SWOT Science Team Hydro splinter 1: Arctic lake science and AirSWOT observations

Laurence Smith[1,2] (presenter), Jessica Fayne[2], Sarah Cooley[1], Ethan Kyzivat[1], Lincoln Pitcher[2], Tamlin Pavelsky[3]

[1]Brown University IBES/DEEPS
[2]UCLA Department of Geography
[3]UNC Department of Geological Sciences

Motivations

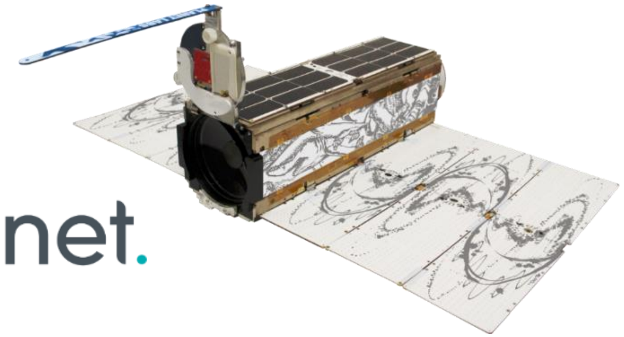
The Earth's Arctic/sub-Arctic latitudes are home to the world's **highest abundance of lakes**, making this region critically important for CH_4 emissions, ecological habitat, landscape disturbance (thermokarst), and traditional subsistence cultures

The polar regions are **highly seasonal**, yet research on **sub-seasonal dynamics** of Arctic/sub-Arctic lakes has been limited by lack of *in situ* and high temporal/spatial resolution satellite of dA/dt and dH/dt

Motivations

The Earth's Arctic/sub-Arctic latitudes are home to the world's **highest abundance of lakes**, making this region critically important for CH_4 emissions, ecological habitat, landscape disturbance (thermokarst), and traditional subsistence cultures.

The polar regions are **highly seasonal**, yet research on **sub-seasonal dynamics** of Arctic/sub-Arctic lakes has been limited by lack of *in situ* and high temporal/spatial resolution satellite of dA/dt and dH/dt.



planet.

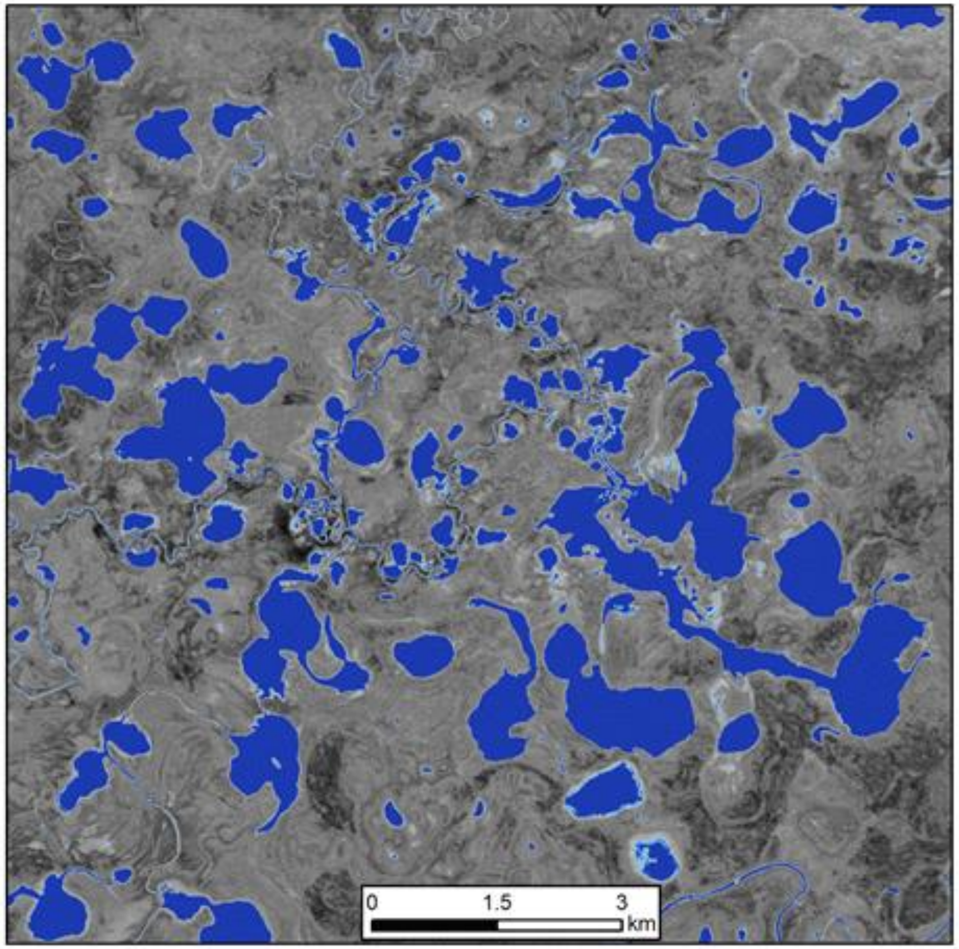
Recently, hundreds of **CubeSats** began collecting near-daily observations of Arctic lakes at 3 - 5 m resolution, and the NASA Arctic-Boreal Vulnerability Experiment (ABoVE) conducted the world's largest acquisition of **AirSWOT InSAR and CIR camera airborne data** in 2017.

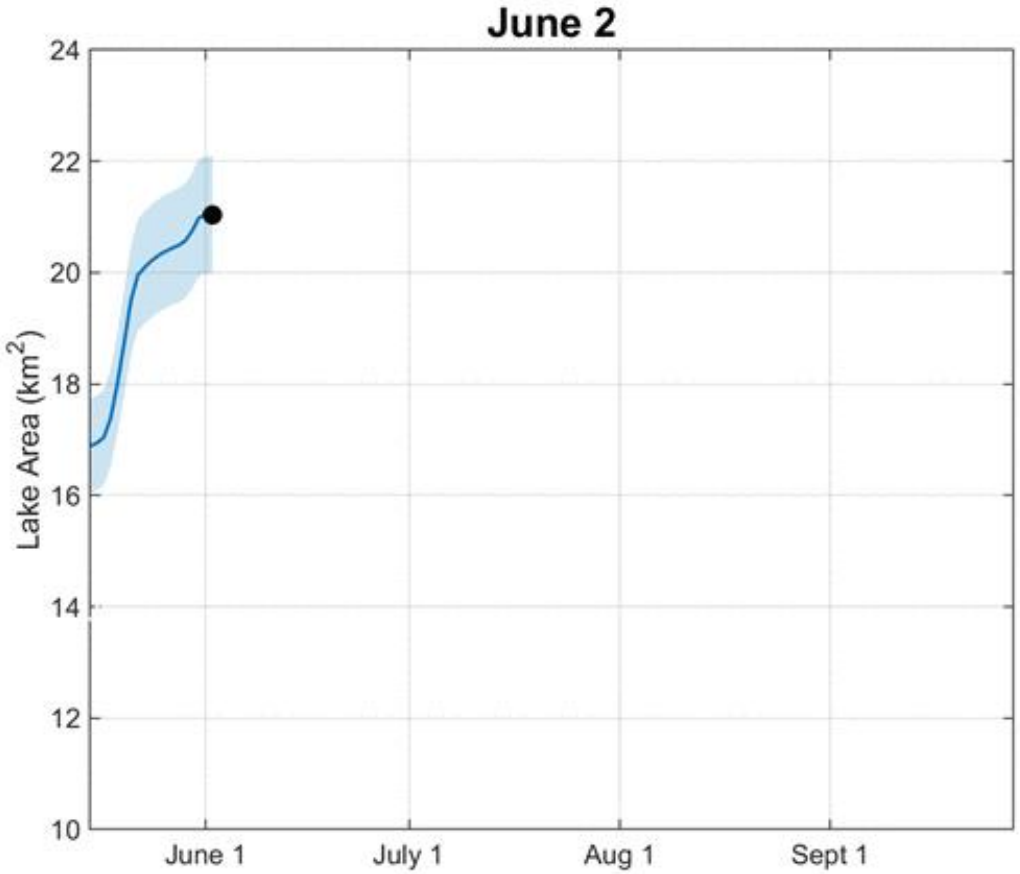
ABoVE

ARCTIC – BOREAL VULNERABILITY EXPERIMENT

CubeSat Lake Tracking Method (Cooley et al., GRL, 2019)

Initial image selection → Create initial buffered water mask → Classify water fraction → Create lake area time series → Filter lake area time series





Cooley et al. (2019), Arctic-Boreal Lake Dynamics Observed using CubeSat Imagery, *Geophysical Research Letters*, doi:10.1029/2018GL081584

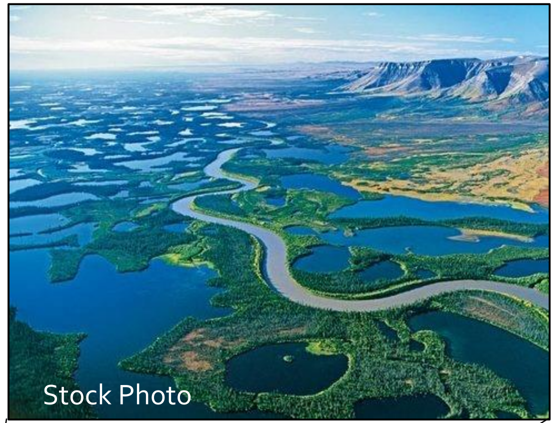
Study Areas

Cooley et al. (2019), Arctic-Boreal Lake Dynamics Observed using CubeSat Imagery, *Geophysical Research Letters*, doi:10.1029/2018GL081584

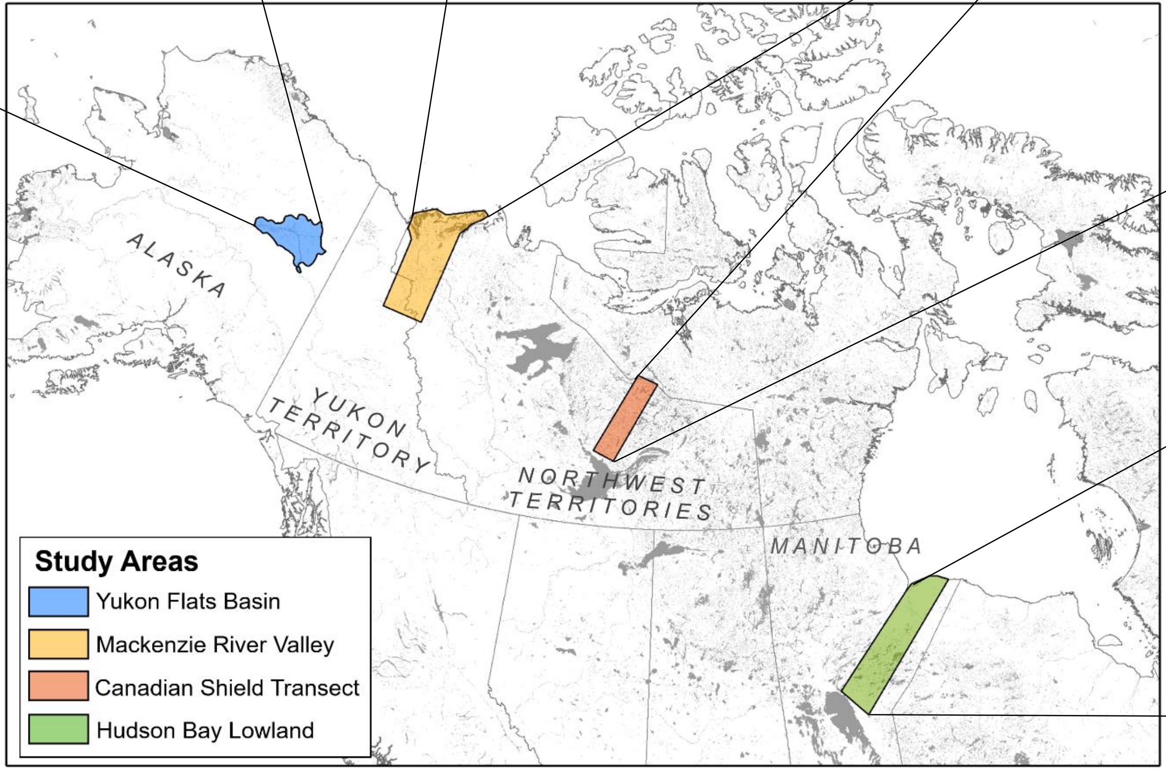
Yukon Flats Basin, Alaska

USFWS

Mackenzie River Valley, NWT



Stock Photo

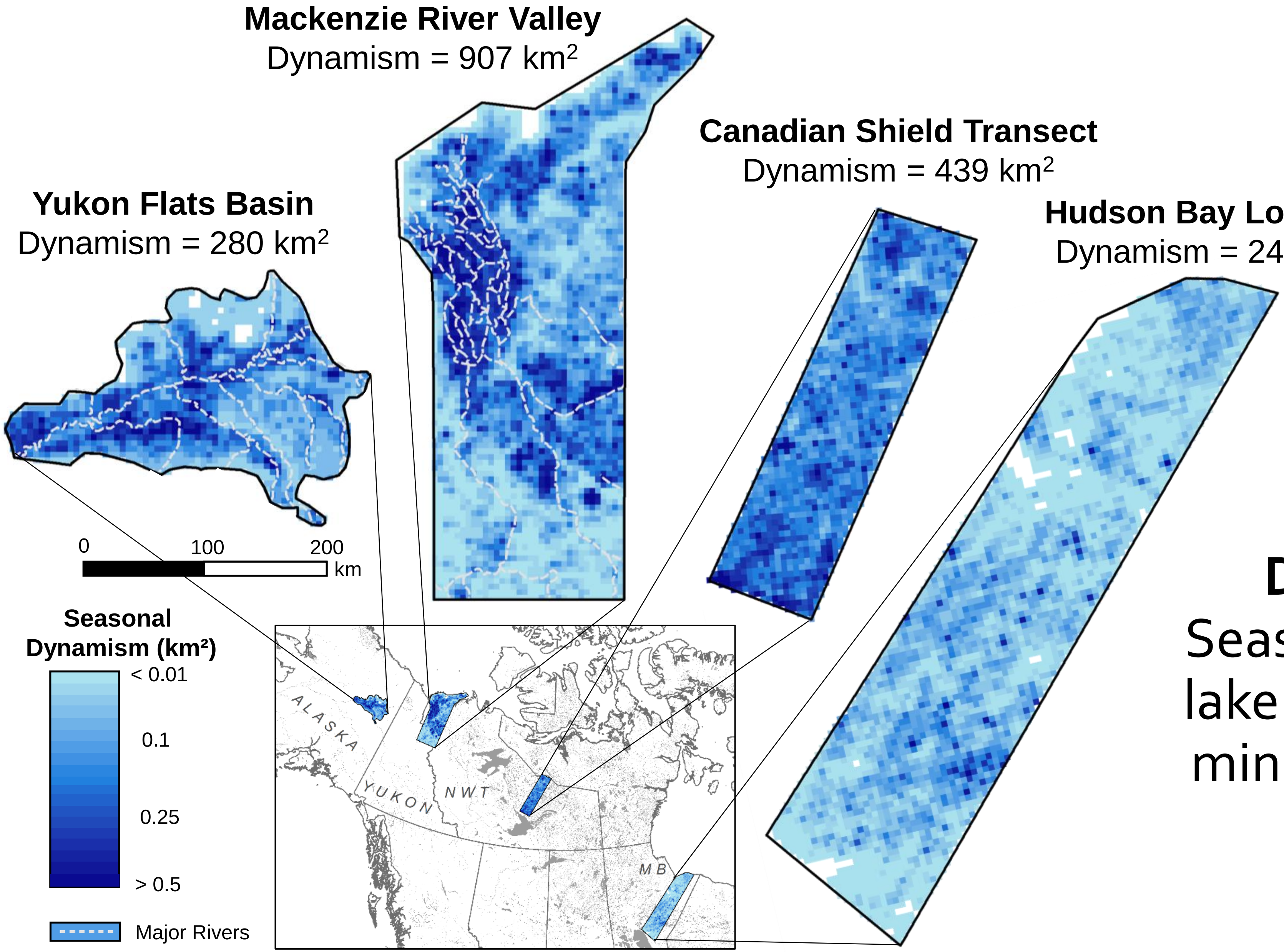


Canadian Shield Transect, NWT

Hudson Bay Lowland, Manitoba

Gord McKenna

2. Sub-seasonal dynamics in total lake area



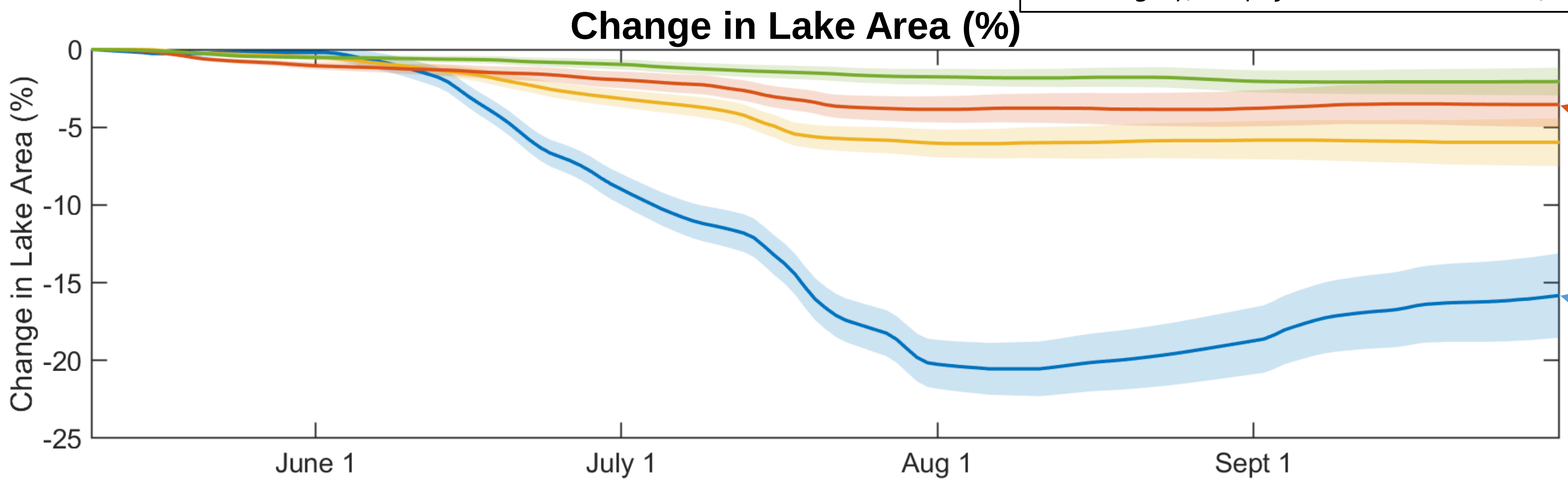
Dynamism = Seasonal maximum lake area – seasonal minimum lake area (km²)

Sub-seasonal lake dynamics are important

Cooley et al. (2019), Arctic-Boreal Lake Dynamics Observed using CubeSat Imagery, *Geophysical Research Letters*, doi:10.1029/2018GL081584

Lake Change

Lake Area

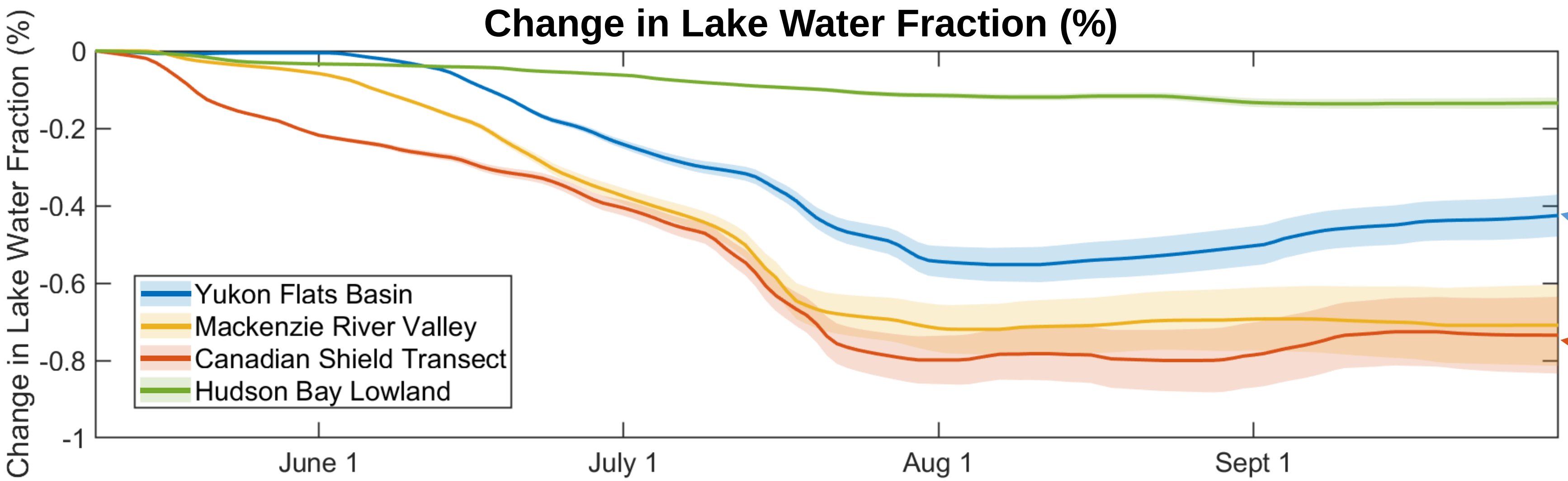


Canadian Shield Transect

Yukon Flats Basin

Lake Change

Land Area



Yukon Flats Basin

Canadian Shield Transect

Lakes on the Canadian Shield are surprisingly dynamic, with the greatest absolute change in water fraction

2017 ABoVE AirSWOT flight and field campaigns

In summer 2017, NASA flew ten airborne platforms across the ABoVE domain including coincident flight tracks with **AirSWOT** (Ka-band InSAR and high-resolution color infrared (CIR) camera data), **LVIS** (waveform LiDAR), **AVIRIS-NG** (hyperspectral vis/NIR imagery) and **UAVSAR** (L- and P-band polarimetric radar

Extensive field cal/val GPS surveys led by UCLA with help from many others including Cretaux, Calmant from France

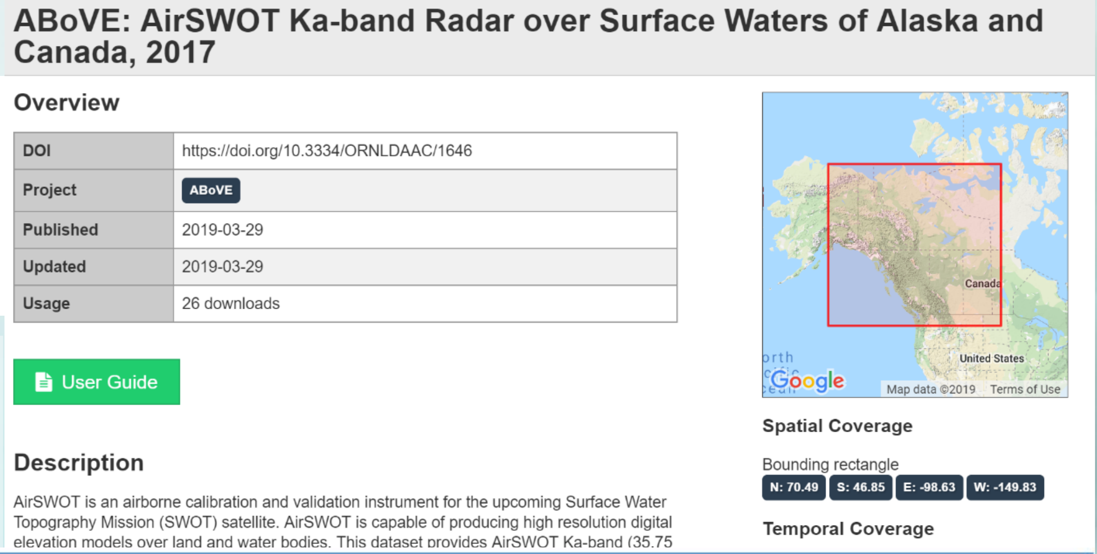
Region	Code
Arctic-boreal wetlands	
Canadian Shield Margin	CSM
Yukon Flats Basin	YFB
Mackenzie River Delta	MRD
Peace-Athabasca Delta	PAD
Canadian Shield	
Canadian Shield	CSH
Lowland river valleys	
Sagavanirktok River	SAG
Mackenzie River Valley	MRV
Slave River	SLR
Athabasca River	ATR
Prairie Pothole regions	
Prairie Potholes North	PPN
Prairie Potholes South	PPS
Thermokarst regions	
Old Crow Flats	OCF
Tuktoyaktuk Peninsula	TKP

🟨 AirSWOT flight lines

Available AirSWOT InSAR products *(Fayne et al., 2018)*

The 2017 ABoVE AirSWOT data are publically available on

ORNL-DAAC: https://daac.ornl.gov/cgi-bin/dsviewer.pl?ds_id=1646



ABoVE: AirSWOT Ka-band Radar over Surface Waters of Alaska and Canada, 2017

Overview

DOI	https://doi.org/10.3334/ORNLDAAC/1646
Project	ABoVE
Published	2019-03-29
Updated	2019-03-29
Usage	26 downloads

Spatial Coverage

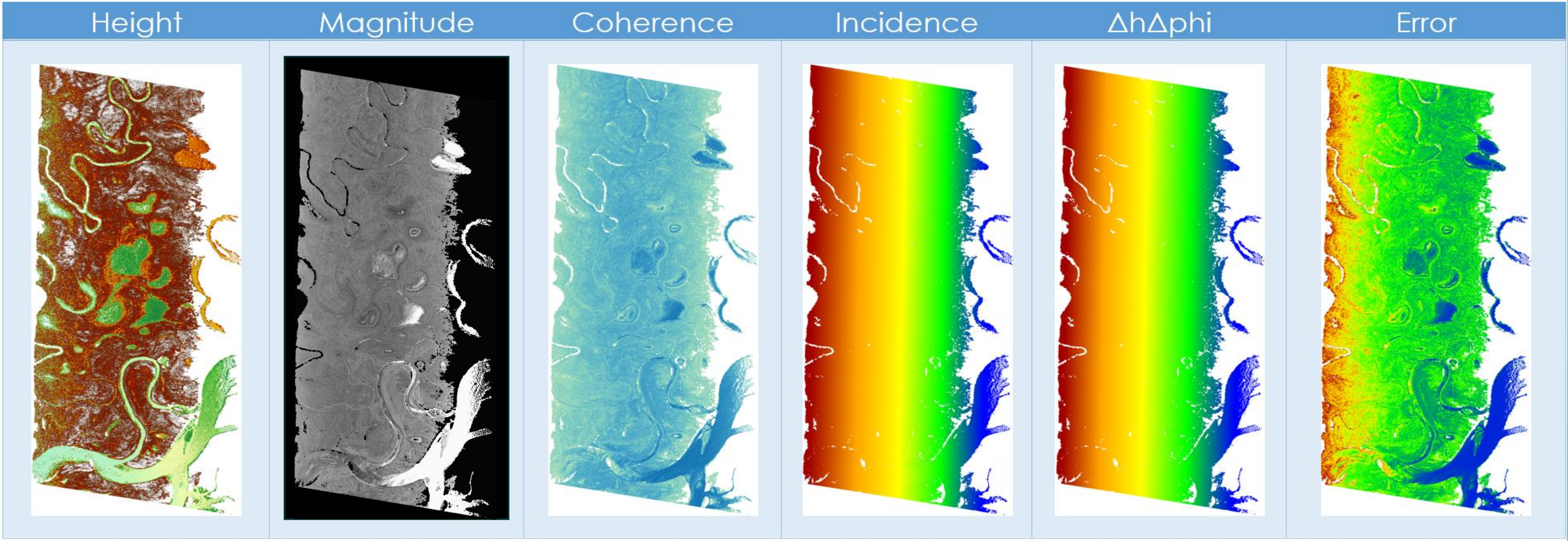
Bounding rectangle

N: 70.49 S: 46.85 E: -98.63 W: -149.83

Temporal Coverage

Description

AirSWOT is an airborne calibration and validation instrument for the upcoming Surface Water Topography Mission (SWOT) satellite. AirSWOT is capable of producing high resolution digital elevation models over land and water bodies. This dataset provides AirSWOT Ka-band (35.75



Available AirSWOT color-infrared imagery and open-water masks

(Kyzivat et al. 2018, 2019)

DAAC Home > Get Data > NASA Projects > Arctic-Boreal Vulnerability Experiment (ABoVE) > User guide

ABoVE: AirSWOT Color-Infrared Imagery Over Alaska and Canada, 2017

Documentation Revision Date: 2018-11-26

Data Set Version: 1

Summary

This dataset contains georeferenced three-band orthomosaics of green, red, and near-infrared (NIR) digital imagery at 1m resolution collected over selected surface waters across Alaska and Canada between July 9 and August 17, 2017. The orthomosaics were generated from individual images collected by a Cirrus Designs Digital Camera System (DCS) mounted on a Beechcraft Super King Air B200 aircraft from approximately 8-11 km altitude. Flights were over the following areas: Saskatchewan River, Saskatoon, Inuvik, Yukon River including Yukon Flats, Sagavanirktok River, Arctic Coastal Plain, Old Crow Flats, Peace-Athabasca Delta, Slave River, Athabasca River, Yellowknife, Great Slave Lake, Mackenzie River and Delta, Daring Lake, and other selected locations. Most locations were imaged twice during two flight campaigns in Canada and Alaska extending roughly SE-NW then NW-SE up to a month apart. The data were georeferenced using 303 ground control points (GCPs) across the study region.

These data are intended to validate surface water extent to aid interpretation of AirSWOT Ka-band radar returns as part of the AirSWOT ABoVE project. The core of AirSWOT is the Ka-band SWOT Phenomenology Airborne Radar (KaSPAR). It collects two swaths of across-track interferometry data - between nadir and 1 km and between 1 km and 5 km, respectively - which can be used to obtain centimeter-level topographic maps of water surfaces. In addition, KaSPAR has an along-track interferometer that can be used to measure the temporal decorrelation of water surfaces, as well as the water radial velocity.

There are 335 data files with this dataset. This includes 330 orthomosaics in GeoTIFF (.tif) format, four shapefiles compressed in .zip format, and one comma-separated file (.csv). The shapefiles and .csv provide the ground control point data. Companion files: we include the 330 orthomosaic data files and three shapefiles transformed to .kmz format for viewing in Google Earth.

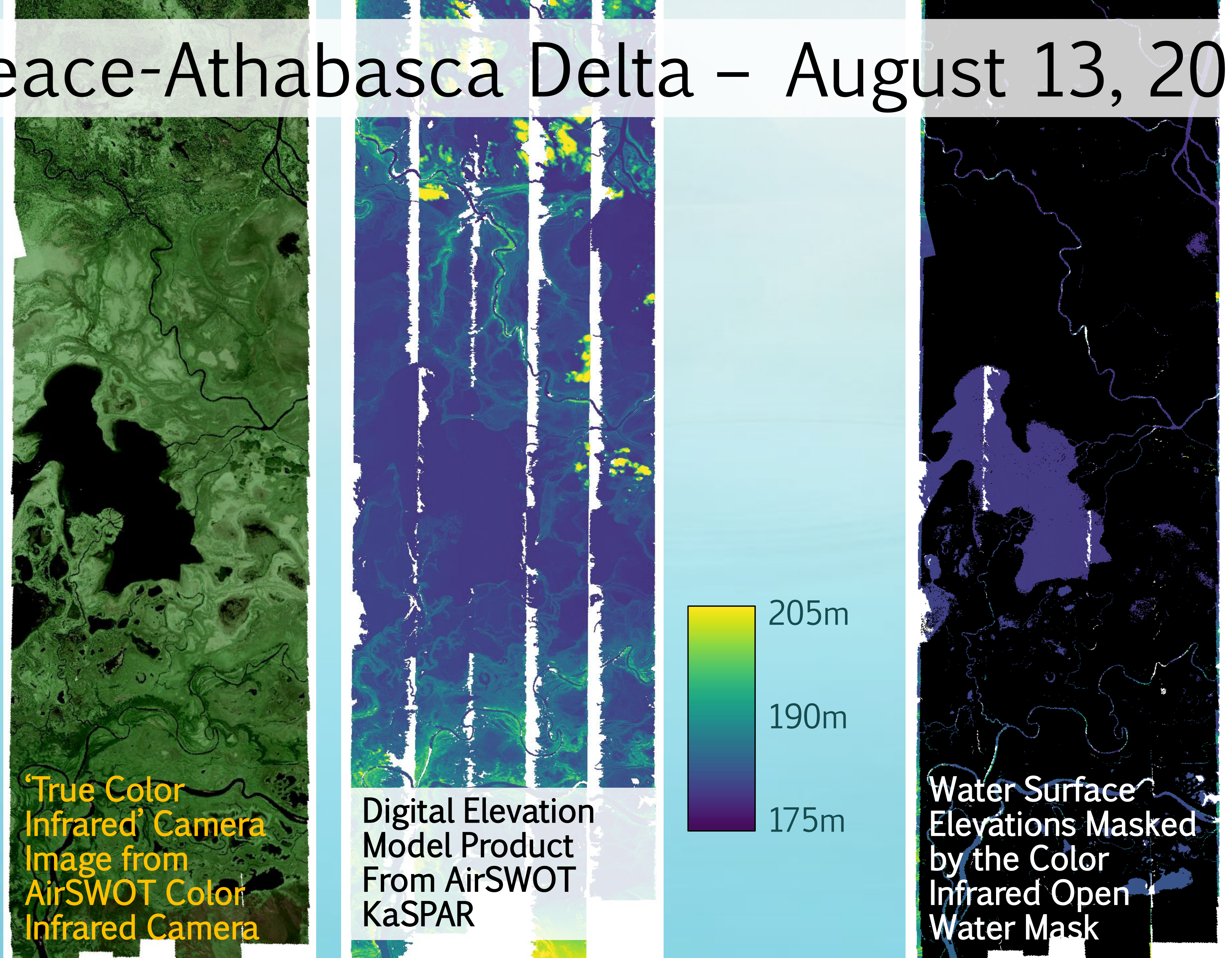
Figure 1. This figure shows open surface waters (black areas) for a location northwest of Fort Saskatchewan, Canada. This image for ABoVE grid ch078v097 was acquired July 9, 2017.

- 1m pixel size with georeferencing accuracy assessed for each image
- Covers 38% of foundational AirSWOT flight lines
- 3,167 km^2 of open water mapped
- Water mask dataset to be posted soon
- https://doi.org/10.3334/ORNLDAAC/1643

How well did AirSWOT Ka-band Radar interferometry map water surface elevations (WSEs) across the ABoVE domain? (Jessica Fayne, UCLA)

- To answer this question, we used:
  - In-situ WSE measurements from GPS, supported by pressure transducers to compare across time
  - High Resolution Water mask derived from the AirSWOT CIR Camera (*Kyzivat et al, 2019*)
  - Airborne waveform LiDAR from the Land, Vegetation and Ice Sensor (LVIS)

Peace-Athabasca Delta – August 13, 2017



'True Color Infrared' Camera Image from AirSWOT Color Infrared Camera

Digital Elevation Model Product From AirSWOT KaSPAR

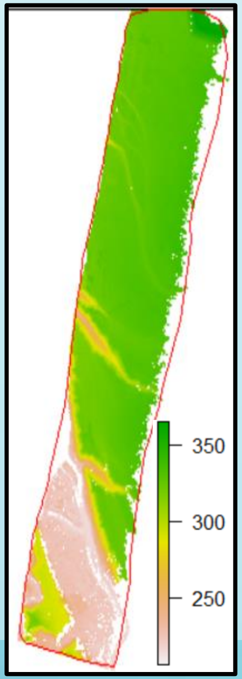
Water Surface Elevations Masked by the Color Infrared Open Water Mask

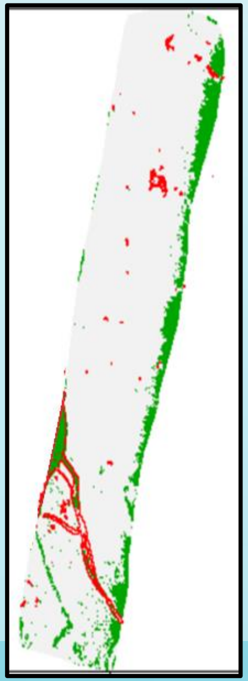
Kyzivat et al., 2019, in progress

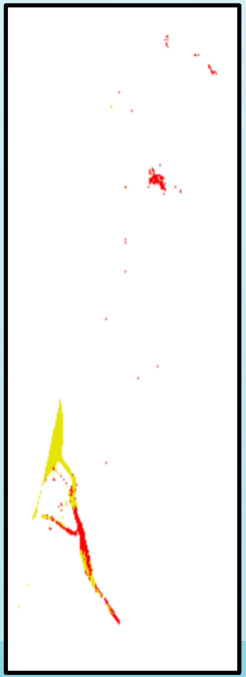
1. Results: No Data Fraction (including ‘dark water’)

Estimate fraction of ‘no data’ on irregular swath

Whole Line	Within CIR Water Mask	Within Water Mask and 5-17°	Within Water Mask and <4.1°
16%	66%	57%	48%

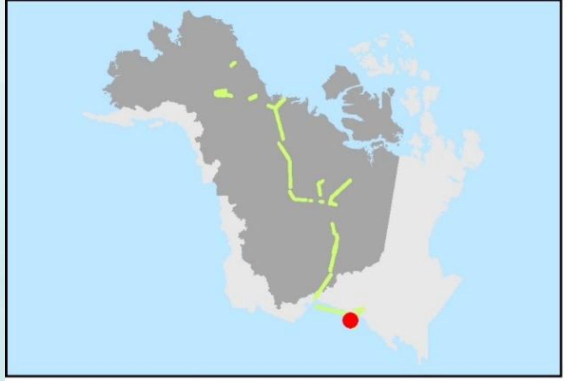


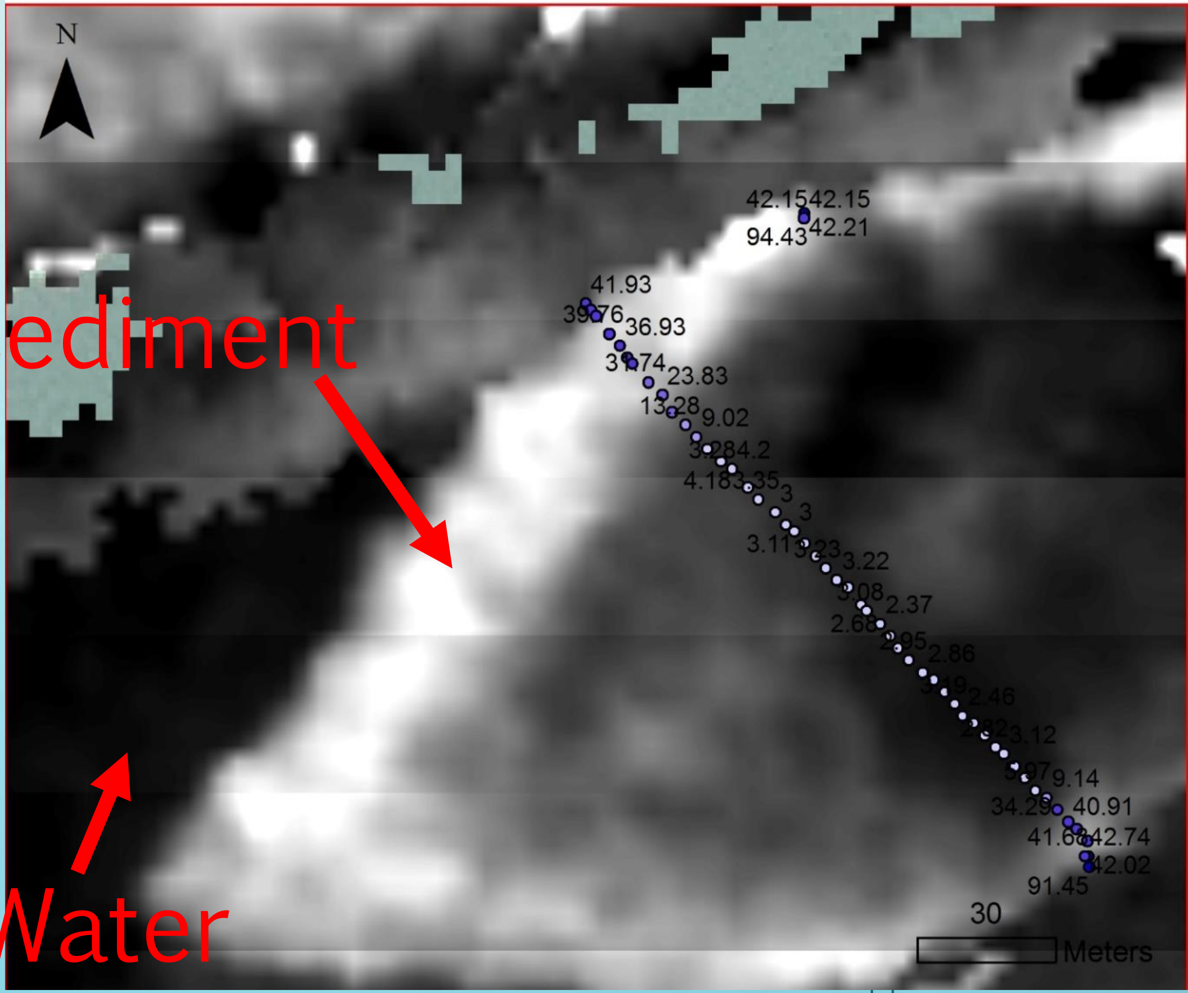




“Bright mud” (actually sand) high Ka-band returns along the North Saskatchewan River, Canada

- GPS survey of shorelines
- In situ measurement transects across sandbar soil moisture gradients

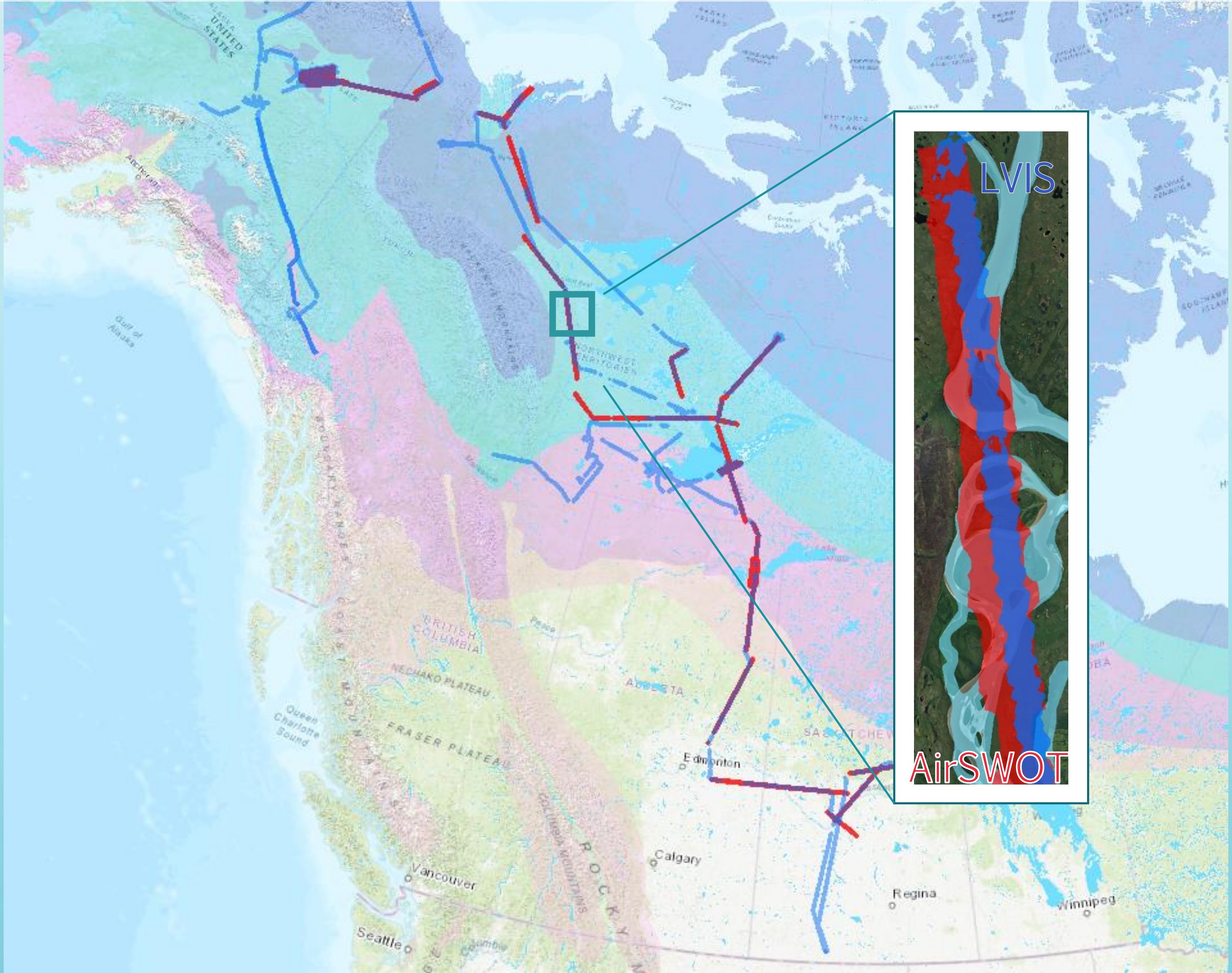




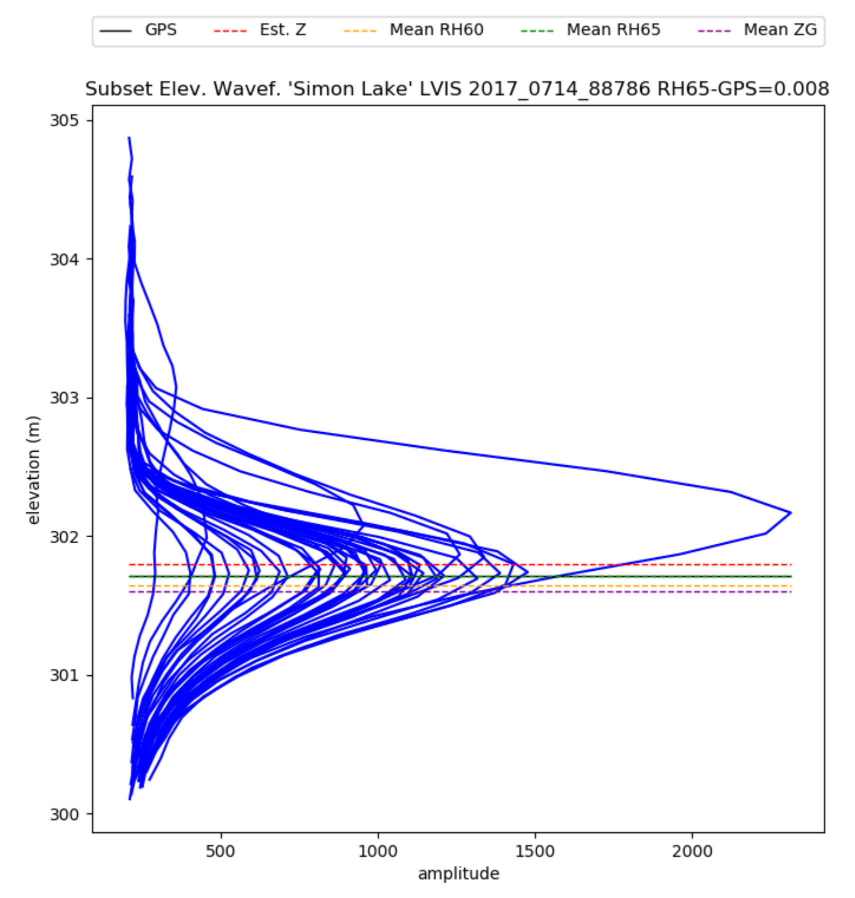
Bright sediment

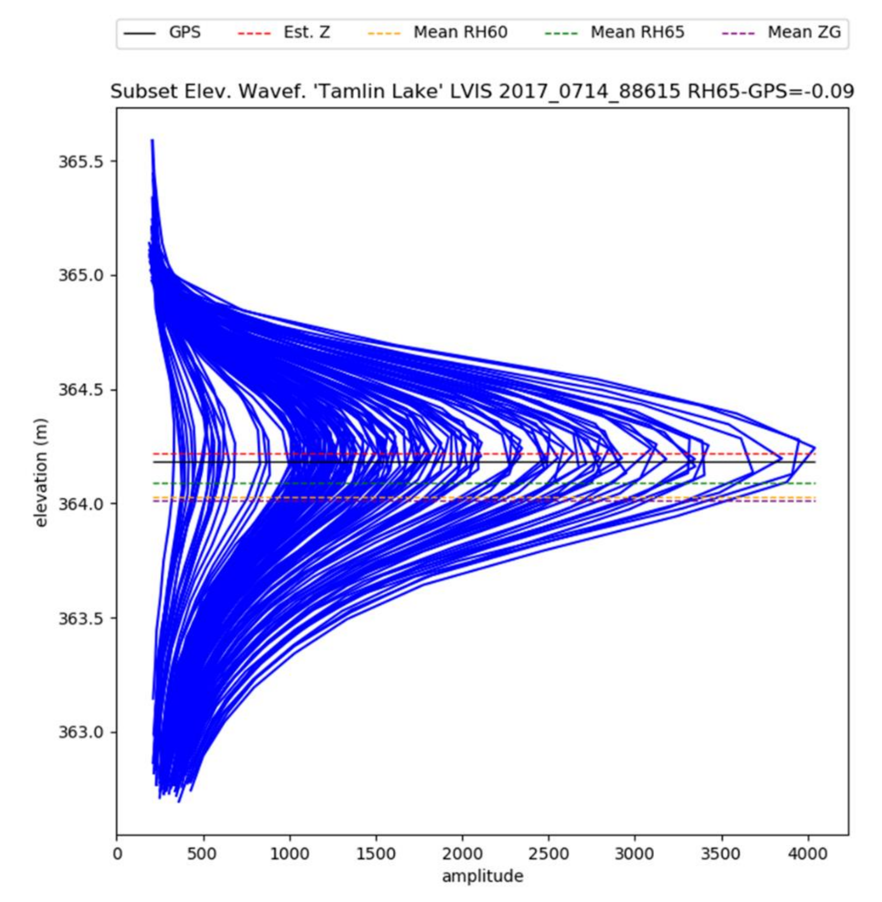
Dark Water

AirSWOT Ka-Band InSAR and LVIS LiDAR acquired along the same flight paths



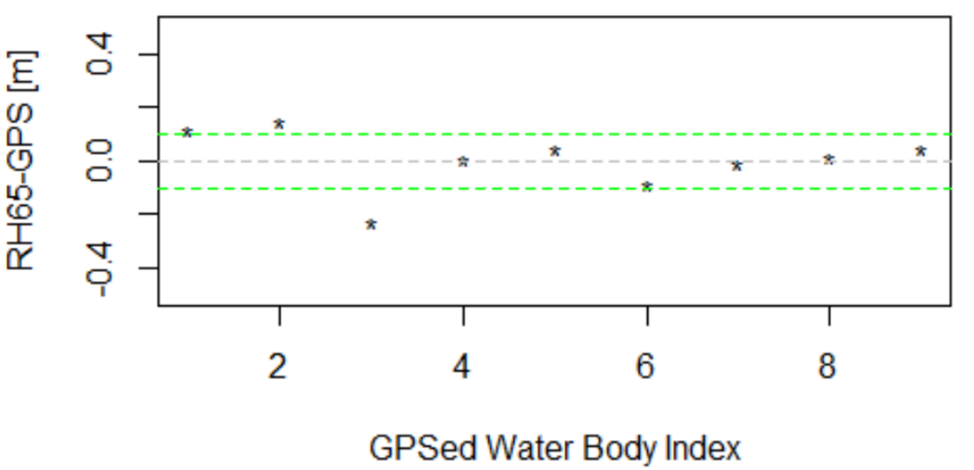
2. Results: LVIS Waveform Elevation Selection

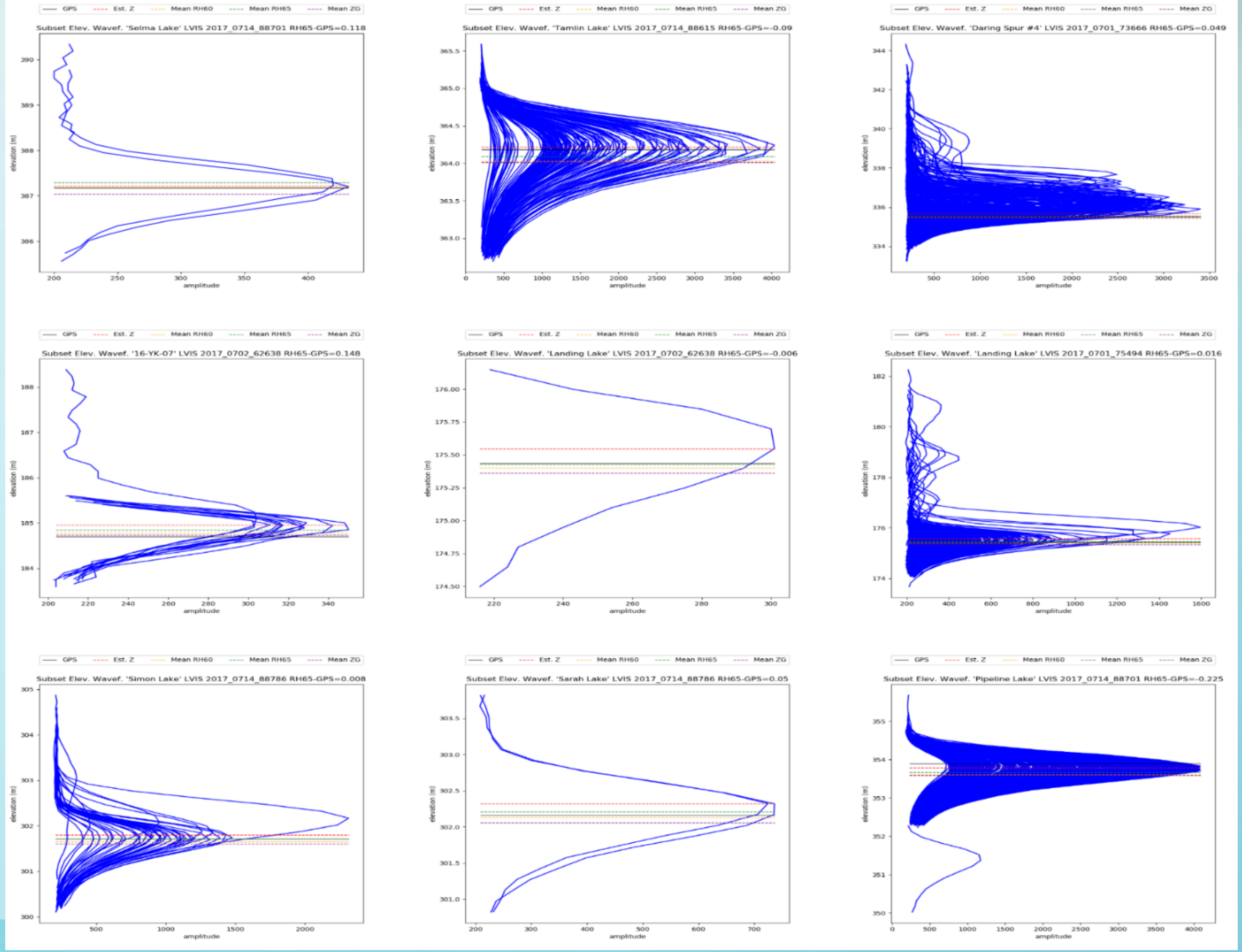




2. Results: LVIS Waveform Elevation Selection

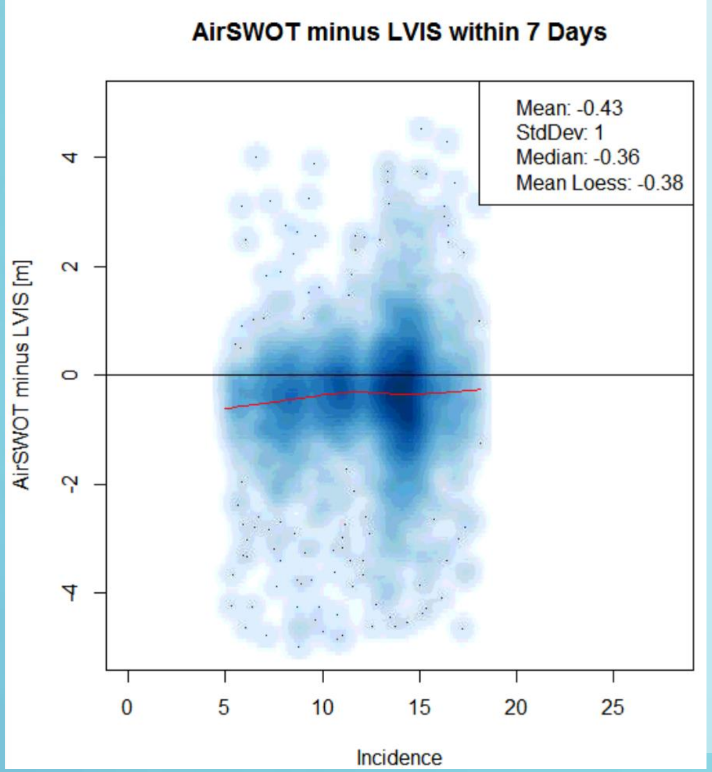
1. Compare GPS data to LVIS Waveform for 9 surveyed lakes
   - i. The difference between RH65 energy returns and GPS is within the GPS error tolerance (0.1m)

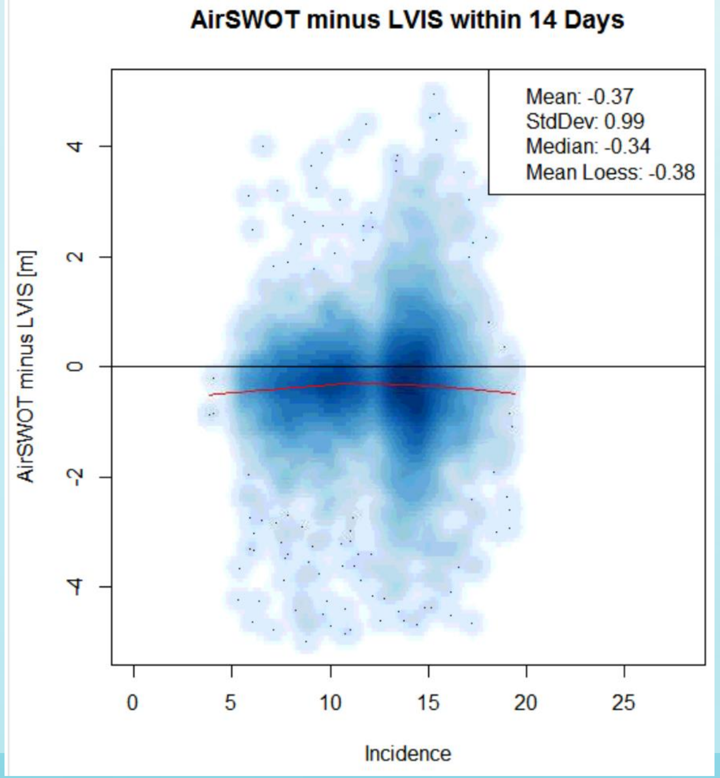


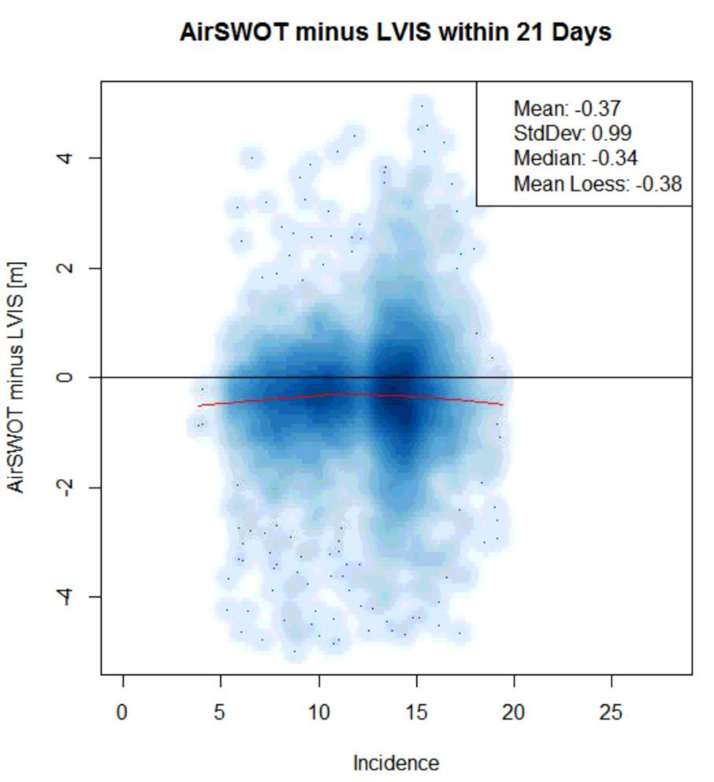


3. Results: Compare the LVIS RH65 with AirSWOT

1. Compare LVIS RH65 with AirSWOT
    - i. Minimal Incidence Angle Dependence
    - ii. Mean bias -39 cm


AirSWOT minus LVIS within 7 Days


AirSWOT minus LVIS within 14 Days


AirSWOT minus LVIS within 21 Days

4. Results: Identify filtering suggestions

Exclude area <150m^2

1. Exclude Incidence

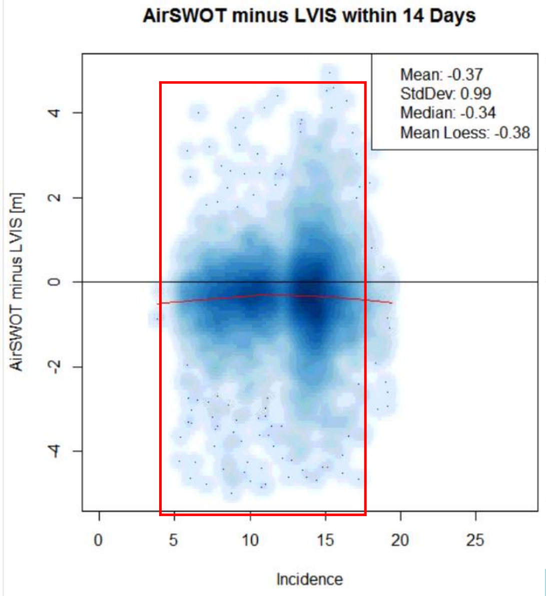
   x<5° or x>17°

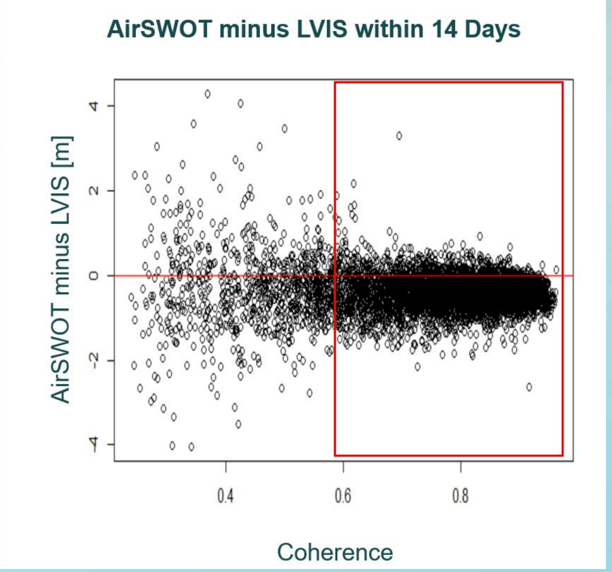
2. Exclude Coherence
   x>0.6

3. Exclude Magnitude
   x<5 dB

4. Exclude 'Error' *(Height Uncertainty)*

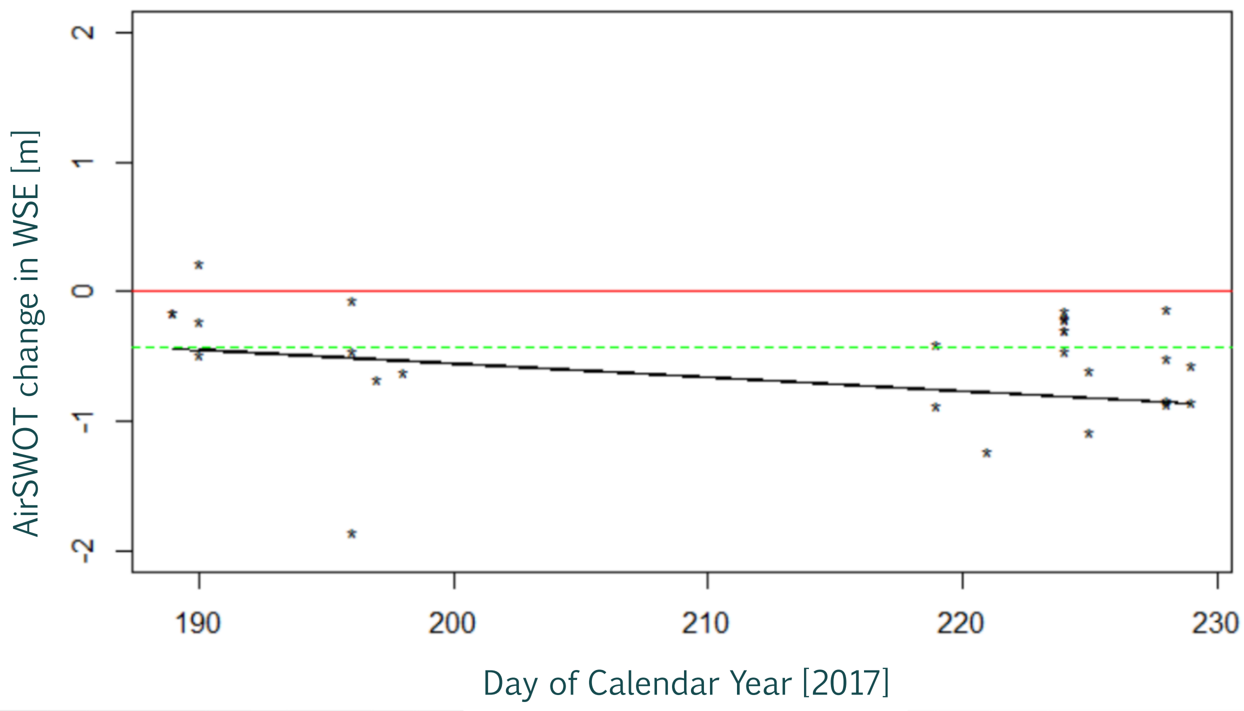
   x>2 m





5. Results: Demonstrate Landscape Scale Hydrologic Drawdown

Comparing AirSWOT with LVIS over subscales allows users to Estimate landscape-scale WSE change over between July and August, 2017



Conclusion

- Arctic/sub-Arctic lakes are globally important but their fine-scale spatial and temporal dynamics are poorly understood. Preliminary pre-SWOT studies using CubeSats and AirSWOT reveal strong sub-seasonal lake changes including surprisingly dynamic (in absolute terms) lakes on the Canadian Shield
- Based on field GPS cal/val surveys and LVIS, AirSWOT WSEs appear to have a ~40-45 cm systematic bias. Work is ongoing at JPL to better understand and correct this bias.
- AirSWOT color-infrared camera imagery (CIR) is critical for assessing Ka-band water detection algorithms. Data loss from “dark water” and misclassification from “bright mud” are evident in AirSWOT data including at low, SWOT-like incidence angles.
- Because of high spatial standard deviations and data gaps, it is not currently advised to use the 2017 ABoVE AirSWOT radar data for localized study areas (<150 km^2) or individual lakes. However, a broad-scale hydrological drawdowns are revealed over large areas when hundreds of lake WSEs are analyzed.

This research was funded by NASA

Special thanks to The JPL AirSWOT Radar Data Processing Group: Curtis Chen, Michael Denbina, Albert Chen, and Xiaoqing Wu

BACKUP SLIDES

Methods

- Assess prevalence of usable AirSWOT returns over water
  - Percent over whole swath range, recommended swath range, and near-SWOT incidence angles (outer swath AirSWOT only)
- Select the appropriate LVIS Geolocated Waveform elevation level to use as elevation reference
- Conduct pixel-pixel nearest-neighbor comparison of AirSWOT vs. LVIS
- Identify best practices for filtering and reducing WSE height errors
- Test the utility of the AirSWOT elevation for measuring landscape scale sub-seasonal hydrologic change (July and August)

Data

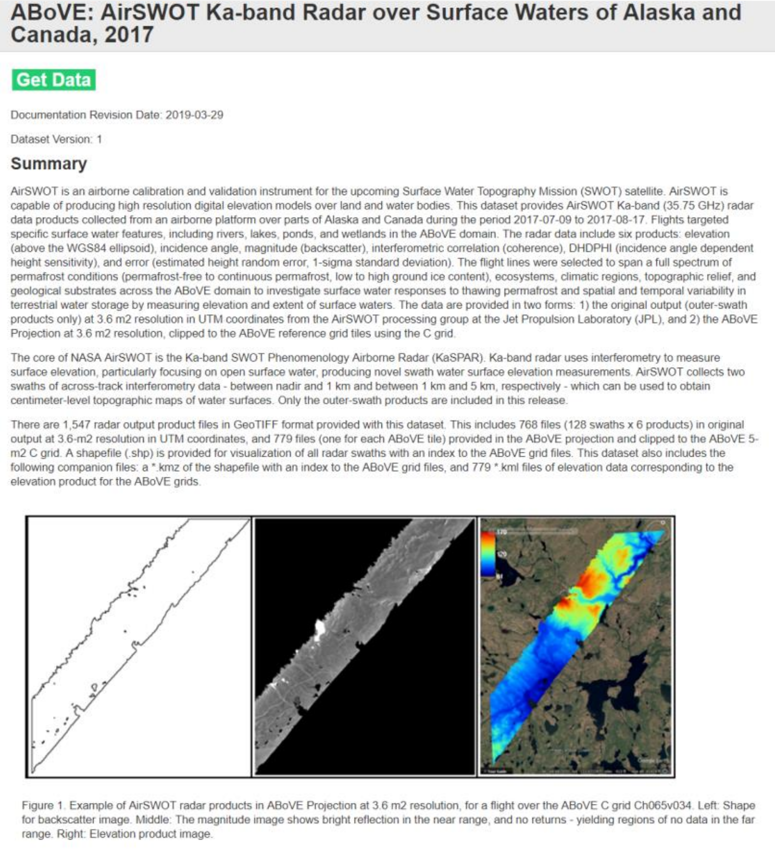
- **Airborne Data**
  - AirSWOT Radar
    - Elevation, magnitude, incidence, coherence,dhdphi (height sensitivity), error (height uncertainty)
  - AirSWOT CIR
    - Color Infrared Open Water (Kyzivat et al- In Prep)
  - LVIS (Land Vegetation and Ice Sensor)
    - LiDAR geolocated waveforms (*Hofton et al 1997, 2017*)
- **Field Data**
  - GPS
    - Lake Drifts and River Drags (*Pitcher et al –In Prep*)
  - Pressure Transducers
    - Long-term water surface elevations (seasonal, corrected by GPS)
- **AirSWOT Processing**
  - MERIT DEM (Yamazaki et al 2018), EGM1996 GEOID-15minute (NGA)
    - Explain basic processing steps (bundle adjustment corrections, automatic + manual QA, visual inspections)
  - Global Surface Water (Pekel et al 2016)
    - Phase unwrapping, bundle adjustment (land adjustments)

AirSWOT in ABoVE

ARCTIC – BOREAL VULNERABILITY EXPERIMENT

The 2017 ABoVE AirSWOT data is publically available on ORNL-DAAC:

https://daac.ornl.gov/cgi-bin/dsviewer.pl?ds_id=1646



ABoVE: AirSWOT Ka-band Radar over Surface Waters of Alaska and Canada, 2017

Documentation Revision Date: 2019-03-29

Dataset Version: 1

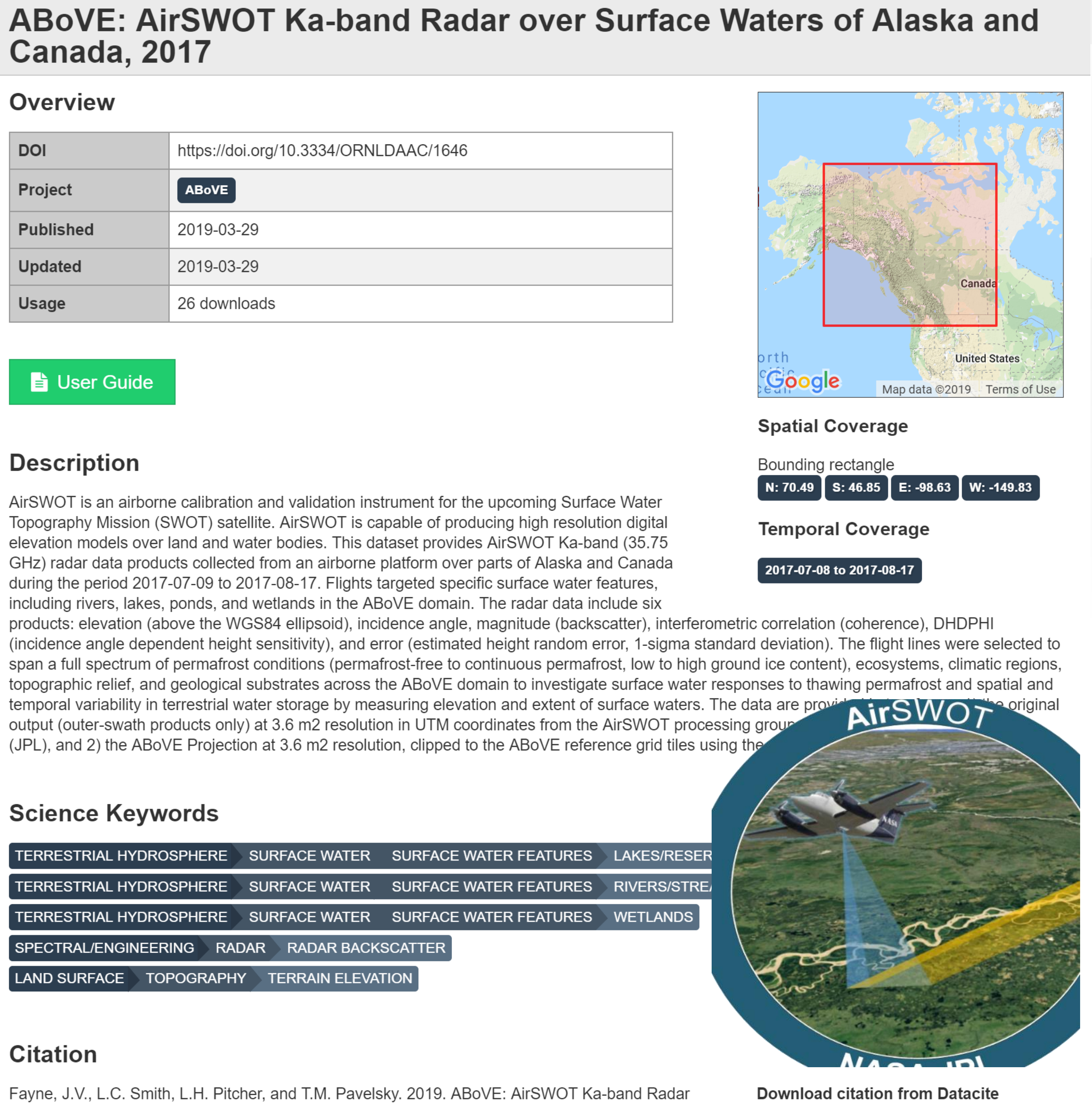
Summary

AirSWOT is an airborne calibration and validation instrument for the upcoming Surface Water Topography Mission (SWOT) satellite. AirSWOT is capable of producing high resolution digital elevation models over land and water bodies. This dataset provides AirSWOT Ka-band (35.75 GHz) radar data products collected from an airborne platform over parts of Alaska and Canada during the period 2017-07-09 to 2017-08-17. Flights targeted specific surface water features, including rivers, lakes, ponds, and wetlands in the ABoVE domain. The radar data include six products: elevation (above the WGS84 ellipsoid), incidence angle, magnitude (backscatter), interferometric correlation (coherence), DHDPHI (incidence angle dependent height sensitivity), and error (estimated height random error, 1-sigma standard deviation). The flight lines were selected to span a full spectrum of permafrost conditions (permafrost-free to continuous permafrost, low to high ground ice content), ecosystems, climatic regions, topographic relief, and geological substrates across the ABoVE domain to investigate surface water responses to thawing permafrost and spatial and temporal variability in terrestrial water storage by measuring elevation and extent of surface waters. The data are provided in two forms: 1) the original output (outer-swath products only) at 3.6 m2 resolution in UTM coordinates from the AirSWOT processing group at the Jet Propulsion Laboratory (JPL), and 2) the ABoVE Projection at 3.6 m2 resolution, clipped to the ABoVE reference grid tiles using the C grid.

The core of NASA AirSWOT is the Ka-band SWOT Phenomenology Airborne Radar (KaSPAR). Ka-band radar uses interferometry to measure surface elevation, particularly focusing on open surface water, producing novel swath water surface elevation measurements. AirSWOT collects two swaths of across-track interferometry data - between nadir and 1 km and between 1 km and 5 km, respectively - which can be used to obtain centimeter-level topographic maps of water surfaces. Only the outer-swath products are included in this release.

There are 1,547 radar output product files in GeoTIFF format provided with this dataset. This includes 768 files (128 swaths x 6 products) in original output at 3.6-m2 resolution in UTM coordinates, and 779 files (one for each ABoVE tile) provided in the ABoVE projection and clipped to the ABoVE 5-m2 C grid. A shapefile (.shp) is provided for visualization of all radar swaths with an index to the ABoVE grid files. This dataset also includes the following companion files: a *.kmz of the shapefile with an index to the ABoVE grid files, and 779 *.kml files of elevation data corresponding to the elevation product for the ABoVE grids.

Figure 1. Example of AirSWOT radar products in ABoVE Projection at 3.6 m2 resolution, for a flight over the ABoVE C grid Ch065v034. Left: Shape for backscatter image. Middle: The magnitude image shows bright reflection in the near range, and no returns - yielding regions of no data in the far range. Right: Elevation product image.



ABoVE: AirSWOT Ka-band Radar over Surface Waters of Alaska and Canada, 2017

Overview

DOI	https://doi.org/10.3334/ORNLDAAC/1646
Project	ABoVE
Published	2019-03-29
Updated	2019-03-29
Usage	26 downloads

Spatial Coverage

Bounding rectangle

N: 70.49 S: 46.85 E: -98.63 W: -149.83

Temporal Coverage

2017-07-08 to 2017-08-17

Description

AirSWOT is an airborne calibration and validation instrument for the upcoming Surface Water Topography Mission (SWOT) satellite. AirSWOT is capable of producing high resolution digital elevation models over land and water bodies. This dataset provides AirSWOT Ka-band (35.75 GHz) radar data products collected from an airborne platform over parts of Alaska and Canada during the period 2017-07-09 to 2017-08-17. Flights targeted specific surface water features, including rivers, lakes, ponds, and wetlands in the ABoVE domain. The radar data include six products: elevation (above the WGS84 ellipsoid), incidence angle, magnitude (backscatter), interferometric correlation (coherence), DHDPHI (incidence angle dependent height sensitivity), and error (estimated height random error, 1-sigma standard deviation). The flight lines were selected to span a full spectrum of permafrost conditions (permafrost-free to continuous permafrost, low to high ground ice content), ecosystems, climatic regions, topographic relief, and geological substrates across the ABoVE domain to investigate surface water responses to thawing permafrost and spatial and temporal variability in terrestrial water storage by measuring elevation and extent of surface waters. The data are provi the original output (outer-swath products only) at 3.6 m2 resolution in UTM coordinates from the AirSWOT processing grou (JPL), and 2) the ABoVE Projection at 3.6 m2 resolution, clipped to the ABoVE reference grid tiles using the

Science Keywords

TERRESTRIAL HYDROSPHERE › SURFACE WATER › SURFACE WATER FEATURES › LAKES/RESER
TERRESTRIAL HYDROSPHERE › SURFACE WATER › SURFACE WATER FEATURES › RIVERS/STRE
TERRESTRIAL HYDROSPHERE › SURFACE WATER › SURFACE WATER FEATURES › WETLANDS
SPECTRAL/ENGINEERING › RADAR › RADAR BACKSCATTER
LAND SURFACE › TOPOGRAPHY › TERRAIN ELEVATION

Citation

Fayne, J.V., L.C. Smith, L.H. Pitcher, and T.M. Pavelsky. 2019. ABoVE: AirSWOT Ka-band Radar

Download citation from Datacite

AirSWOT color-infrared imagery

- 1m pixel size with georeferencing accuracy assessed for each image
- Covers 38% of foundational flight lines
- 3,167 km^2 of open water mapped
- Water mask dataset to be posted
- https://doi.org/10.3334/ORNLDAAC/1643

DAAC Home > Get Data > NASA Projects > Arctic-Boreal Vulnerability Experiment (ABoVE) > User guide

ABoVE: AirSWOT Color-Infrared Imagery Over Alaska and Canada, 2017

Documentation Revision Date: 2018-11-26

Data Set Version: 1

Summary

This dataset contains georeferenced three-band orthomosaics of green, red, and near-infrared (NIR) digital imagery at 1m resolution collected over selected surface waters across Alaska and Canada between July 9 and August 17, 2017. The orthomosaics were generated from individual images collected by a Cirrus Designs Digital Camera System (DCS) mounted on a Beechcraft Super King Air B200 aircraft from approximately 8-11 km altitude. Flights were over the following areas: Saskatchewan River, Saskatoon, Inuvik, Yukon River including Yukon Flats, Sagavanirktok River, Arctic Coastal Plain, Old Crow Flats, Peace-Athabasca Delta, Slave River, Athabasca River, Yellowknife, Great Slave Lake, Mackenzie River and Delta, Daring Lake, and other selected locations. Most locations were imaged twice during two flight campaigns in Canada and Alaska extending roughly SE-NW then NW-SE up to a month apart. The data were georeferenced using 303 ground control points (GCPs) across the study region.

These data are intended to validate surface water extent to aid interpretation of AirSWOT Ka-band radar returns as part of the AirSWOT ABoVE project. The core of AirSWOT is the Ka-band SWOT Phenomenology Airborne Radar (KaSPAR). It collects two swaths of across-track interferometry data - between nadir and 1 km and between 1 km and 5 km, respectively - which can be used to obtain centimeter-level topographic maps of water surfaces. In addition, KaSPAR has an along-track interferometer that can be used to measure the temporal decorrelation of water surfaces, as well as the water radial velocity.

There are 335 data files with this dataset. This includes 330 orthomosaics in GeoTIFF (.tif) format, four shapefiles compressed in .zip format, and one comma-separated file (.csv). The shapefiles and .csv provide the ground control point data. Companion files: we include the 330 orthomosaic data files and three shapefiles transformed to .kmz format for viewing in Google Earth.

Figure 1. This figure shows open surface waters (black areas) for a location northwest of Fort Saskatchewan, Canada. This image for ABoVE grid ch078v097 was acquired July 9, 2017.

Lake size distributions follow power-law relationships

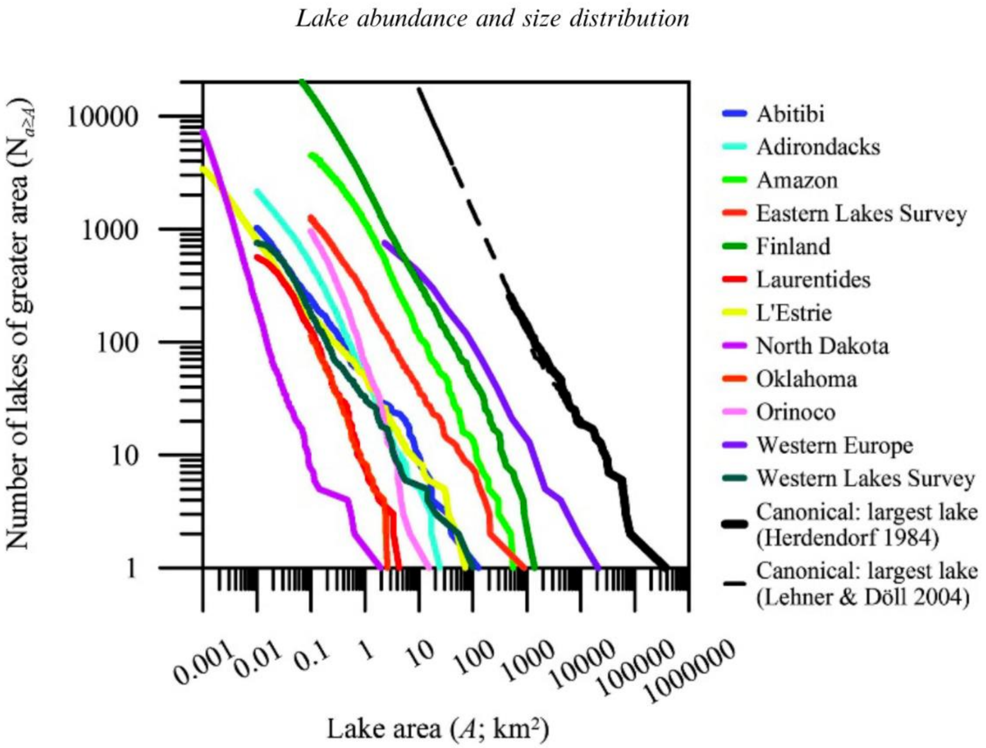


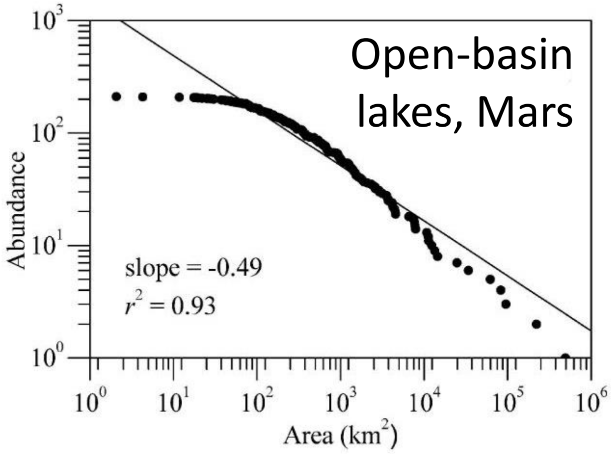
Fig. 4. Plots of data on the axes implied by Eq. 3. Statistical fits of Eq. 3 to these data are shown in Table 1. Data are only plotted throughout the range of lake sizes that could be reasonably expected to be comprehensively censused using the resolution of GIS coverages available (see Table 1). The black lines represent canonical (complete) censuses of world lakes (Herdendorf 1984; Lehner and Döll 2004).

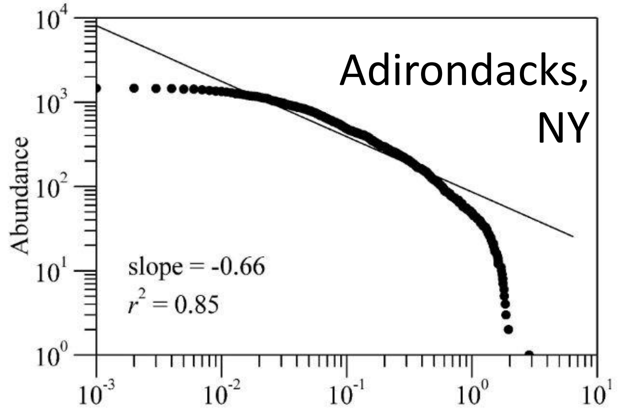
Downing et al. 2006, *L&O*

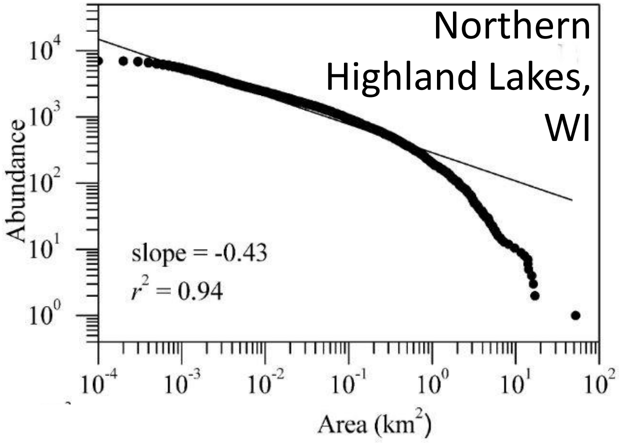
- From a global dataset of lakes larger than 0.001 km^2 (0.1 ha)
- Power law evident as straight line on log-log CDF

Lake size distributions follow power-law relationships

- Lake sizes follow an exponential-like distribution on Earth and Mars!
- Regional differences
- Different regime for small areas







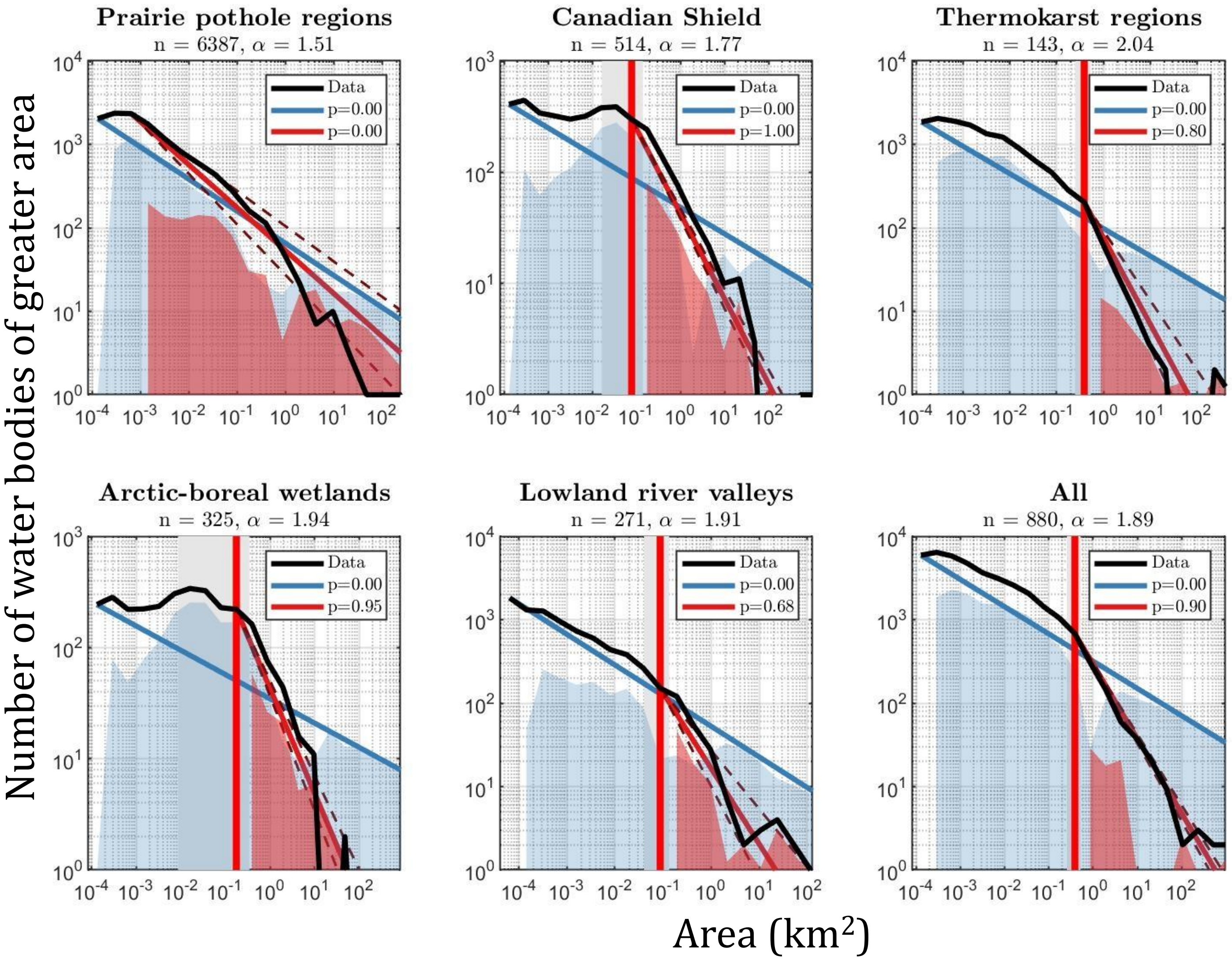
Seekell and Pace 2011, *L&O*
Fasset and Head 2008, *Icarus*

ethan_kyzivat@brown.edu
February 11, 2019

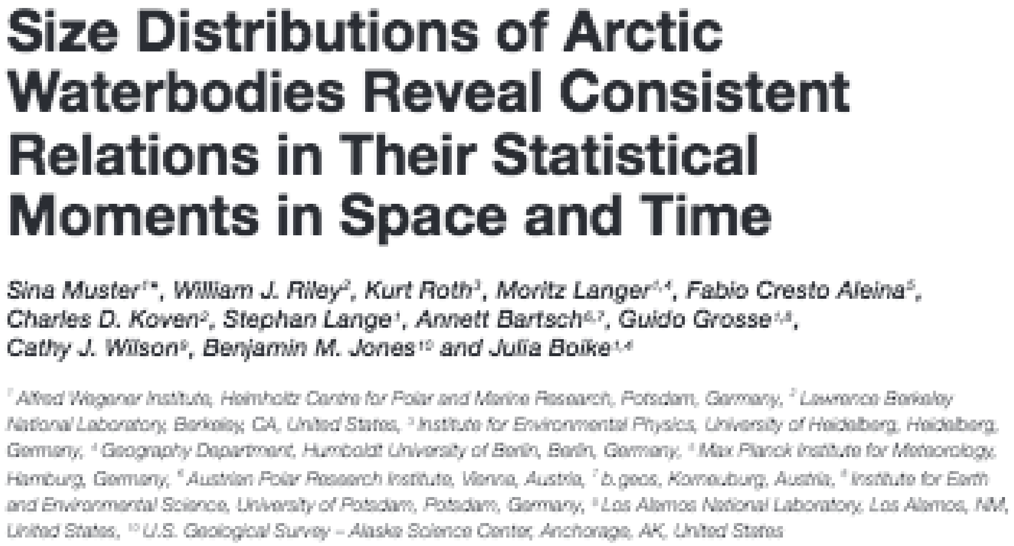
AirSWOT CIR Power laws vary by physiographic region

(E. Kyzivat, in prep)

- All categories except prairie pothole lakes could fit a power law over a portion of their area domains
- For the entire dataset, this regime begins at 0.34 ± 0.13 km^2



AirSWOT CIR high-resolution water maps modify previous findings

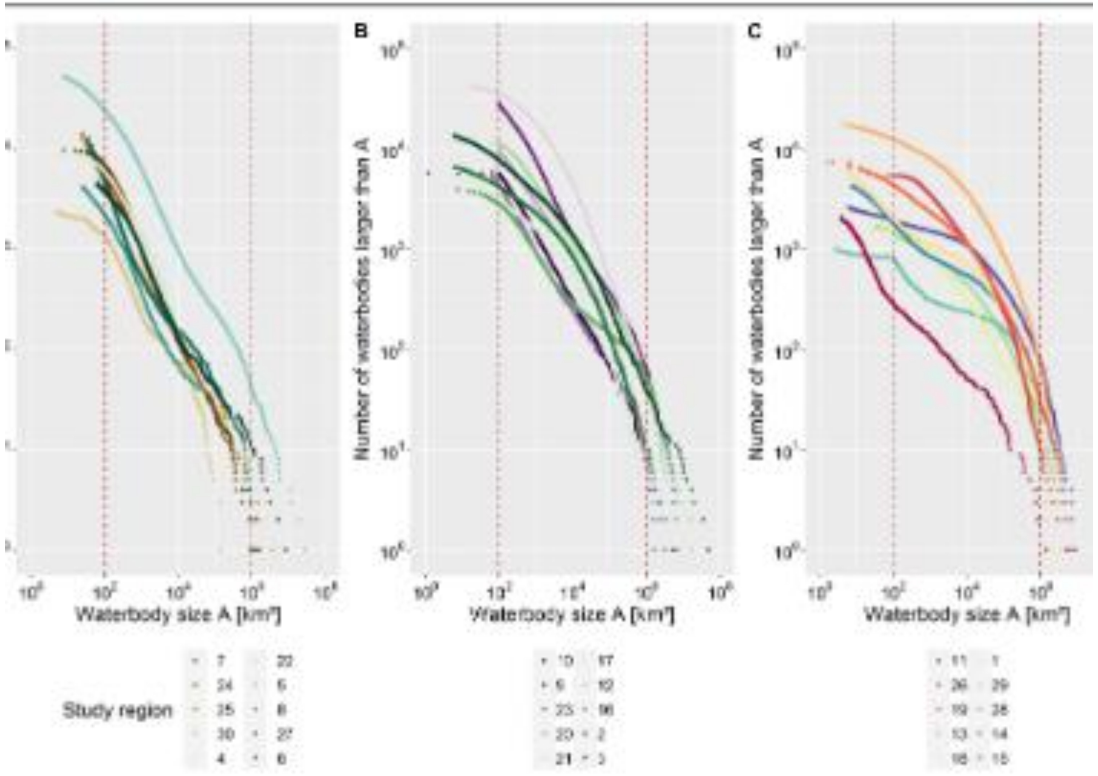


Size Distributions of Arctic Waterbodies Reveal Consistent Relations in Their Statistical Moments in Space and Time

Sina Muster[1], William J. Riley[2], Kurt Roth[3], Moritz Langer[1,4], Fabio Cresto Aleina[5], Charles D. Koven[2], Stephan Lange[1], Annett Bartsch[6,7], Guido Grosse[1,8], Cathy J. Wilson[9], Benjamin M. Jones[10] and Julia Boike[1,4]*

[1] Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Potsdam, Germany, [2] Lawrence Berkeley National Laboratory, Berkeley, CA, United States, [3] Institute for Environmental Physics, University of Heidelberg, Heidelberg, Germany, [4] Geography Department, Humboldt University of Berlin, Berlin, Germany, [5] Max Planck Institute for Meteorology, Hamburg, Germany, [6] Austrian Polar Research Institute, Vienna, Austria, [7] b.geos, Korneuburg, Austria, [8] Institute for Earth and Environmental Science, University of Potsdam, Potsdam, Germany, [9] Los Alamos National Laboratory, Los Alamos, NM, United States, [10] U.S. Geological Survey – Alaska Science Center, Anchorage, AK, United States

Muster et al. 2019, *Frontiers in Earth Sci.*



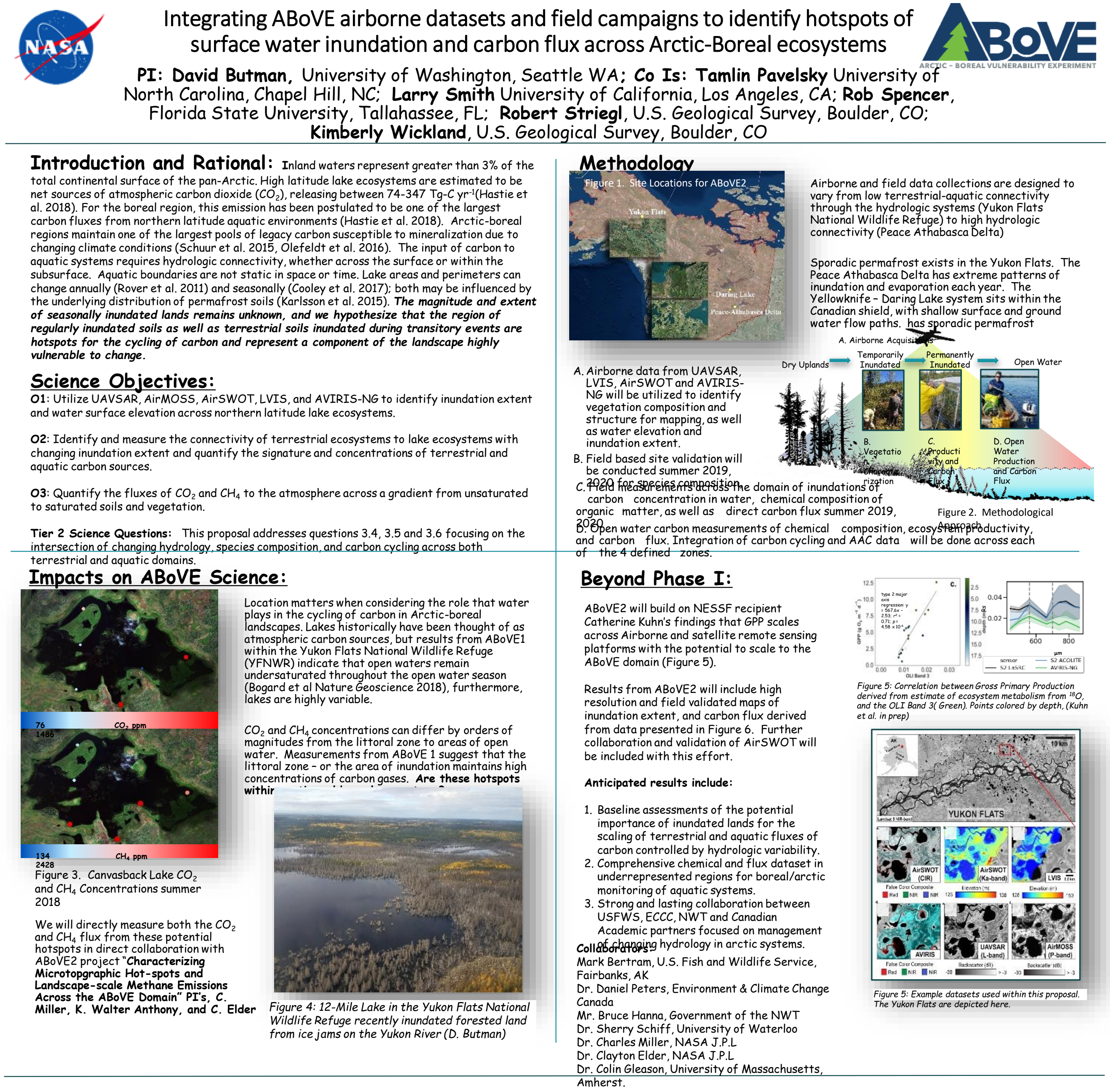
-C) A cumulative histogram or rank/frequency plot of waterbody sizes in the thirty study regions (split into three groups). Dotted lines in
er size limits used for the analysis (0.0001 and 1 km^2, respectively). Study regions are sorted according to their mean waterbodies size (
th the x and y axes are plotted on logarithmic scales. For study region numbers see **Figure 1** and **Supplementary Table 1**.

ethan_kyzivat@brown.edu
February 11, 2019

Preliminary Conclusions (E. Kyzivat)

1. An object-based, connectivity-preserving water classification is suitable for identifying open water pixels to extract WSEs from imagery
2. There is no regionally-consistent size-area distribution for global lakes and ponds.
3. The global number and size of lakes and ponds is still unknown and must be determined empirically.
4. Methane models should make use of high-resolution water distribution metrics.

New Phase 2 ABoVE project (led by David Butman, UW) will have a CH4 focus…



Integrating ABoVE airborne datasets and field campaigns to identify hotspots of surface water inundation and carbon flux across Arctic-Boreal ecosystems

PI: David Butman, University of Washington, Seattle WA; **Co Is: Tamlin Pavelsky** University of North Carolina, Chapel Hill, NC; **Larry Smith** University of California, Los Angeles, CA; **Rob Spencer**, Florida State University, Tallahassee, FL; **Robert Striegl**, U.S. Geological Survey, Boulder, CO; **Kimberly Wickland**, U.S. Geological Survey, Boulder, CO

Introduction and Rational:

Inland waters represent greater than 3% of the total continental surface of the pan-Arctic. High latitude lake ecosystems are estimated to be net sources of atmospheric carbon dioxide (CO_2), releasing between 74-347 Tg-C yr^{-1}(Hastie et al. 2018). For the boreal region, this emission has been postulated to be one of the largest carbon fluxes from northern latitude aquatic environments (Hastie et al. 2018). Arctic-boreal regions maintain one of the largest pools of legacy carbon susceptible to mineralization due to changing climate conditions (Schuur et al. 2015, Olefeldt et al. 2016). The input of carbon to aquatic systems requires hydrologic connectivity, whether across the surface or within the subsurface. Aquatic boundaries are not static in space or time. Lake areas and perimeters can change annually (Rover et al. 2011) and seasonally (Cooley et al. 2017); both may be influenced by the underlying distribution of permafrost soils (Karlsson et al. 2015). ***The magnitude and extent of seasonally inundated lands remains unknown, and we hypothesize that the region of regularly inundated soils as well as terrestrial soils inundated during transitory events are hotspots for the cycling of carbon and represent a component of the landscape highly vulnerable to change.***

Science Objectives:

O1: Utilize UAVSAR, AirMOSS, AirSWOT, LVIS, and AVIRIS-NG to identify inundation extent and water surface elevation across northern latitude lake ecosystems.

O2: Identify and measure the connectivity of terrestrial ecosystems to lake ecosystems with changing inundation extent and quantify the signature and concentrations of terrestrial and aquatic carbon sources.

O3: Quantify the fluxes of CO_2 and CH_4 to the atmosphere across a gradient from unsaturated to saturated soils and vegetation.

Tier 2 Science Questions: This proposal addresses questions 3.4, 3.5 and 3.6 focusing on the intersection of changing hydrology, species composition, and carbon cycling across both terrestrial and aquatic domains.

Impacts on ABoVE Science:

Location matters when considering the role that water plays in the cycling of carbon in Arctic-boreal landscapes. Lakes historically have been thought of as atmospheric carbon sources, but results from ABoVE1 within the Yukon Flats National Wildlife Refuge (YFNWR) indicate that open waters remain undersaturated throughout the open water season (Bogard et al Nature Geoscience 2018), furthermore, lakes are highly variable.

CO_2 and CH_4 concentrations can differ by orders of magnitudes from the littoral zone to areas of open water. Measurements from ABoVE 1 suggest that the littoral zone – or the area of inundation maintains high concentrations of carbon gases. **Are these hotspots within**

Figure 3. Canvasback Lake CO_2 and CH_4 Concentrations summer 2018

We will directly measure both the CO_2 and CH_4 flux from these potential hotspots in direct collaboration with ABoVE2 project "**Characterizing Microtopgraphic Hot-spots and Landscape-scale Methane Emissions Across the ABoVE Domain" PI's, C. Miller, K. Walter Anthony, and C. Elder**

Figure 4: 12-Mile Lake in the Yukon Flats National Wildlife Refuge recently inundated forested land from ice jams on the Yukon River (D. Butman)

Methodology

Figure 1. Site Locations for ABoVE2

Airborne and field data collections are designed to vary from low terrestrial-aquatic connectivity through the hydrologic systems (Yukon Flats National Wildlife Refuge) to high hydrologic connectivity (Peace Athabasca Delta)

Sporadic permafrost exists in the Yukon Flats. The Peace Athabasca Delta has extreme patterns of inundation and evaporation each year. The Yellowknife – Daring Lake system sits within the Canadian shield, with shallow surface and ground water flow paths. has sporadic permafrost

A. Airborne data from UAVSAR, LVIS, AirSWOT and AVIRIS-NG will be utilized to identify vegetation composition and structure for mapping, as well as water elevation and inundation extent.

B. Field based site validation will be conducted summer 2019, 2020 for species composition.

C. Field measurements across the domain of inundations of carbon concentration in water, chemical composition of organic matter, as well as direct carbon flux summer 2019, 2020

D. Open water carbon measurements of chemical composition, ecosystem productivity, and carbon flux. Integration of carbon cycling and AAC data will be done across each of the 4 defined zones.

Figure 2. Methodological Approach

Beyond Phase I:

ABoVE2 will build on NESSF recipient Catherine Kuhn's findings that GPP scales across Airborne and satellite remote sensing platforms with the potential to scale to the ABoVE domain (Figure 5).

Results from ABoVE2 will include high resolution and field validated maps of inundation extent, and carbon flux derived from data presented in Figure 6. Further collaboration and validation of AirSWOT will be included with this effort.

Anticipated results include:

1. Baseline assessments of the potential importance of inundated lands for the scaling of terrestrial and aquatic fluxes of carbon controlled by hydrologic variability.
2. Comprehensive chemical and flux dataset in underrepresented regions for boreal/arctic monitoring of aquatic systems.
3. Strong and lasting collaboration between USFWS, ECCC, NWT and Canadian Academic partners focused on management of changing hydrology in arctic systems.

Collaborators:
Mark Bertram, U.S. Fish and Wildlife Service, Fairbanks, AK
Dr. Daniel Peters, Environment & Climate Change Canada
Mr. Bruce Hanna, Government of the NWT
Dr. Sherry Schiff, University of Waterloo
Dr. Charles Miller, NASA J.P.L
Dr. Clayton Elder, NASA J.P.L
Dr. Colin Gleason, University of Massachusetts, Amherst.

Figure 5: Correlation between Gross Primary Production derived from estimate of ecosystem metabolism from ^{18}O, and the OLI Band 3(Green). Points colored by depth, (Kuhn et al. in prep)

Figure 5: Example datasets used within this proposal. The Yukon Flats are depicted here.