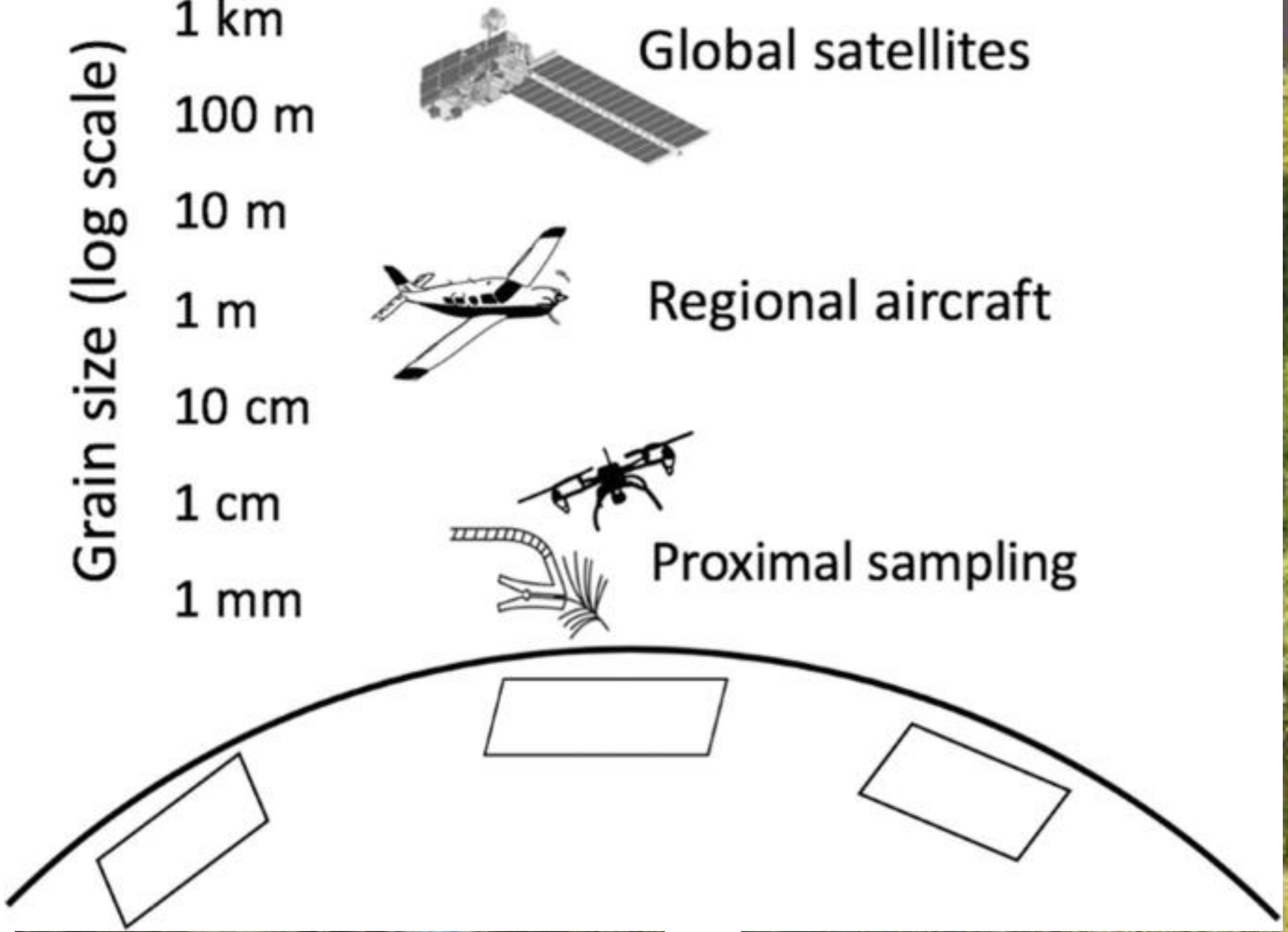
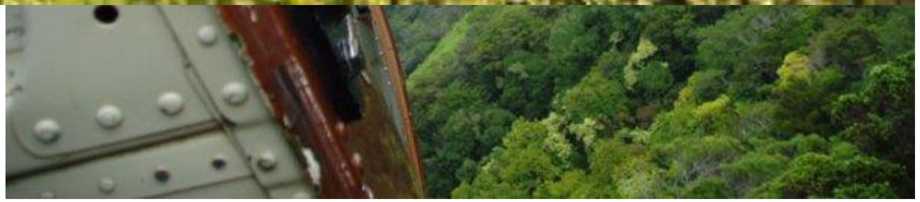
Overview of wetland remote sensing technologies

Dr. Meghan Halabisky (she/her)
School of Environmental and Forest Sciences,
University of Washington
Senior Science Advisor, Digital Earth Africa


Grain size (log scale)
1 km
100 m
10 m
1 m
10 cm
1 cm
1 mm
Global satellites
Regional aircraft
Proximal sampling



Wetlands are important nature-based solutions to climate change

- Wetlands, which cover only 3% of the earth's land surface, store 30% of all land-based carbon.
- Mitigate impacts of flooding and drought.
- Regulate streamflow, climate refugia, water storage etc..
- U.S. has lost ~ 50% of wetlands.

Citation: Convention on Wetlands. (2021). Global Wetland Outlook: Special Edition 2021. Gland, Switzerland: Secretariat of the Convention on Wetlands.

Photo credit: Maria Troitino, Ramsar

Ecosystem Services of Wetlands

- Flood mitigation
- Water storage
- Wildlife habitat
- Sediment removal
- Groundwater recharge and stream flow maintenance
- Food and medicine production
- Recreation
- Carbon sequestration
- Cultural values
- Climate refugia
- and more…

In a Drought, California Is Watching Water Wash Out to Sea

Heavy storms have flooded parts of California, but the state has been unable to capture billions of gallons of water that are flowing unchecked into the ocean. Los Angeles is embarking on an ambitious new program to change that.

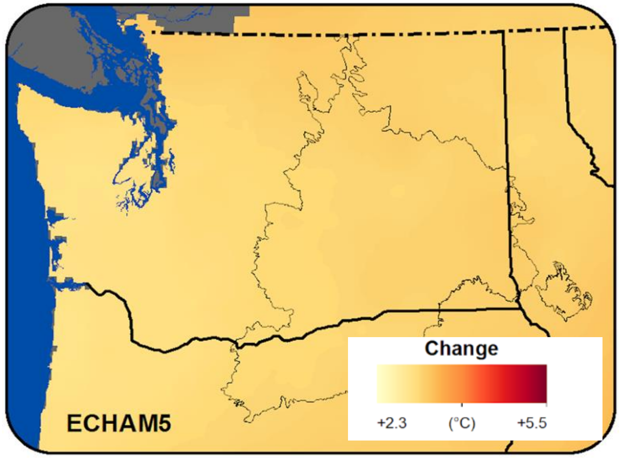
Give this article   388

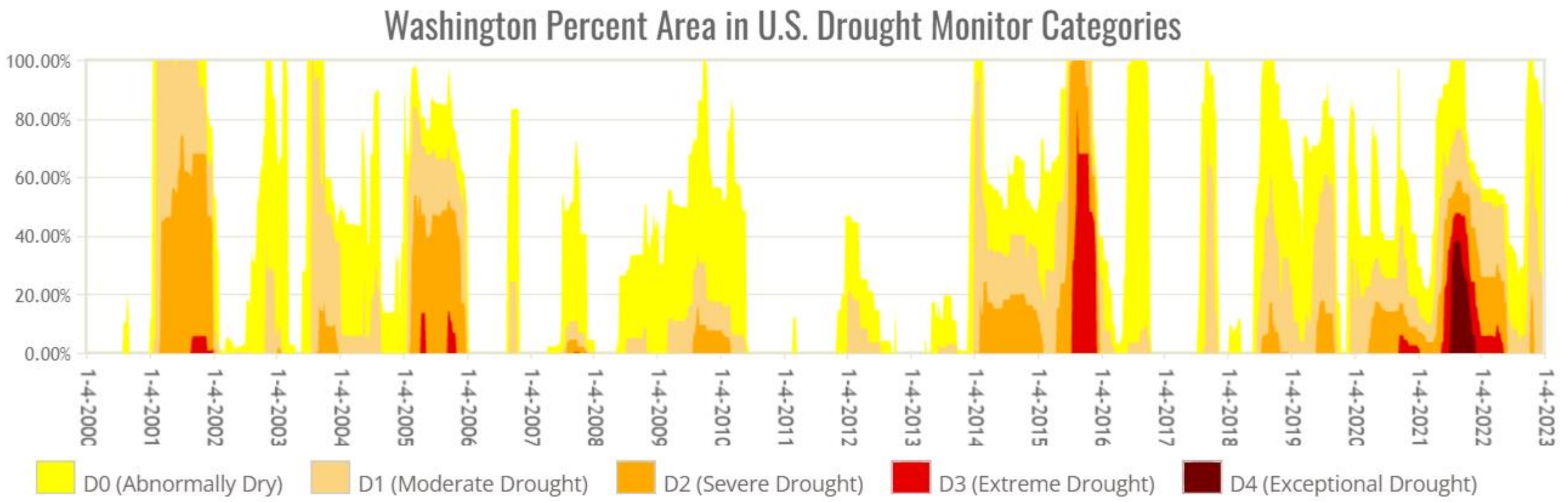
By Ralph Vartabedian   Photographs by Mette Lampcov

Published Jan. 13, 2023   Updated Jan. 14, 2023

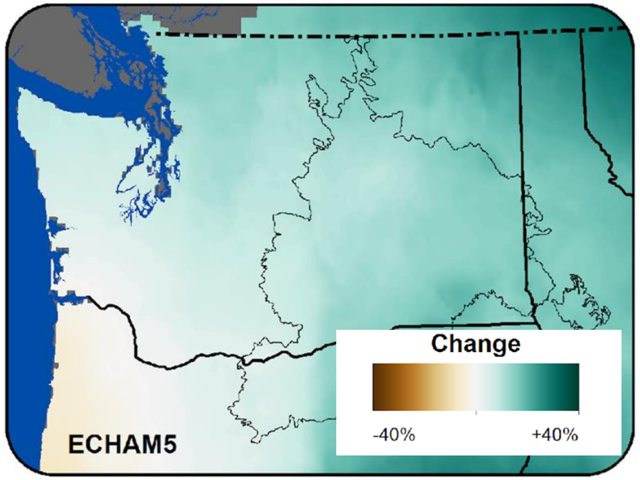
How will wetlands respond to climate change? How do we build back more resilience into our landscape?

Annual Temperature 2080s





Precipitation March – Oct 2080s



Outline

- Challenges of modelling wetlands
- What is remote sensing?
- Remote sensing toolbox – Sensors, methods, models
- Spatial, spectral, temporal resolution – Picking the right sensors
- Building a Wetland EO toolkit
- Example 1 – Mapping Teal Carbon (wetland carbon)
- Example 2 – Reconstructing the past to model the future of wetland dynamics.
- What's next?

Wetlands are challenging to understand

Dynamic Hydrology - What are normal patterns of hydrology - What are abnormal patterns? climate change, land use change, disturbance)

Many wetland types – Coastal wetlands

Many wetland types – Inland wetlands

Different flooding regimes & hydrologic drivers

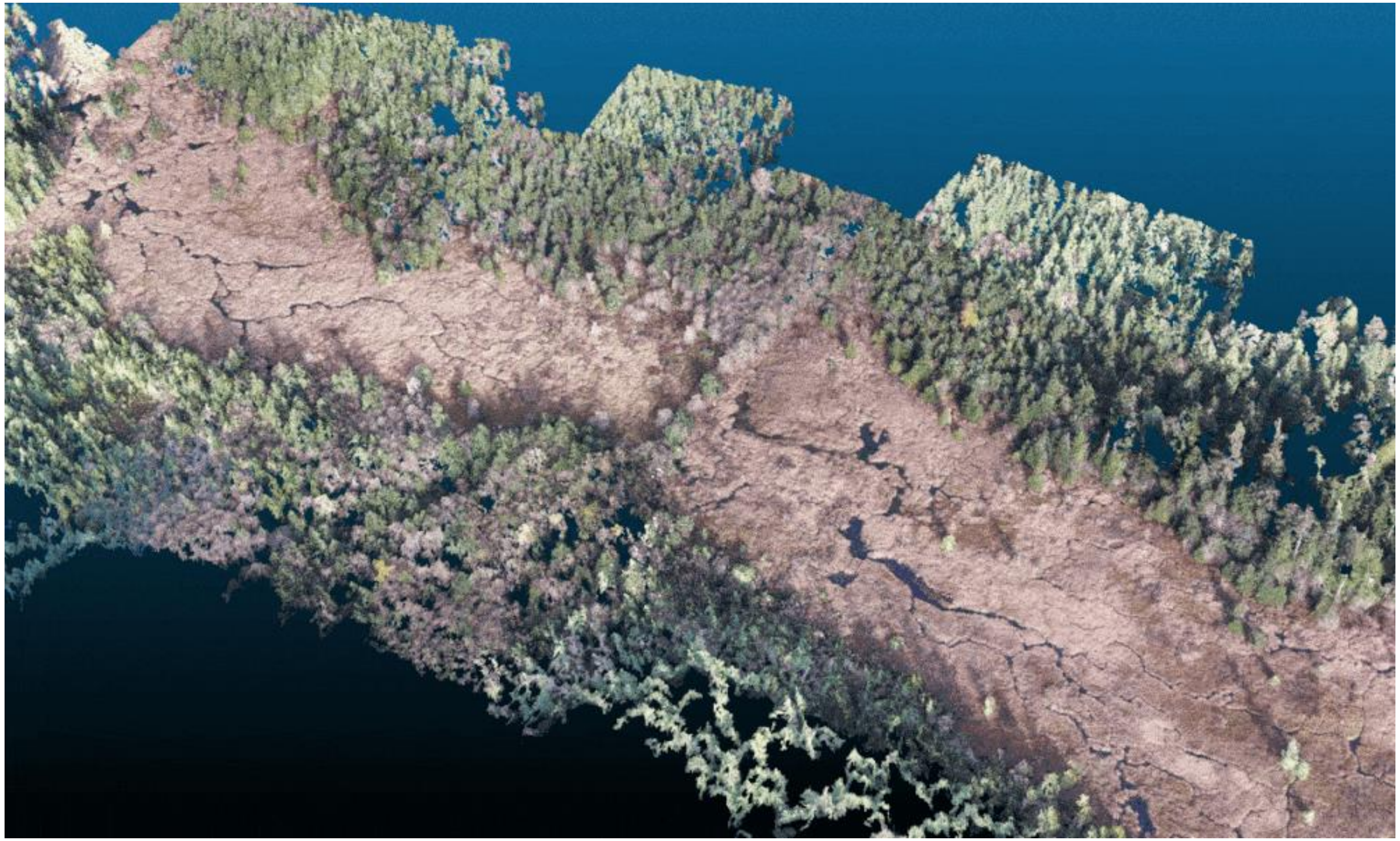
Good condition v. Disturbed

Challenges of modeling wetland ecosystems

- Wetlands are dynamic.
- Wetlands are diverse.
- Wetlands vary in condition

= Lack of adequate baseline data

Earth Observation (aka remote sensing) provides powerful toolset to understand the past, present, and project the future. Useful for monitoring impacts and decision-making.



What is remote sensing actually sensing?

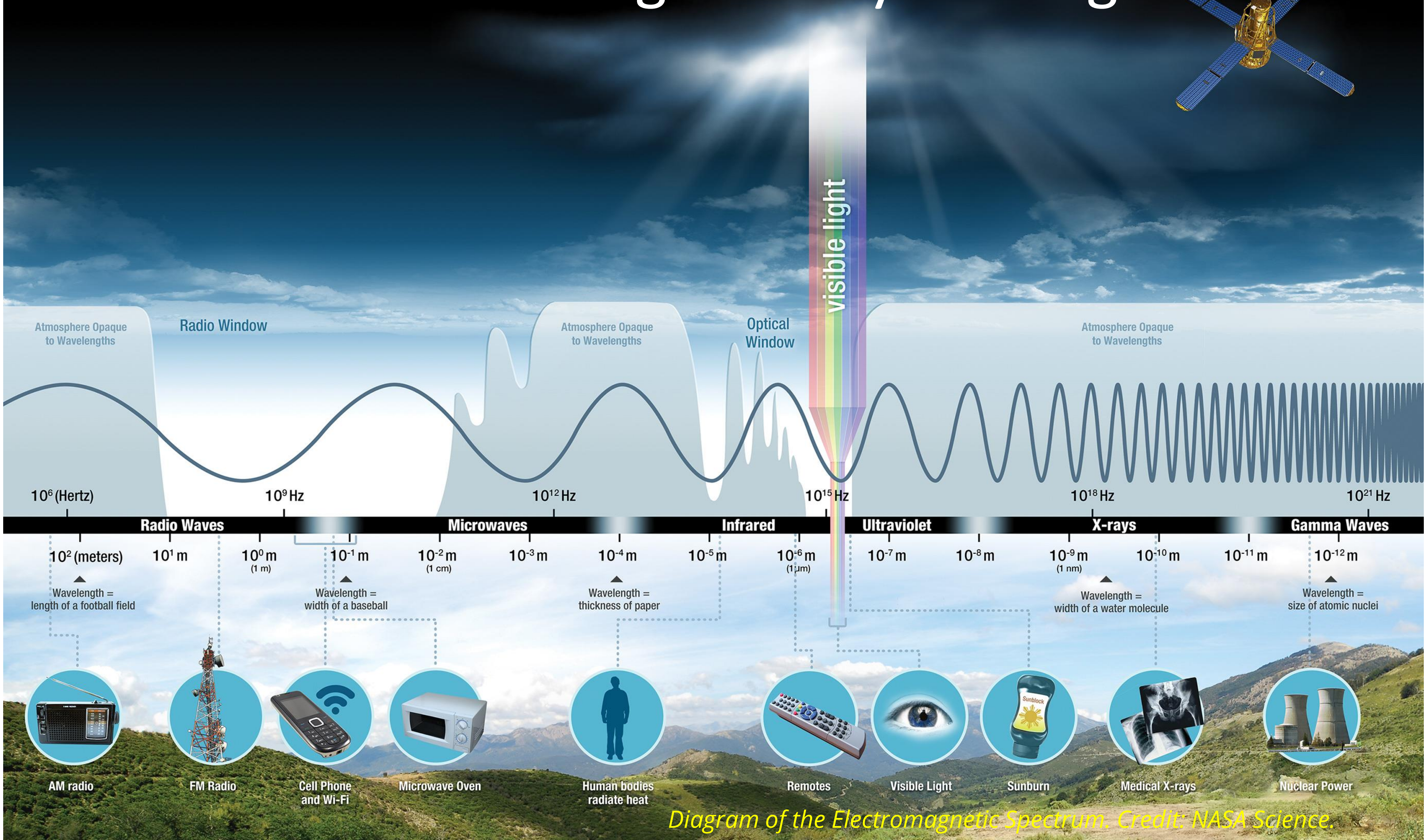
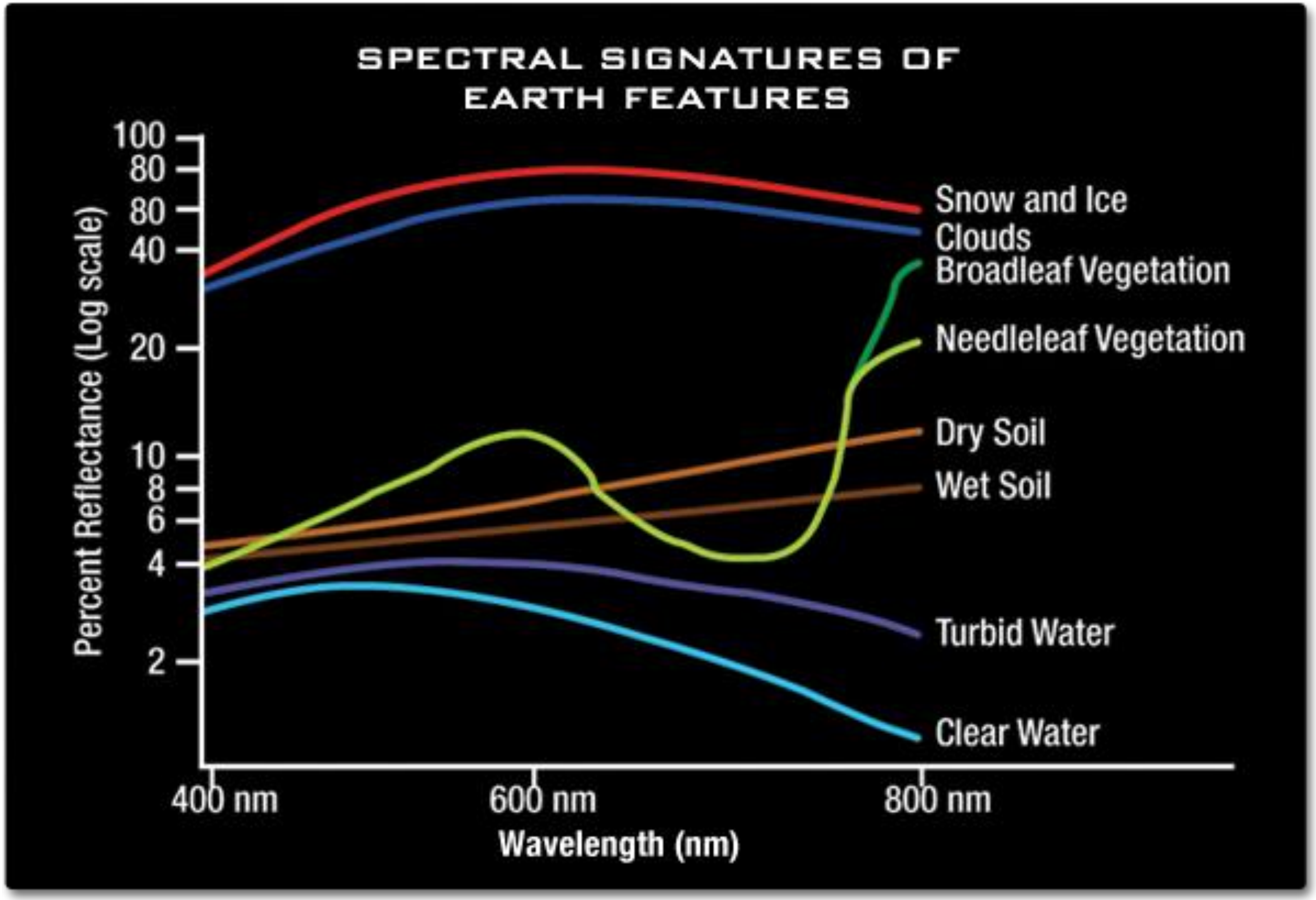
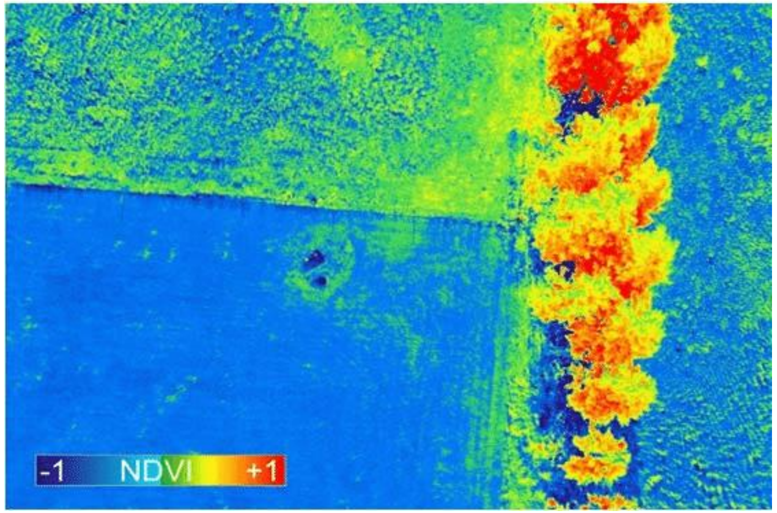


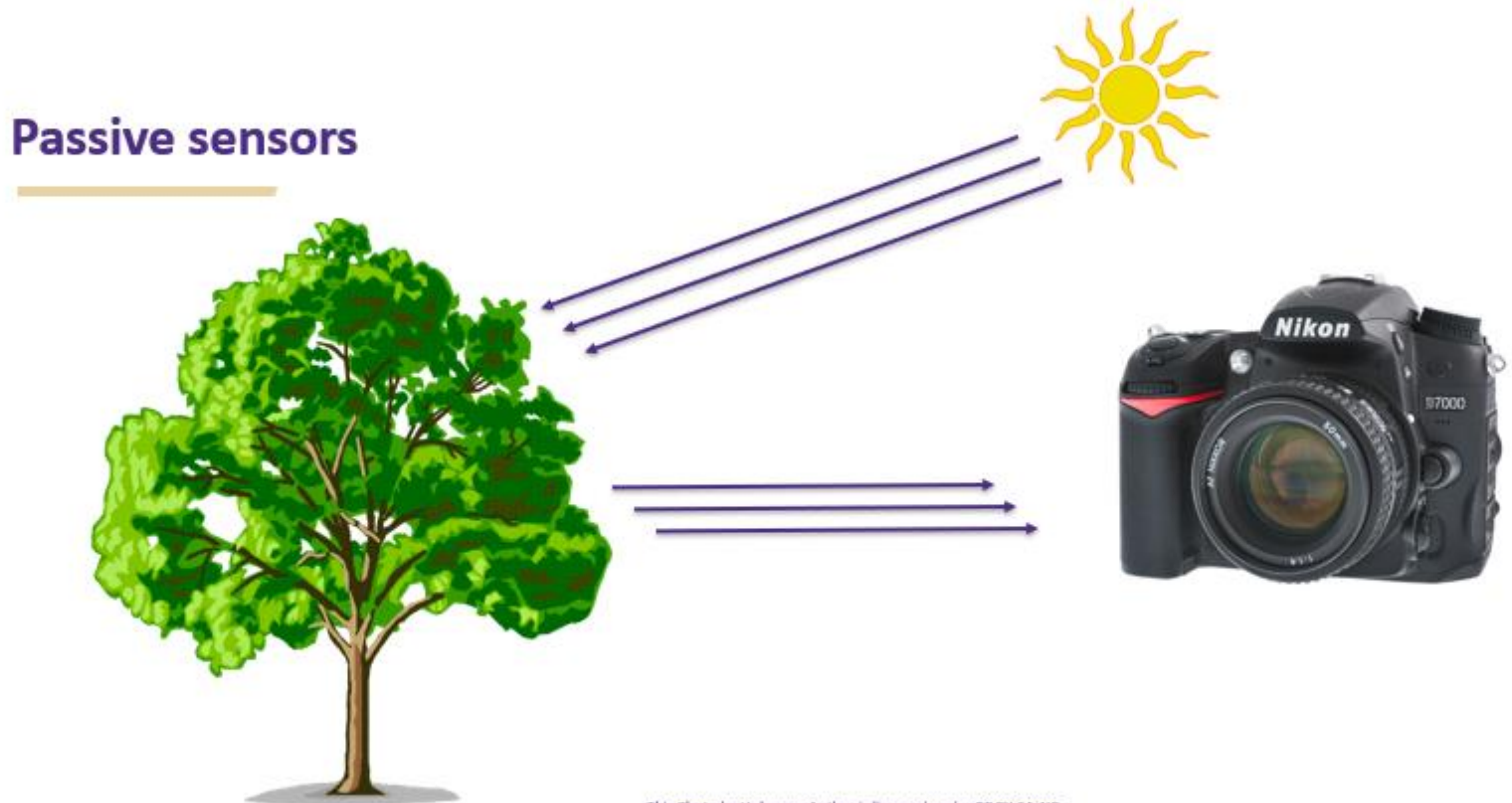
Diagram of the Electromagnetic Spectrum. Credit: NASA Science.



Spectral signatures of different Earth features within the visible light spectrum. Credit: Jeannie Allen.



Difference between active and passive remote sensors

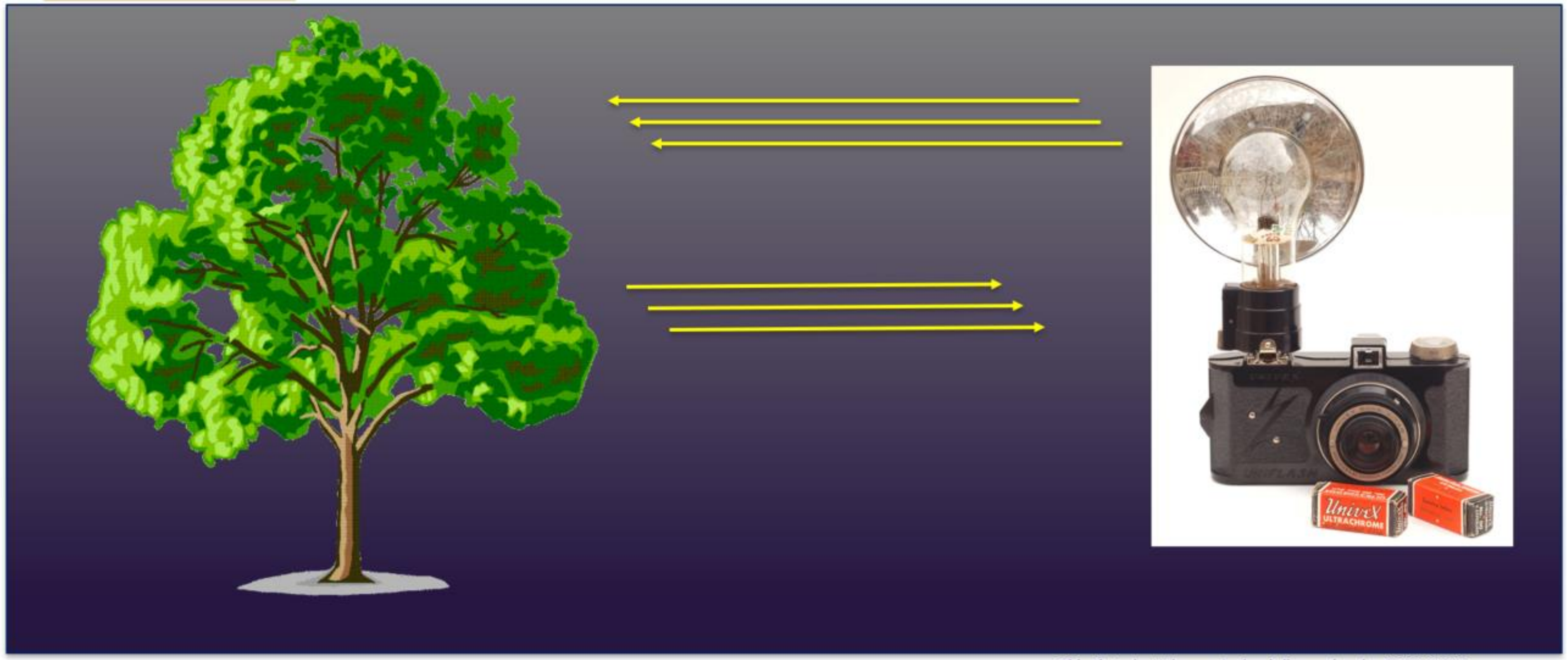


Passive Remote Sensing

Multispectral
Landsat-8
Sentinel-2
PlanetScope
MODIS

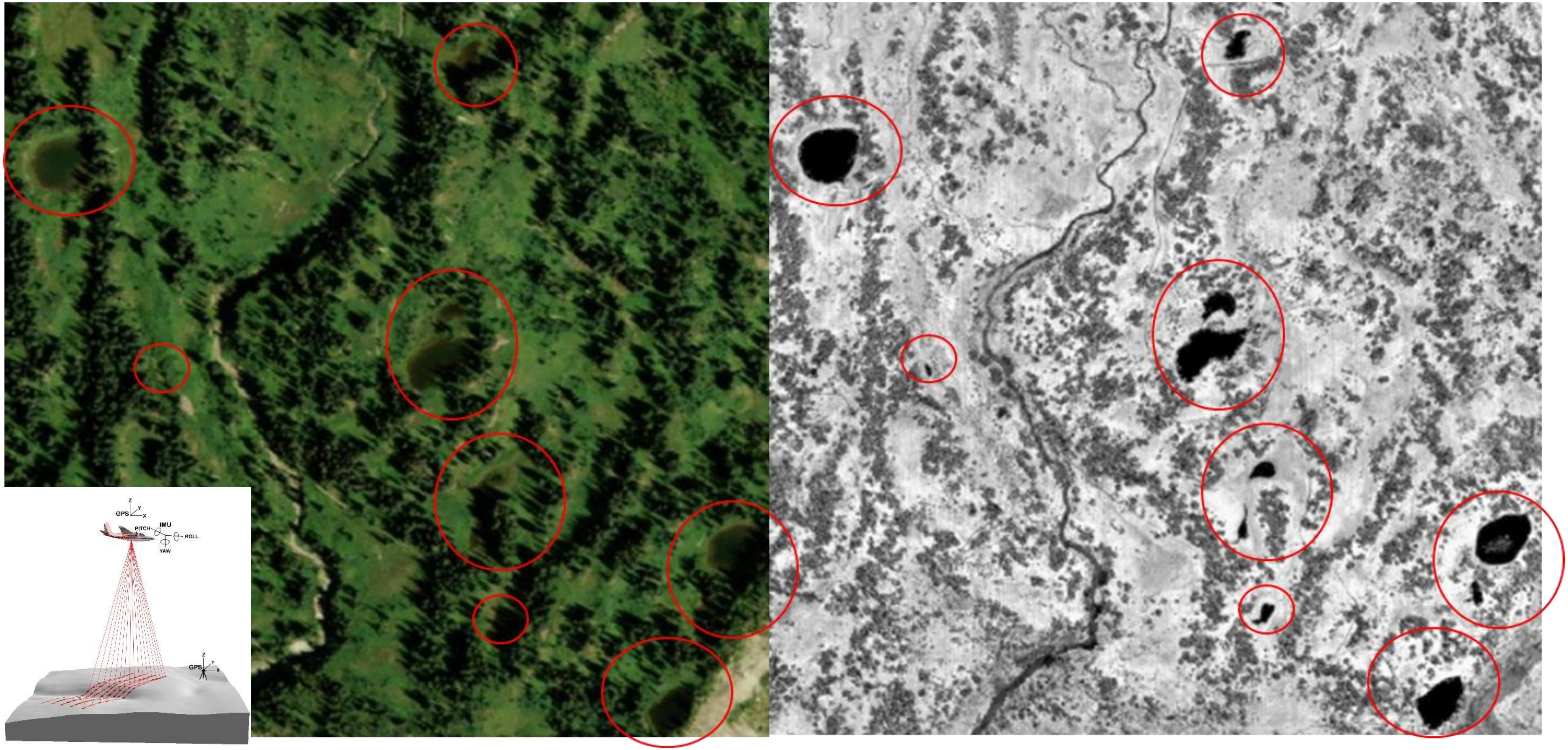
Difference between active and passive remote sensors

Active sensors



Active Remote Sensing

Lidar
Radar
Sonar
GRACE
Sentinel-1


GPS
IMU
PITCH
ROLL
YAW
GPS

The remote sensing toolbox

Sensors / imagery:

e.g., RGB camera on a plane, hyperspectral imagery on a satellite, lidar, radar, etc…

Methods:

e.g., Looking at an image, rule-based methods, machine learning (Artificial Intelligence), statistical methods (e.g., Bayesian).

Models:

e.g., Combine with in-situ data (on the ground) to train and model a multitude of ecosystem services or develop processes to identify wetlands.

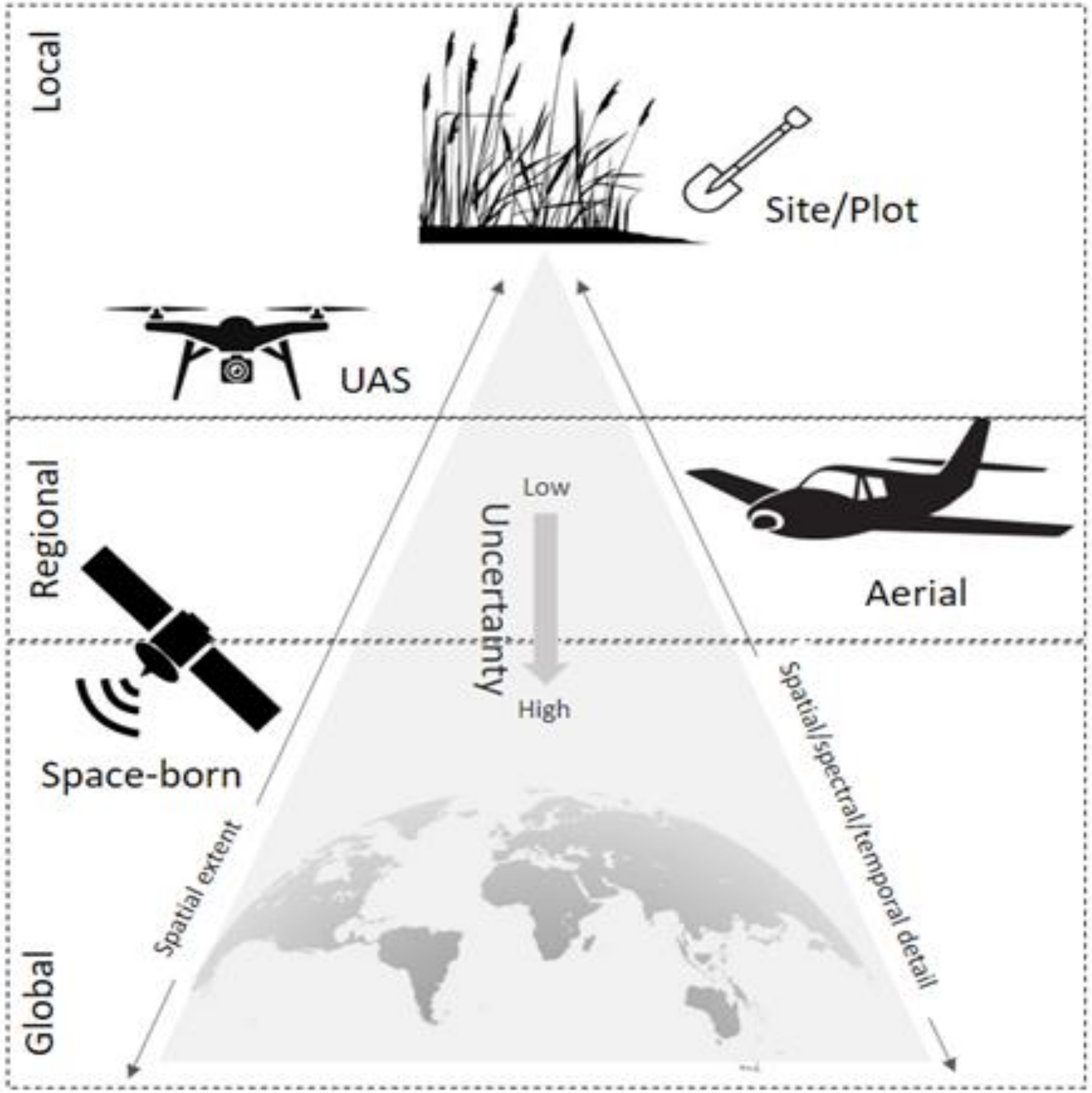


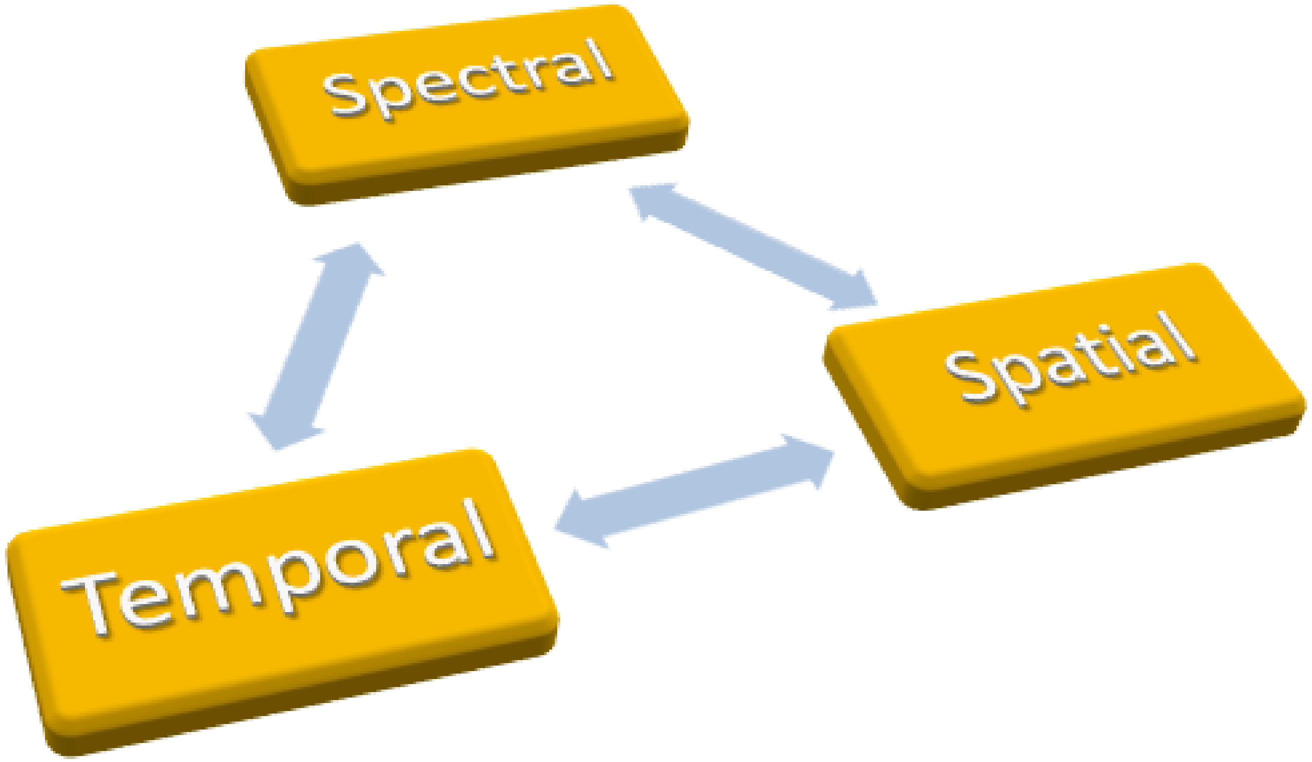
Figure credit: L. Monika Moskal

Sensors can be attached to many different platforms – that affect the resolution

Common Sensors used for remote sensing in the US:

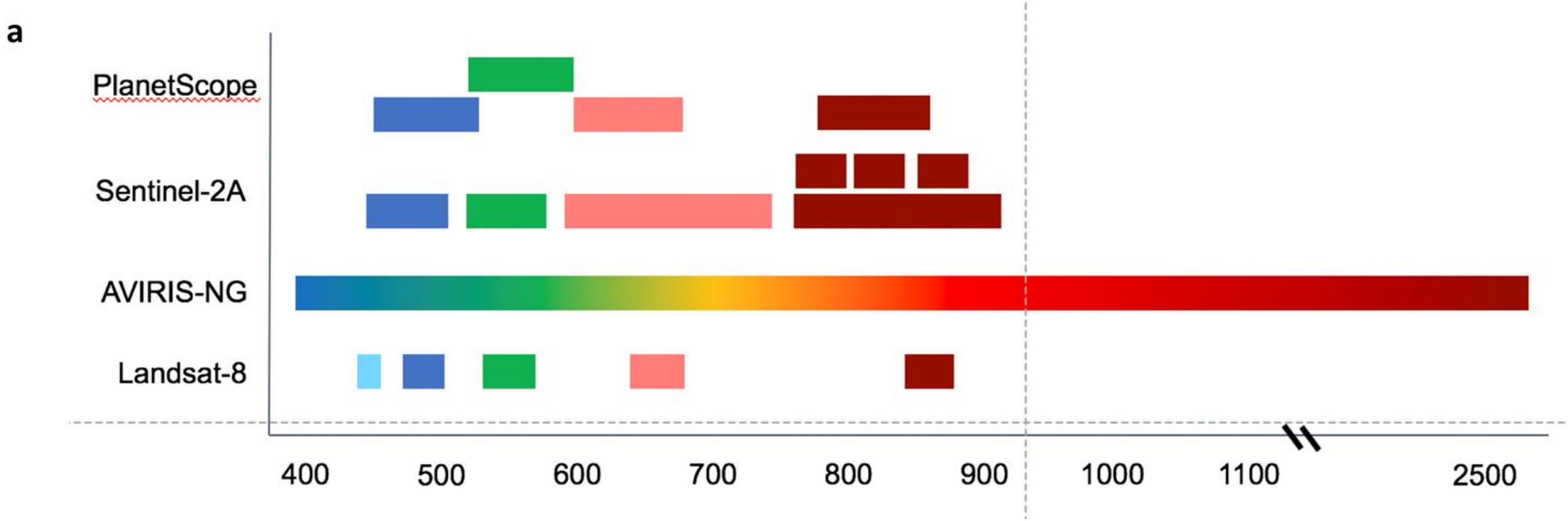
Lidar – e.g., 3DEP program, GEDI
Radar – e.g., Sentinel-1, ALOS
Multi-band imageryn – e.g., Landsat, Sentinel-2
High-resolution imagery – e.g., Planet, NAIP

Remote Sensing Resolution Domains



Spectral Domain

Spectral resolution: The number of areas a sensor measures along the electromagnetic spectrum. black and white – hyperspectral



Spatial Domain

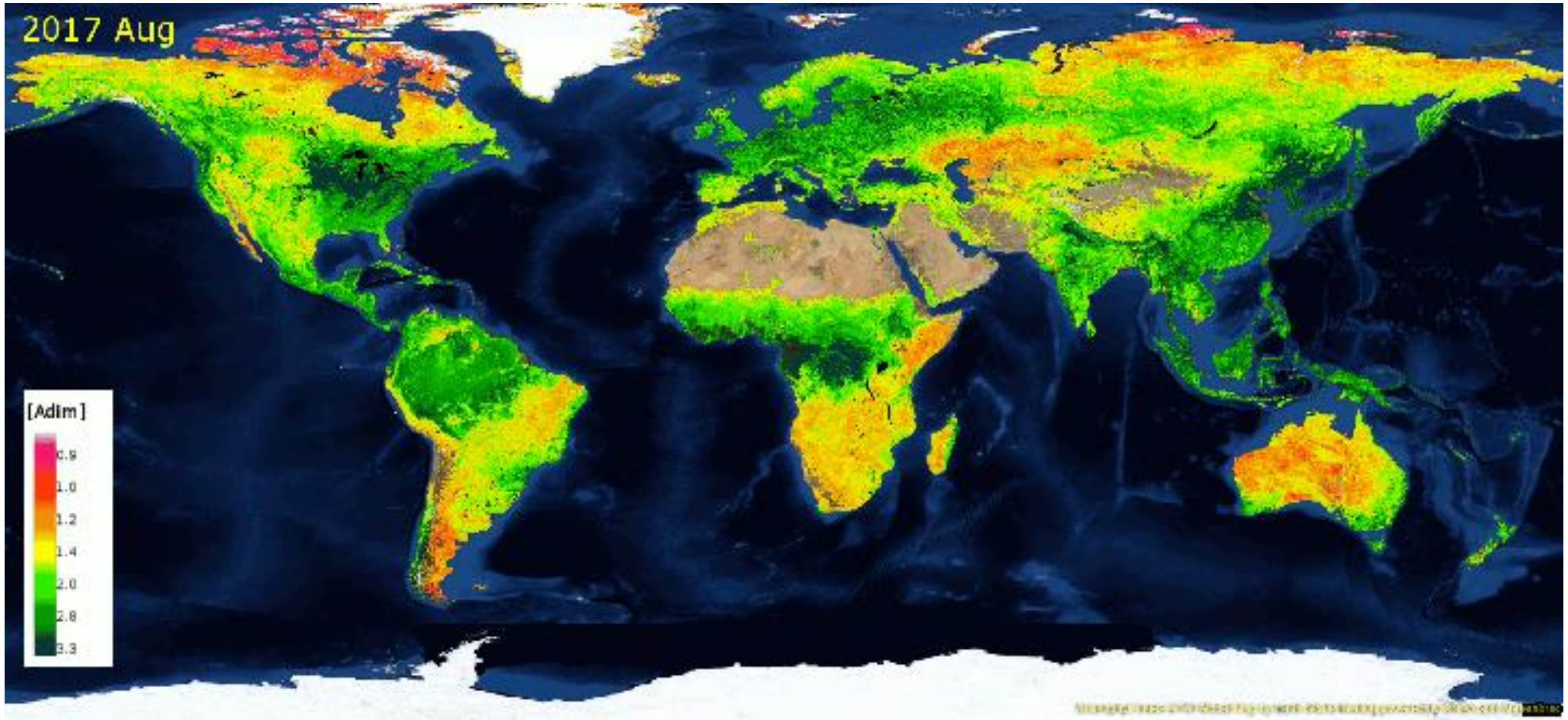
Spatial resolution: Count every tree - Change in % greenness of an area

Spatial extent: Measure a plot, sample an area – Measure a state or region

Temporal domain

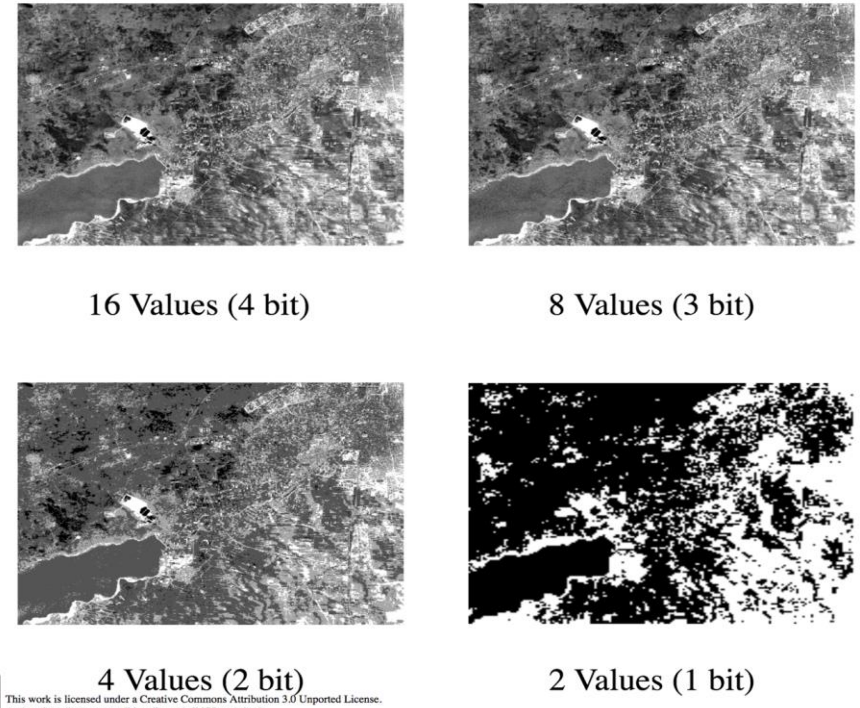
Temporal resolution: every day v. every 16 days.

Temporal extent: Across 40 years – Across a single year. Archive sensor goes back to 1984 .



Additional considerations and tradeoffs

Radiometric resolution: The number of brightness levels a sensor can register (e.g., 256 values (8 bit))
Cost: From free to very expensive
Accessibility: e.g., available on the Google Earth Engine platform - Requires permission from a vendor.



Challenges of modeling wetland ecosystems

- Wetlands are dynamic.
- Wetlands are diverse.
- Wetlands vary in condition

= Lack of adequate baseline data

Challenges of modeling wetland ecosystems

- Wetlands are dynamic.
- Wetlands are diverse.
- Wetlands vary in condition
- Lack of data

= Remote Sensing Challenge

What are you trying to map or measure?

What is the necessary detail to see an observable impact?

What methods are required – visual, automated?

How much uncertainty is acceptable?

Can you combine sensors to improve spatial and temporal resolution?

Building a Wetland EO toolkit

1.) Map and characterize

2.) Historic reconstruction

3.) Projecting the future

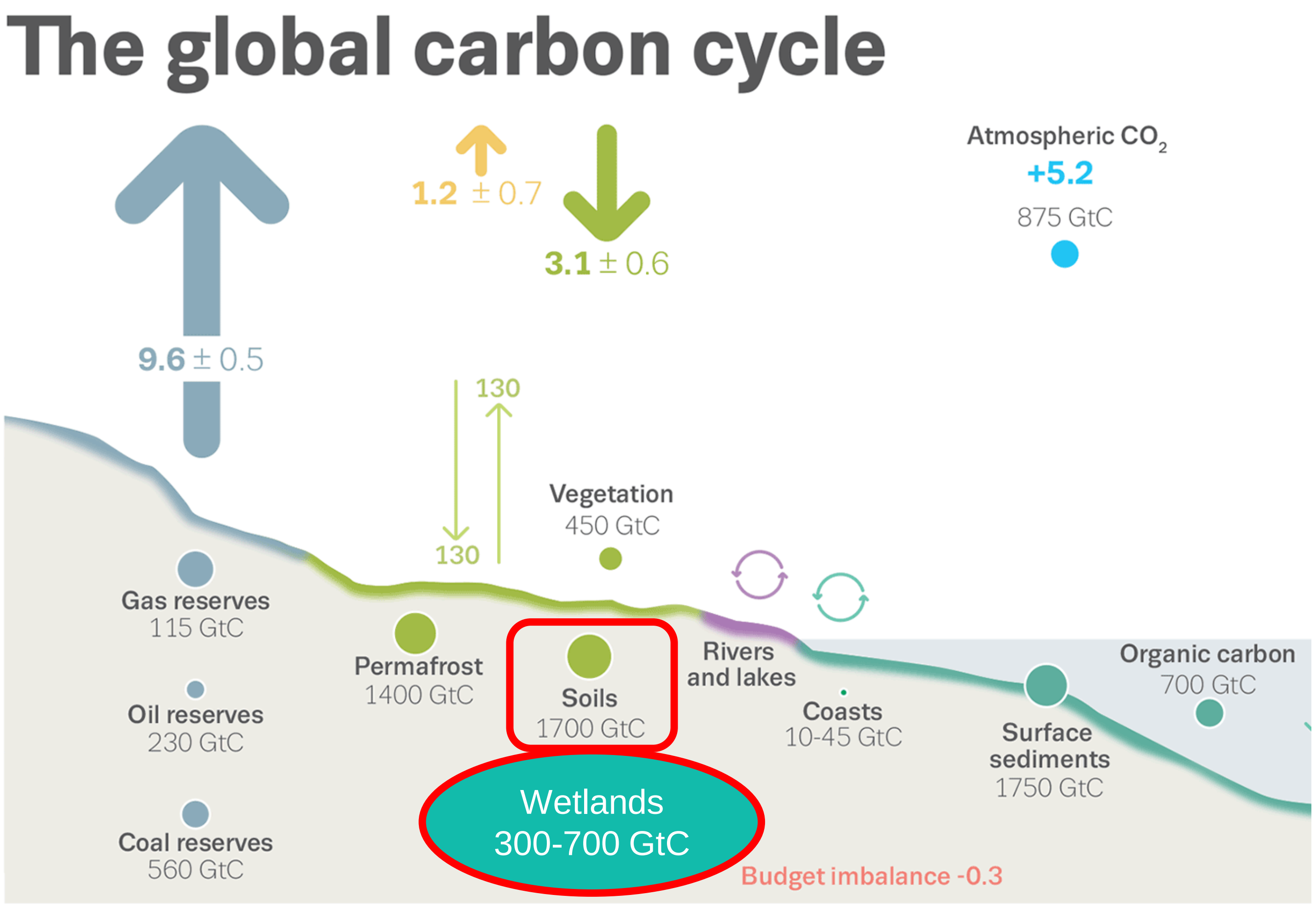
4.) Have Impact – Connecting with communities

Example # 1
Cryptic carbon: wetland identification under perennial forest cover enhances spatially explicit modeling of soil carbon stock

Anthony J. Stewart[1] Meghan Halabisky[1], Chad Babcock[2], David E Butman[1], David V D'Amore[3], and L. M. Moskal[1]

(1)University of Washington, (2)University of Minnesota, (3) USDA Forest Service

Traditional Lands of the Hoh, Quinault, Quileute, and Coast Salish Indigenous People



Friedlingstein et al., 2022; Campbell et al., 2022; Lal, 2008; Poulter et al., 2022

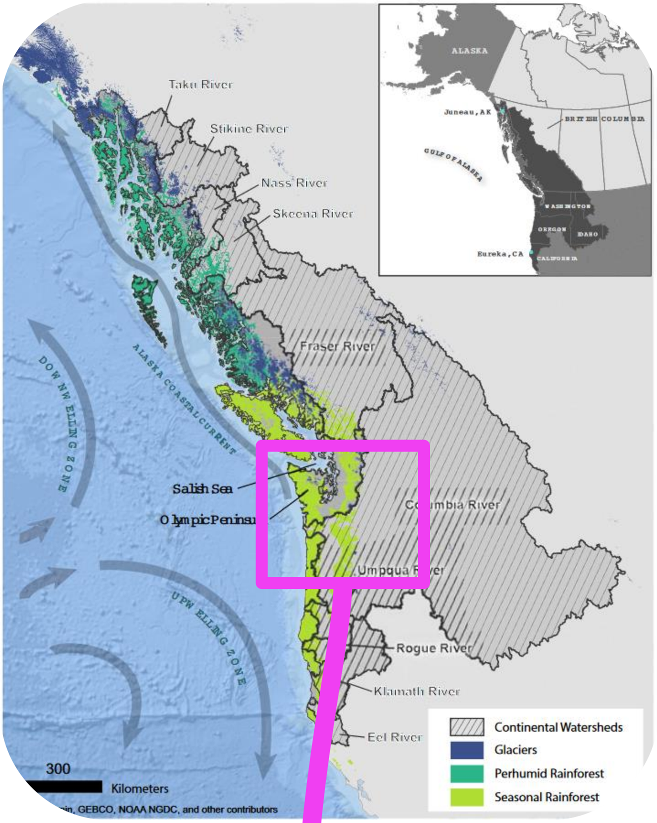
Inland Wetland Carbon "Teal Carbon"

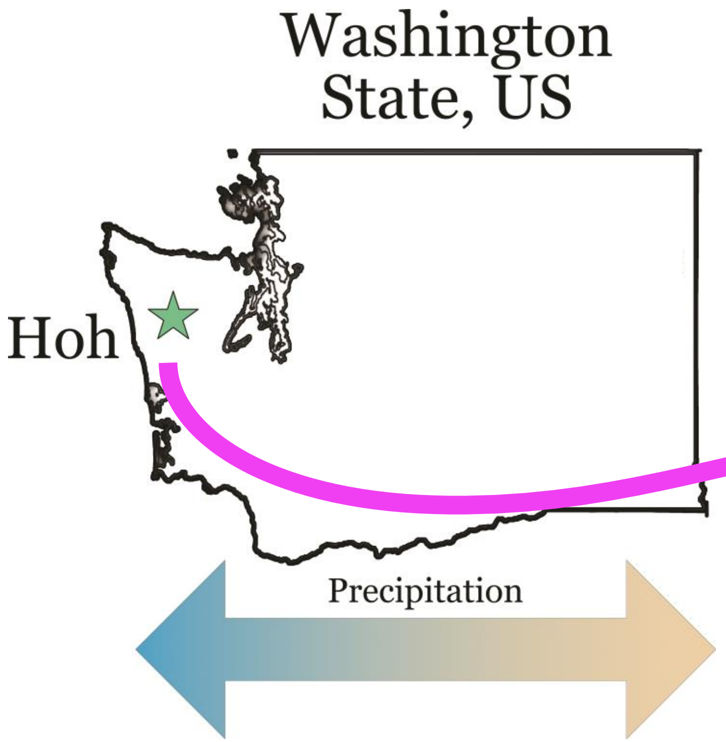
Nahlik and Fennessey 2016

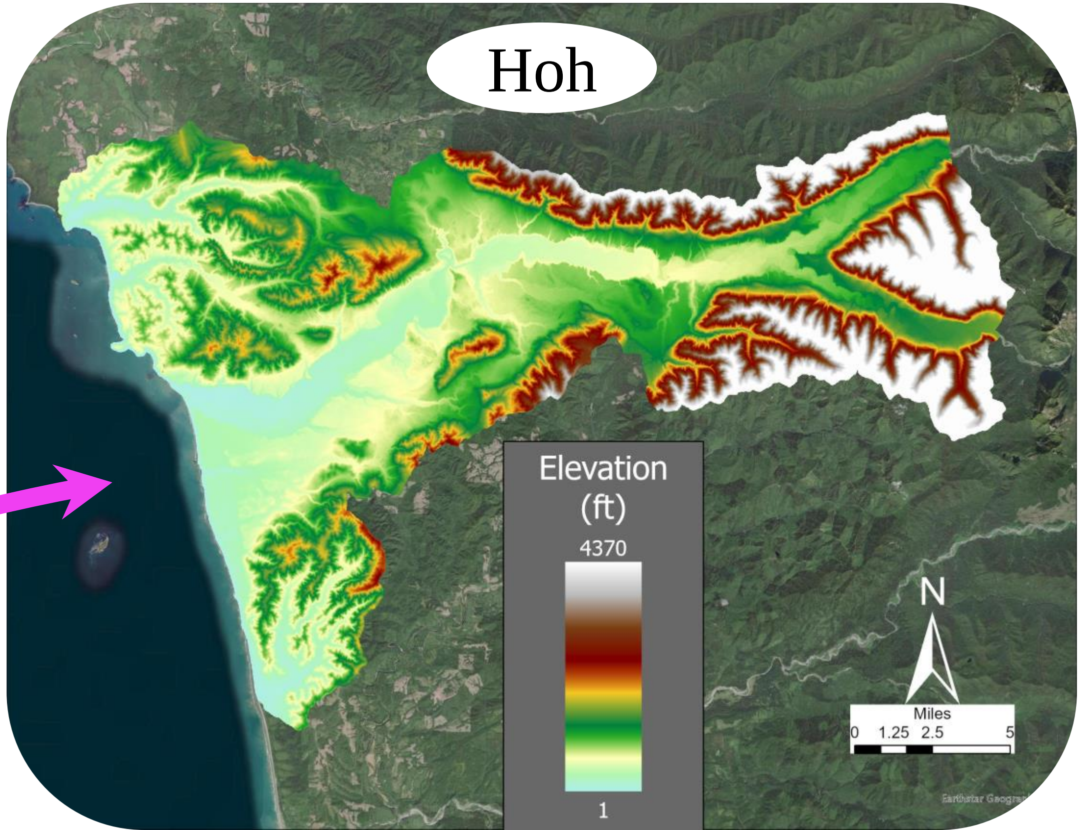
Wetlands store **20-30% of global soil carbon** despite occupying only **5-8% of the land surface**

1) How can we improve identification of ”Cryptic Wetlands”?

2) How can this improvement be used to model soil carbon stocks? “Cryptic Carbon”







The remote sensing toolbox

Sensors / imagery:

Lidar, NAIP aerial imagery, Sentinel – 2 and Landsat imagery

Methods:

Machine learning (Artificial Intelligence)

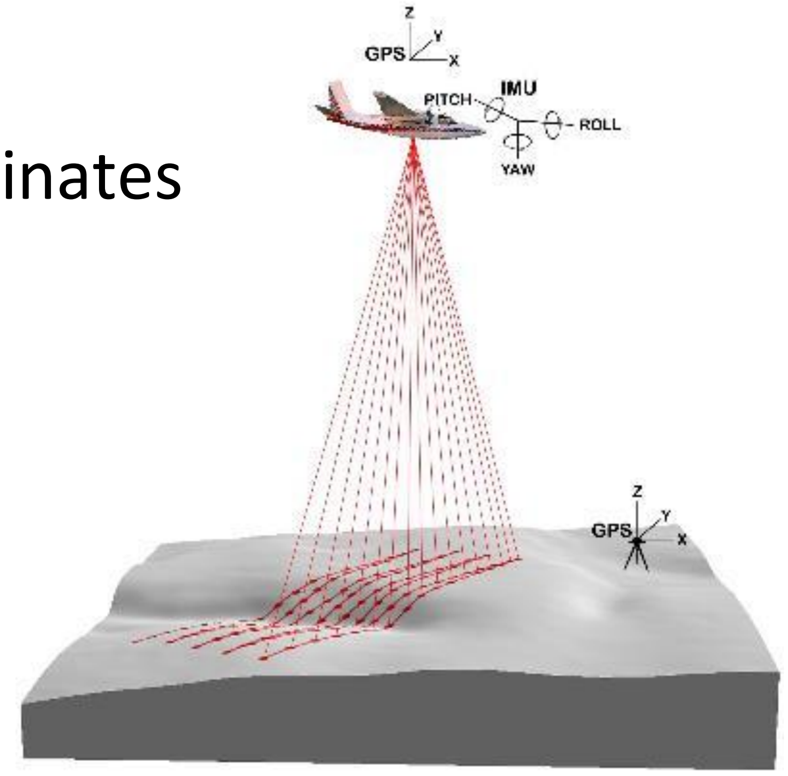
Statistical methods (e.g., Bayesian)

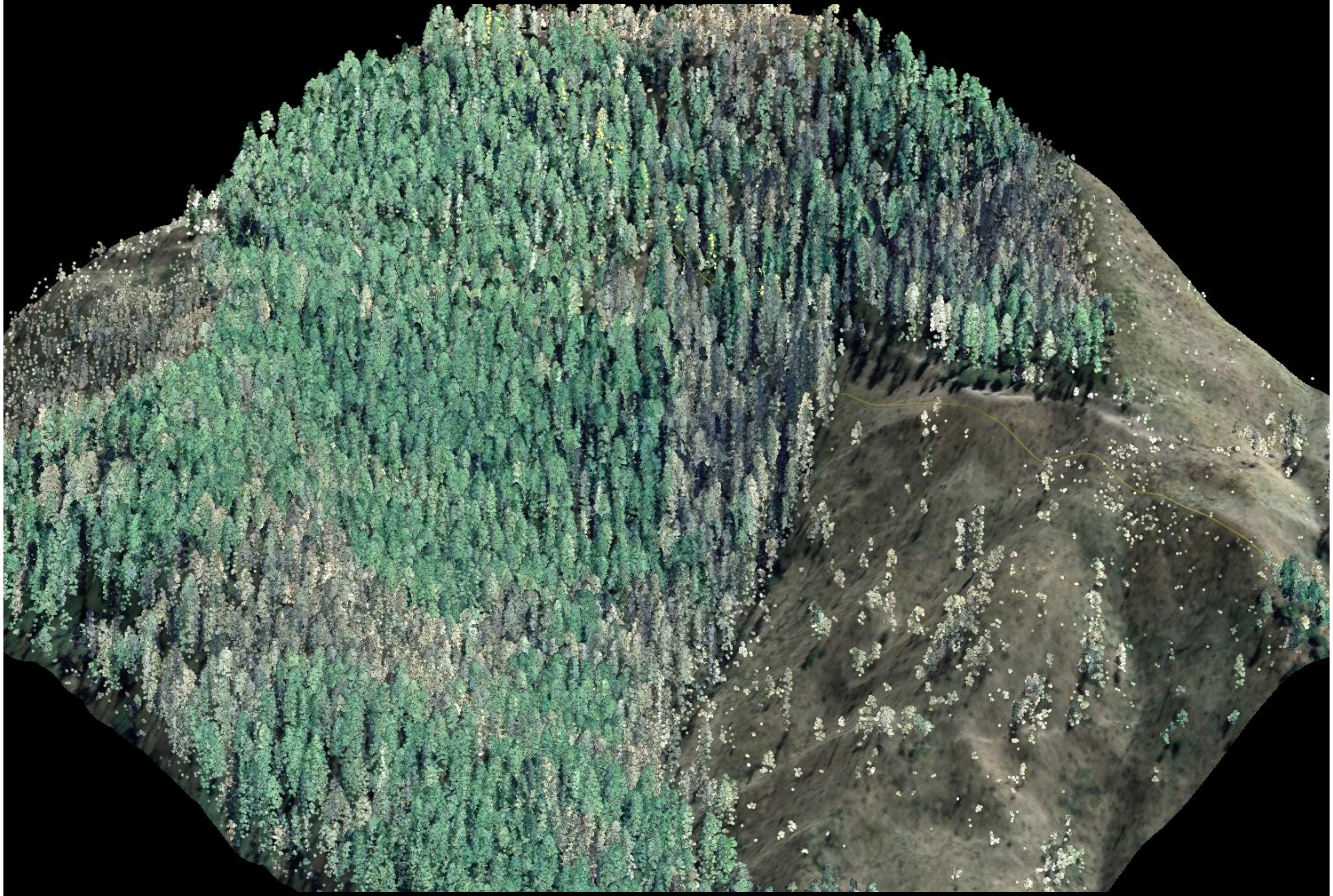
Models:

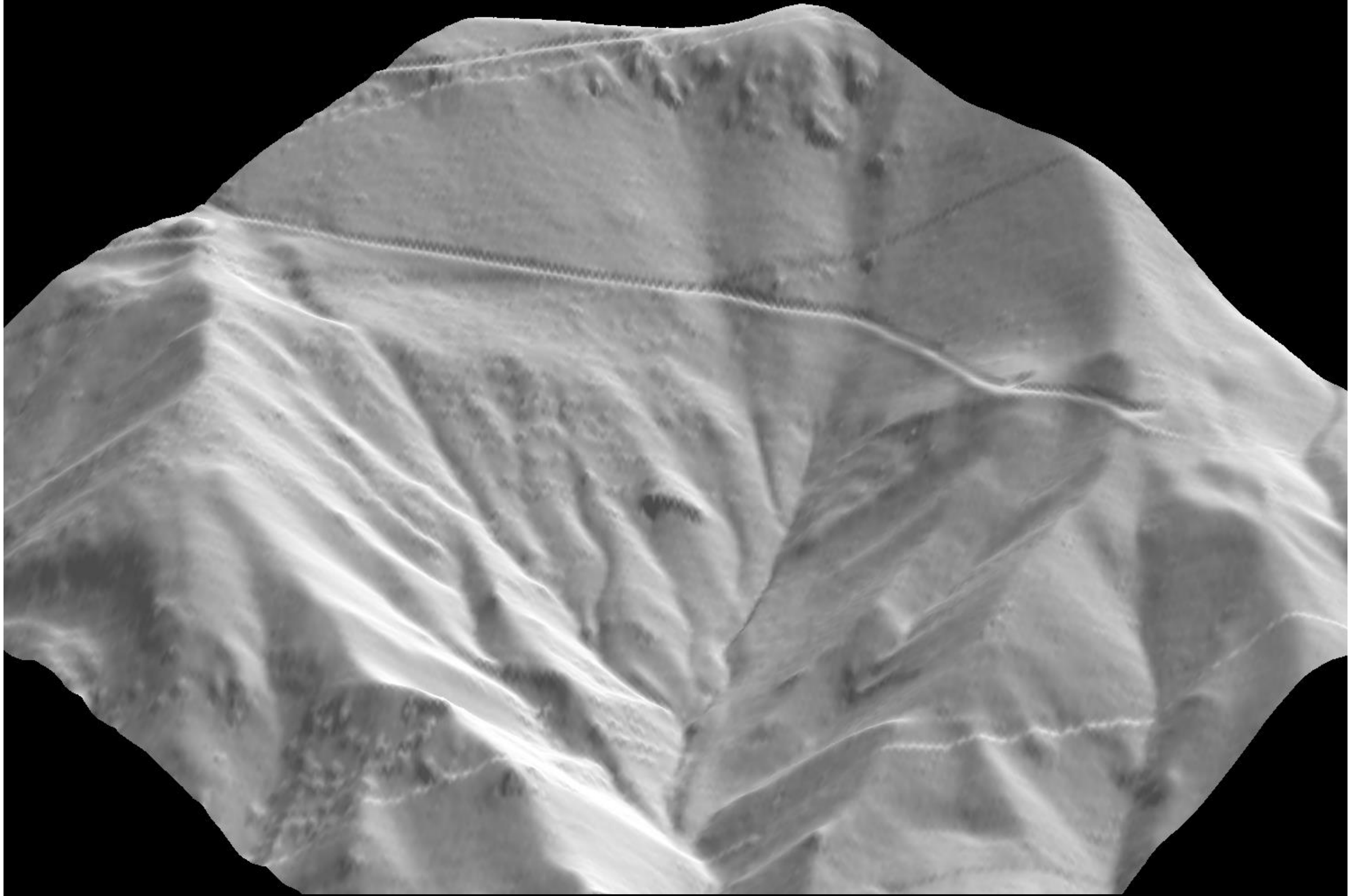
Combine in-situ plot data (soil) to map wetland carbon for Washington State & US

Key technology used: LiDAR - Light Detection and Ranging

- Active airborne laser scanner
- Returns are points with X, Y and Z coordinates
- LiDAR Products:
  - Ground model
  - Canopy Surface model
  - Slope
  - Intensity image

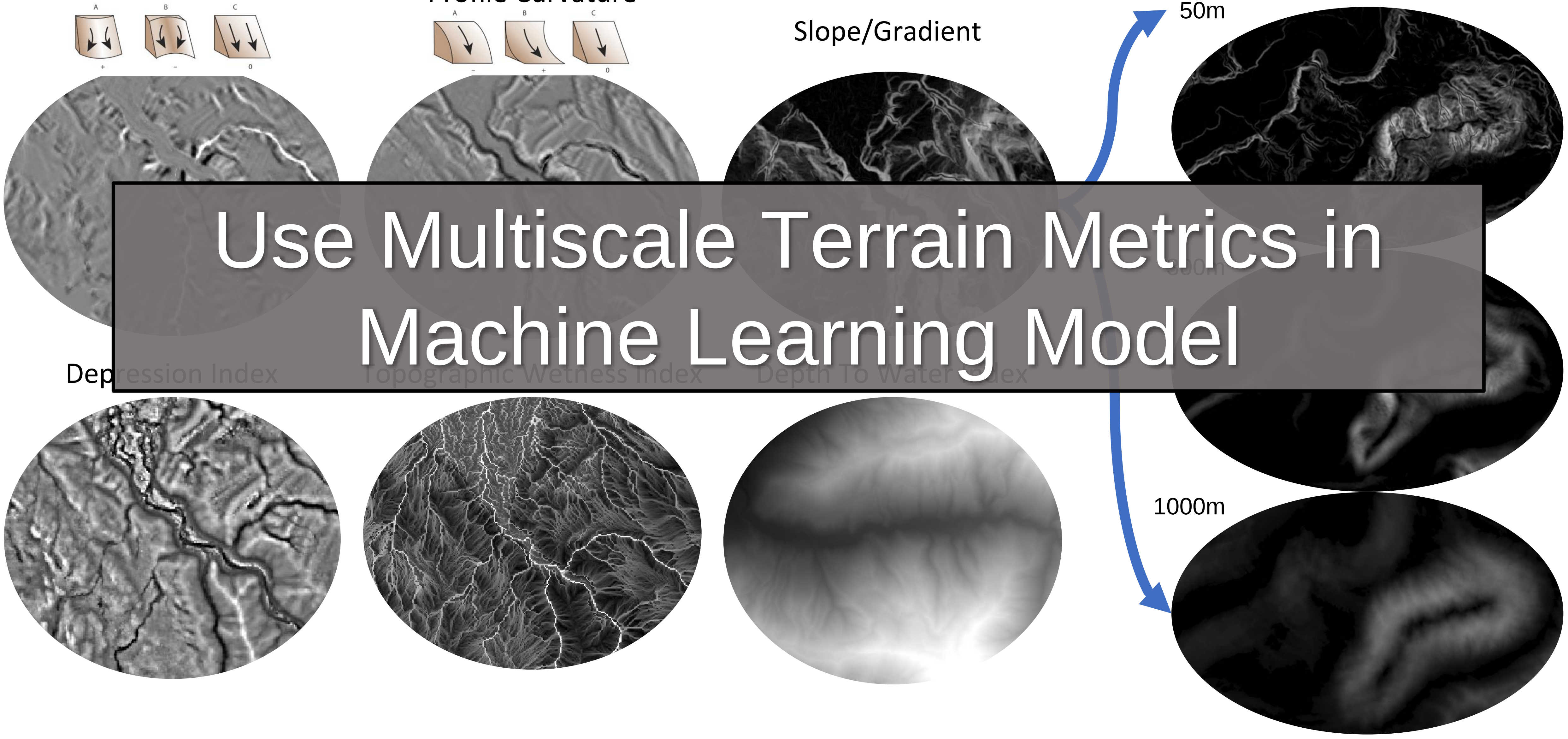






Identifying Cryptic Wetland Predictors: Terrain Metrics From Digital Elevation Models (DEMs)

Variable Length Scale of Terrain Metrics



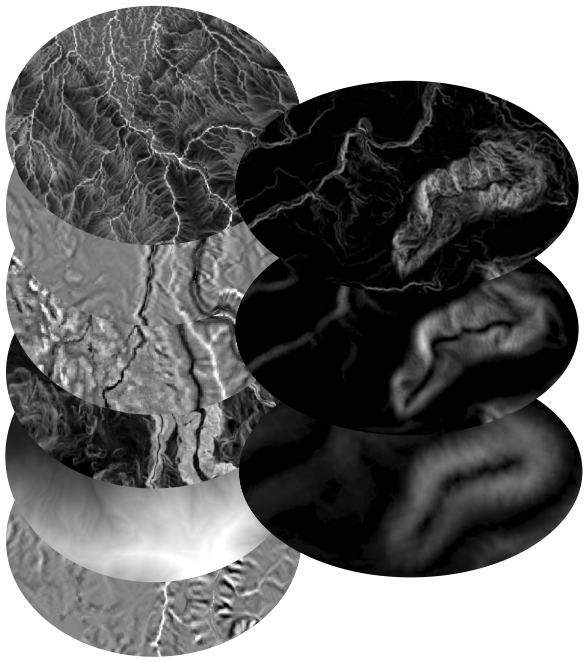
Use Multiscale Terrain Metrics in Machine Learning Model

Maxwell et al., 2016

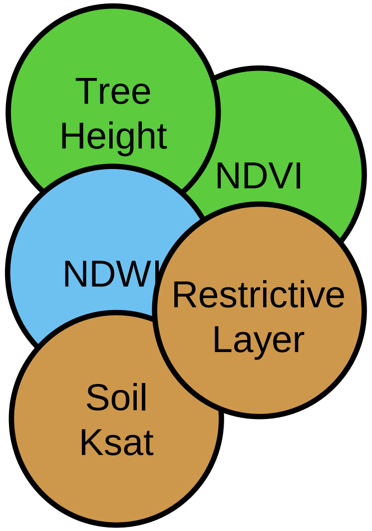
Wetland Identifier:
Wetland Intrinsic Potential (WIP) Tool

Halabisky et al., 2022 (In Review)

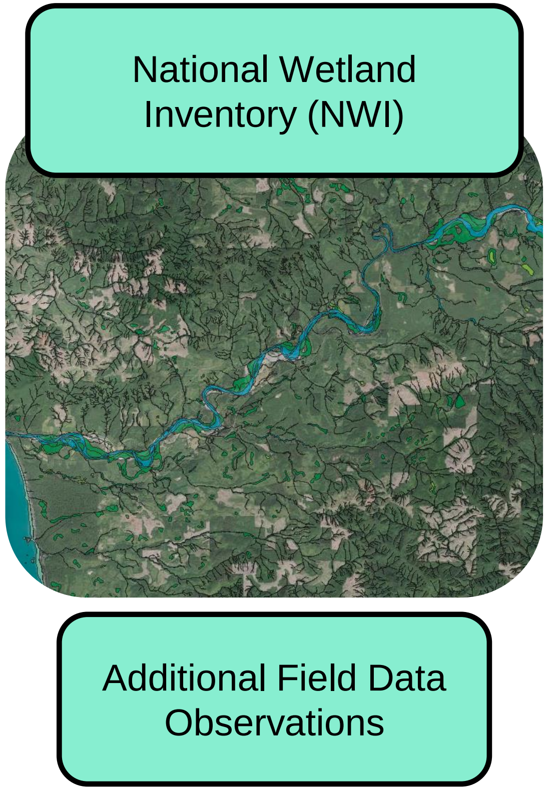
Generates Multiscale Terrain Metrics



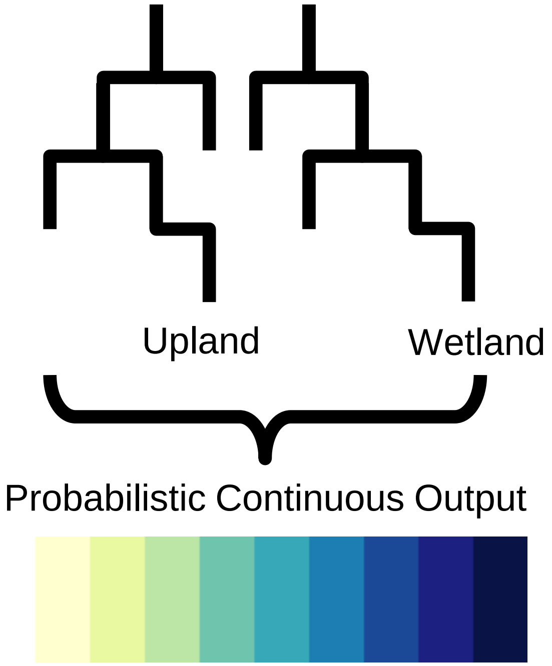
Integrates Additional Predictor Variables



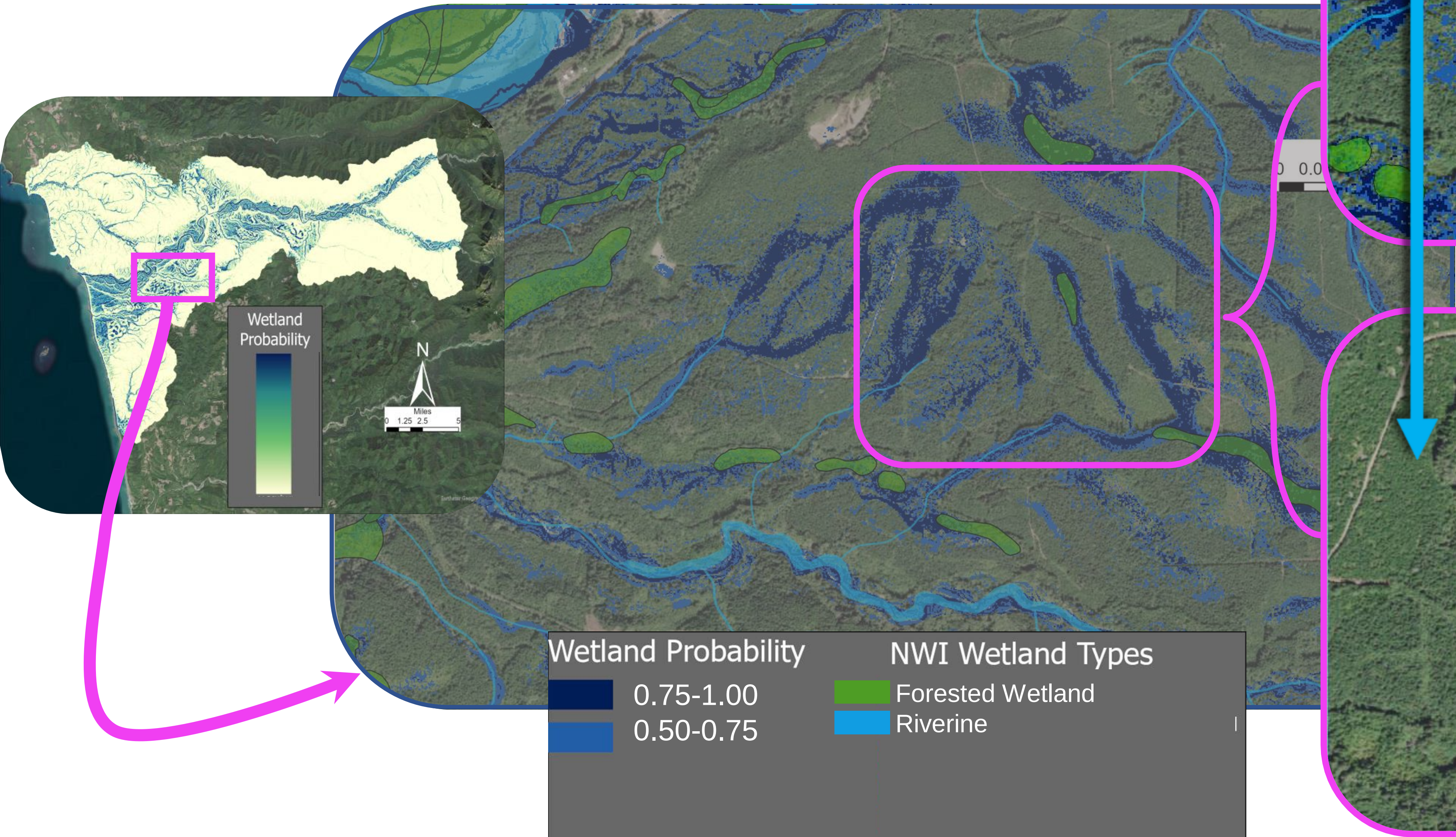
Creates and Uses Robust Training Data

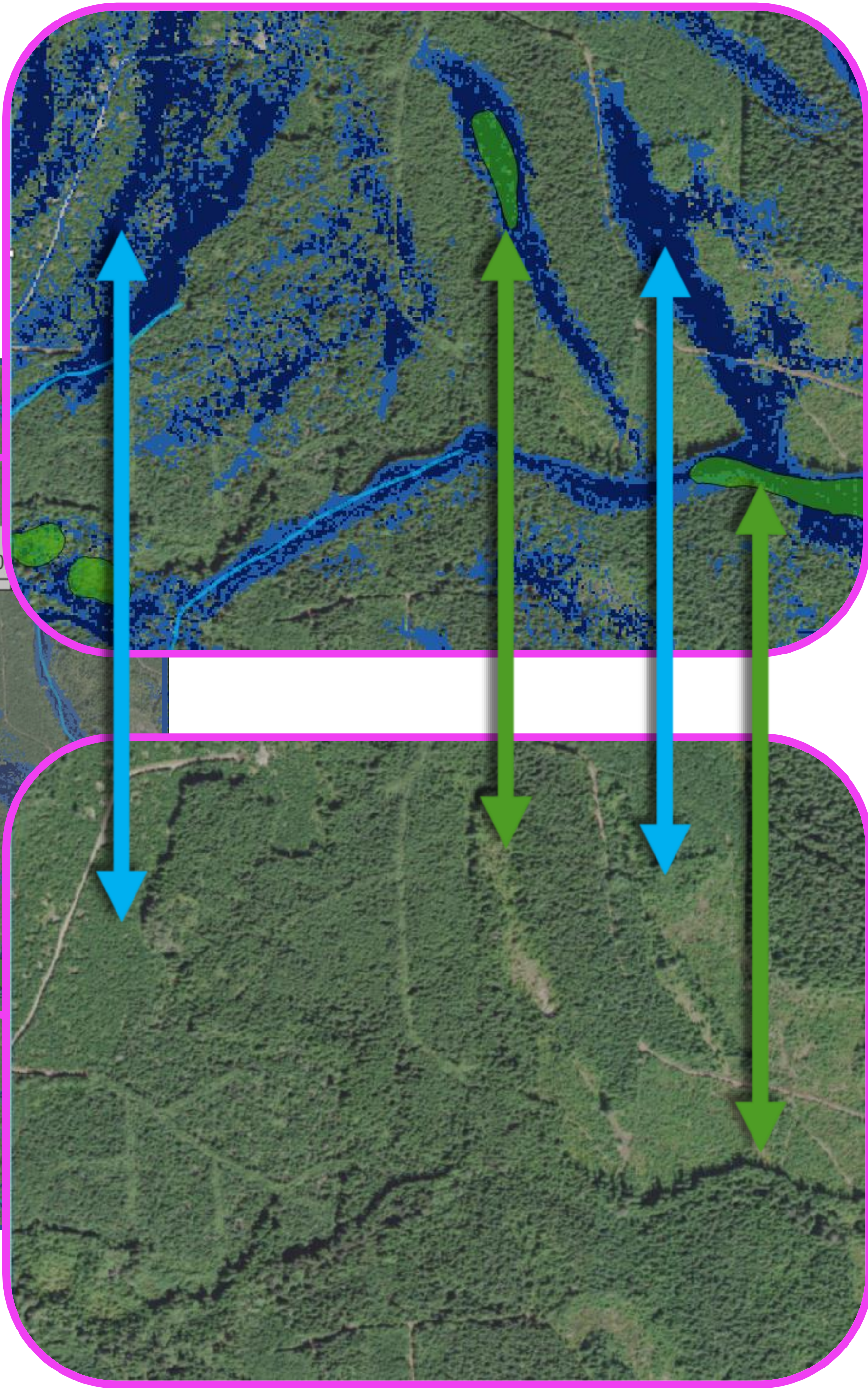


Predicts with Random Forest Classifier



WIP Identified Wetlands Compared to National Wetland Inventory (NWI)





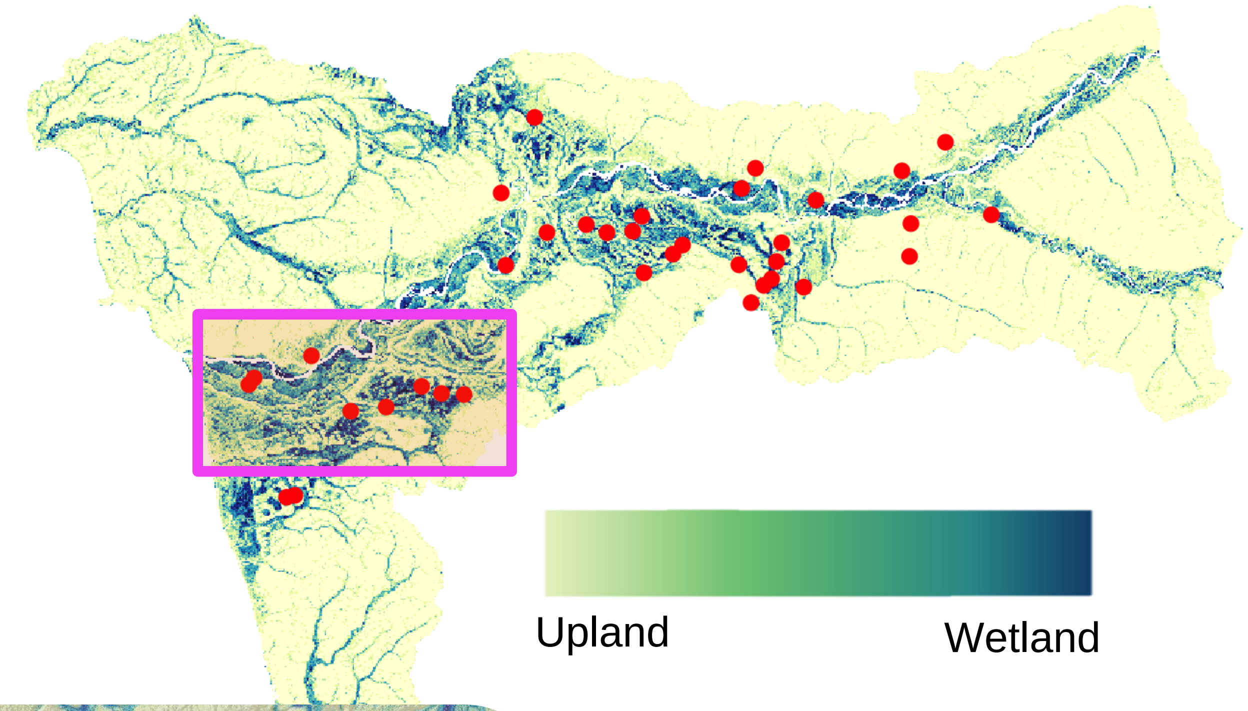
Fieldwork for Cryptic Carbon Sampling

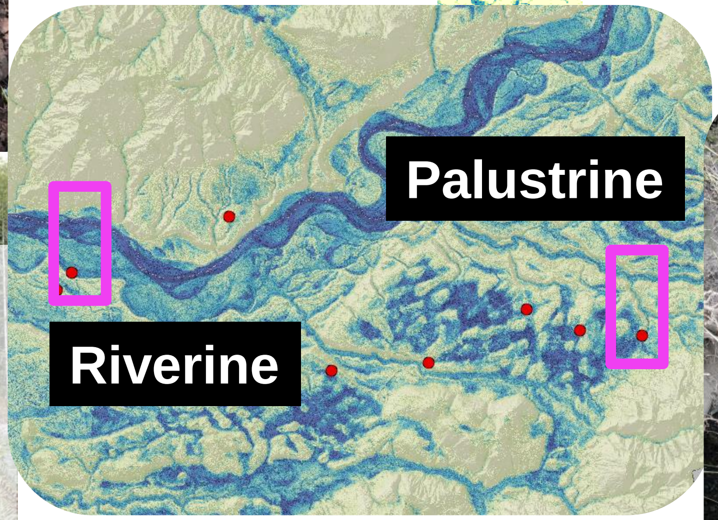
Thanks to:
Anthony Stewart, Claire Johnson, Hazel Sanders, Abby Nesper, Thomas Kakatsakis

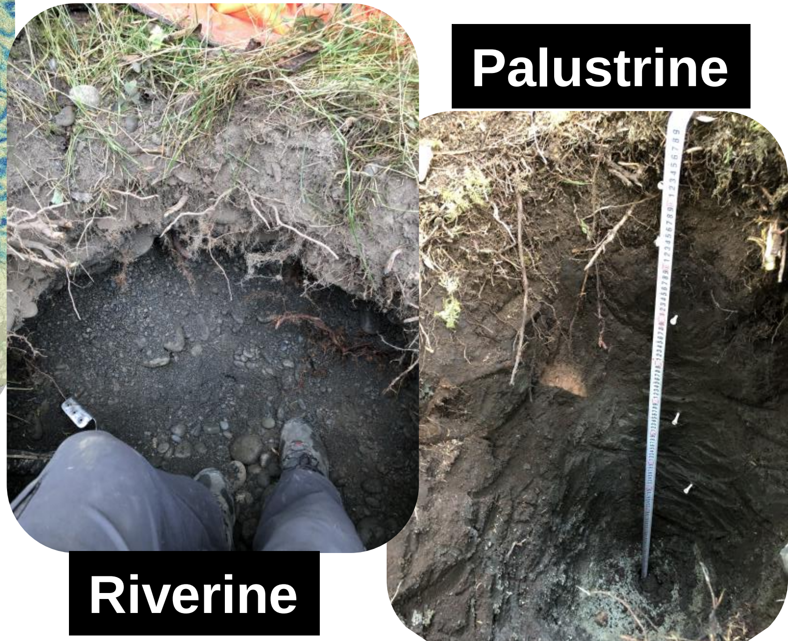
36 Soil Pits in 22 Workdays

Soil pit characterization

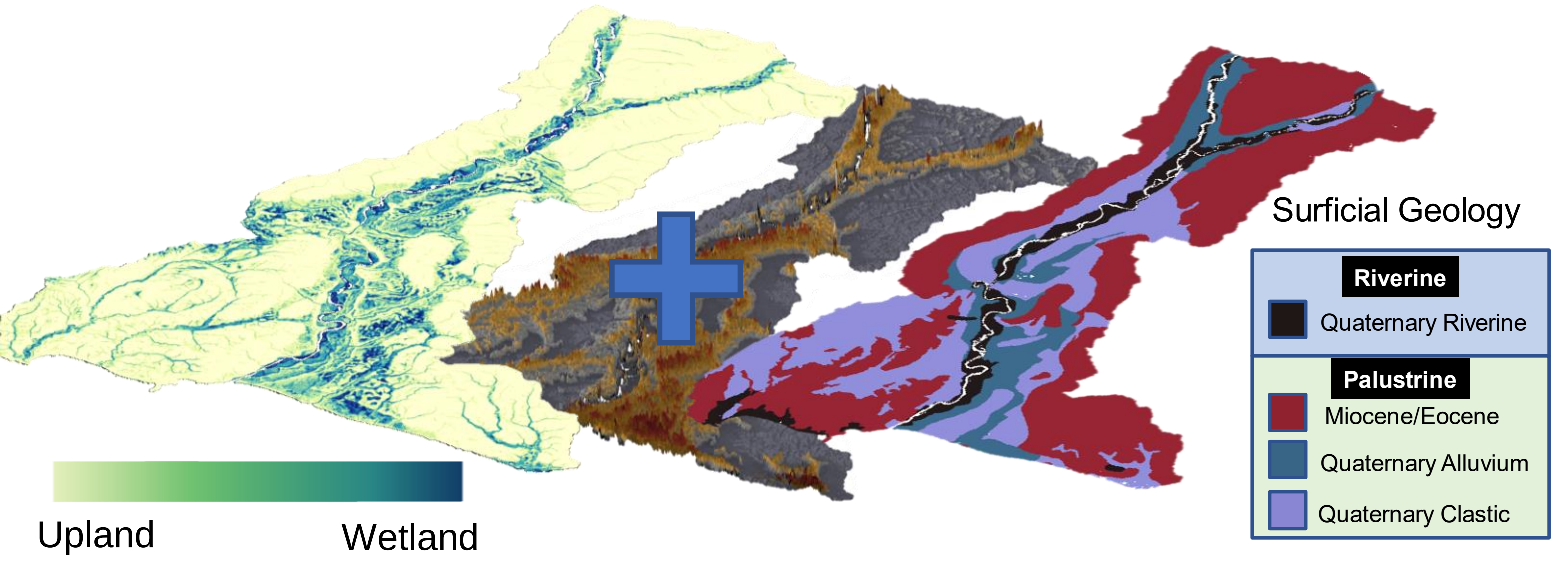
- 1m Depth or more
- Soil survey (horizons, color, texture)
- Vegetation survey (hydrophytic)
- Top level HGM and Cowardin classification
- Bulk Density and Total Carbon sampling

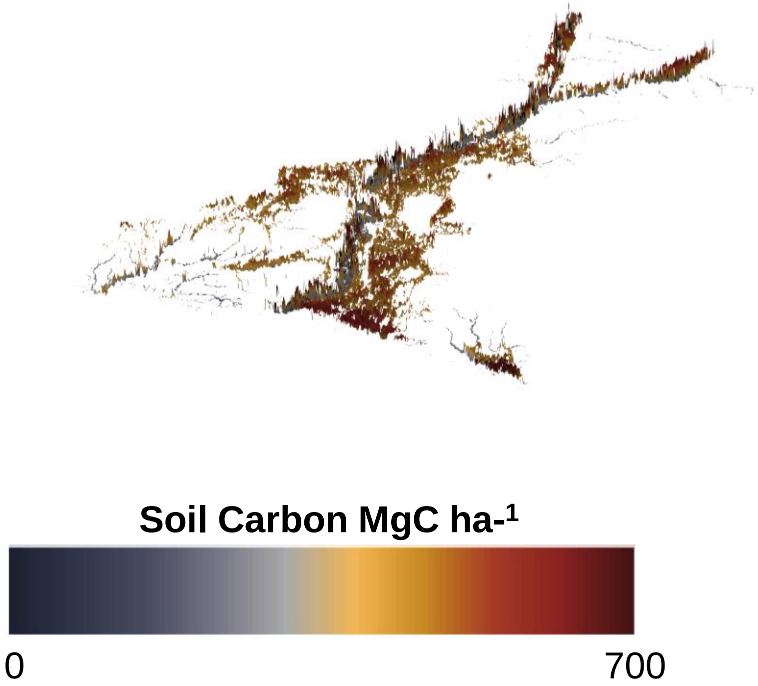






Cryptic Carbon Mapping Results





	Total Landscape	WIP Wetlands	WIP Outside NWI
Surface Area (ha)	68,135	6,114 (9%)	**4,401** (+181%)
Total Soil Carbon (TgC)	9.6	1.8 (19%)	**1.4** (+246%)
Average Soil Carbon Density (MgC ha^{-1})	140.4	296.8 (+111%)	**309.0** (+79%)

Example # 2
Can We Conserve Wetlands Under a Changing Climate?
Mapping Wetland Hydrology Across an Ecoregion and Developing Climate Adaptation Recommendations

Meghan Halabisky (UW- RSGAL), **Se-Yeun Lee** (UW- CIG), **Sonia Hall** (SAH Ecologia LLC), **Mike Rule** (USFW), **Alan Hamlet** (Notre Dame), **Maureen Ryan** (Conservation Science Partners), **Monika Moskal** (UW)

Great Northern
LANDSCAPE CONSERVATION COOPERATIVE

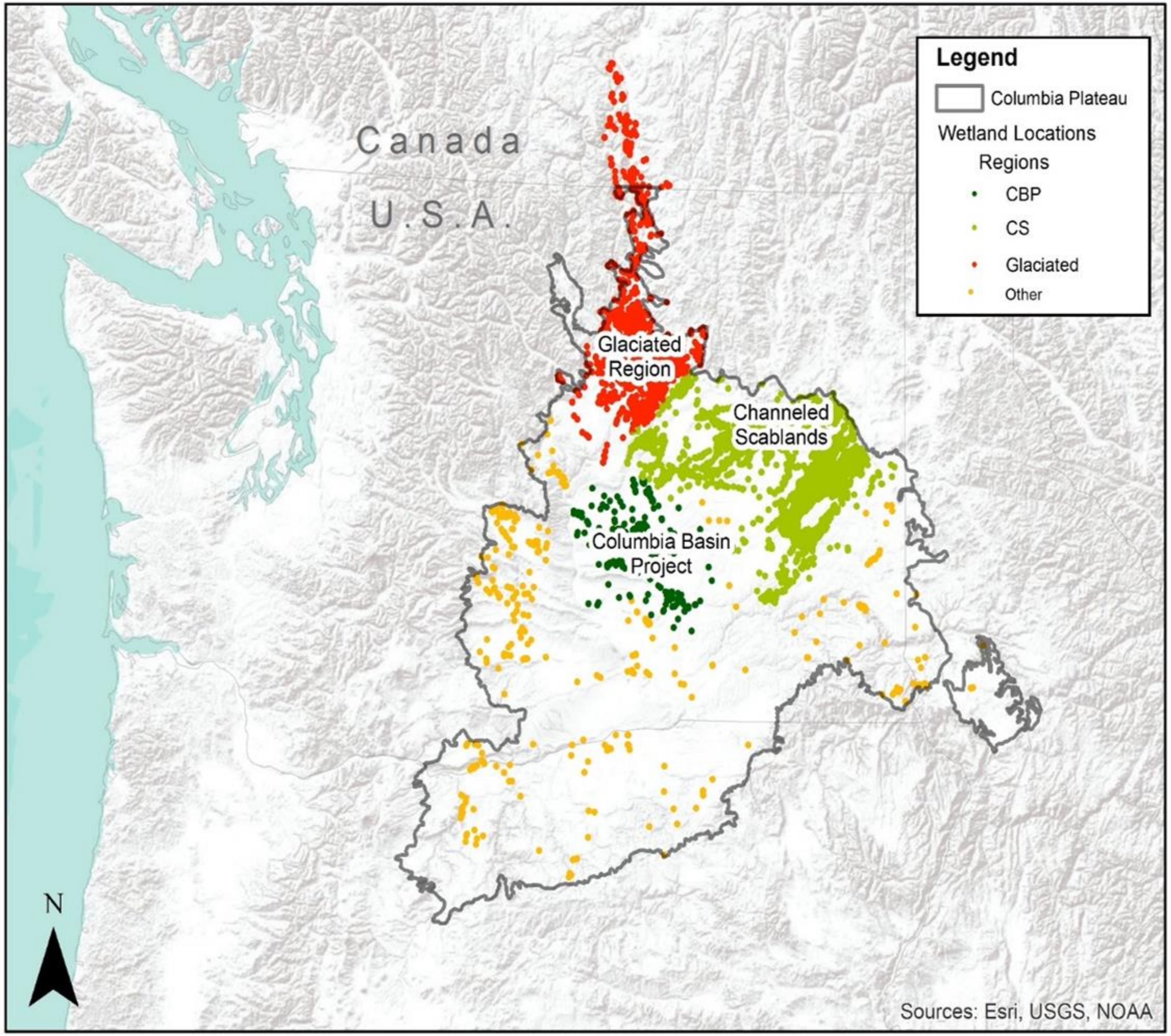
NWCSC
Northwest Climate Science Center

How will wetlands respond to climate change?

Are all of them going to dry out and disappear?

Study Area: Columbia Plateau

- Depressional wetlands



The remote sensing toolbox

Sensors / imagery:

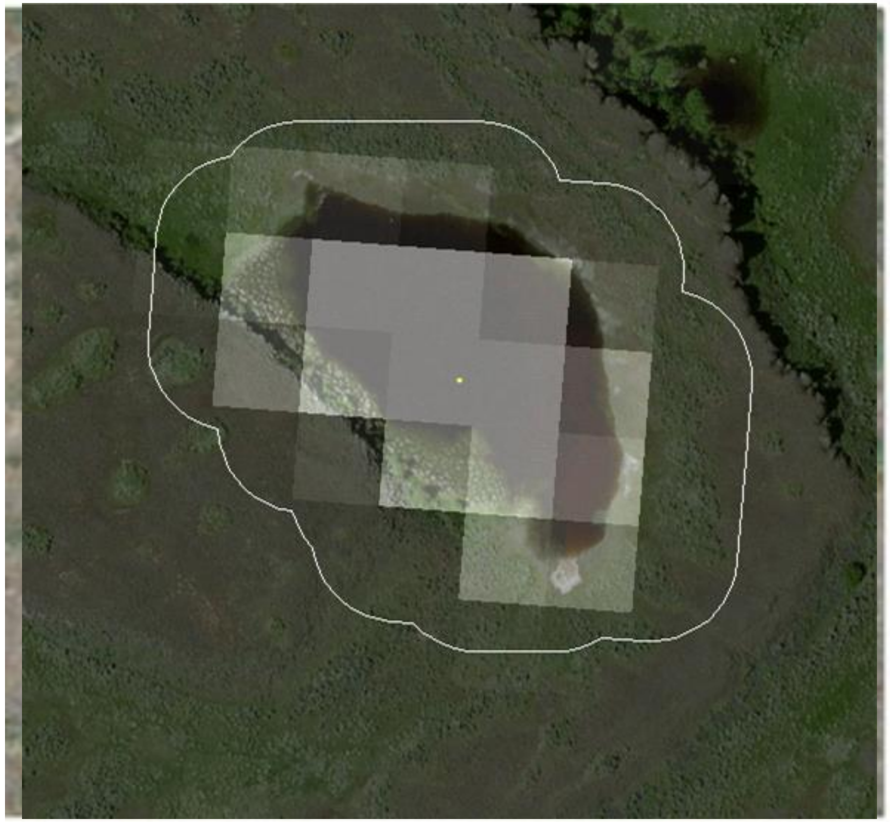
NAIP aerial imagery, Landsat imagery

Methods:

Spectral mixture analysis

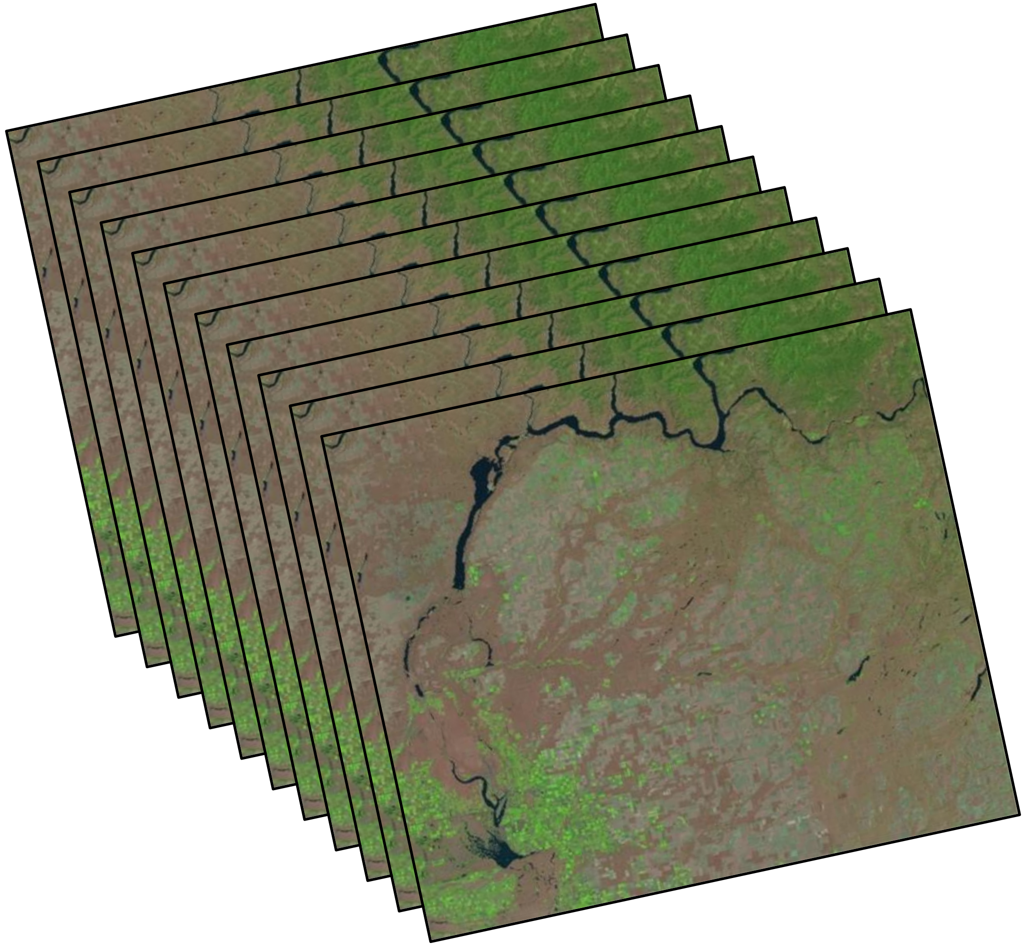
Regression (climate modelling)

Remote Sensing Methods

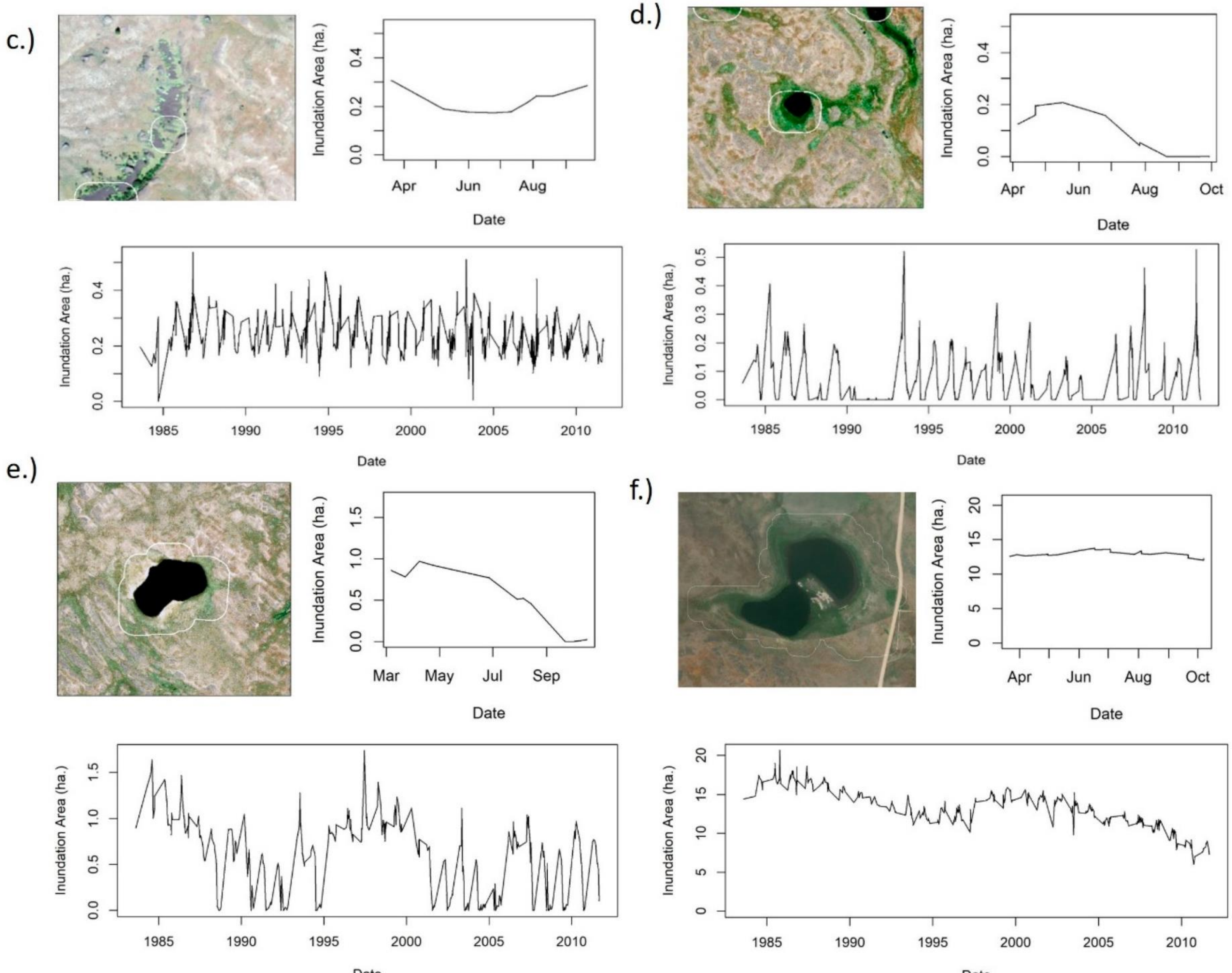


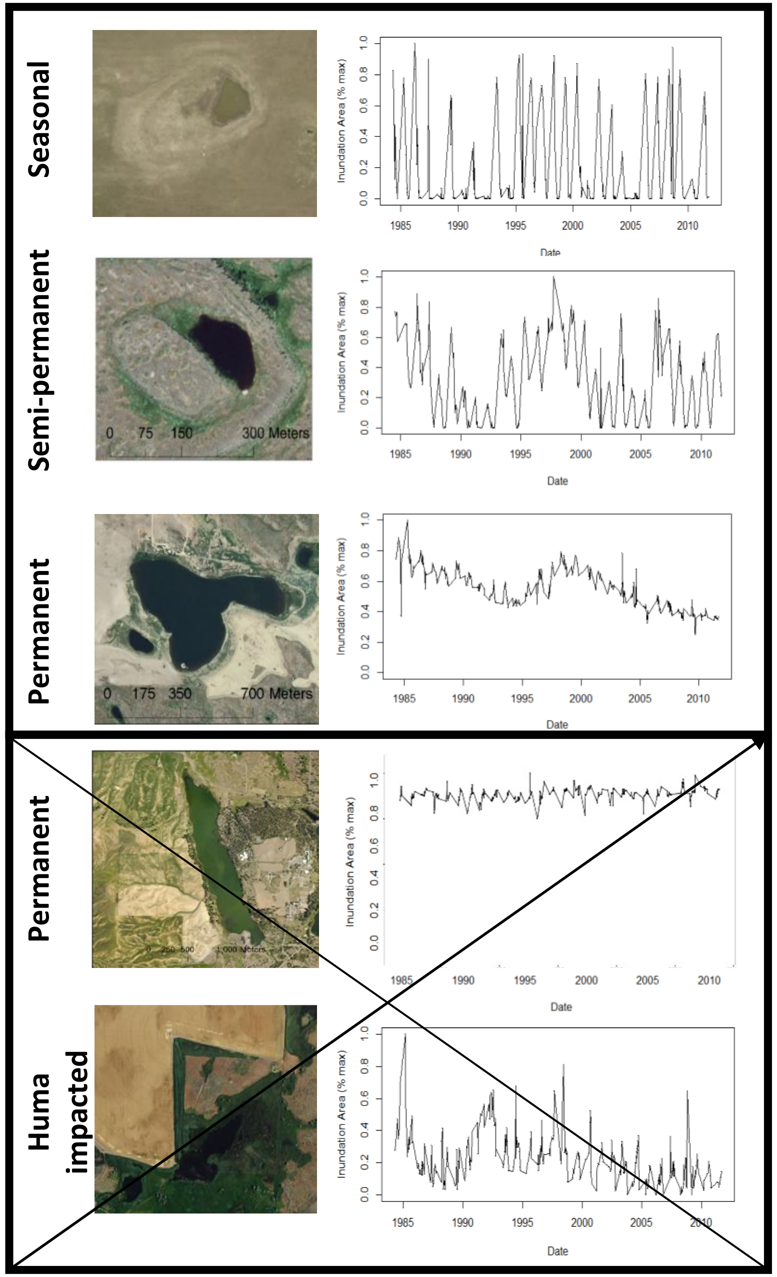
Computer aided pattern recognition

+



Landsat satellite archive (1984 – 2011) to measure changes in surface water for each wetland.


c.)
Inundation Area (ha.)
0.0
0.2
0.4
Apr
Jun
Aug
Date
1985
1990
1995
2000
2005
2010
d.)
0.0
0.1
0.2
0.3
0.4
0.5
Oct
e.)
0.5
1.0
1.5
Mar
May
Jul
Sep
f.)
0
5
10
15
20



Surface Water

VIC variables:

Soil Moisture Layer1

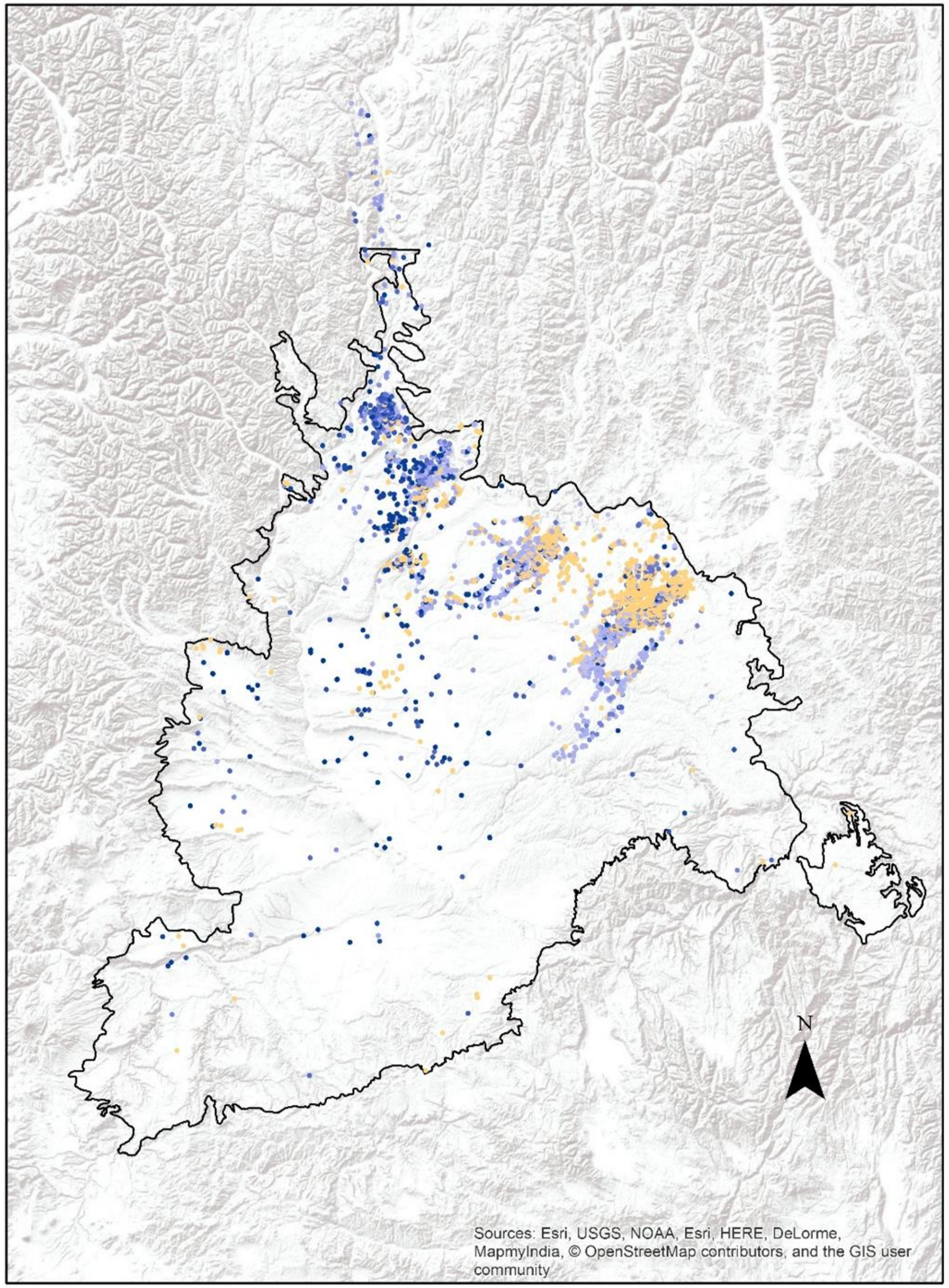
Soil Moisture Layer2

Soil Moisture Layer3

CDFM : Precip – ET

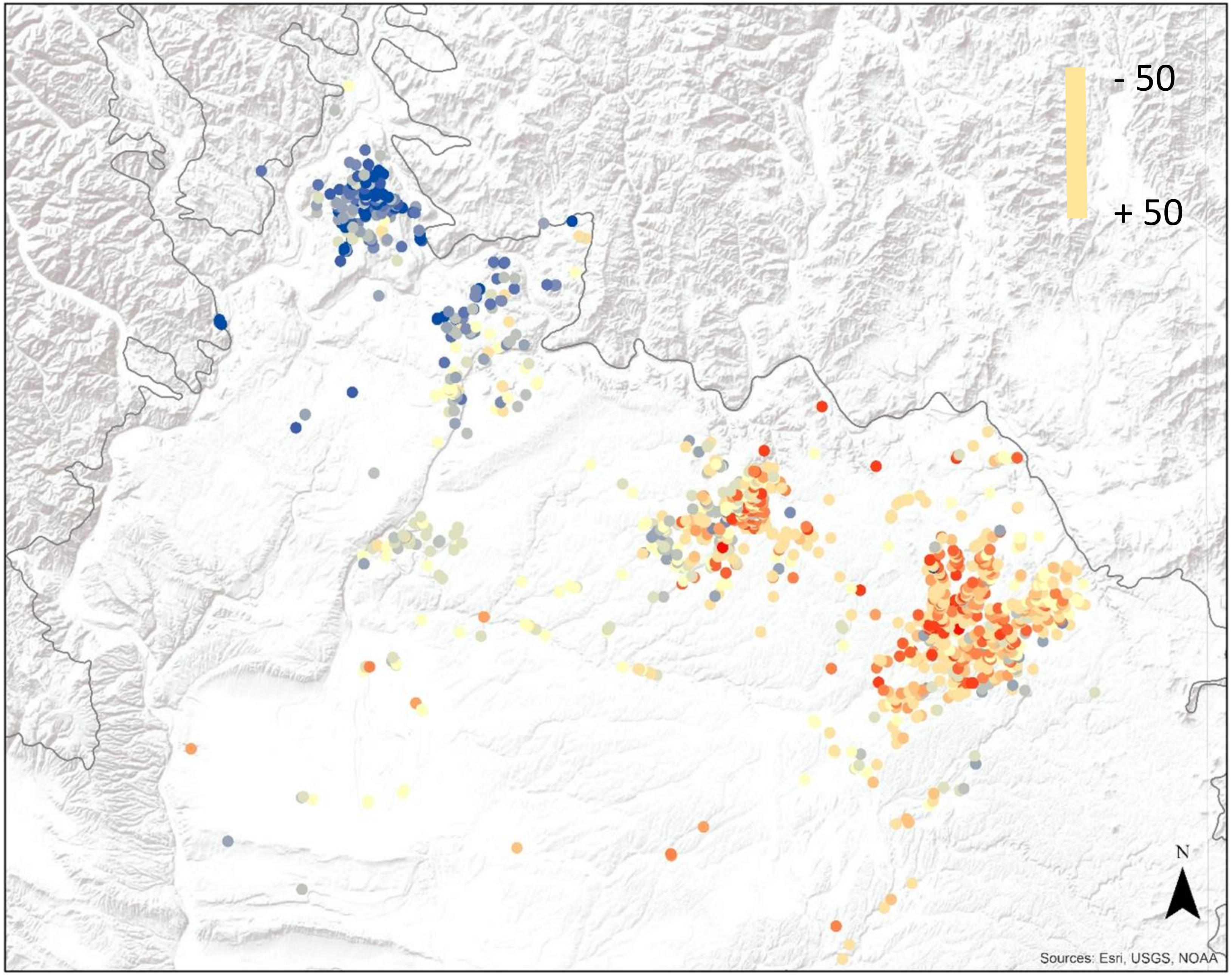
CDFM : Precip

Ground Water



How will wetland hydrology change?

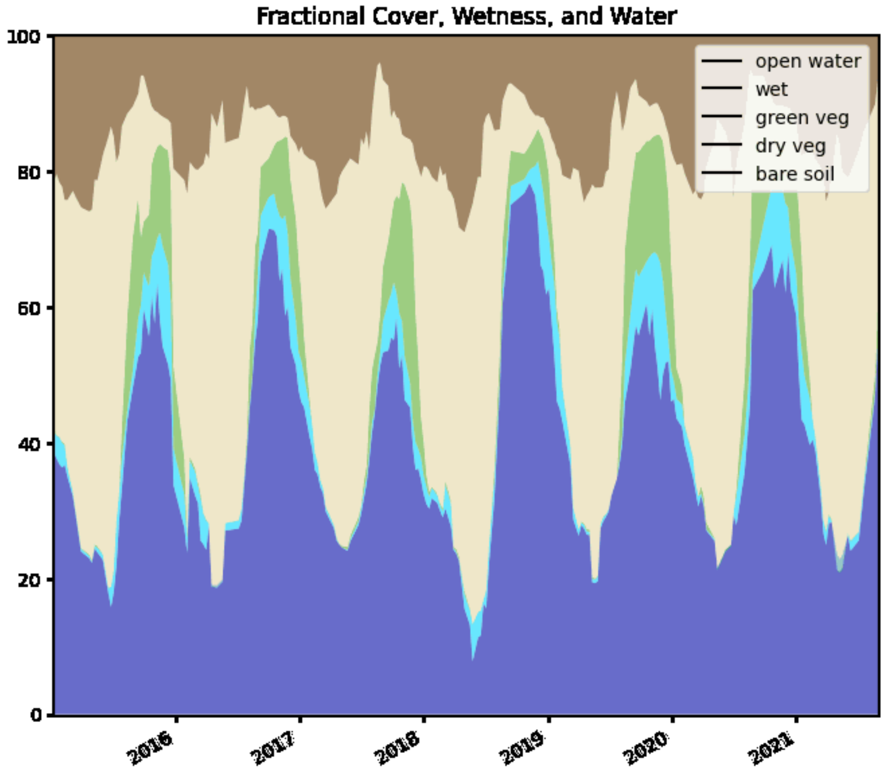
Change in drying frequency (years out of 100)



Outline

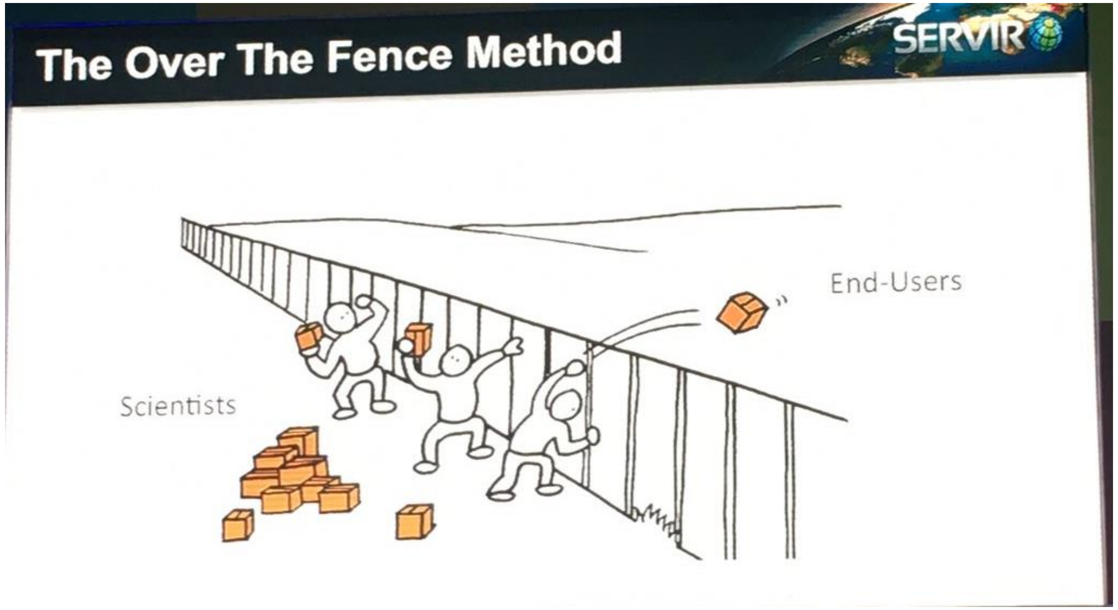
- Challenges of modelling wetlands
- What is remote sensing?
- Remote sensing toolbox – Sensors, methods, models
- Spatial, spectral, temporal resolution – Picking the right sensors
- Building a Wetland EO toolkit
- Example 1 – Mapping Teal Carbon (wetland carbon)
- Example 2 – Reconstructing the past to model the future of wetland dynamics.
- What's next?

Digital Earth Africa – From science and technology to decisionmaking



Impact - How do we connect this information to communities and decisionmakers?

- Outdated idea of static maps – Iterative processes that include people and communities into the process.
- Radically diversify the field of remote sensing so that we bring different issues and ideas to the field. [https://www.usgs.gov/media/videos/earth-observation-user-case-study-ladies-landsat]
- Lower the bar to entry and use.
- Increase open source / open science



Thank you!

Halabisk@uw.edu

mhalabisky@gmail.com