BE/BAT 485/585

Remote Sensing Data and Methods

Lab - 9

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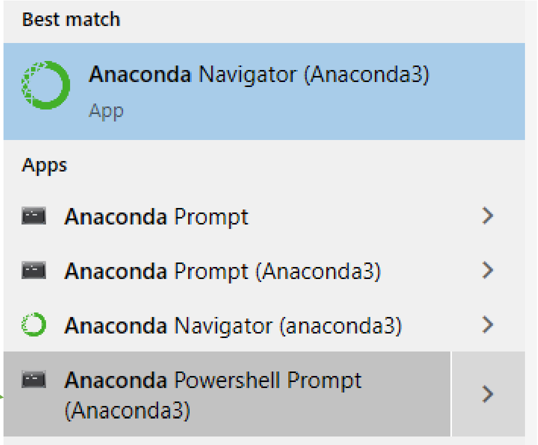
vip.arizona.edu

vegetation index & phenology Lab.

...Understanding a piece of the Earth system

GDAL: Geospatial Data Abstraction Library

https://gdal.org/



Install this geospatial package using the *conda* command from the forge distribution channel.

- **In the "Anaconda Command Prompt/Terminal" type:**

- `conda install -c conda-forge gdal`
- `conda install -c conda-forge geopandas`
- `conda install -c conda-forge basemap`
- `conda install -c conda-forge rasterio`
- `conda install -c conda-forge earthpy`

TIFF and GeoTIFF

TIFF file format

- Tagged Image File Format (**TIFF** or **TIF** are same thing)
- ***TIFF*** is a lossless storage format (as opposed to structures like BSQ, BIL, etc.) meant to preserve the content, and is well suited for quantitative analysis.
- TIFF files aren't compressed because they are meant to preserve full quality/quantity
- They also offer the options to use tags (metadata data) and layers (3D).
    - Tags are additional items of information, that inform about the content and more, making the file self describing.
    - Tools that do not have means to work and/or understand how to use the extra tags will simply ignore the info. Tools that know how to read/work with Tags can manage the file without extra effort from the user (like image size, data type, etc.)
    - **BigTIFF**, an extension of TIFF format to handle TIF images that are larger than 4 GB.
- A derivative from TIFF is GeoTIFF

GeoTIFF file format

- A **GeoTIFF** is also a TIF file (end in ***.tif** extension just like any TIF file)
- GeoTIFF contains additional tags that provide georeferencing/projection information for that image as specified by the GeoTIFF standard.
- Capable tools can automatically capture the geolocation and projection information from the image.

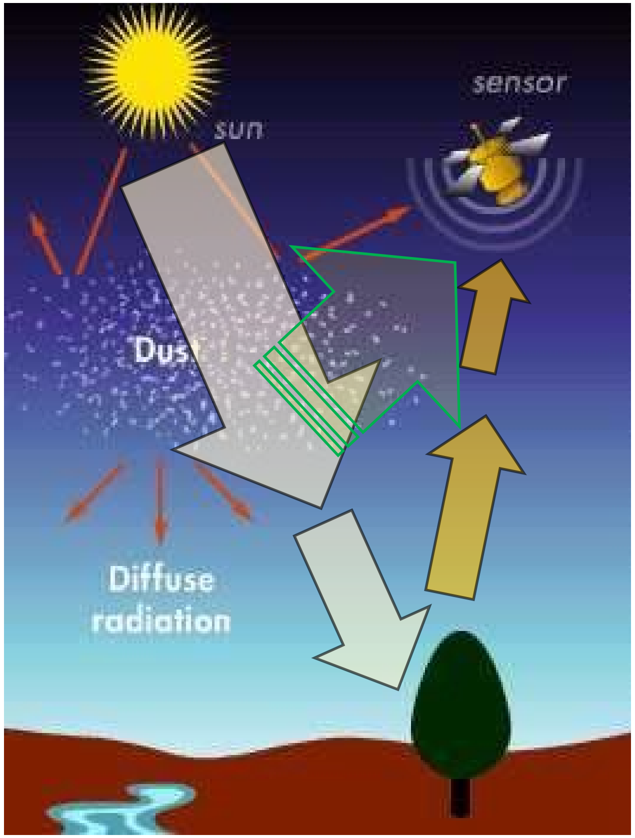
Atmospheric Correction Model

To retrieve surface reflectance from RS imagery

- Relationship between radiance received at the sensor (above atmosphere) and radiance leaving the ground

$$Ls = E.\rho.T + Lp$$

- *Ls* – at sensor radiance
- *E* – total downwelling radiance (incoming)
- *ρ* – reflectance of target (this is intrinsic to the object)
- *T* – atmospheric transmittance (to say only a certain portion made it)
- *Lp* – atmospheric path radiance (everything we do not want)
- (wavelength dependent). We need to account for this and that is the core of atm. correction.



Atmospheric correction methods

- Image – based methods
  - Dark pixel, Regression, Histogram, Empirical line methods
- Radiative transfer models (state of the art, physically based, and most accurate and complex)
  - MODTRAN, 6S, 6SV, etc…
- Relative correction method

Atmospheric correction: SIMPLE

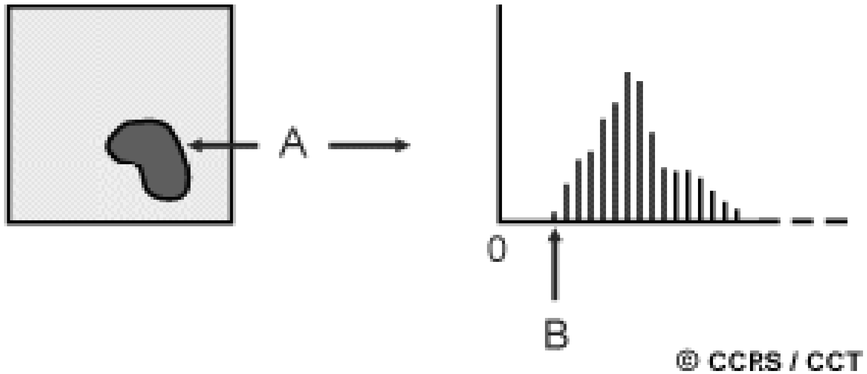
- Remove the impact of the atmosphere from the data, i.e., convert
  - sensor DN into apparent surface DN
  - sensor DN into apparent surface reflectance
  - sensor radiance into apparent surface reflectance
- Simple empirical methods
  - Histogram minimization
  - Dark Object Subtraction
  - Regression line
  - Others … all fairly similar to these

Simple atmospheric correction techniques usually only correct for path radiance

Atmospheric correction methods

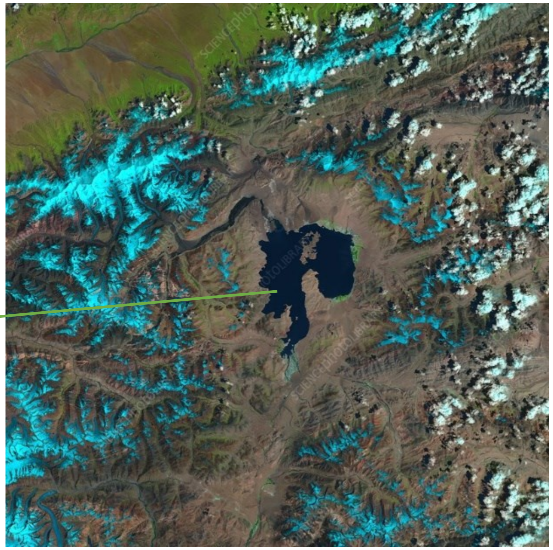
- Various methods of atmospheric correction can be applied ranging from detailed modeling of the atmospheric conditions during data acquisition, to simple calculations based solely on the image data.

- An example of the latter method is to **examine the observed brightness values** (digital numbers), in an area of shadow or for a very dark object (such as a large clear lake - A) and determine the minimum value (B).
- The correction is applied by subtracting the minimum observed value, determined for each specific band, from all pixel values in each respective band.



Dark pixel Subtraction Method

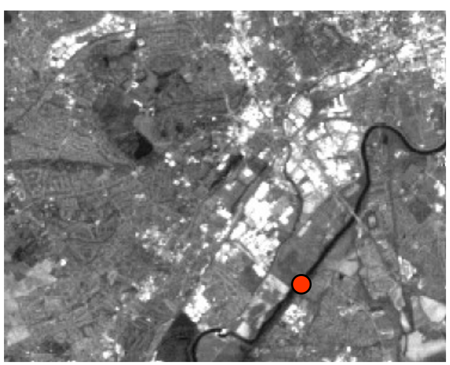
- Pixel values of low reflectance areas near zero
  - Exposure of dark colored rocks
  - Deep shadows
  - Clear water
- Lowest pixel values in visible and NIR are approximation to atmospheric path radiance
  - Remember path radiance is what we want to remove
- Minimum values subtracted from image

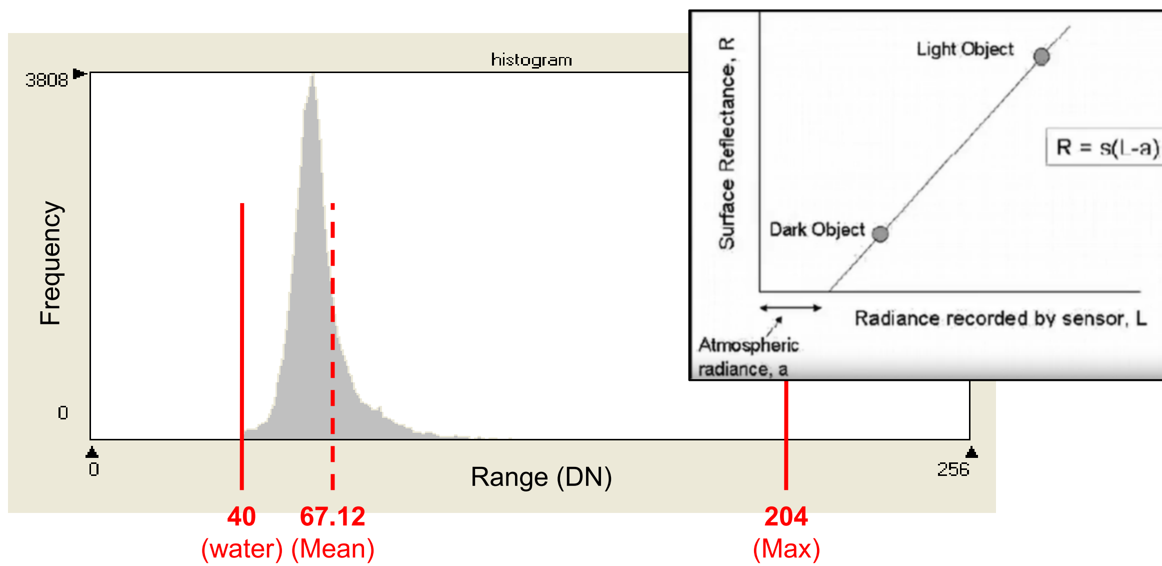


Should be Zero/Close to Zero
Any recorded value (at sensor) is likely due to path radiance (contribution of atmosphere) hence we can deduce how much to correct.

Dark Object Subtraction

- Lowest pixel values in visible and NIR are approximation of atmospheric path radiance
  - This Minimum values subtracted from image (Assumed to impact the whole image equally, so need to be removed)
- Find a pixel over a dark object that you know should have very low reflectance (or ZERO)
  - clear water
  - Very dense forest
  - Deep shadows
  - Exposures of dark colored rocks (volcanic)
- Assume that the pixel DN value is due only to atmospheric path radiance and not due to any surface reflectance
  - Then subtract the pixel value from all the pixel values in that image band





Dark Object Subtraction (DOS)

- The Dark Object Subtraction (DOS) is a family of image-based atmospheric corrections. There are basic assumptions that within the image:
- Some pixels are in complete shadow and their radiances received at the satellite are due to atmospheric scattering (path radiance). This assumption is combined with the:
  - Fact that very few targets on the Earth’s surface are absolute black, so an assumed one-percent minimum reflectance is better than zero percent”. It is worth pointing out that
  - The accuracy of image-based techniques is generally lower than physically-based corrections, but they are very useful when no atmospheric measurements are available as they can improve the estimation of land surface reflectance.
  - The path radiance is given by :

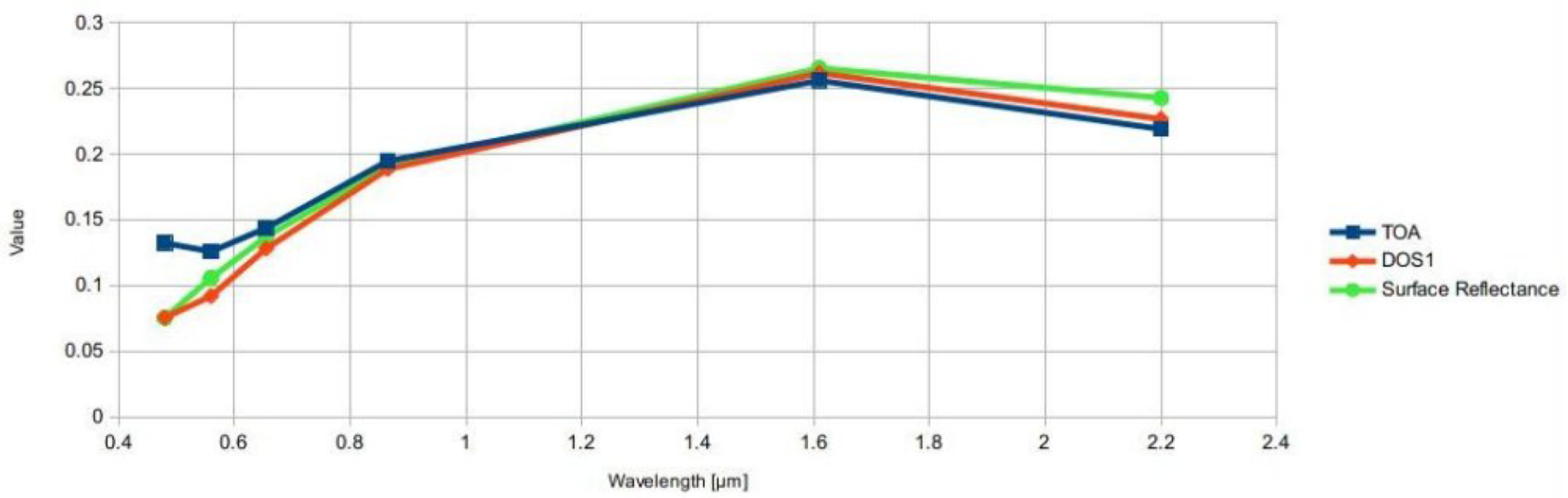
$$L_p = L_{min} - L_{DO1\%}$$

Where:

- L_{min}= “radiance that corresponds to a digital count value for which the sum of all the pixels with digital counts lower or equal to this value is equal to the 0.01% of all the pixels from the image considered” (Sobrino, et al., 2004, p. 437), therefore the radiance obtained with that digital count value (DN_{min})
- $L_{DO1\%}$ = radiance of Dark Object, assumed to have a reflectance value of 0.01

Example: DOS Corrected data

- Example comparison of TOA reflectance, DOS1 corrected reflectance and the Landsat Surface Reflectance High Level Data Products (ground truth) is shown.



Regression Method

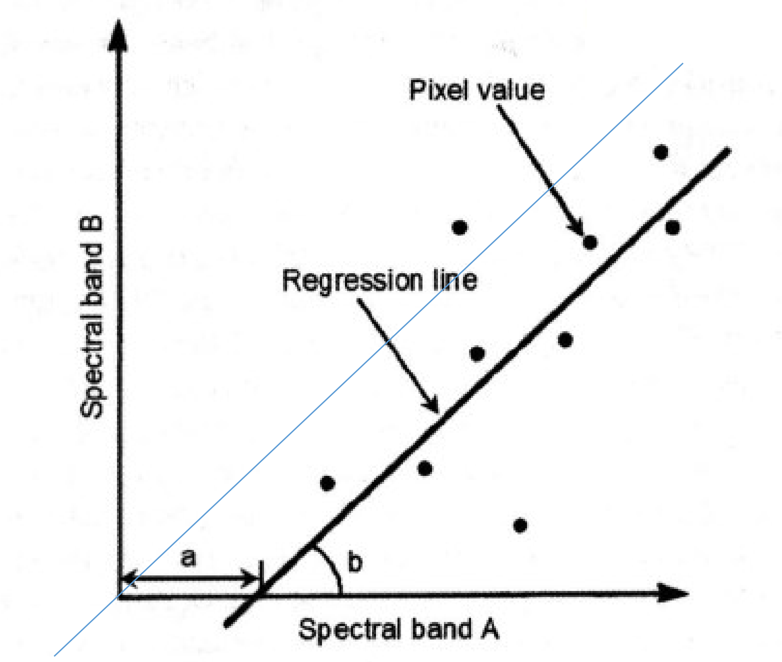
- NIR pixel values are plotted against values in other bands
- Apply a straight line using the least square method (regression)
- If there was no haze (atmosphere), then
  - The line would pass through origin
  - Resulting offset is approximation for atmospheric path radiance offset subtracted from all pixels in image

Regression Line Method

Select pixels with a range of DN values from low to high in two spectral bands

Assume that the pixels with the lowest DN are from areas with ~zero surface reflectance

- exposures of dark colored rocks
- deep shadows
- clear water



Create a regression line, the regression offset (a) is assumed to be due only to atmospheric path radiance

Subtract (a) from the band (A) to get an approximate atmospheric correction in terms of DN or radiance.

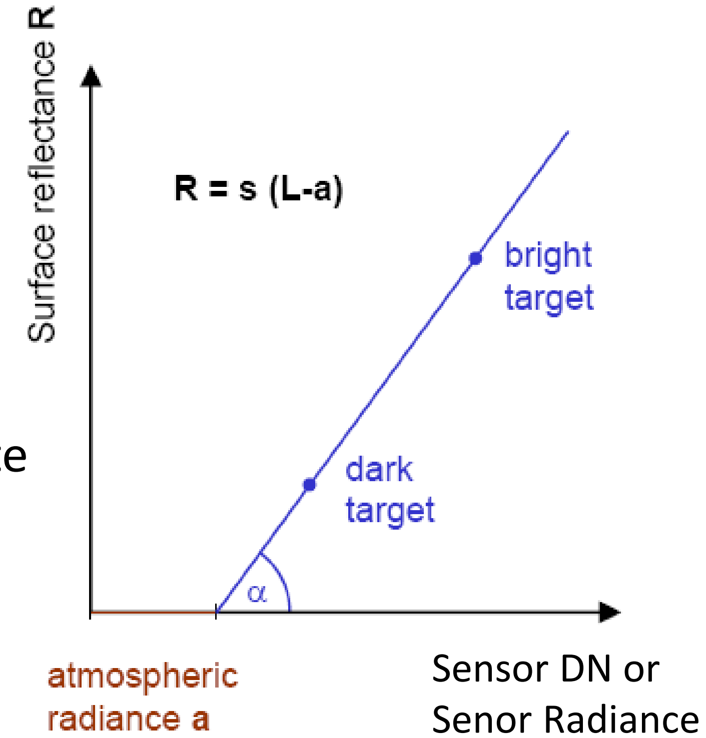
Empirical Line Correction

- Use target of “known”, low and high reflectance in given spectral band
  - e.g. non-turbid water & desert, or dense dark vegetation & snow
  - assume target reflectance is temporally stable (not a good assumption)

- Or better, measure the reflectance of low and high reflectance targets in the field in the same spectral bands as the satellite, preferably at the same time of satellite acquisition

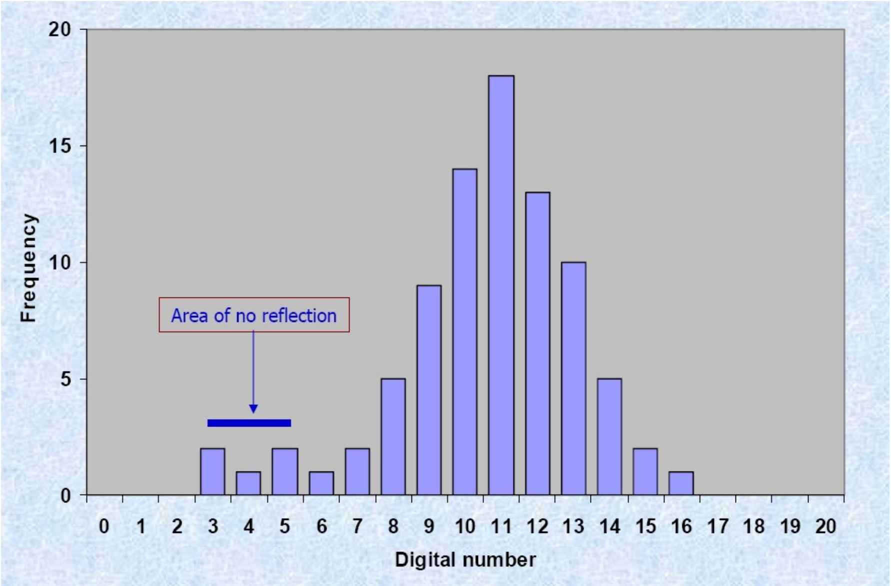
Create a regression line, the regression offset (a) is assumed to be due only to atmospheric path radiance

Subtract (a) from the band to get an approximate atmospheric correction in terms of reflectance.



Histogram Minimization

Histogram of pixel values in the spectral band to be corrected



Assume that the pixels with the lowest DN are from areas with near-zero surface reflectance, i.e.

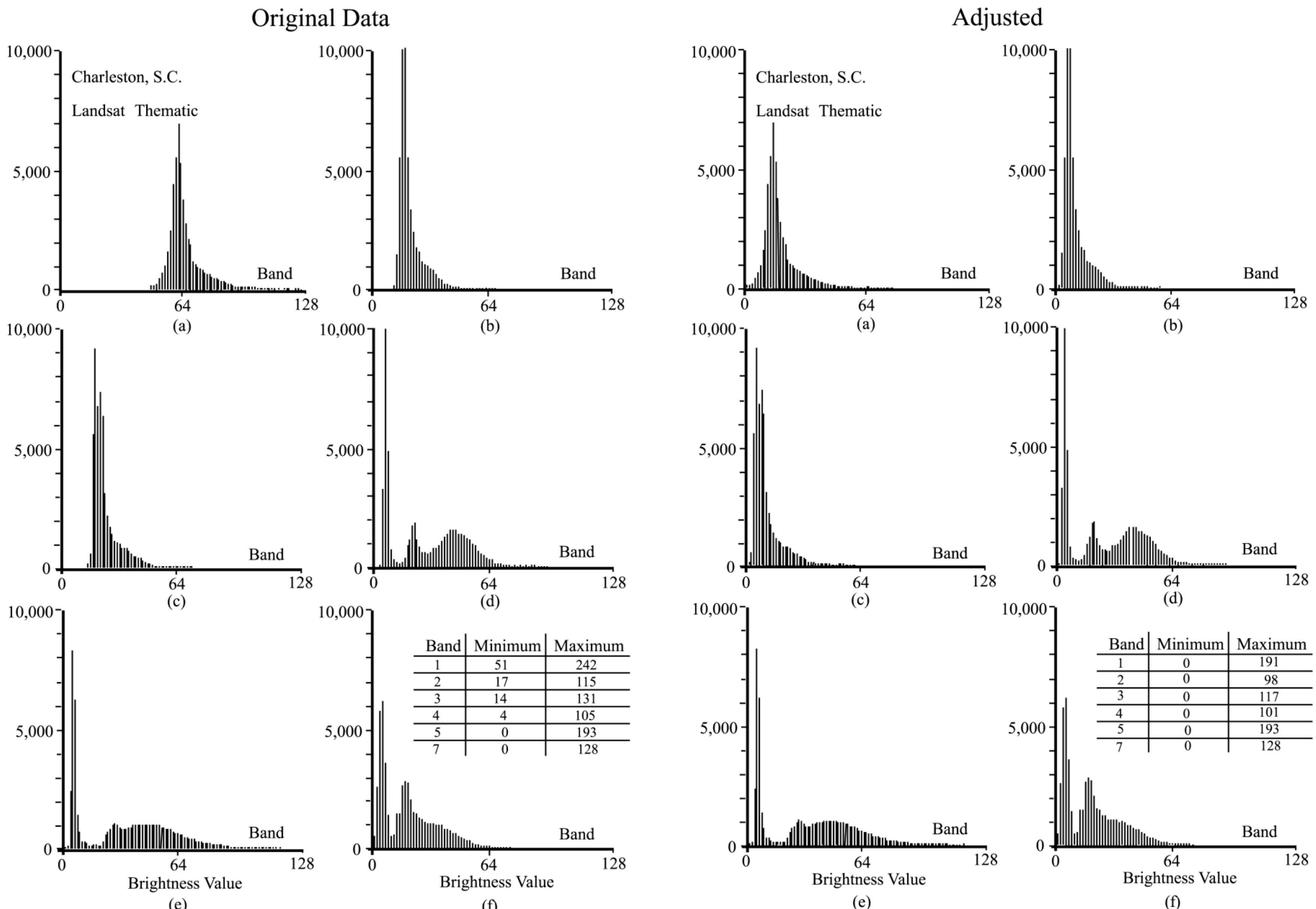
- exposures of dark colored rocks
- deep shadows
- clear water

Assume that these lowest DN values are due only to atmospheric path radiance

Subtract the lowest DN value from the band to get an approximate atmospheric correction in terms of DN or radiance.

Dark Object Subtraction – Follow the same principal but select the lowest DN value pixel by visual inspection and interactive means.

Dark Subtraction Using Band Minimum



Original Data

Band	Minimum	Maximum
1	51	242
2	17	115
3	14	131
4	4	105
5	0	193
7	0	128

Adjusted

Band	Minimum	Maximum
1	0	191
2	0	98
3	0	117
4	0	101
5	0	193
7	0	128

Issues with these simple atmospheric correction methods

- Per-band not per pixel so assume
  - solar irradiance the same across scene
  - atmospheric effects (scattering, absorption) the same across scene

- Only recommended for narrow field of view instruments (e.g., Landsat) not wide field of view sensors (e.g., MODIS)

- Not applicable to processing large number of satellite data on a systematic basis

Radiative Transfer Models

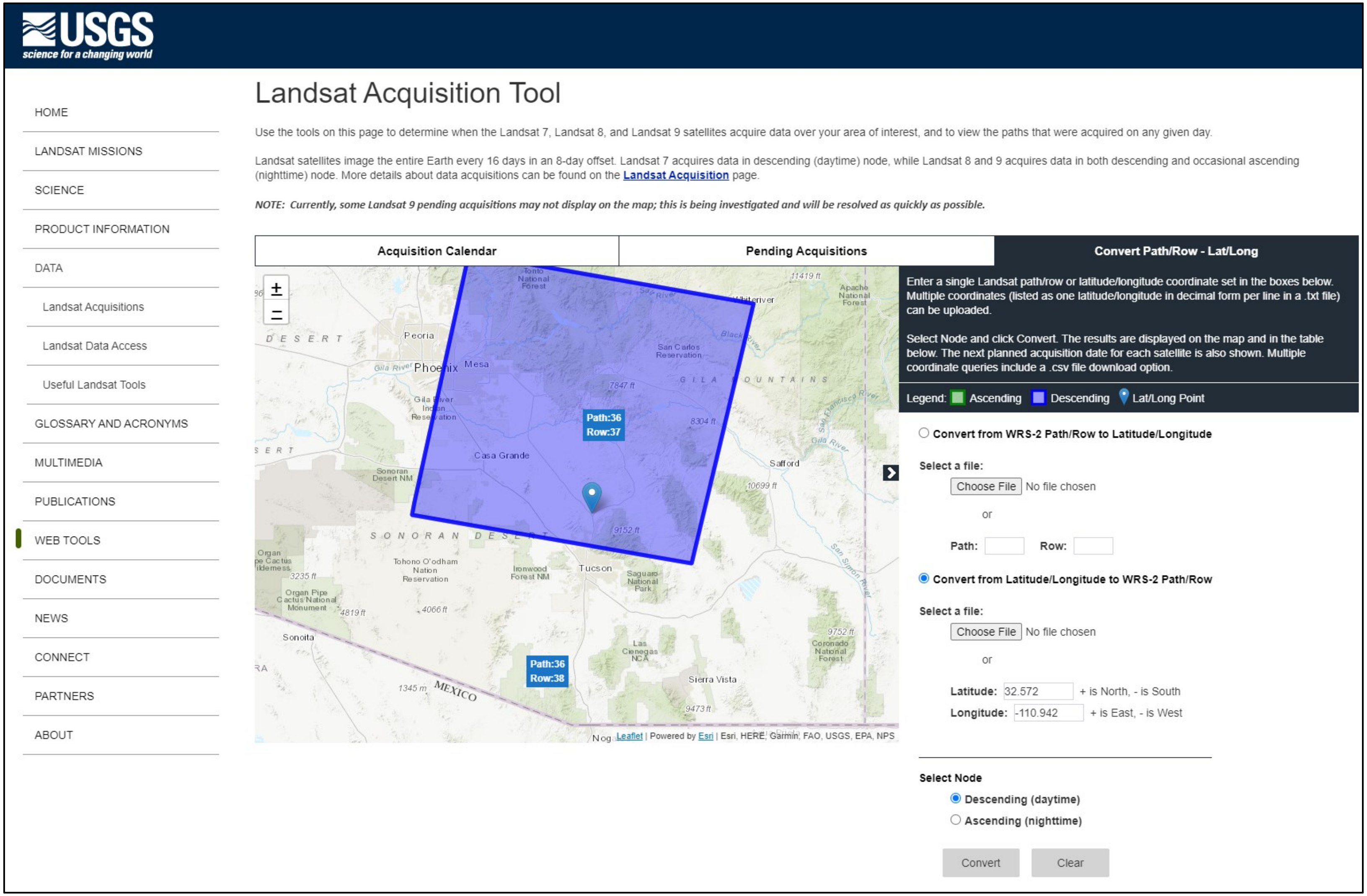
- Limited by the need to supply data about atmospheric conditions at time of acquisition
  - Needed to parameterize the model
- Mostly used with "standard atmospheres"
  - Predefined atmosphere with known characteristics
- There are many powerful numerical models that will correct the data
  - LOWTRAN 7
  - MODTRAN 4
  - ATREM
  - ATCOR
  - 6S (Second Simulation of the Satellite Signal in the Solar Spectrum) and 6SV

Worldwide Reference System

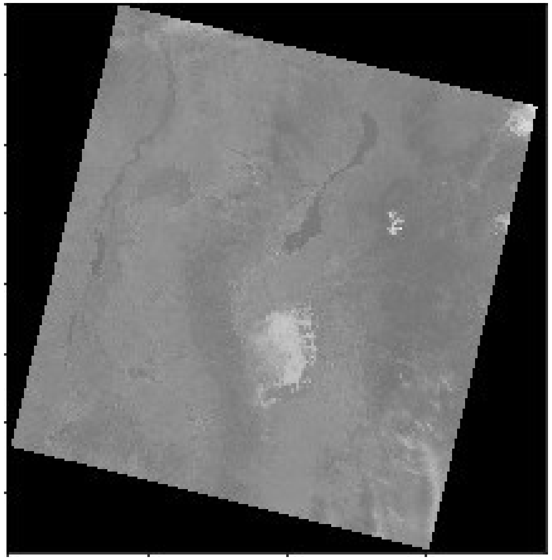
- The Worldwide Reference System (WRS) is used to identify the **path** and **row** of each Landsat image. The path is the descending orbit of the satellite. Each path is segmented into 119 rows, from north to south. The Landsat MSS sensor had a swath width of 180 km and global coverage required **251** paths. The Landsat TM, ETM and OLI sensors have a swath width of 185 km and require only **233** paths for complete coverage. MSS and TM scenes share common rows, but in most cases the paths will be different.
- Because of this difference, MSS scenes are identified using WRS I while TM, ETM and OLI scenes use WRS II path/row designations. The data archive section of the CEO web site uses the WRS II designation for all path/row images.

Conversion *LatxLon* to *PathxRow*

- https://landsat.usgs.gov/landsat_acq#convertPathRow



Exercise #1: Atmospheric correction



- **Introduction**
  - Basic gdal/gtif
  - Read Landsat geotif files
    - Red, Green, Blue, NIR, MIR bands
  - Perform (simple) Atmospheric correction
    - Dark object subtraction (DOS)
    - Histogram minimization
  - Compare histograms (before & after)
  - Display bands before and after
- **Homework**
  - Create histograms for input bands: Green, Blue and MIR
  - Complete the atmospheric correction (both methods) to each band: Green, Blue and MIR
  - For bands NIR, Green, Blue and MIR complete histograms similar to the presented example for RED

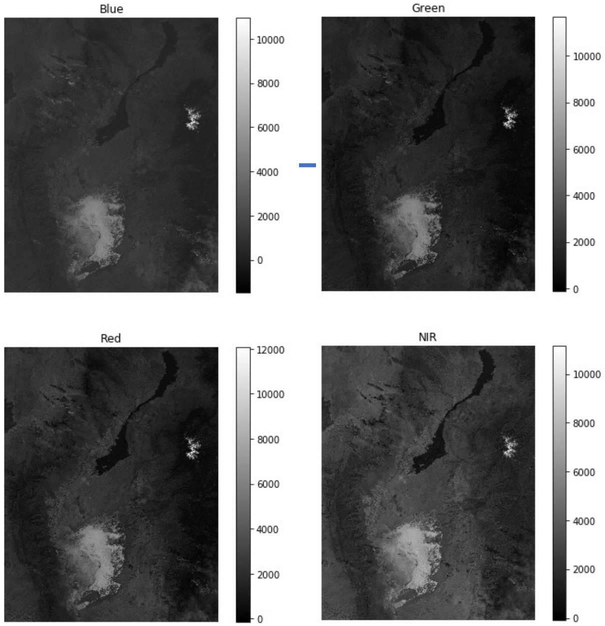
Instructions:

- Download files:
  - Data files: Landsat images (see next slide)
  - Library: viplab_lib4.py
  - Python Startup script: BE485_Lab9_Ex1.ipynb

Landsat files for this lab

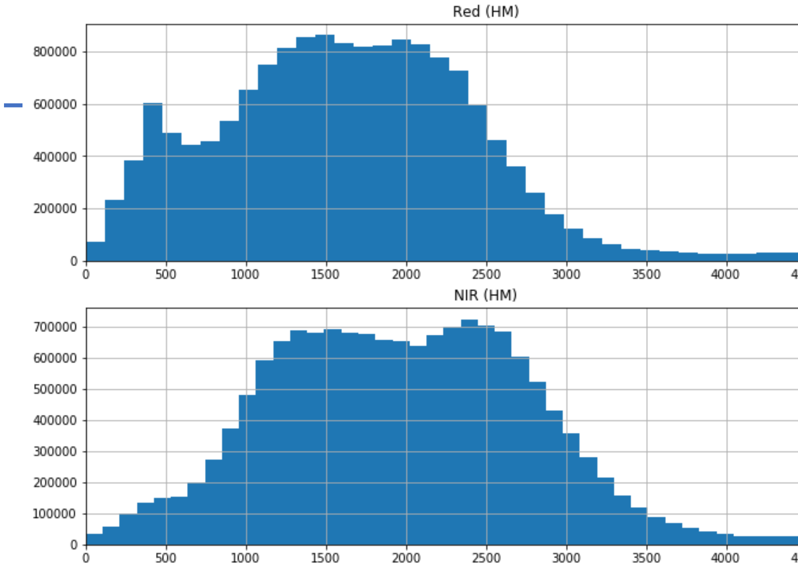
- **Landsat 8/OLI: Path:33, Row:37,   03/21/2020**
  - Landsat images are stored one band per file. Each file uses the geotiff format.
  - LC08_L1TP_033037_20200321_20200321_01_RT_sr_band1.tif
  - LC08_L1TP_033037_20200321_20200321_01_RT_sr_band2.tif
  - LC08_L1TP_033037_20200321_20200321_01_RT_sr_band3.tif
  - LC08_L1TP_033037_20200321_20200321_01_RT_sr_band4.tif
  - LC08_L1TP_033037_20200321_20200321_01_RT_sr_band5.tif
  - LC08_L1TP_033037_20200321_20200321_01_RT_sr_band6.tif
  - LC08_L1TP_033037_20200321_20200321_01_RT_sr_band7.tif

geoTIFF: standard which allows georeferencing information to be embedded within a TIFF file.

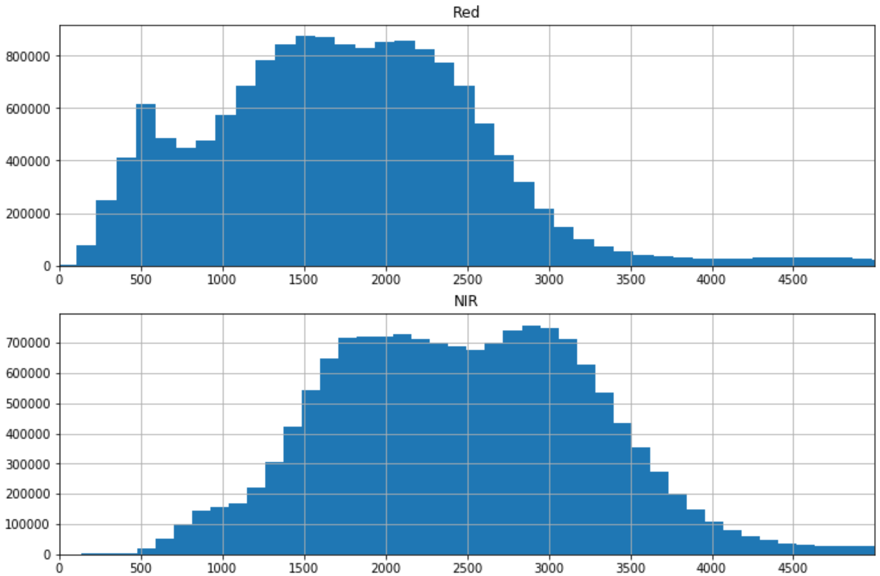


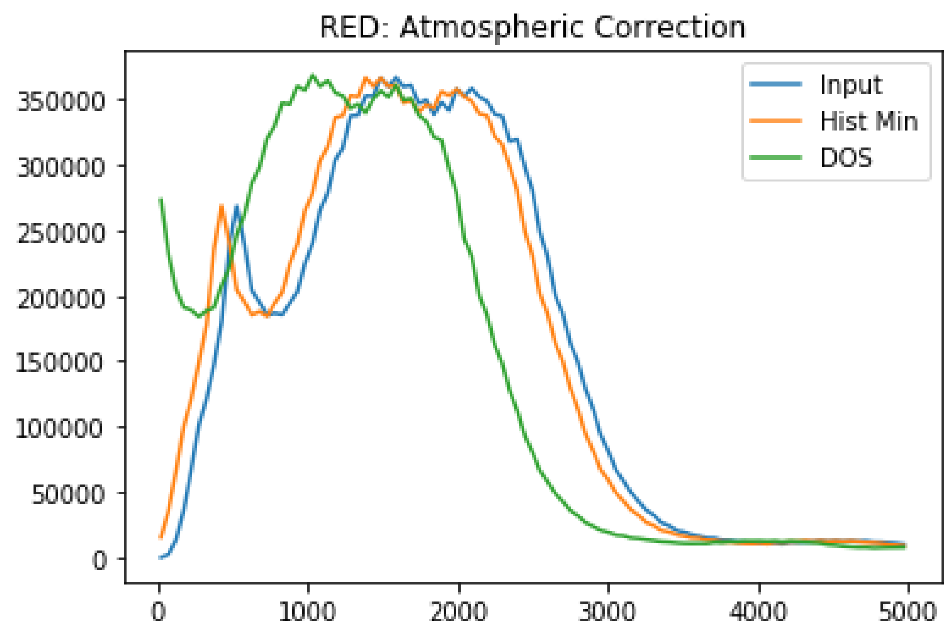
Gray scale input bands

Histogram minimization

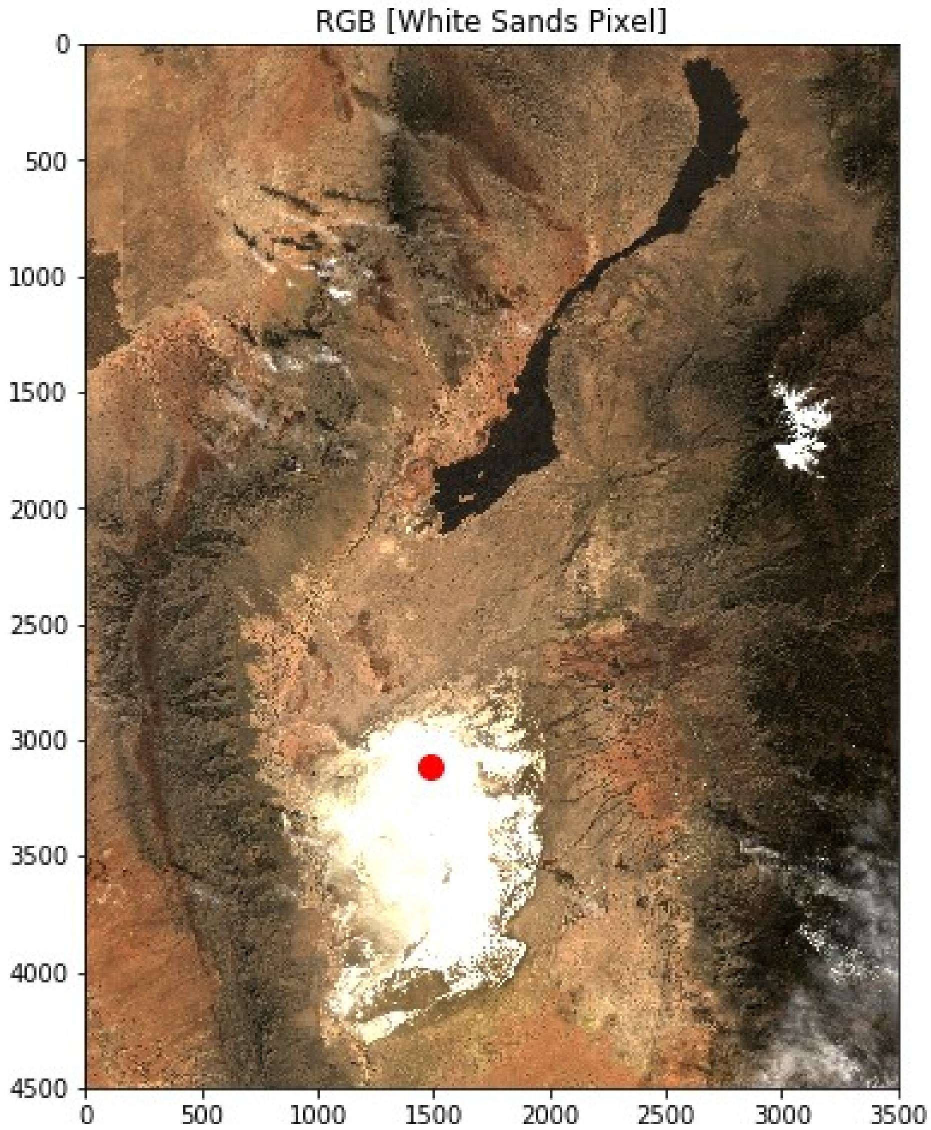


Dark Object Subtraction





Extracting values at different window size (pixel based)




```
Extracting for white Sand
```

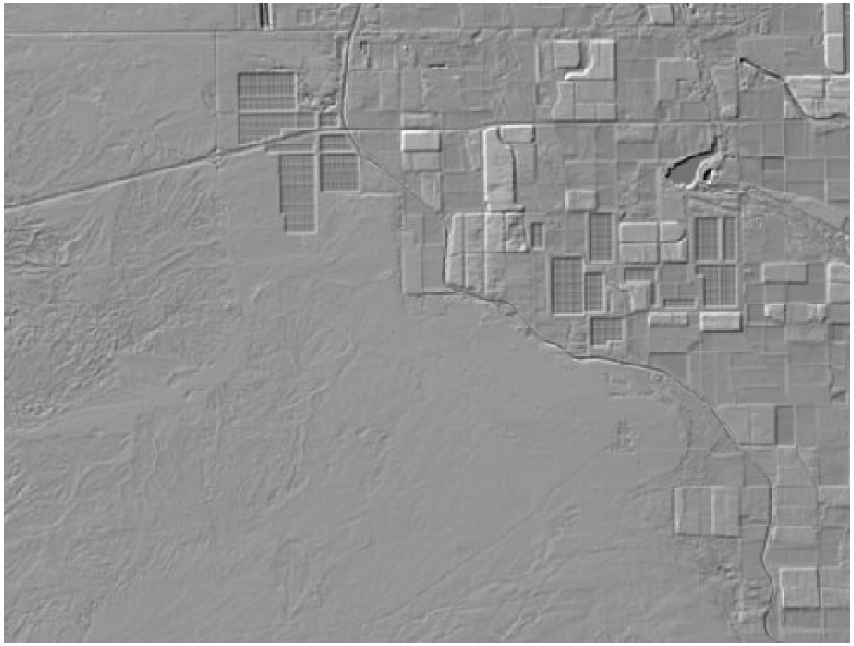
	red	nir	blue
1	6898.000000	7408.000000	5033.000000
3	6645.222222	7139.333333	4928.666667
5	6715.880000	7231.720000	4970.400000
9	6733.135802	7246.518519	4978.814815
11	6752.809917	7265.157025	4989.727273
15	6780.800000	7292.684444	5014.222222

Using pandas to display a table

Repeat for water, snow, and Pine forest

Exercise #2: Filters

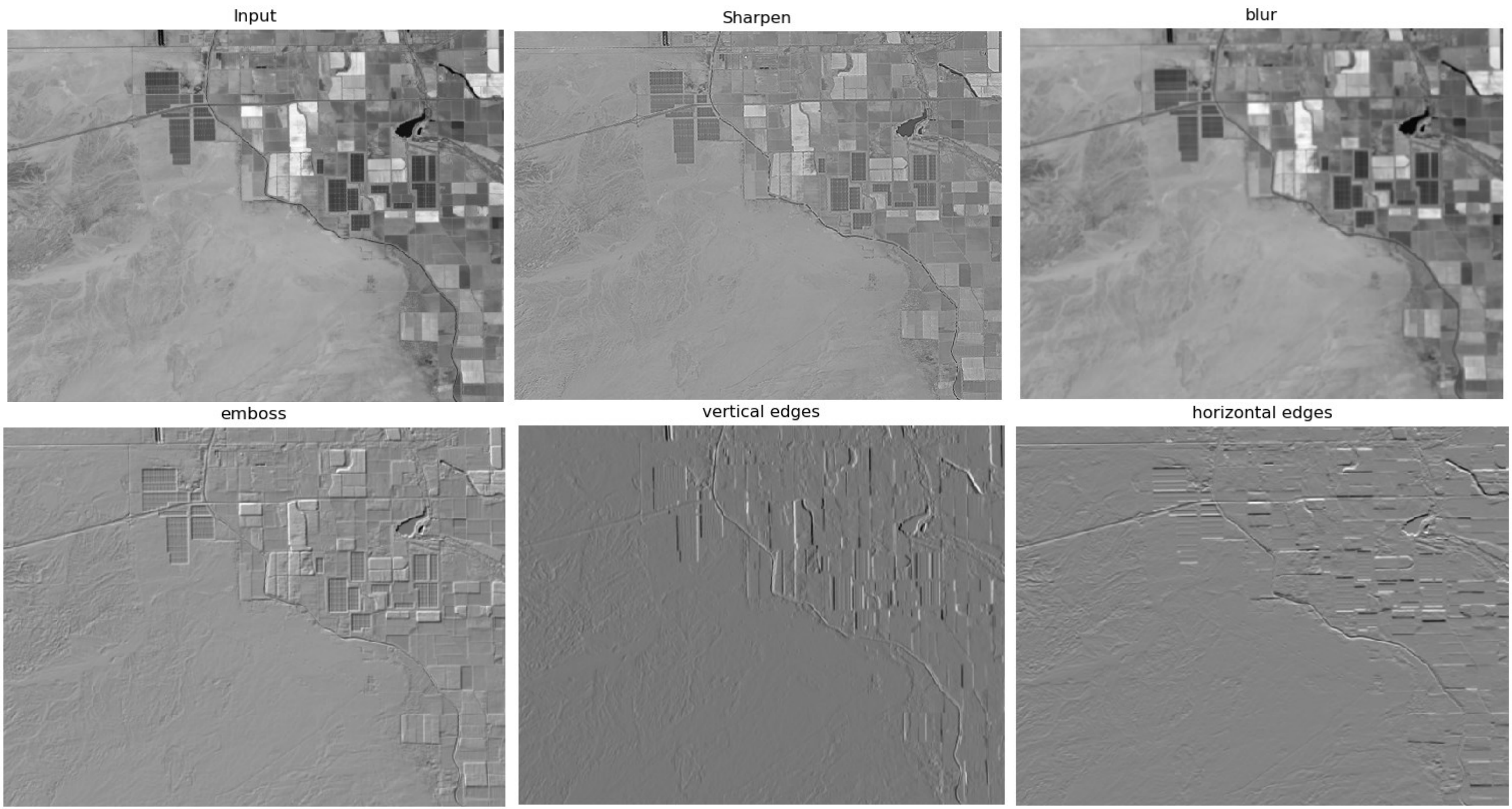
- **Read BSQ File**
- Use a subset from NIR band
- Use 3x3 kernel filters for
  - Blur
  - Sharpen
  - Edge detection
  - Emboss
- Display results
- Homework:
  - Create example 5x5 kernels and compare against 3x3
  - Look (search the internet) for different (up to 3) kernels and try them
    - Explain what they are doing



Instructions:
- Download files:
  - BSQ file: LANDSAT08.A2018261.YUMA.bsq, DRONE_IMAGE.bsq
  - Python script: BE485_Lab9_Ex2.ipynb

Image Filters

- What do you think these filters are helpful with?

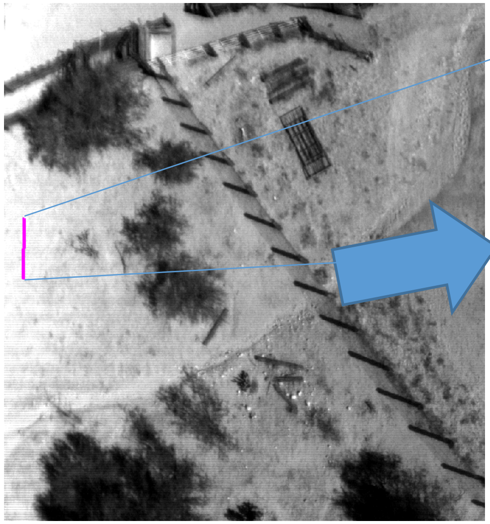


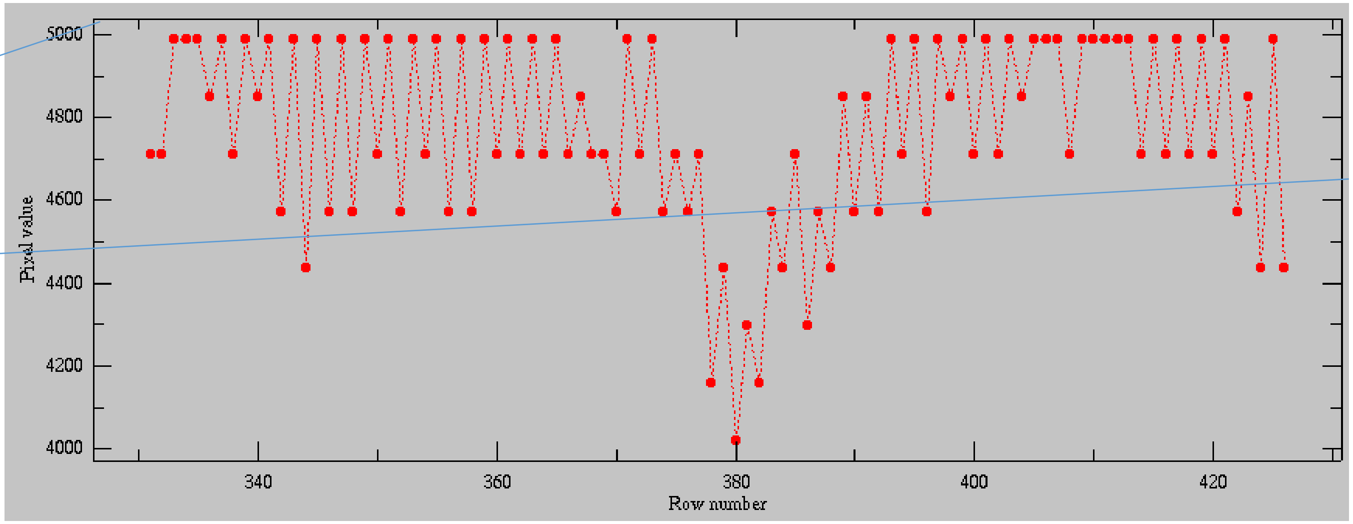
Exercise #3: Correcting Data problems

Instructions:

- Reusing the code form this lab/Ex-2 design a python program that will:
  - Remove the stripes form the drone image
  - DRONE_IMAGE.bsq (from D2L)
  - Plot the before and after transect across the stripes

Nrows=800
Ncols=750
Data:INT16



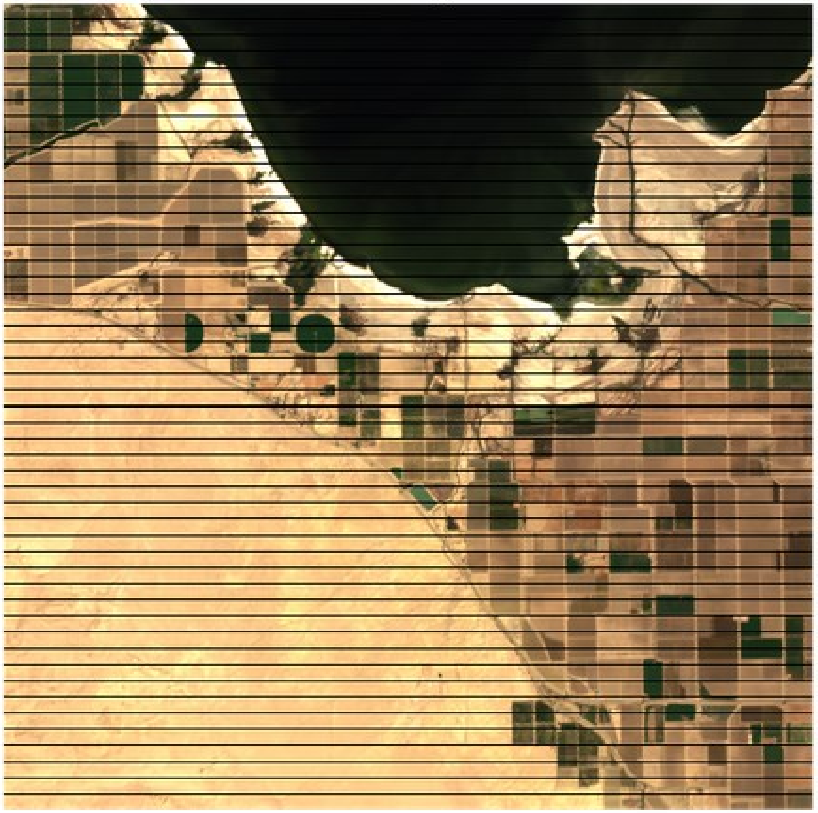


Optional Challenge – Extra Credits

- Use filters to remove the stripping from the image

Normal Image

Image with Stripes that needs correction



- BSQ file: LANDSAT08.A2018261.YUMA.bsq
- Python script: BE485_Lab9_Ex3.ipynb