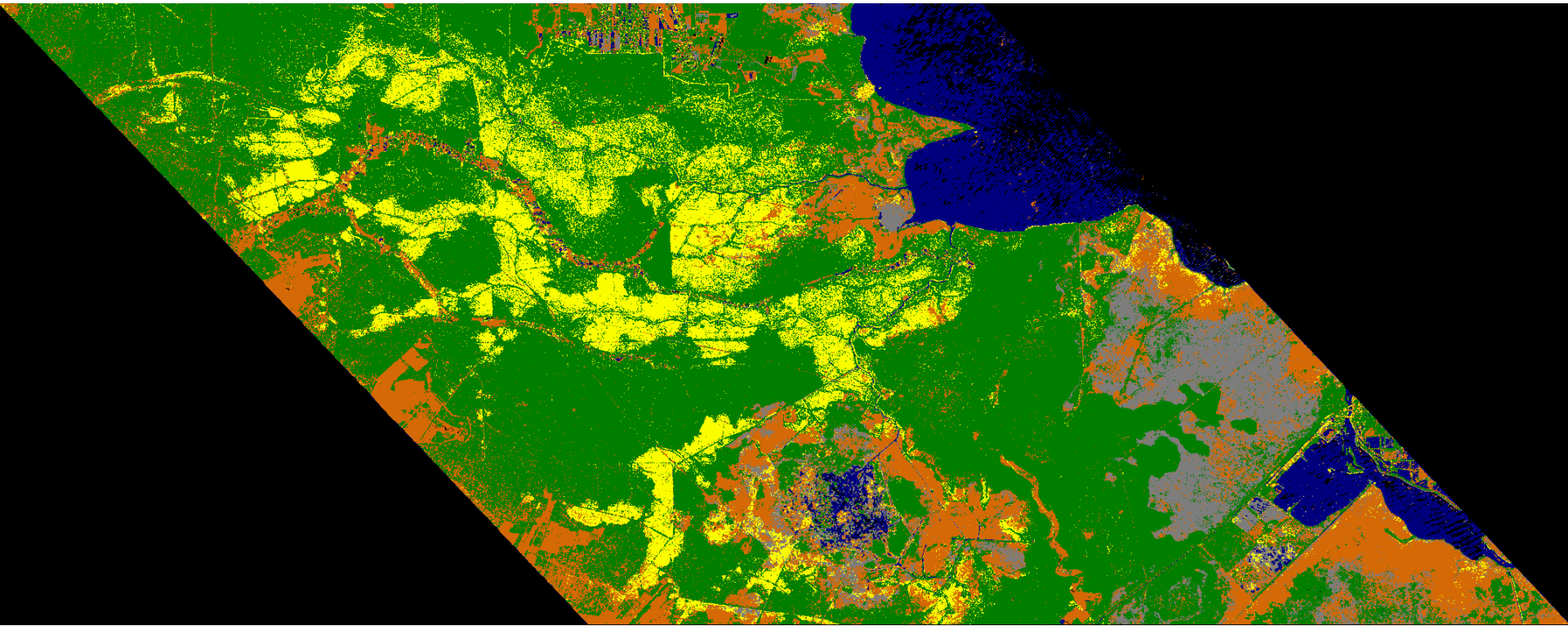
For this step, you might need to write your own code, or use software that lets you input data and process the data based on the input values.









t_i , t_v , t_s , and t_d are empirical thresholds
 $t_i=0.1$, $t_v=0.01$, $t_s=0.02$, and $t_d=0.01$

Classification

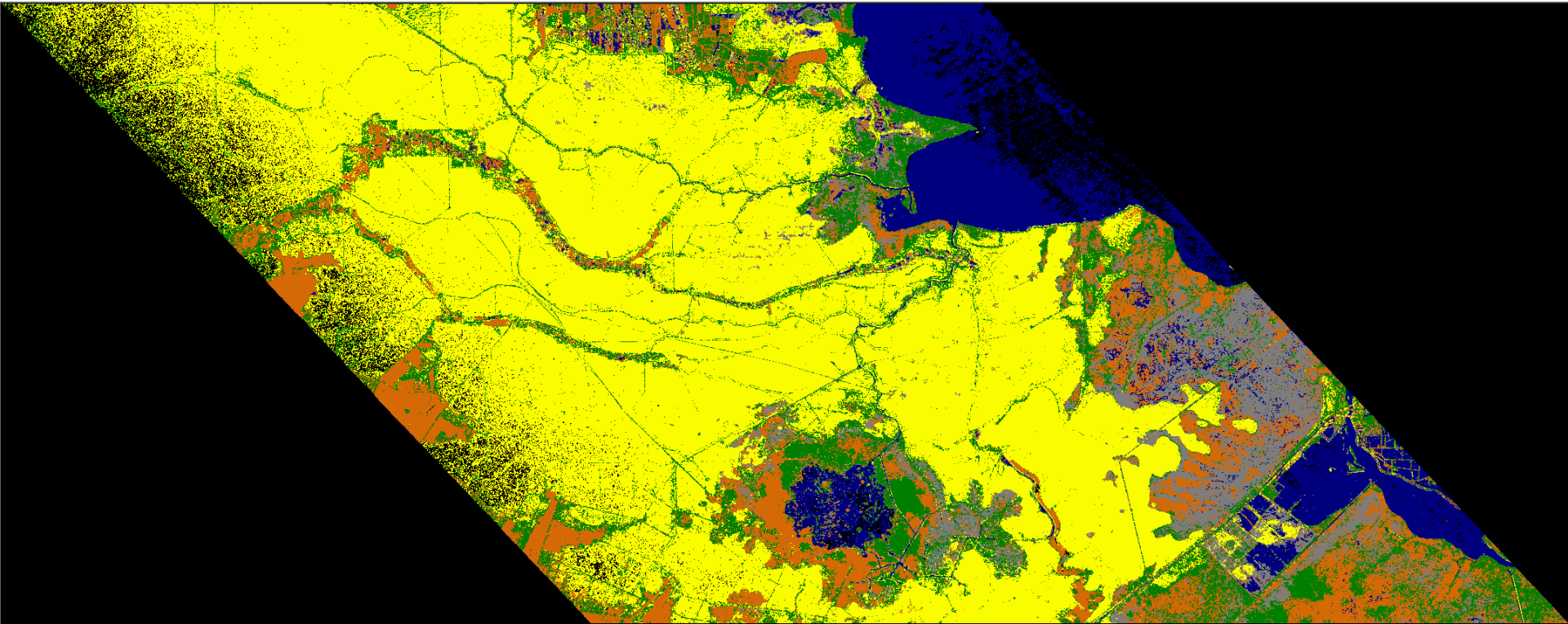
June 2011









-  bare grounds/fields
-  inundated woody vegetation
-  open water
-  shrubs or forest
-  unclassified
-  no data or below noise

Classification

January 2010

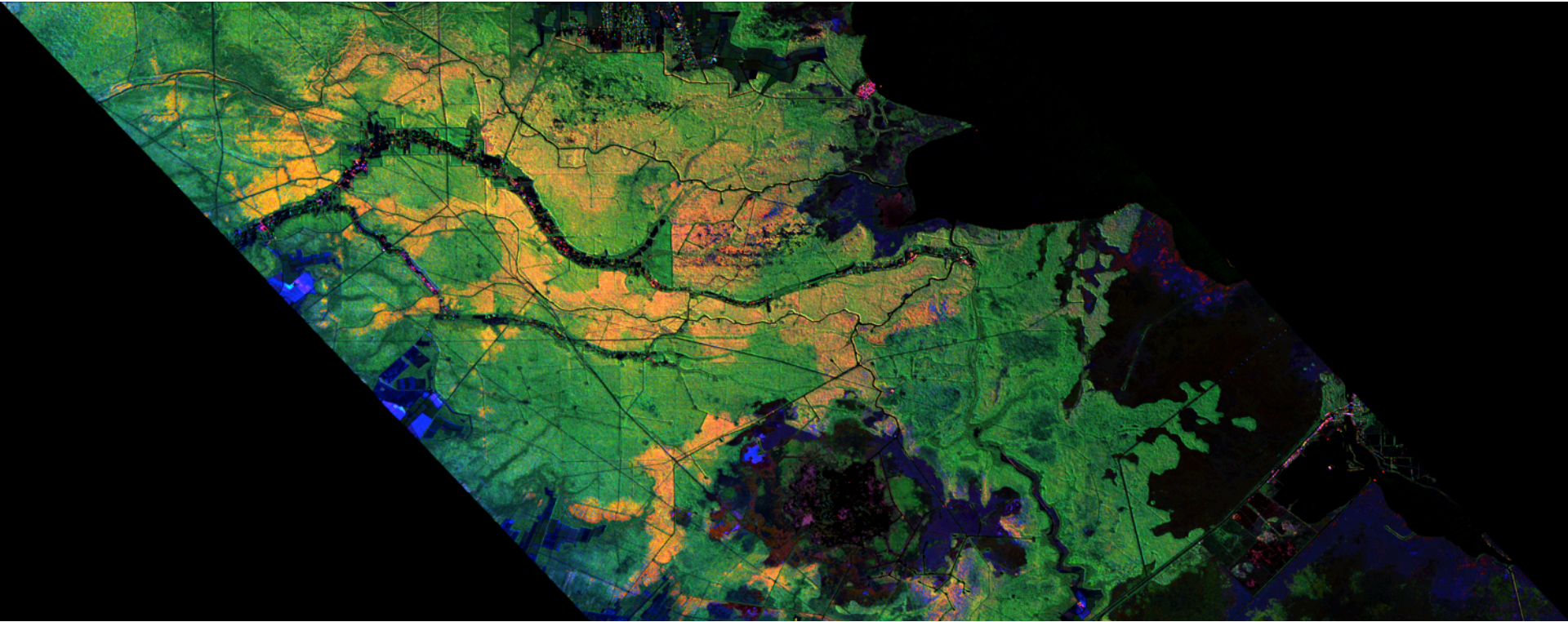


-  bare grounds/fields
-  inundated woody vegetation
-  open water
-  shrubs or forest
-  unclassified
-  no data or below noise

Color composite

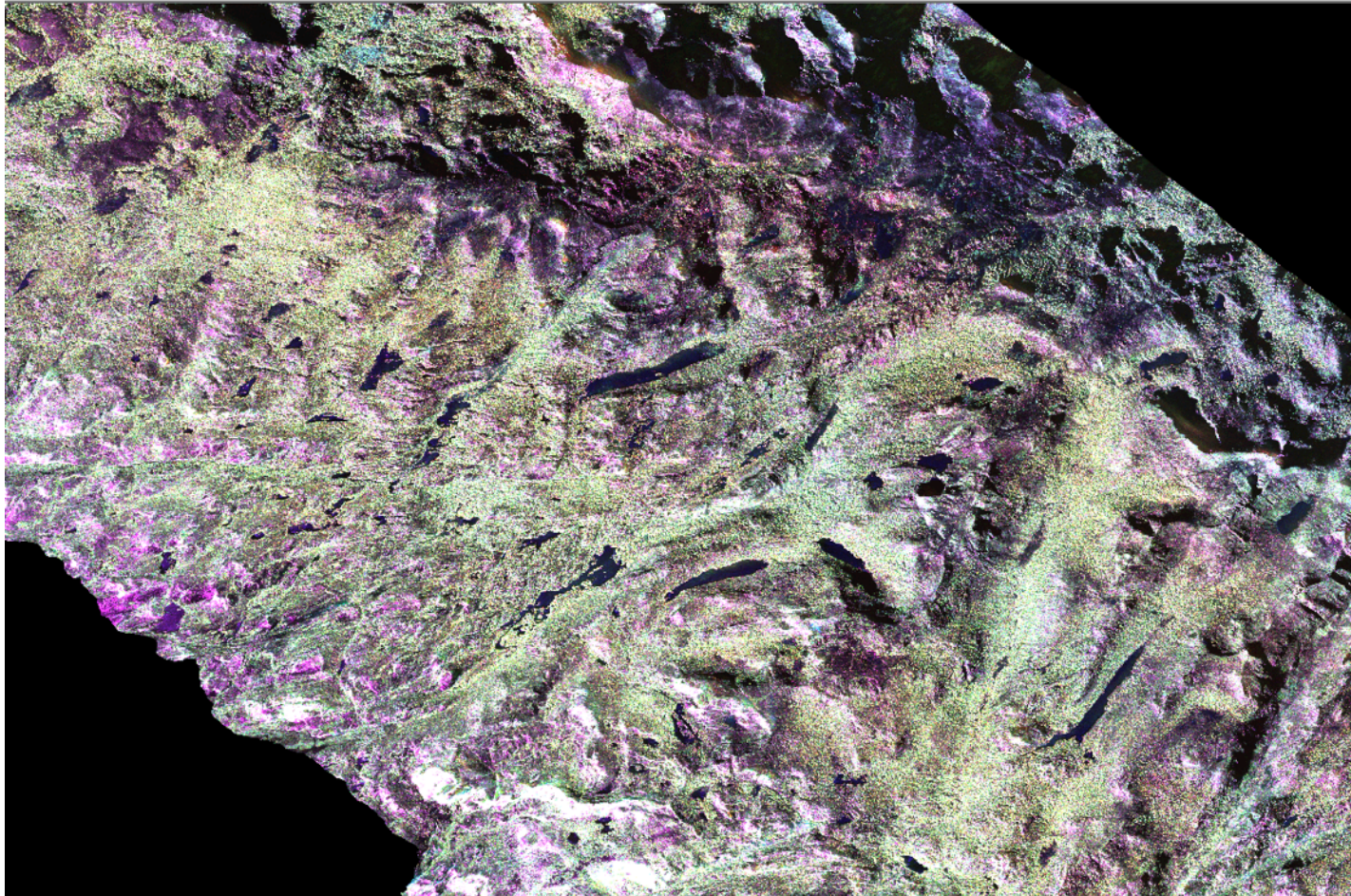
If you can't classify the data this way, you can make a color composite of P_d (red), P_v (green), and P_s (blue), and visually interpret the data

June 2011



Classification

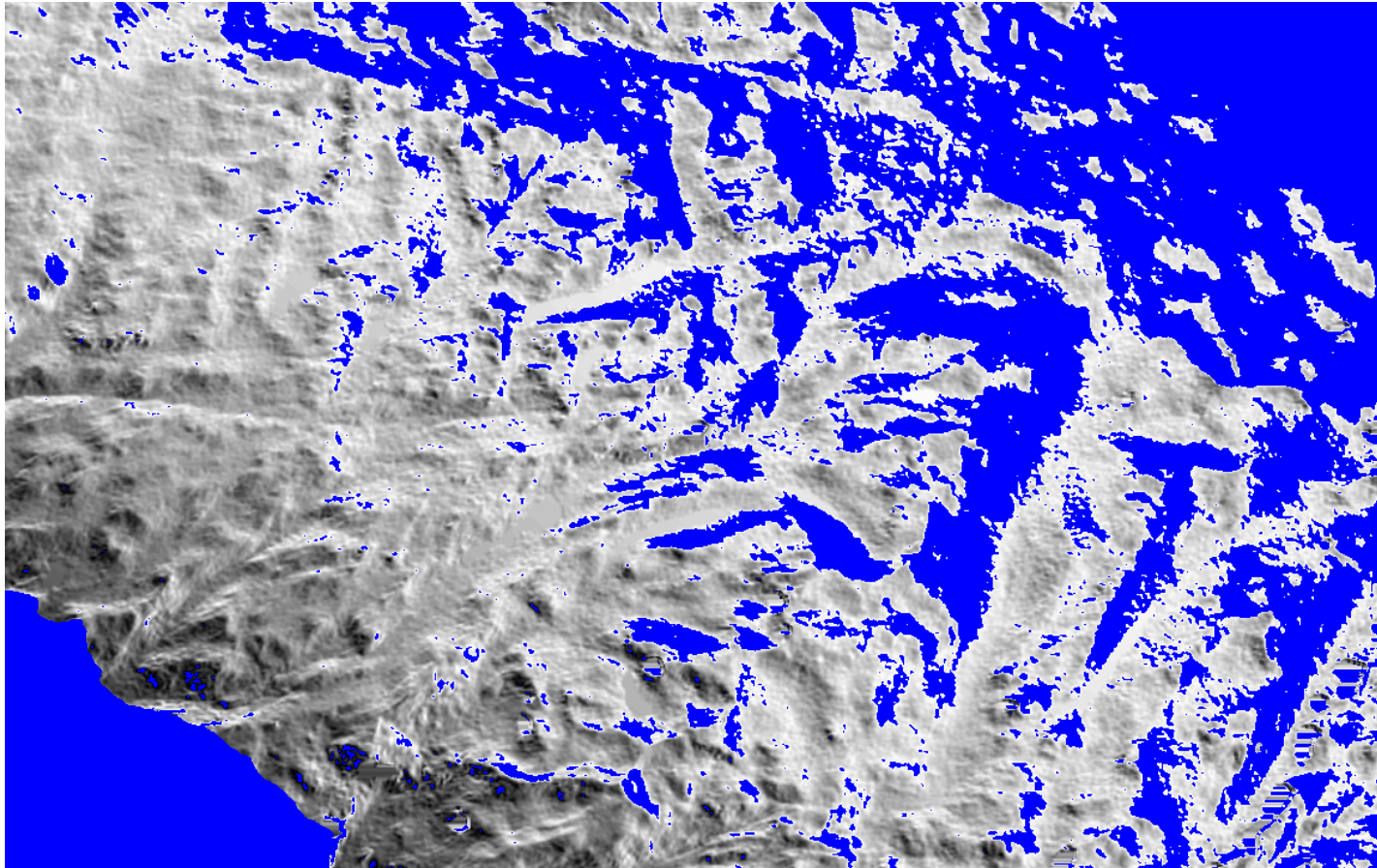
What if we select an image with a lot of topography, where inundation is not the dominant feature of the image? We can use the incidence angle that is distributed with the UAVSAR data (based on the SRTM DEM) to help remove false detections at very small and large incidence angles.



Near Yosemite, August 14, 2014.

Classification

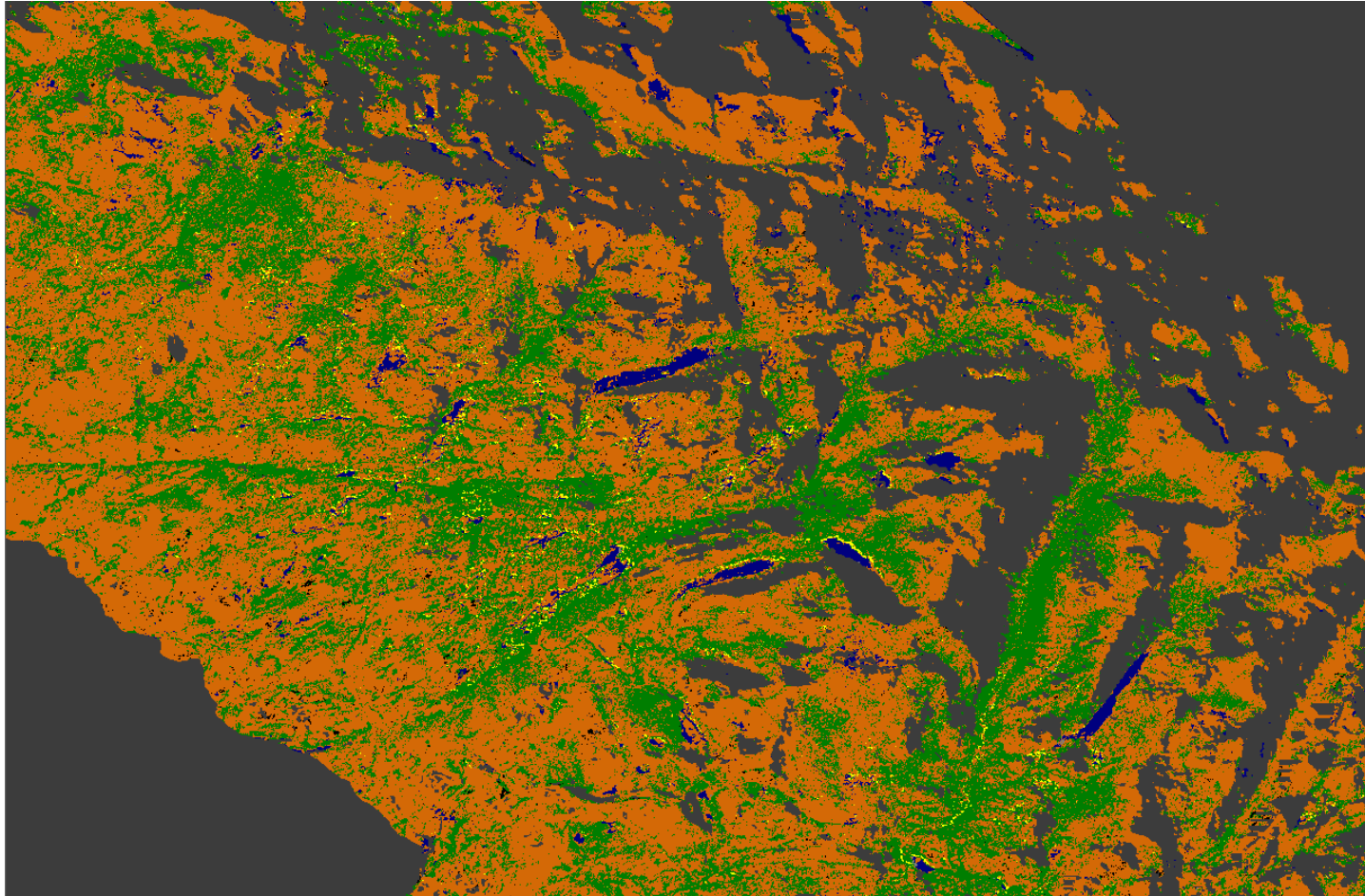
Wetlands are generally pretty flat areas, but nearby areas with topography can cause confusion. The incidence angle can be used to mask areas imaged at very large or small incidence angles. Here, we mask incidence angles greater than 63 degrees and less than 9 degrees. These are areas that are more likely to be in error.



Near Yosemite, August 14, 2014.

Classification

Classification from Freeman-Durden polarimetric decomposition using the same parameters as those used for louisiana, plus masking based on incidence angle



Near Yosemite, August 14, 2014.

Thank you

This was written at the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.