Processing of Multispectral Imagery (MSI) for Cultural Heritage using ENVI

Roger L. Easton, Jr.
Chester F. Carlson Center for Imaging Science
Rochester Institute of Technology
Rochester, New York, USA, 14623-5604
easton@cis.rit.edu
1-585-475-5969

Goal of MSI Image Processing

- Construct “combinations” of input bands that enhance the feature(s) of interest
- Combinations may be:
  - Different bands in RGB-color image (“pseudocolor rendering”)
  - Arithmetic weighted sums or differences
    - Sums attenuate features that change over bands (“integrals”), and therefore enhance features that are constant over bands (“derivatives”)
    - Differences attenuate features that are constant over bands, enhance features that vary over bands

Combinations may be determined by:

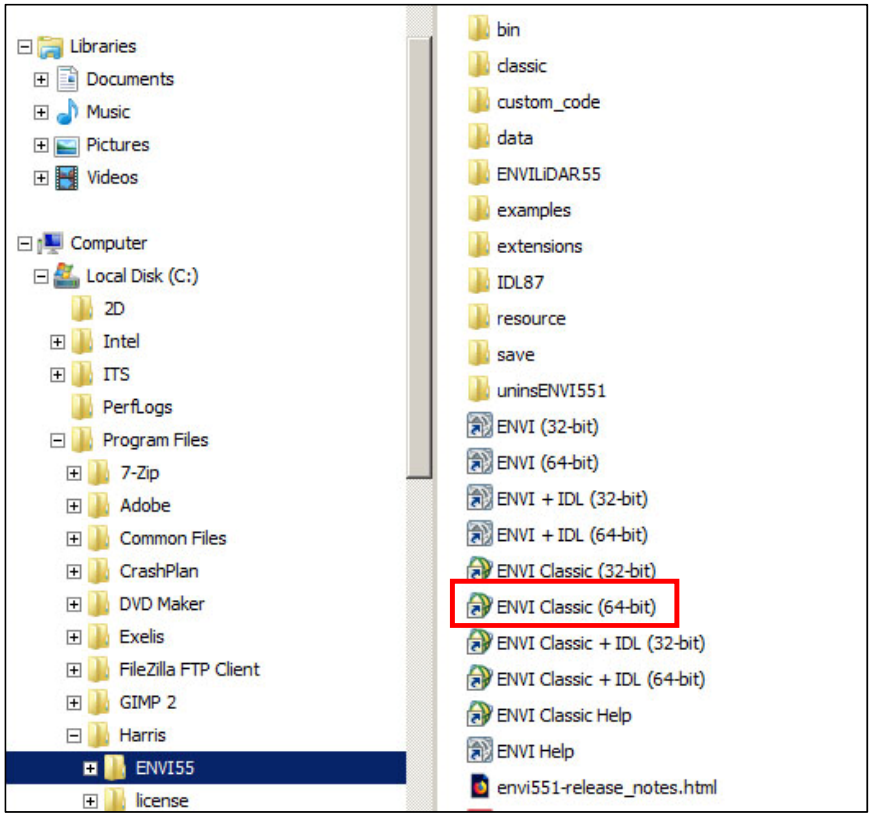
- Trial and error
- Statistical calculations, customized for each leaf

Image Processing Software Tools

- ENVI™, now by L3HARRIS GEOSPATIAL SOLUTIONS
- Adobe Photoshop™
- Matlab
  - https://www.mathworks.com/products/matlab.html
- ImageJ
  - https://imagej.nih.gov/ij/
- Hoku
  - Keith Knox (knox@cis.rit.edu)

Image Processing in ENVI™: Select GUI

- Shortcuts are listed in ENVI folder
- We're using "ENVI Classic"



ENVI™ “Classic” GUI

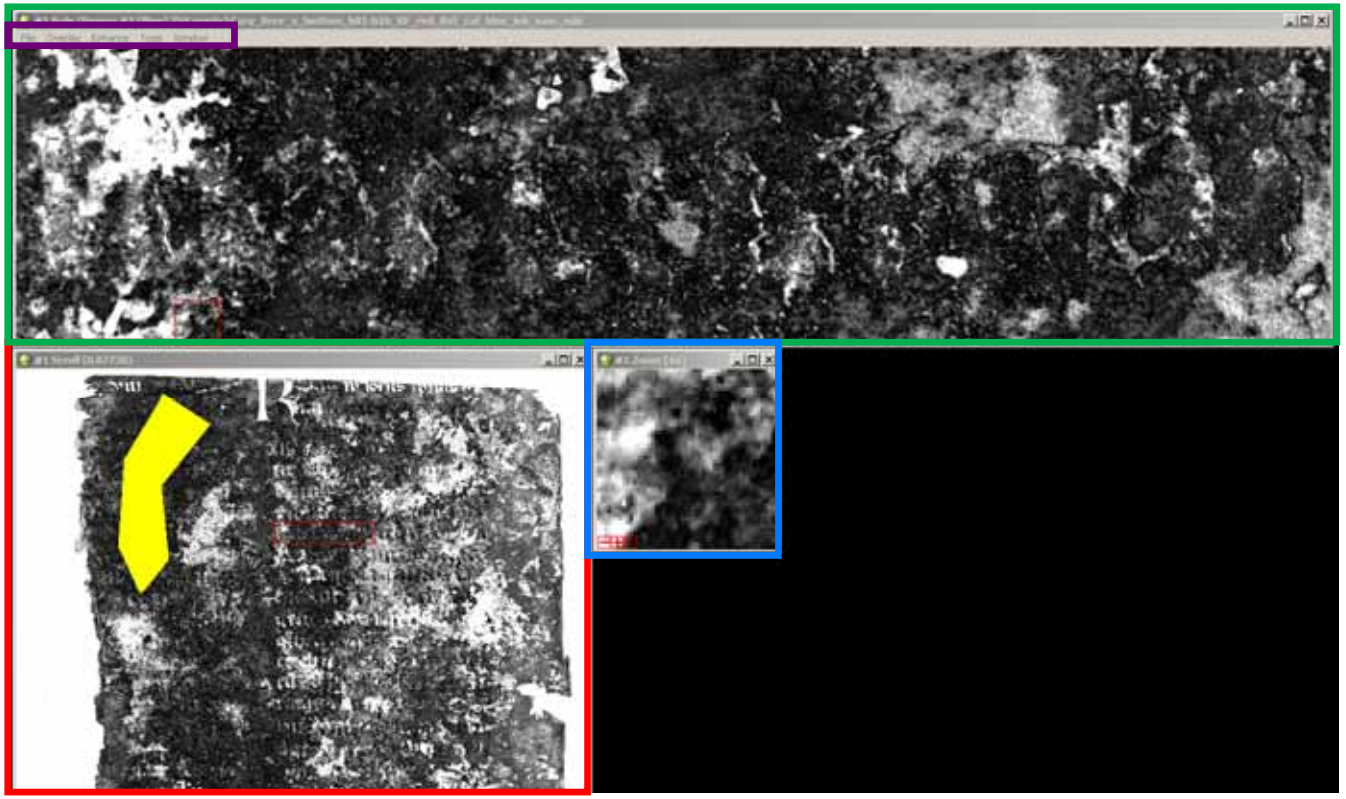
- Main Menu, with pulldown submenus

- Submenus of most importance to us:
  - File
  - Basic Tools
    - Spectral Math
    - Region of Interest
    - Preprocessing
  - Transform
    - Principal Components
    - Independent Components
    - MNF
  - Filter
    - Convolutions and Morphology
  - Spectrum
    - SAM Target Finder with BandMax

Image Display in ENVI™ “Classic” GUI

- 3 Image “Windows,” which may be rescaled as desired
  - “Scroll” (full-frame image scaled to fit)
  - “Image” (subset of “Scroll,” **with secondary menu bar)**
  - “Zoom” (subset of “Image”)

- Secondary Menu Bar
  - File
    - save image as TIFF
  - Enhance
    - 18 options to change rendering
  - Tools
    - Profiles
    - Color Mapping
    - Cursor Location/Value



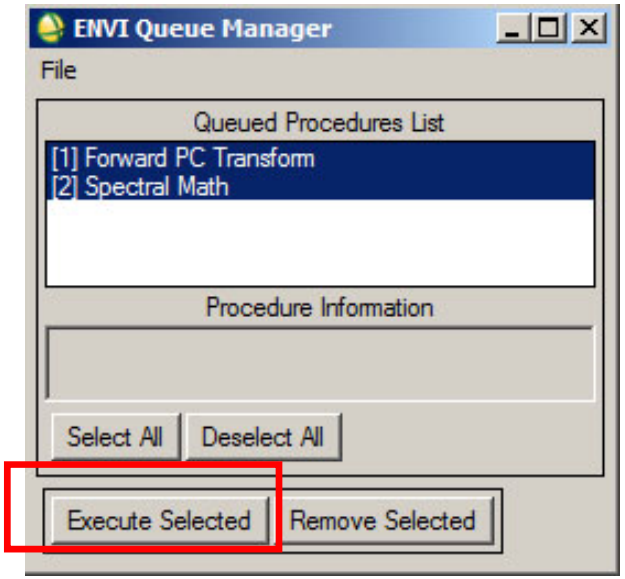
Sequence of Tasks in ENVI™

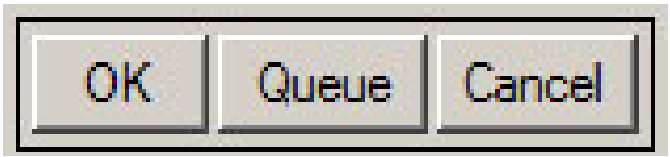
1. Create image cube(s) from collected data, create data format $f[n,m,\lambda_p]$
   - May be useful to create different image cubes for reflective, fluorescence, and transmissive images
   - Calibrated differently and may be combined subsequently for processing that includes images from multiple collection modes.
2. Edit image header to include filenames **AND** wavelengths
3. Use reference standards to calibrate gray values
4. Display image(s), using various rendering options to look for features of interest and/or select bands that show features most clearly or prominently.
   - ***ENVI*** can render “black & white” or 3-band “color” or “pseudocolor”
5. Export images to TIFF or JPEG format (if needed).
6. Process data using one or more built-in programs
   - “Spectral Angle Mapping” (SAM)
   - “Principal Component Analysis” (PCA)
   - “Independent Component Analysis” (ICA)
7. Render and export processed images as 8-bit TIFF or JPEG (monochrome) or as 24-bit RGB or pseudocolor.
8. Loop to 6!!

Sidebar: ENVI™ Queue Manager

- Means to set up batches of multiple operations
- **Cannot** set up “sequential” batches
  - e.g., output of one operation in “Queue” becomes input for next operation

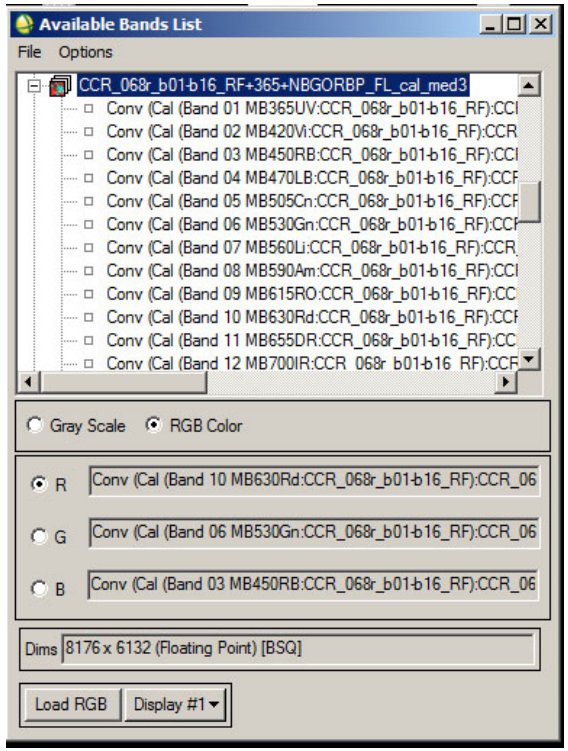
“File” → “ENVI Queue Manager”





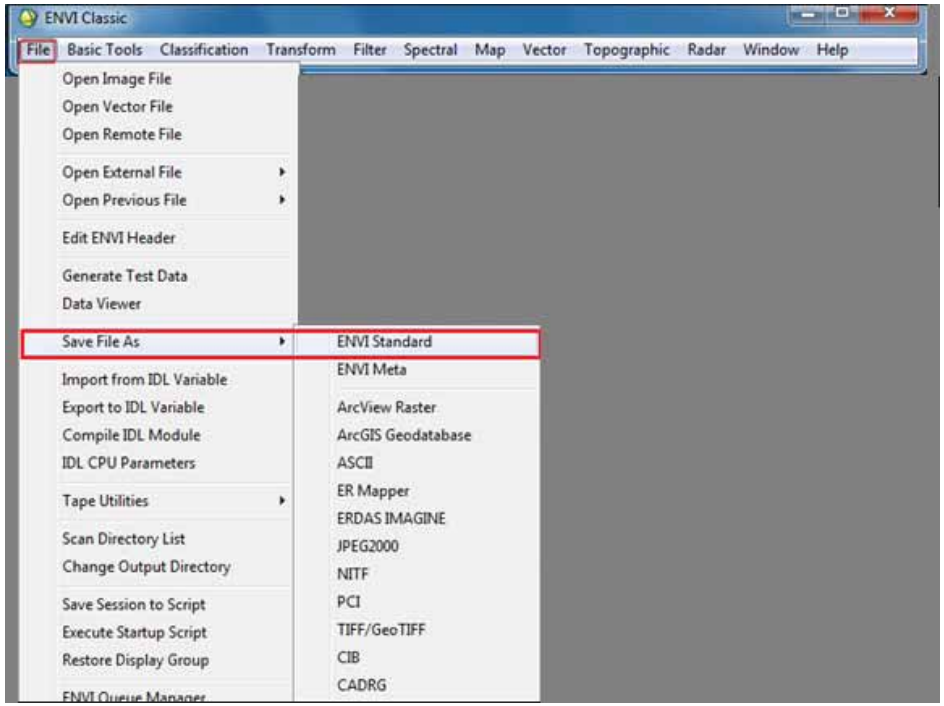
Task #1: Make Image "Cube"

- **File → Open Image File**
- Select the image bands to be included in the cube and then click: **Open**
- Files will show up in window ***Available Bands List***.

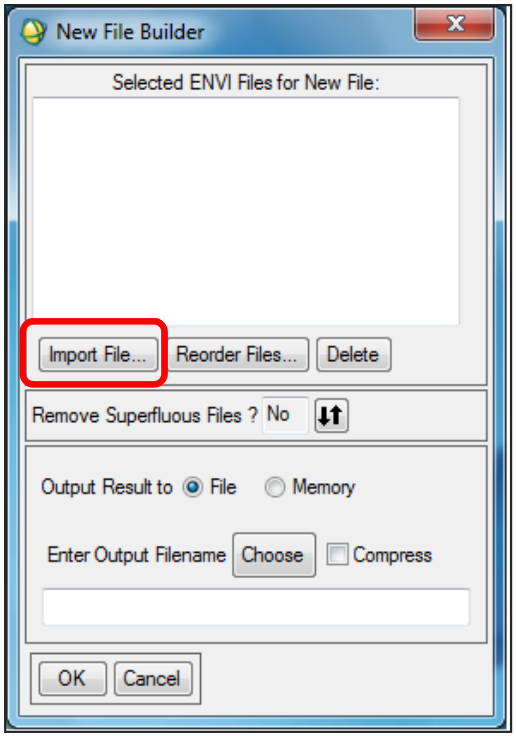


Saving Cube

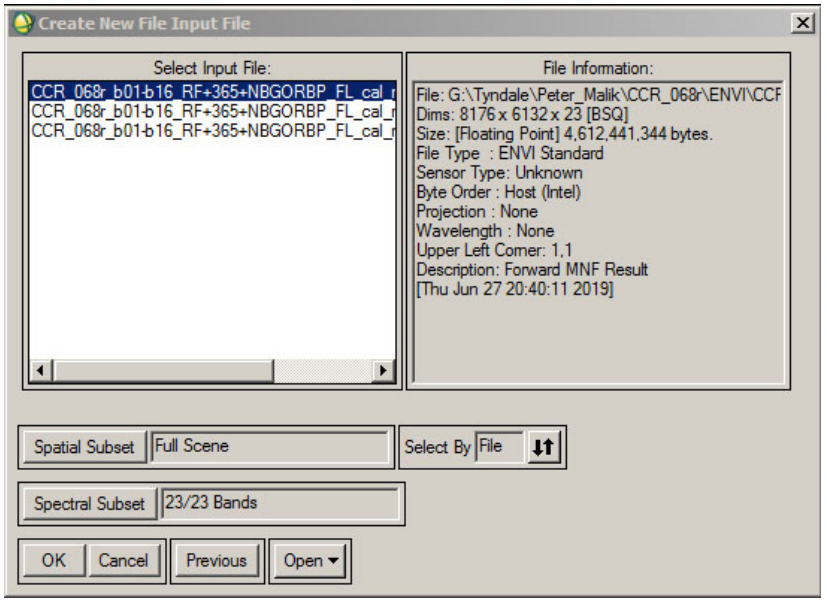
- **File → Save File As → *ENVI* Standard**



- *New File Builder* will be displayed, click on: **Import File**

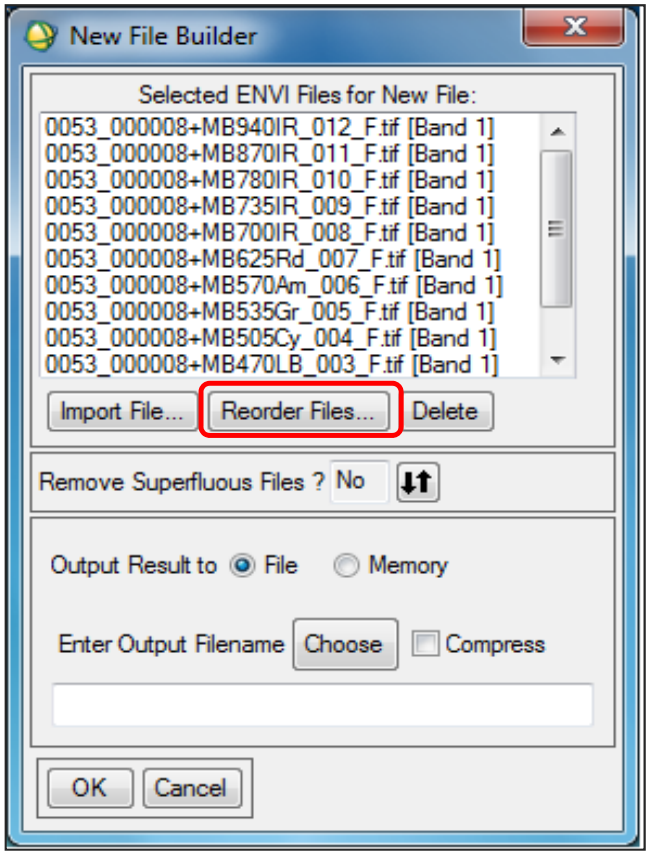


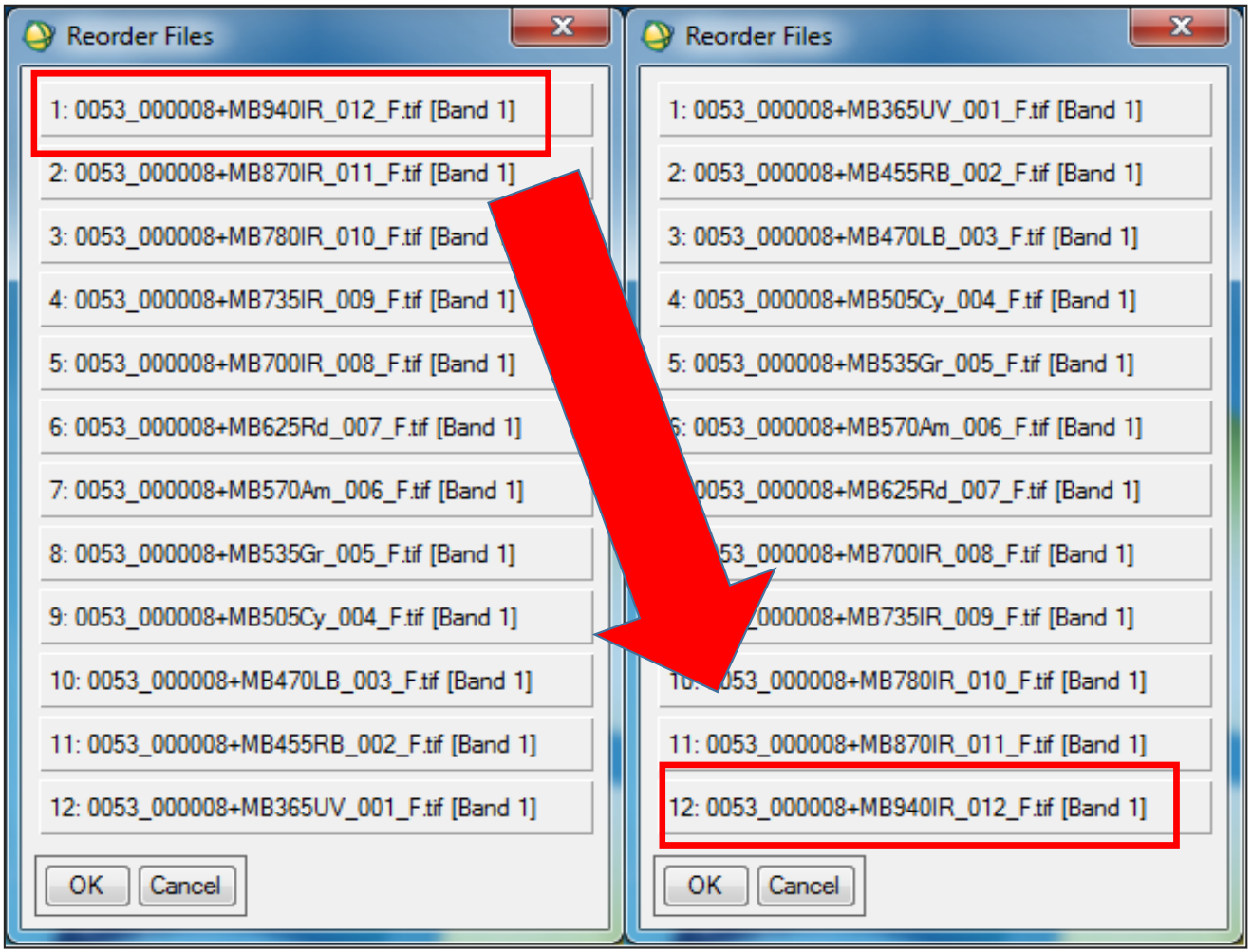
- *Create New File Input File* window
  - Click to select files to include in the image cube
  - If all files on list need be selected, click on first name, hold down SHIFT key when clicking last name
- click on: **OK**



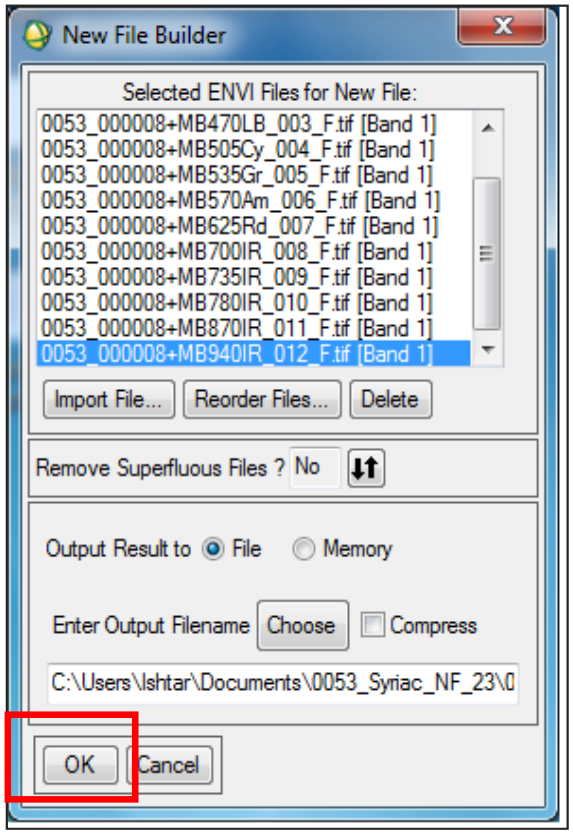
To Reorder File Names in *Builder*:

- Click on: **Reorder Files**
- Click and drag **OR click “center” mouse button (or wheel)** to reverse sequence
- Click **OK**




Reorder Files
1: 0053_000008+MB940IR_012_F.tif [Band 1]
2: 0053_000008+MB870IR_011_F.tif [Band 1]
3: 0053_000008+MB780IR_010_F.tif [Band
4: 0053_000008+MB735IR_009_F.tif [Band 1]
5: 0053_000008+MB700IR_008_F.tif [Band 1]
6: 0053_000008+MB625Rd_007_F.tif [Band 1]
7: 0053_000008+MB570Am_006_F.tif [Band 1]
8: 0053_000008+MB535Gr_005_F.tif [Band 1]
9: 0053_000008+MB505Cy_004_F.tif [Band 1]
10: 0053_000008+MB470LB_003_F.tif [Band 1]
11: 0053_000008+MB455RB_002_F.tif [Band 1]
12: 0053_000008+MB365UV_001_F.tif [Band 1]
OK
Cancel
Reorder Files
1: 0053_000008+MB365UV_001_F.tif [Band 1]
2: 0053_000008+MB455RB_002_F.tif [Band 1]
3: 0053_000008+MB470LB_003_F.tif [Band 1]
4: 0053_000008+MB505Cy_004_F.tif [Band 1]
5: 0053_000008+MB535Gr_005_F.tif [Band 1]
6: 0053_000008+MB570Am_006_F.tif [Band 1]
0053_000008+MB625Rd_007_F.tif [Band 1]
53_000008+MB700IR_008_F.tif [Band 1]
000008+MB735IR_009_F.tif [Band 1]
053_000008+MB780IR_010_F.tif [Band 1]
11: 0053_000008+MB870IR_011_F.tif [Band 1]
12: 0053_000008+MB940IR_012_F.tif [Band 1]
OK
Cancel

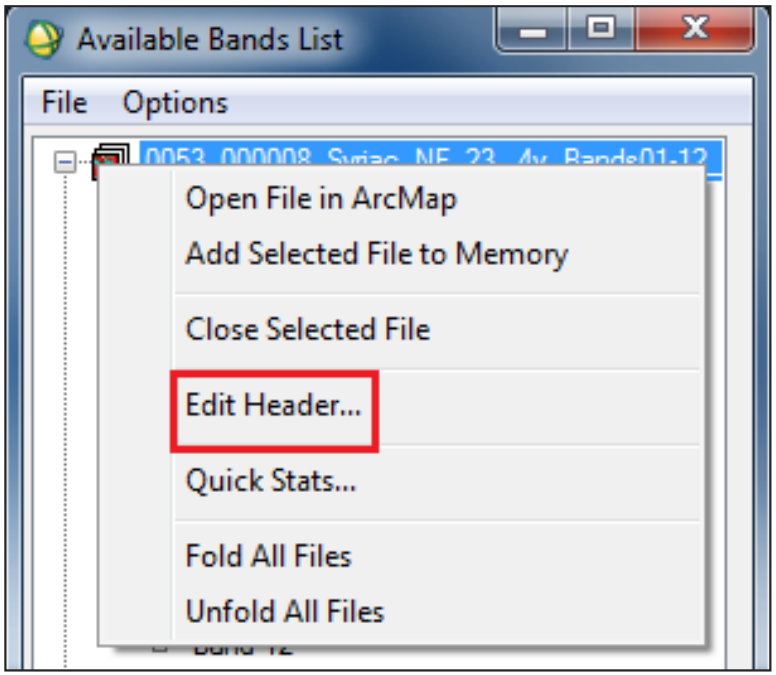
- ***ENVI*** returns to *New File Builder* window
- In section *Enter Output Filename*, type or choose desired **filename**
  - I often use shelfmark + leaf number + suffix indicating nature of data ("-RF" for "reflective, "-FL" for fluorescence, or "-TX" for transmissive)
  - I generally choose **NO** filename extension
- click: **Open**
- To save new cube file click: **OK**



- *Create New File* will be displayed
  - progress bar will give rough estimate of how much time is required for the process to finish
    - (HINT: it's longer than you want it to be) ;-)

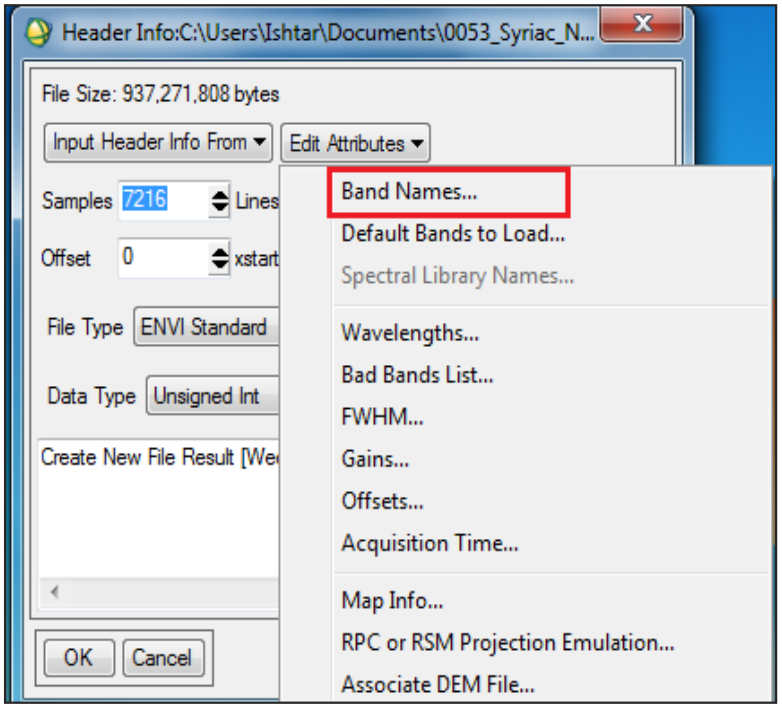
Edit Image Header (band names + wavelengths)

- In the window *Available Bands List* right click on name of new cube to display directory
- select: **Edit Header**



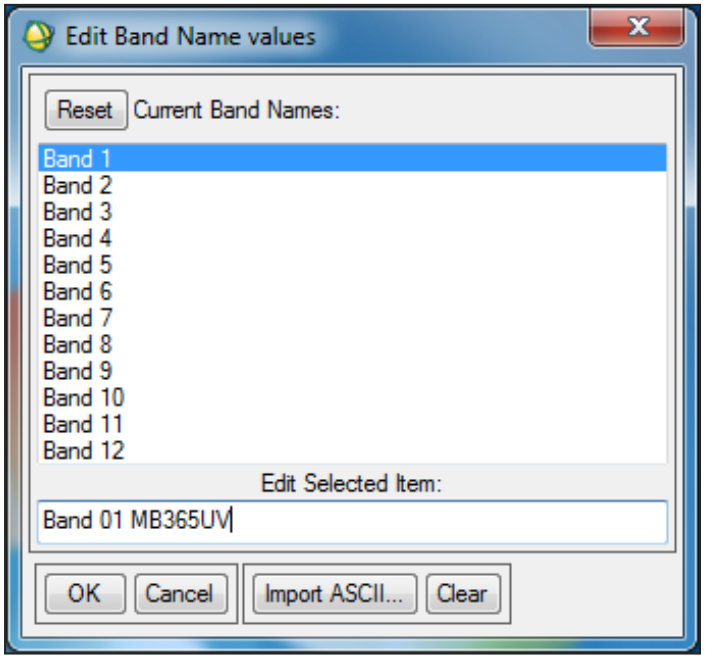
window ***Header Info*** is displayed

- **Edit attributes → Band Names**

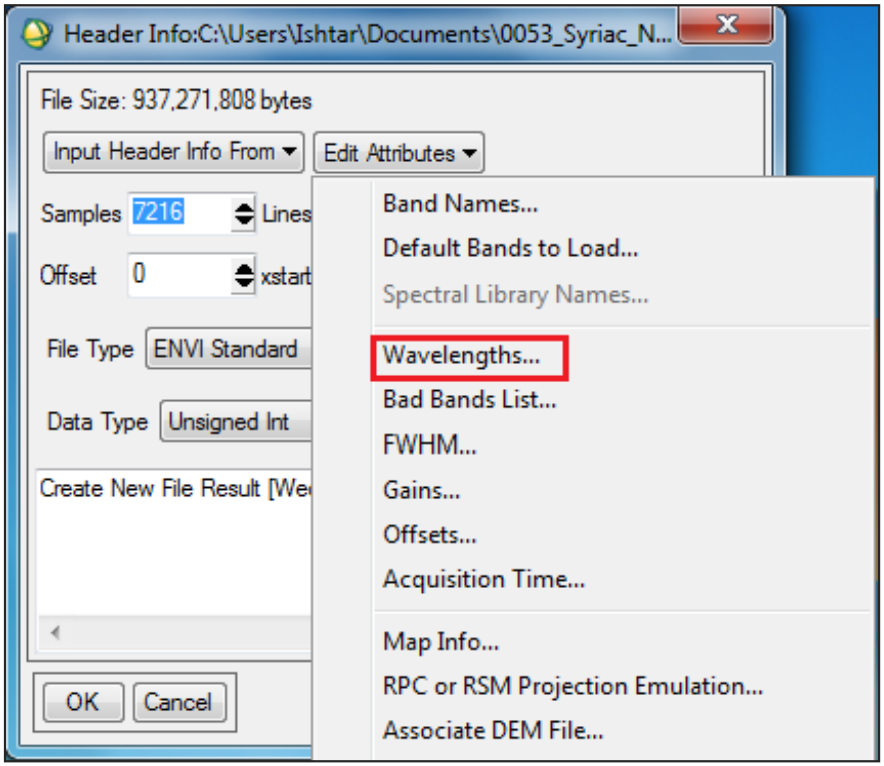


window ***Edit Band Name values*** is displayed

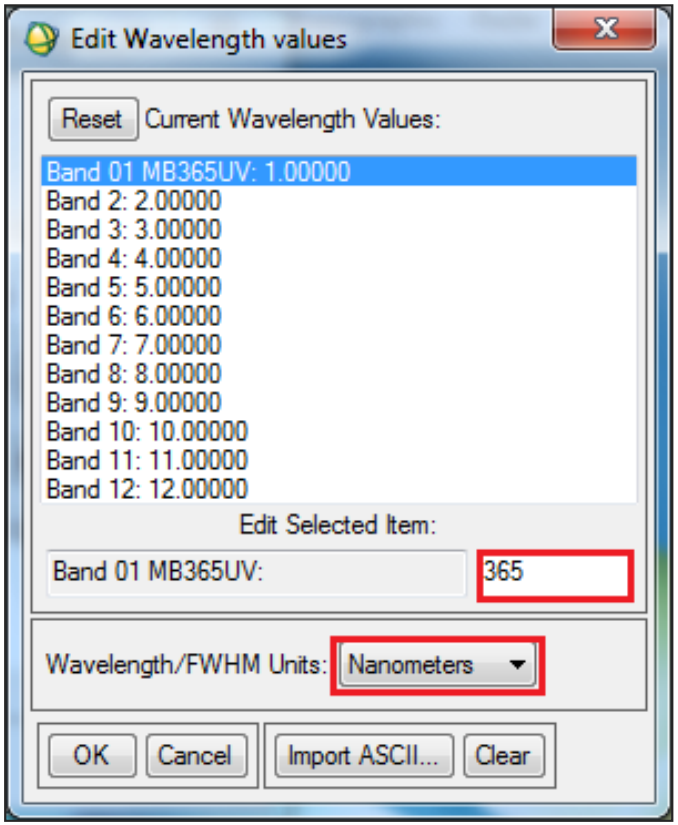
- Type band names in *Edit Selected Item*
- After typing all new band names click on: **OK**



reflectance or transmissive bands, click on: **Edit Attributes → Wavelengths**



- ***ENVI*** will display *Edit Wavelength values* window
  - select band in *Edit Selected Item:*
  - type wavelength value
  - In section *Wavelength/FWHM Units:* select **Nanometers**
  - Click on: **OK**
- display returns to **Header Info**
- click on: **OK**



ENVI
description = {
Create New File Result [Mon May 24 11:49:39 2019]}
samples = 8176
lines = 6132
bands = 12
header offset = 0
file type = ***ENVI*** Standard
data type = 12
interleave = bsq
sensor type = Unknown
byte order = 0
wavelength units = Unknown

ENVI
description = {
Create New File Result [Mon May 24 11:49:39 2019]}
samples = 8176
lines   = 6132
bands   = 12
header offset = 0
file type = ***ENVI*** Standard
data type = 12
interleave = bsq
sensor type = Unknown
byte order = 0
wavelength units = Unknown

ENVI
description = {
Create New File Result [Mon May 24 11:49:39 2019]}
samples = 8176
lines   = 6132
bands   = 12
header offset = 0
file type = ***ENVI*** Standard
data type = 12
interleave = bsq
sensor type = Unknown
byte order = 0
wavelength units = nanometers
wavelength = {
365.000000, 450.000000, 465.000000,
505.000000, 535.000000, 592.000000,
625.000000, 638.000000, 730.000000,
780.000000, 850.000000, 940.000000}

Close image cube file

- click on: **File → Close All Files**
  - *It is recommended to close all original image bands after creating cube to free up memory space*
  - *Quickest way to do this is to close all files via*

File → Close All Files

- *followed by*

File → Open Image File

Calibrate Image Cube

- select region of interest (RoI) used to evaluate statistics

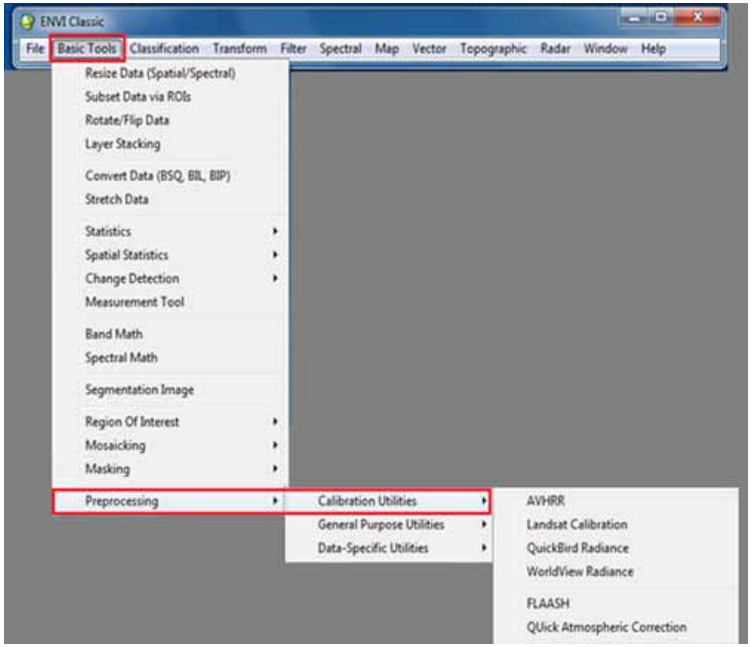
Basic Tools → Region of Interest → ROI Tool

- ***ENVI*** will display **#1 ROI Tool** window
- In tab: **ROI Type** select: **Polygon**
- To outline new RoI in Image window, click: **New Region**
  - ROI window will list color of ROI to be outlined
  - click on region number to highlight it
  - **Polygon**, click around image window to create ROI
  - right click to end selection.
- click on **File → Save ROIs**
  -

Calibration:

- In main menu of ***ENVI*** *Classic* select:

  Basic Tools → Preprocessing → Calibration Utilities → Flat Field



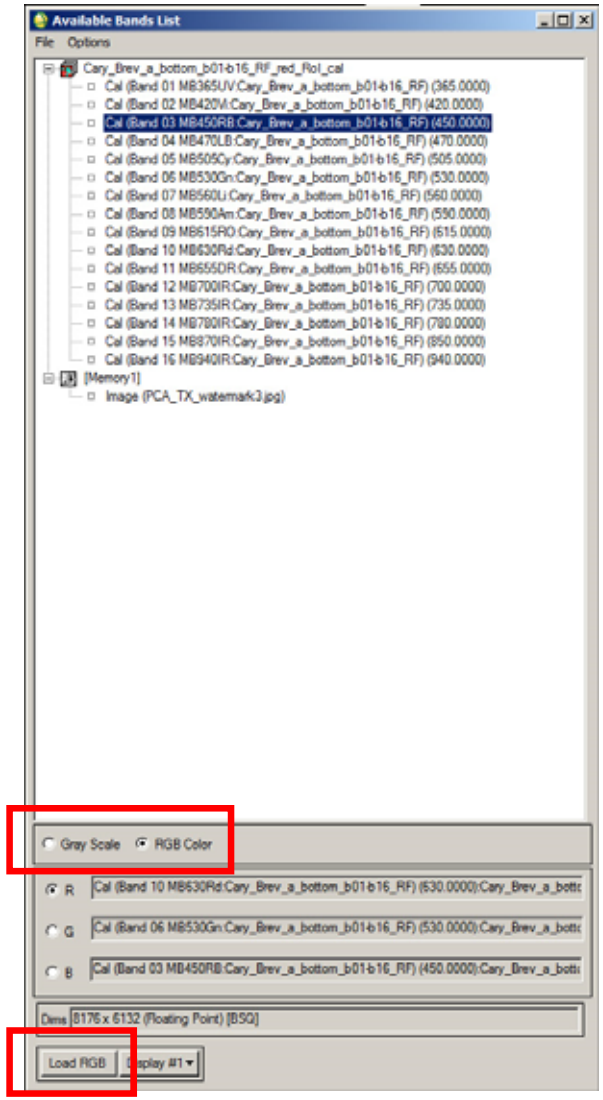
Calibration (continued)

- window *Calibration Input File* will be displayed
- In section *Select Input File:* choose cube file to be calibrated
- display window **Flat Field Calibration Parameters**,
  - highlight ROI to be used in section *Select ROI for Calibration*
- **Enter Output Filename** (add suffix ".cal")
- click: **OK**

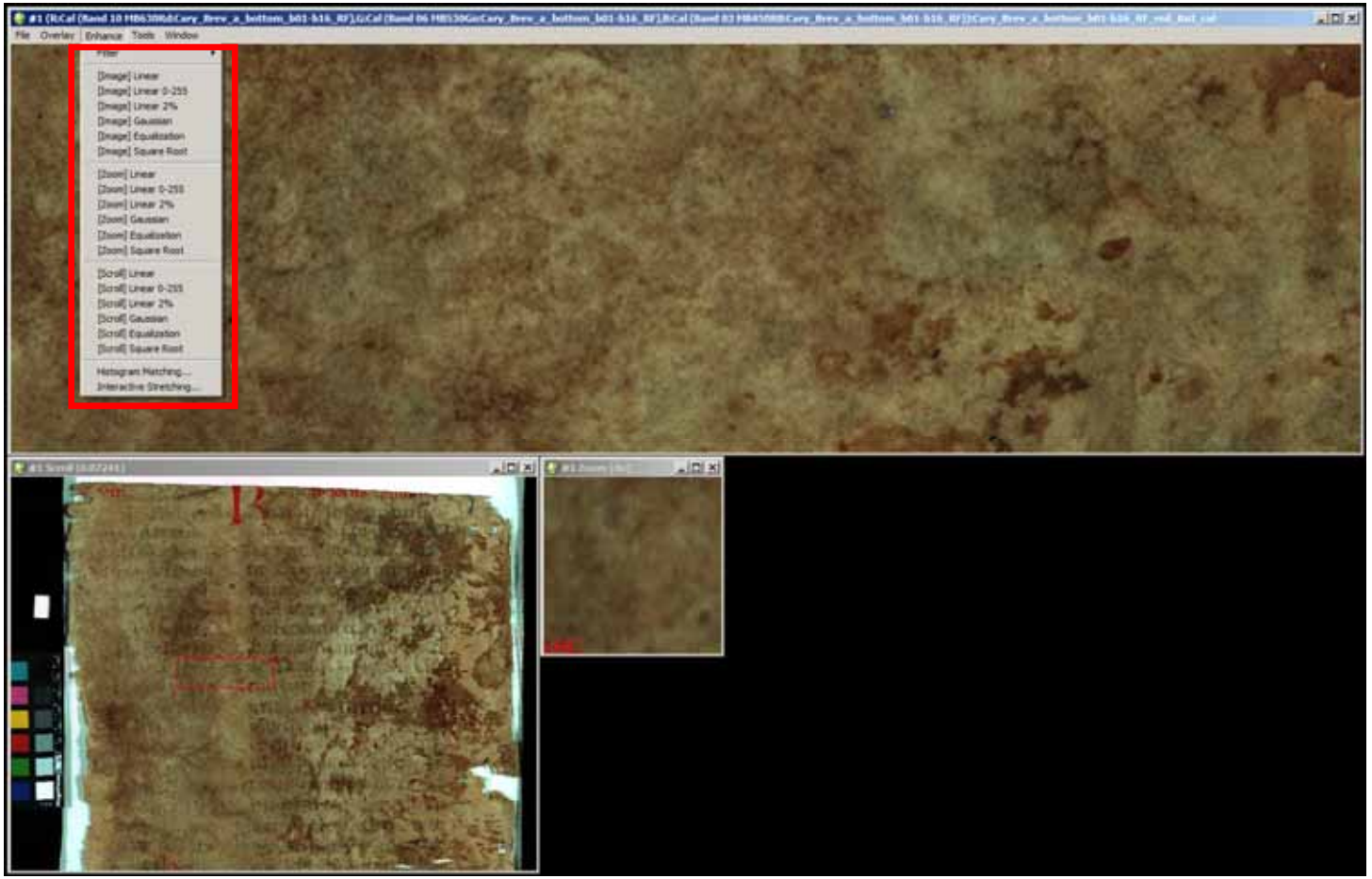
- **Calibration converts "16-bit integers" to "32-bit floating point numbers"**
  - DOUBLES the file size (from 100 megabytes / band to 200)

Display Images

- Gray Scale or RGB



Enhance the Displayed Image



Enhance

- Changes image based on statistics in one of the three windows
- Default is “[Scroll] Linear 2%”
  - Looks at histogram (probability distribution) of entire image
  - Throws out 2% each of “lightest” and “darkest” pixels
  - Linear Stretch of remaining pixels
    - Darkest 2% become “black” in each displayed band
    - Lightest 2% become “white” in each displayed band
    - Other pixels are scaled in proportion

Display Enhancements

- Use [Zoom] options to scale to small region
  - [Zoom] Linear 2%
  - [Zoom] Gaussian (mean μ → "127", $\mu+3\sigma$ → 255, $\mu-3\sigma$ → 0
  - [Zoom] Square Root (stretches "darks", compresses "whites")
- Use [Image] options to scale to larger region

Export Image

- Converts floating-point file to 8-bits per channel
- Discards MUCH data … do not expect to import back to ENVI

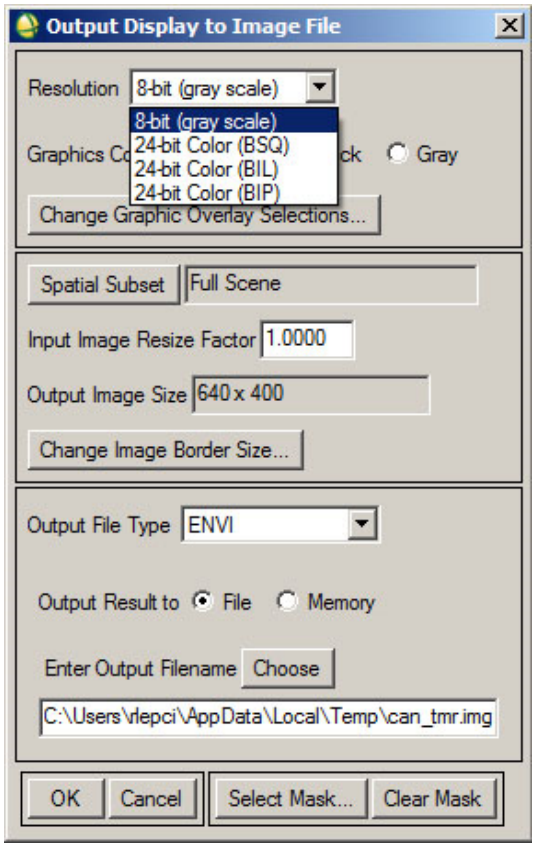
File → Save Image As → Image File

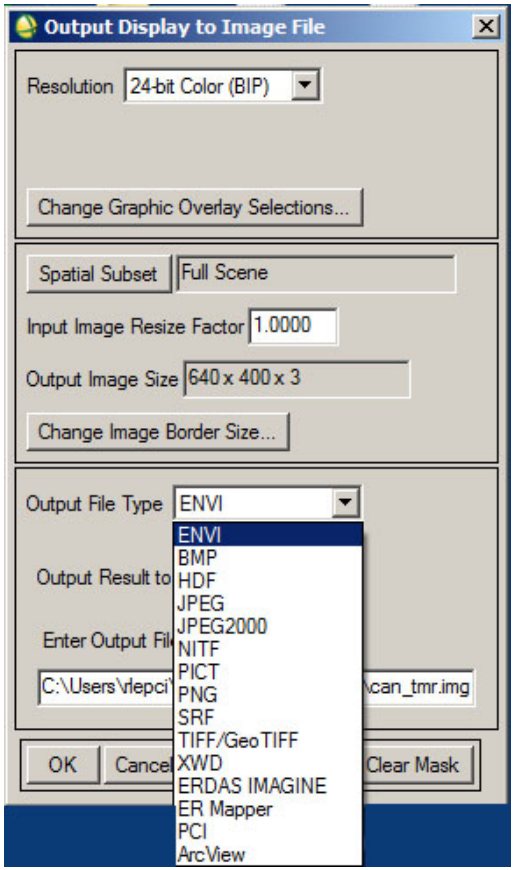
- window "Output Display to Image File"
  - Select gray-scale "resolution" (8-bit gray or 24-bit color)
  - Select format:

    BSQ = "band-sequential" (optimal for accessing spatial)

    BIP = "band interleaved by pixel" (optimal for accessing spectra)

    BIL = "band-interleaved by line" (compromise)


Output Display to Image File
Resolution
8-bit (gray scale)
8-bit (gray scale)
24-bit Color (BSQ)
24-bit Color (BIL)
24-bit Color (BIP)
Graphics Co
ck
Gray
Change Graphic Overlay Selections...
Spatial Subset
Full Scene
Input Image Resize Factor
1.0000
Output Image Size
640 x 400
Change Image Border Size...
Output File Type
ENVI
Output Result to
File
Memory
Enter Output Filename
Choose
C:\Users\rlepci\AppData\Local\Temp\can_tmr.img
OK
Cancel
Select Mask...
Clear Mask


Output Display to Image File
Resolution
24-bit Color (BIP)
Change Graphic Overlay Selections...
Spatial Subset
Full Scene
Input Image Resize Factor
1.0000
Output Image Size
640 x 400 x 3
Change Image Border Size...
Output File Type
ENVI
ENVI
BMP
HDF
JPEG
JPEG2000
NITF
PICT
PNG
SRF
TIFF/GeoTIFF
XWD
ERDAS IMAGINE
ER Mapper
PCI
ArcView
Output Result to
Enter Output Fil
C:\Users\rlepci
\can_tmr.img
OK
Cancel
Clear Mask

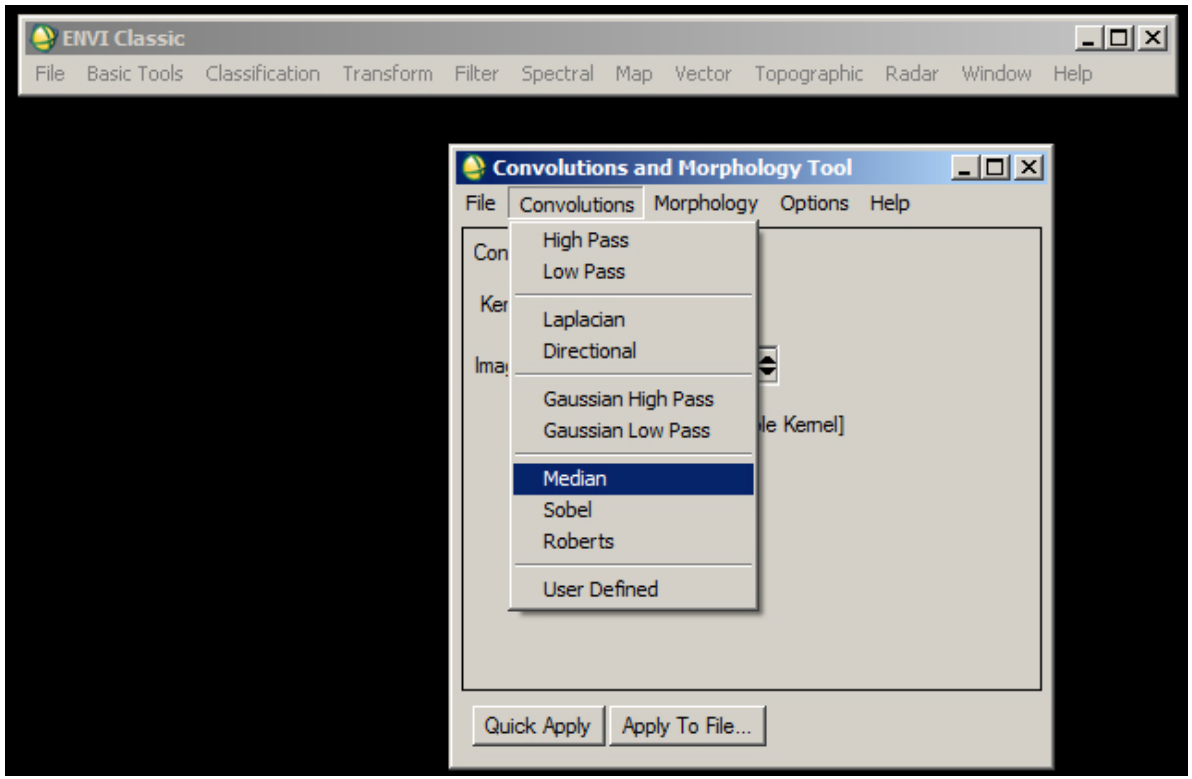
Filtering

- **Filter → Convolutions and Morphology**
  - Highpass
  - **Lowpass**
    - "blurring" filter, attenuates "sharpness", used for "blur-and-divide" preprocessing to attenuate background variations
  - **Median**
    - Useful for attenuating "salt-and-pepper" noise from fluorescence bands

Filter → Convolutions and Morphology → Median

Median

- Never used any size > 3 × 3



Lowpass

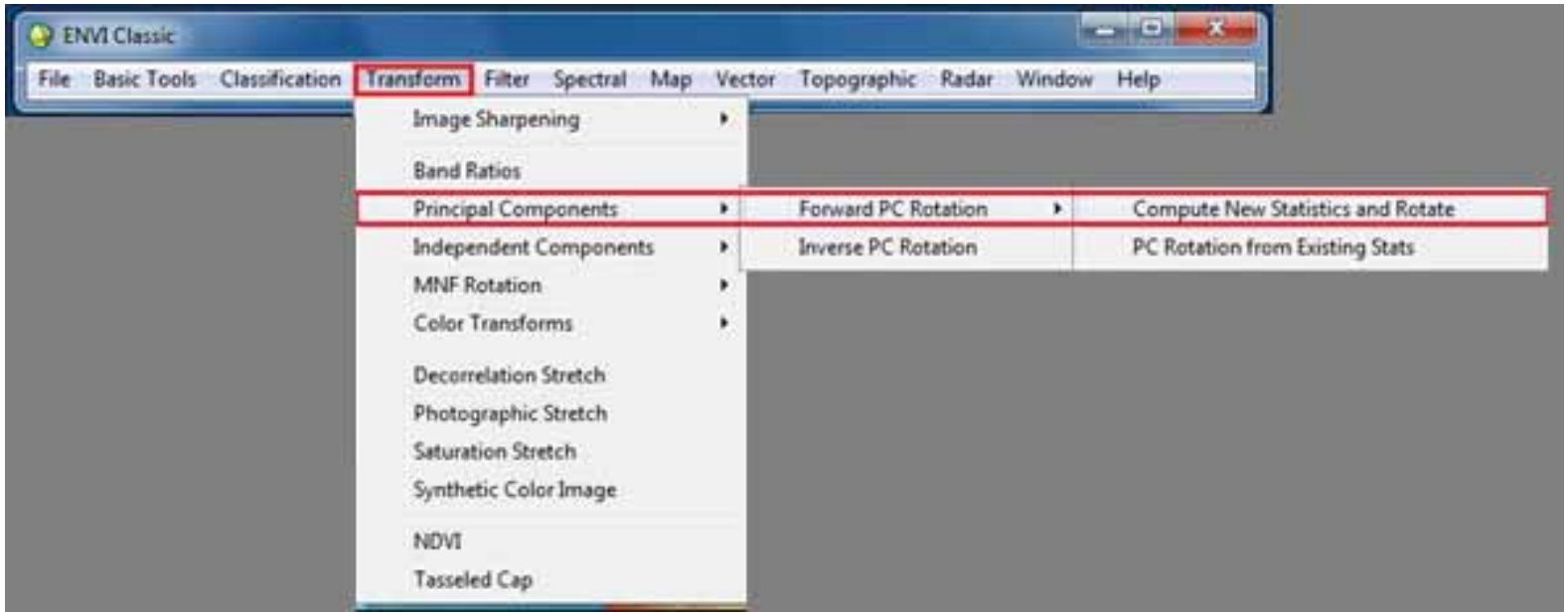
- **FILTER → Convolutions and Morphology**
- **Convolutions → <u>Low Pass</u>**
- Click on “up arrow” option for “Kernel Size”
  - only odd numbers are available
  - kernel must have well-specified “center” pixel
  - Size > “stroke width”, rule of thumb is 2x
- “**Apply to File (and WAIT)**

Divide (Spectral Math)

- **Basic Tools → Spectral Math**
- Enter Expression → "(**float**(S1))/(**float**(S2))"
- Click "**Add to List**"
- Click "**OK**"
- In "**Variables to Spectra Pairing**" window:
- Click on "**Map Variable to Input File**" (which brings up the "**Spectral Math Input File**" menu and which selects all bands of the file)
- Select file name of numerator for "**S1**" (original or median filtered)
- Click on "**S2**"
- Click on "**Map Variable to Input File**"
- Select file name of denominator for "**S2**" (result of convolution)
- Click "**OK**"
- Select **Name of Output File**
- Click "**OK**"

Principal Component Analysis (PCA)

- **Transform → Principal Components → Forward PC Rotation**
- **→ Compute New Statistics and Rotate**



PCA 2

- Window *Principal Components Input File* is displayed
  - Select image cube to process from list
  - Click **OK**
- Window *Select Statistics Subset* is displayed
  - In the section *Calculate Stats On* select:

ROI/EVF

  - In section *Select ROI/EVF,* select ROI to use
  - Click **OK**

PCA 3

- window ***Forward PC Parameters***
  - choose or type names of:
    (1) ***Output Stats Filename*** (*.sta)
    (2) ***Enter Output Filename***, then click: **OK**
- window ***Principal Components Rotation*** is displayed
- Watch progress bar not move – cup of coffee? 🕐