Water Classification of Satellite Imagery Using Python and ArcGIS Pro

Master of GIS | Capstone Project at Penn State University

Daniel Clement | March 11th, 2022

Master’s Capstone Project

- The water classification script/tool was developed for an Advanced Python for GIS course at Penn State University
- The goal of my capstone project will be to create an ArcGIS Notebooks walkthrough of a section of the code
  - The notebook will have an educational and tutorial purpose and allow readers to run code and visualize the results
- Readers of the notebook will learn how to fuse remote sensing analysis and Python coding

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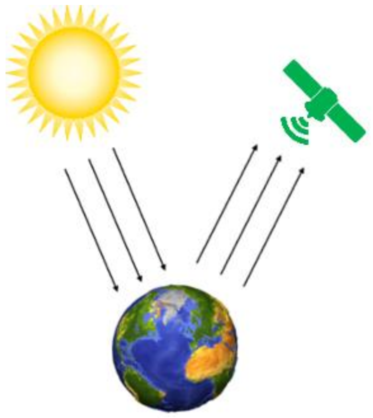
Remote Sensing Basics

Passive

- Only receive incoming radiation reflectance
- Operate on principles of Electromagnetic (EM) radiation
- Require the sun’s radiation to collect information
- Can only collect imagery in Daylight



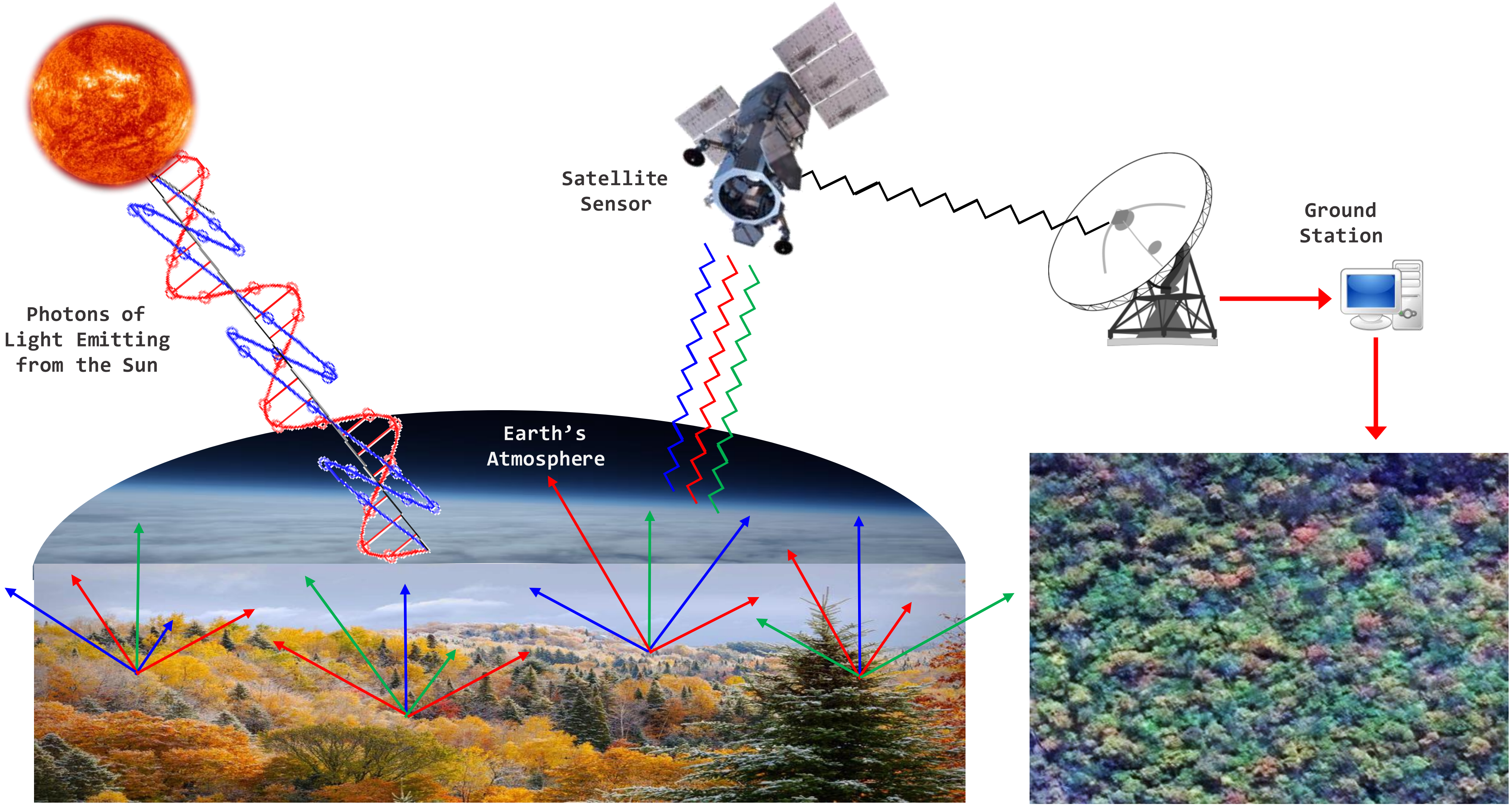
Passive Remote Sensing

Active Remote Sensing

Active

- Emit their own radiation and record the reflectance:
  - Light as lasers (LiDAR)
  - Radio waves (Radar)
  - Sound waves (Sonar)
- Based on the principles of the EM spectrum.
- Do not require the suns radiation as they emit their own.
- Can collect imagery at night!

Passive Sensors



Principles of Electro-Optical (EO) Sensors

- The Electromagnetic (EM) Spectrum is the scientific principle all Remote Sensing is based on

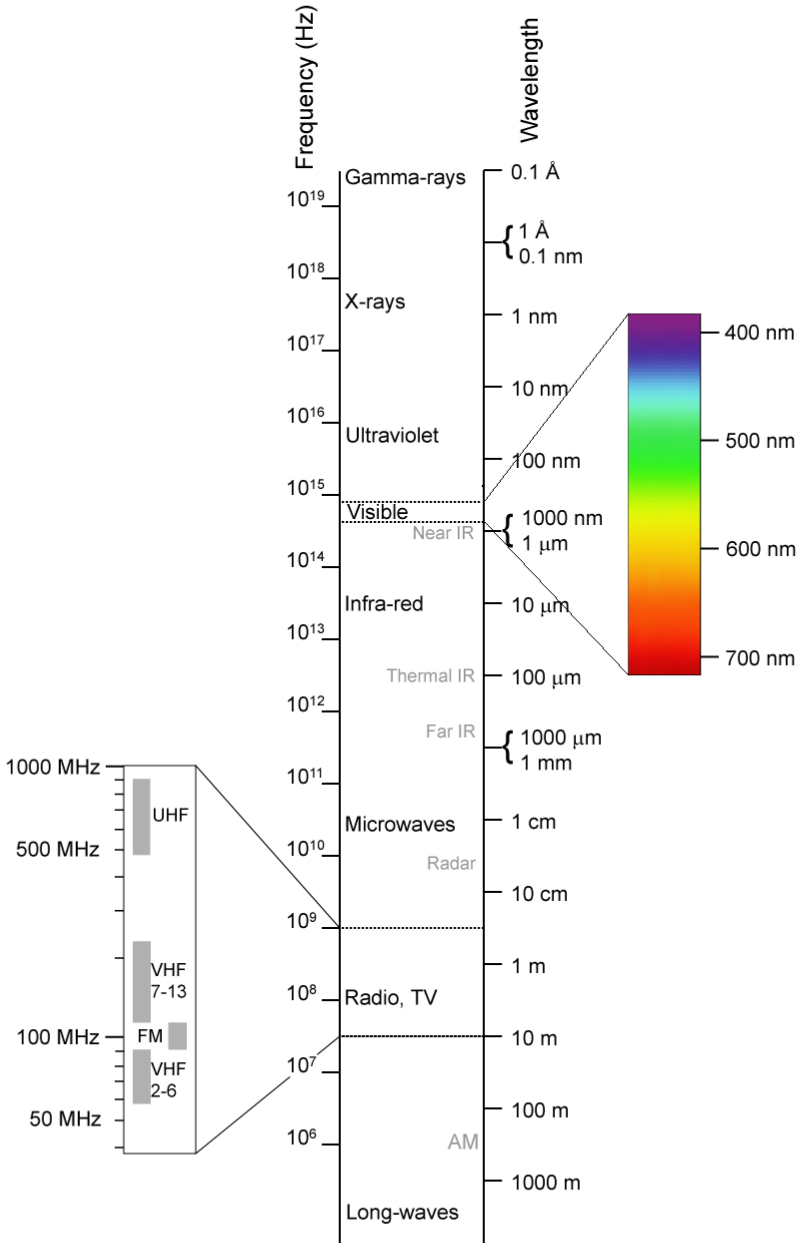
- Human eyes can see a very narrow spectrum of light, known as the “Visible” range

- Satellite sensors collect data in different “**bands**”, which are simply small subsets of the EM spectrum. These are measured in wavelength (λ)

- EO sensors are able to “see” areas of the spectrum that humans cannot. This is often referred to as “Multi-Spectral” or “MS” imagery

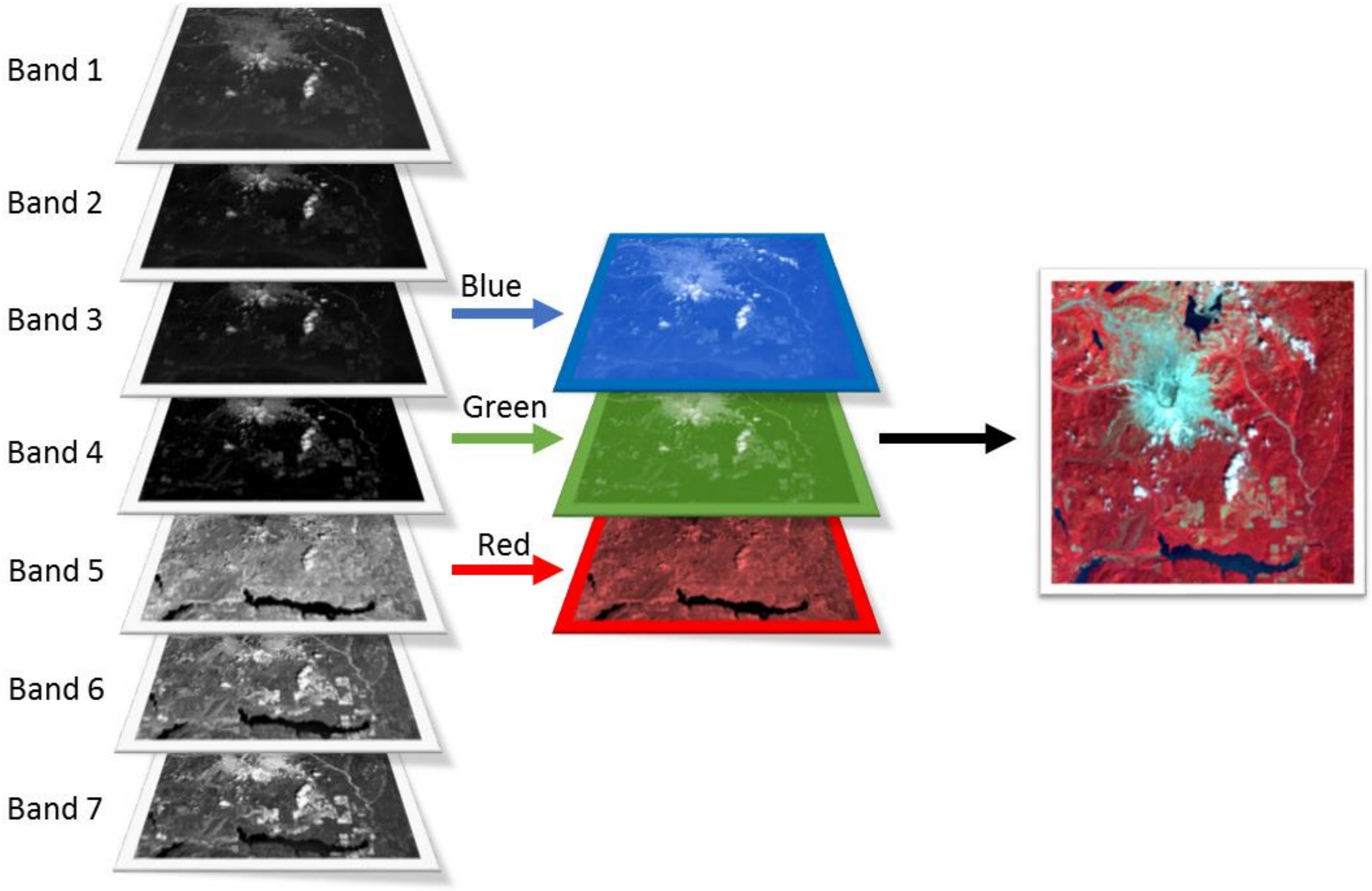
- **Spectral Resolution** is a descriptive term used to characterize the number and width of bands that a sensor is able to collect data on

    - More bands with a finer width = higher Spectral Resolution



What can we do with different bands?

Band Combinations



Common Band Combinations

Natural Color:

Red = Red Band
Green = Green Band
Blue = Blue Band

False Color Infrared:

Red = Near Infrared Band
Green = Red Band
Blue = Green Band

Spectral Indices

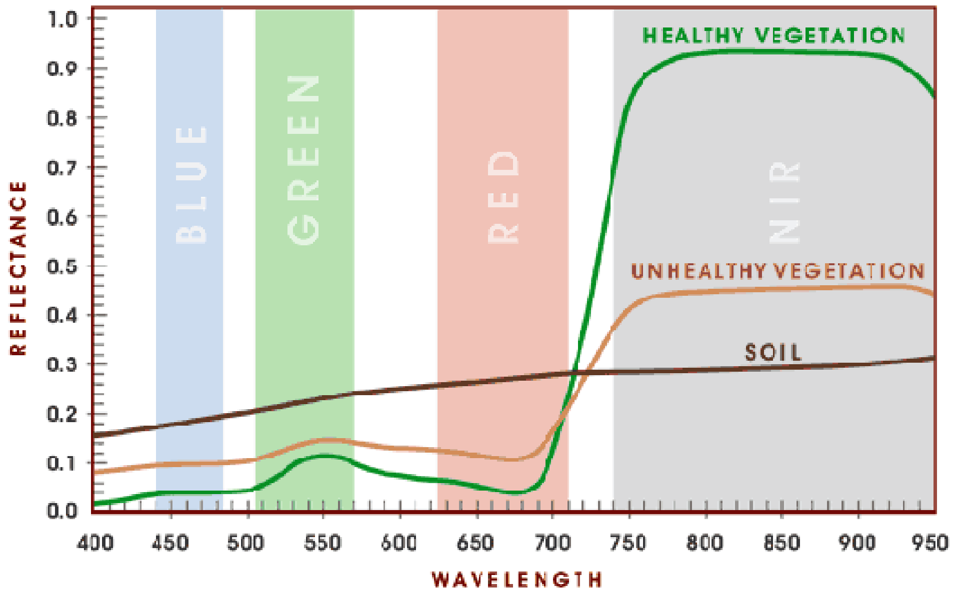
- Spectral Indices are essentially mathematical formulas which take advantage of the reflective properties of various materials

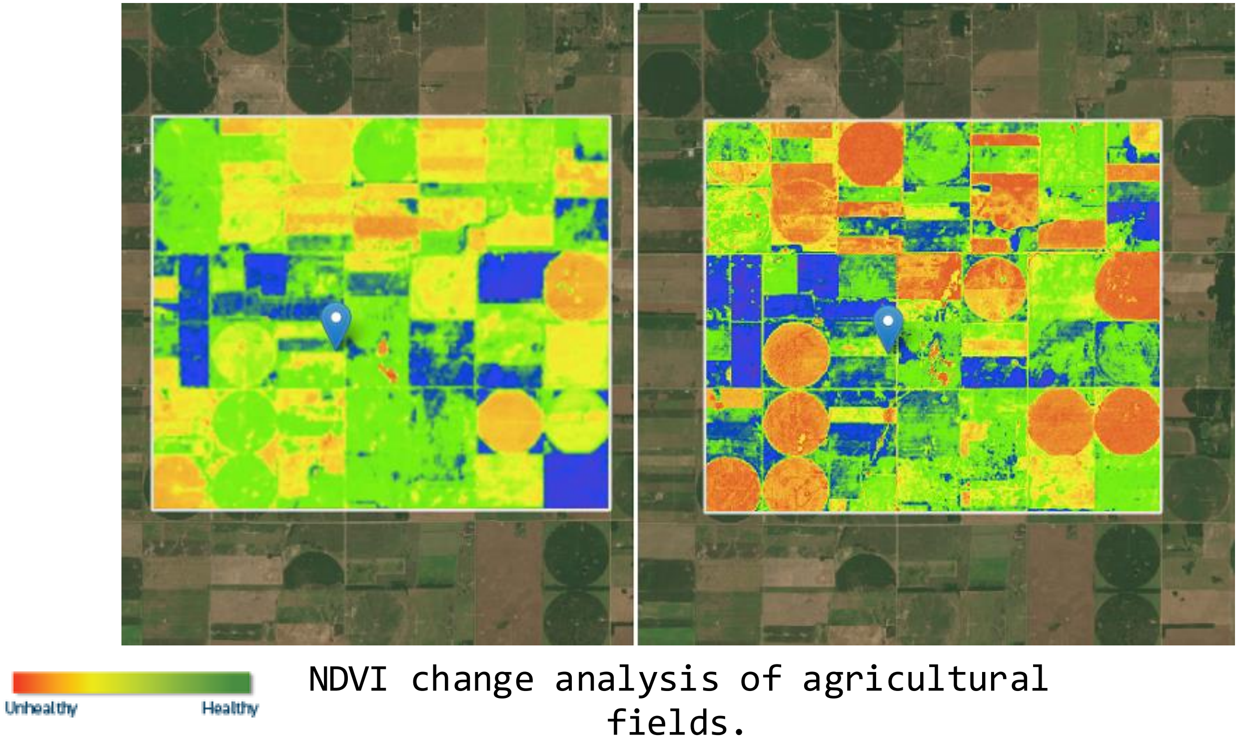
- These indices, which number in the hundreds, are used to analyze and identify things such as:
  - Vegetation
  - Water
  - Man-made areas
  - Burned areas

- One common index is the Normalized Difference Vegetation Index (NDVI), and is calculated by using the following formula:

$$\text{NDVI} = \frac{(\text{NIR} - \text{Red})}{(\text{NIR} + \text{Red})}$$

- The NDVI takes advantage of the fact that vegetation, and specifically healthy vegetation reflect high amounts of Near Infrared (NIR)





NDVI change analysis of agricultural fields.

What problem is my tool solving?

Problem: Standing Water

Identifying standing water is an important task for many geospatial and remote sensing scientists

Supports **natural disaster** relief and response efforts:

Identifying flooded areas post disaster. Allowing better allocation of resources

Supports **disease eradication** and research efforts:

Many insect borne diseases are transmitted by insects who breed in standing water. Ex: Malaria, West Nile virus, and Dengue

How can we approach and solve the problem using remote sensing technologies?

Tool Overview

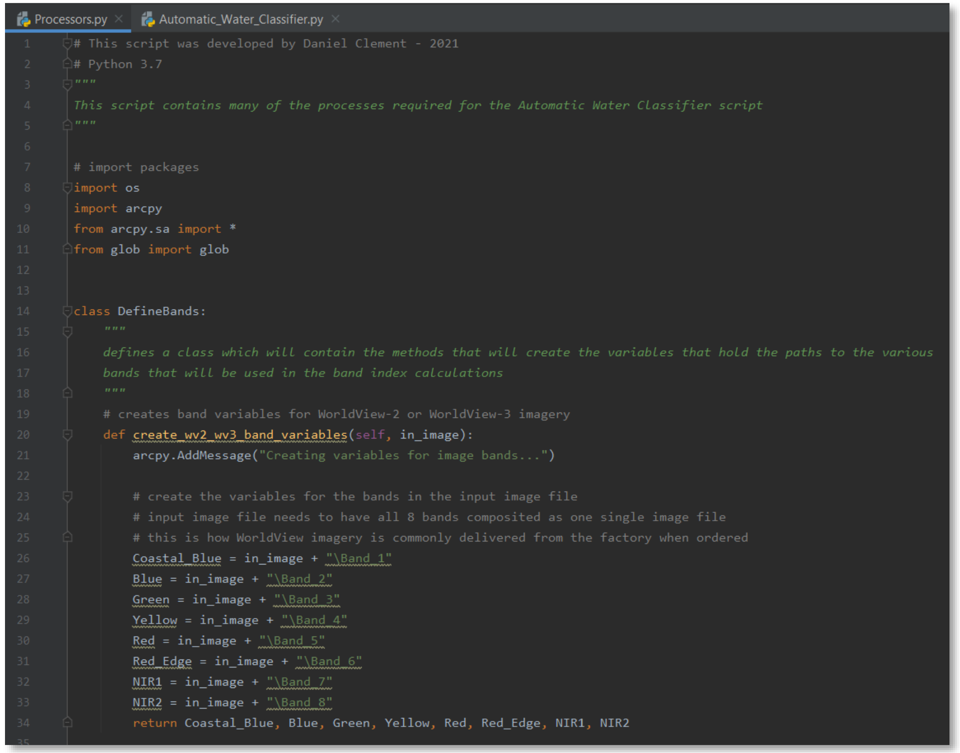
The tool classifies satellite imagery to identify and map standing water

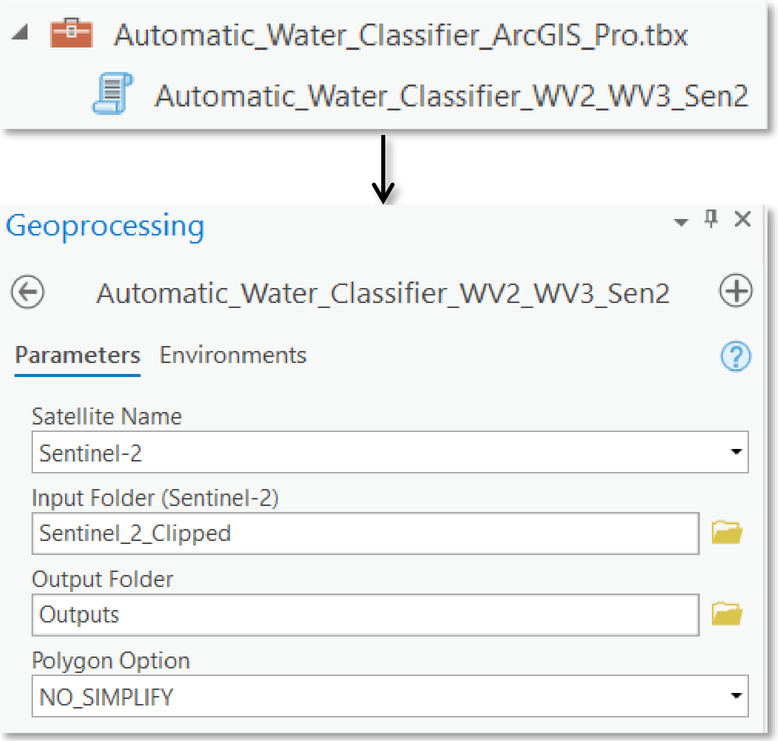
- Python tool utilizing various packages including ArcPy
  - Able to be run in python via Command Line or IDE
  - An ArcToolBox Script tool was also created, allowing the tool to be run within ArcGIS Pro
  - Utilizes spectral indices and automatic thresholding to identify water
- Outputs the classified water in both raster and vector formats
- Currently works for:
  - Maxar’s WorldView-2 & WorldView-3
  - European Space Agency's Sentinel-2

Tool Format

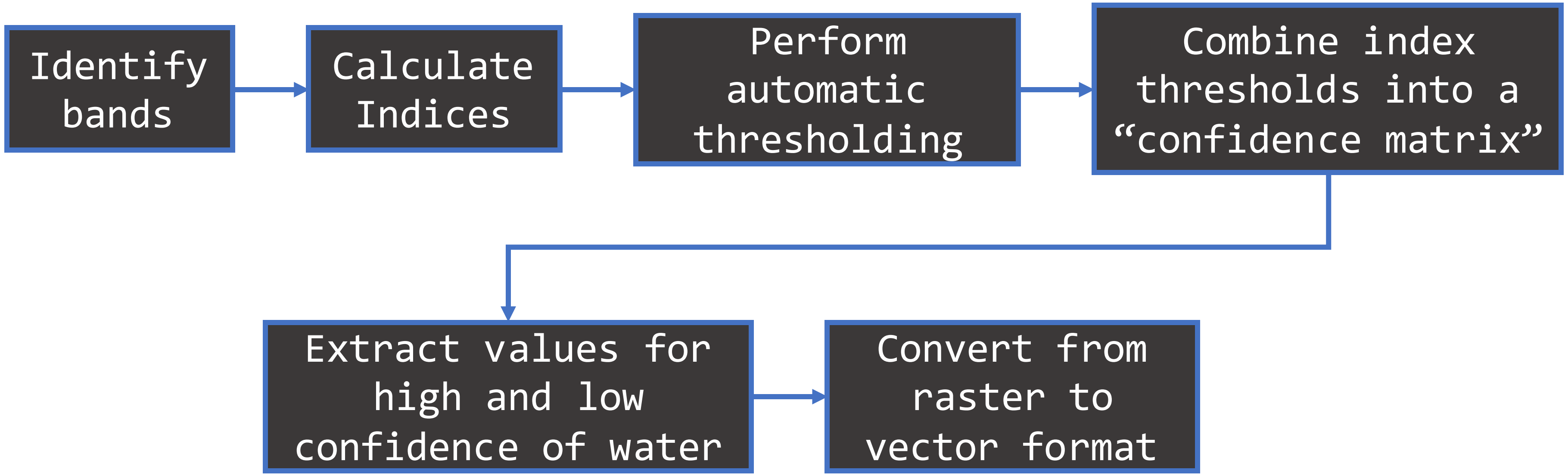
Currently the tool is in the format of two Python script files. These files contain the processing functions necessary to perform the classification (Shown Left)

Also built for the tool is integration with an ArcToolbox Script Tool allowing the tool to be used within a GUI interface in ArcGIS Pro (Shown Right)





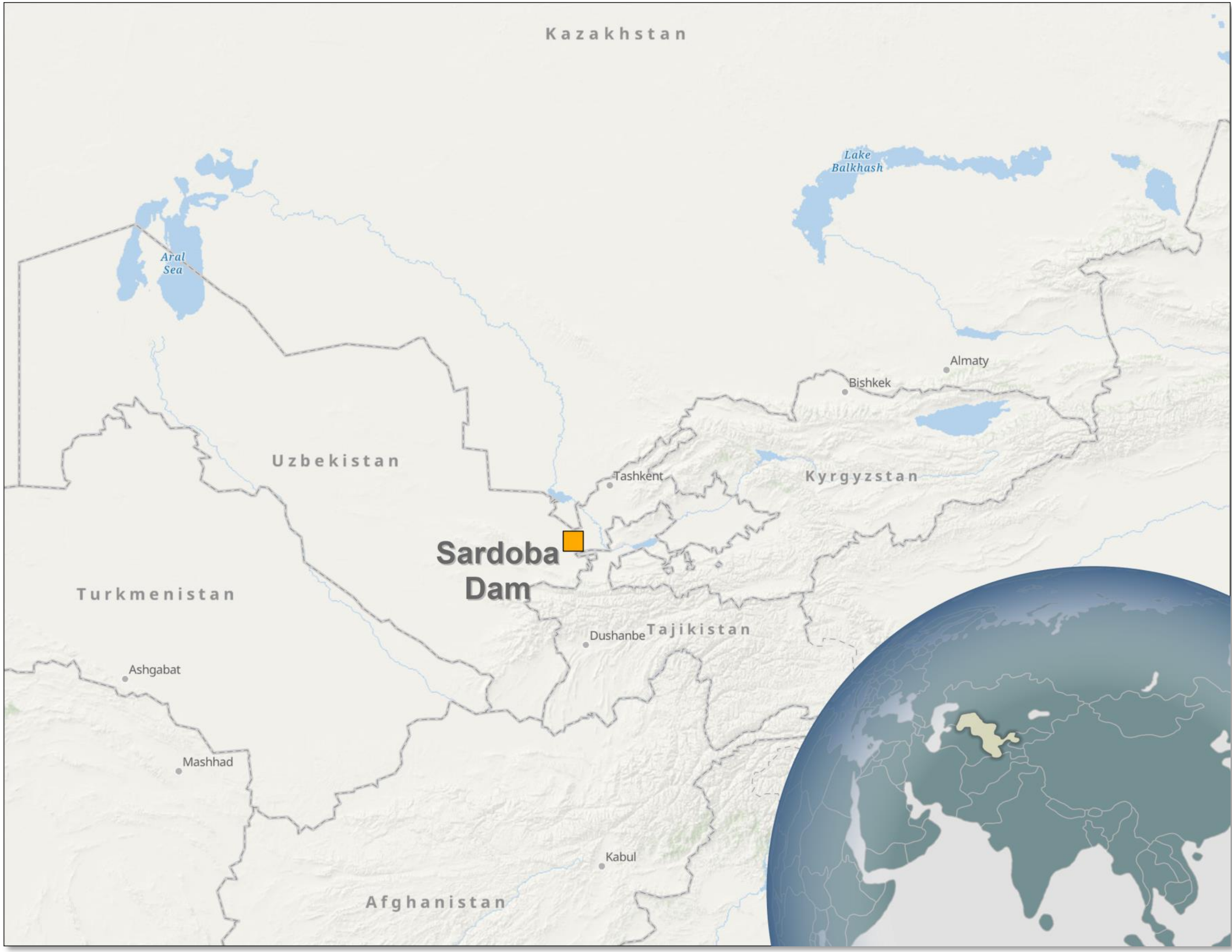
Tool Process Workflow



Case Study: Sardoba dam, Uzbekistan

In April of 2020, the Sardoba dam suffered a breach in its containing wall, the subsequent flood of water inundated large areas of the surrounding land

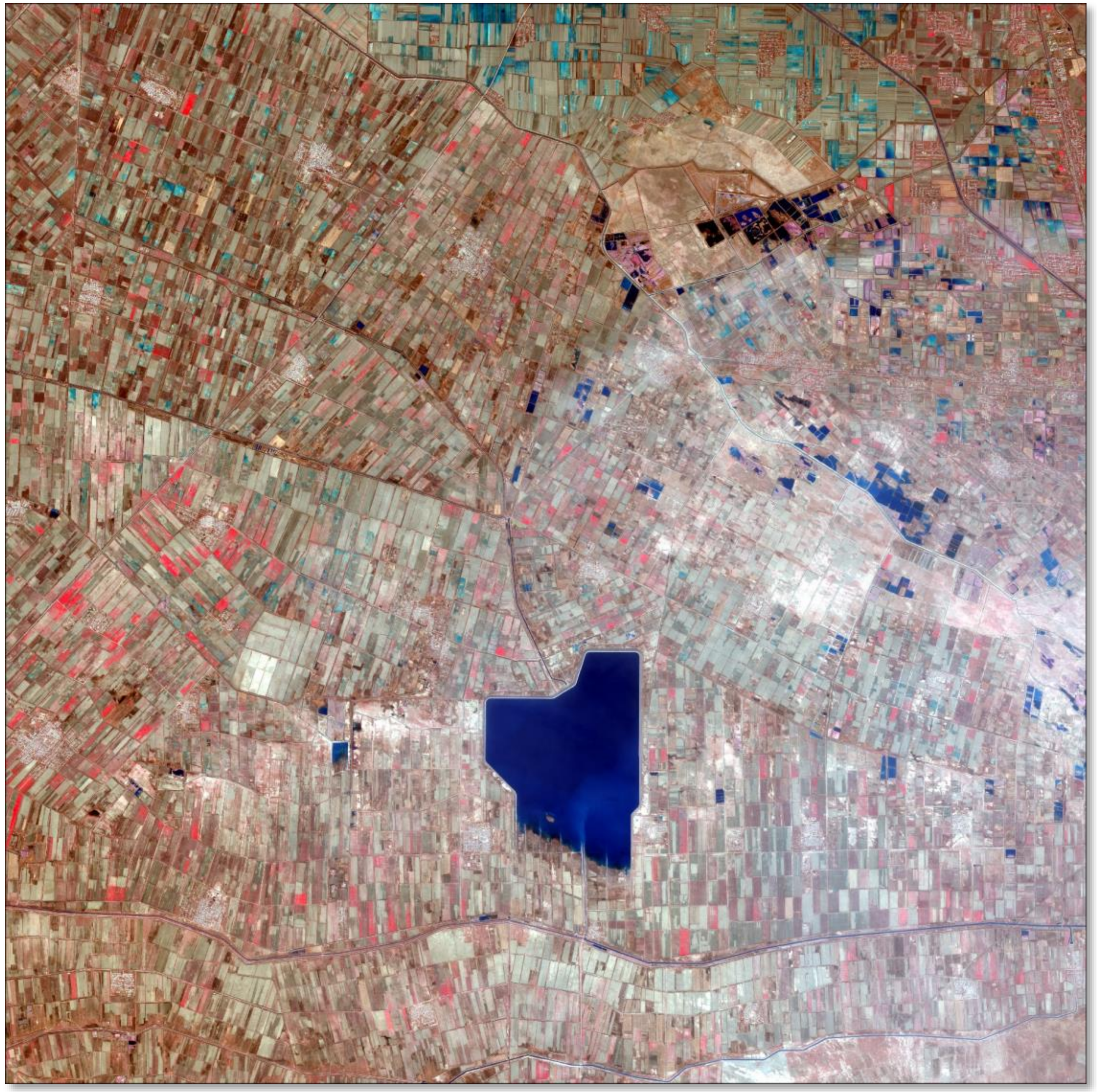
Sardoba Dam Breach. Image Source: kun.uz



Map by: Daniel Clement

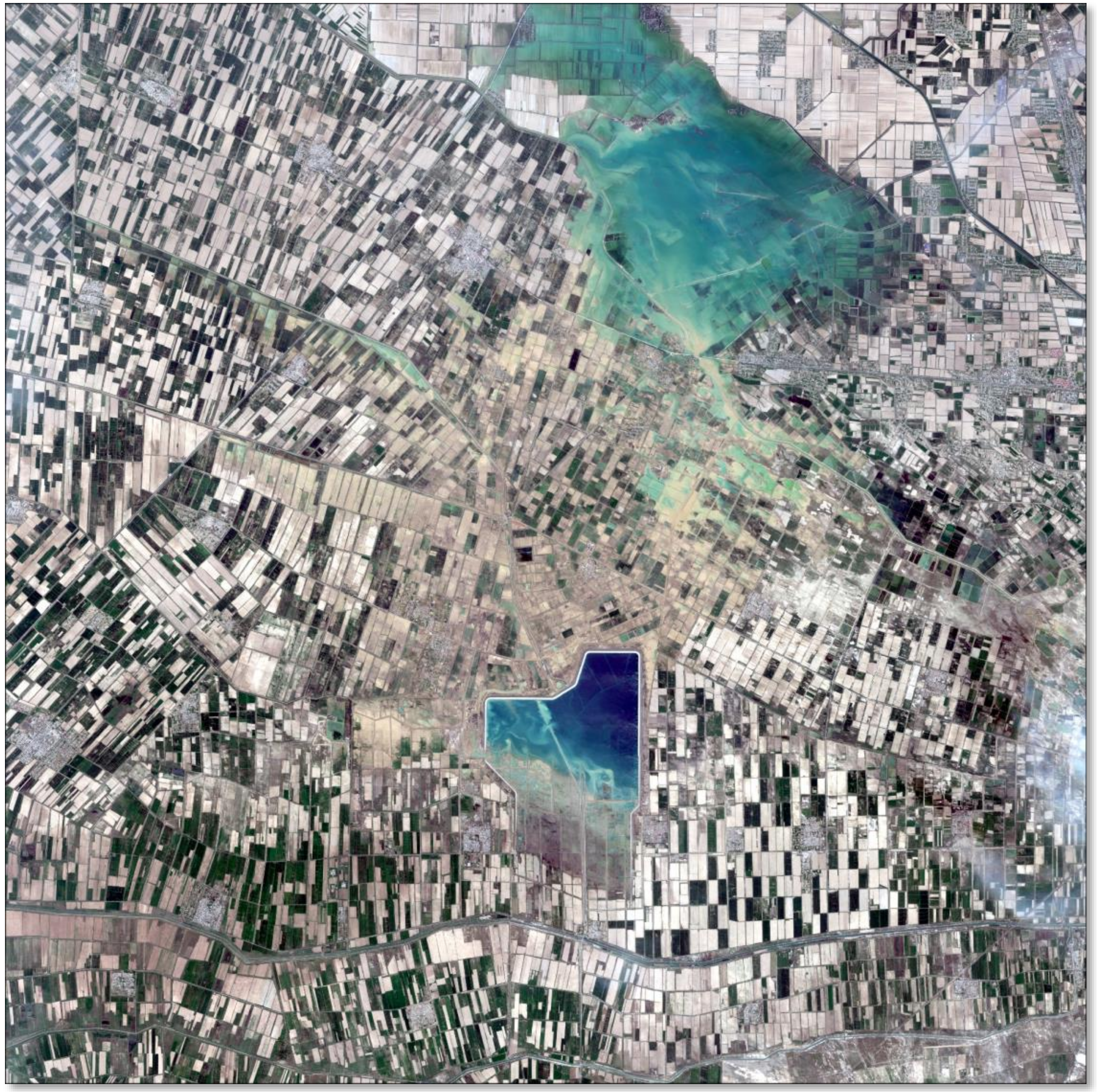
Before Dam Breach – February 4, 2020

Natural Color imagery of Sardoba Dam - Sentinel-2

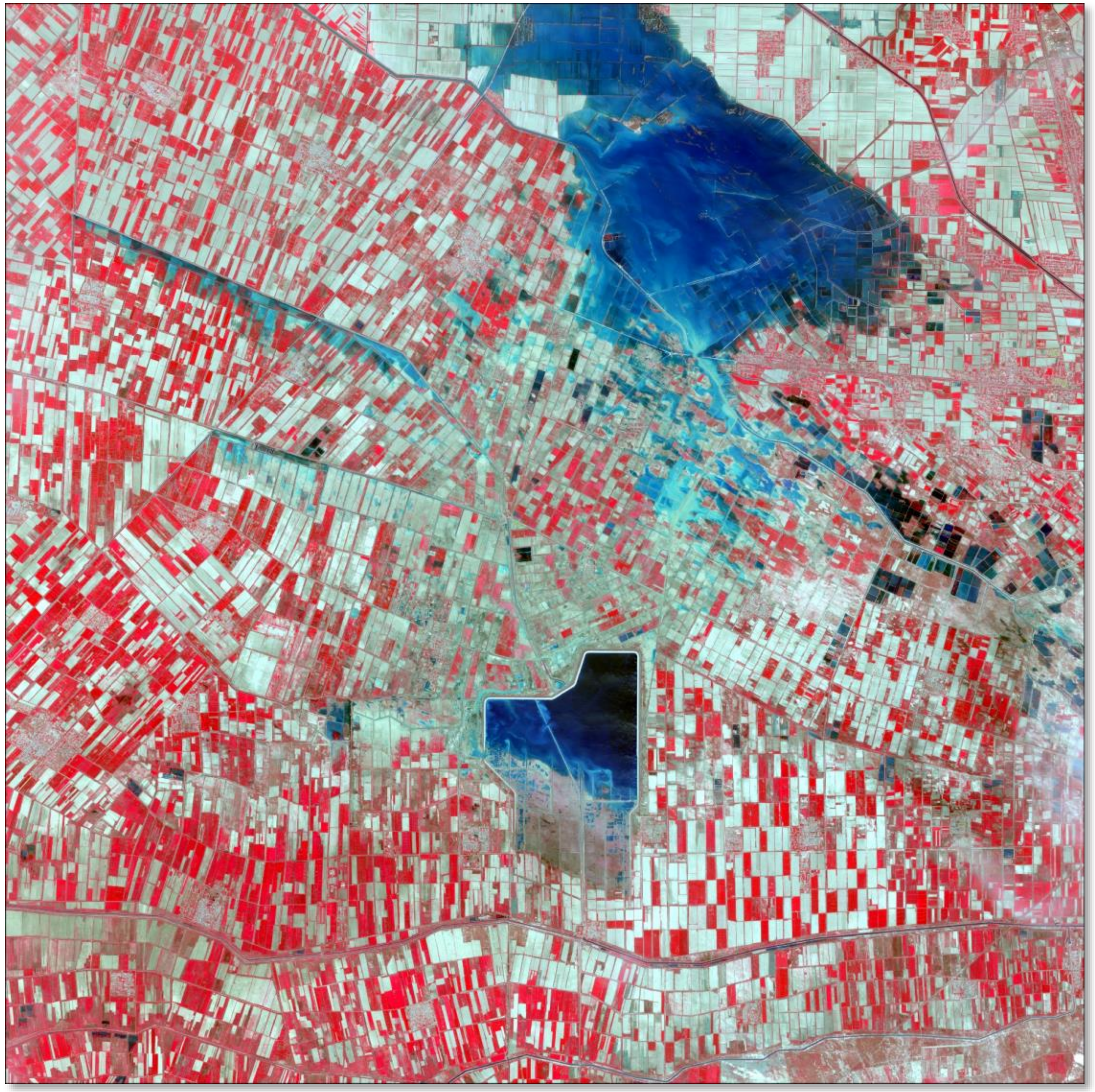


False Color Infrared imagery of Sardoba Dam - Sentinel-2

After Dam Breach – February 4, 2020



Natural Color imagery of Sardoba Dam - Sentinel-2

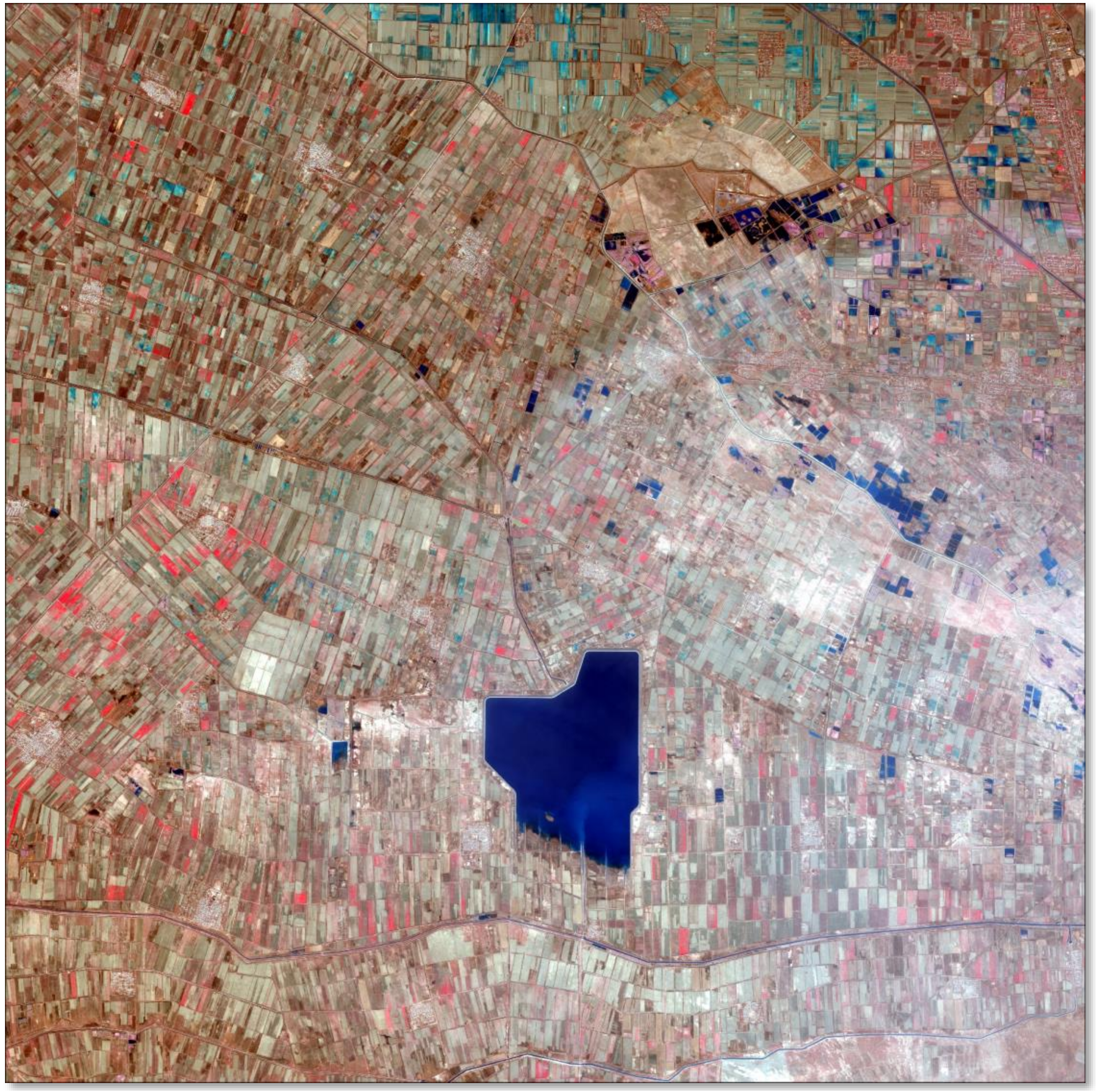


False Color Infrared imagery of Sardoba Dam - Sentinel-2

After Dam Breach – February 4, 2020

Sardoba Dam breach - Sentinel-2

Before Dam Breach – February 4, 2020



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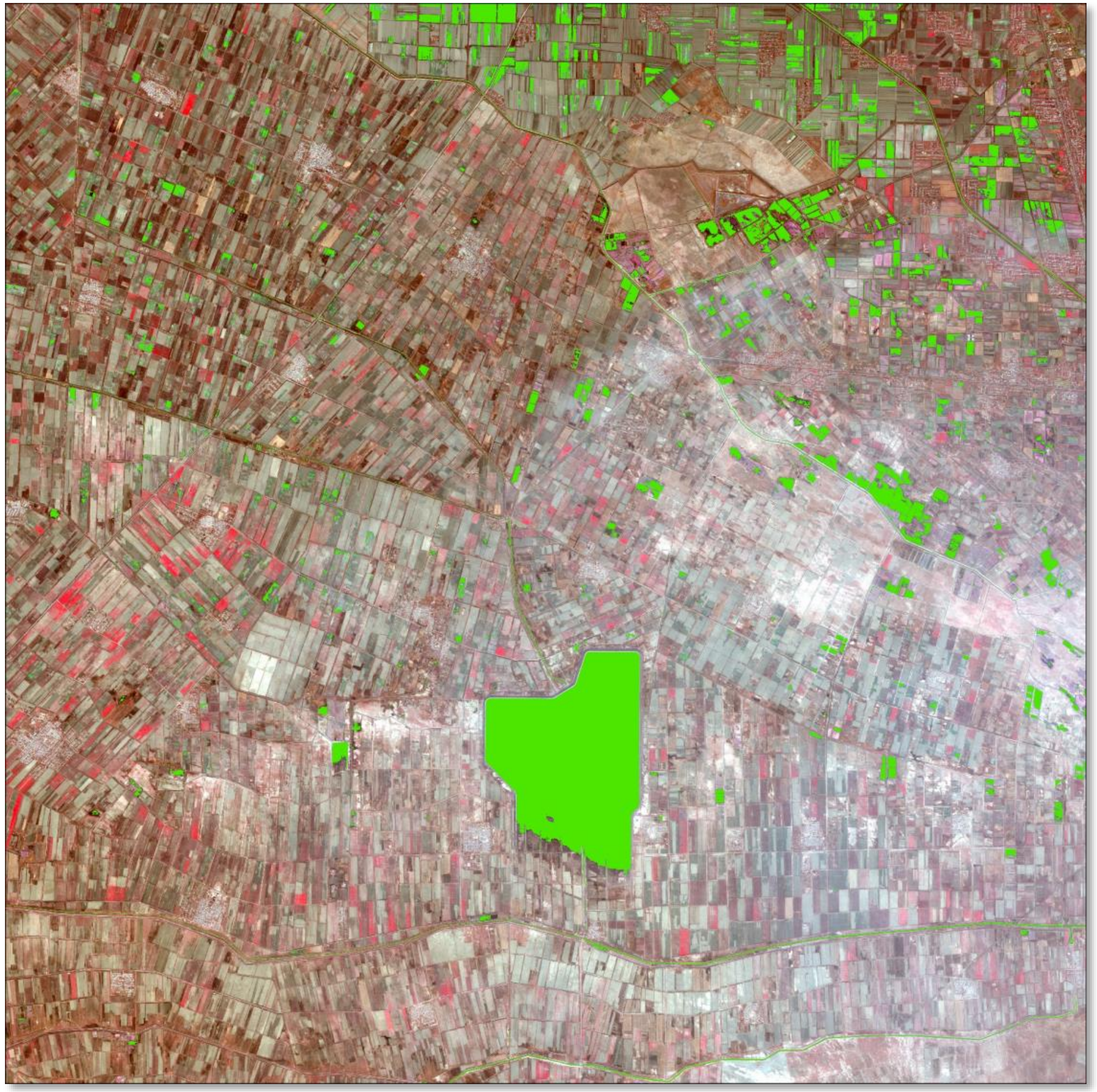
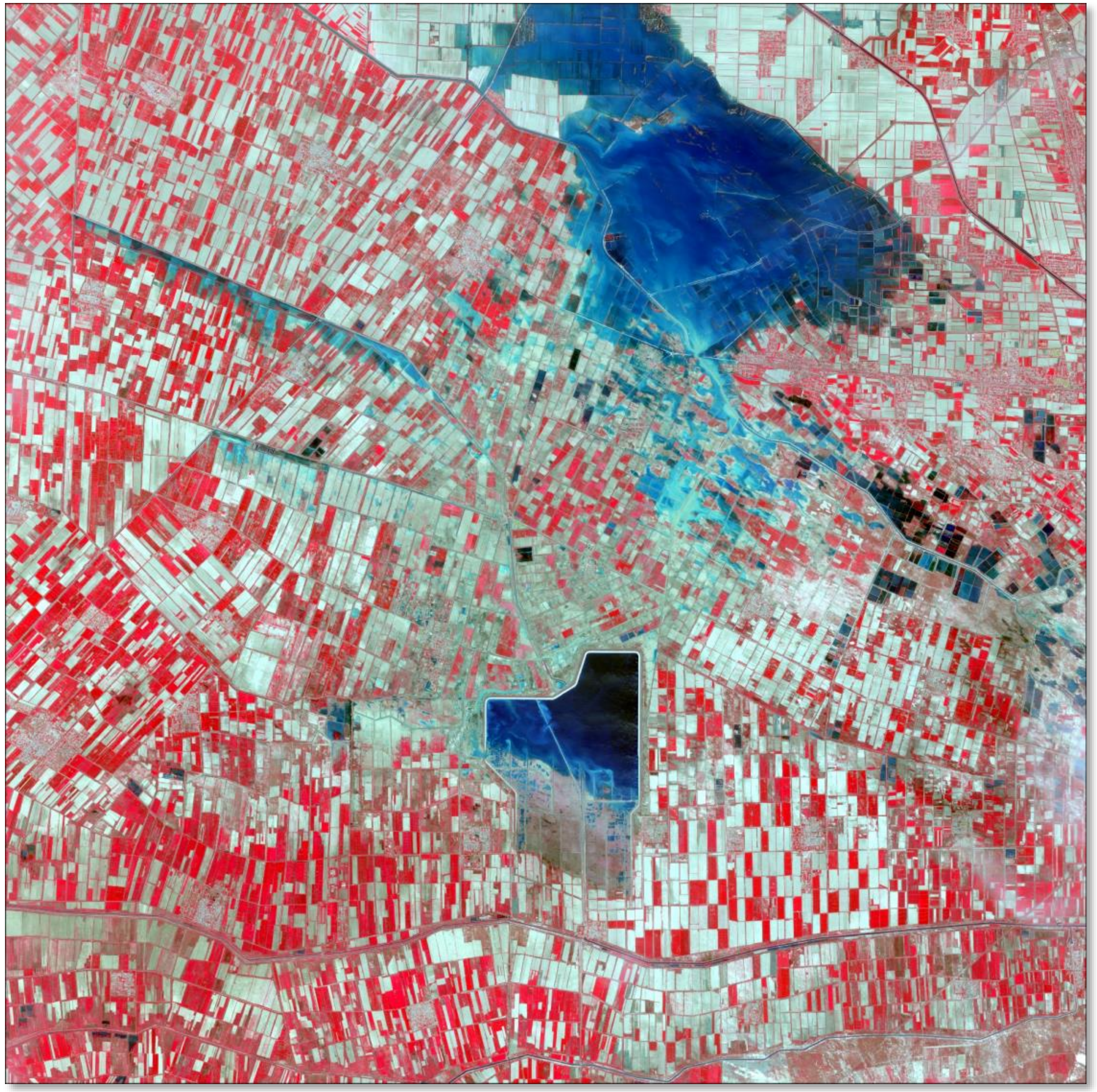


Areas Classified as Water – Shown in Green

After Dam Breach – February 4, 2020



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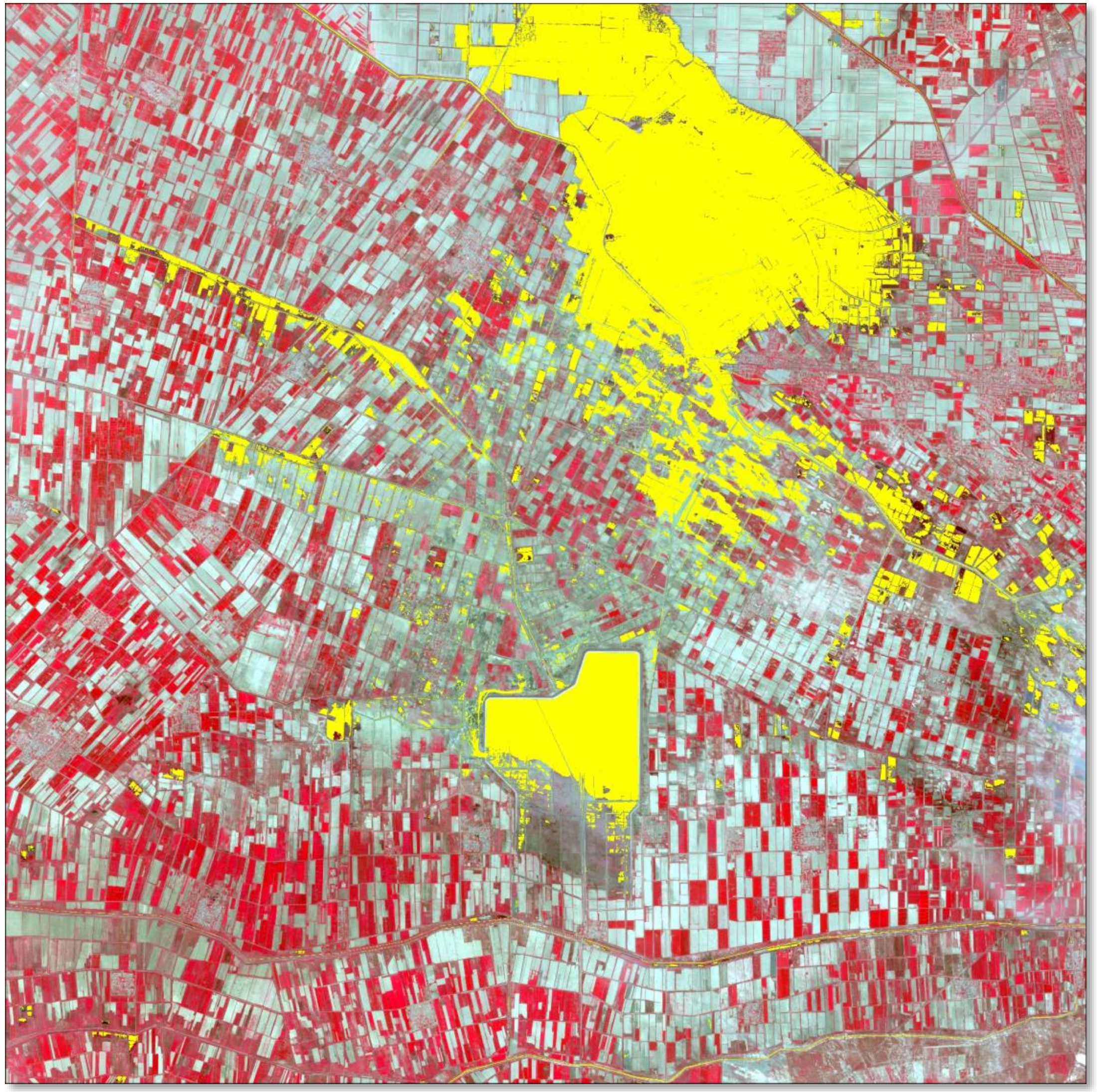
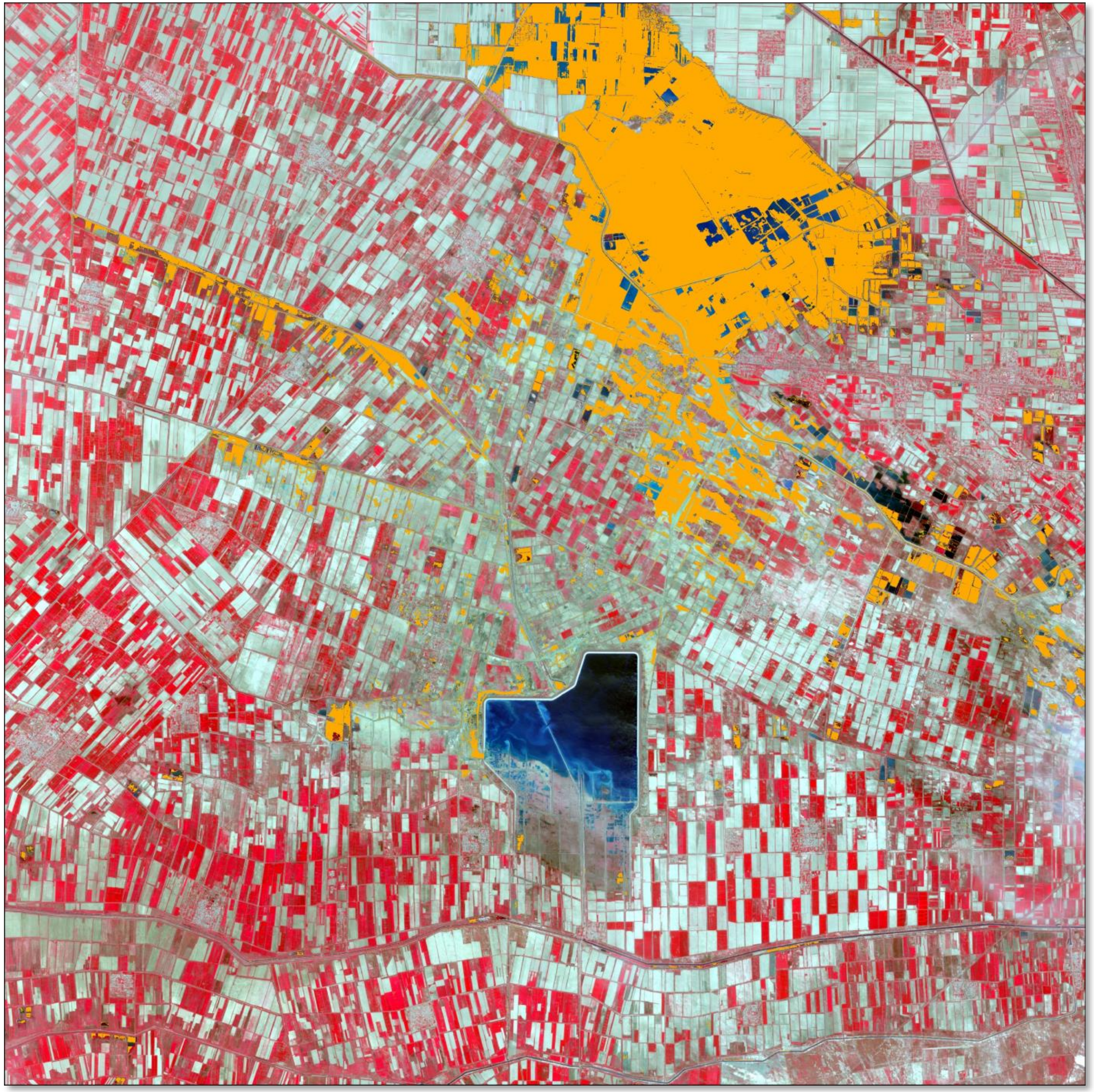


Areas Classified as Water – Shown in Yellow

Applications

Change

Areas where water existed before, are removed from the After water area. This analysis results in a raster containing only the areas which are new waterbodies or inundated areas.



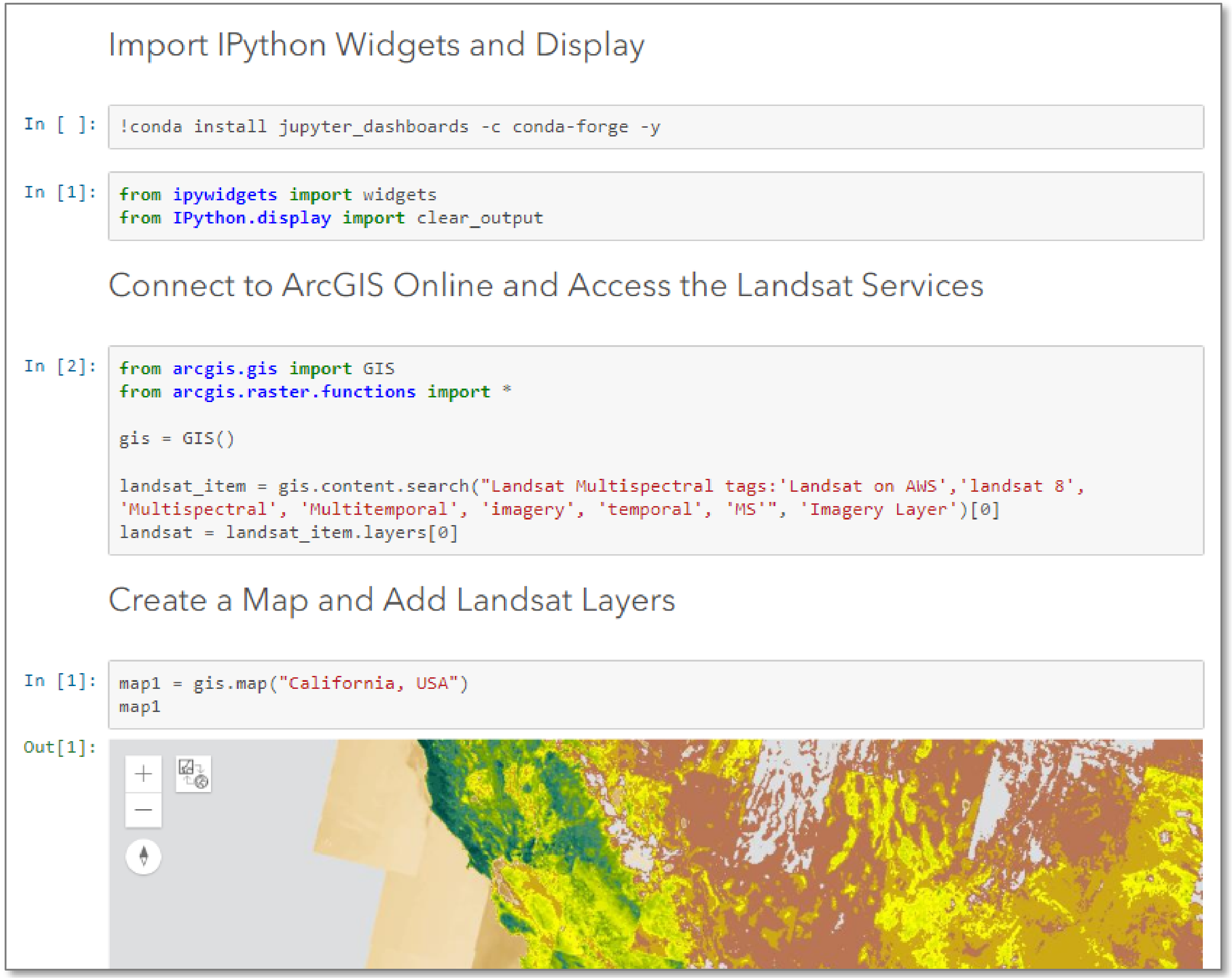
Areas Classified as New Water (change) – Shown in Orange

Next Steps?

- Identify the section of the code which will be used for the ArcGIS Notebook

- Build out the notebook

- Share with colleagues and fellow students.



Example Jupyter Notebook – Source: esri.com


Questions?