Mer Bleue Arctic Surrogate Simulation Study
"MBASSS"

Raymond Soffer, H. Peter White, George Leblanc, Margaret Kalacska, Matt Maloley, Dennis Nazarenko

IDEAS L1 Meeting - Davos, Switzerland - Dec 8 - 9, 2015

APVE I

DOCUMENT

Workshop Report: 1st International Arctic and High-Latitude Products Validation and Evolution Workshop, Ottawa, Canada, 12-13 November 2014

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European Space Agency
Agence spatiale européenne

Motivations for this workshop:

- High-Latitudes areas and the Arctic are sparsely populated, extremely remote, with a challenging and harsh environment.

Expectations of the APVE WS:

- To clearly identify the areas for improvement for existing algorithms and products in High-Latitude and the Arctic

Bojan Bokov – APVE I opening address

APVE I Highlights and Recommendations

- It is important for the users to understand the limitation of the data/products (i.e. confidence, consistency).
- Multi-temporal analysis shown as important in all presentations.
- In the Arctic there are few control/validation data for biophysical parameters, thus it is hard to perform extensive EO product validation.
- Simulators may not be sufficiently robust to be reliable for sensor definition.

Are there more easily accessible analogue sites that could be used to develop and validate procedures in a cost efficient way before deploying to the test sites of interest in the north/arctic?

Mer Bleue Arctic Surrogate Simulation Study "MBASSS"

↓

MBASSS Landsat 8 Validation Project (IDEAS+)

MBASSS Presentations at APVE II (Oct. 27-28, 2015)

APVE II Land Session 1 / 2 (this talk)

- **Mer Bleue Arctic Surrogate Simulation Study "MBASSS"**
  - **Raymond Soffer**[1], H. Peter White[2], George Leblanc[1], Margaret Kalacska[3], Matt Maloley[2], Dennis Nazarenko[3]

APVE II Land Session 2 / 2 (Tomorrow afternoon 13:30)

- **Long-term measurements of the ecology, hydrology and carbon biochemistry of a northern peatland – projects for remote sensing calibration**
  - Roulet, NT[1]., Moore TR[1]., Humphreys, E[2]., Lafleur, PM[3]., Kalacska, M[1]., Bubier, J.[4], Talbot, J.[5], Soffer, R.[6] and **Leblanc, G.**

- **Airborne hyperspectral vegetation products over Mer Bleue Canada: its use as a surrogate northern bog**
  - **George Leblanc**[1,2], Margaret Kalacska[2], Ray Soffer[1], H. Peter White[3] and Dennis Nazarenko[4]

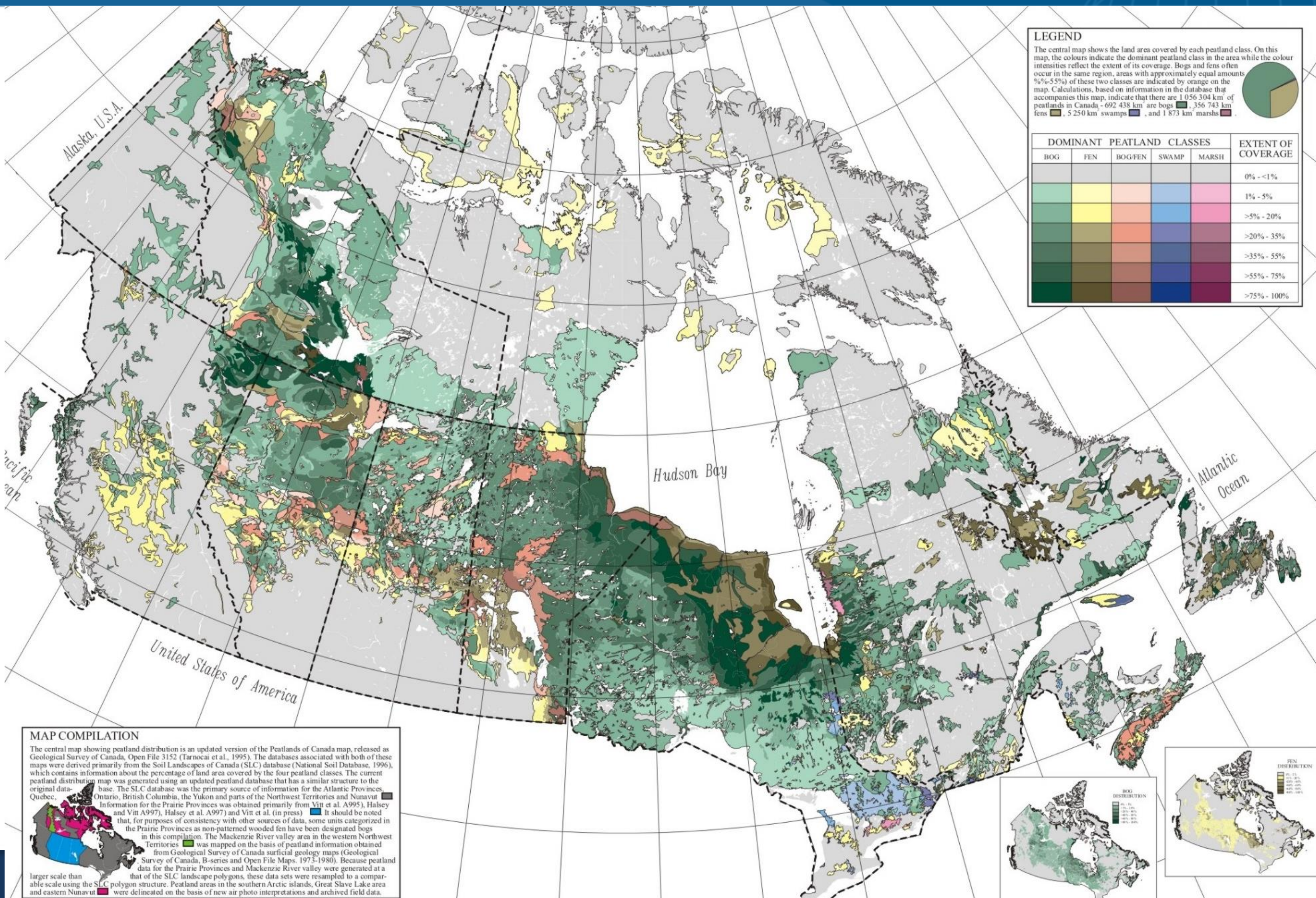
- **Spectral image simulation of the Mer Bleue Arctic surrogate study site (MBASSS) and ISDAv2**
  - **H. Peter White**[1], Lixin Sun[1], Matthew Maloley[1], Anu Garcha[2,1], Raymond Soffer[3], Margaret Kalacska[4], George Leblanc[3], Dennis Nazerenko[5]

Outline

- Overview of Mer Bleue and its suitability for use as an arctic peatland surrogate.
- Brief discussion on the satellite data product sensitivity analysis.
- Description of the Mer Bleue Peatland Observatory (MBPO).
- An initial look at Mer Bleue Data Products for Airborne Hyperspectral.
- Approach to satellite simulations.
- Sensitivity Analysis.
- Approach to MBASSS Landsat 8 Validation Project study.
- Introduce the current team and responsibilities.

Wetlands, Peatlands and Bogs – Why the interest?

Peatland distribution in Canada: cover about 1 million km^2 of which about 75% is bogs (green shading)



Wetlands, Peatlands and Bogs – Why the interest?

- Wetlands account for 14% of Canada's landmass providing 20% of the global wetlands inventory.
- Canadian northern peatlands estimated to have accumulated between 60 and 80 Pgrams of Carbon since the last ice age.
- Wetlands perform several valued functions:
  - Storing/purifying water
  - Recharging aquifers
  - Retaining nutrients in floodplains
  - Carbon storage
  - Biodiversity conservation
  - Sensitive habitat for many species
  - Natural flood prevention
  - Mine waste filtration
- Canada's arctic wetlands contain sensitive habitats that are impacted by climate change and by the exploitation of natural resources.
- Region is remote, often with little or inadequate access.
- Limited snow-free periods, limited solar illumination periods.
- Advance spectral techniques required to support monitoring of these regions.

Mer Bleue Suitability as an Arctic Peatland Surrogate
(45.30°N, 75.61°W)

- Ombrotrophic (cloud fed) Peatland
- Designated conservation area protected by the National Capital Commission (NCC)
- Designated a Wetland of International Significance under the Ramsar Convention in 1995
- Representative of northern boreal peatlands (Lafeur et al., 2001)
  - Complete ground cover of sphagnum mosses with a shrub canopy dominated by ericaceous shrubs, with secondary communities of deciduous shrubs, discontinuous patches of black spruce and larch.
- 28 km^2 area suitable for Landsat 8/Sentinel-2 comparisons
- Proximity to NRC aircraft home base (13 km) and ground support teams
- Mer Bleue Peatland Observatory (MBPO)

MER Bleue Peatland Observatory (MBPO)

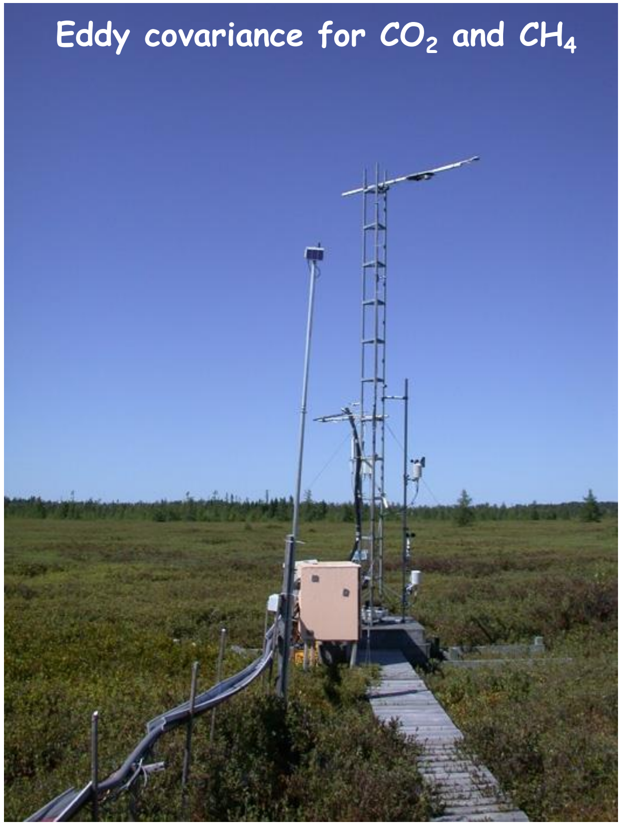
- MBPO began continuous measurements of the fluxes of water, energy and carbon gases in May 1998
  - Longest continuous record from a northern peatland in the world
  - Net sink of atmospheric CO_2 of ~60 g C m^{-2} yr^{-1}
  - Loses carbon via CH_4 efflux and water borne export of dissolved organic carbon (each ~5-10 g C m^{-2} yr^{-1})
- Significant logistical and scientific infrastructure
- 2 boardwalks (scientific, public) permitting access
- 100++ peer reviewed scientific papers
- 50+ student thesis

Mer Blue Peatland Observatory

Peat Profile – up to 5 m deep

Manual and automated chambers for CH_4

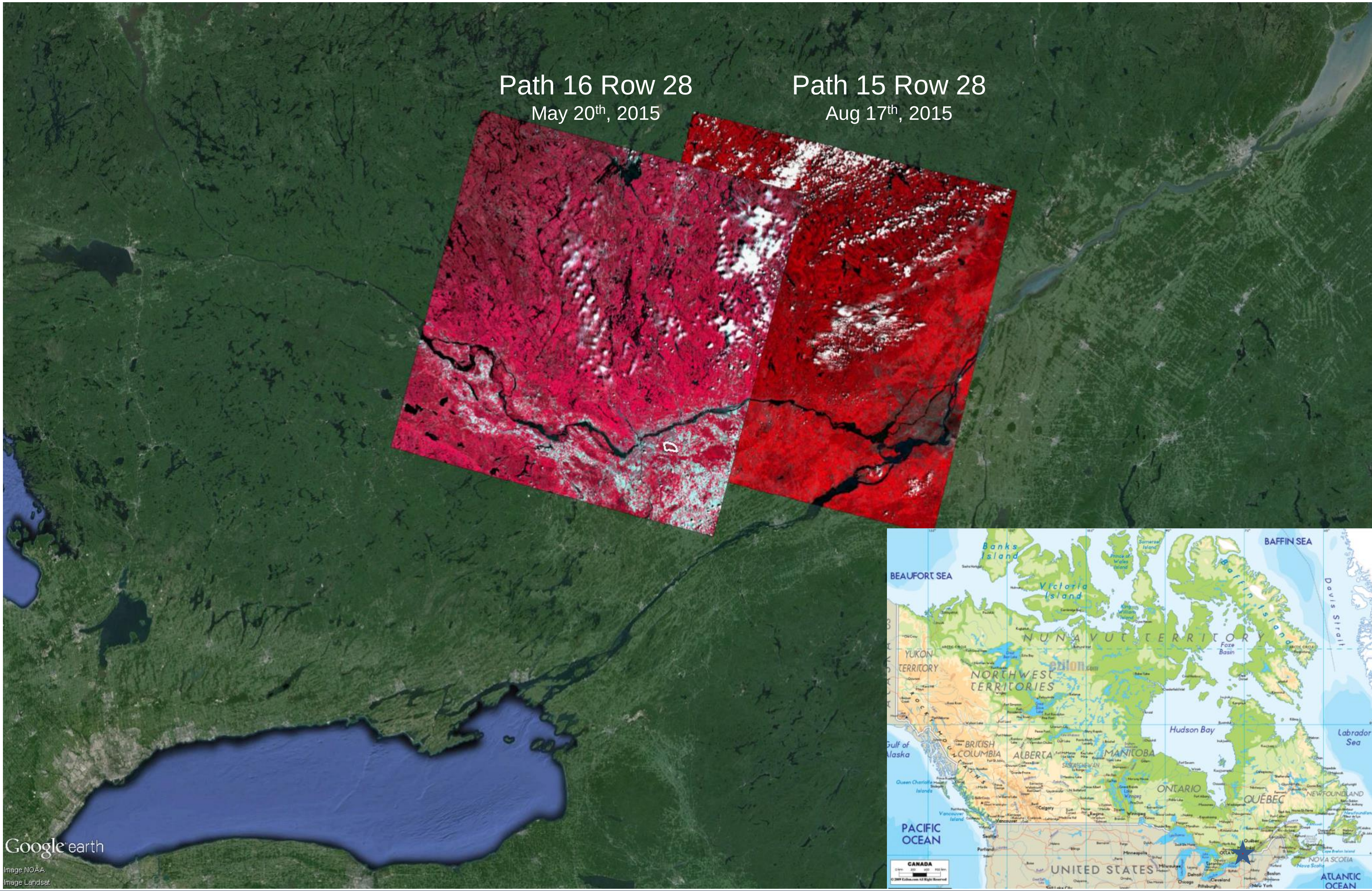
Discharge and [DOC] at the outflow



Eddy covariance for CO_2 and CH_4

Beavers and their damn dams

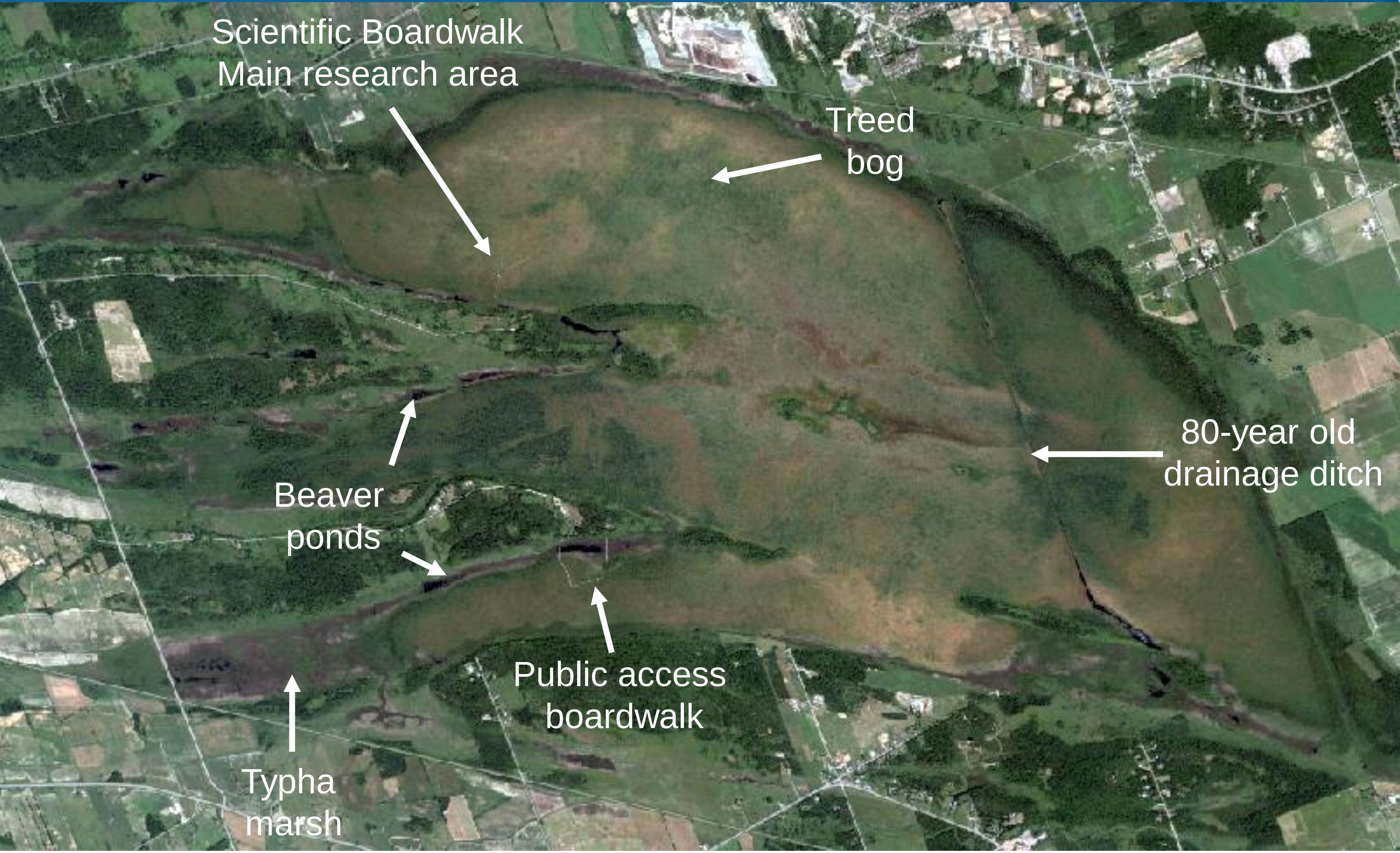
Initial MBASSS study will look at Landsat 8 Land Data Product Validation



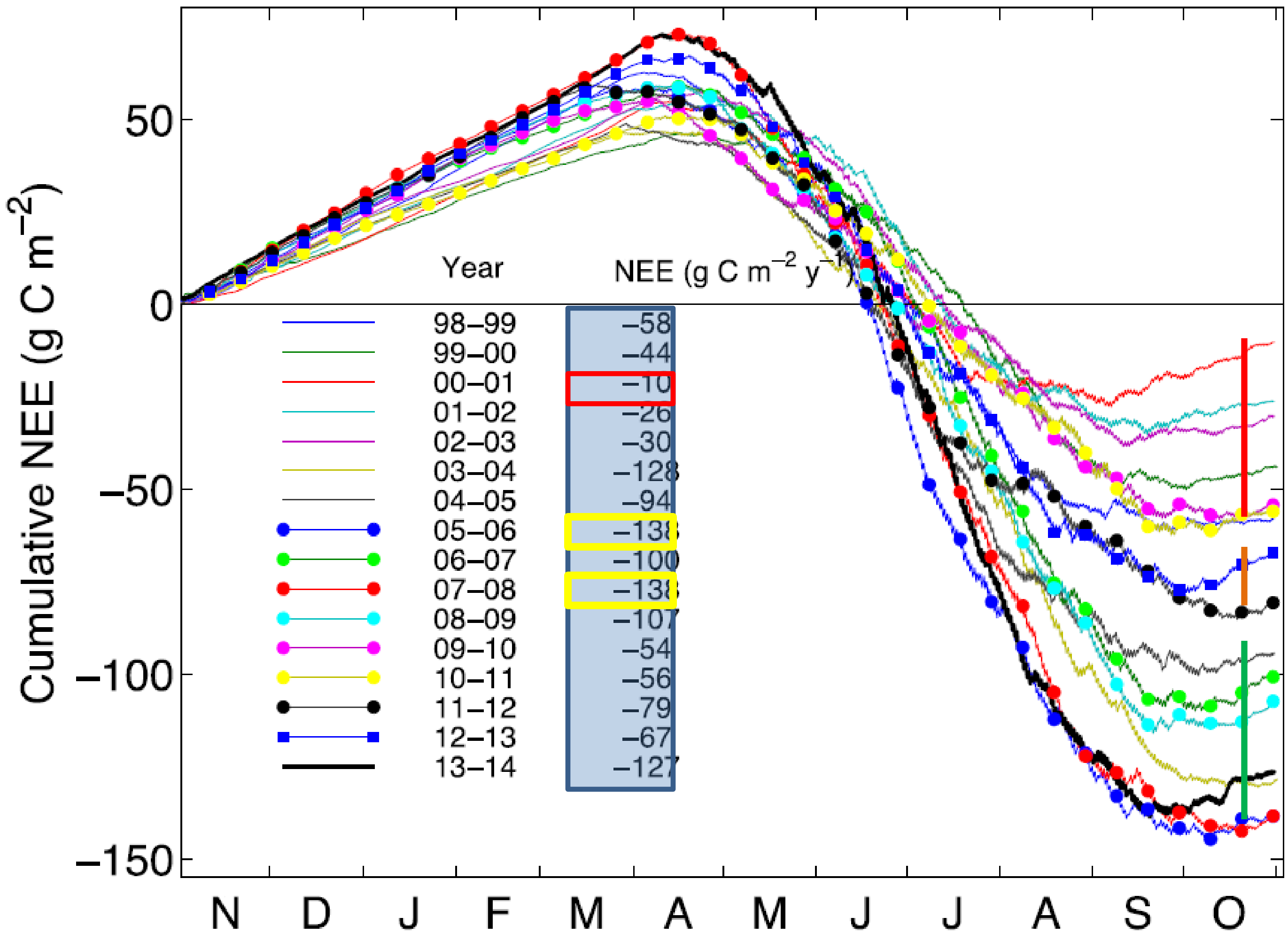
NRC·CNRC

Landsat 8 OLI - NDVI – Path 15 Row 28 – August 17th, 2015

Mer Bleue peatland



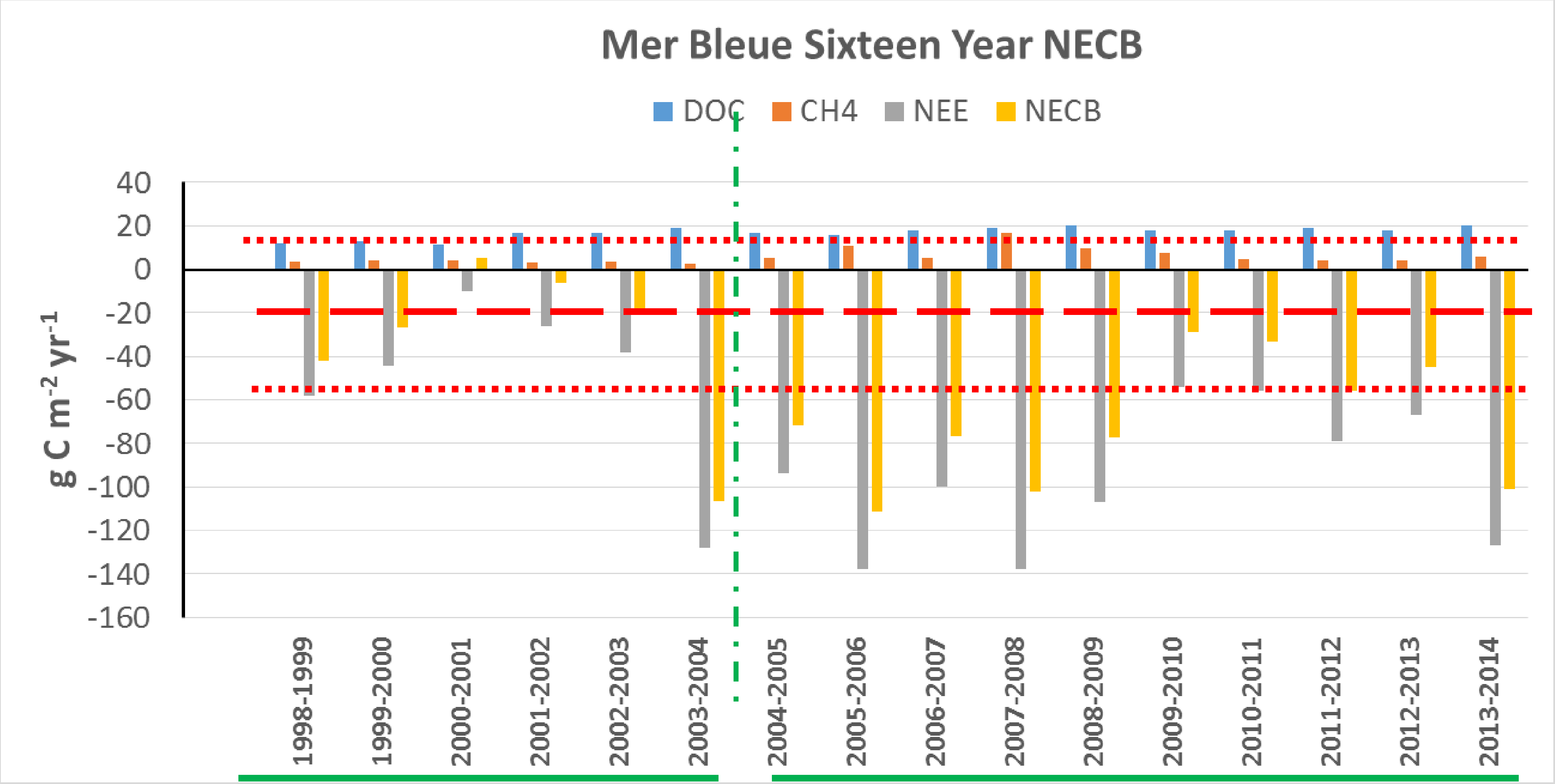
16 year budget
Net Ecosystem Exchange (NEE)



(Slide from Elyn Humphreys, Carleton University with modifications)

Mer Bleue Net Ecosystem Carbon Budget

1998 - 2014 -56 ± 36 g C m^{-2} yr^{-1}



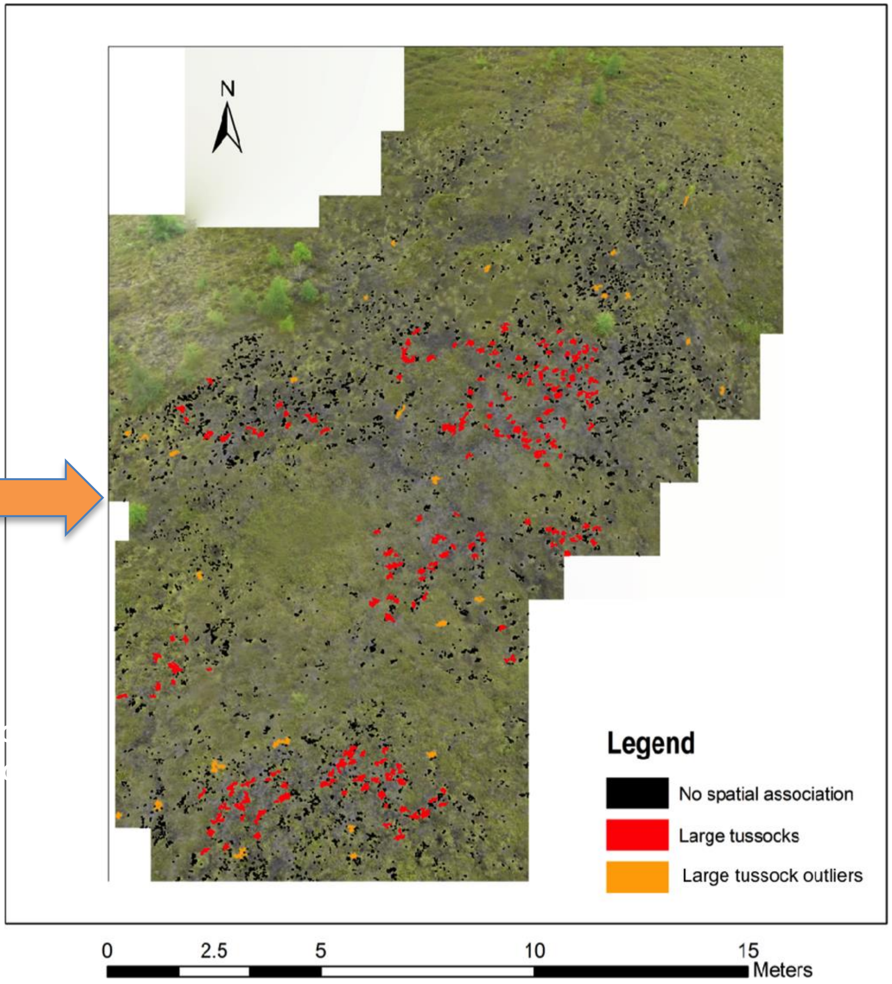
1998-2004

-32 ± 36 g C m^{-2} yr^{-1}

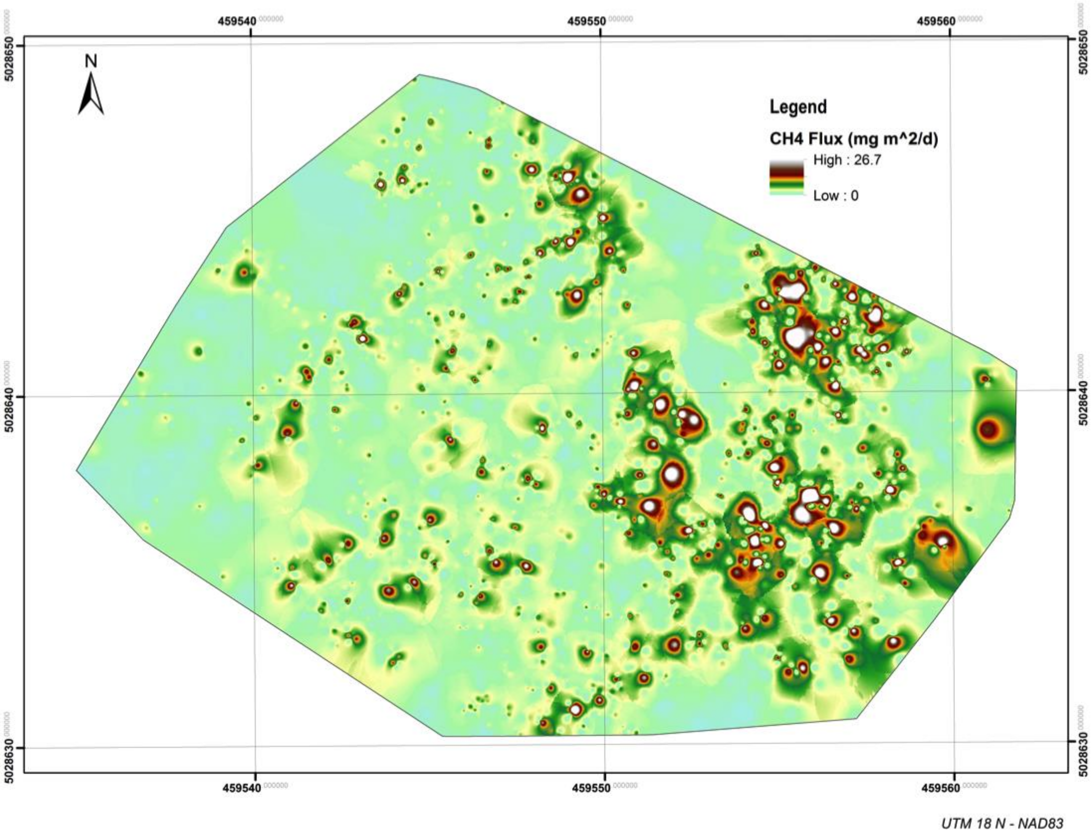
2004-2014

-70 ± 28 g C m^{-2} yr^{-1}

Videographic Analysis of *Eriophorum vaginatum* (cotton grass)



Methane flux map interpolated from the estimated basal area of the *cotton grass* tussocks. A growing season average flux of 233 $mg \cdot m^{-2} \cdot d^{-1}$ for 2007 is illustrated.



Outcome: a cost effective, non-destructive method to determine the total aerial extent of tussocks.

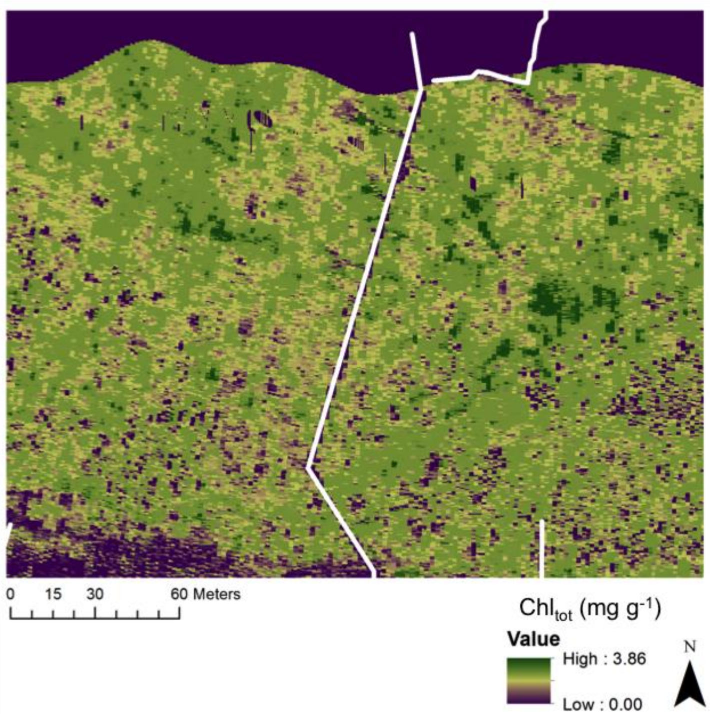
Accurate area of cotton grass needed to determine bog level flux to atmosphere.

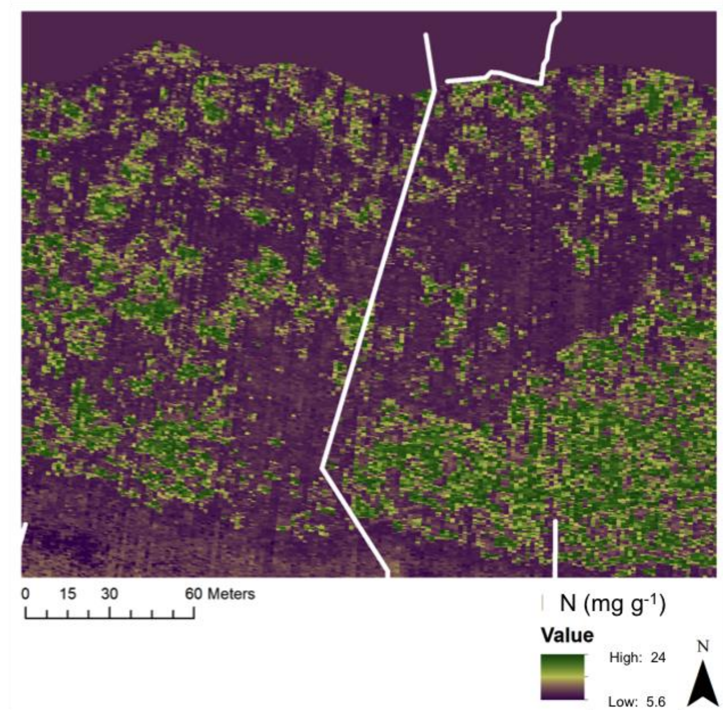
8% of NEE C loss for the bog is from CH_4 released to atmosphere.

Kalacska M., Arroyo-Mora J.P., de Gea J. Snirer E., Herzog C., Moore T.R. Videographic Analysis of *Eriophorum vaginatum* Spatial Coverage in an Ombrotrophic Bog. *Remote Sensing* **2013**, *5*, 6501-6512.

Estimation of foliar chlorophyll and nitrogen content from hyperspectral data: scaling from leaf to image

Objective: to derive a model insensitive to plant functional type, species and season, and fundamentally scale the model from *in-situ* data to airborne imagery.



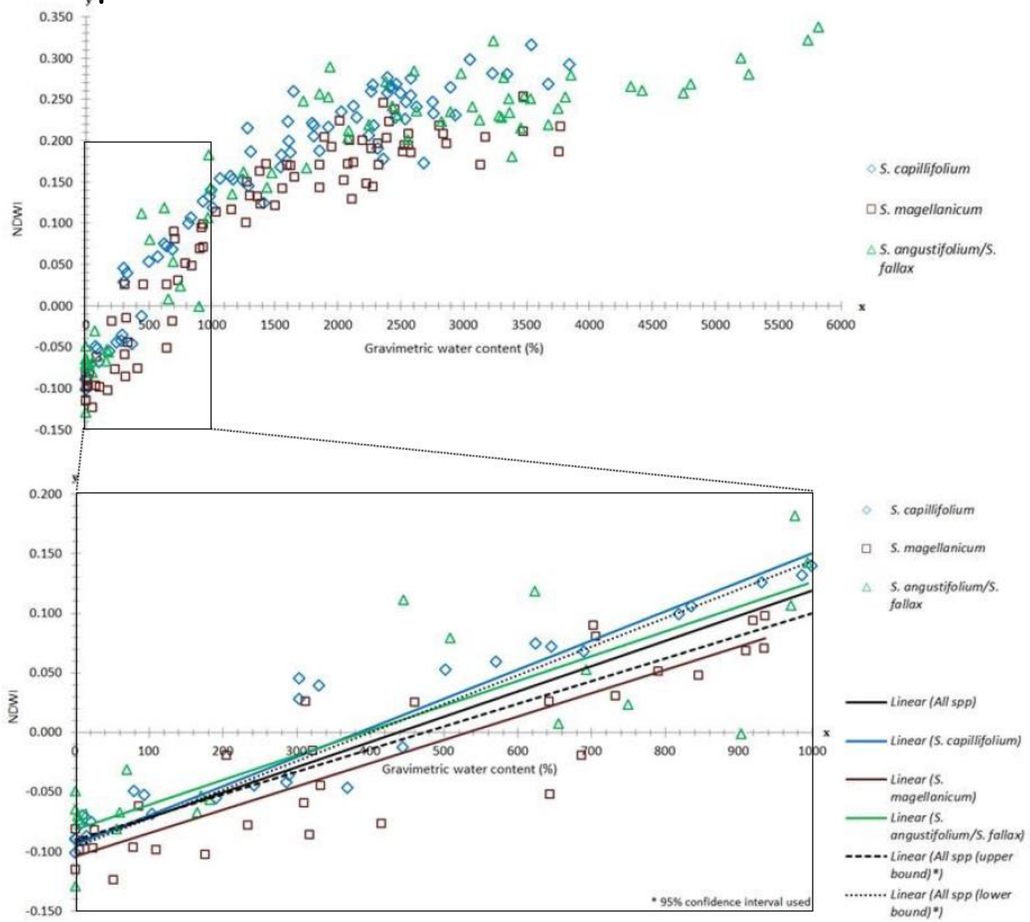


Maps of predicted chlorophyll and N concentrations as estimated from an August 2009 CASI-2 72 band image (40 cm spatia

Kalacska M., Lalonde M., Moore T.R. Estimation of foliar chlorophyll and nitrogen content in an ombrotrophic bog from hyperspectral data: scaling from leaf to image. *Remote Sensing of Environment* **2015**, 169: 270-279.

Determination of *Sphagnum* water content from hyperspectral data

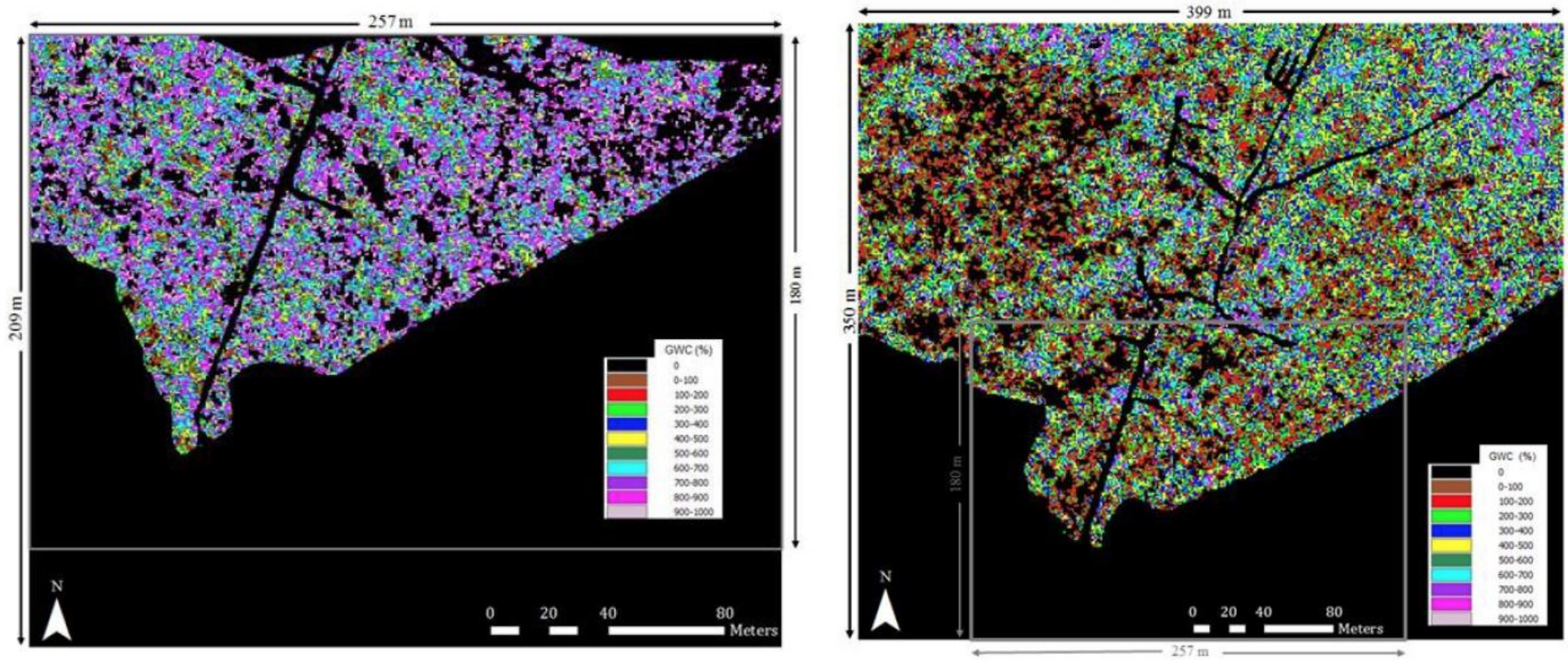
Objective: to derive a model for predicting *Sphagnum* sp. water content from *in-situ* samples and airborne HSI



Relationships between the NDWI and gravimetric water contents (top) and gravimetric water contents ranging from 0-1000% (bottom) for *Sphagnum capillifolium*, *S. magellanicum*, *S. angustifolium* and *S. fallax*.

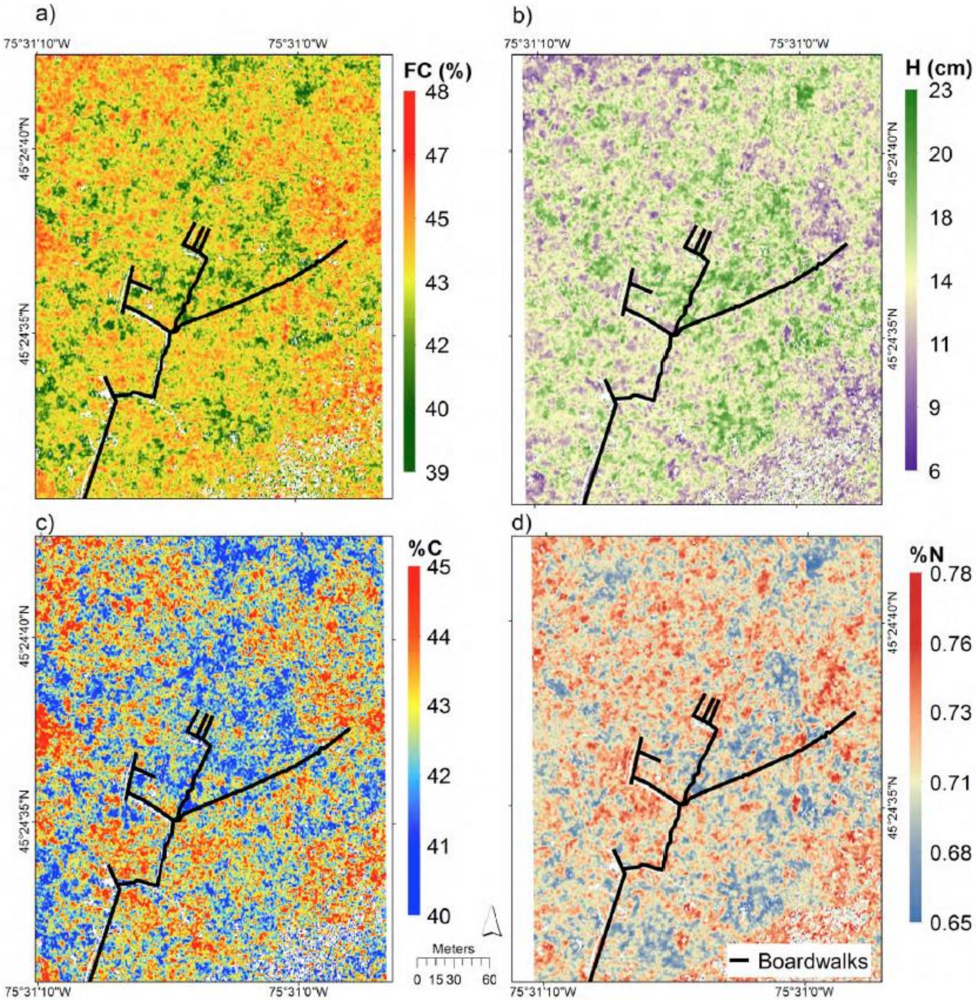
Lalonde, M. The hyperspectral determination of Sphagnum water content in a bog. MSc Thesis, Department of Geography McGill University **2013** 93pp.

Determination of *Sphagnum* water content from hyperspectral data



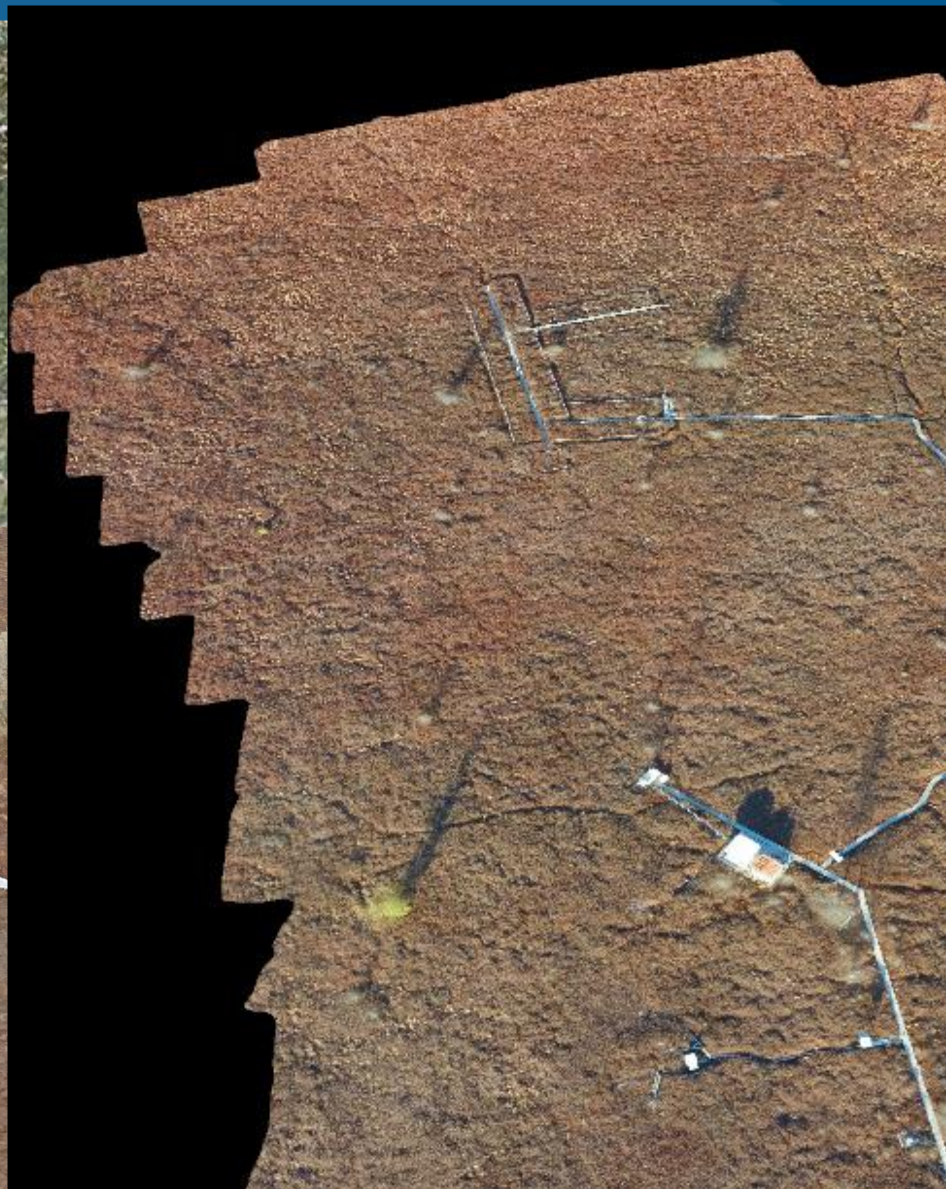
Sphagnum Gravimetric Water Content (GWC) maps for top 5cm *Sphagnum* sp. layer for August 14, 2009 (left), and July 20, 2011 (right). Moss layer drier in July 2011 than Aug 2009.

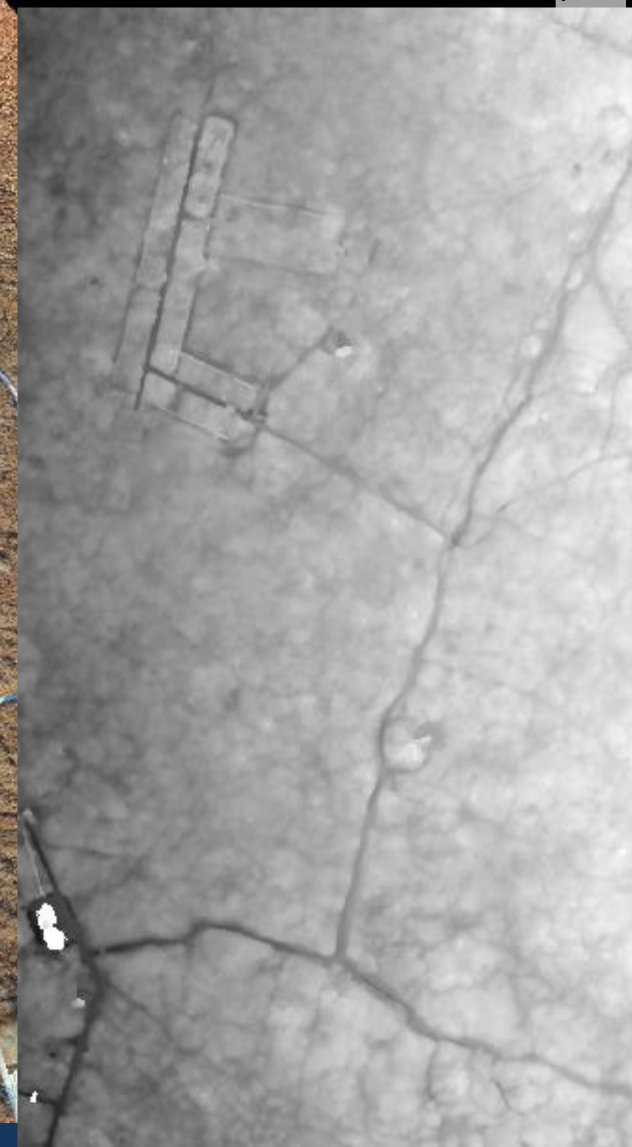
Estimating biophysical and biochemical peatland vegetation characteristics with hyperspectral data - a) moss fractional cover (FC), b) vascular plant height (H), c) C%, d) N%



Soto C., Kalacska M., Arroyo-Mora J.P., Strachan I. Estimating biophysical and biochemical peatland characteristics with hyperspectral data. *Remote Sensing*. Submitted 2015.

UAV Based Videography and 3D reconstruction for Peatland Vegetation Structure and Composition Determination



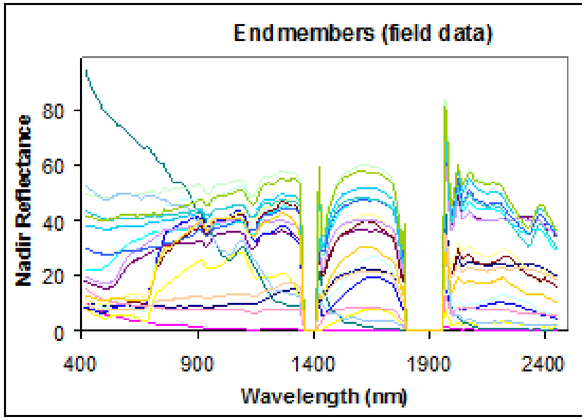


Mer Bleue Field Spectral Measurements

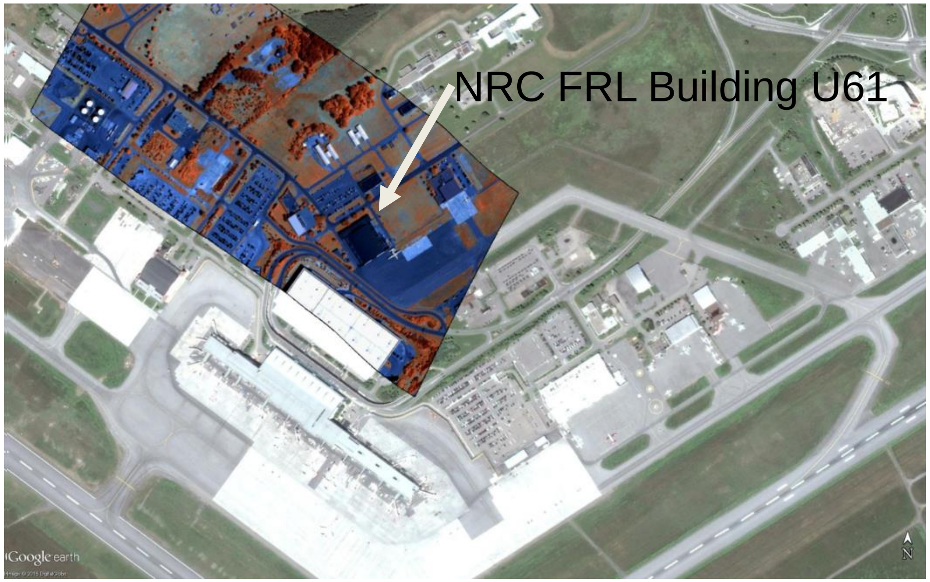
Digital Hemispherical Sky photos

McGill Field Team (ASD FeldSpec3)

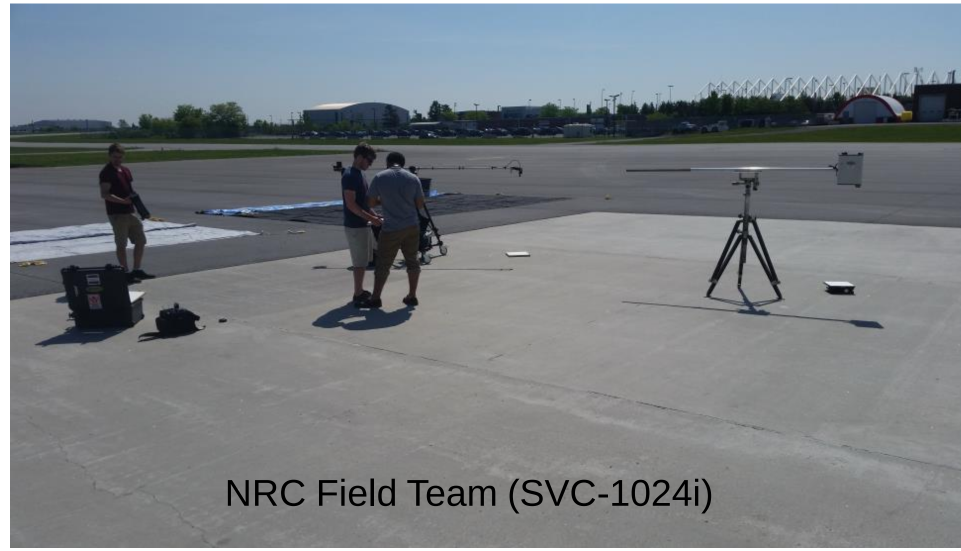
NRCan Field Team (SVC-1024i)



U61 Ground Spectral Measurements (Cal/Val Targets)



Ottawa International Airport

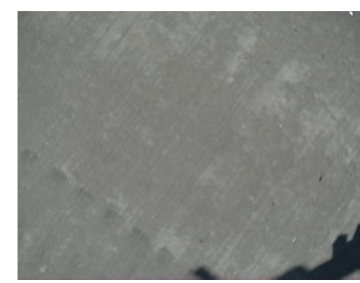


Grass

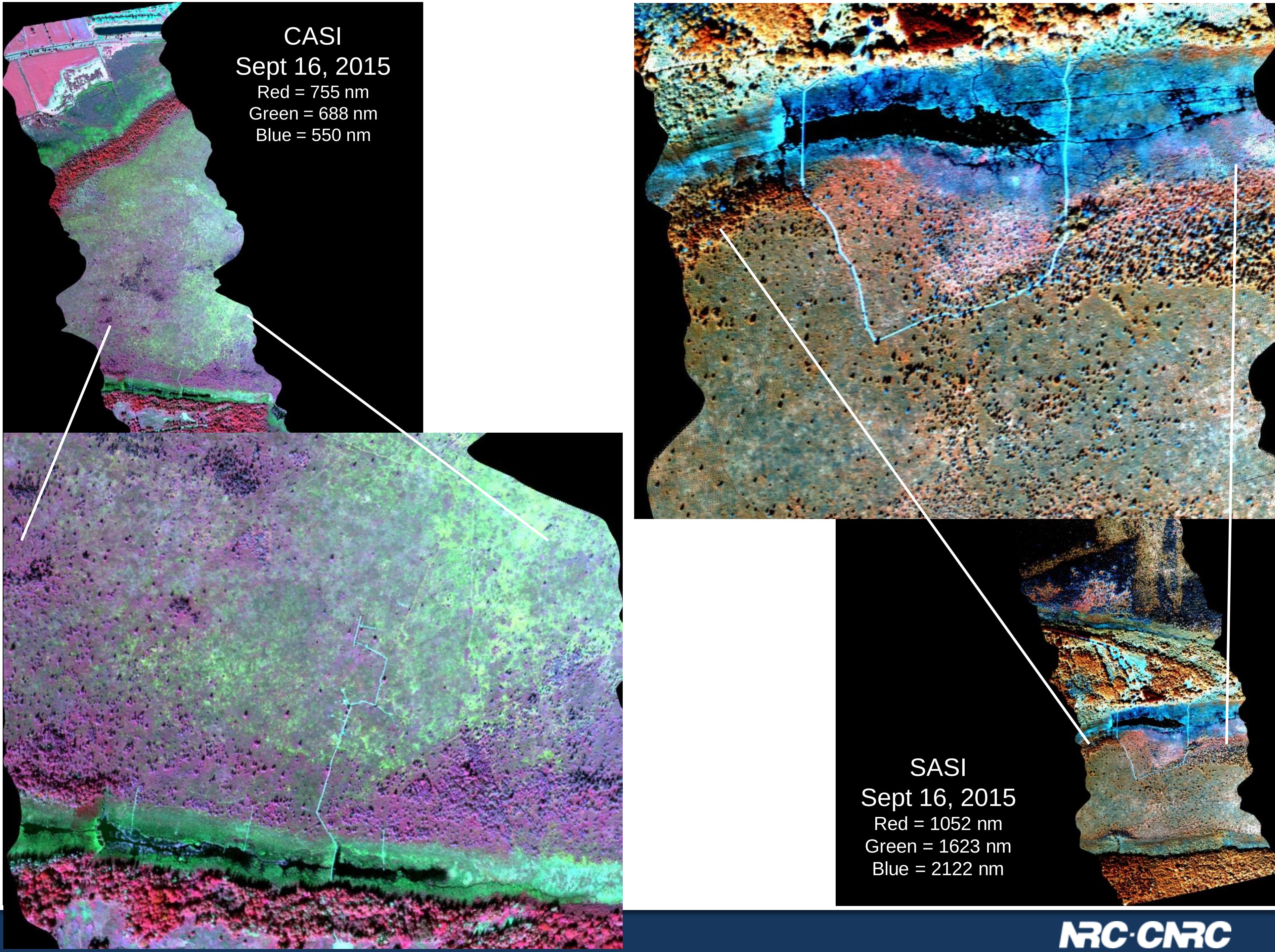
Black Tarp

Grey Tarp

Asphalt



Concrete


CASI
Sept 16, 2015
Red = 755 nm
Green = 688 nm
Blue = 550 nm
SASI
Sept 16, 2015
Red = 1052 nm
Green = 1623 nm
Blue = 2122 nm

Satellite Simulations (1 of 2)

Canada Centre for Remote Sensing – Natural Resources Canada

Why?

- Evaluate and prepare for regular multi-sensor space-borne optical acquisitions of Canada's arctic.
  - To handle both spectral and spatial information.
  - Support continuity between sensors.
  - Advance our capacity to interpret and disseminate information.
    (less empirical → more physical)
- Support initiatives like GEODE (Canadian Federal Geoanalytics Earth Observation Data Environment), a central EO data repository and analysis environment - (NRCan)
  - Emergency response, resource management, environmental processes and mitigation monitoring.

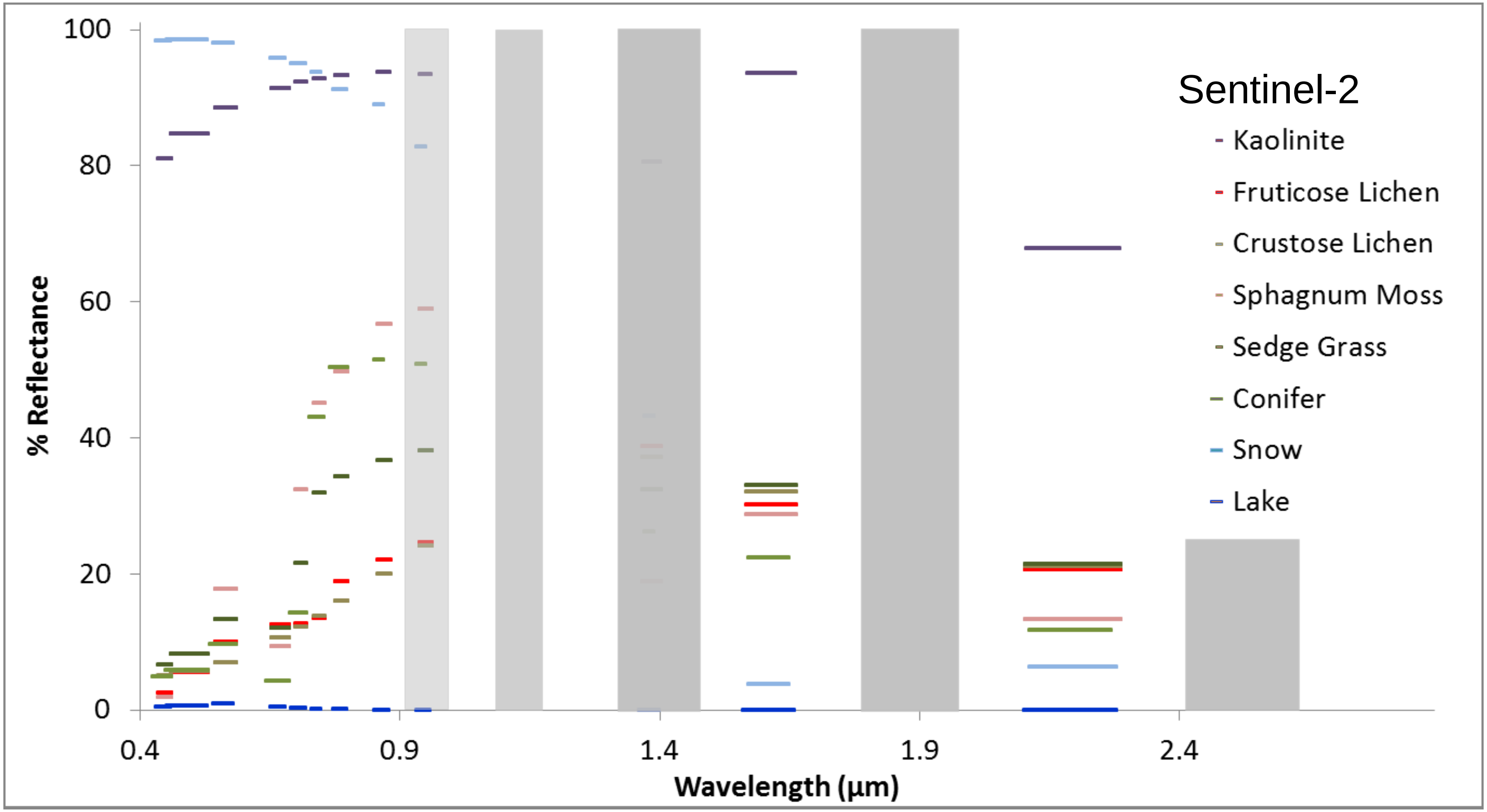
Satellite Simulations (2 of 2)

Canada Centre for Remote Sensing – Natural Resources Canada

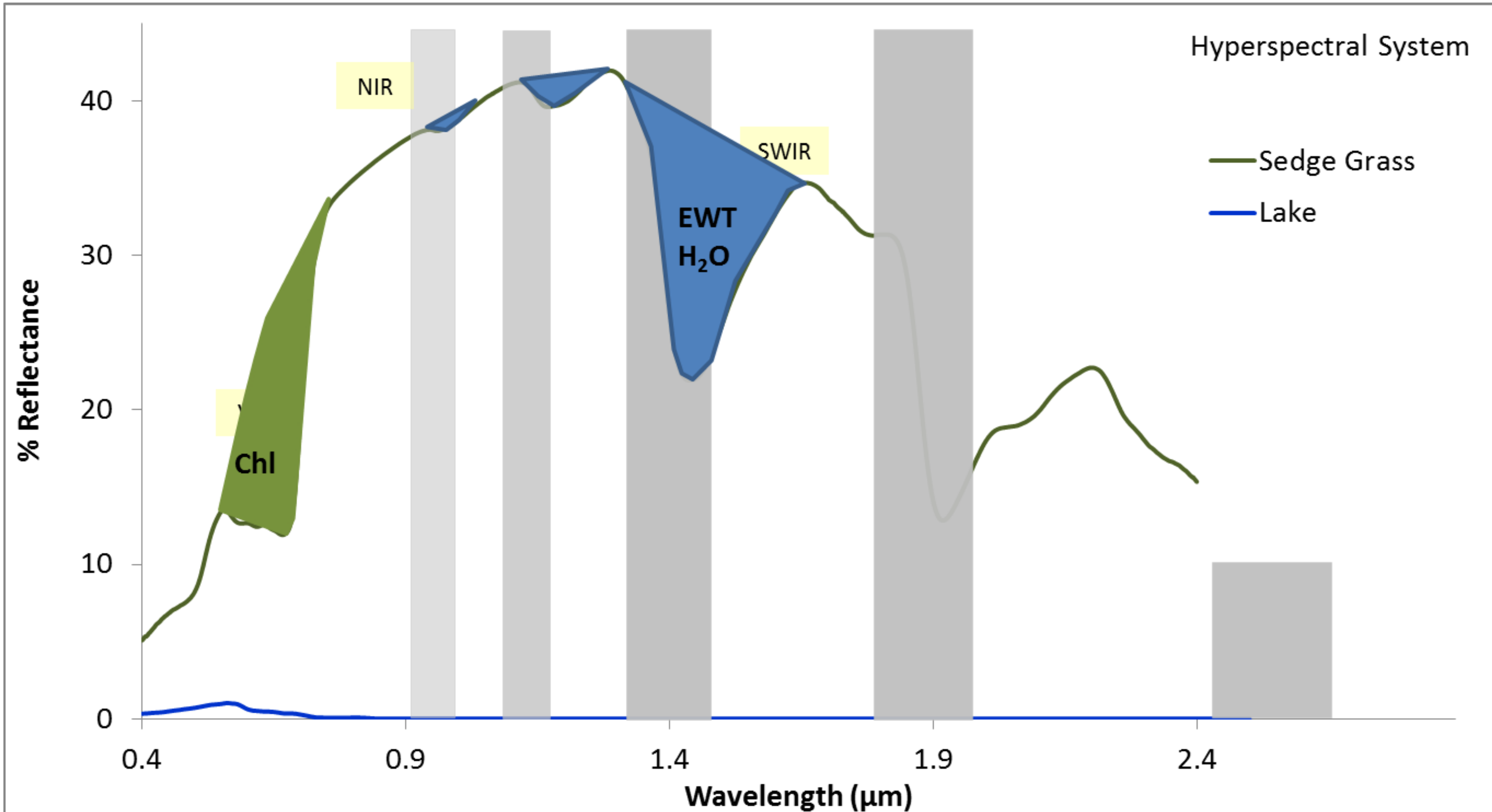
"Best Practice…"

- Support continuity between sensors
  - Information products between sensors are often advertised as "good agreement".
  - Value of understanding why not "perfect agreement".
  - Differences in sensor characteristics can equate to different sensitivities, dynamic range, and even applicability of an application.
- Simulation lets us evaluate models.
  - If we can simulate what the sensor observes using models, we can examine the efficacy of the model. (highlighted by Salomon Eliasson with cloud models)
  - "*Nothing happens in contradiction to nature, only in contradiction to what we know of it. And that's a place to start*." – Dana Scully, X-Files

Impact of Sensor Characteristics on Spectral Signatures of Different Target Types



Spectral Signatures and Spectral Indices



General Processing Scheme – ISDASv2

At-Sensor Imagery

Data Preprocessing

Information Extraction

Information

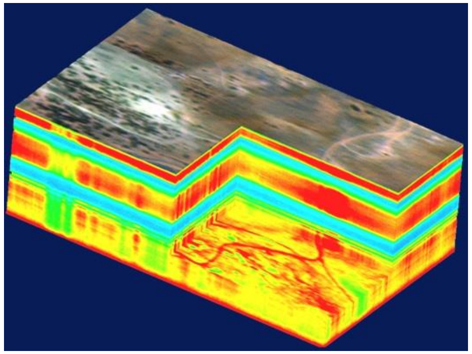
Observed Data Cube

Assess and Calibrate for Sensor/Calibration/Platform Artefacts (Noise, Smile, Keystone, Offsets)

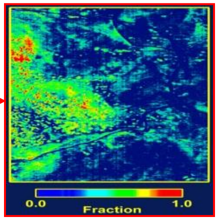
Correct for Atmospheric Influences

At-Surface Reflectance Information Extraction

Information Product



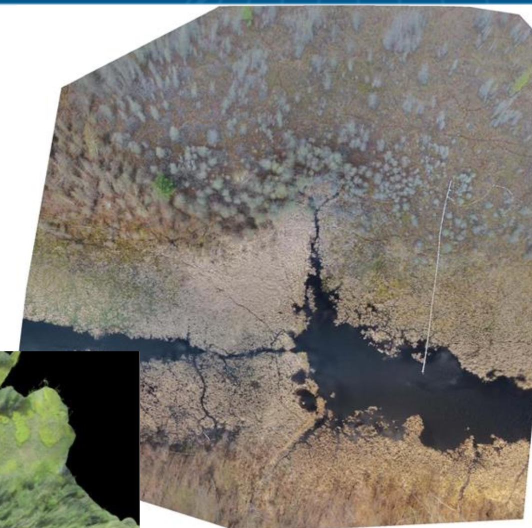
Spectral Library

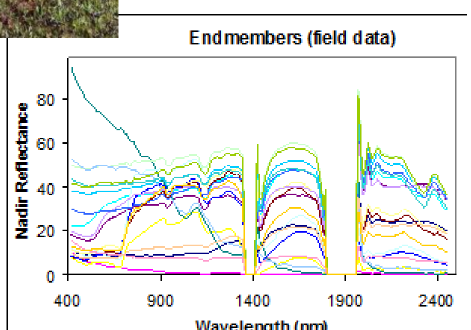


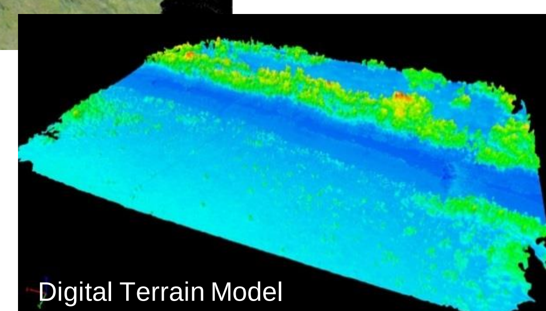
All arrows are in both directions.

Mapping Landcover

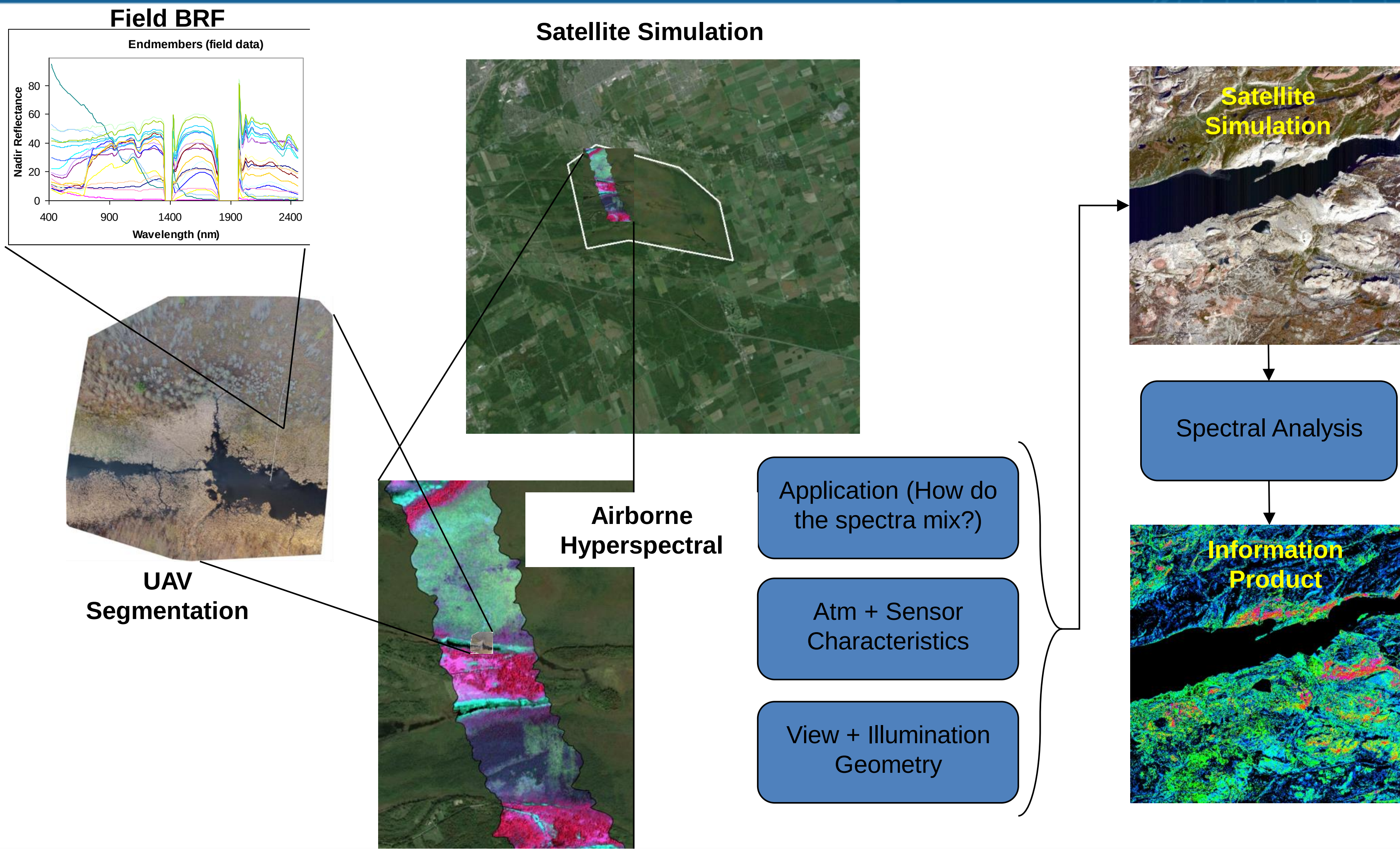
- Aerial photography
  → Orthomosaic, point cloud (DTM)
- Field Spectrometry





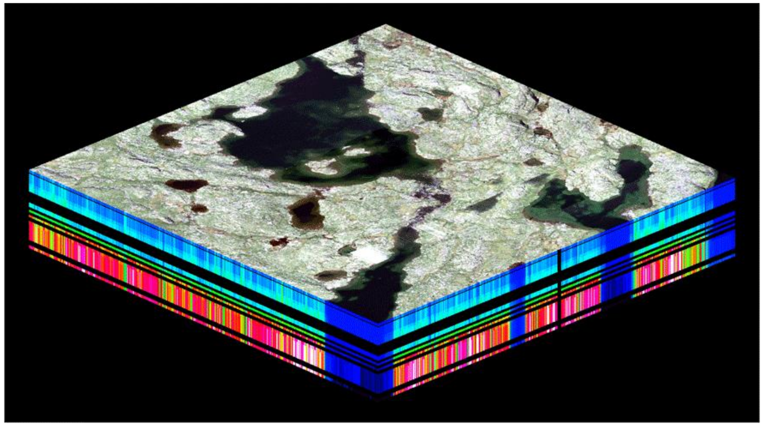


Sensor Simulation – Step-by-Step

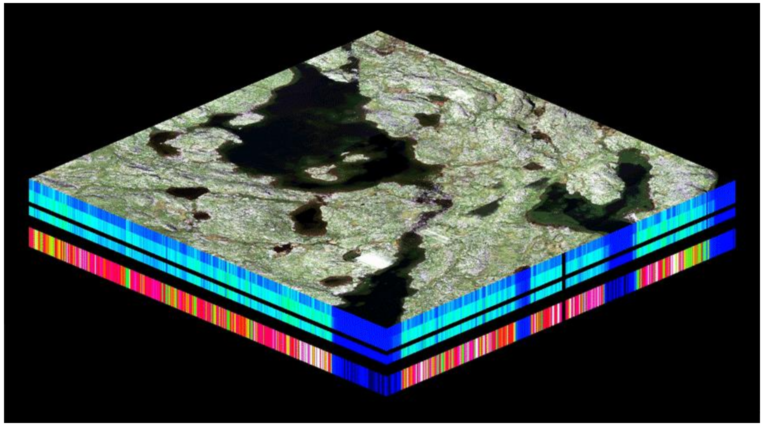


Simulation

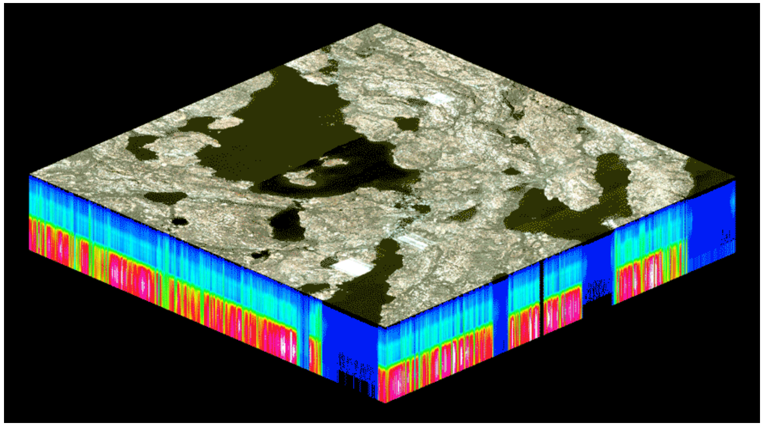
- Relate the application to the sensor
- Cross-sensor migration



Simulated Sentinel-2 bands



Simulated Landsat bands



Simulated EnMAP bands

Airborne Hyperspectral Imagery 2015

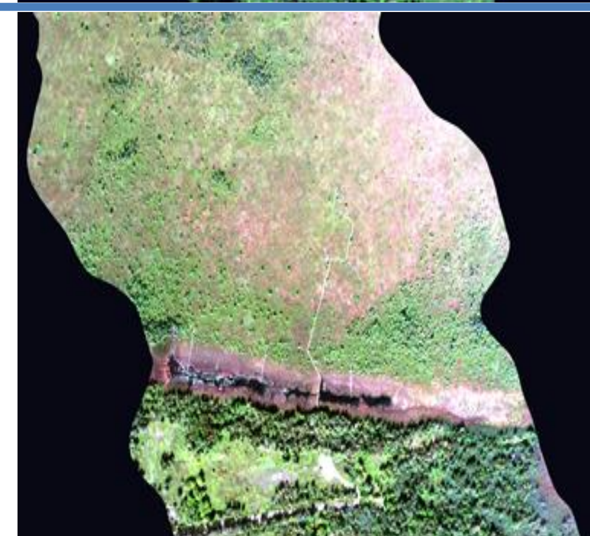
True Colour

April
29 2015

June
4 2015

August
28 2015

September
16 2015

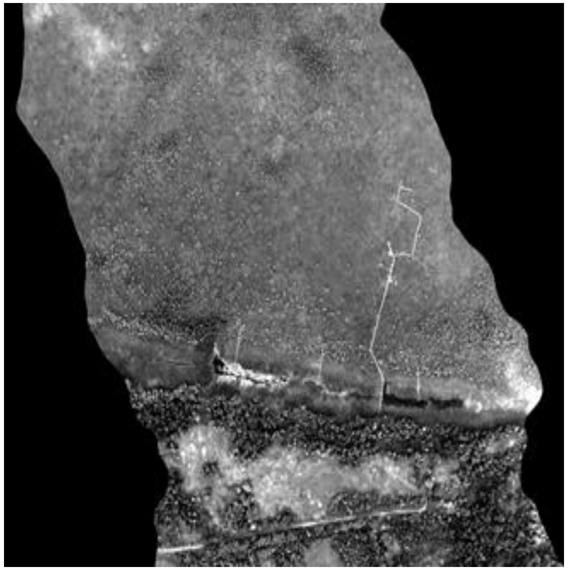


VI's for August 28 2015 as an Example

NDVI

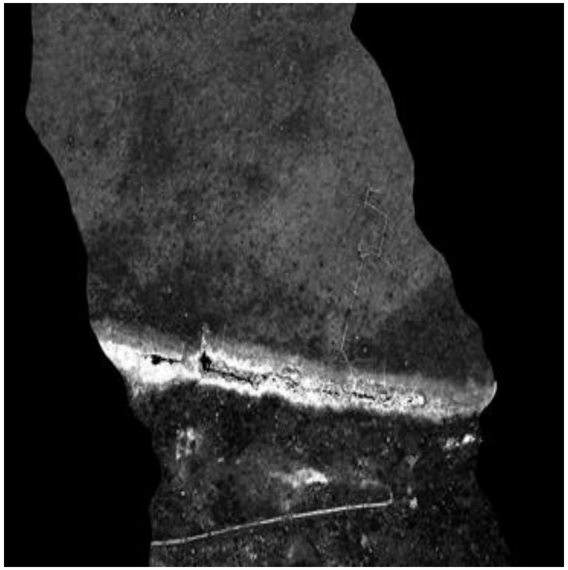
Range -1 to 1
Healthy veg 0.2-0.8
Study area 0.06-0.98
Indicates increased Chlorophyll to NIR

SGI



Range 0.0-0.5
Healthy veg 0.1-0.25
Study area 0.01-0.5
Indicates increased broadband "greeness"

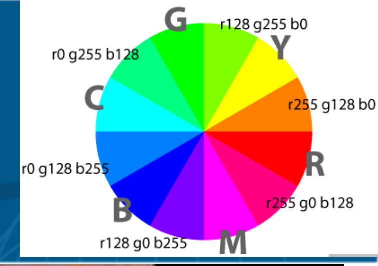
SIPI

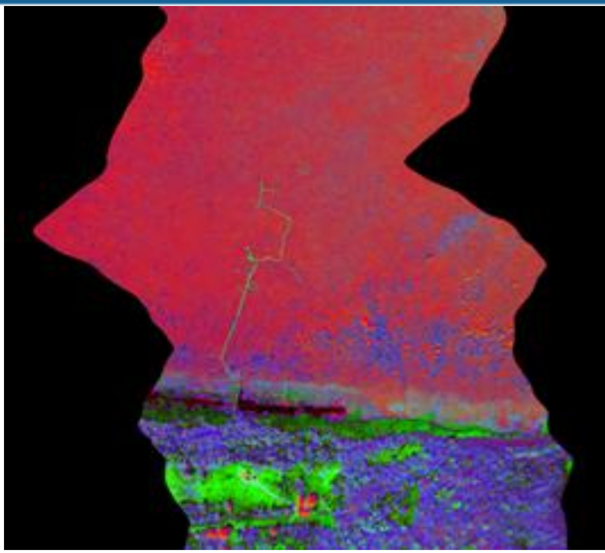


Range 0.0-2.0
Healthy veg 0.8-1.8
Study area 1.03-1.82
Indicates increased canopy stress

Issues with each VI…e.g. NDVI does not increase at same rate of increased greeness in high biomass areas.

NDVI (R), SGI(G), SIPI(B)





April
29 2015

Poor healthy
veg. cover

Tress in stress

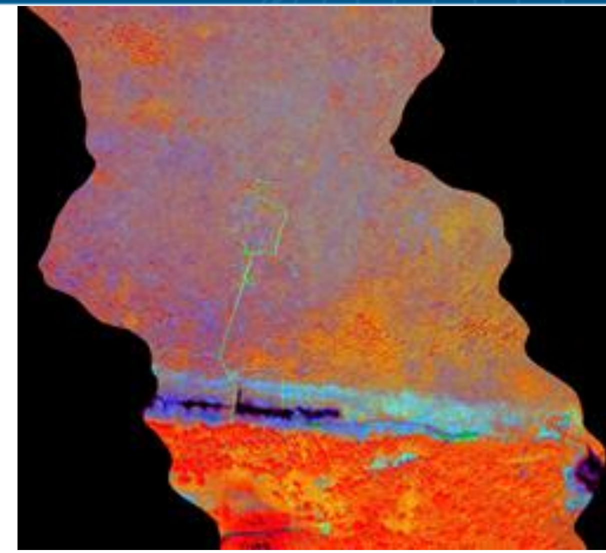
Grasses
Starting to
grow

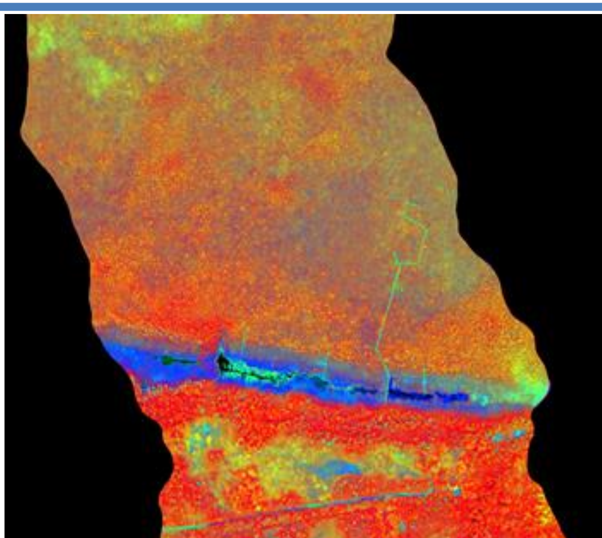
June
4 2015

Growth going
well.

Healthy trees

Greening of
veg





August
28 2015

Some reduction
In greeness

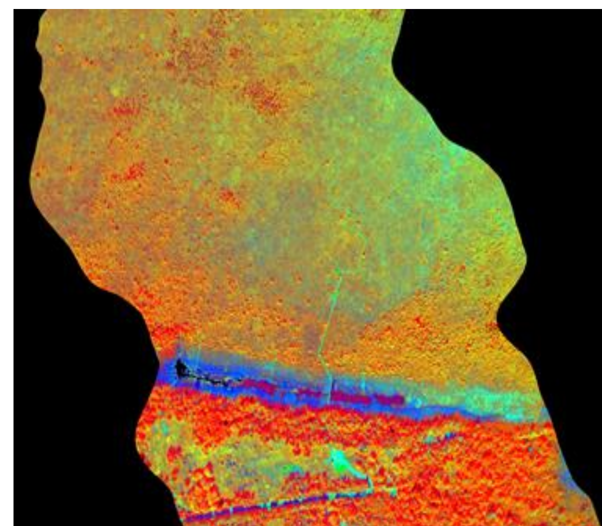
Still mostly
heathy veg.

Grasses showing
stress

September
16 2015

Increased stress
and decreased
greeness

After senesense

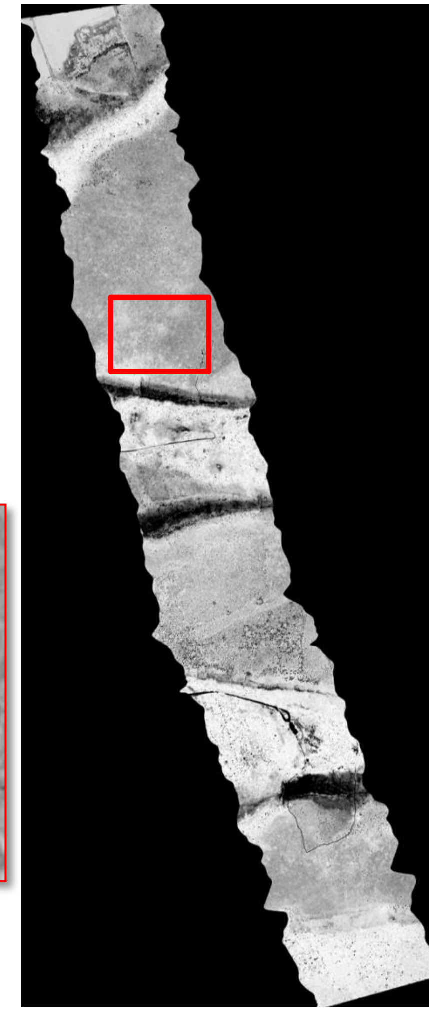


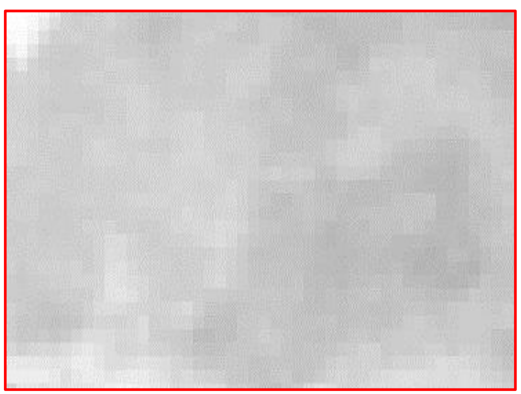
Landsat 8 Derived NDVI Compared to Airborne

August 18 2015

Range -1 to 1
Healthy veg 0.2-0.8

August 28 2015



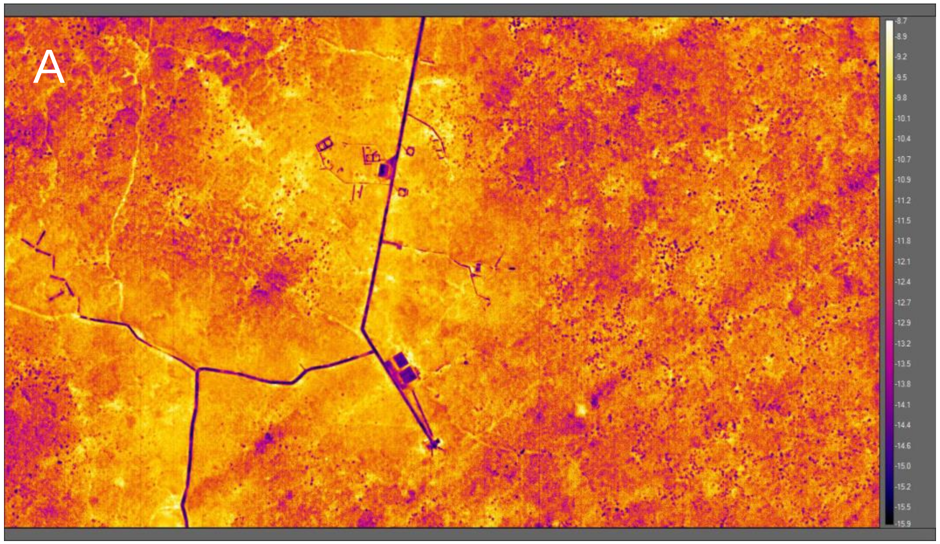


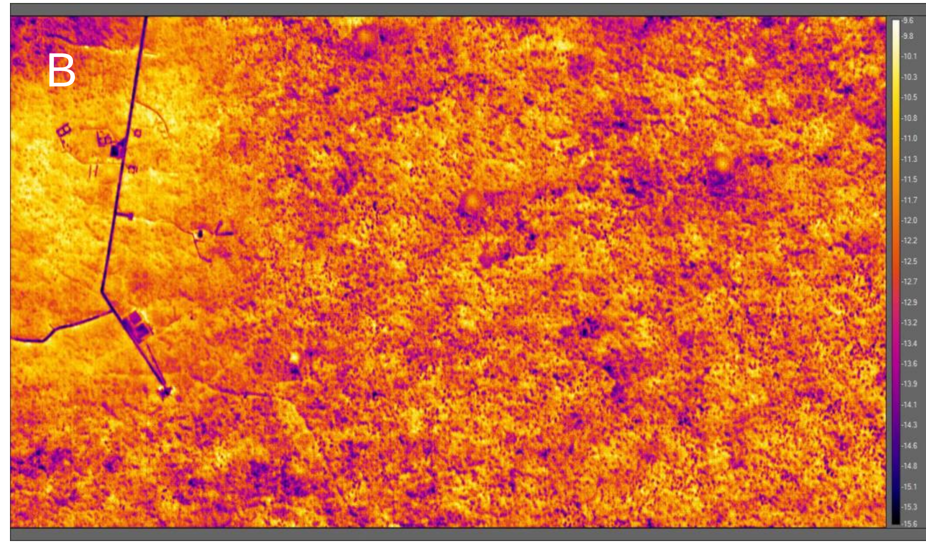
Study area 0.70-0.9

NRCan to Upscale to Satellite level

Study area 0.4-0.9
Boardwalk not included

Mid-Wave Infrared (3.5 – 4.9 μm) Imagery of Mer Bleue
Nov 25th, 2017 (Mostly clear with significant haze)



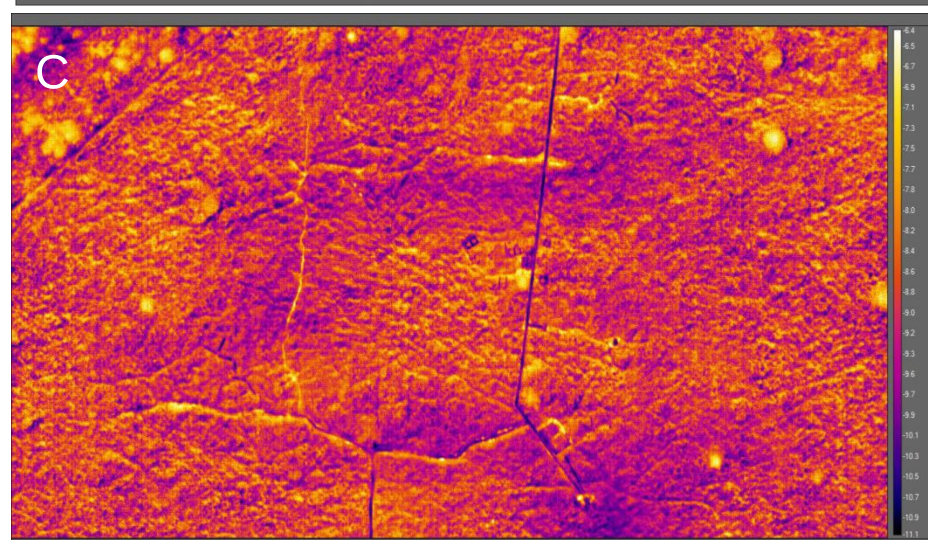


A) 16:00 EDT
SZA = °, Full Moon 20° above horizon
Temp = -0.3°C, RH = 82%

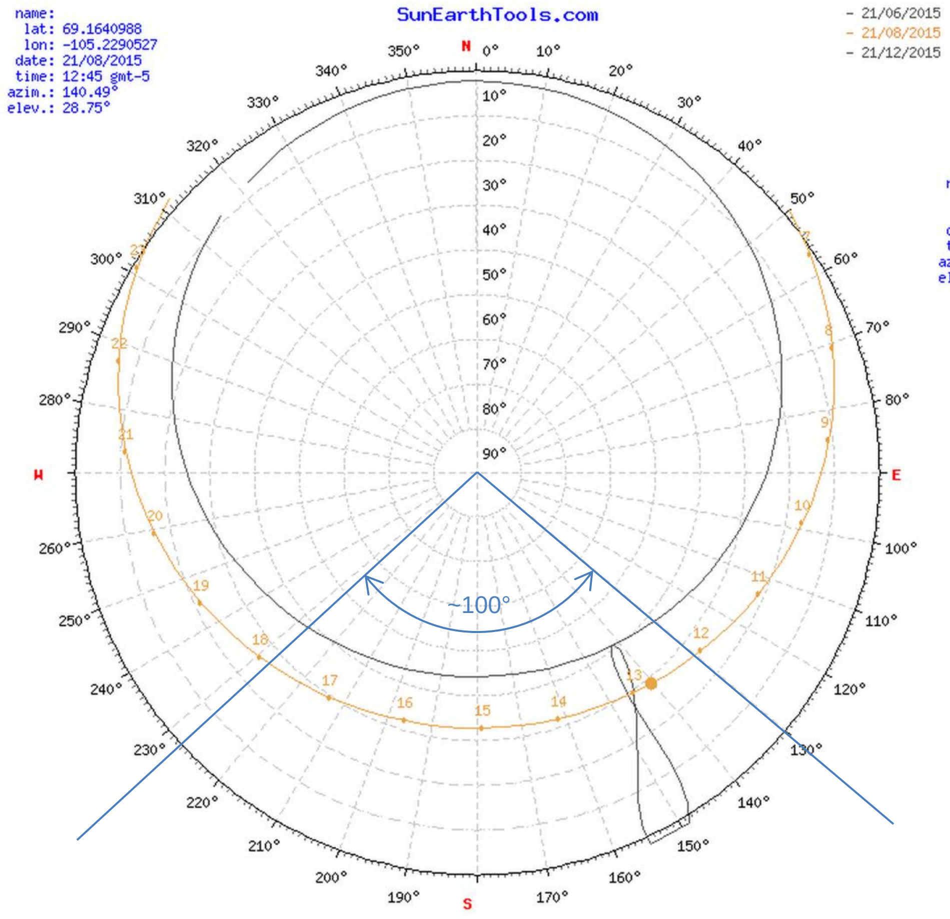
B) 19:00 EDT
Full Moon 20° above horizon
Temp = -1.0°C, RH = 90%

C) 22:30 EST
Full Moon 50° above horizon
Temp = -0.5°C, RH = 89%

Sunset at 16:23 EDT

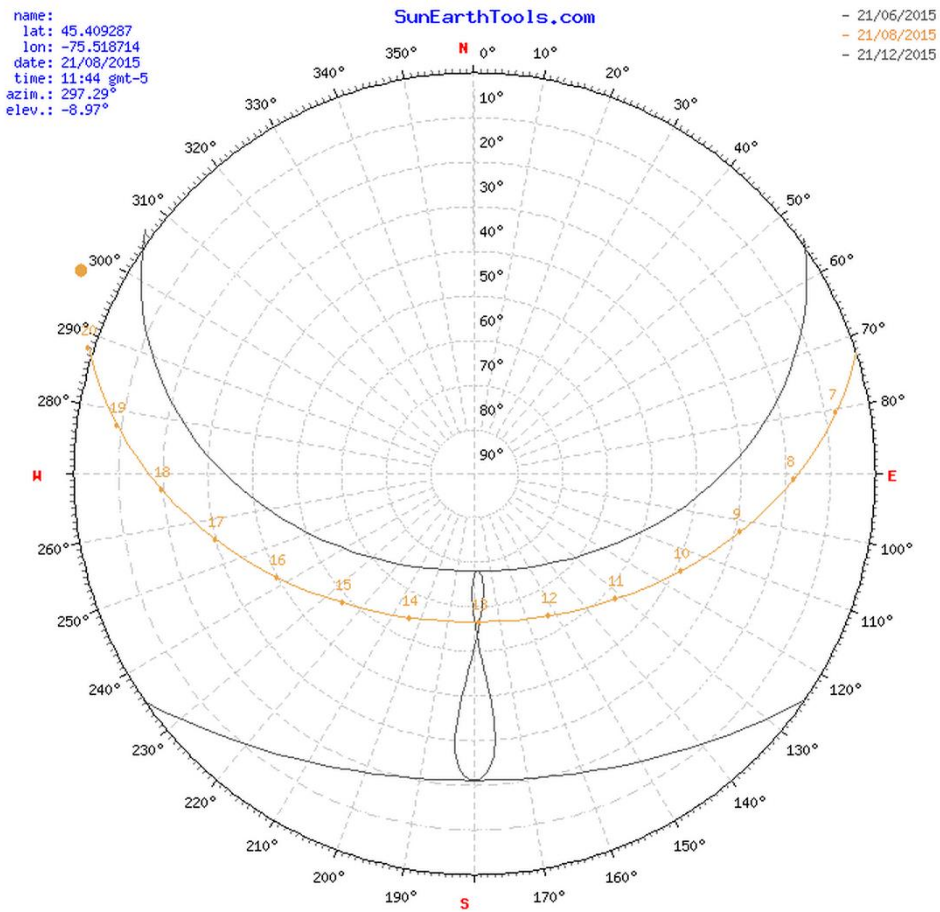


SZA/SAA Sensitivity Study Considerations: Solar Azimuth Angle

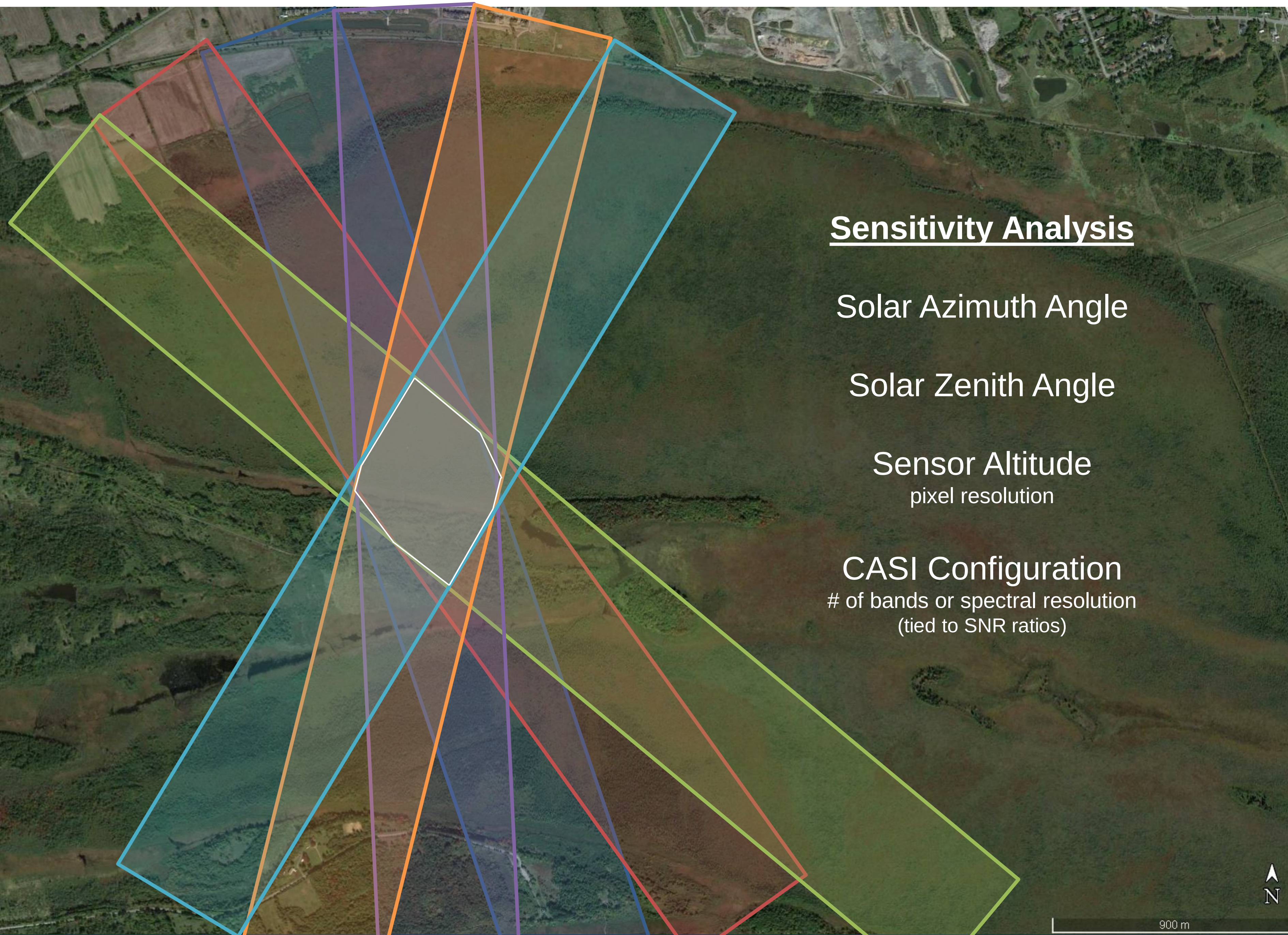


Cambridge Bay, NWT

Mer Bleue, Ottawa, ON



NRC·CNRC



Sensitivity Analysis

Solar Azimuth Angle

Solar Zenith Angle

Sensor Altitude
pixel resolution

CASI Configuration
# of bands or spectral resolution
(tied to SNR ratios)

MBASSS – Approach to Initial Study (Landsat 8 validation) – Data Acquisition

- Acquisition of airborne hyperspectral mosaic imagery (CASI 1500, SASI 644) of Mer Bleue during any Landsat 8 pass (sky conditions permitting) over an entire growing season (snow off)
- Acquisition of ground spectra for each hyperspectral flight for validation/correction of atmospheric correction of airborne imagery
- Acquisition of Mer Bleue ground spectra for:
  - development of a Mer Bleue spectral library
  - Spectral verification at time of airborne data acquisition
- Production of a high resolution Digital Terrain Model to assist with modelling
- Acquisition of airborne hyperspectral imagery (individual flight lines) over boardwalks for sensitivity analysis to address:
  - Solar Zenith Angle
  - Flight angle relative to Solar Azimuth Angle
  - Airborne flight altitude (pixel resolution)
  - CASI Configuration (# of bands, spectral resolution - tied to SNR of original data)
- Sunphotometer measurements (AEROCAN/NET calibrated Cimel sun tracking sunphotometer, Microtops II handheld sunphotometer)

MBASSS – Approach to Initial Study – Data Processing

- Hyperspectral imagery
  - Spectroradiometric calibration
  - Geocorrection and mosaicking
  - Atmospheric correction (ATCOR-4)
  - Validation of imagery against ground spectra (correction if necessary)
- Ground Spectra
  - Conversion of ground measurements to reflectance
    - Lab reference and primary field panel to be calibrated at University of Arizona (tie result to NIST standard).

MBASSS Projects – Current and Future

- European Space Agency to provide initial MBASSS funding (2015 – 2016)!
  - **MBASSS Landsat 8 Validation Project**
- Potential for future ESA funding of MBASSS projects
- Interests expressed by additional groups in terms of both funding and collaboration
- Future projects, using the MBASSS lessons learned, will hopefully lead to airborne and ground campaigns in the Canadian north

The MBASSS Team

- **NRC - Raymond Soffer, George Leblanc**
  - Project Management
  - Airborne Hyperspectral Data Acquisition
  - Ground spectral measurements in support of Airborne Hyperspectral Imagery Cal/Val
  - Airborne Hyperspectral Pre-Processing
    - Spectroradiometric calibration
    - Geocorrection
    - Atmospheric correction
  - Post-Processing of Airborne HIS (production of data products)

National Research Council Canada Conseil national de recherches Canada

- **McGill University – Nigel Roulet, Tim Moore, Margaret Kalacska, Pablo Arroyo-Mora**
  - Mer Bleue Peatland Observatory (MBPO) logistics
  - MBPO ground spectral measurements
  - MBPO Auxiliary measurements
  - Data storage and database development

- **NRCan – H. Peter White, Matthew Maloley, Lixin Sun**
  - Ground spectral measurements
  - Auxiliary field measurements (UAV imagery)
  - Satellite simulations

Natural Resources Canada Ressources naturelles Canada

- **LOOKNorth – Dennis Nazarenko**
  - Technical Reports
  - Public Outreach
  - Northern deployment logistic (future projects)

Summary

- A readily accessible, closely monitored peatland site has been identified
- Airborne and ground-based techniques evaluated for validation of space-borne EO optical end product data products
- Leverage ongoing research and infrastructure at the Mer Bleue Peatland Observatory
- Simulation of EO satellite data building upon ongoing efforts at NRCan
- Research team has been assembled to address:
  - Airborne hyperspectral data acquisition
  - Ground based support measurements
  - Simulation of satellite EO data products
  - Evaluation of simulations with respect to actual EO data products
  - Sensitivity analysis of simulation results to various mission/operational parameters
- An initial project in development to validate Landsat 8 data products

Conclusion

- The process of acquiring **airborne hyperspectral imagery and ground-based measurements** for the purpose of **validating satellite optical EO multi/hyperspectral data product**s of **northern/sub-arctic peatlands** is to be evaluated in a **cost efficient manner** at the easily accessible **MBASSS Site** complete with a **sensitivity analysis** of the resulting simulations to a variety mission/operational variables.

- Valuable insights will be obtained into planning of future airborne/ground validation campaigns to remote northern/subarctic locations.

Thanks for your interest!

Questions?

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