Delta-X Open Data Workshop: Airborne Visible/Infrared Imaging Spectrometer—Next Generation (AVIRIS-NG)

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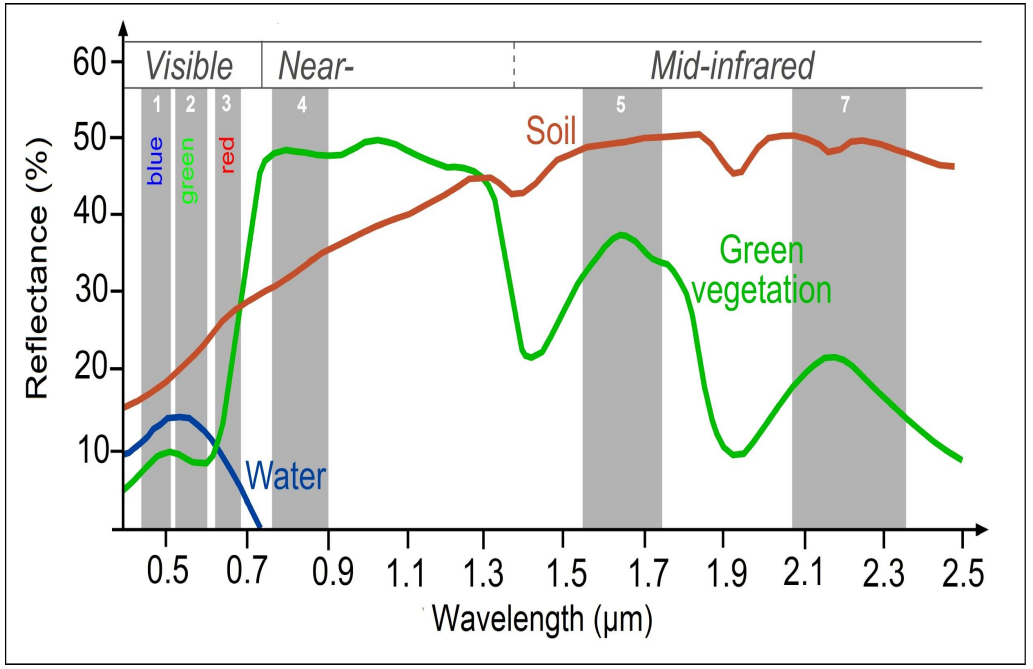
Using Remote Sensing Data for Wetland Applications

- Optical remote sensing allows us to examine landscape-scale distributions and processes in wetlands
  - E.g. vegetation type and health, land changes, water quality
  - Multispectral satellite instruments (e.g. Landsat, MODIS)
    - Measure radiance/reflectance in several bands



(https://seos-project.eu/classification/classification-c01-p05.html)

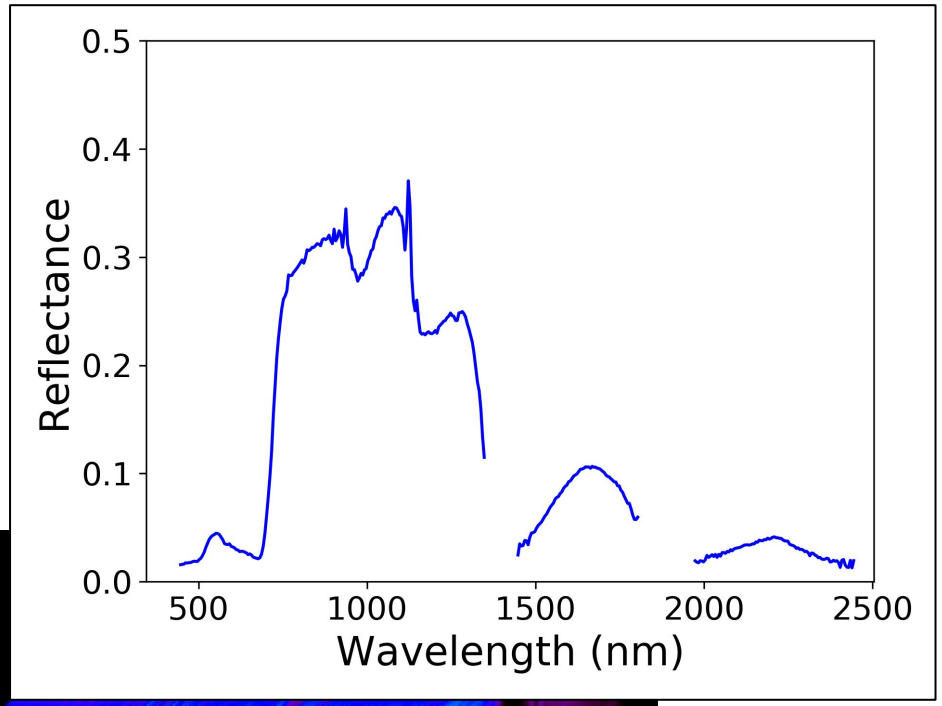
(https://www.nasa.gov/mission_pages/landsat/overview/index.html)

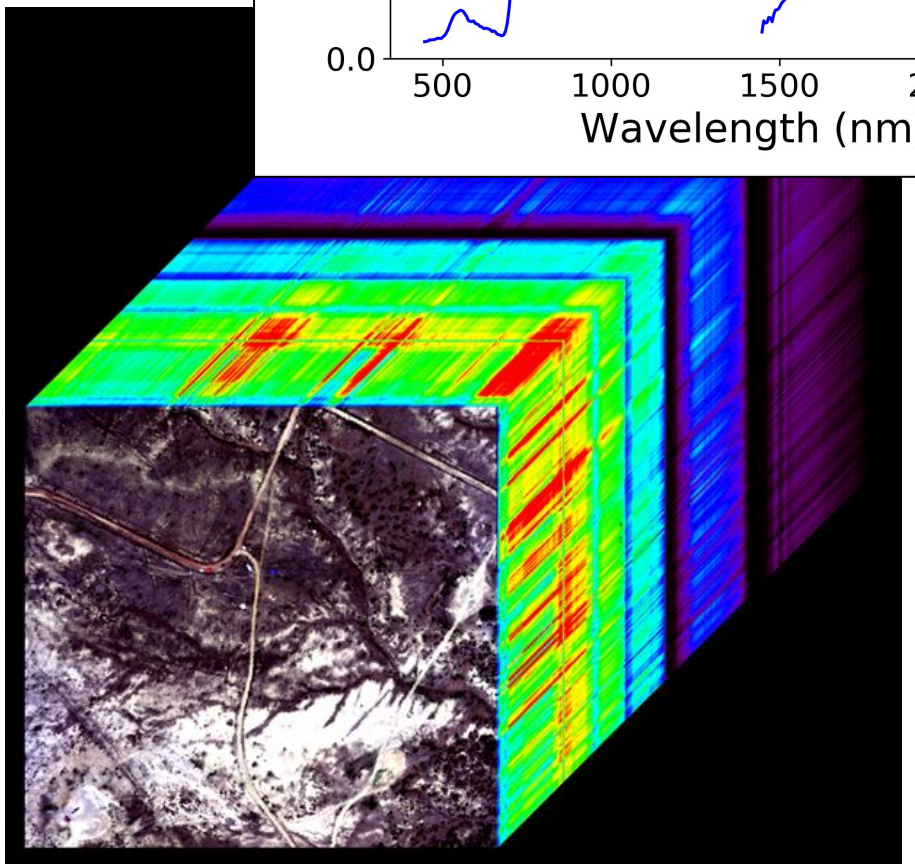
Using Remote Sensing Data for Wetland Applications

- What is imaging spectroscopy/hyperspectral data?
  - Continuous radiance measurements surface reflectance
    - ”Image Cube” approximating VSWIR reflectance properties per pixel
  - Spectral characteristics associated with plant structural and biochemical properties
    - Unique spectral signatures enable land cover/vegetation mapping

- Future NASA mission: Surface Biology and Geology

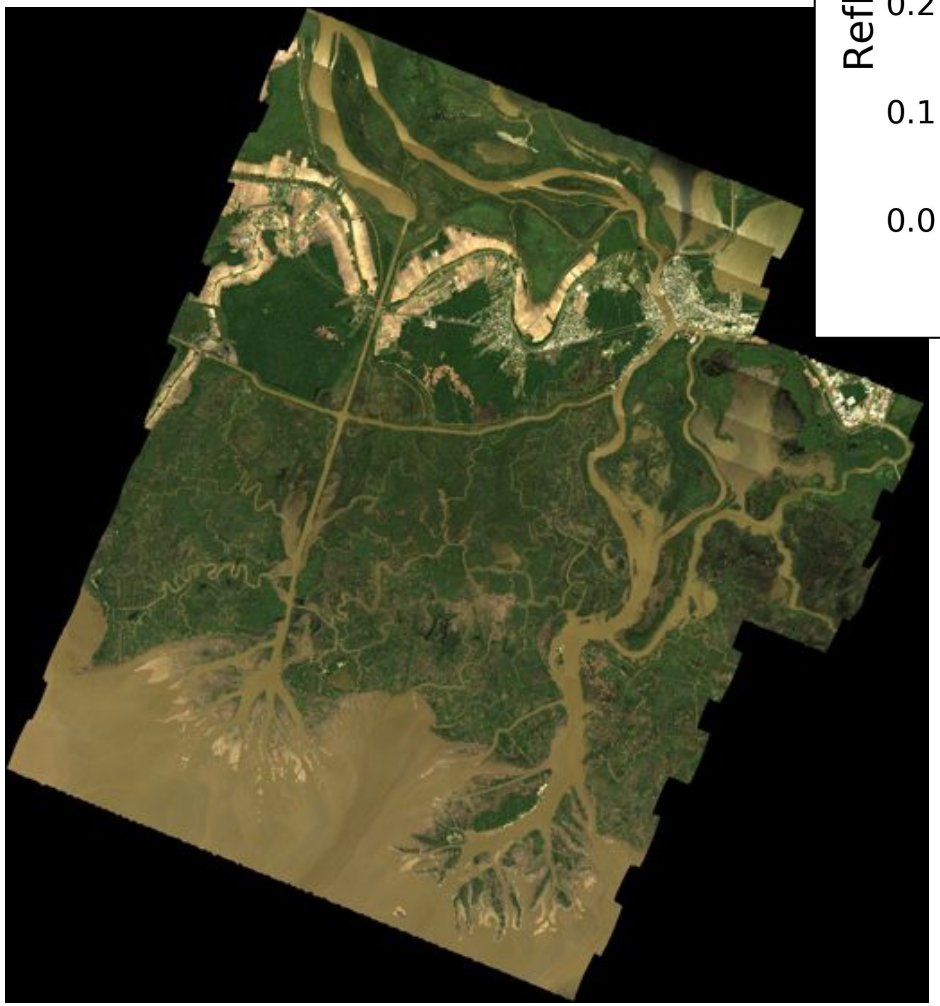
(https://aviris-ng.jpl.nasa.gov/science.html)

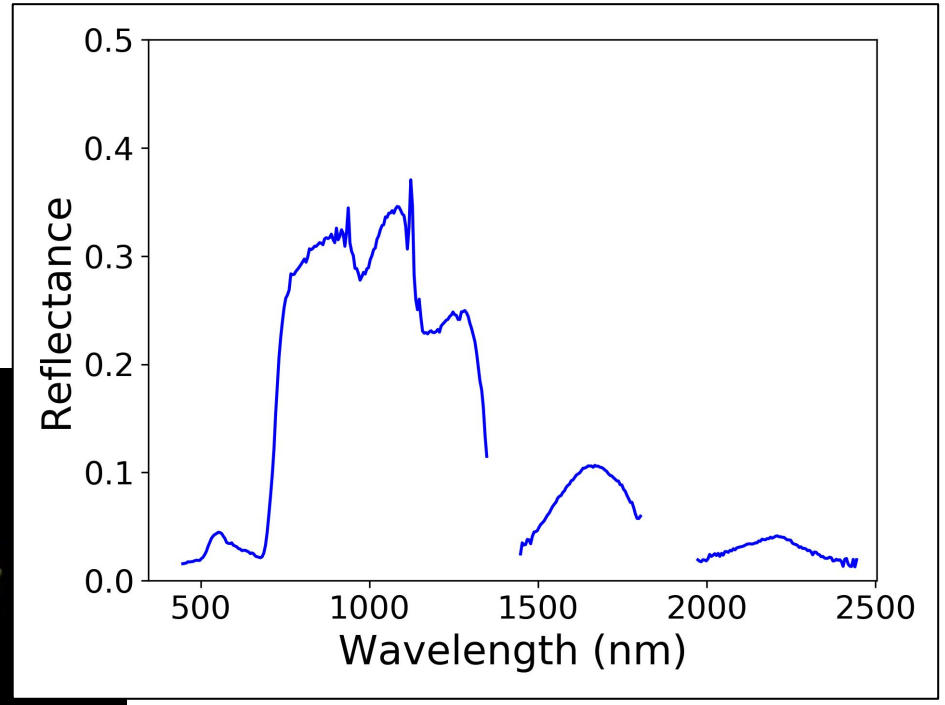




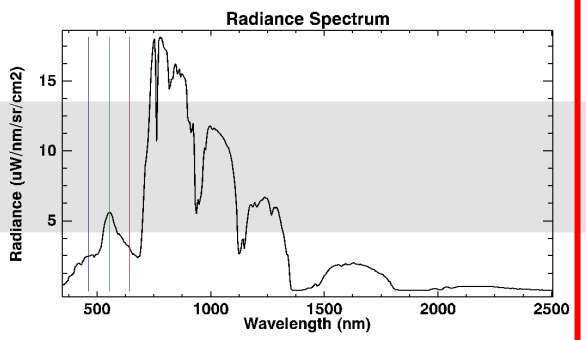
AVIRIS-NG Data Characteristics

- Wavelengths: ~380 – 2500 nm
- ~5 nm sampling
  - 425 bands
- ~5 m spatial resolution
- 3 airborne campaigns conducted 2021:
  - April, August, September (Post-Ida)
- Spatially/spectrally complex region



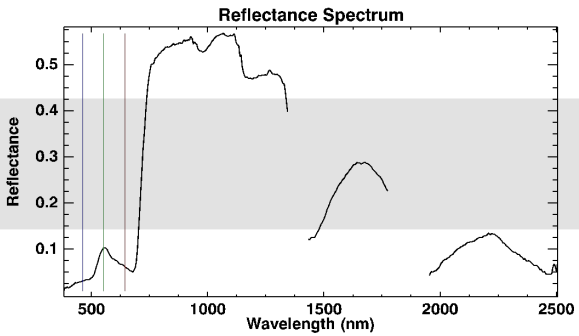


Airborne Visible/Infrared Imaging Spectrometer–Next Generation (L1-L3)

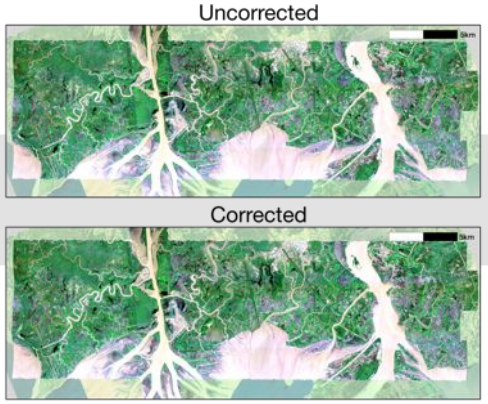


(Image courtesy of David Thompson & Evan Greenberg)

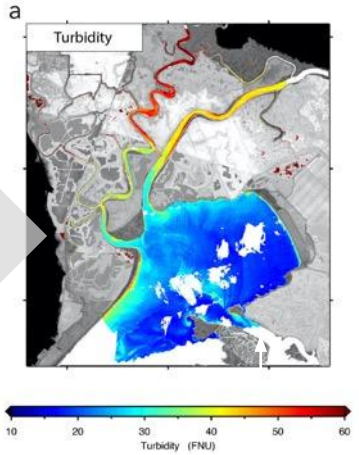
Radiance at sensor



Surface Reflectance (HRDF)



BRDF and glint correction

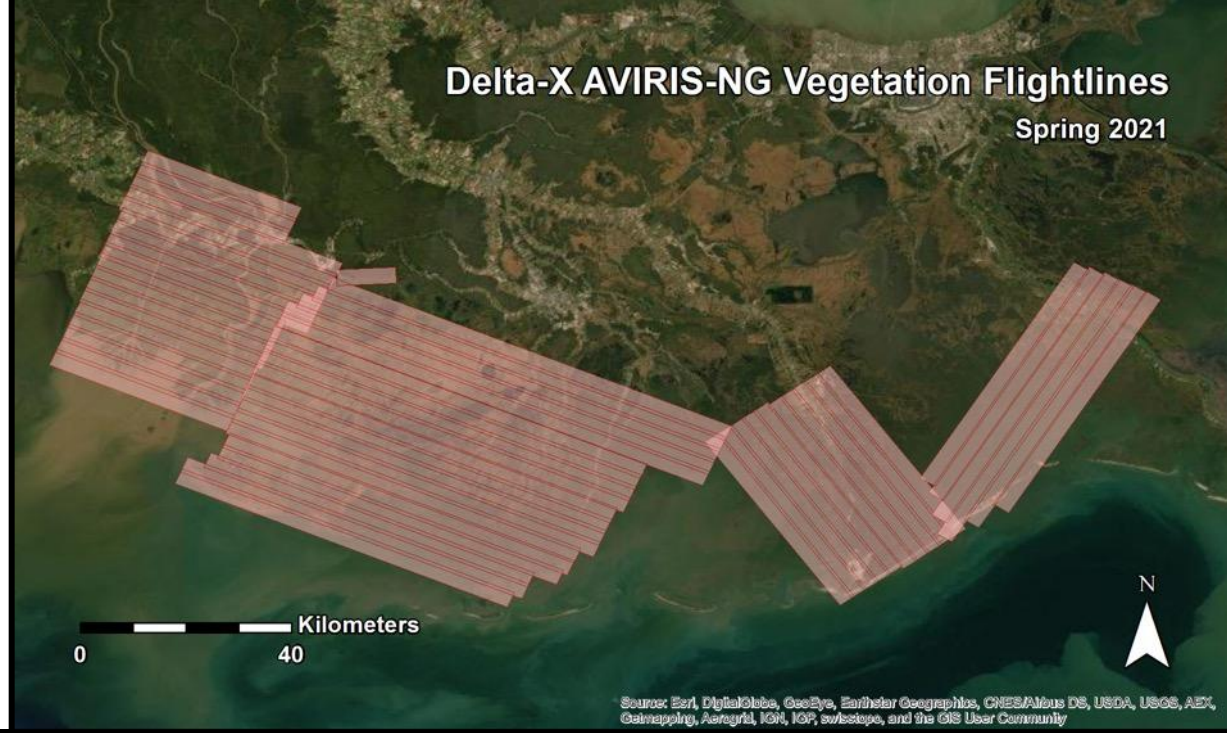


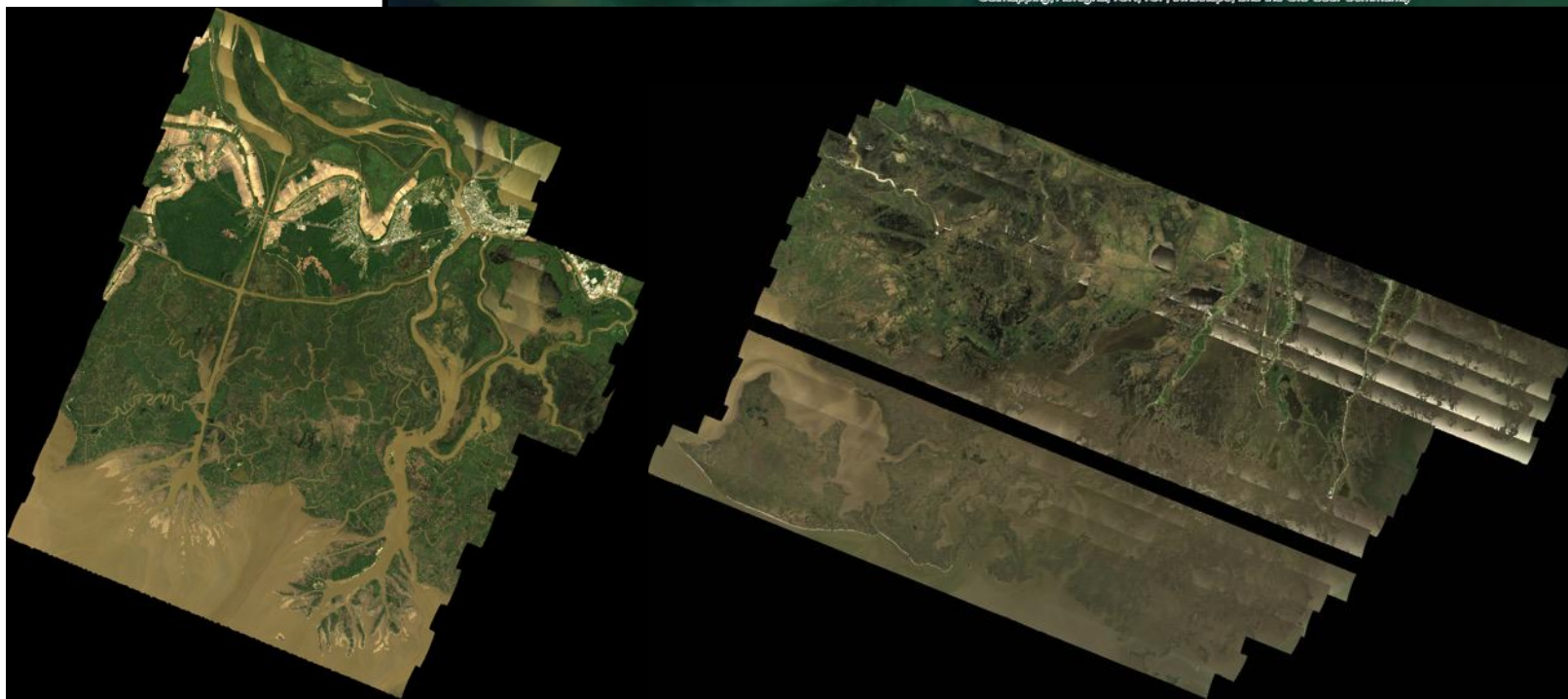
Vegetation and water sediment maps

- Radiance products use May 2021 hangar calibration data (Chapman et al. 2019) and atmospheric features for in-flight wavelength calibration adjustments (Thompson et al. 2015)
- Atmospheric correction is the EMIT mission approach of Optimal Estimation (Thompson et al. 2018, 2019) with speed enhancements (Thompson et al. 2020)
- BRDF correction via FlexBRDF (Queally et al., 2022) and simultaneous sunglint correction (Greenberg et al. 2022)

Delta-X AVIRIS-NG Data Products

- Spring, Fall, Post-Ida Deployments: 144 Terrestrial Vegetation flightlines, 44 Water Quality flightlines
- L1
  - Radiance at Sensor flightlines
- L2
  - Surface Reflectance flightlines
- L2B
  - BRDF and Glint-Corrected flightlines
  - BRDF and Glint-Corrected mosaics
- L3
  - Vegetation Type and Biomass Maps
  - Water Quality (Suspended Sediment Concentration)
- Hosted by ORNL DAAC
  - DAAC Home > Get Data > NASA Projects > Delta-X
  - daac.ornl.gov/cgi-bin/dataset_lister.pl?p=41





AVIRIS-NG Workshop Outline

- **Module 1: AVIRIS-NG Data Introduction**
  - Open data
  - Visualize/Export bands
  - Plot spectra
- **Module 2: Normalized Difference Vegetation Index**
  - Compute NDVI
  - Plot NDVI histogram
  - Generate land/water mask
- **Module 3: Principal Components Analysis**
  - Perform PCA dimension reduction on image
  - Plot explained variance and visualize component bands
- **Module 4: Classification**

https://github.com/djjensen/DeltaX_Applications_Workshop_AVIRIS-NG

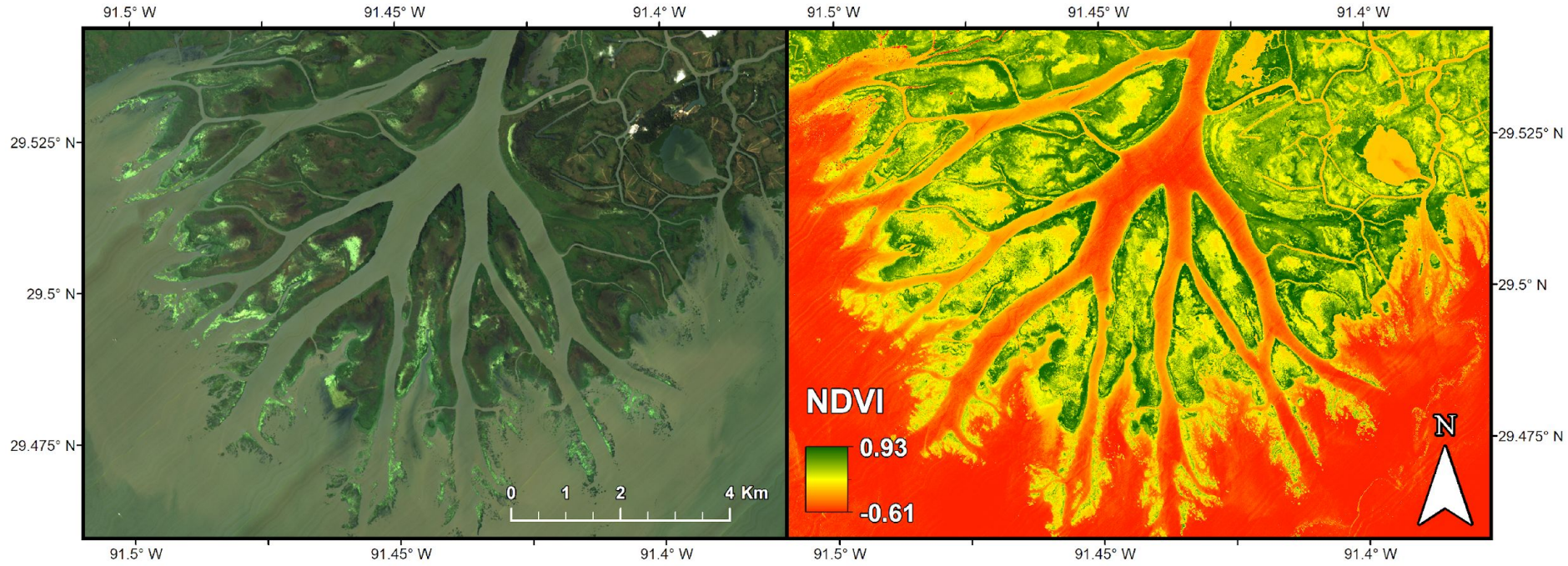
Module 1: AVIRIS-NG Data Introduction

- Objectives:
  - Open and explore an AVIRIS-NG L2 surface reflectance image
  - Visualize bands and plot pixel spectra
  - Export RGB true color composite

- https://github.com/djjensen/DeltaX_Applications_Workshop_AVIRIS-NG

Module 2: Normalized Difference Vegetation Index

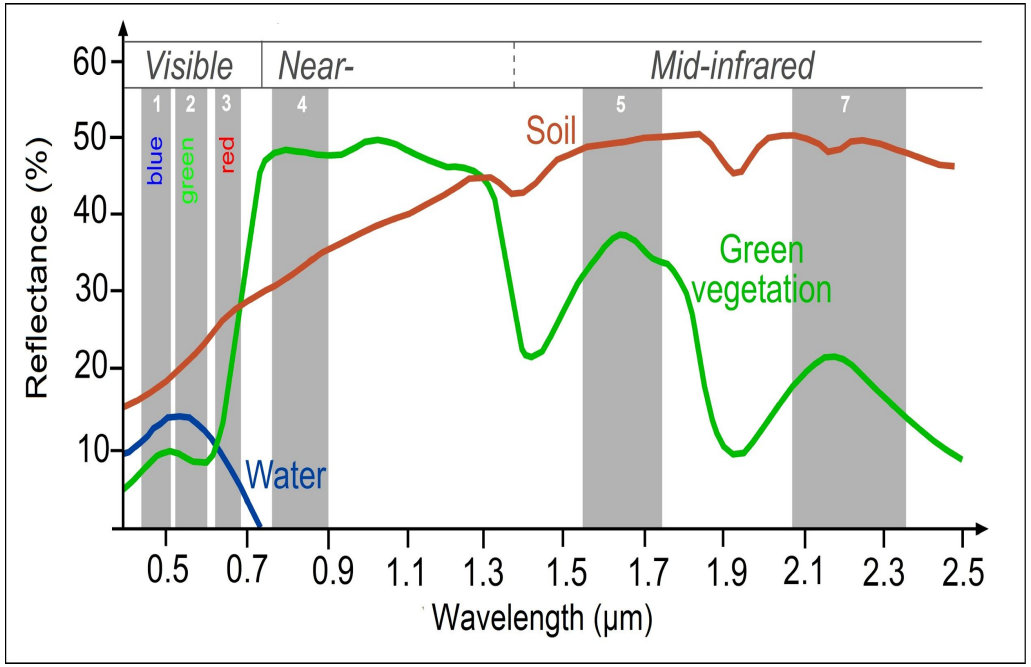
- Objectives:
  - Calculate an NDVI image
  - Plot histogram of NDVI values
  - Generate a land/water mask for the image



- Normalized Difference Vegetation Index (NDVI):

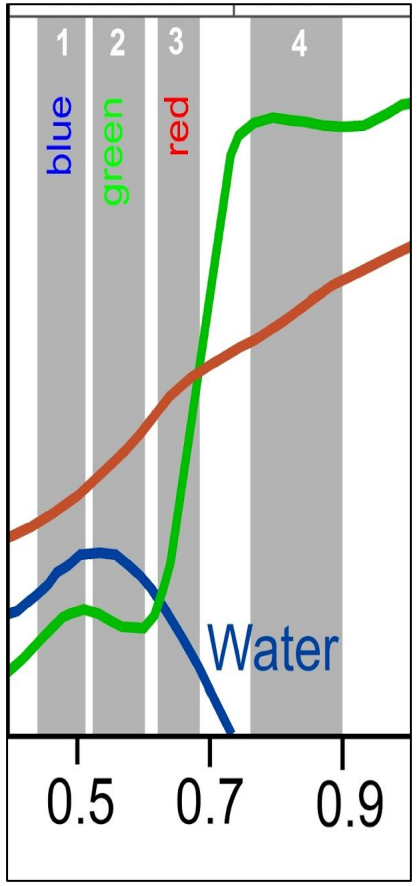
$$NDVI = \frac{NIR - red}{NIR + red}$$

- Index to estimate net primary production/photosynthetic activity
- Applications include:
  - monitoring vegetation phenology
  - assessing growing season length
  - general plant health

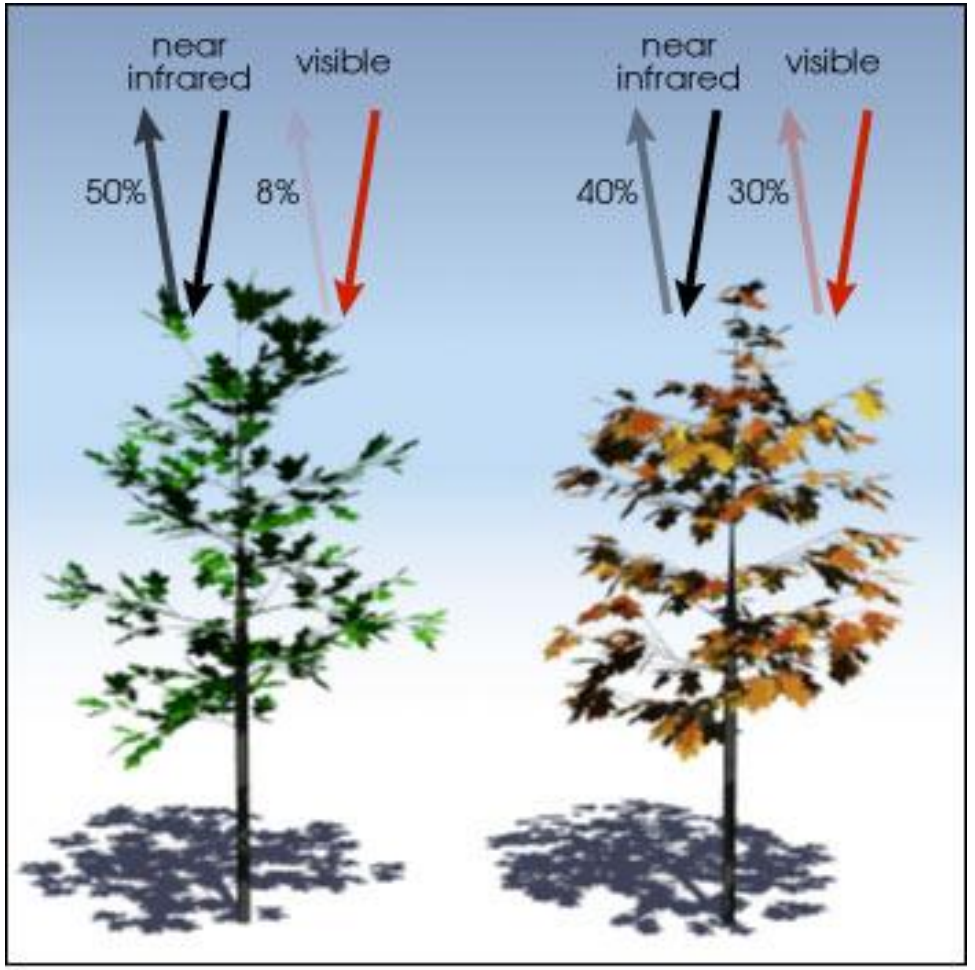


(https://seos-project.eu/classification/classification-c01-p05.html)

- Red Edge (~ 690-730 nm)
  - Low vegetation reflectance in the red region followed by a sharp increase to the high reflectance in the near-infrared Measure of "greenness" of a pixel
- NDVI Range of -1 to 1
- Brighter pixel = more green, i.e. the greater the amount of photosynthesizing ("healthy") vegetation present



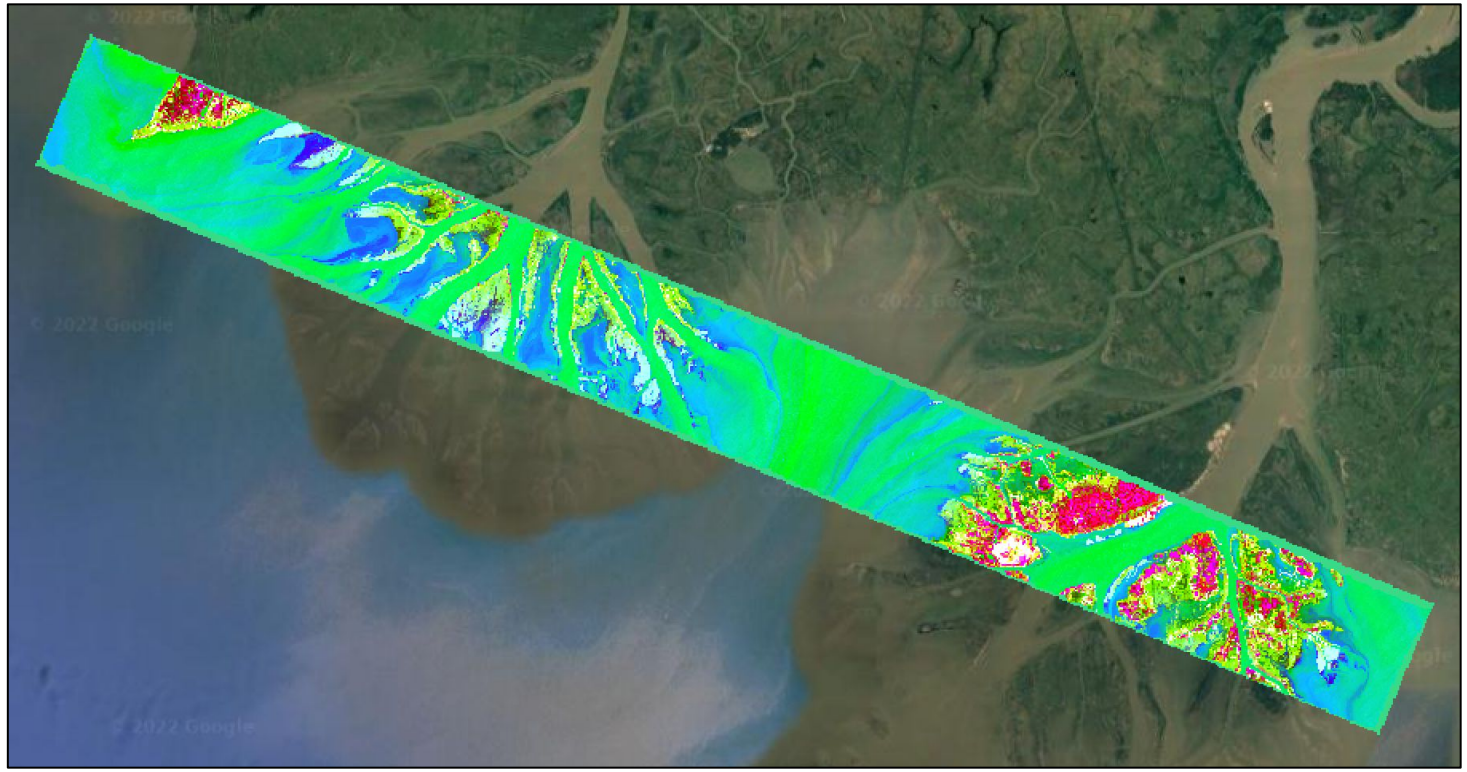
(https://seos-project.eu/classification/classification-c01-p05.html)



(http://earthobservatory.nasa.gov/Features/MeasuringVegetation/)

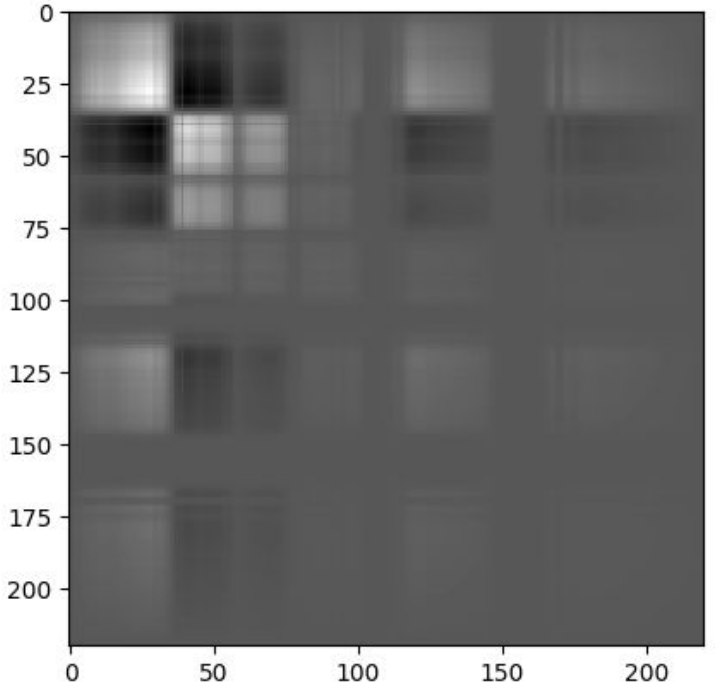
Module 3: Principal Components Analysis

- Objectives:
  - Perform PCA dimension reduction on image
  - Plot explained variance
  - Visualize component bands
  - Export output selection

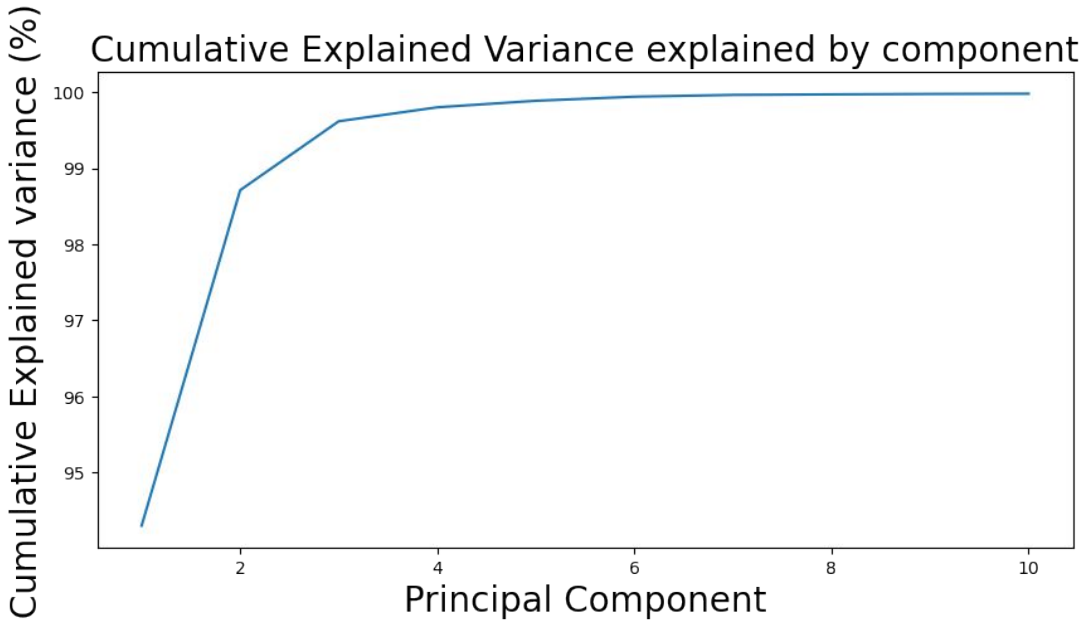


Principal Components Analysis

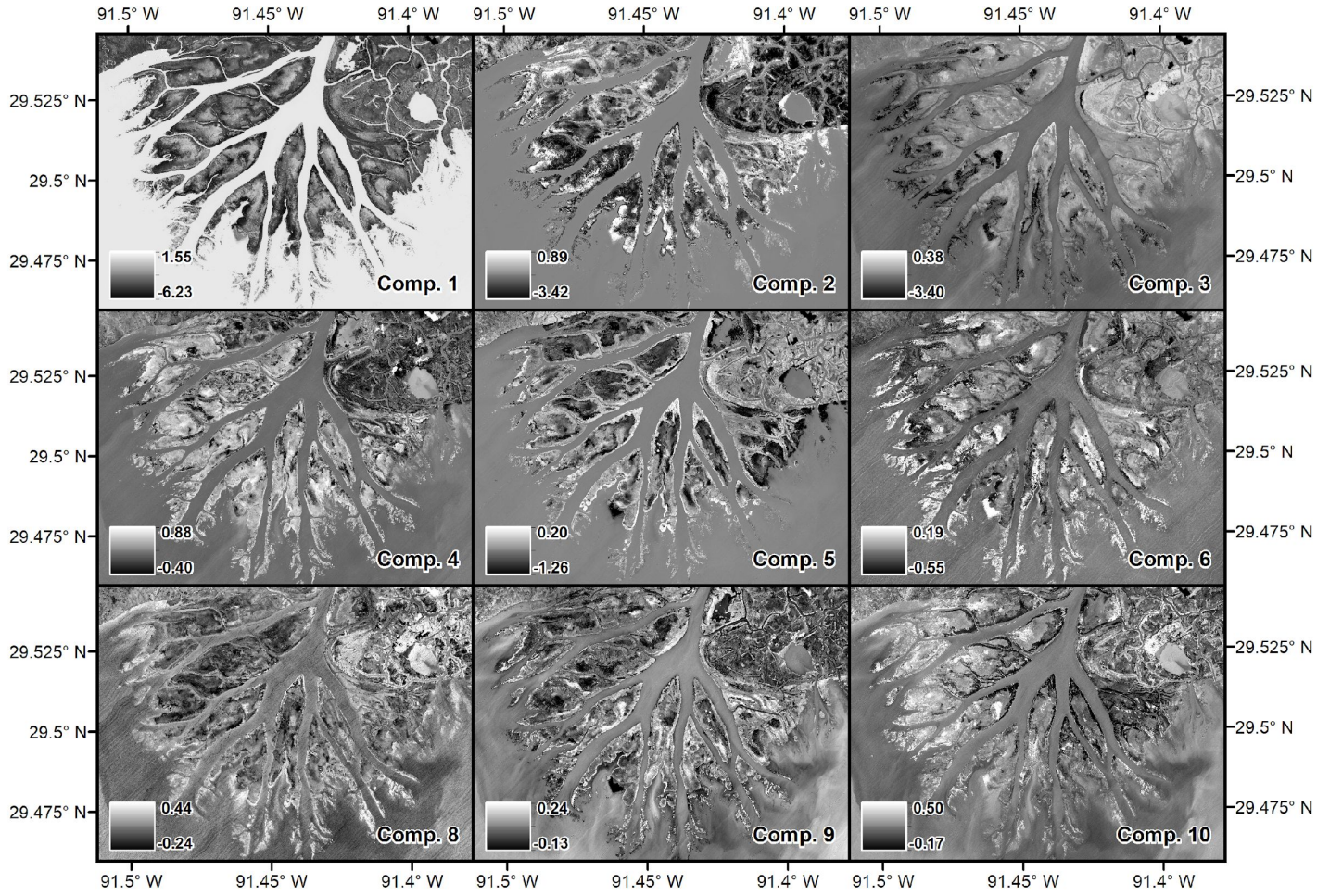
- PCA is a linear dimensionality reduction technique
  - Well suited for high-dimensionality (i.e. 425 bands) imaging spectrometer data
- A principal component is a projection of the original data that captures the variance inherent in the original data
  - First component always captures the most variance
  - Components are uncorrelated (correlated features in original data contribute to the same principal component)



(https://www.spectralpython.net/algorithms.html)



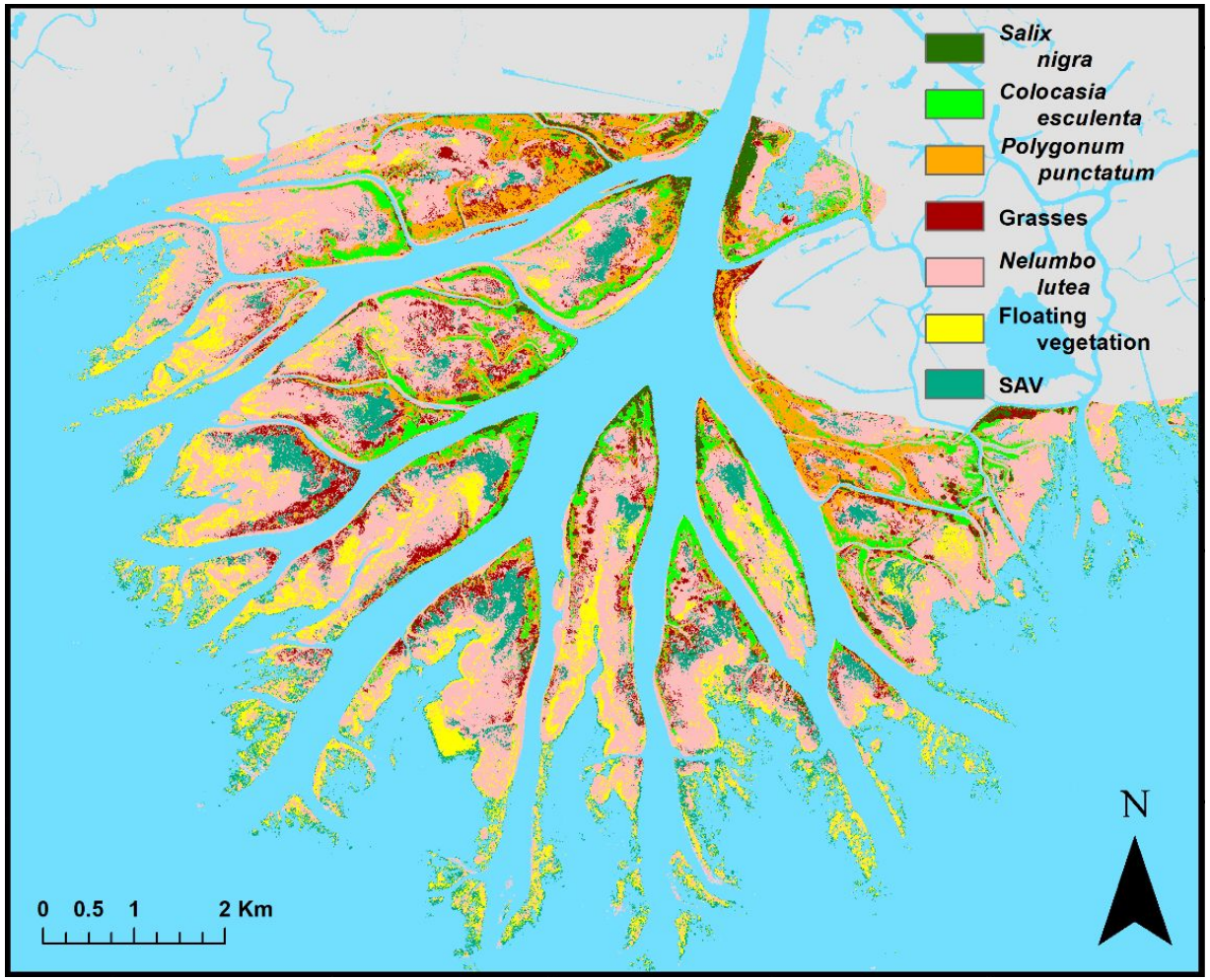
- PCA for imaging spectrometer data like AVIRIS-NG:
  - Reduce correlated bands while explaining vast majority of variance in image
  - Capture surface properties
  - Enable efficient and improved classification



(Jensen et al. 2020)

Module 4: Classification

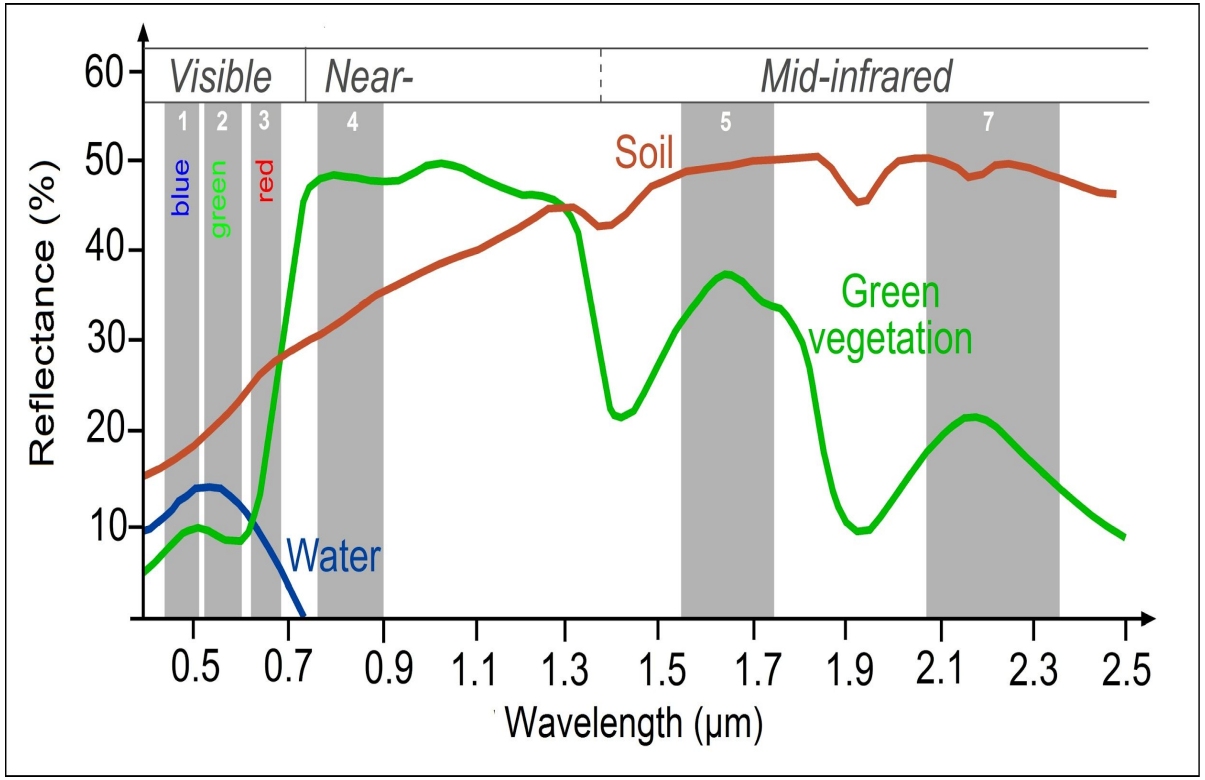
- Objectives:
  - Perform an unsupervised K-Means classification on the PCA output
  - Generate a preliminary landcover classification of the image



(Jensen et al. 2020)

Unsupervised Classification

- Generate given number of clusters from input bands
  - Band selection
  - Additional data sources
    - E.g. Digital Elevation Model
  - Principal Components Analysis
- Assign classes from cluster output
- Most common algorithms: ISODATA, K-means



(https://seos-project.eu/classification/classification-c01-p05.html)

Supervised Classification

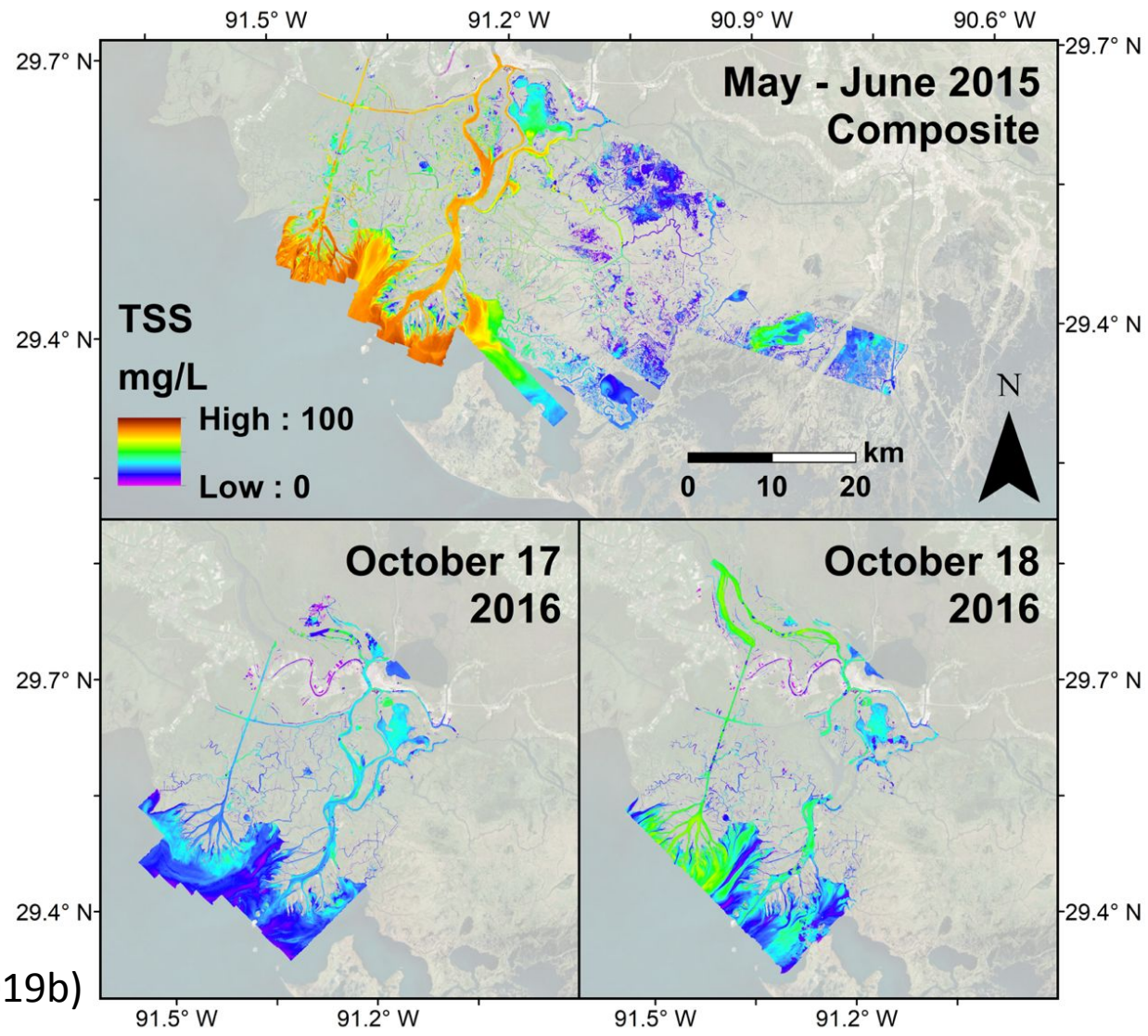
- Create a training dataset/spectral library
  - Select training areas corresponding to remote sensing data to generate spectral signatures
  - OR compile spectral library from known sources
- Classify image based on input signatures

- Example algorithms:
  - Maximum Likelihood, Minimum Distance, Spectral Angle Mapper
  - Machine Learning: Random Forests, Support Vector Machines

(Jensen et al. 2019a)

Module 5: Partial Least Squares Regression and Water Quality

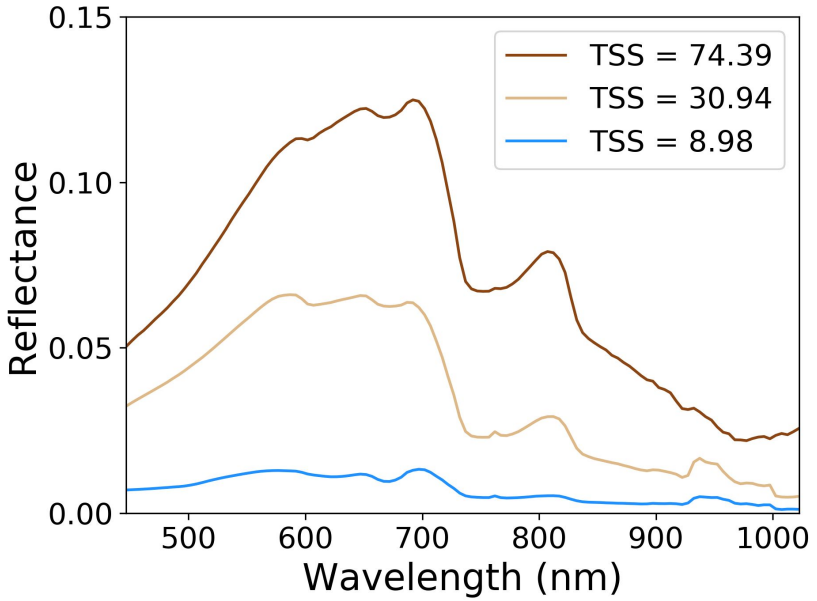
- Objectives:
  - Use in situ water sample and reflectance data to generate a suspended sediment concentration model
  - Create a map of estimated Total Suspended Solids (mg/L)



(Jensen et al. 2019b)

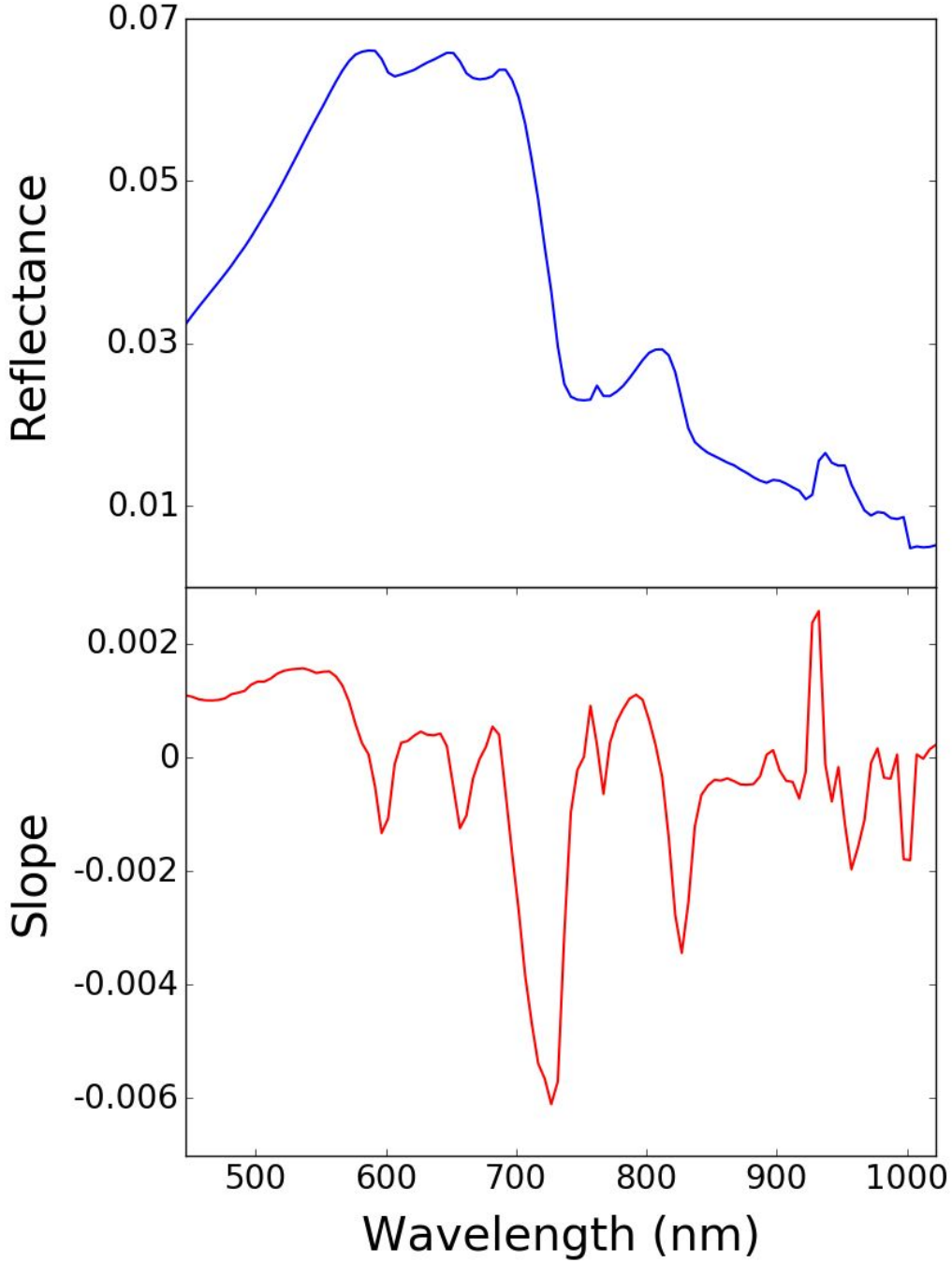
Field Data (October 2016)

- Water samples
  - Total Suspended Solids (mg/L)
- ASD Field Spectrometer
  - 35 samples



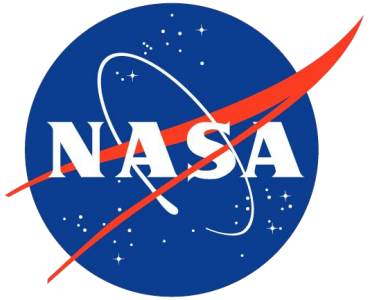
Imaging Spectroscopy and Regression for TSS

- Ordinary Least Squares Regression
  - Predictor variables independent/ not collinear
  - Large sample size
- Partial Least Squares Regression ideal for constructing predictive models with many collinear factors
- Reflectance vs. Derivatives
  - Less sensitive to intensity differences
  - Sensitive to absorption features and spectral shape



Acknowledgements

- Delta-X, Jet Propulsion Laboratory, California Institute of Technology
  - (deltax.jpl.nasa.gov)
- Oak Ridge National Laboratory Distributed Active Archive Center
  - (https://daac.ornl.gov/cgi-bin/dataset_lister.pl?p=41)



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