QUANTIFYING RESTORATION OF JUVENILE SALMON HABITAT WITH AN UNMANNED AERIAL VEHICLE SYSTEM

~UAS Post Mission Review~

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26 April 2016

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~OUTLINE~

Project summary -- Roegner 

UAS Permitting & Drone performance -- Ryka Team

Ground Control Station surveys -- Borde

Image processing & Analytics -- Coleman

Technology Readiness Level status -- Roegner

Questions/comments

Project Scope

1. Wetlands directly benefit endangered juvenile salmon by supporting diverse vegetation communities.

2. Restoration of degraded wetlands leads to vegetation and topographic changes that require comprehensive monitoring – difficult to accomplish w/traditional means.

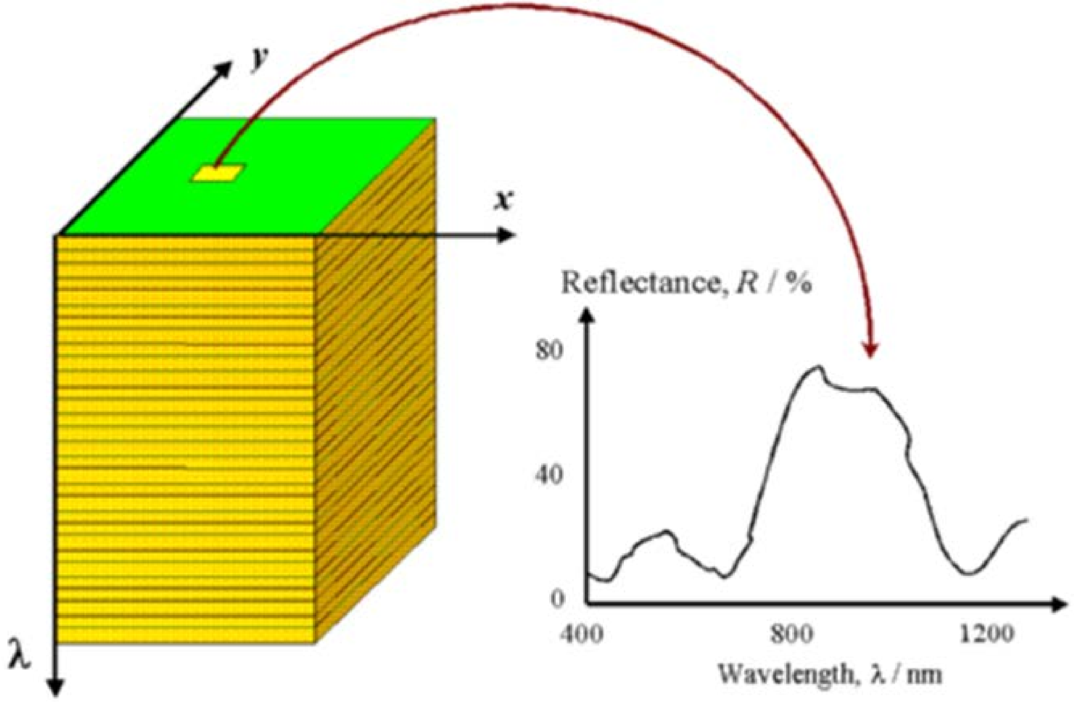
3. Our project: Develop remote sensing techniques employing hyperspectral imagery on a UAV to monitor wetland restoration trajectories.

Project Goals

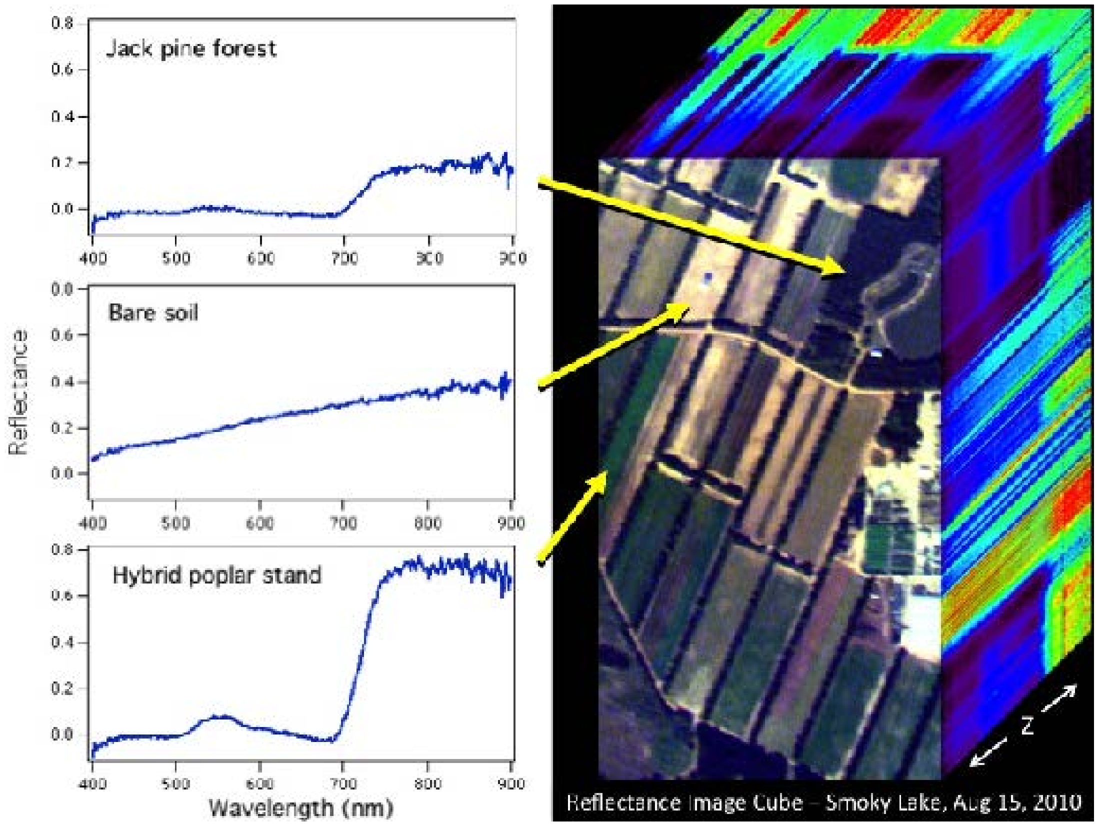
1. *Equip* a UAV system with a hyperspectral imager
2. *Conduct* field measurements, and build Spectral Library
3. *Develop* data analysis routines and analytics for critical metrics
4. *Test* flight optimization and evaluation missions at additional tidal wetland systems
5. *Codify* protocols for remote sensing to aid evaluation of wetland restoration trajectories and management decision making

Principals of Hyperspectral Imagery

<u>Hyperspectral Datacube</u>:
(Spatial pixels) * spectral channels
(X * Y) * λ



Spectral signatures used for object identification



Principles of Remote Sensing - Centre for Remote Imaging, Sensing …<u>www.crisp.nus.edu.sg</u>

SPECTRAL LIBRARY

CATALOG OF OBJECT-SPECIFIC SPECTRA

DATA ACQUISITION

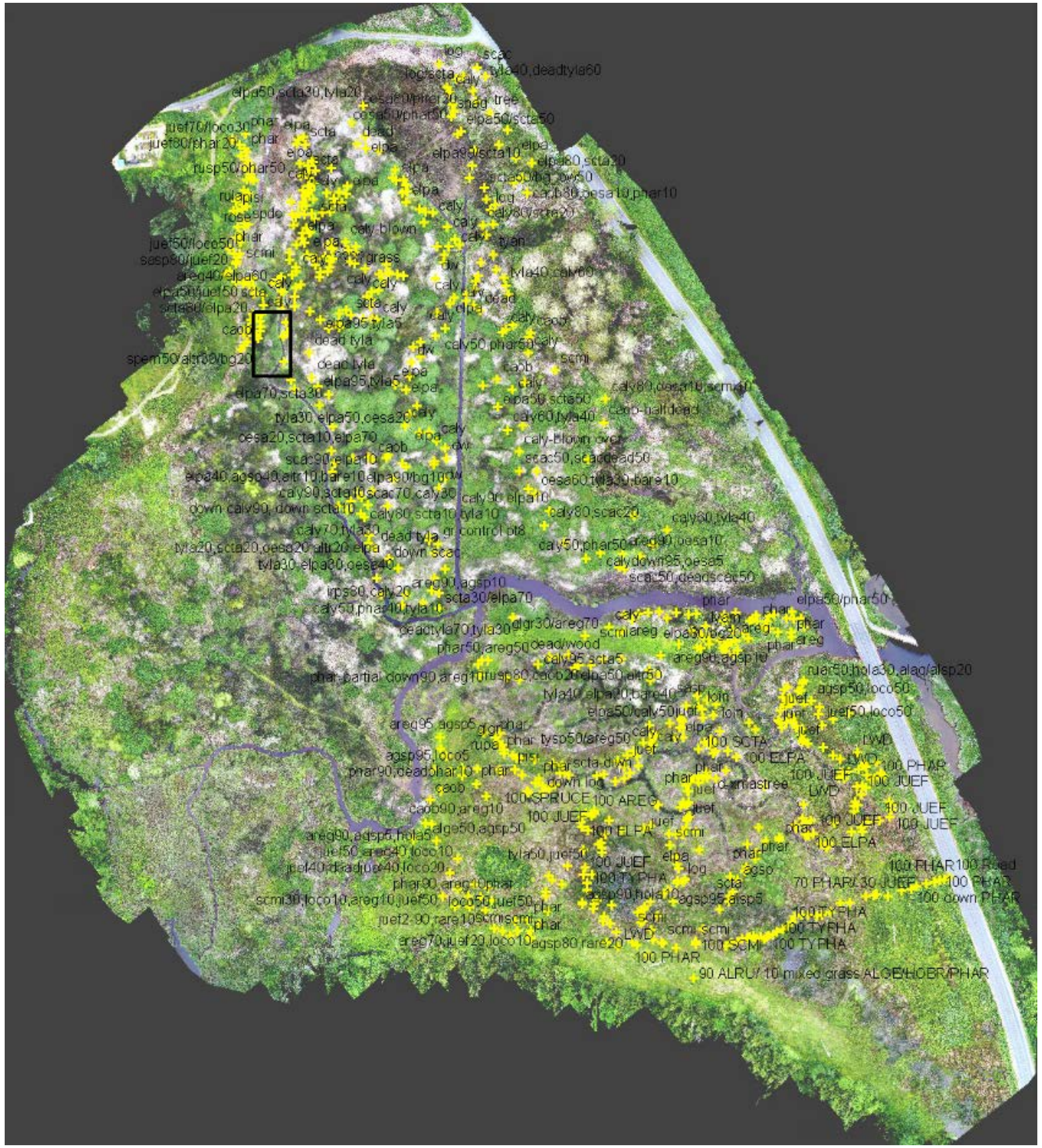
SPECTRAL SIGNATURES OF VEGETATION AND TOPOGRAPHIC FEATURES:

Herb	Shrub	Tree	Other Object
Sps 1	Sps1	Sps 1	Bare Ground
Sps 2	Sps 2	Sps 2	Water
Sps 3…	Sps 3…	Sps 3…	Structure

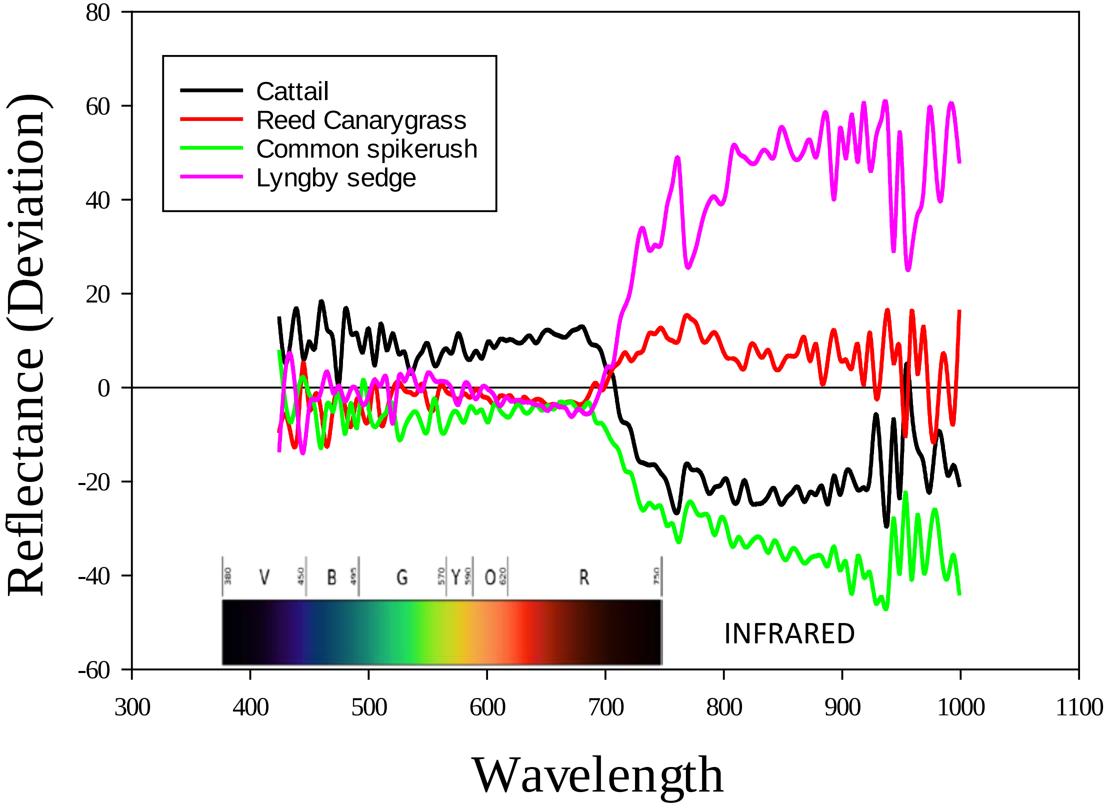
SPECTRAL LIBRARY

1. GROUND-TRUTHED FOR PNW HABITATS
2. OPEN SOURCED

National Park Service's Colewort Creek Wetland Restoration Site



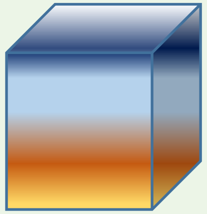
Spectral signatures of Key vegetation Types



Automation of Object Identification

Data Collection

Survey wetlands



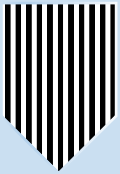
DataCube

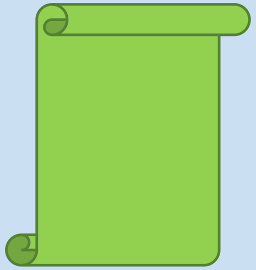
Analyitics

Spectral Library

Herb	Shrub	Tree	Other Object
Sps 1	Sps1	Sps 1	Bare Groun d
Sps 2	Sps 2	Sps 2	Water
Sps 3...	Sps 3...	Sps 3...	Struct ure

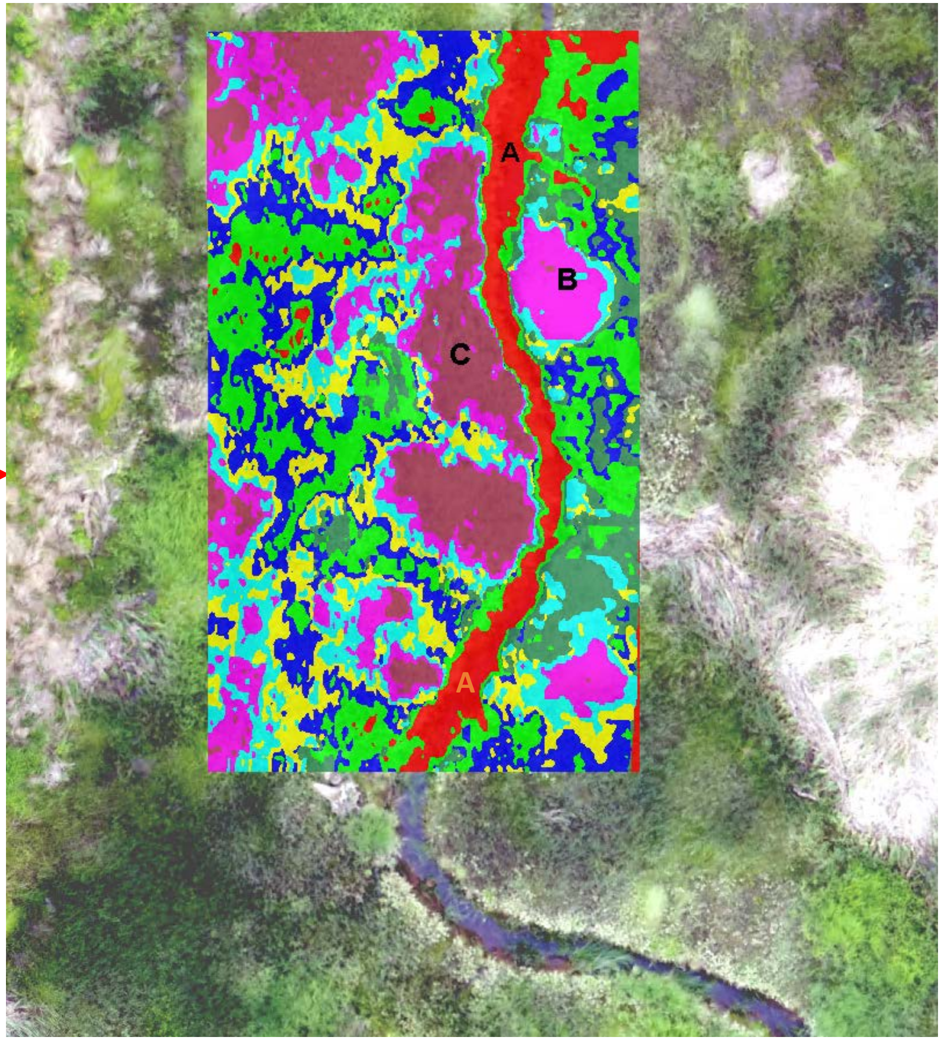
Filters





Dialogs

Output (categorized maps & statistics)



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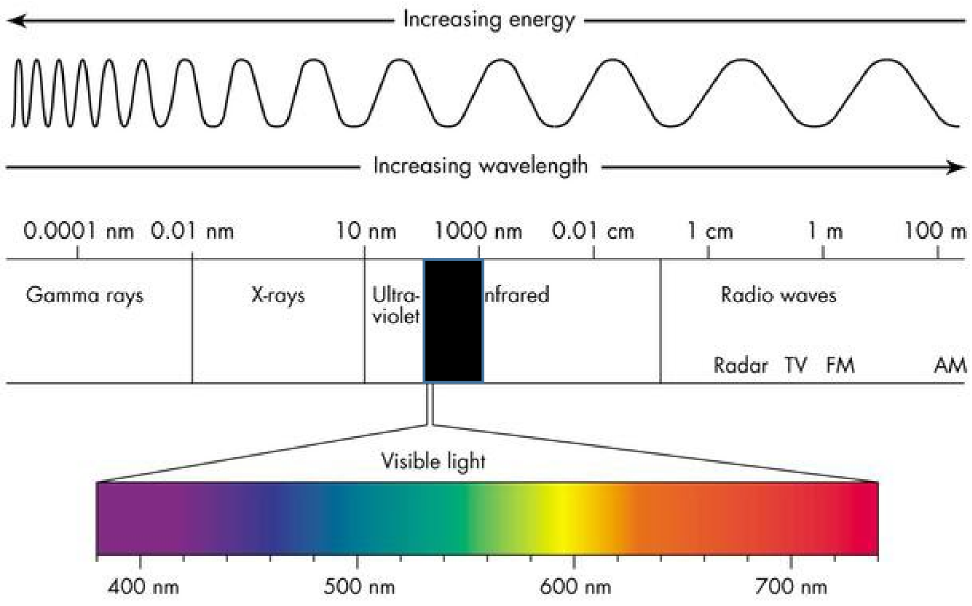
Hyperspectral Camera Characteristics

BaySpec OCI-100 BP150

- Pushbroom Hyperspectral Imager
- Spatial Pixels: 2000 pix x scan-length
- Spectral Range: 400-1000nm
- Spectral Resolution: 5nm
- Spectral Bands: 119
- Speed: 60 fps



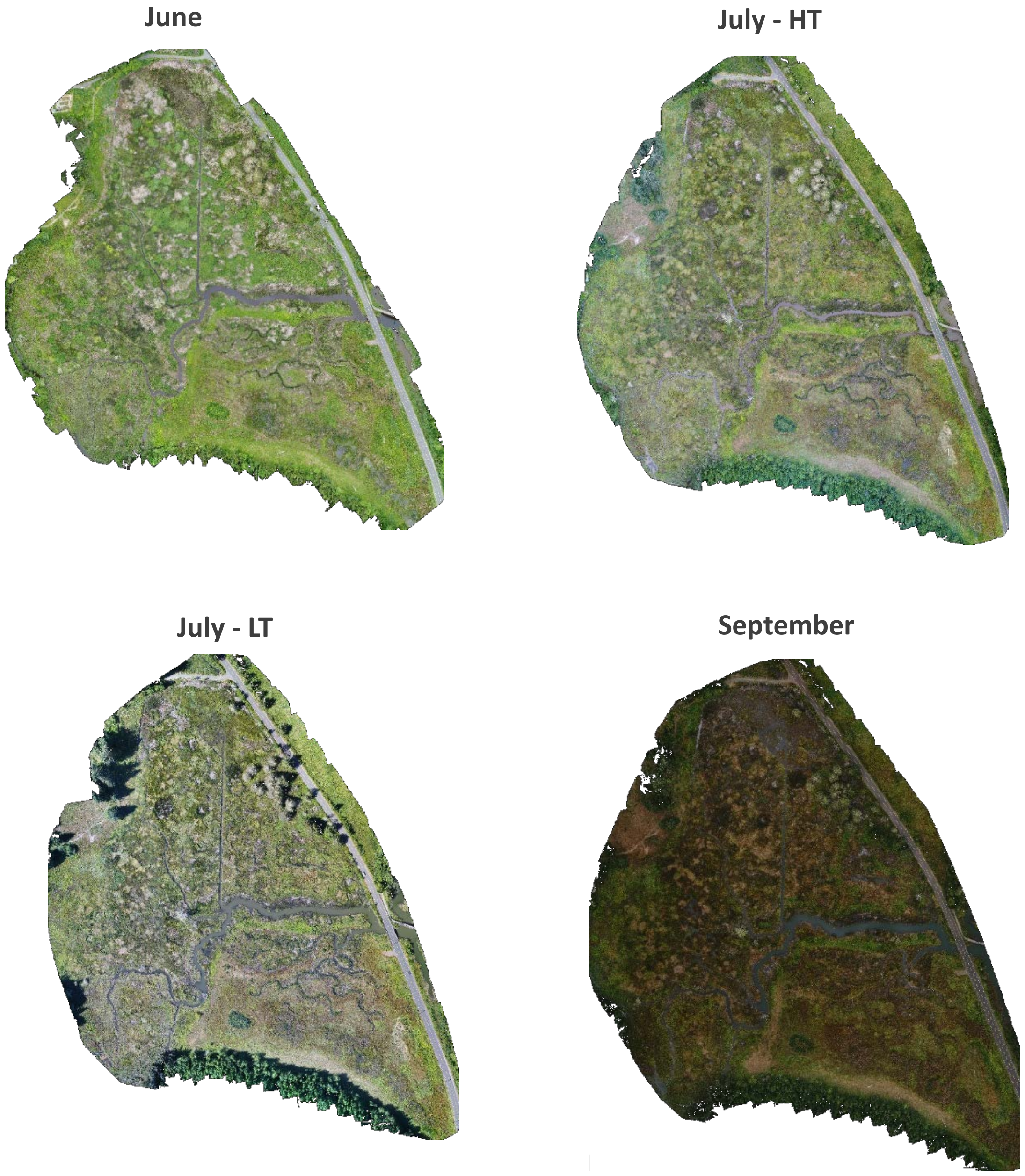
Outfitting the Matrice

Platform: DJI Matrice 600

- Created an adapter plate to mount sensor and onboard computer to Ronin MX
- Modified Battery System to power the sensors on board computer
- Connected UAS transmitter to sensors trigger and added video downlink
- Modified flight scripts to time sensors aperture per flight transects
- Documented implementation and procedures for set up

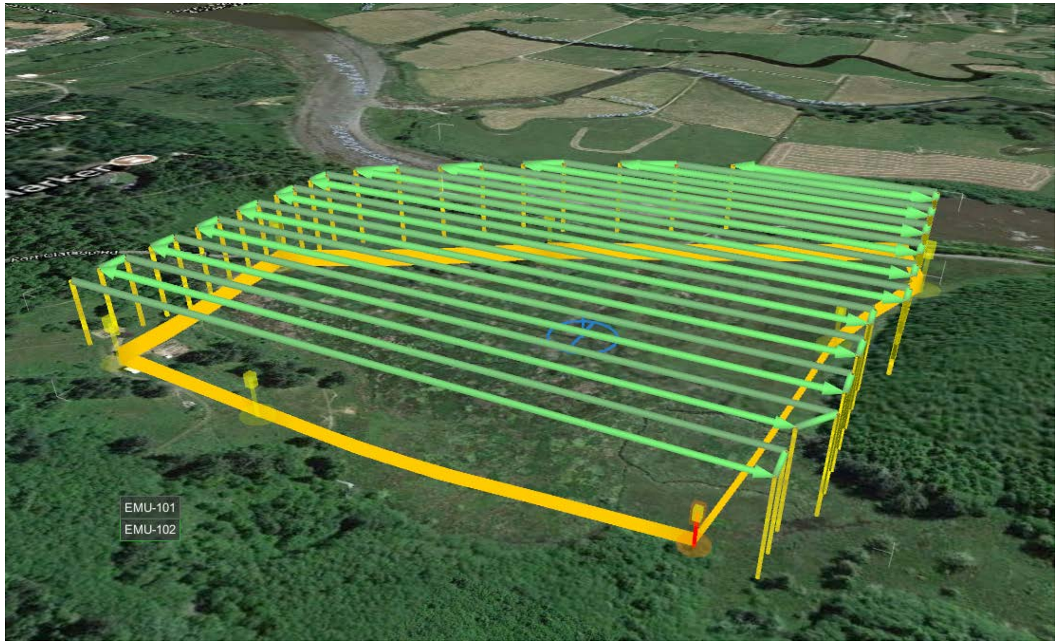
Flight Details

- Surveyed a total of 7 days (35 hours flight time)
- Captured 120 band hyperspectral imagery and RGB orthophotography at 2cm resolution
- Surveyed during low/high tides
- Surveyed multiple project locations within Lewis and Clark NPS



Flight Details cont.

- Used UGCS to plan flight transects, adding triggering commands for the push broom type sensor
- Calibrated each flight for atmospheric conditions including using a calibrated reflectance panel for white balance.
- Set 16 ground control points and markers
- Segmented flights to maximize flight time



Flight Permitting

- Longest permitting time was the FAA
- Worked with the FAA, NOAA, and the NPS to obtain permits
- FAA issued a COA to operate under section 333
- Restricted airspace extended the permitting time
- Permitting will improve with the FAA implementation of LAANC for this specific area

Challenges

Sensor Operation

Project area has inconsistent cloud cover causing atmospheric conditions to change frequently.

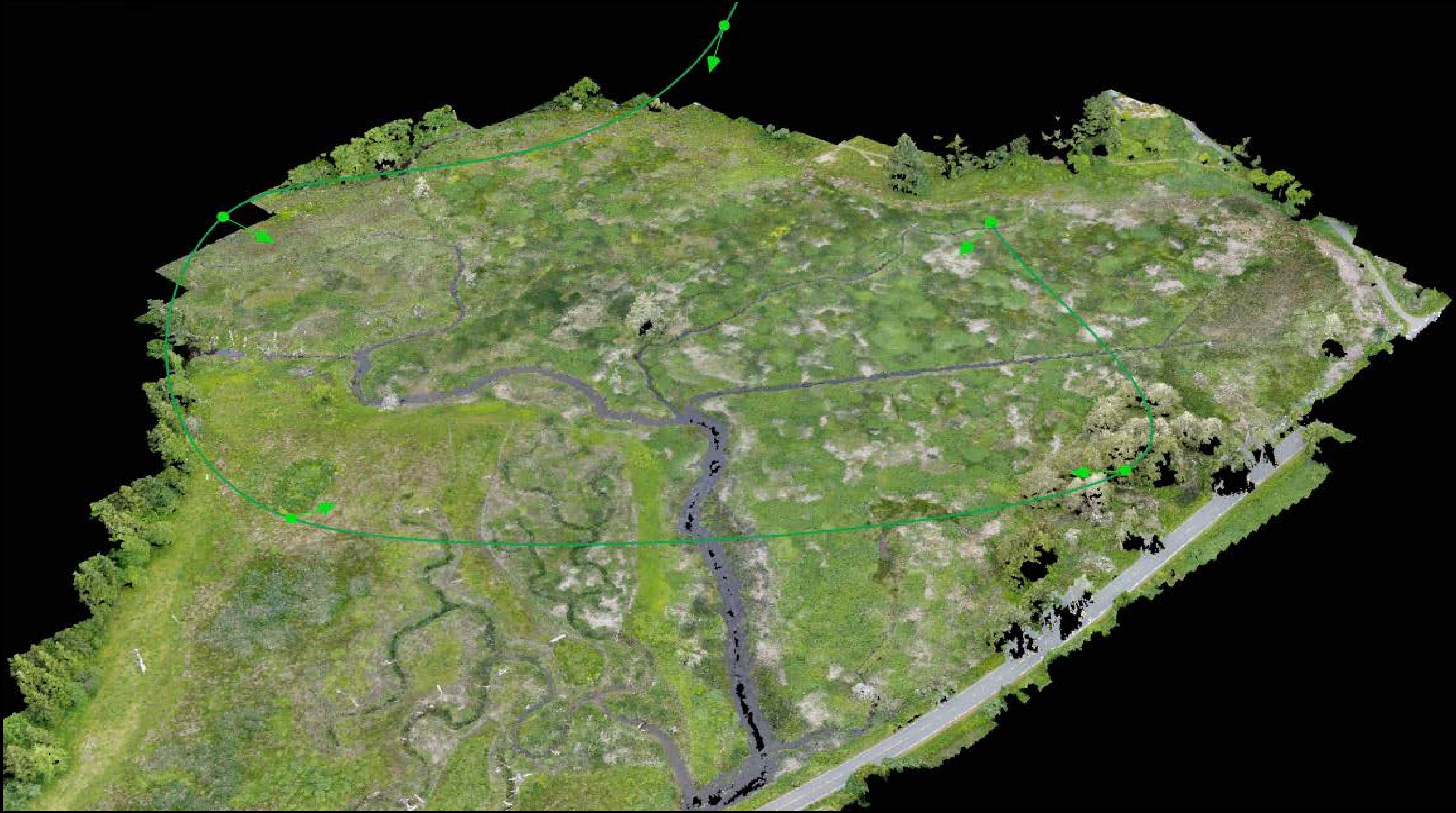
Limited documentation on the sensors operation and interface.

Flight Operations

Heavy payload shortened the flight times.

Flight Planning tools did not support triggering sensor out of the box.

Orthophotogammetry



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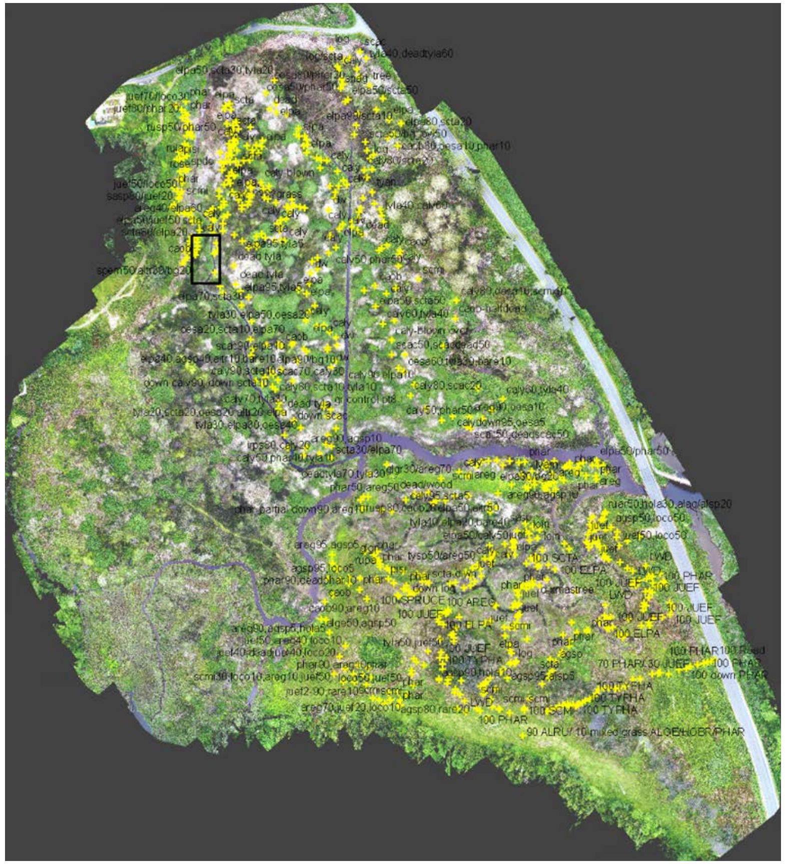
- Technology Readiness Level status -- Roegner
- Questions/comments

Vegetation Ground Truth Collections

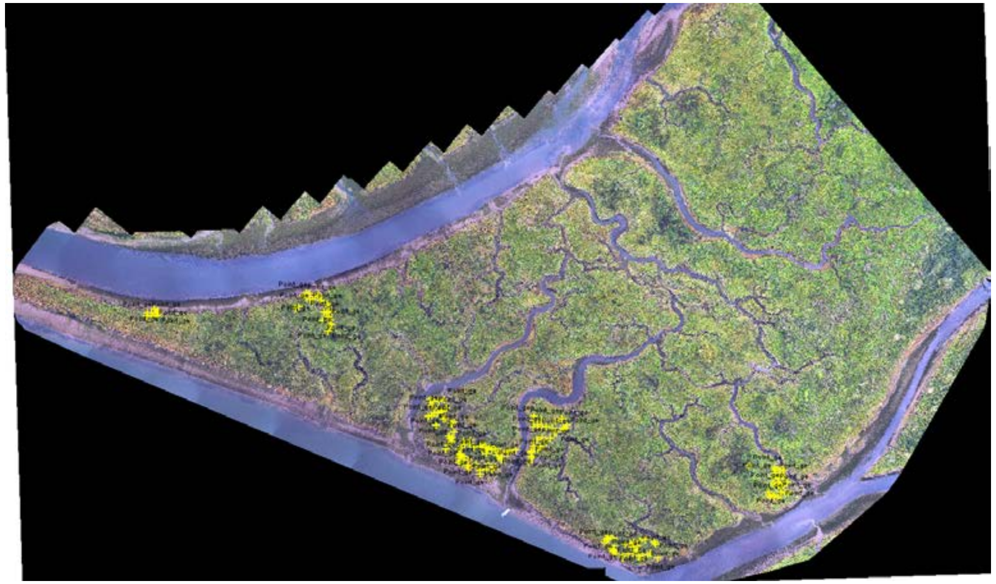
- 794 veg ID’d points collected at Colewort
- 379 veg ID’d points collected at Steamboat Slough
- 243 veg ID’d points collected at Karlson Island

Vegetation Ground Truth Collections

COLEWORT



KARLSON



STEAMBOAT

Common Vegetation Types

CODE	Species	Common Name	Wetland Status	Native
ALTR	Alisma triviale	Northern water plaintain	OBL	Yes
CALY	Carex lyngbyei	Lyngby sedge	OBL	Yes
ELPA	Eleocharis palustris	Common spikerush	OBL	Yes
OESA/D-TYLA/BG	Oenanthe sarmentosa / dead Typha latifolia / bare ground	Water parsley / dead common cattail / bare ground	OBL	Yes
OESA/TYLA/BG	Oenanthe sarmentosa / Typha latifolia / bare ground	Water parsley / common cattail / bare ground	OBL	Yes
PHAR	Phalaris arundinacea	Reed canary grass	FACW	No
SCTA	Schoenoplectus tabernaemontani	Softstem bulrush, tule	OBL	Yes
SCTA/ELPA	Schoenoplectus tabernaemontani / Eleocharis palustris	Softstem bulrush, tule / Common spikerush	OBL	Yes
SCTA/OESA	Schoenoplectus tabernaemontani / Oenanthe sarmentosa	Softstem bulrush, tule / water parsley	OBL	Yes
TYAN/D-SCTA	Typha angustifolia / dead Schoenoplectus tabernaemontani	Narrowleaf cattail / Dead softstem bulrush, tule	OBL	Yes/No
WRACK	-	Dead and deposited material	-	-

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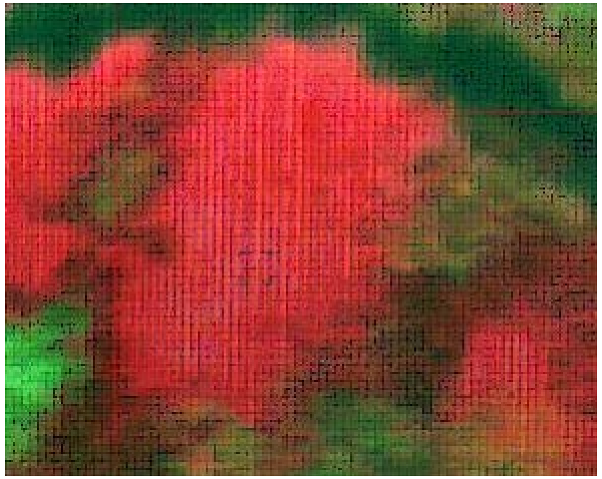
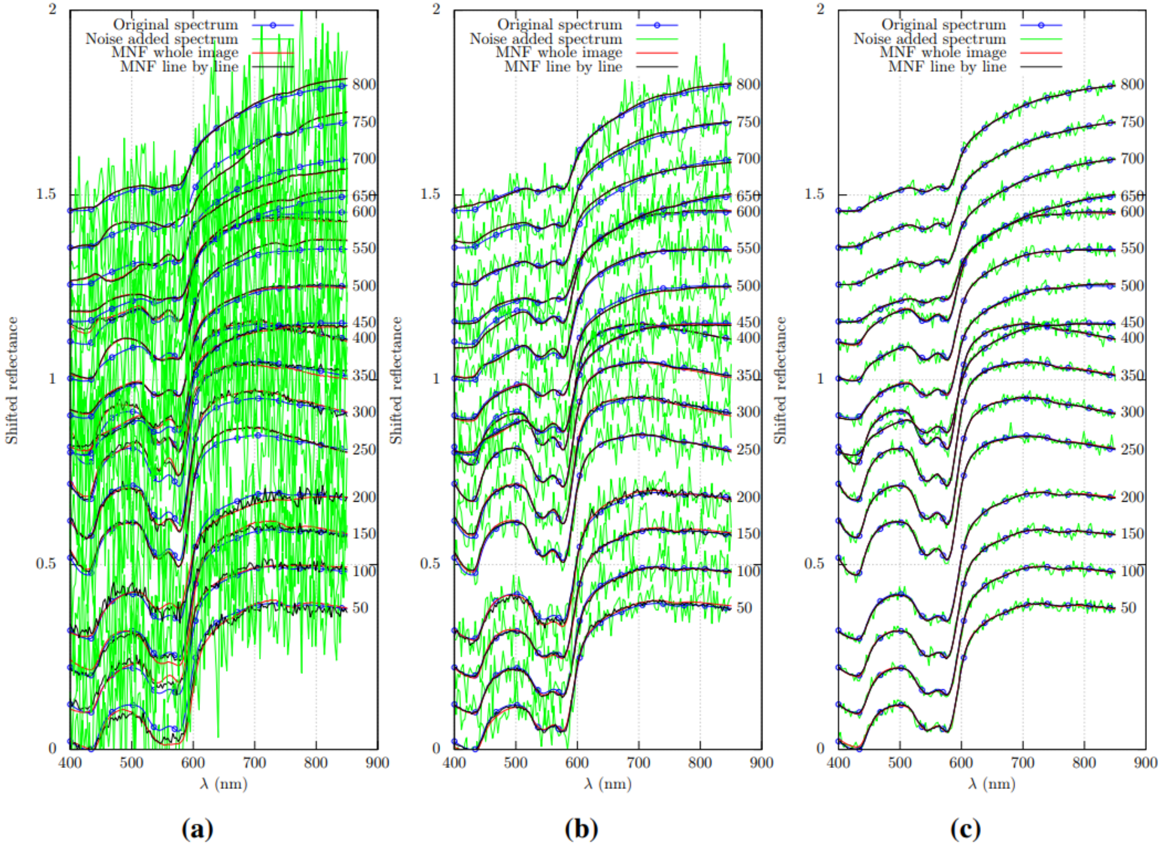
Sensor Observations for Analytics

- Sensor calibration provided good spectral consistency between scenes, particularly between 500-900 nm
- Scanline noise is evident, but is limited beyond the near-infrared spectral range
- Considerable noise in the short wavelength bands (<500 nm)
- Some lag in the sensor where bright targets bleed into darker targets



Analytics – Pre-processing

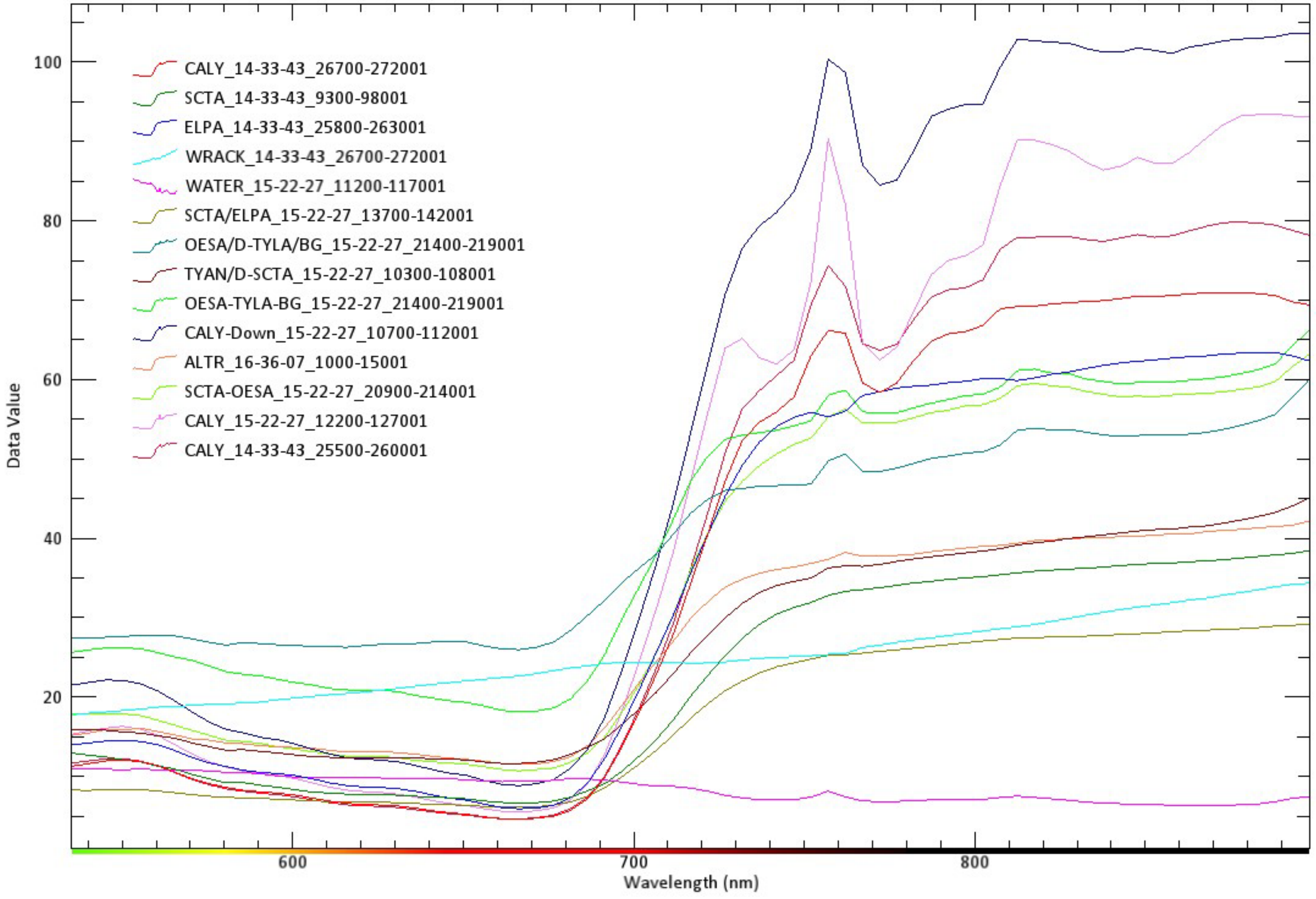
- Noise and Dimensionality Reduction
  - Implement Minimum Noise Fraction (MNF) transform
  - Uses PCA to spectrally and spatially separate noise
  - Data dimensionality reduction performed; ordered by signal to noise ratio
  - Lower bands contain spatial structure and most important information
  - Higher bands contain most of the noise
  - Results in the elimination of spectral bands that don't contribute to classification because of noise or redundancy



Bjorgan and Randeberg, 2015

SPECTRAL LIBRARY DEVELOPMENT

- A spectral library was built to capture the particular spectral signature for common vegetation types
- Used as a training library for classification of new imagery
- All spectral signals based on an area-of-interest and not just a single pixel

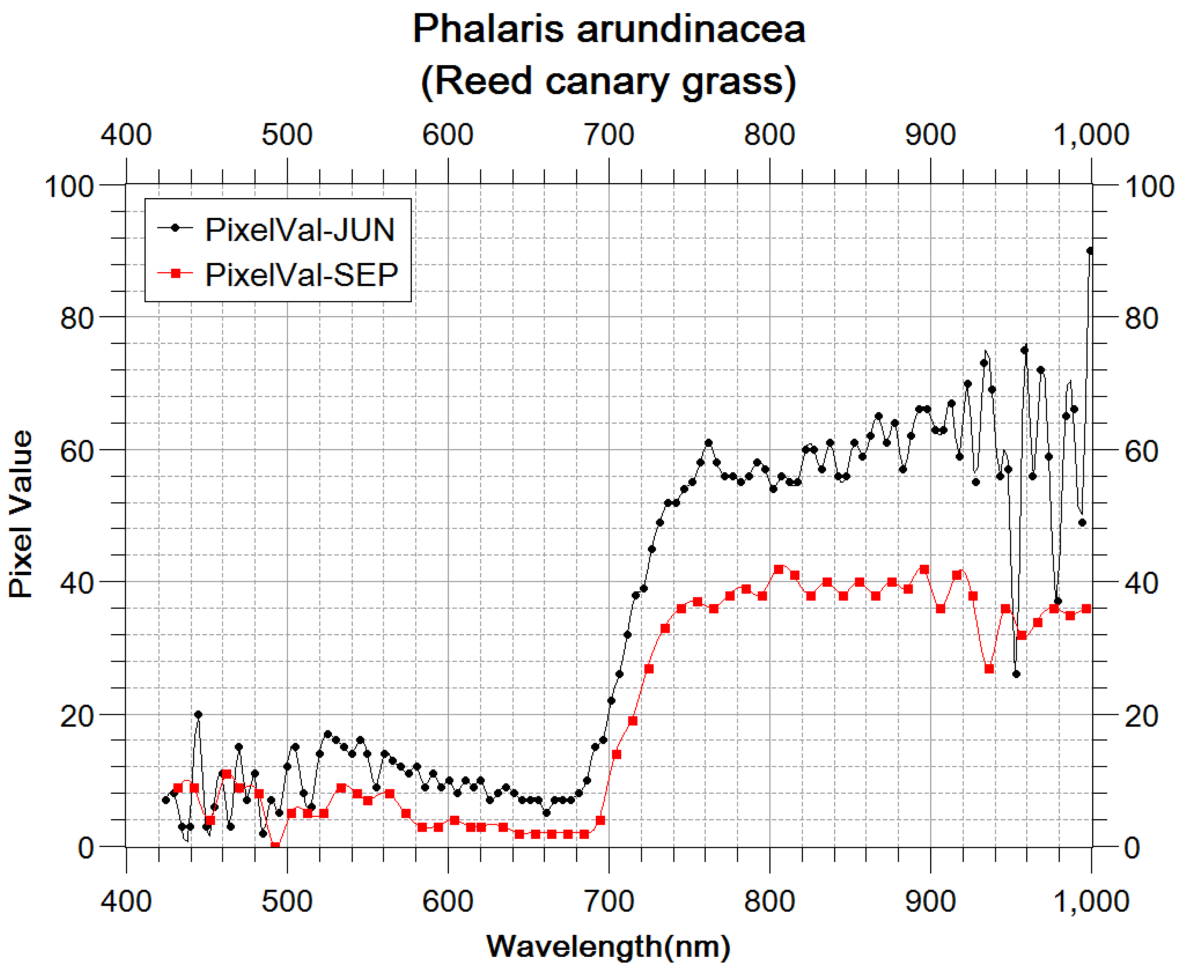


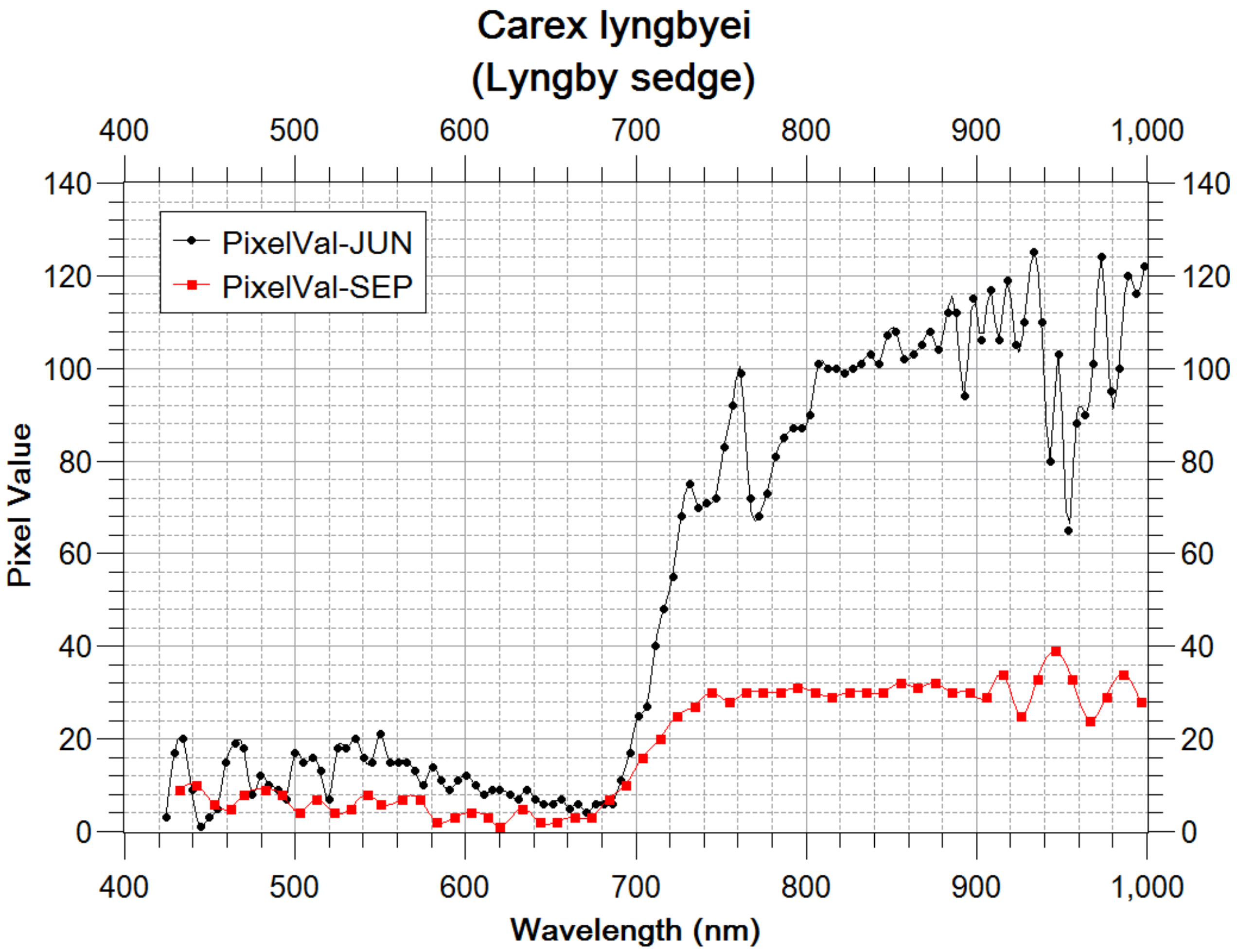
Column 1: Wavelength
Column 2: Min: ROI #5~~2##255,0,0
Column 3: Mean-StdDev: ROI #5~~21##0,200,0
Column 4: Mean: ROI #5~~0##0,0,0
Column 5: Mean+StdDev: ROI #5~~21##0,200,0
Column 6: Max: ROI #5~~2##255,0,0

424.380005	1.000000	14.139880	38.315443	62.491006	239.000000
429.420013	1.000000	13.281277	35.152833	57.024390	190.000000
434.459991	1.000000	12.643673	30.105347	47.567022	148.000000
439.500000	1.000000	11.032027	26.038907	41.045786	152.000000
444.540009	1.000000	10.613009	24.626097	38.639186	95.000000
449.579987	1.000000	10.243748	23.619912	36.996076	84.000000
454.619995	1.000000	10.850562	23.255387	35.660212	83.000000
459.660004	1.000000	10.296635	22.206504	34.116374	72.000000
464.700012	1.000000	10.074958	21.572027	33.069096	95.000000
470.000000	1.000000	10.036382	20.719473	31.402564	66.000000
474.779999	1.000000	9.666672	20.785315	31.903958	66.000000

SPECTRAL LIBRARY DEVELOPMENT

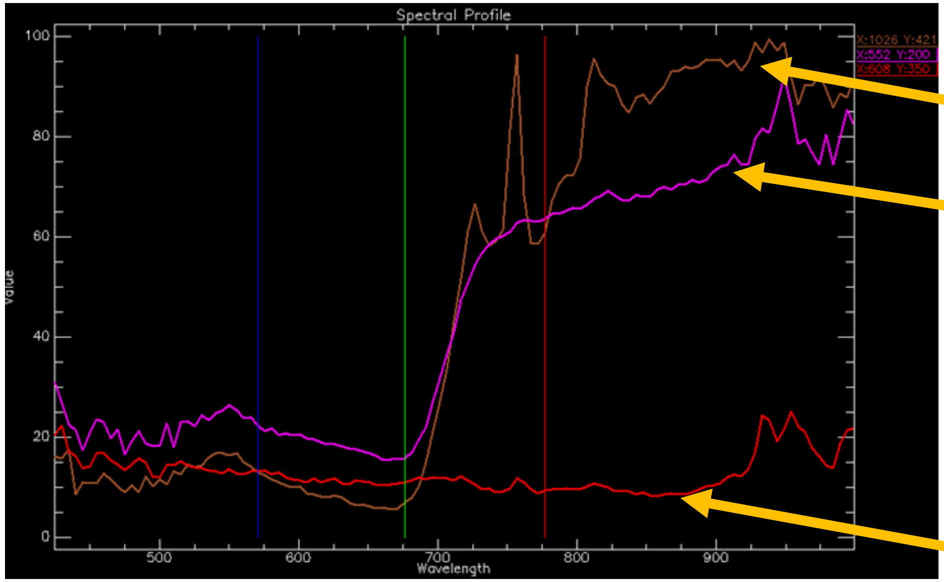
- A unique aspect to the library is the capture of the seasonal phenology signal

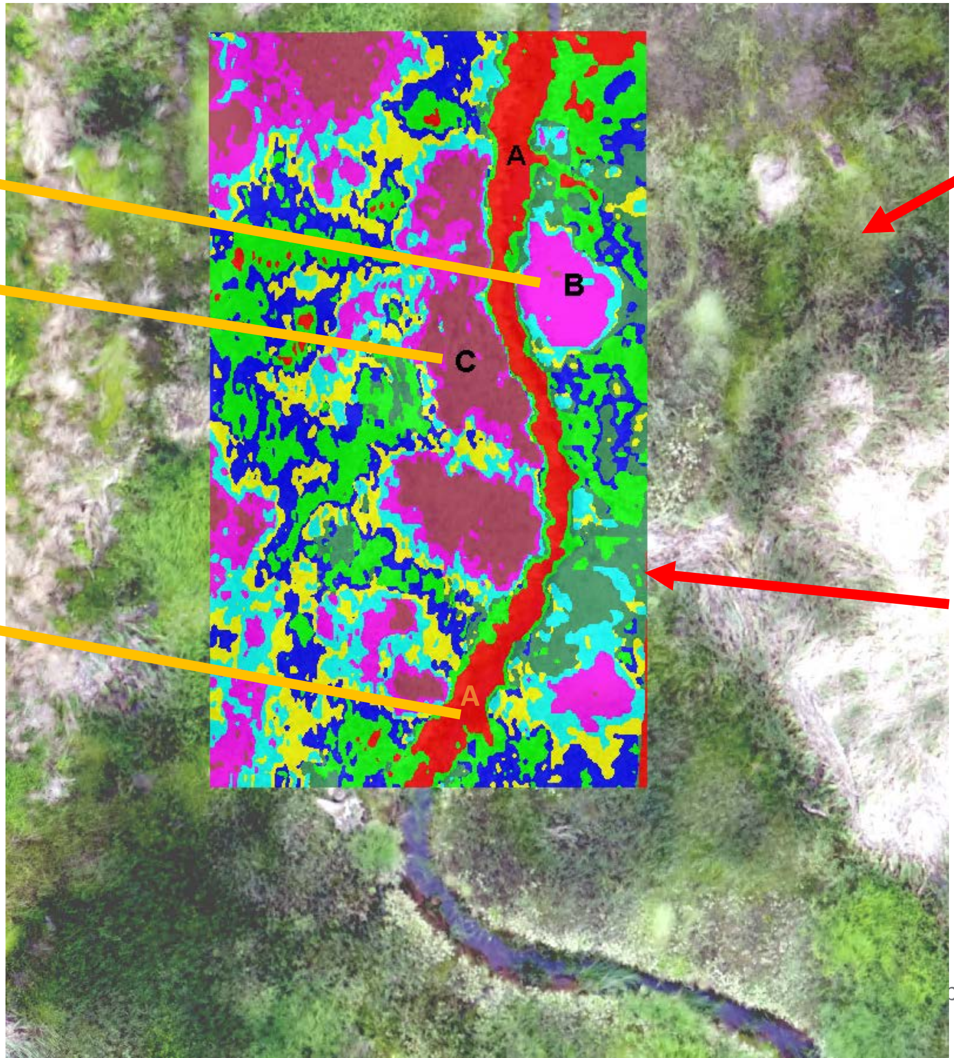




Hyperspectral Processing: Colewort Creek NHP test site

- Example Hyperspectral Classification
  - Distinct spectral signature





RGB IMAGE

Classified Image

- A = Water
- B = Common spikerush & bentgrass
- C = Lyngby sedge

Dead Typha latifolia (common cattail)

Carex lyngbyei (Lyngby sedge)

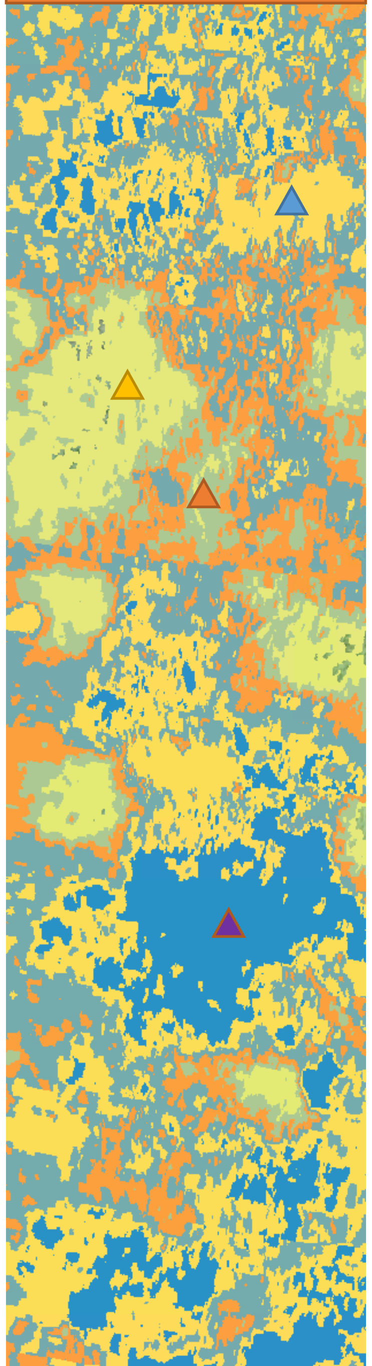
Eleocharis palustris (Common spikerush)

Bare Ground & 20% Eleocharis palustris (Common spikerush)

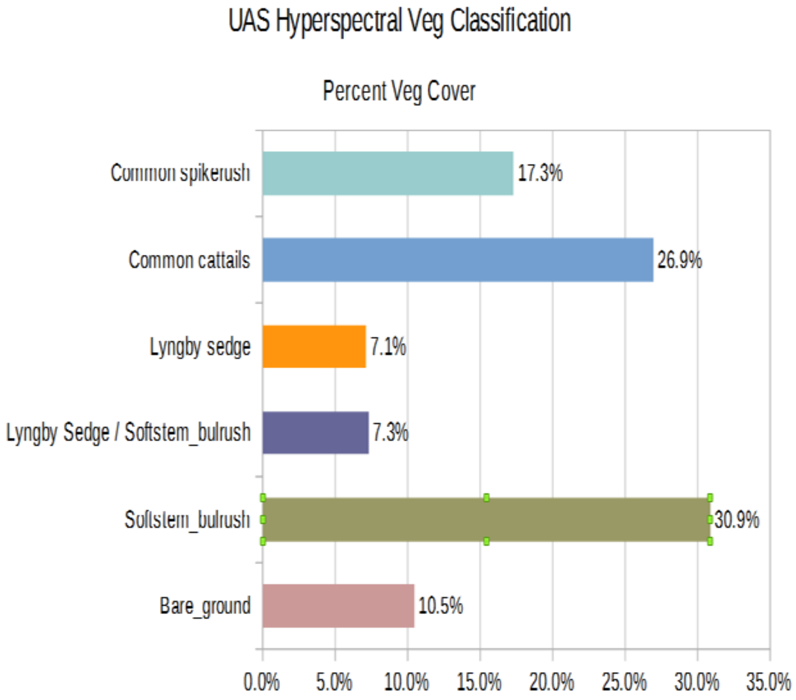
True Color (RGB)

Hyperspectral

Classified



Statistical Output



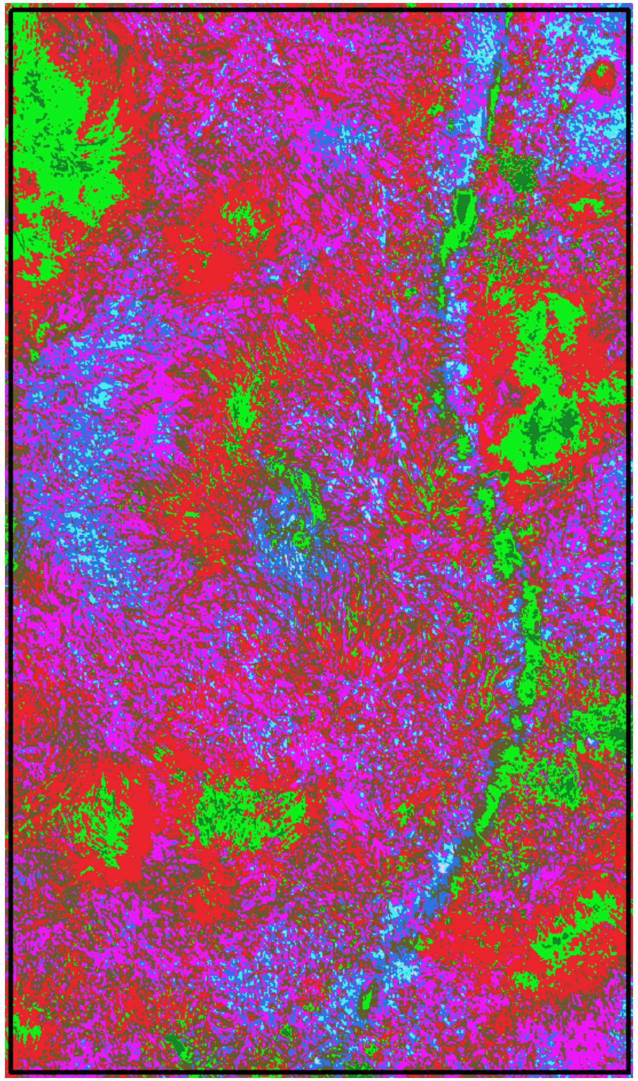
Utility

1. Mapping habitats
2. Restoration trajectory
3. Tidal channel evolution
4. Invasive monitoring
5. Spatial modeling
6. ....others!

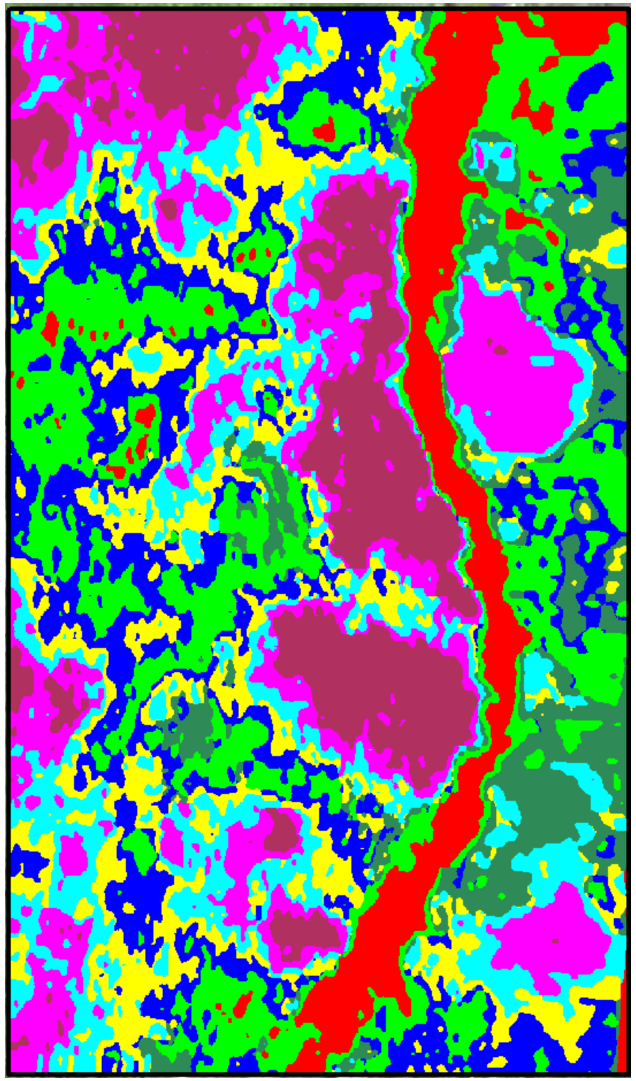
RGB True Color Classification

- Limited spectral information in RGB data leads to poor discrimination in classification for environments with complex vegetation

RGB



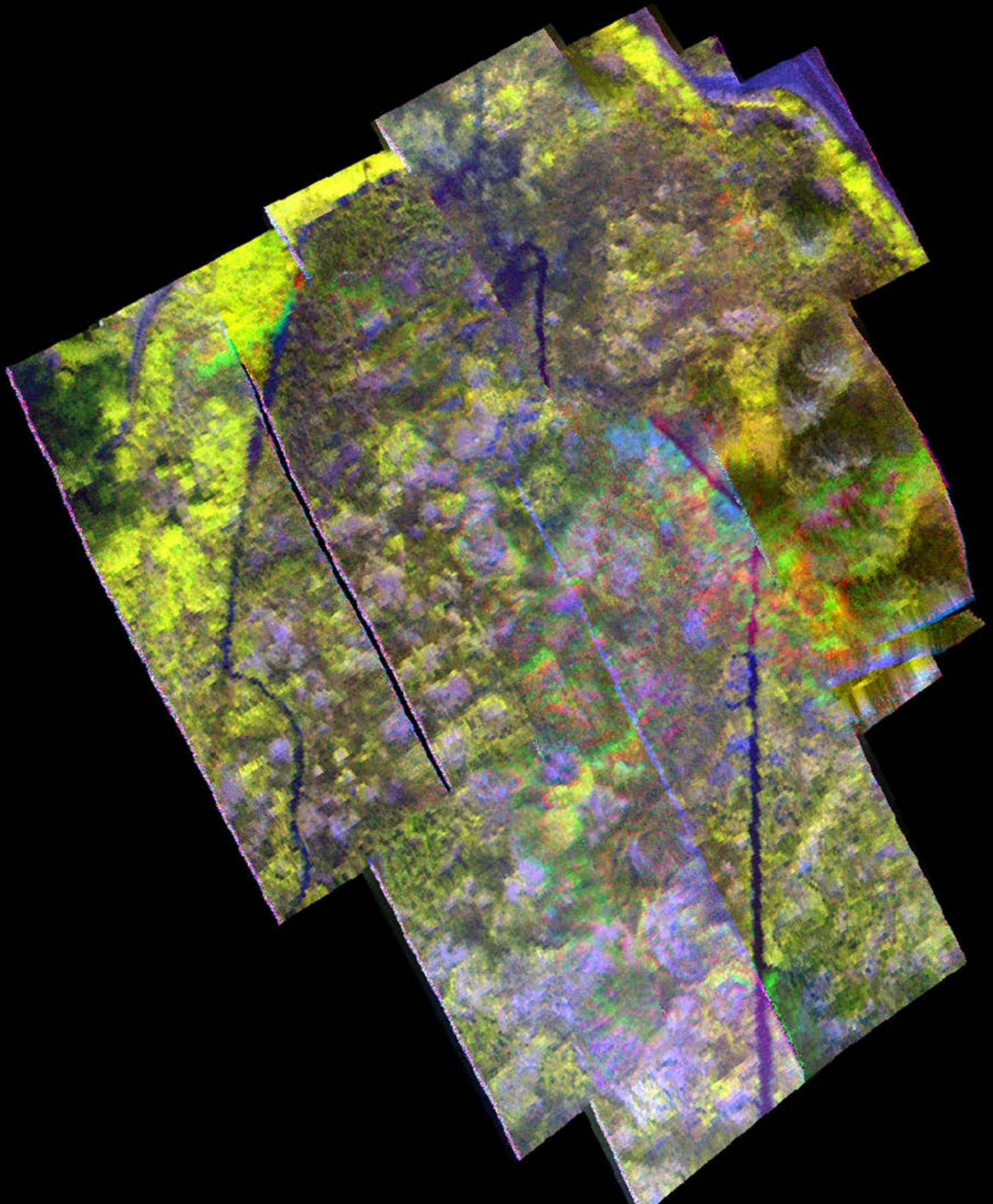
Hyperspectral



IMPROVEMENTS

- Need to work with vendor to establish more seamless and semi-automated workflow for georeferencing imagery

- Experimentation with abundance mapping
  - Spectral unmixing to retrieve spectral endmembers (pure materials) and estimate fractional proportions of vegetation in each pixel/pixel group



Conclusions

- Successful implementation of a complex high-sensitivity sensor on a UAS platform
  - Traditionally, vibration and variable stability of a UAS platform have made these kinds of collections extremely difficult to use.
- Hyperspectral sensor is key to distinguishing vegetation types in a complex wetland environment
- Processing methodologies have been developed and exercised, though still more validation and testing to be done
- Seasonal spectral library has been developed to capture vegetation phenology

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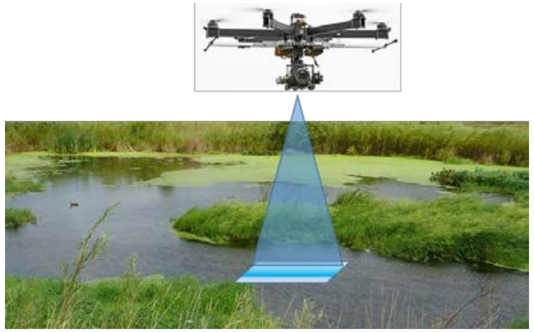
End-user & technology transfer: Remote sensing of varied systems

NOAA UAS project

Direct application to other PNW wetlands



Techniques applicable to wide variety of environments

TASK 5: Project deliverables:

1) establishment of an updateable, open source *spectral library* for estuarine/wetland environments;

2) *protocols for flight operations* including appropriate flight speed and scale impacts due to sample altitude

3) *protocols for image processing*, *analytics, and applications* to wetland feature extraction, vegetation classification, and hydrologic characterization

4) Various manuscripts

Technology Readiness Level

Transition Index	Technology Readiness Level	Description
Research	TRL 1	Basic or fundamental research
Research	TRL 2	Technology concept and/or application
Development	TRL 3	Proof-of-concept
Development	TRL 4	Concept validated in laboratory
Development	TRL 5	Concept validated in relevant environment
Demonstration	TRL 6	Prototype demonstration in relevant environment
Demonstration	TRL 7	Prototype demonstration in operational environment
Demonstration	TRL 8	System demonstration in an operational environment
Application	TRL 9	System totally operational

PROJECT START

YEAR 1

YEAR 2 (if funded)

Funding from NOAA UAS and NOAA Fisheries. *Thank you!*

QUESTIONS ?