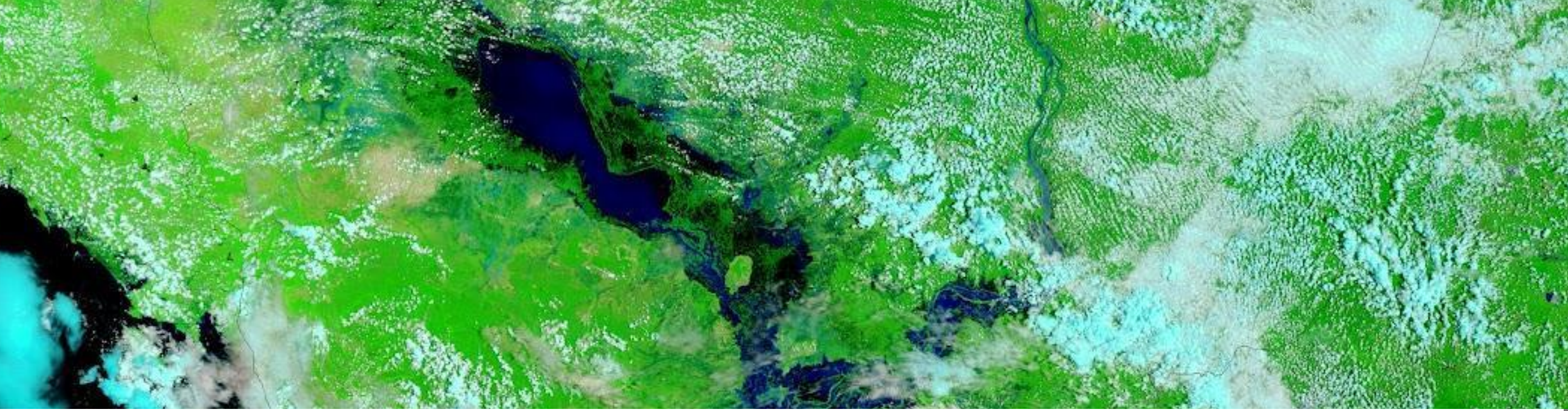
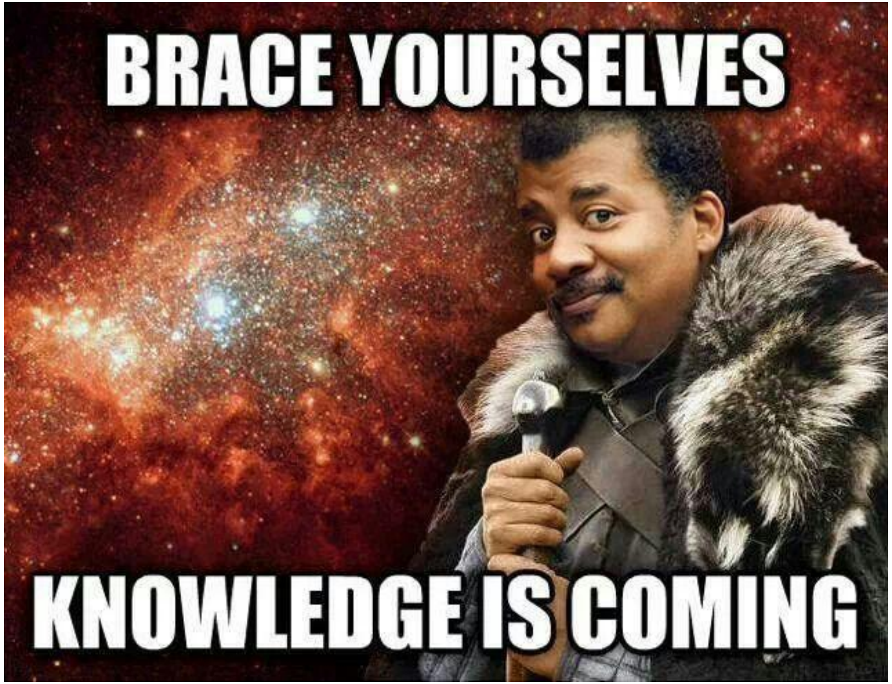


Overview of surface water mapping methods

HYDRAFloods Training
11 October 2021

Outline

- Remote Sensing Overview
- Optical water mapping
- SAR water mapping
- Thresholding algorithms
- Advanced algorithms



Remote Sensing is…

the practice of deriving information about the Earth’s land and water surfaces using images **acquired from an overhead perspective**, by employing **electromagnetic radiation** in one or more regions of the electromagnetic spectrum, **reflected or emitted** from the Earth’s surface.

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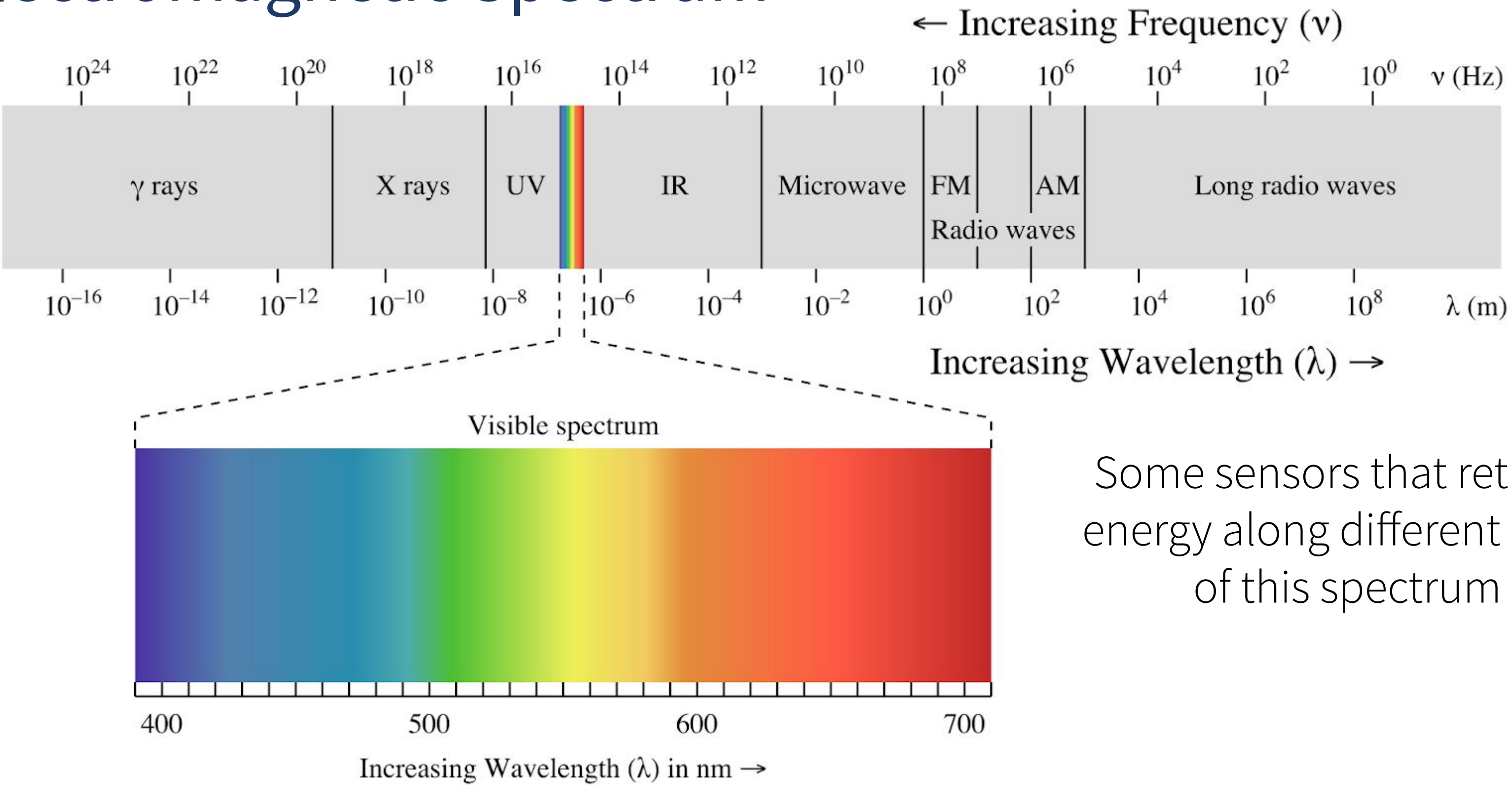
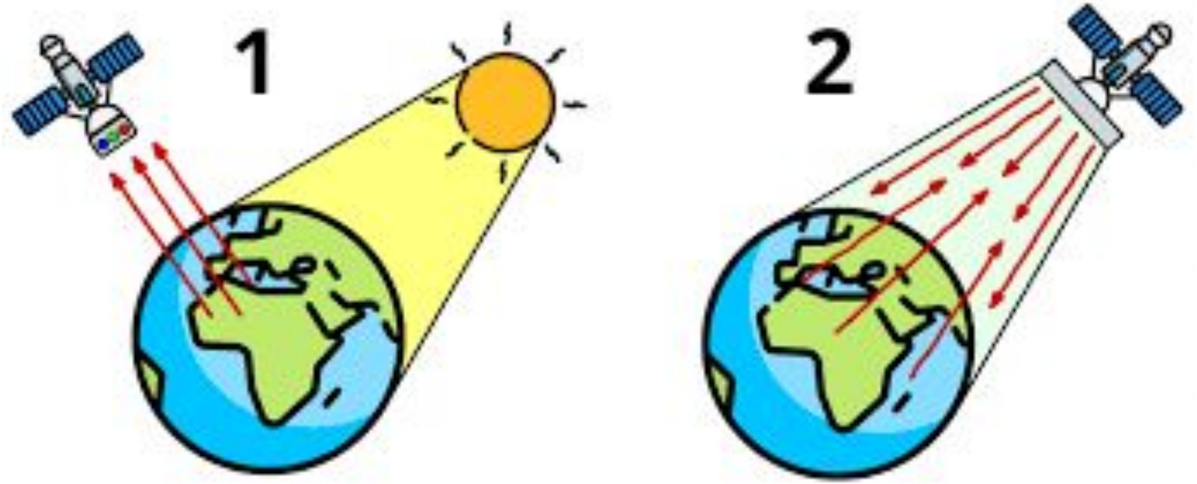
Electromagnetic Spectrum



Some sensors that retrieve energy along different areas of this spectrum

Types of remote sensing

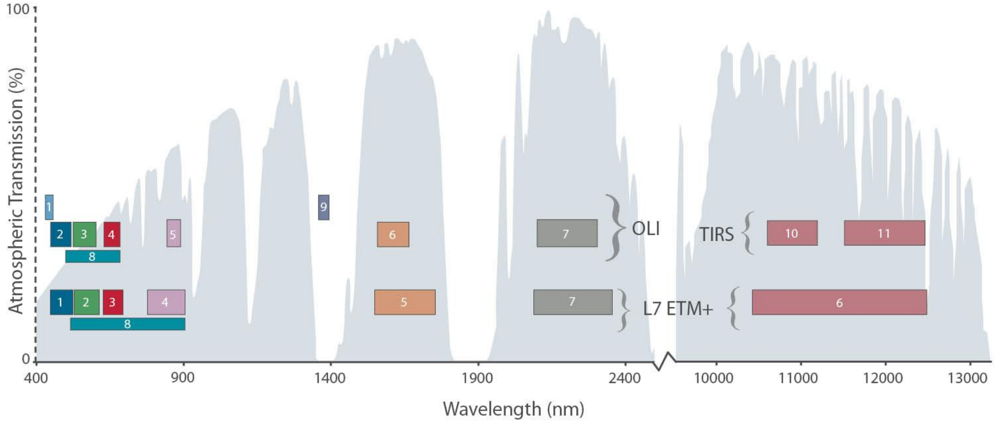
1. Passive Remote Sensing: Energy = Radiation from Earth
2. Active Remote Sensing: Energy = Instrument



https://paititi.info/research-technology/remote-sensing-from-space/

Optical Water Mapping

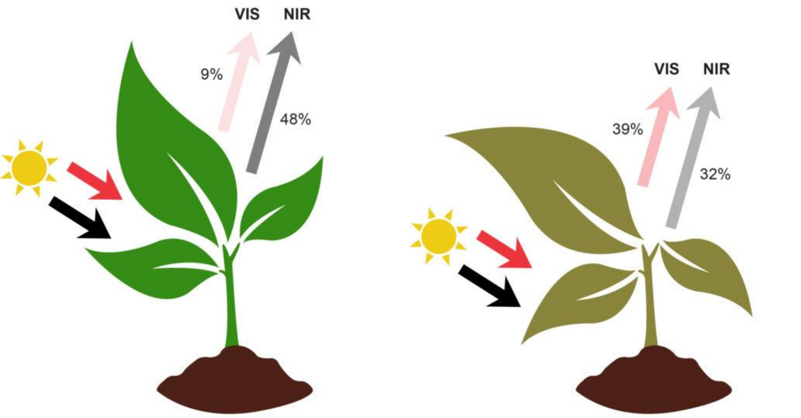
- Measures reflected light from sun in different wavelengths of the EM
- Combinations of bands can highlight different physical properties



https://landsat.gsfc.nasa.gov/landsat-8/landsat-8-overview

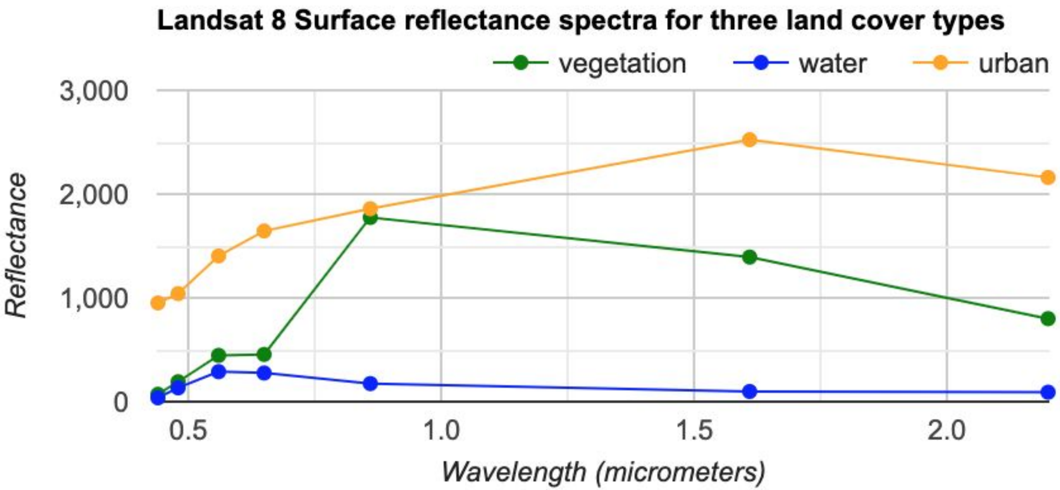
Optical Water Mapping

- Spectral indices are combinations bands from two or more wavelengths that indicate the relative abundance of features of interest



Healthy Plant
(.48 - .09) / .48 + .09) = .68

Stressed Plant
(.39 - .32) / (.39 + .32) = .10

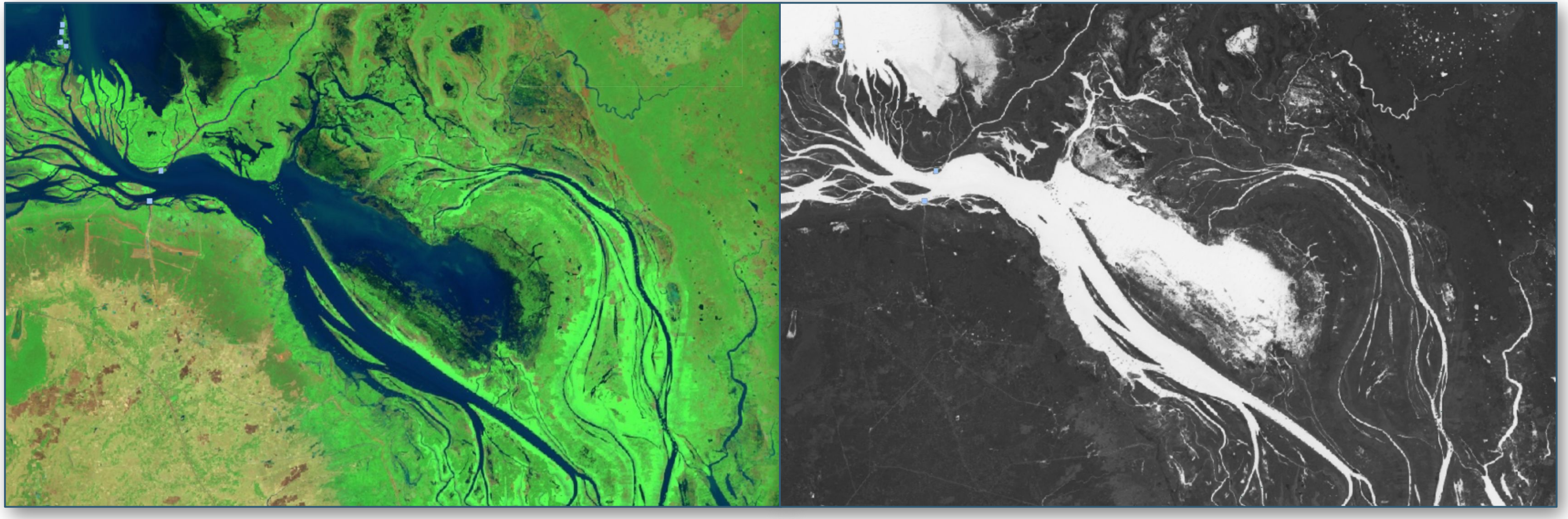


https://midopt.com/healthy-crop/

Band Combinations

Water Indices

- Used to transform multispectral imagery to highlight water
- Rely heavily on shortwave infrared band



Water Indices

Index Name	Equation	Citation
Normalized Difference Water Index	(green - nir) / (green + nir)	https://doi.org/10.1080/01431169608948714
Modified Normalized Difference Water Index	(green - swir1) / (green + swir1)	https://doi.org/10.1080/01431160600589179
Automated Water Extraction Index (no shadow)	4.0 * (green - swir1) - ((0.25 * nir) + (2.75 * swir2))	https://doi.org/10.1016/j.rse.2013.08.029
Automated Water Extraction Index (shadow)	blue + 2.5 * green - 1.5 * (nir + swir1) - 0.25 * swir2	https://doi.org/10.1016/j.rse.2013.08.029
Water Ratio Index	(green + red) / (nir + swir1)	https://doi.org/10.1109/GEOINFORMATICS.2010.5567762.
Land Surface Water Index	(nir - swir1) / (nir + swir1)	https://doi.org/10.1080/01431160802575653

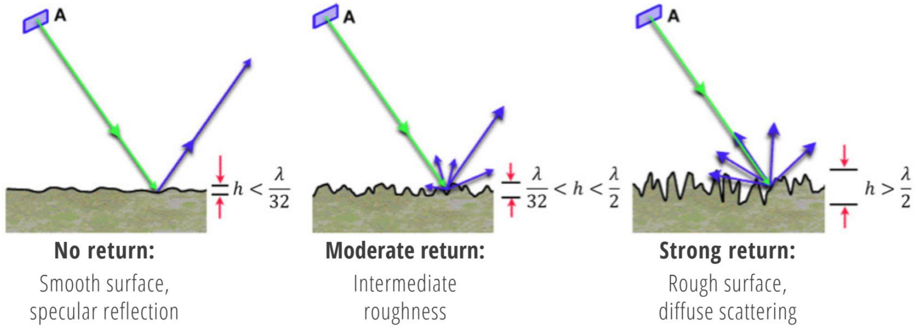
Herndon et al., 2019 Zhou et al., 2017

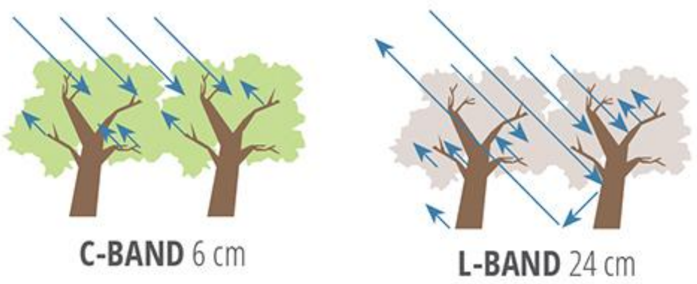
Limitations

- Poor atmospheric conditions can affect water mapping results
- No one best method - best approach to use depends on case
- Clouds!!!

SAR Water Mapping

- **Synthetic Aperture Radar (SAR)** is a type of active remote sensing that is available in all weather conditions
- SAR measures the amount of energy returned to the sensor (backscatter)
- Typically SAR sensors operate in a few frequencies (X, C, L, and P bands)



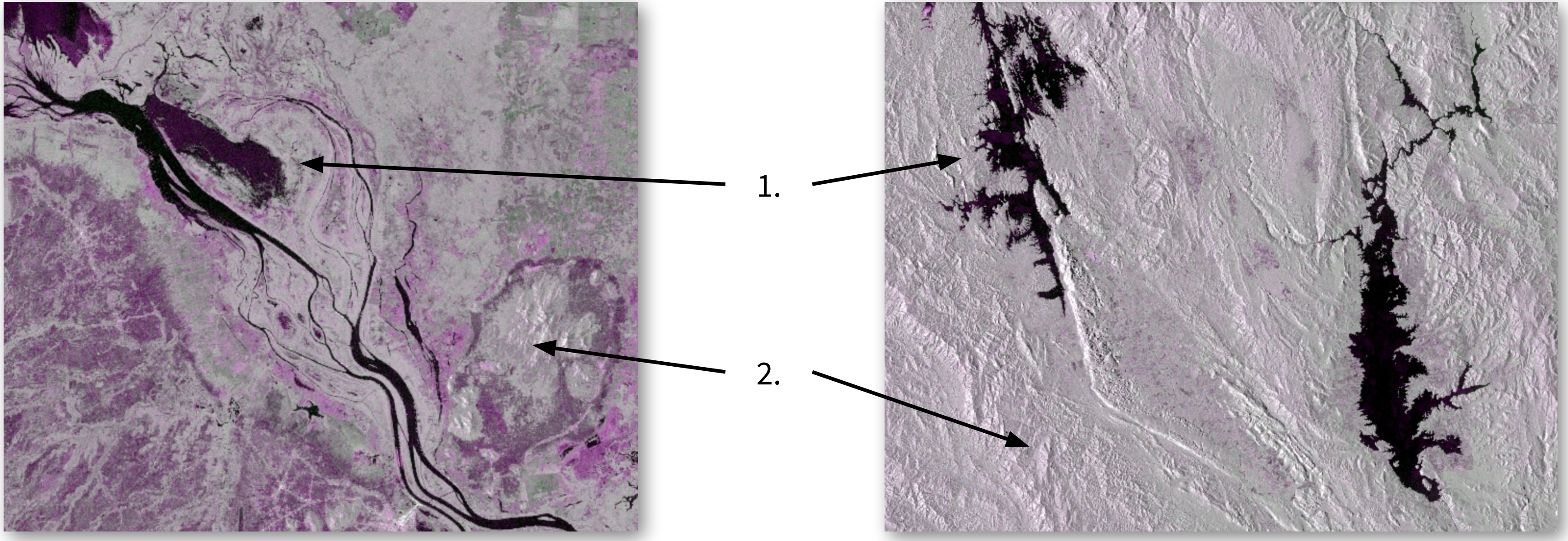


https://gis1.servirglobal.net/TrainingMaterials/SAR/Chp2Content.pdf

https://earthdata.nasa.gov/learn/backgrounders/what-is-sar

SAR Water Mapping

1. Water - specular reflection (low intensity)
2. Land - scattering by vegetation (high intensity)



SAR Water Mapping

1. Water - specular reflection (low intensity)
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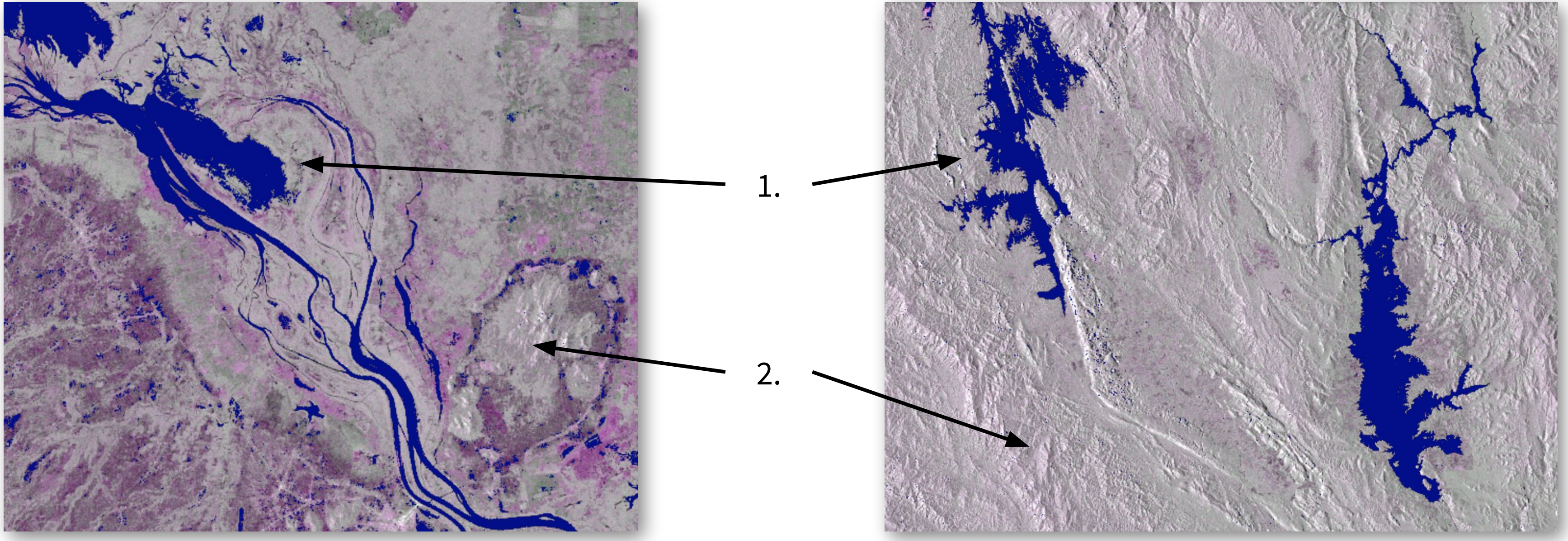
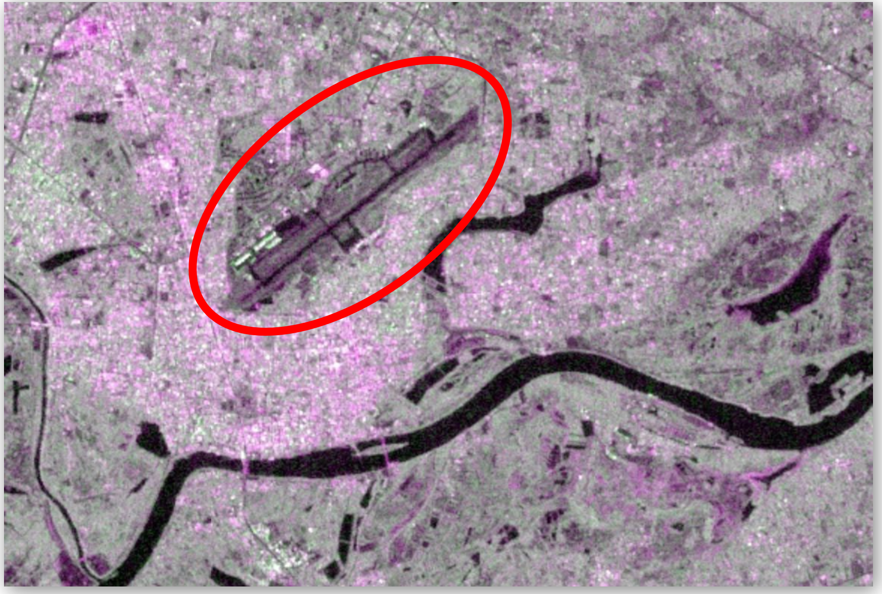


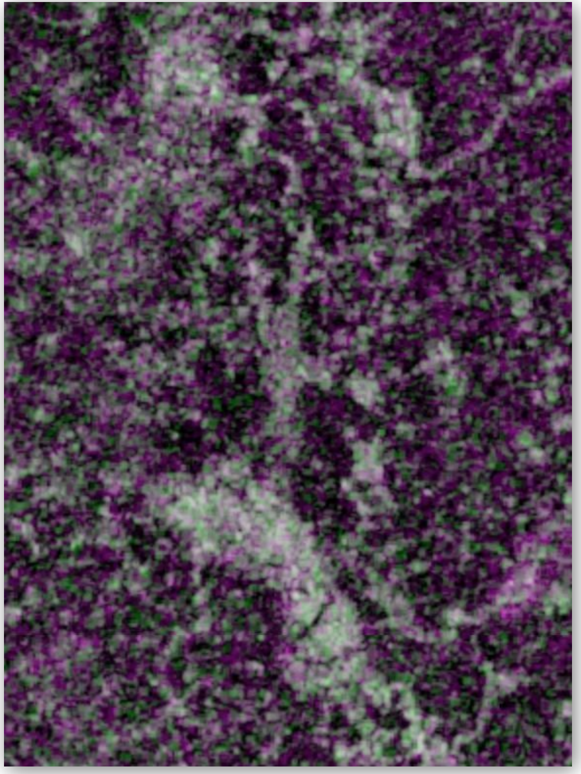
Limitations

- Water mapping with SAR is **based on the specular reflection** of the SAR signal
- Smooth surfaces “look” like water to a SAR sensor



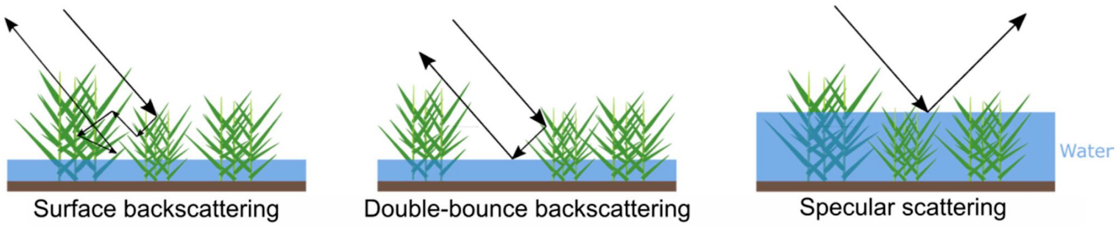
Limitations

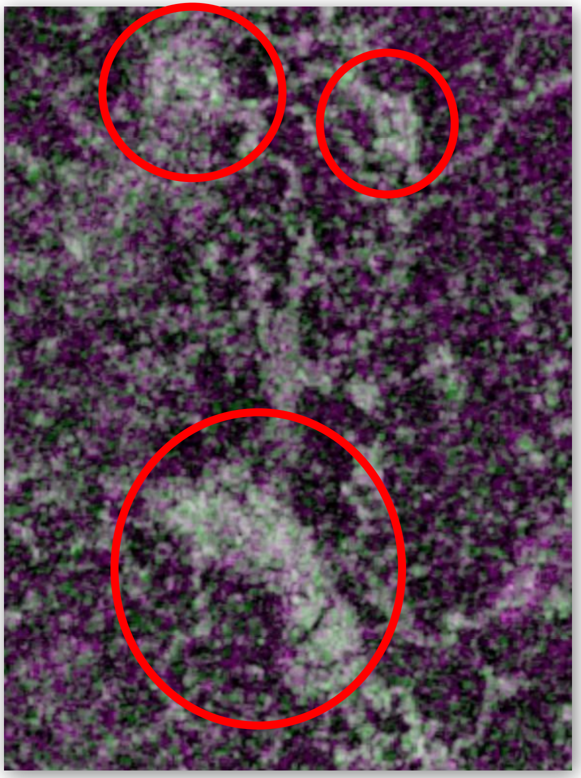
- What is water in this image?



Limitations

- Emergent vegetation can affect signal in water
- Bare, dry soils can produce low backscatter signals





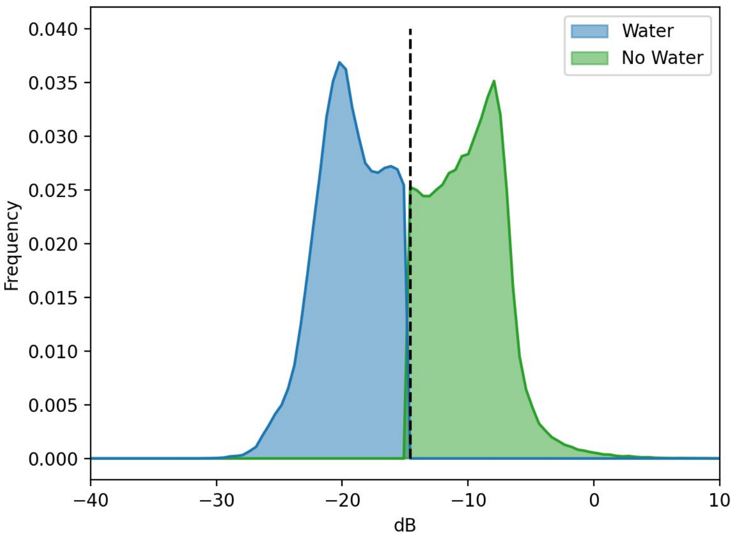
Limitations

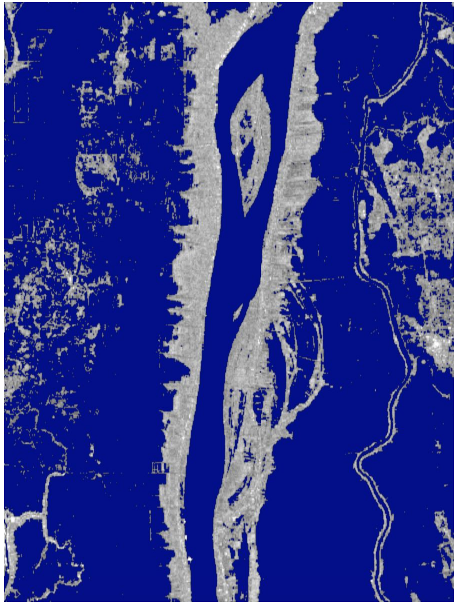
- Good practice to inspect regional conditions before applying workflows


Polar Bear
Cartesian Bear

Thresholding Algorithms

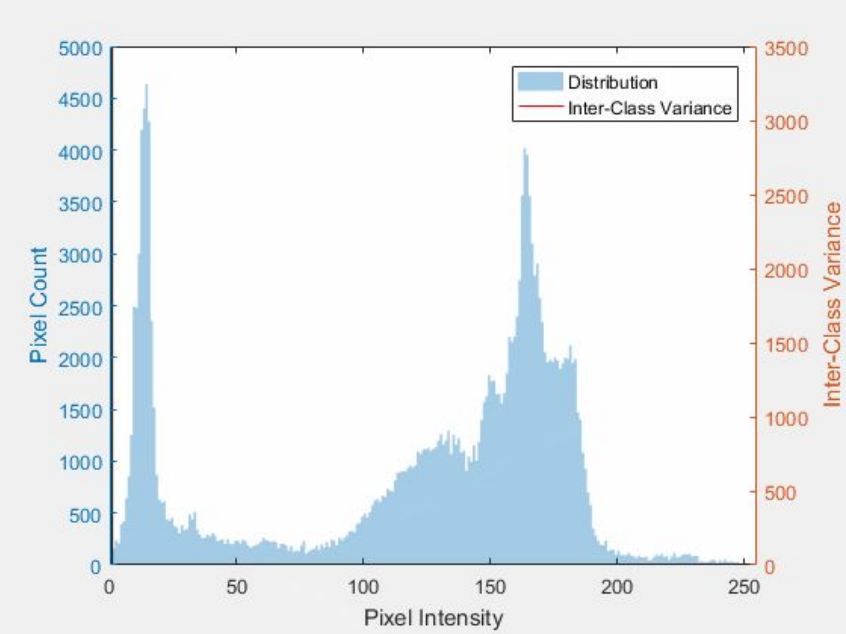
- Simplest form of image segmentation
- Uses a single value to classify image into binary classes
- Manual identification of threshold is timely and subjective





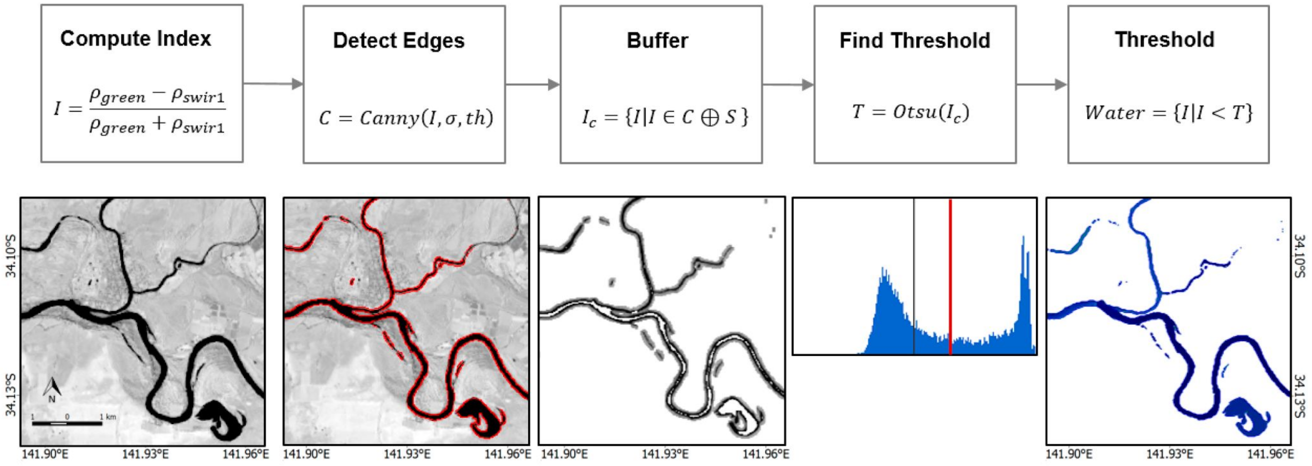
Otsu’s method

- Automated histogram-based thresholding approach
- Maximizes inter-class variance between two classes
- **Assumes there are only two classes**, a background and foreground



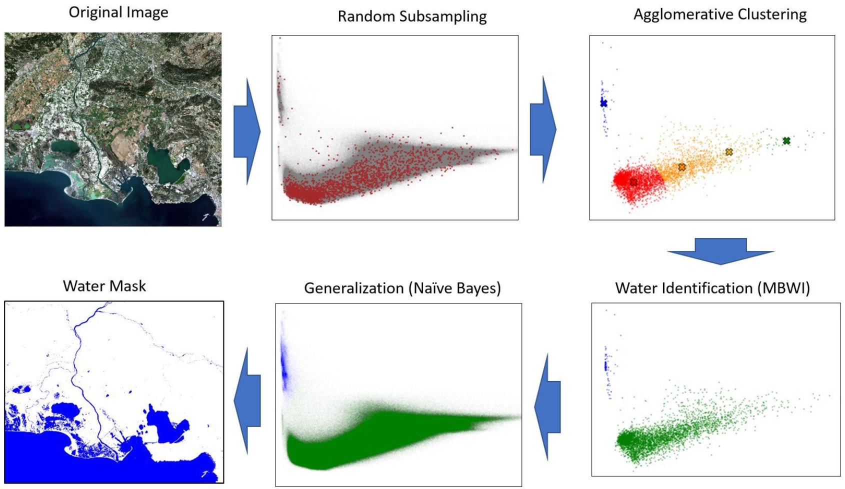
Constraining histogram sampling

- Ensure that thresholding only has two classes to segment (Donchyts et al., 2016, Cao et al., 2019, Markert et al., 2020
- Based on image characteristics (i.e. edges or bimodal areas)



Beyond simple thresholding

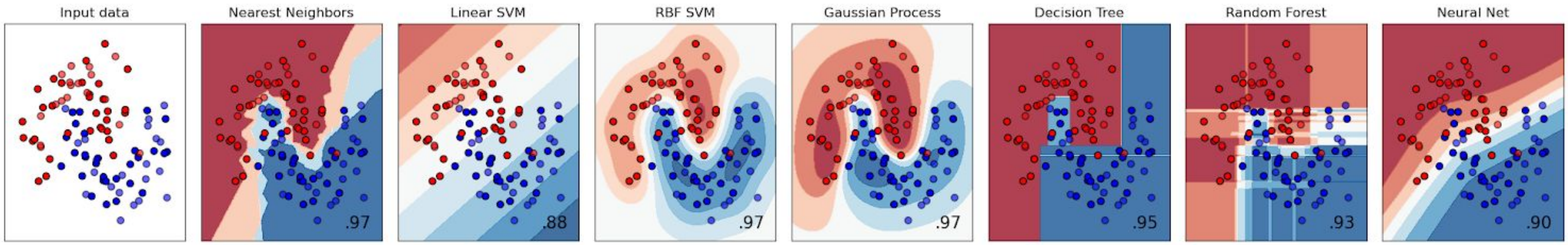
- Clustering algorithms to determine threshold (Chang et al., 2020)
- Clustering then bayesian generalization(Codeiro et al., 2021)



https://github.com/cordmaur/WaterDetect

Classical machine learning

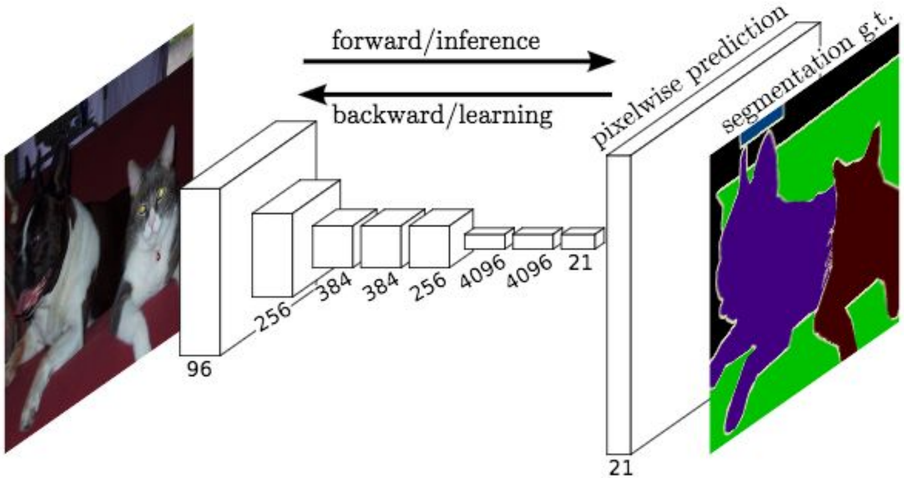
- Take additional dimensionality into account and learn non-linear patterns when mapping water
- Support Vector Machine (SVM) and Random Forest (RF) are popular algorithms and meet many needs



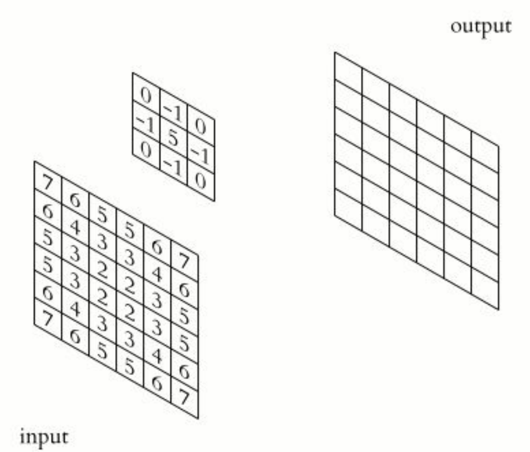
https://scikit-learn.org/stable/auto_examples/classification/plot_classifier_comparison.html#sphx-glr-auto-examples-classification-plot-classifier-comparison-py

Deep Learning

- Use large number (millions) of parameters that the computer "learns" to predict results
- Typically use fully convolutional neural network architecture



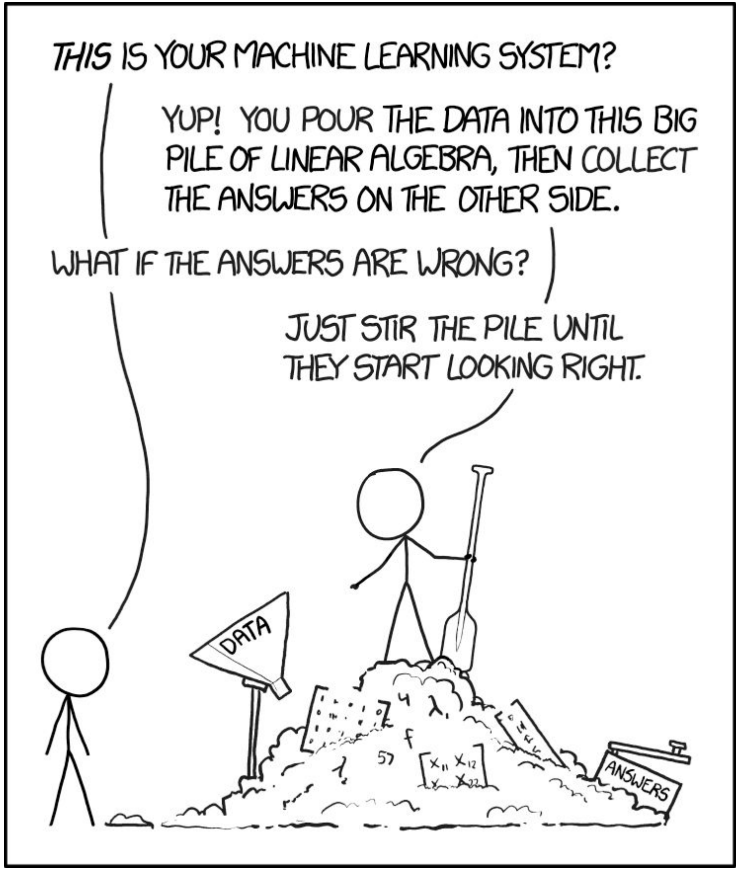
https://arxiv.org/pdf/1411.4038.pdf

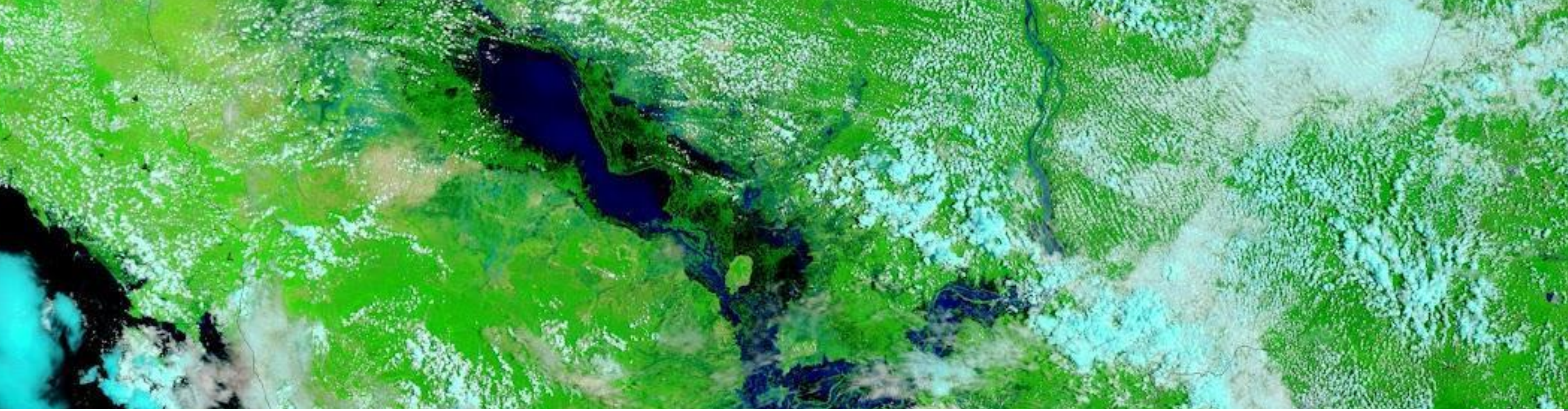


Advanced Algorithms

Limitations

- “No Free Lunch” Theorem
- Sensitive to data inputs and requires a lot of training data
- Requires correct model type/architecture for problem
- Computationally expensive to train models





Thank you for your attention!

kel.markert@nasa.gov