Arctic Boreal Vulnerability Experiment (ABoVE) Airborne Monitoring of Arctic Ecosystem Change

Charles Miller, Deputy Science Lead
Jet Propulsion Laboratory, California Institute of Technology

Peter Griffith, ABoVE Project Manager
and the ABoVE Science Team

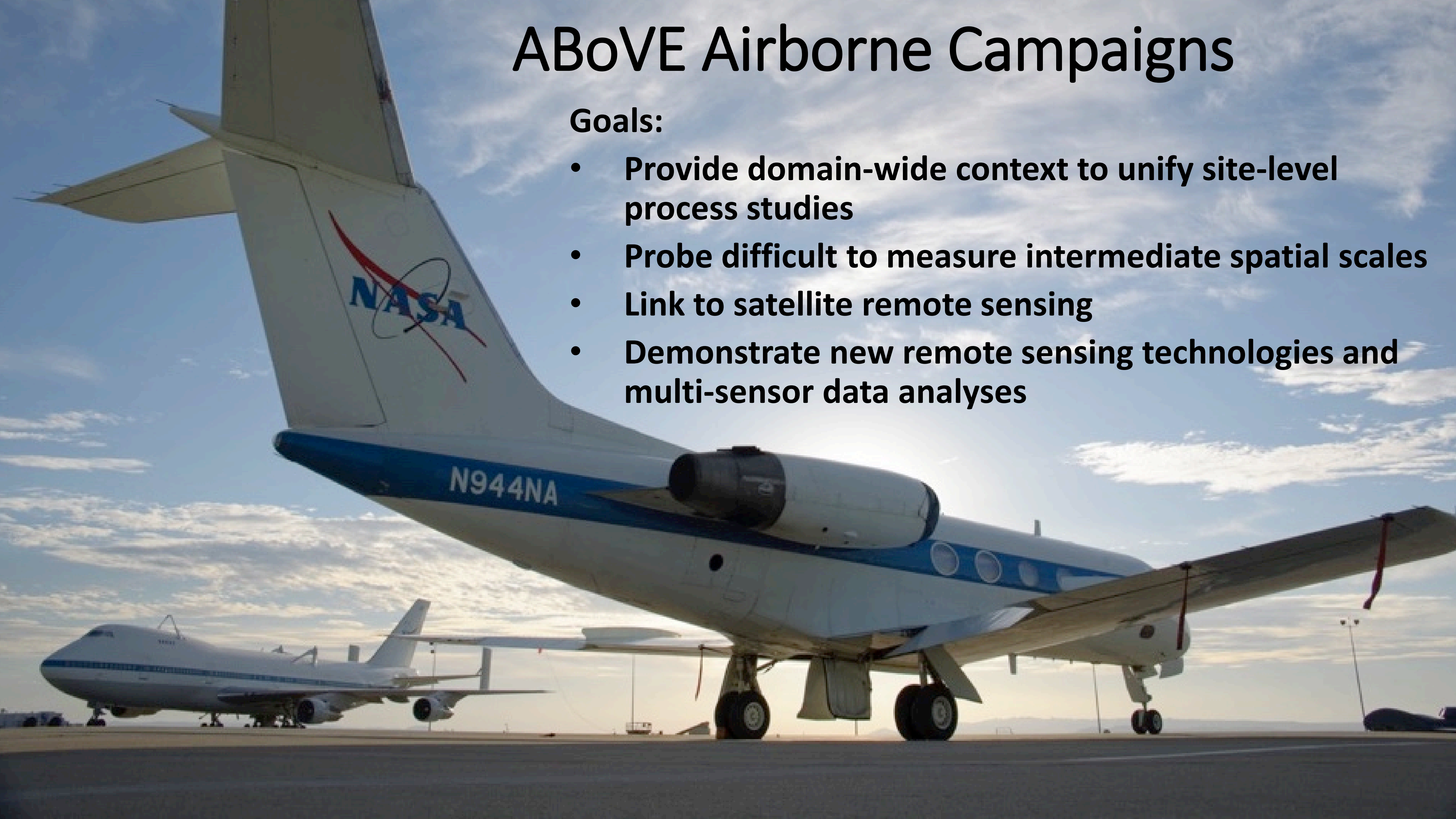
ABoVE Virtual Science Team Meeting

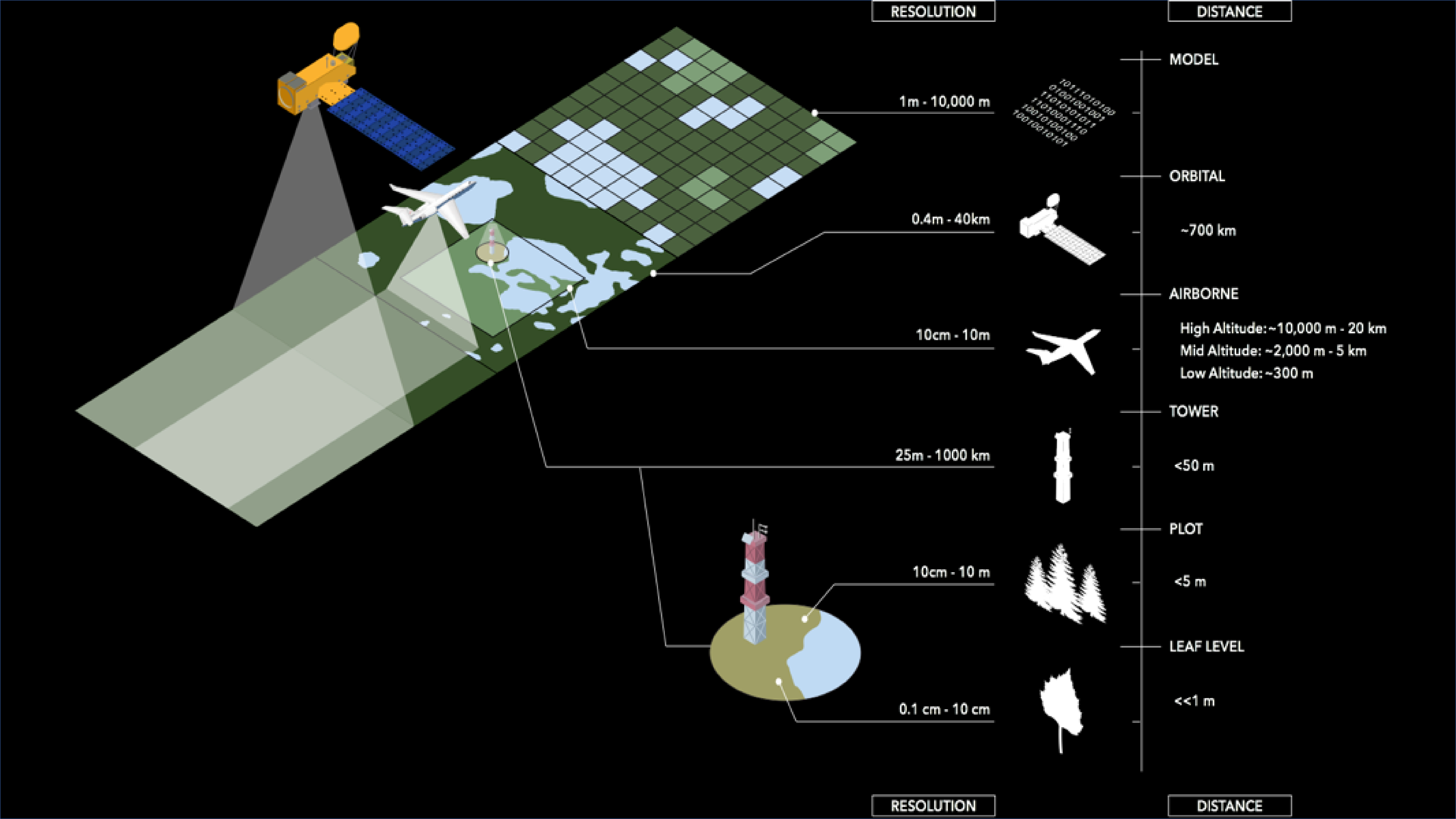
1 June 2020

ABoVE Airborne Campaigns

Goals:

- **Provide domain-wide context to unify site-level process studies**
- **Probe difficult to measure intermediate spatial scales**
- **Link to satellite remote sensing**
- **Demonstrate new remote sensing technologies and multi-sensor data analyses**




RESOLUTION
DISTANCE
MODEL
1m - 10,000 m
ORBITAL
0.4m - 40km
~700 km
AIRBORNE
10cm - 10m
High Altitude:~10,000 m - 20 km
Mid Altitude: ~2,000 m - 5 km
Low Altitude: ~300 m
TOWER
25m - 1000 km
<50 m
PLOT
10cm - 10 m
<5 m
LEAF LEVEL
0.1 cm - 10 cm
<<1 m
RESOLUTION
DISTANCE

Environmental Research Letters

EDITORIAL • OPEN ACCESS

An overview of ABoVE airborne campaign data acquisitions and science opportunities

C E Miller[1], P C Griffith[2], S J Goetz[3], E E Hoy[4], N Pinto[1], I B McCubbin[1], A K Thorpe[1], M Hofton[5], D Hodkinson[2], C Hansen[6] + Show full author list

Published 26 July 2019 •

Environmental Research Letters, Volume 14, Number 8

Resiliency and Vulnerability of Arctic and Boreal Ecosystems to Environmental Change: Advances and Outcomes of ABoVE (the Arctic Boreal Vulnerability Experiment)

Article PDF

Article ePub

2017 AAC flight lines developed based on careful consideration of all objectives and requirements

- SAR flight lines serve as framework & sample important ground truth sites
- Cover bioclimatic gradients across ABoVE domain (~4M km2)
- Lines & grids modified as needed for for PI-led projects

2017: L-band SAR, AVIRIS, LVIS, AirSWOT, CFIS, Arctic-CAP, ASCENDS, P-band SAR

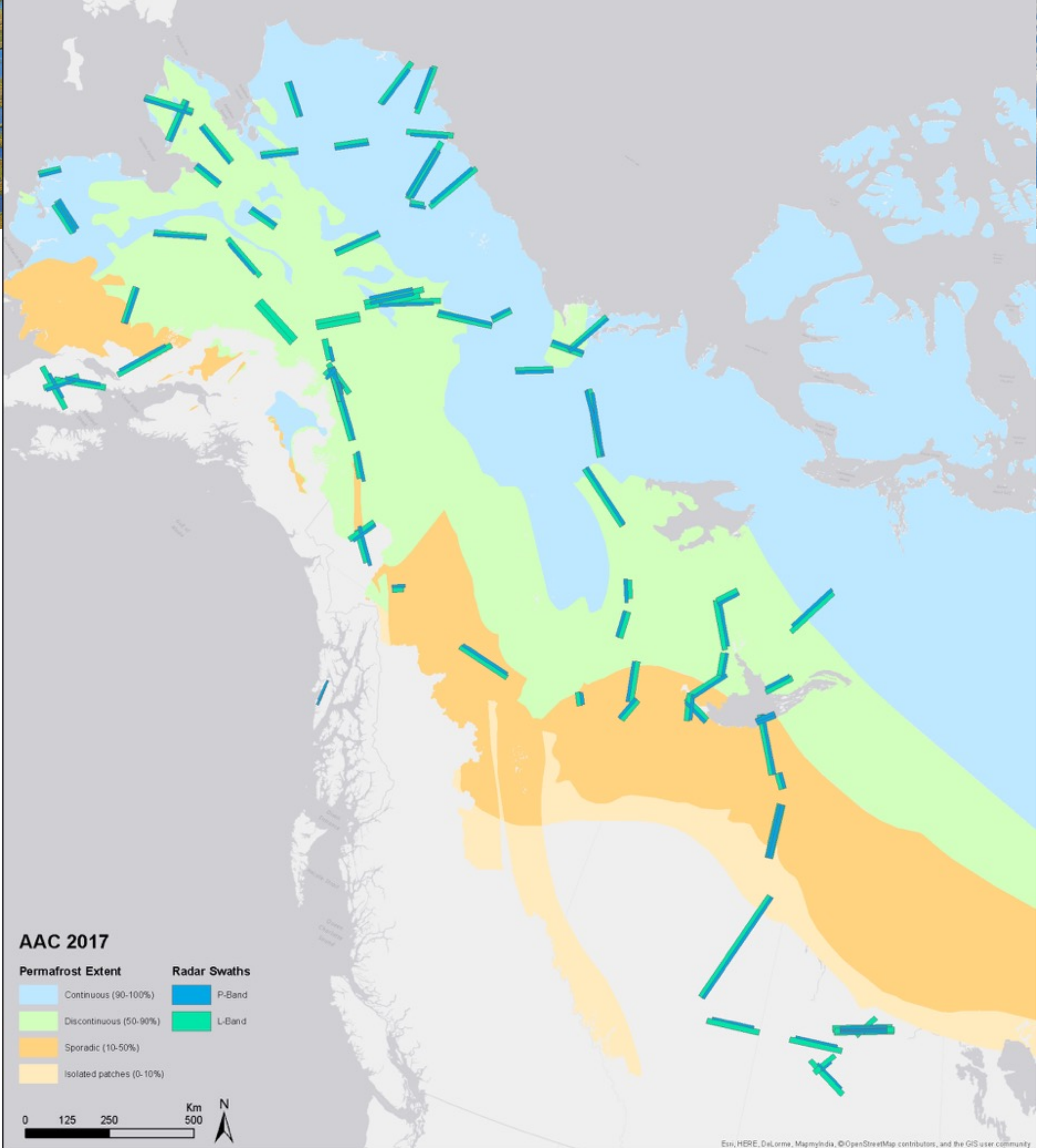
2018: L-band SAR, AVIRIS

2019: L-band SAR, AVIRIS, LVIS

2020: L-band SAR, AVIRIS – Delayed to 2021

2021: SnowEx-ABoVE (TBC)

Miller et al., ERL (2019)



AIRCRAFT, SCIENCE AND ABoVE

http://above.nasa.gov/airborne

National Aeronautics and Space Administration

NASA's Arctic-Boreal Vulnerability Experiment (ABoVE) campaign used aircraft to measure landscape-scale changes in vulnerable arctic-boreal ecosystems that satellites and ground instruments alone could not.

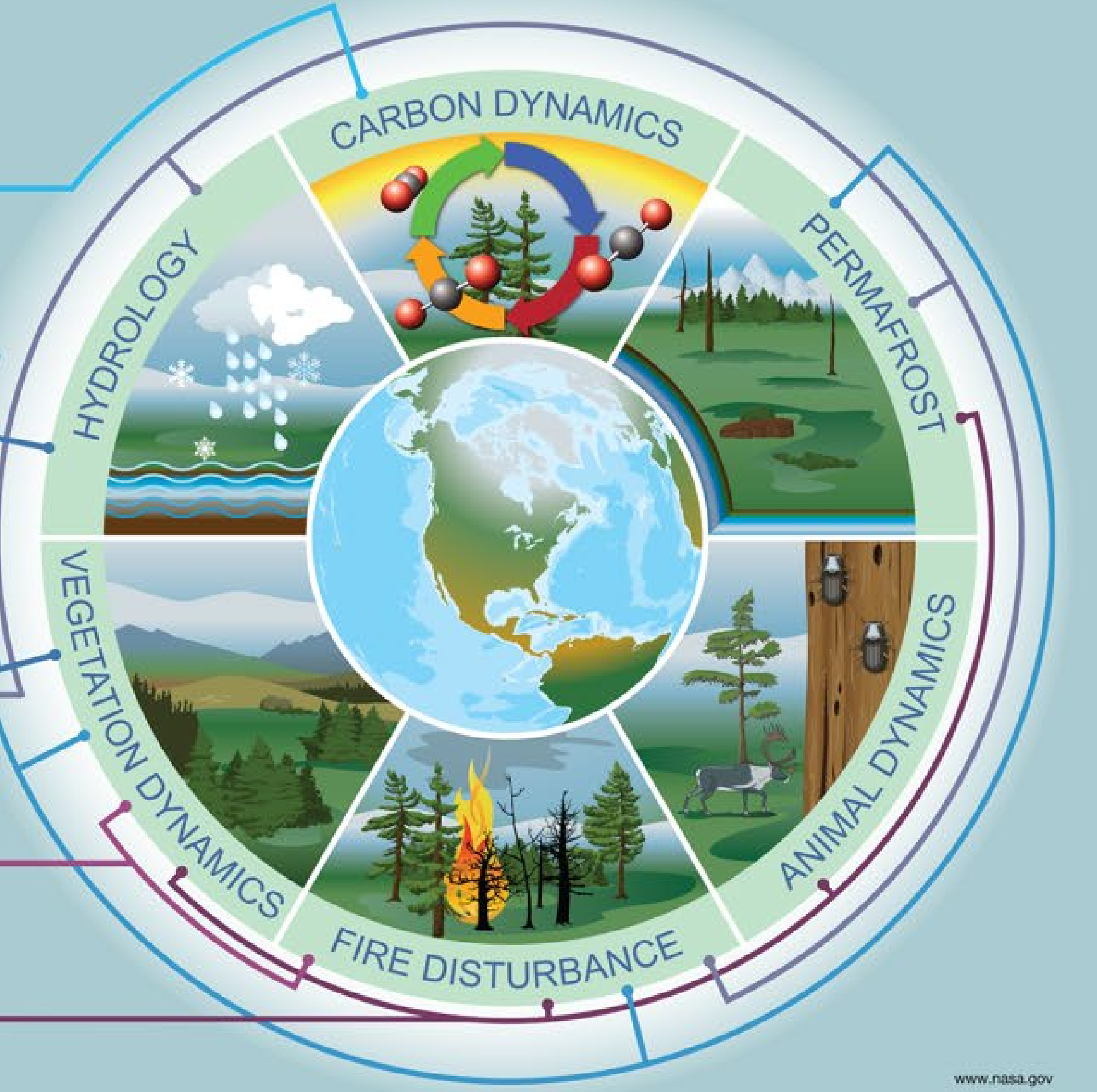
HOW MIGHT EARTH BEHAVE IN A WARMER WORLD?

Rapidly evolving landscapes like the arctic-boreal ecosystems of Alaska and western Canada provide real-time examples of how seasonally frozen landscapes adjust to a changing climate. ABoVE aircraft used their unique perspective to help us understand the regional-scale changes in topography, vegetation and more that satellites and ground instruments can't see.

Here are three things we wouldn't know without ABoVE aircraft data:

- **WILDFIRES ARE CHANGING THE ARCTIC-BOREAL LANDSCAPE:** Measurements aboard the G-III showed where wildfire had thawed permafrost, creating rougher, wetter terrain. This change could have local to global implications, including changes in the distribution and growth of local plant species to the regional acceleration of carbon dioxide (CO_2) and methane (CH_4) released into the atmosphere.
- **WE'RE LEARNING WHAT "GREEN" MEANS:** Changes in NDVI, a measurement of vegetation greeness, indicate how ecosystems respond to changing environmental conditions. Data collected aboard the B-200 are teaching us how to better interpret NDVI in tundra and boreal ecosystems where high NDVI values could mean high concentrations of either moss or vascular plants. This distinction could have wide-ranging consequences for everything from water and carbon fluxes to future fire disturbances.
- **AIRCRAFT CAN HELP US DETERMINE CO_2 AND CH_4 FLUXES ON LARGE AND SMALL SCALES:** Instruments aboard the DC-8 and Mooney observed increases in CH_4 from bacterial respiration and decreases in CO_2 from plant photosynthesis near the surface of the Earth. The DC-8 also detected large-scale boundary condition concentrations of the two gases above the Arctic Ocean. Large changes in CO_2 and CH_4 impact on how our planet regulates temperature.

PLATFORM	SENSORS
DC-8	• AVOCET • Picarro • DACOM/DLH • CO_2 Sounder • ACES
G-III	• L-Band SAR • P-Band SAR
B-200	• LVIS • AirSWOT • AVIRIS
Mooney	• ATM-C
DHC6	• CFIS • NEON AOP
UAV	• SFM



www.nasa.gov

2019 ABoVE Airborne Teams

Arctic-Boreal Vulnerability Experiment

2019 ABoVE Airborne Campaign

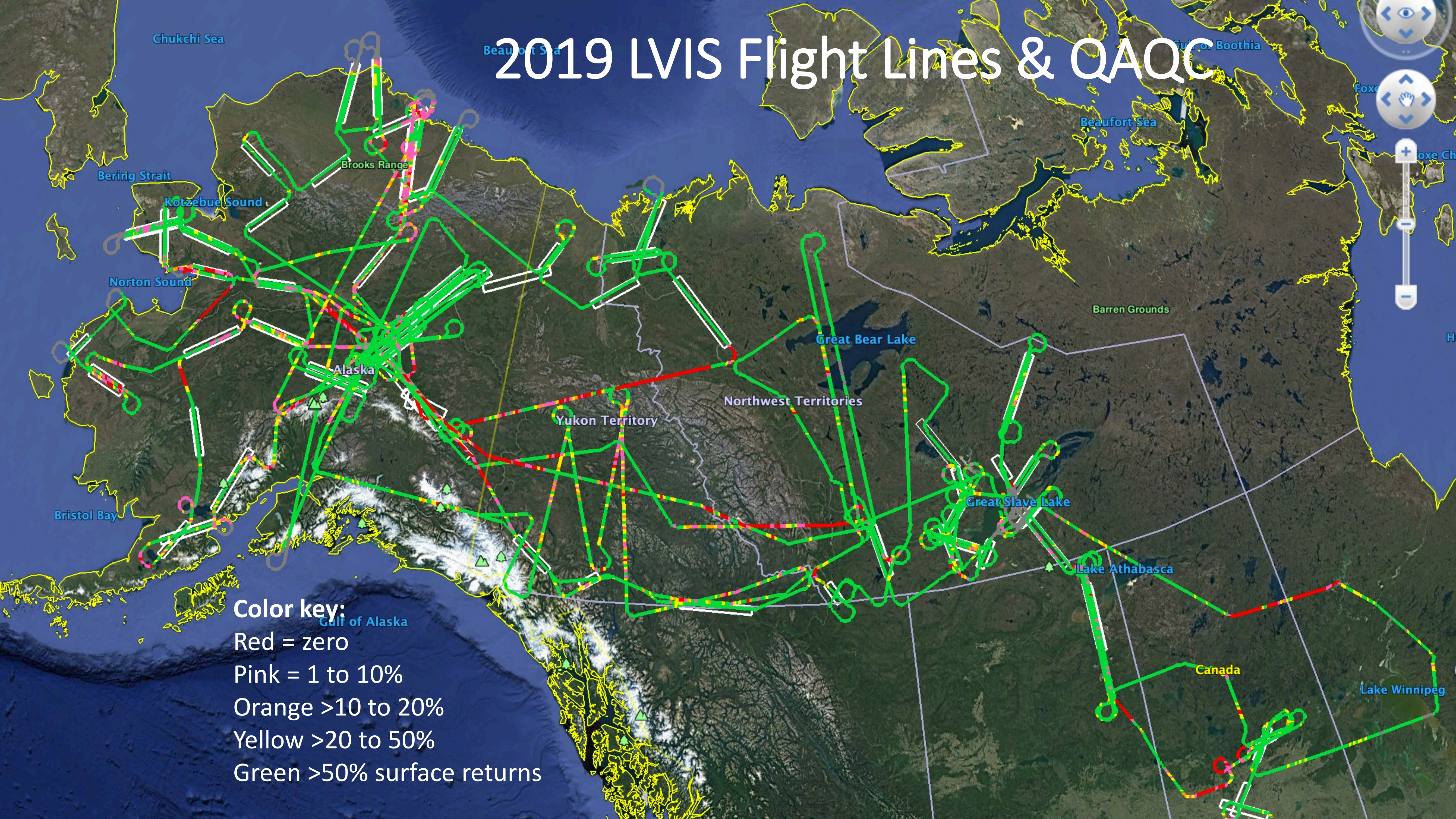
2019 LVISCampaign

2019 LVIS on NASA G-V Significantly Extends ABoVE Coverage from 2017

2019 LVIS Facility & Classic overlap key ABoVE ground sites, transects, and other airborne data

Also underfly multiple IceSat-2 and GEDI tracks

2019 LVIS Flight Lines & QAQC



Color key:

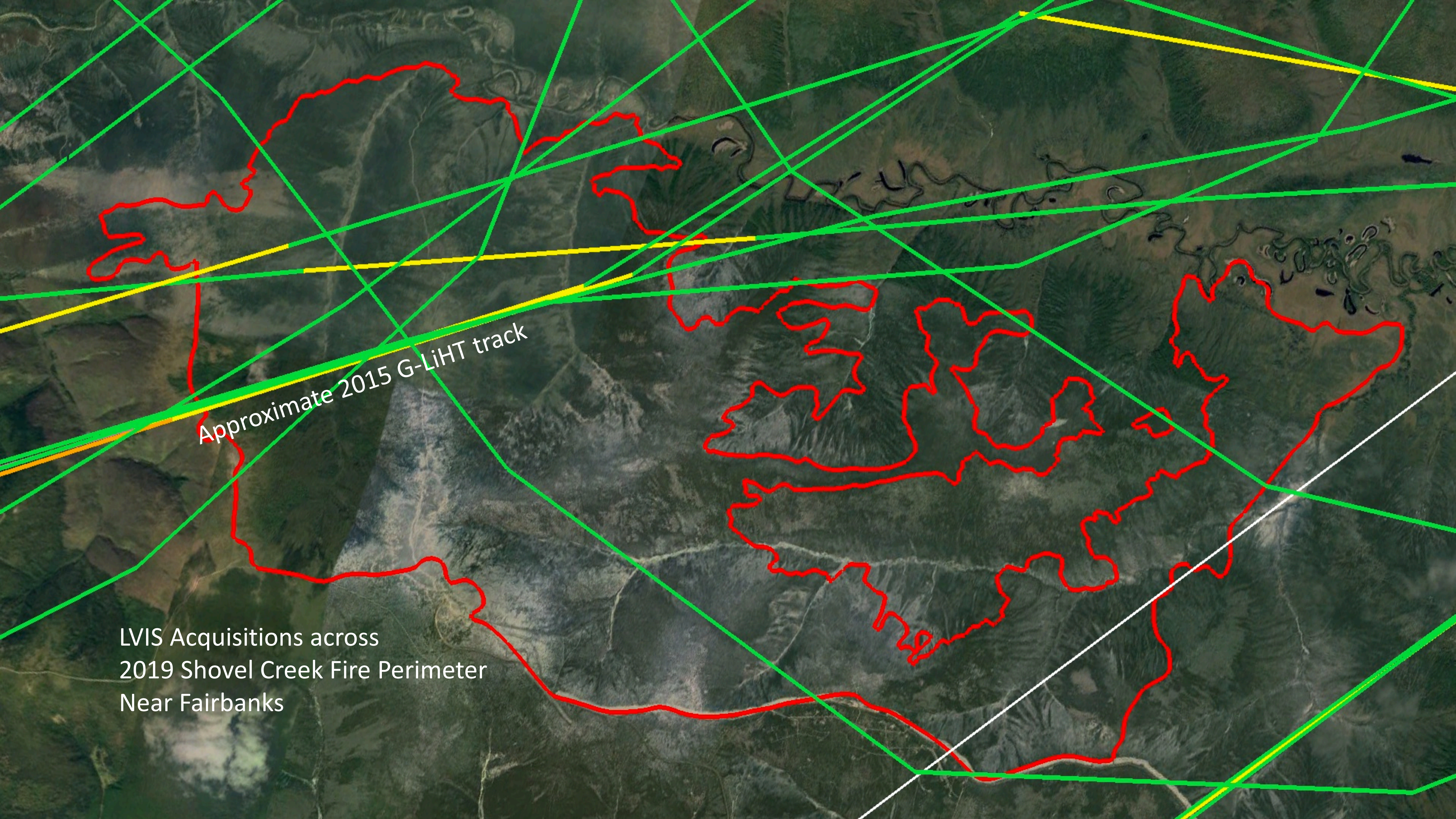
Red = zero

Pink = 1 to 10%

Orange >10 to 20%

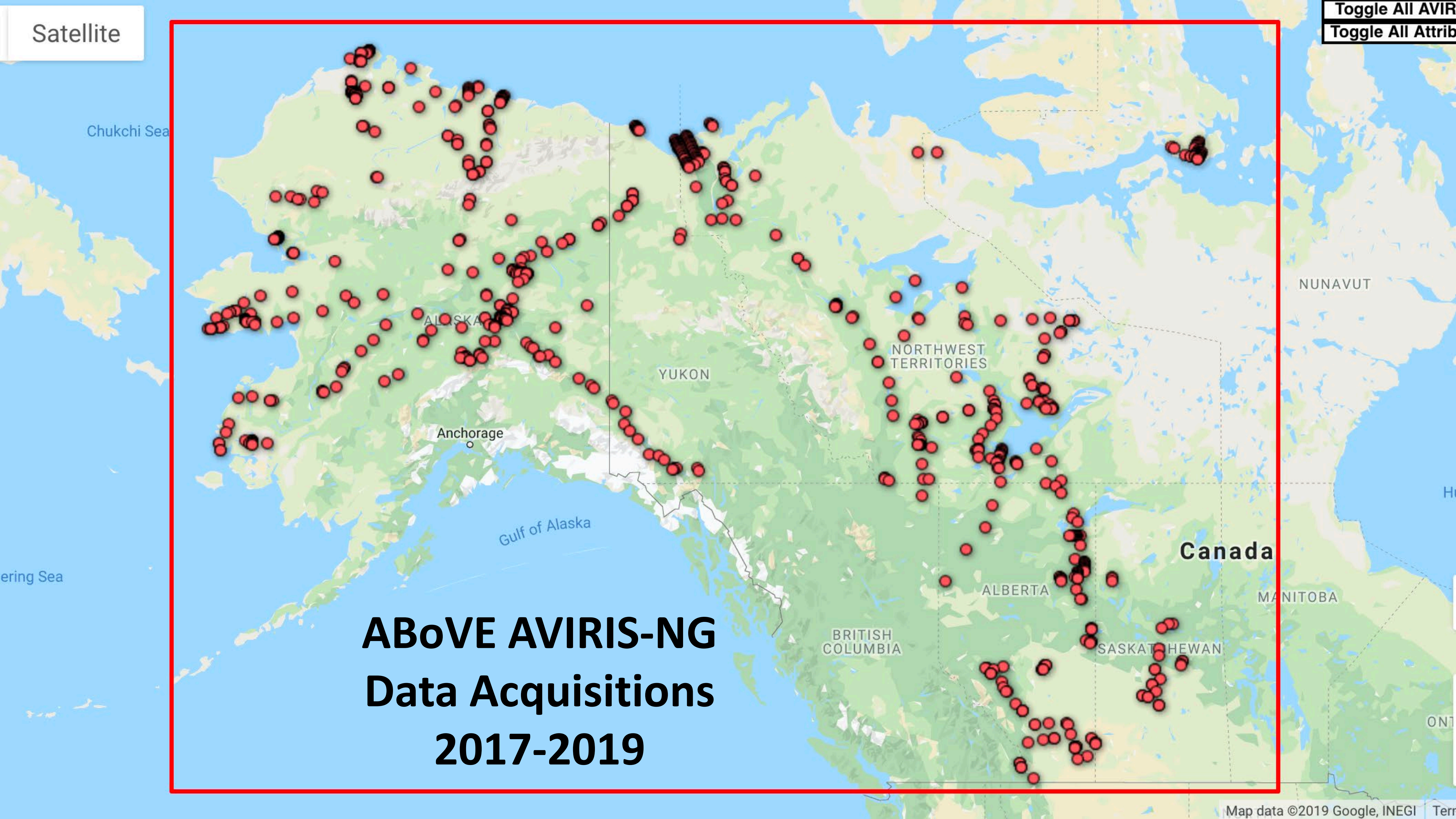
Yellow >20 to 50%

Green >50% surface returns


Approximate 2015 G-LiHT track
LVIS Acquisitions across
2019 Shovel Creek Fire Perimeter
Near Fairbanks

Access 2019 ABoVE LVIS Data

https://nsidc.org/data/lvis

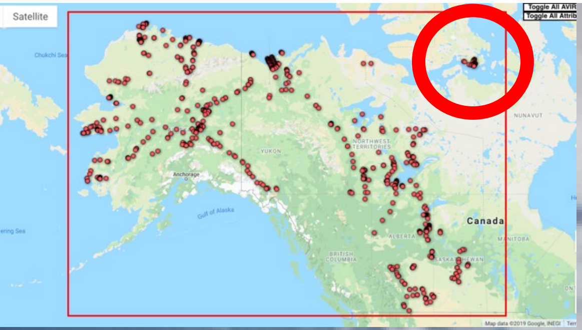


Satellite
Toggle All AVIR
Toggle All Attrib
Chukchi Sea
ALASKA
Anchorage
Gulf of Alaska
ering Sea
YUKON
NORTHWEST TERRITORIES
NUNAVUT
BRITISH COLUMBIA
ALBERTA
SASKATCHEWAN
MANITOBA
Canada
ABoVE AVIRIS-NG
Data Acquisitions
2017-2019
Map data ©2019 Google, INEGI

Arctic-Boreal Vulnerability Experiment

1 August 2019/DOY 213

CHARS



Polar Knowledge Canada's
Canadian High Arctic Research Station (CHARS)

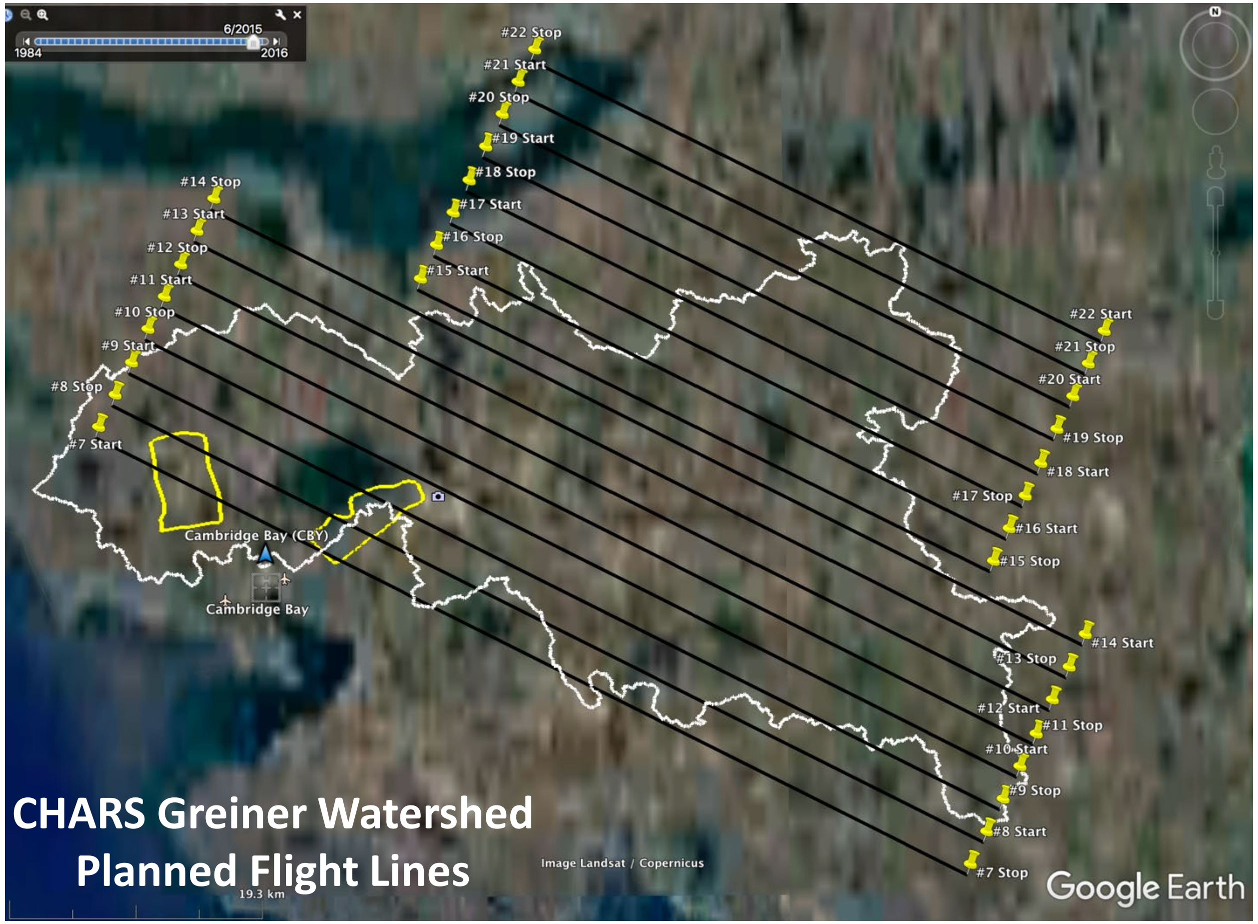
1 August 2019: Summer Field Work @CHARS – Cambridge Bay

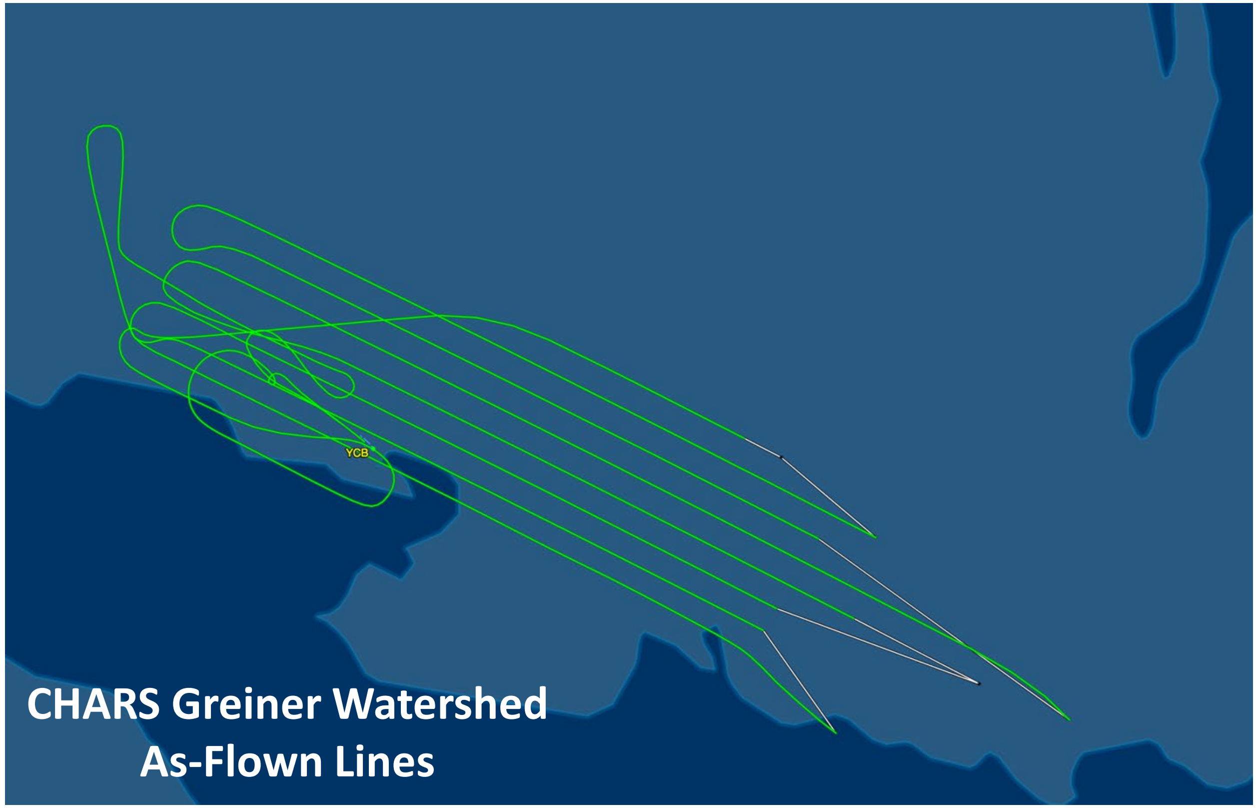
Donald McLennan and Eric Kruger

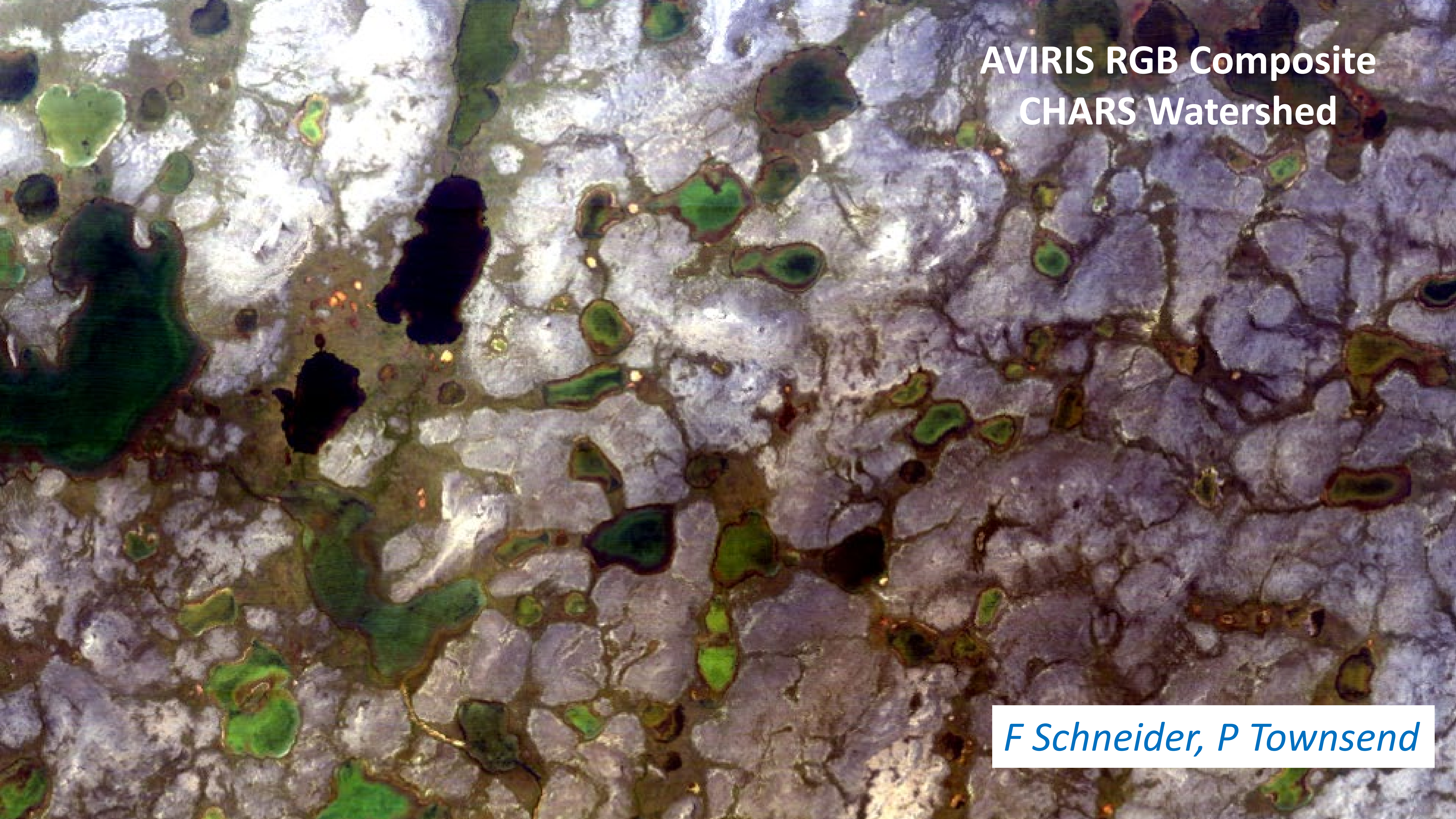
Phil Townsend and Eric Kruger

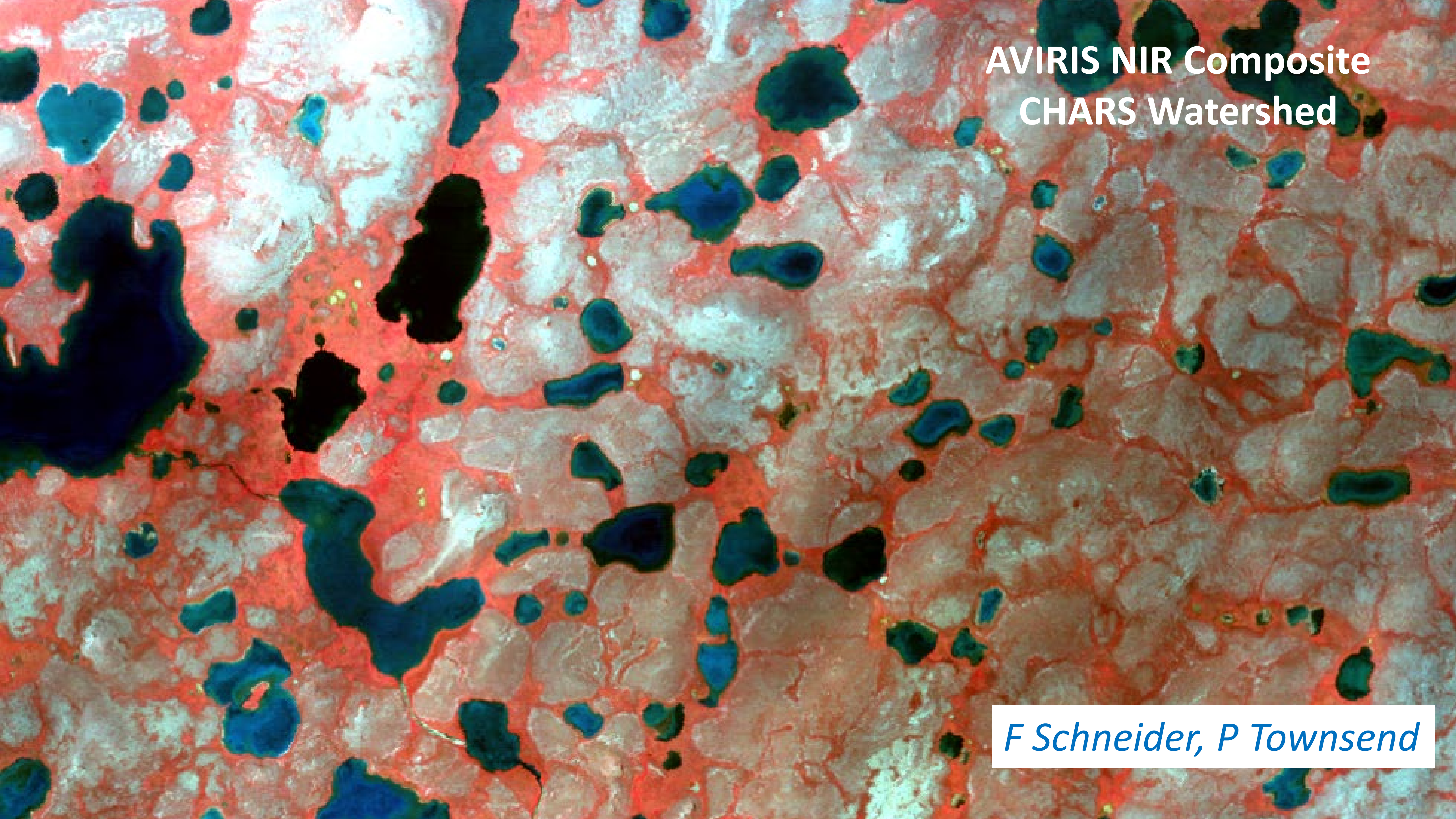
Arctic-Boreal Vulnerability Experiment

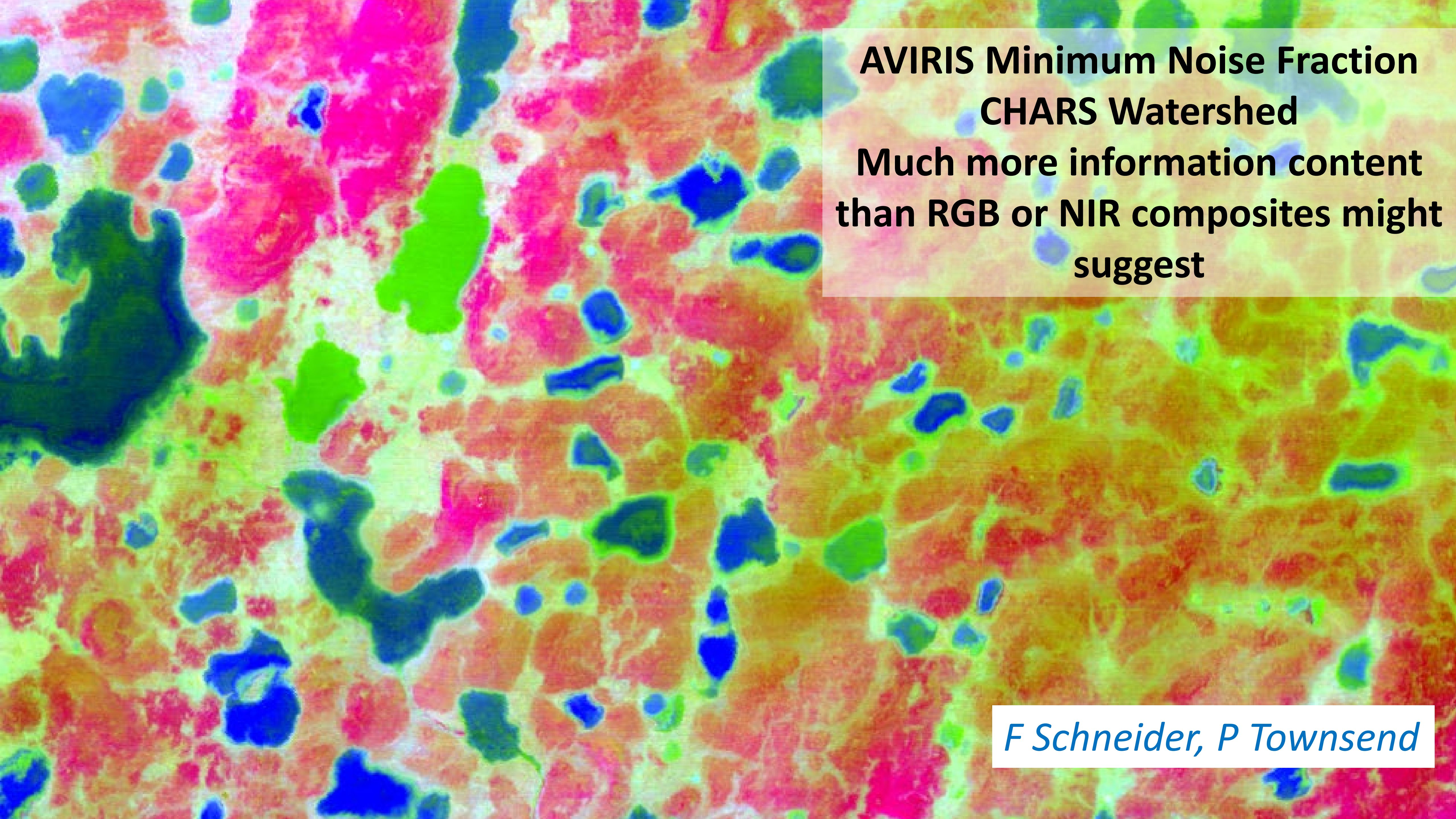
1 August 2019/DOY 213
CHARS – Cambridge Bay Gird #1





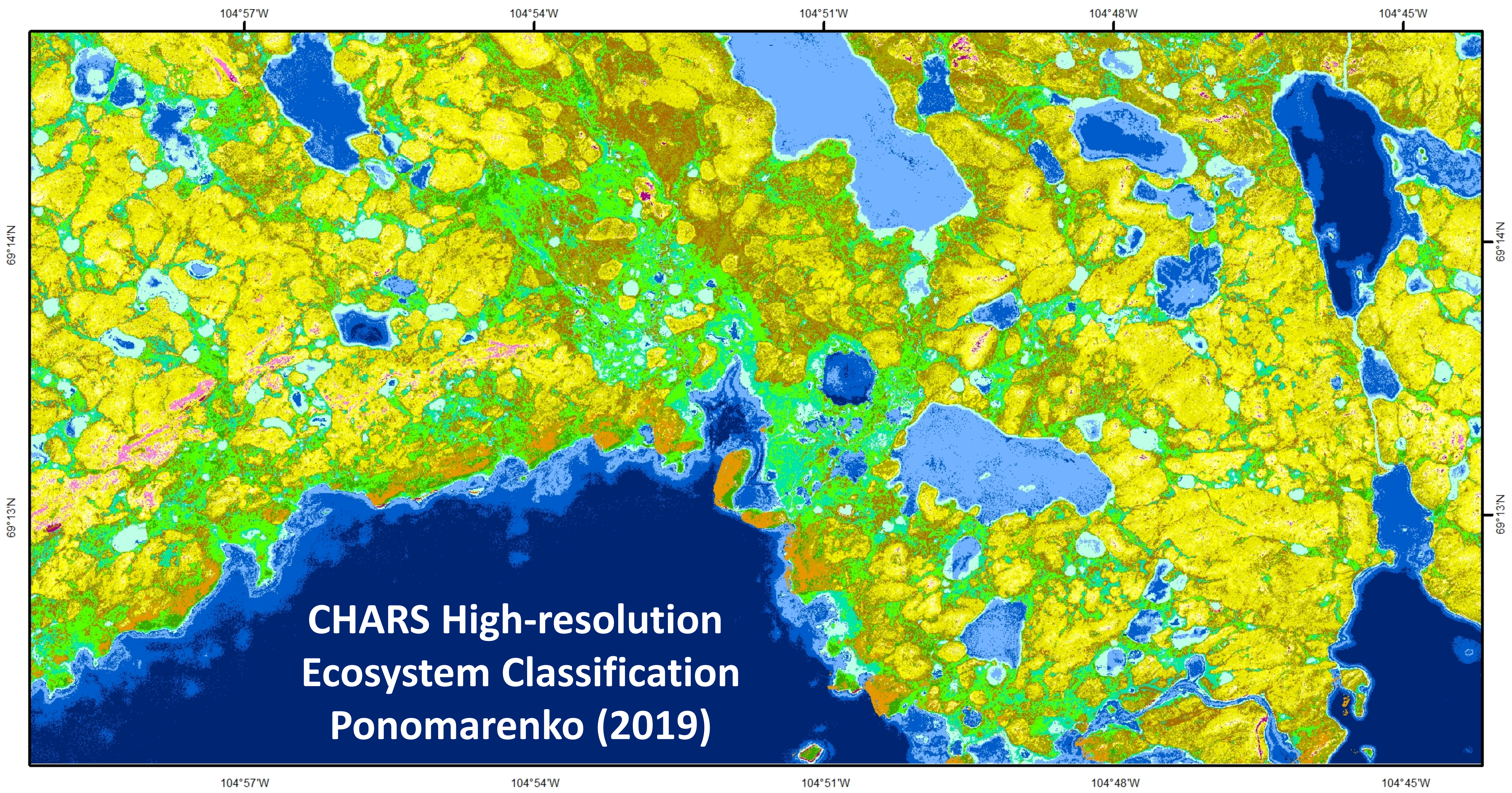

AVIRIS RGB Composite
CHARS Watershed
F Schneider, P Townsend


AVIRIS NIR Composite
CHARS Watershed
F Schneider, P Townsend

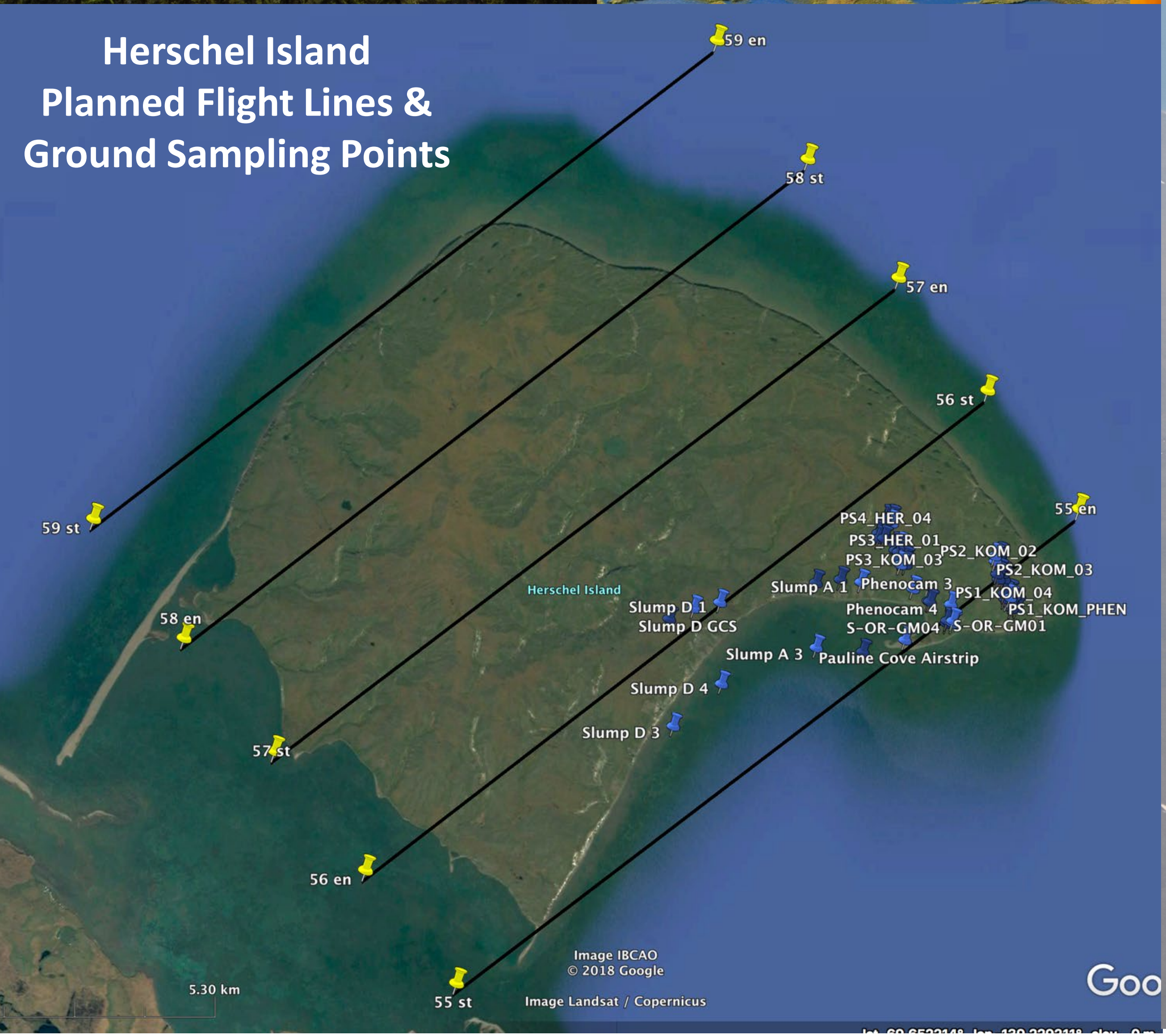


AVIRIS Minimum Noise Fraction
CHARS Watershed
Much more information content than RGB or NIR composites might suggest

F Schneider, P Townsend


104°57'W
104°54'W
104°51'W
104°48'W
104°45'W
69°14'N
69°13'N
CHARS High-resolution
Ecosystem Classification
Ponomarenko (2019)

Qikiqtaruk - Herschel Island
CABO Project/I Meyers-Smith



Arctic-Boreal Vulnerability Experiment

Qikiqtaruk - Herschel Island

2 July 2019/DOY 183

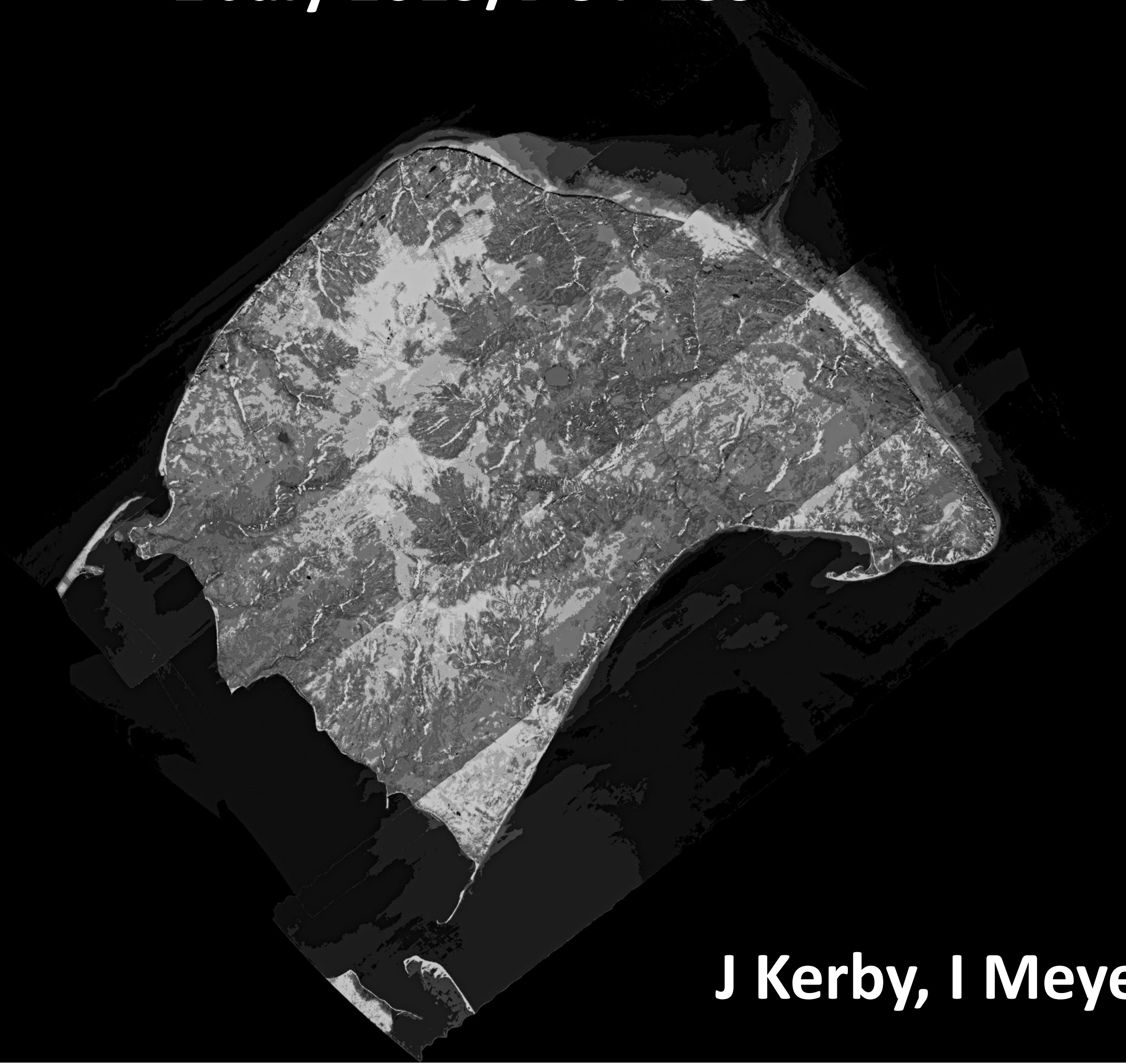
27 July 2019/DOY 208

J Kerby, I Meyers-Smith

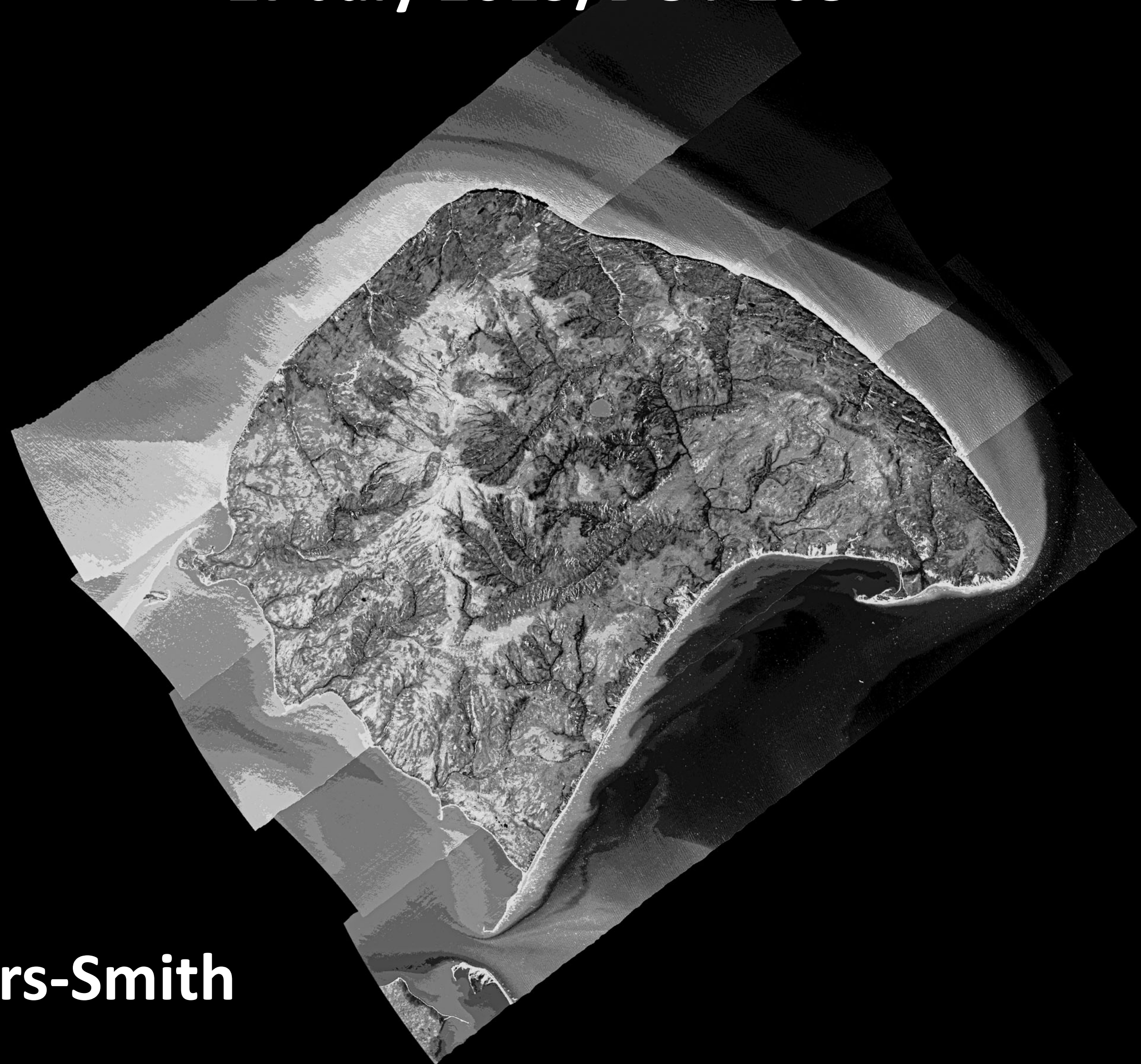
Arctic-Boreal Vulnerability

Qikiqtaruk - Herschel Island

2 July 2019/DOY 183



27 July 2019/DOY 208



J Kerby, I Meyers-Smith

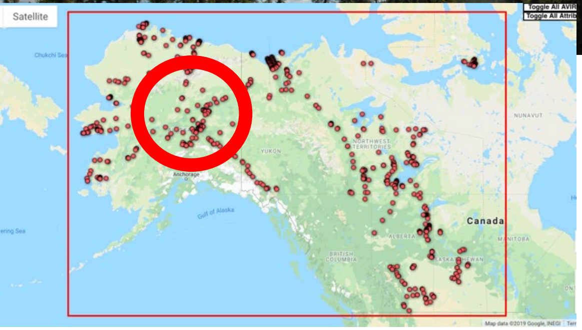
Arctic-Boreal Vulnerability Experiment

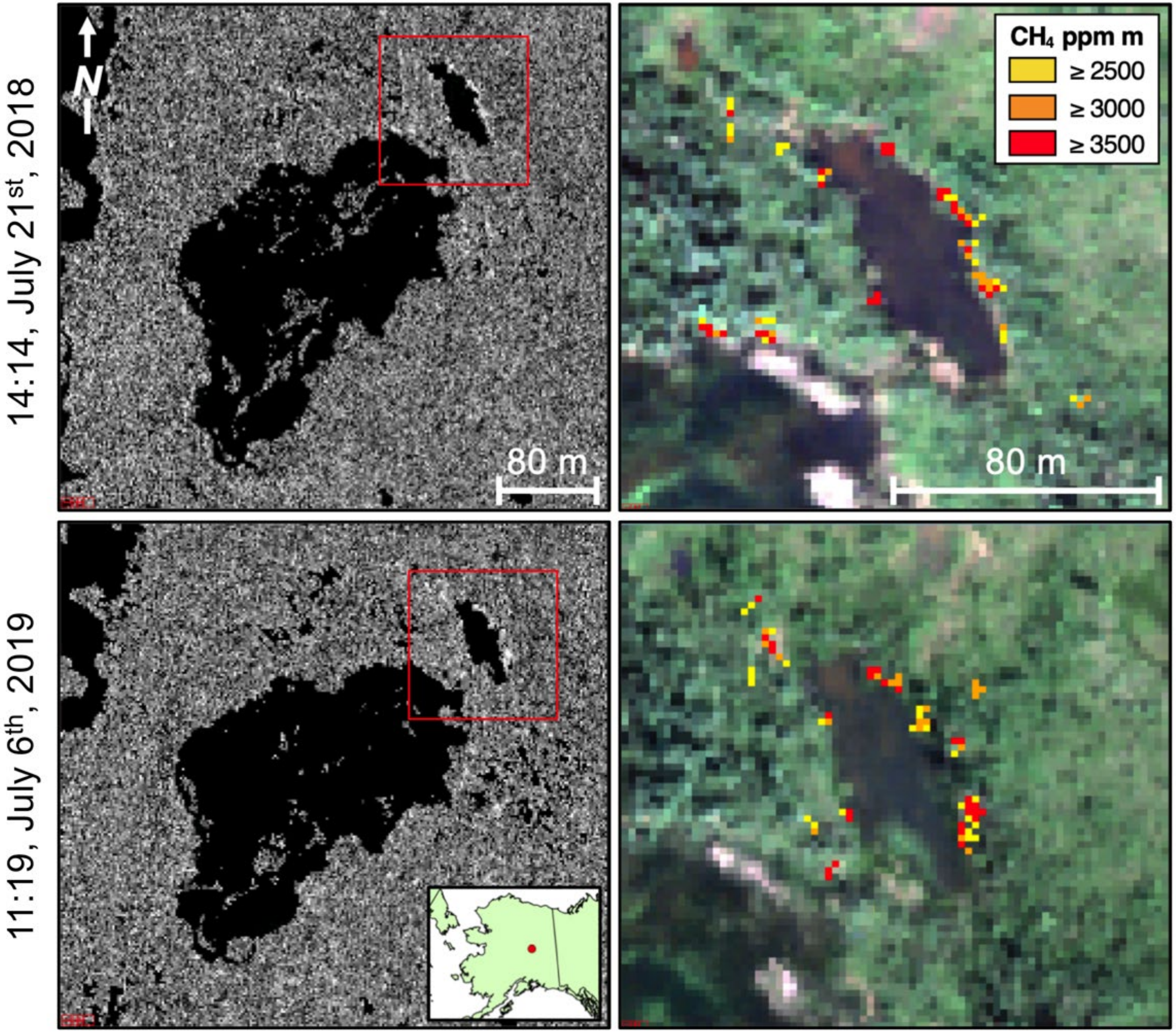
Extreme CH4 Emissions from Recent Thermokarst Lake Hot Spots

Phil Hanke, UAF

Katey Walter Anthony
UAF

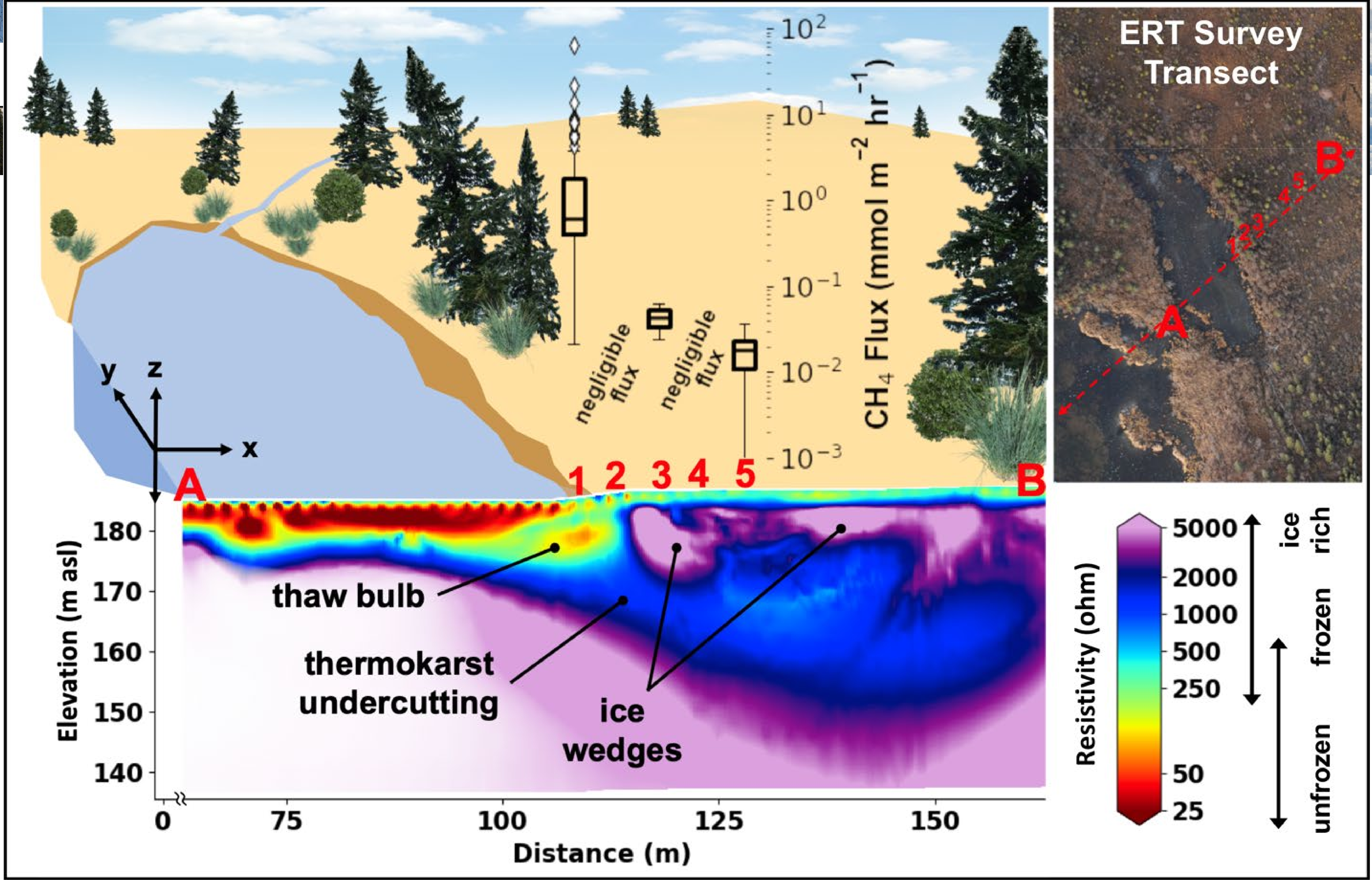
Clayton Elder, JPL





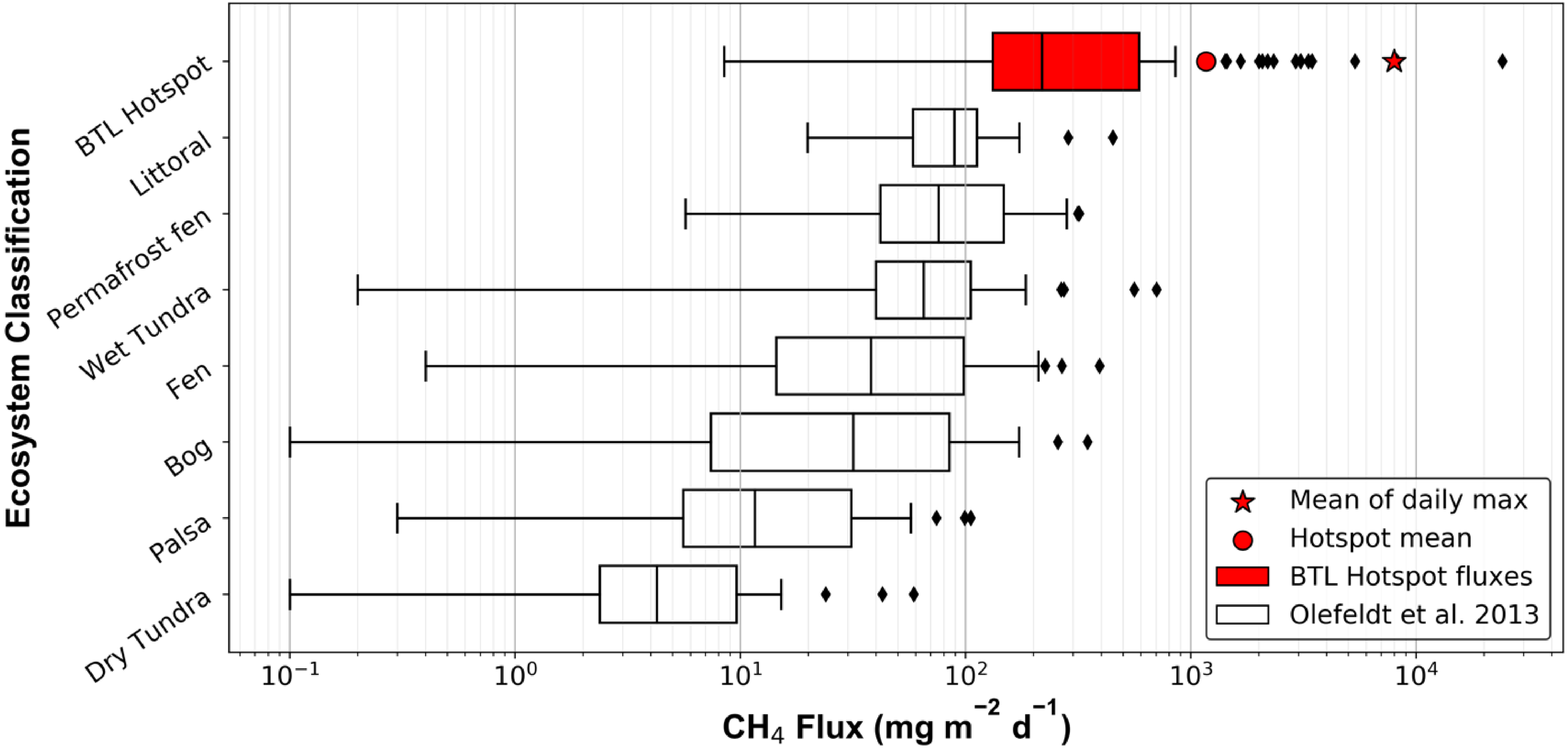
C Elder, in prep

ERT Data – B Minsley



C Elder, in prep

Extreme CH4 Emissions from the BTL Thermokarst Hot Spot

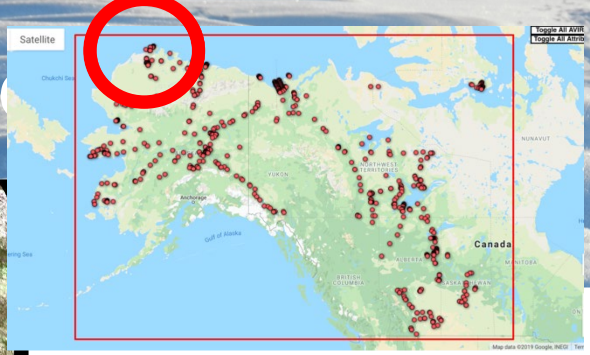


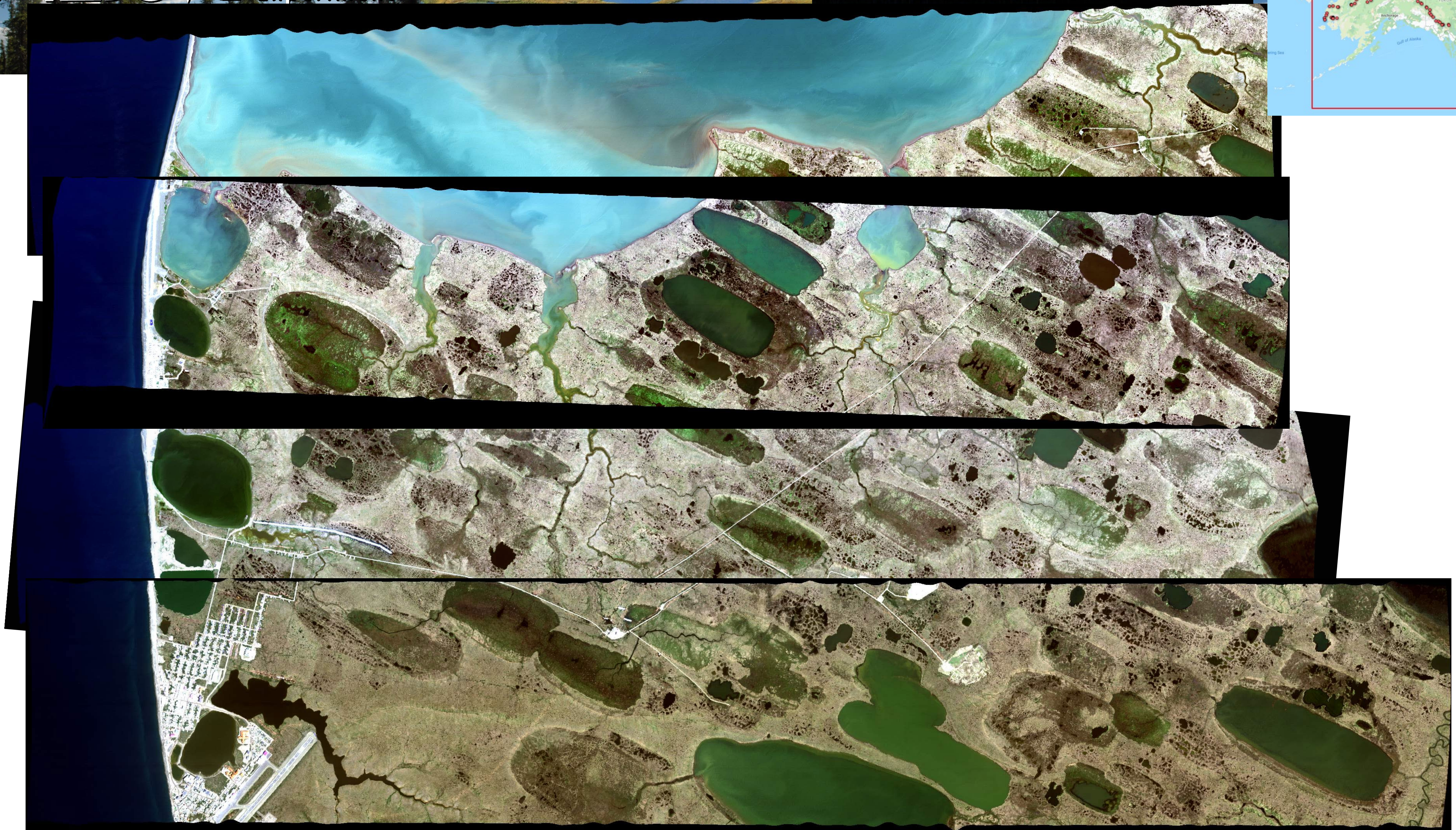
C Elder, in prep

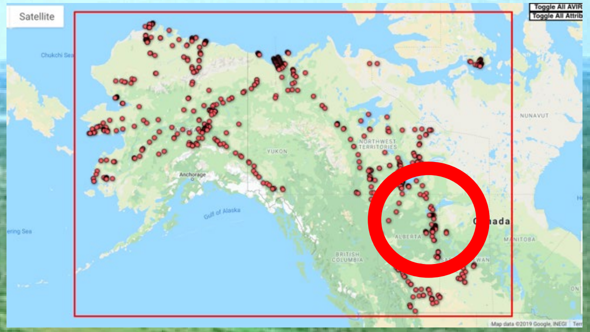

12 July 2019/DOY 193: Barrow
Utqiagvik/Barrow
Focus Area
• Huemmrich
• Tweedie
• Zona/Oechel
• NGEE-Arctic
• NEON
M Eastwood

Arctic-Boreal Vulnerability Experiment

7/12/2019 Barrow Area Comp







Peace-Athabasca Delta Focus Area

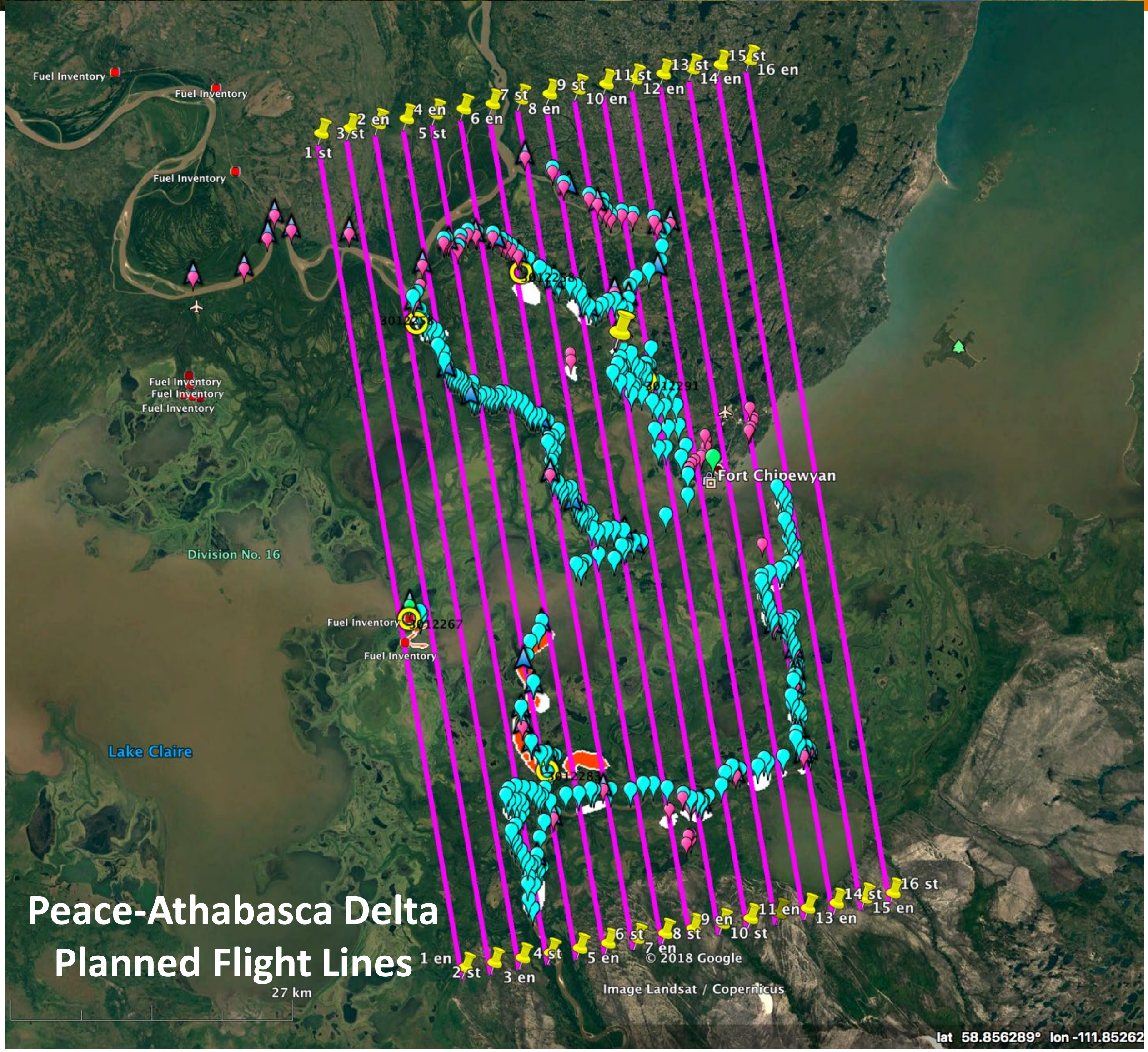
Peace-Athabasca Delta covers more than 6000 sq km

- Largest inland delta in the world
- Critical boreal wetland

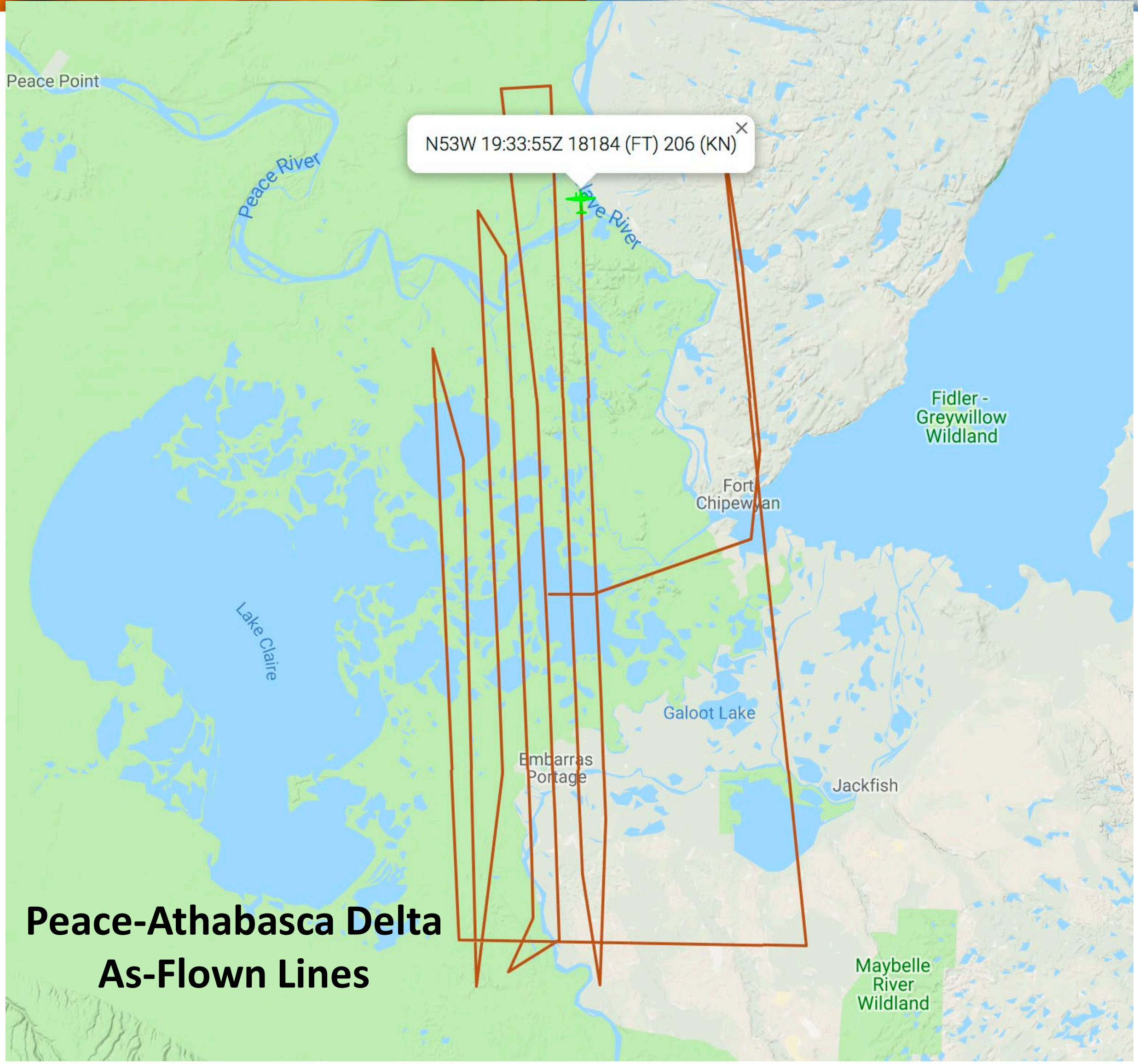

Peace-Athabasca Delta
16 July 2019
D Butman

16 July 2019/DOY 197
AVIRIS: Peace-Athabasca Delta

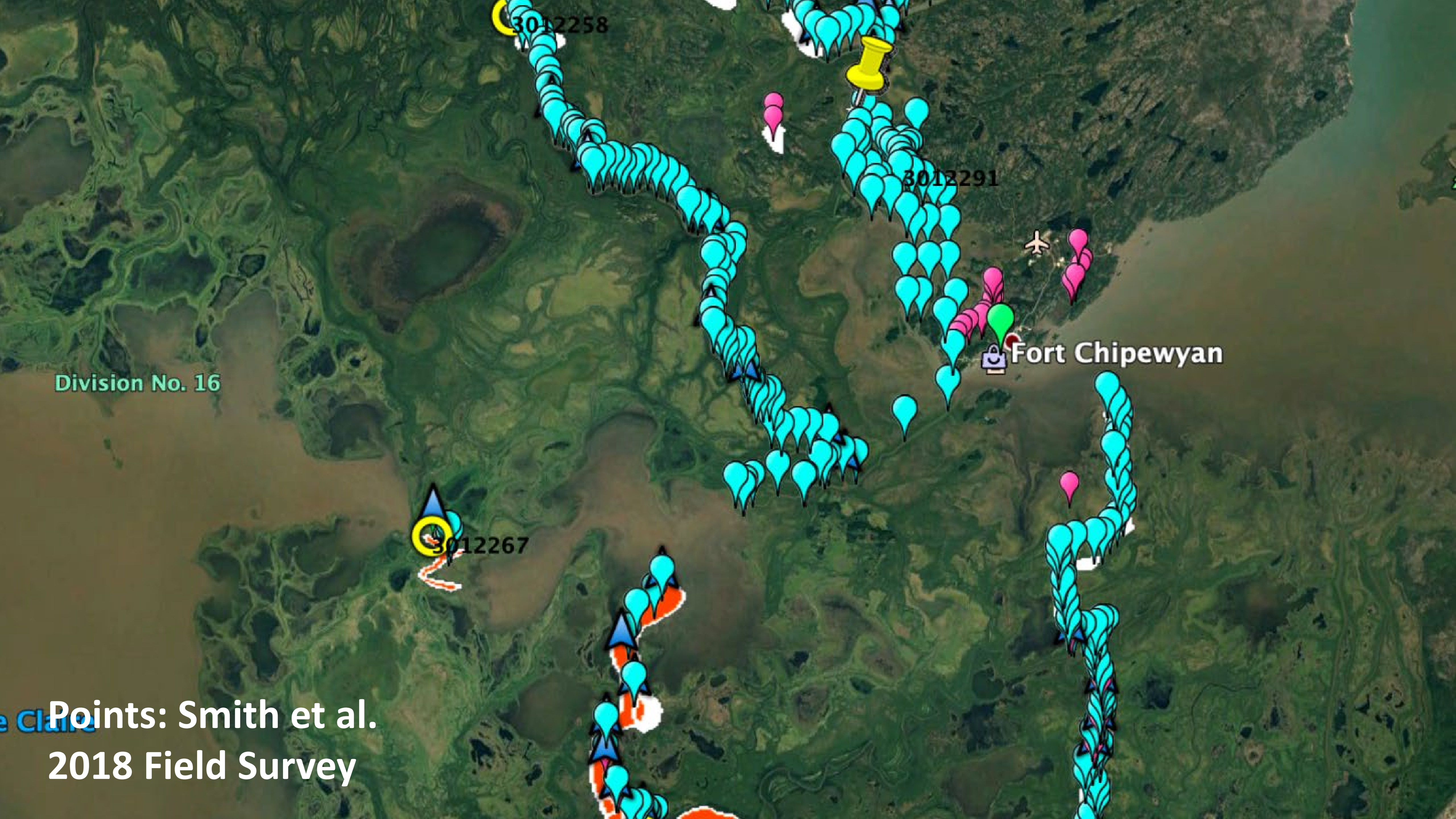
Arctic-Boreal Vulnerability Experiment



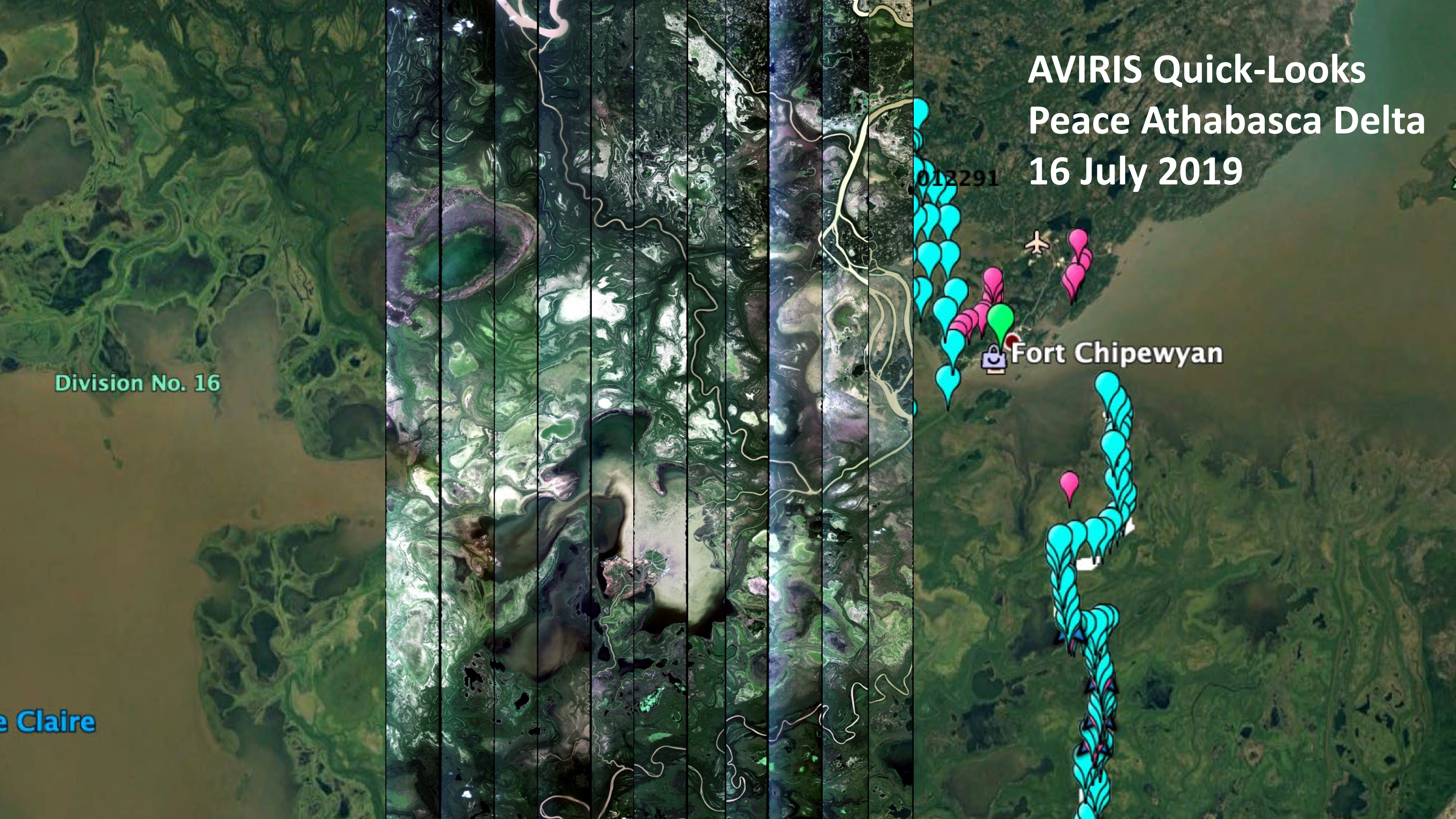
Peace-Athabasca Delta Planned Flight Lines

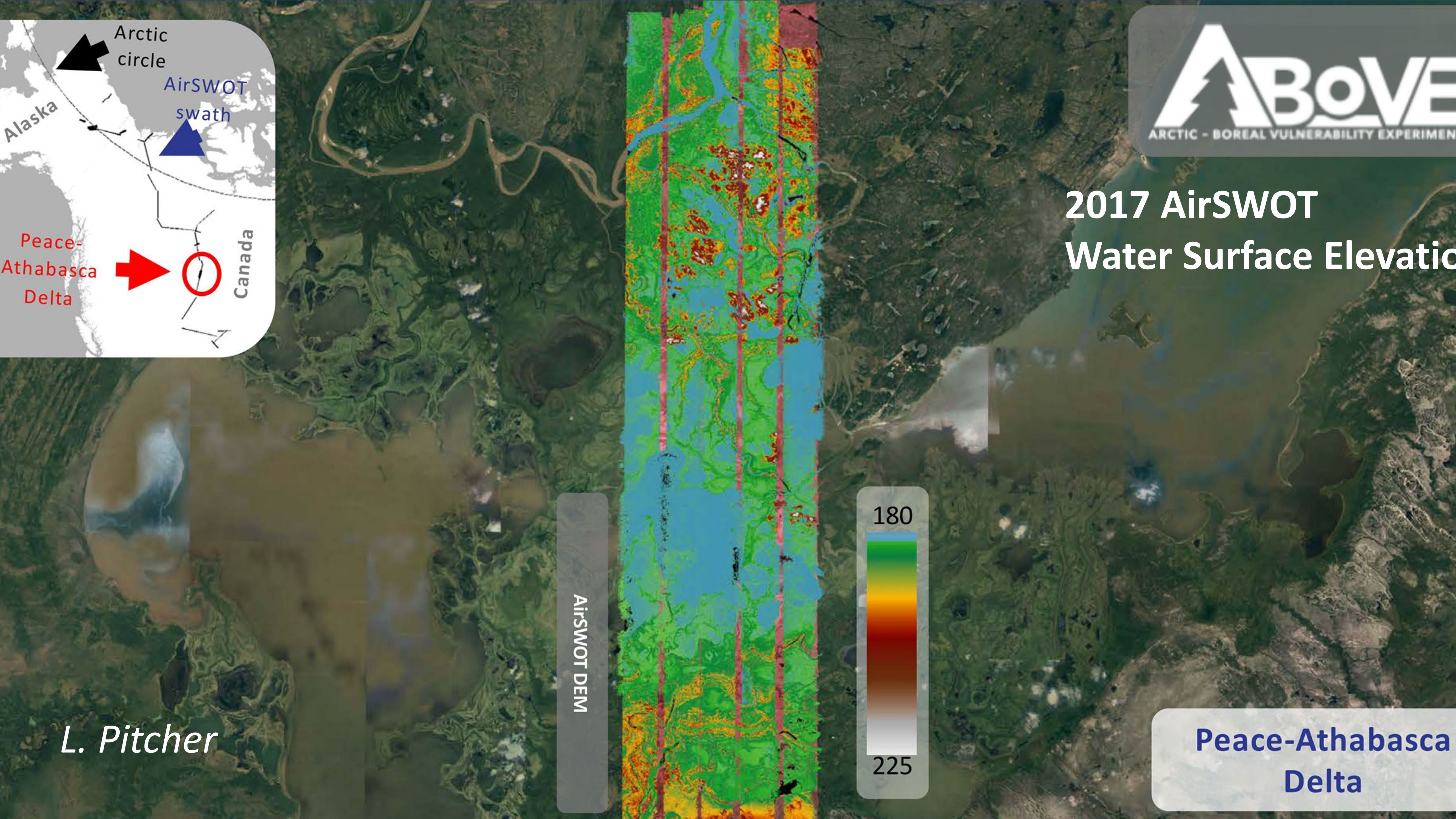


Peace-Athabasca Delta As-Flown Lines

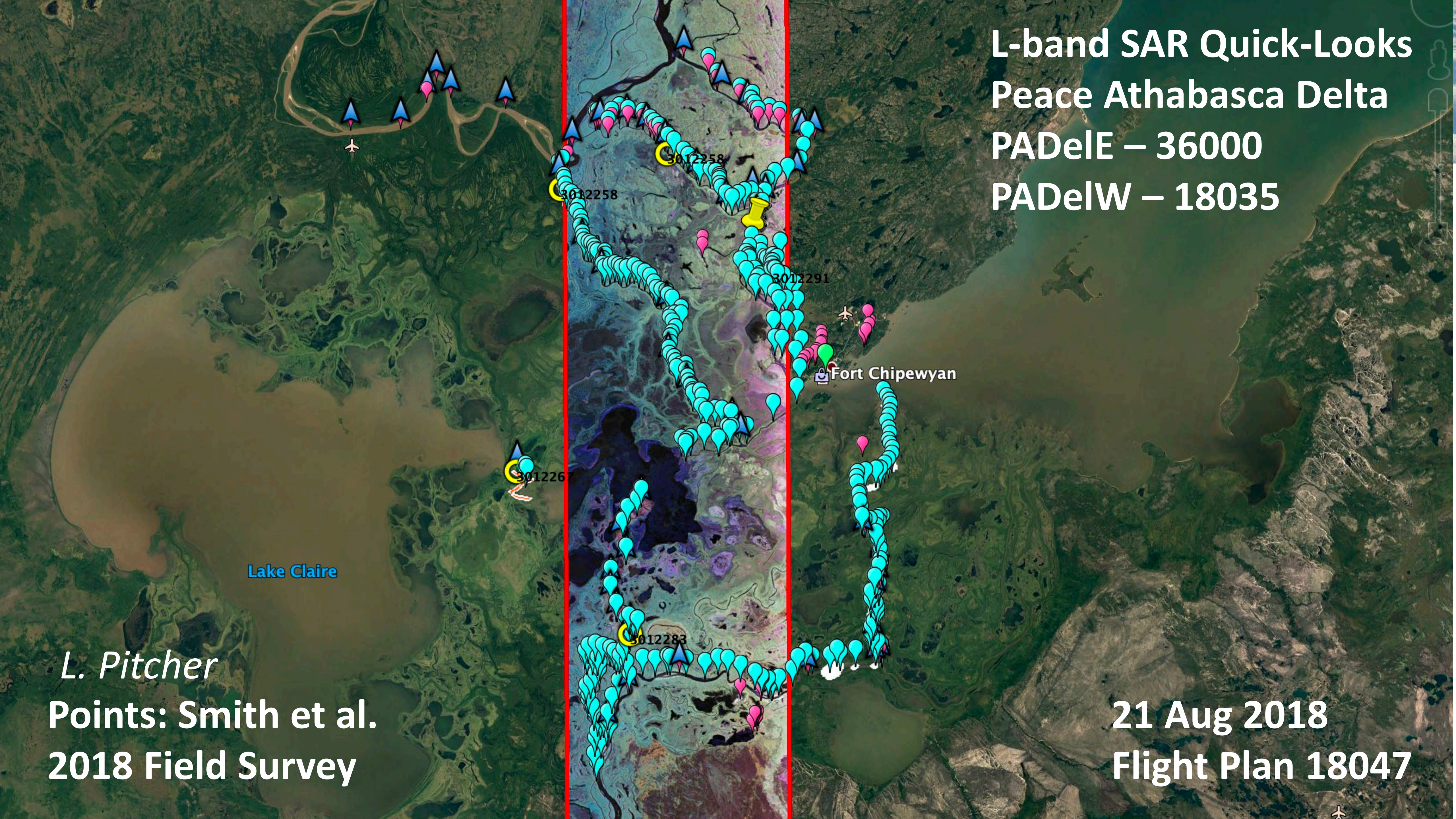

3012258
3012291
Fort Chipewyan
Division No. 16
3012267
Points: Smith et al.
2018 Field Survey

AVIRIS Quick-Looks
Peace Athabasca Delta
16 July 2019





ARCTIC - BOREAL VULNERABILITY EXPERIMEN
2017 AirSWOT
Water Surface Elevatic
Arctic circle
AirSWOT swath
Alaska
Canada
Peace-Athabasca Delta
AirSWOT DEM
180
225
L. Pitcher
Peace-Athabasca Delta


L-band SAR Quick-Looks
Peace Athabasca Delta
PADelE – 36000
PADelW – 18035
3012258
3012258
3012291
Fort Chipewyan
Lake Claire
L. Pitcher
Points: Smith et al.
2018 Field Survey
21 Aug 2018
Flight Plan 18047

A High-Resolution Airborne Color-Infrared Camera Water Mask for the ABoVE Campaign

Arctic-Boreal Vulnerability Experiment

ED Kyzivat, et al. (Sept. 2019) *Remote Sensing 11*

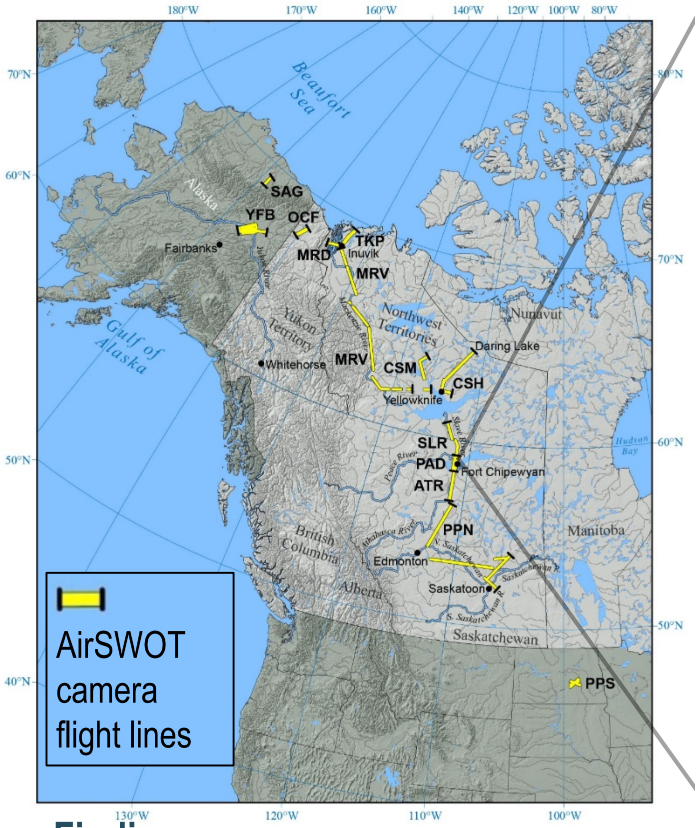
https://doi.org/10.3390/rs11182163

Background:

- The total surface area of water on Arctic-Boreal landscapes is poorly known for water bodies too small to resolve from satellites such as Landsat 8 and Sentinel-2 (<0.001 km2). Yet, these small water bodies are important for greenhouse gas exchange, ecosystem services, and biodiversity.
- The airborne AirSWOT instrument suite, consisting of an interferometric Ka-band synthetic aperture radar and color-infrared (CIR) camera, was deployed to AK and Canada in summer 2017 to measure surface hydrology as part of the NASA Arctic-Boreal Vulnerability Experiment (ABoVE).

Analysis:

- Mapped surface water over 23,380 km^2 of the ABoVE domain using an unsupervised, object-based classification.
- Tested the resulting water body distributions for power-law behavior across a variety of landscapes.



AirSWOT CIR

UAVSAR L-band

Findings:

- Found a power-law cutoff for lakes <0.34 km^2, implying that lake abundance estimates are invalid at smaller scales.
- Many synergies between sensors are unexplored, and this study offers suggestions for how the CIR dataset might assist data collected concurrently from other NASA aircraft.

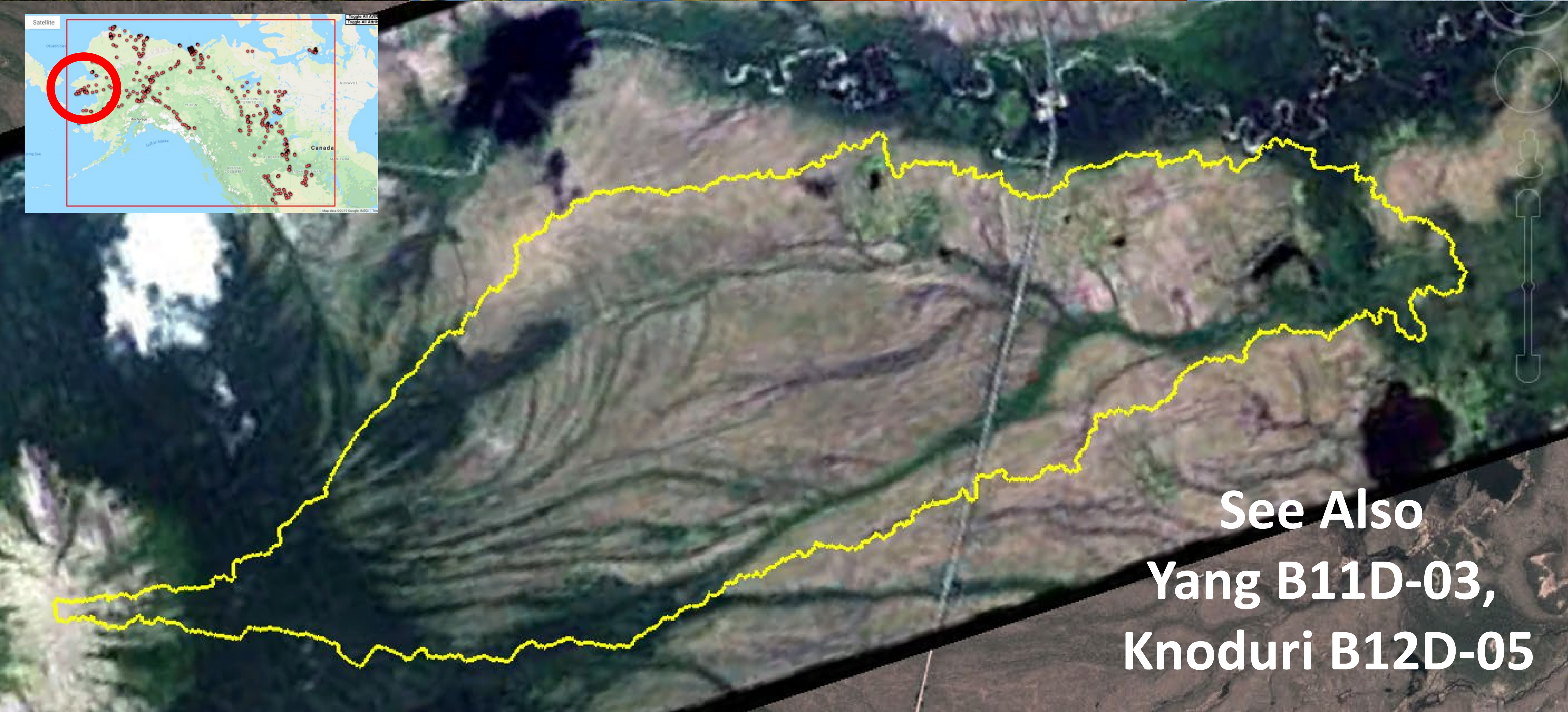
Far left: ABoVE domain map showing AirSWOT flight lines and the 13 regions used for water body distribution analysis.
Right top: 1-meter resolution, color-infrared (CIR) imagery collected as part of the NASA AirSWOT instrument suite in the Peace-Athabasca Delta, AB.
Right bottom: Same scene as imaged by the L-band synthetic-aperture radar flown on NASA's UAVSAR aircraft. Water bodies classified from the CIR imagery are superimposed in blue. The water classification excludes the emergent vegetation fringing the lake, which can be seen as high double-bounce (red) regions in the UAVSAR image.

Significance:

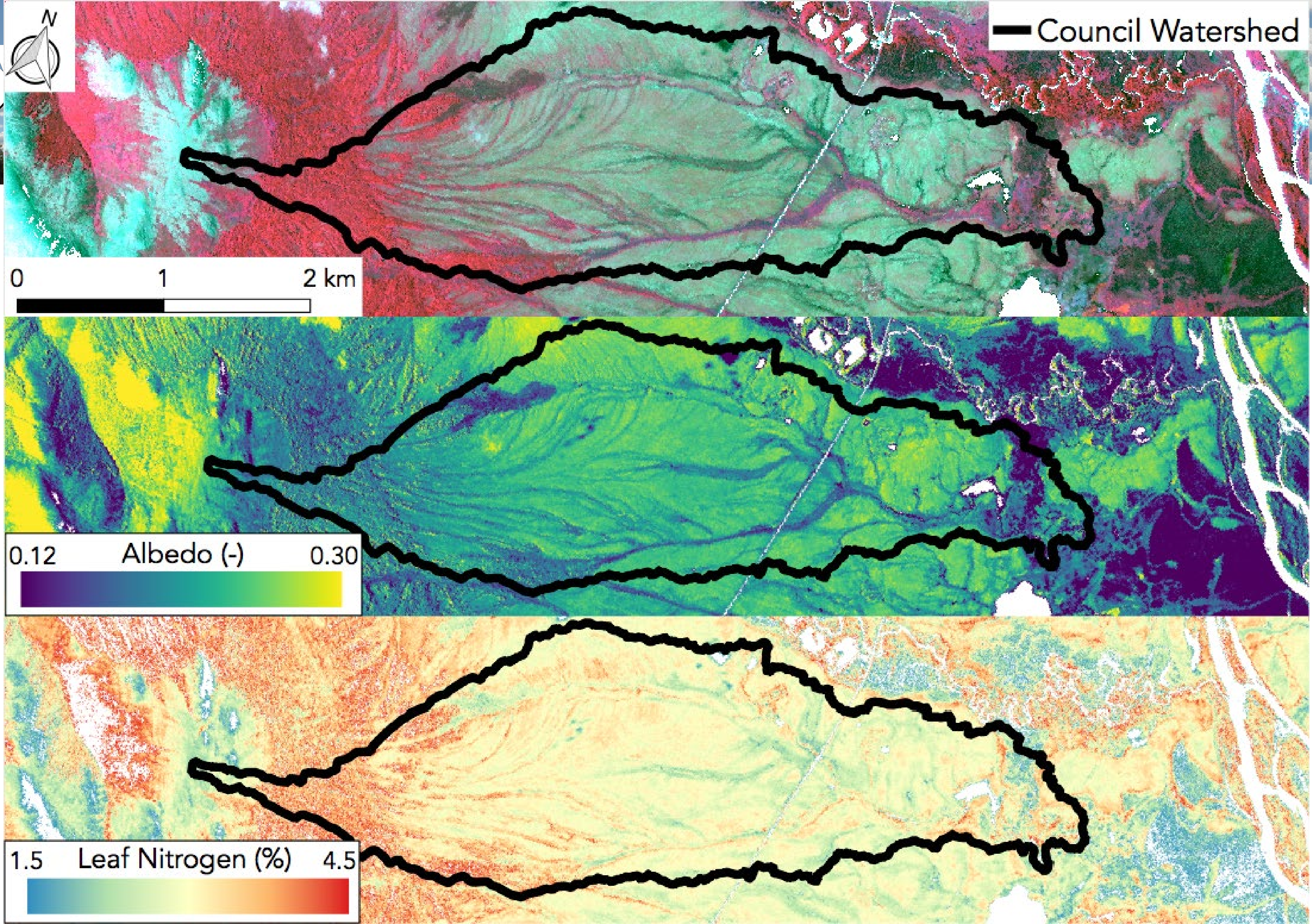
- These data provide a rare, synchronous and co-registered reference for Ka-band water classification algorithms such as will be used for the upcoming NASA Surface Water and Ocean Topography (SWOT) satellite mission.

Arctic-Boreal Vulnerability Experiment

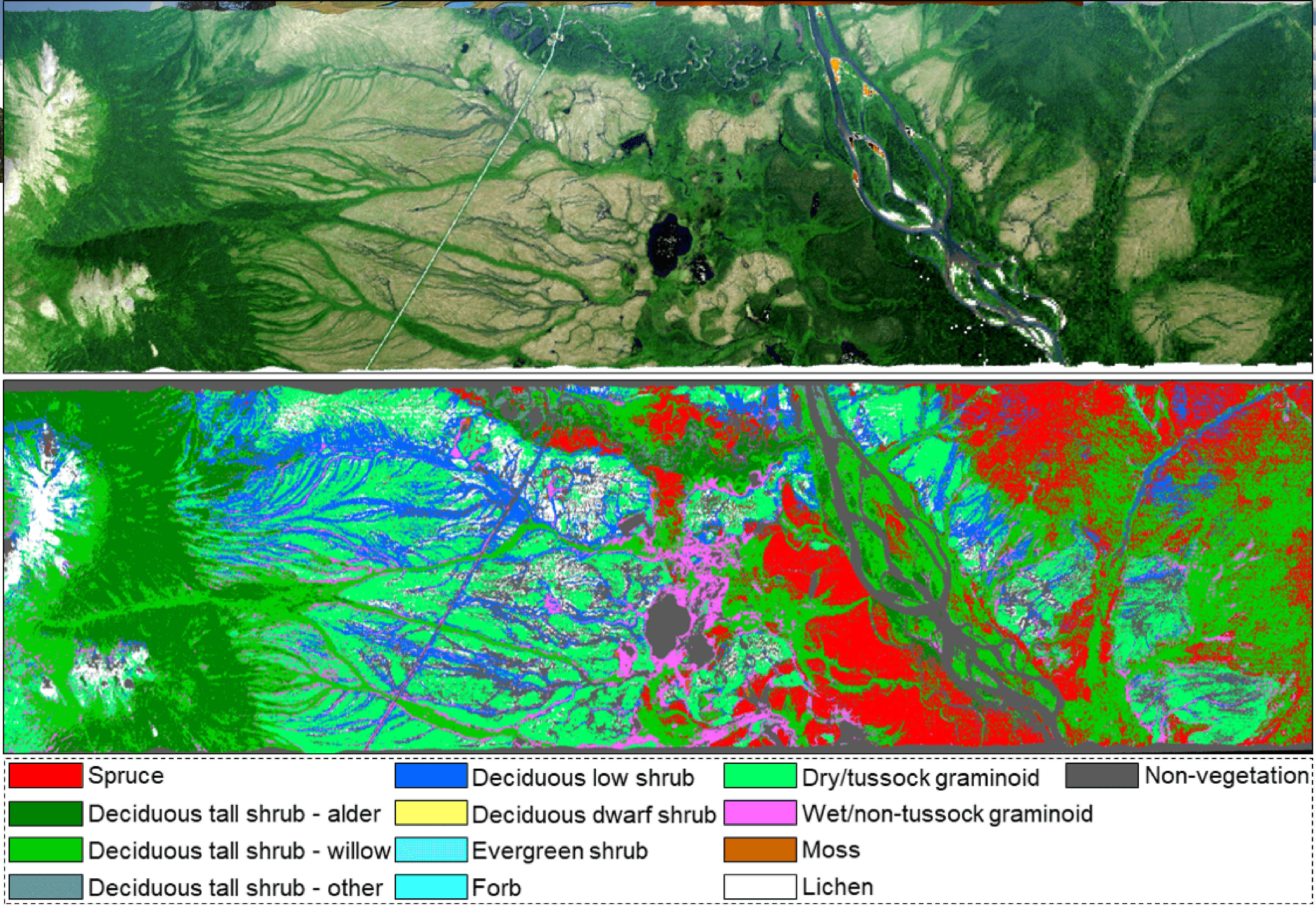
AVIRIS-NG Mapping of the NGEE-Arctic Council AK Watershed



See Also
Yang B11D-03,
Knoduri B12D-05

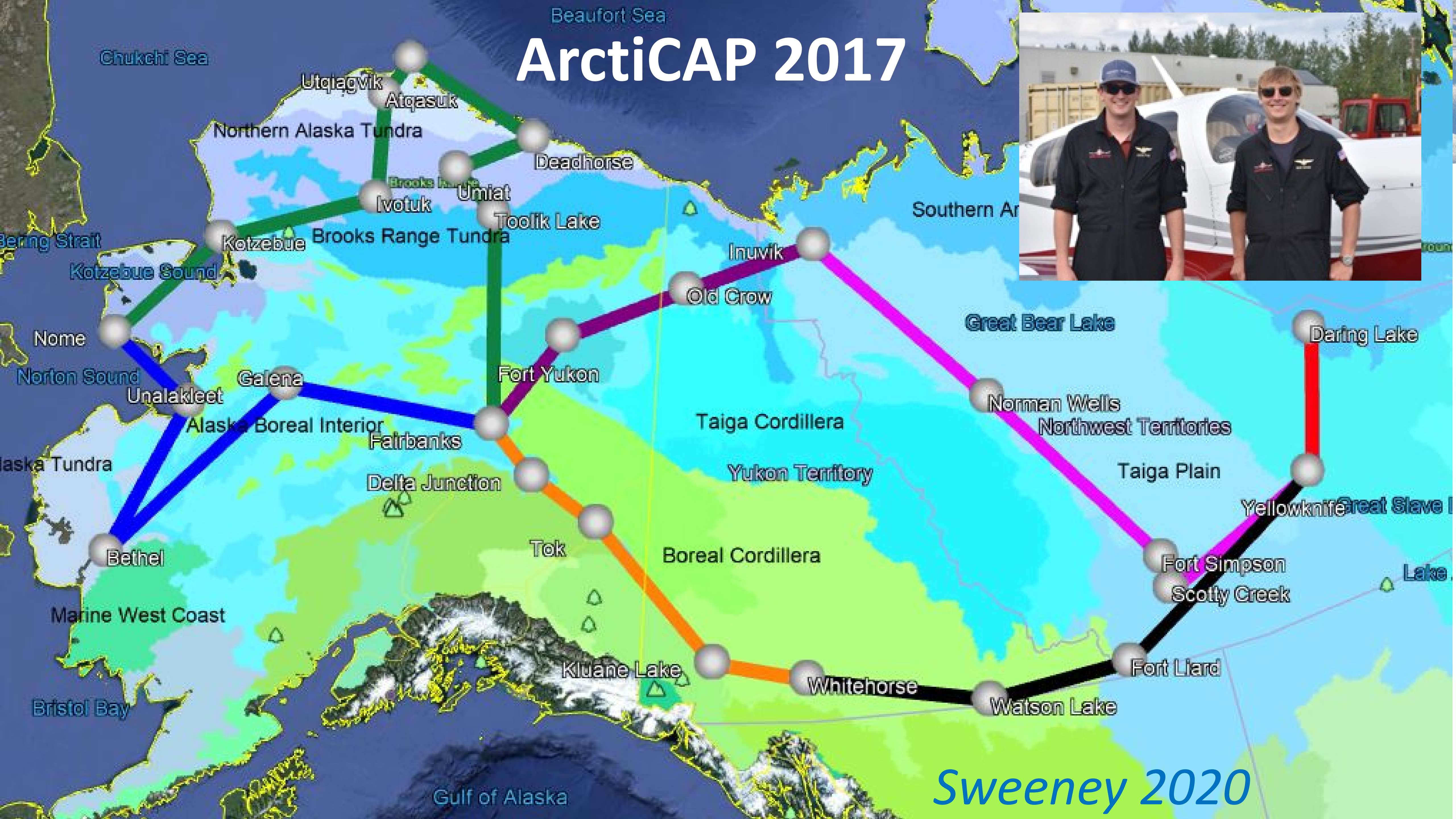

N
Council Watershed
0
1
2 km
0.12
Albedo (-)
0.30
1.5
Leaf Nitrogen (%)
4.5

S Serbin



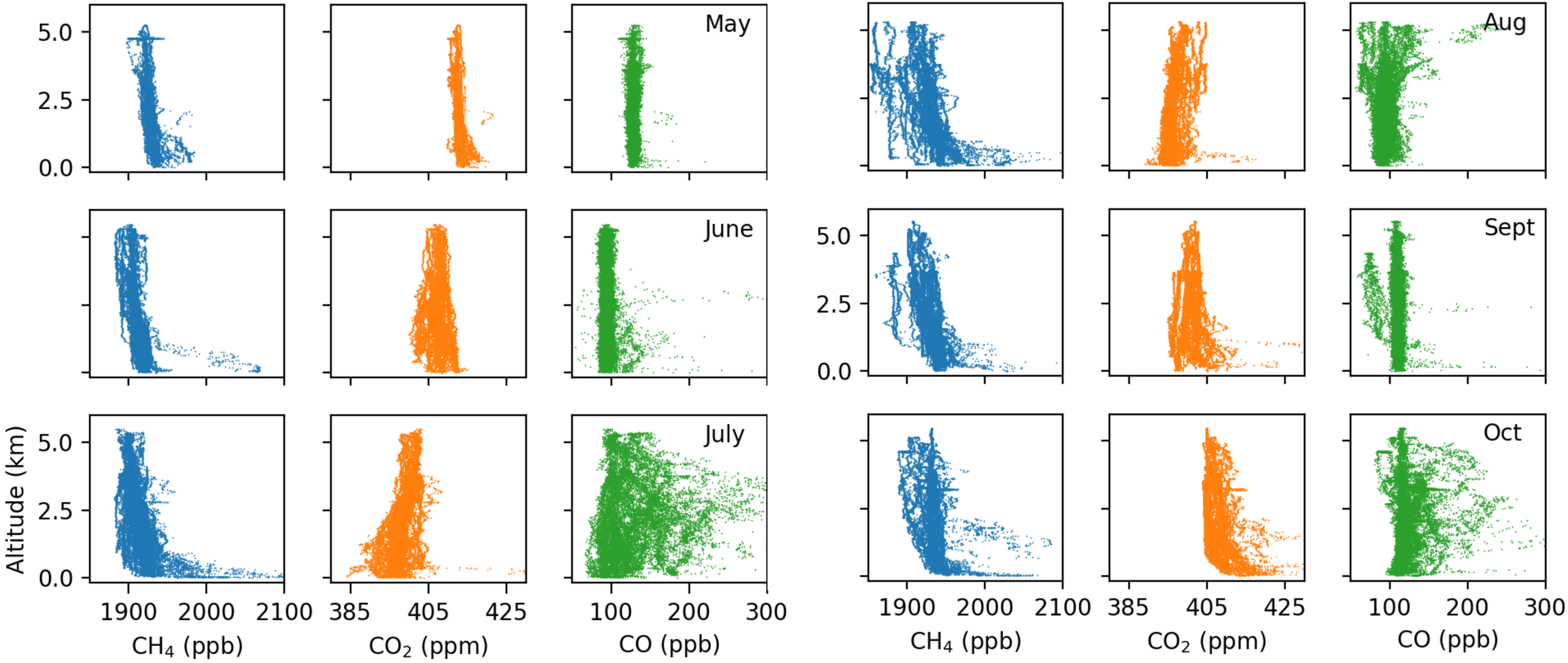
D Yang iPoster

ArctiCAP 2017

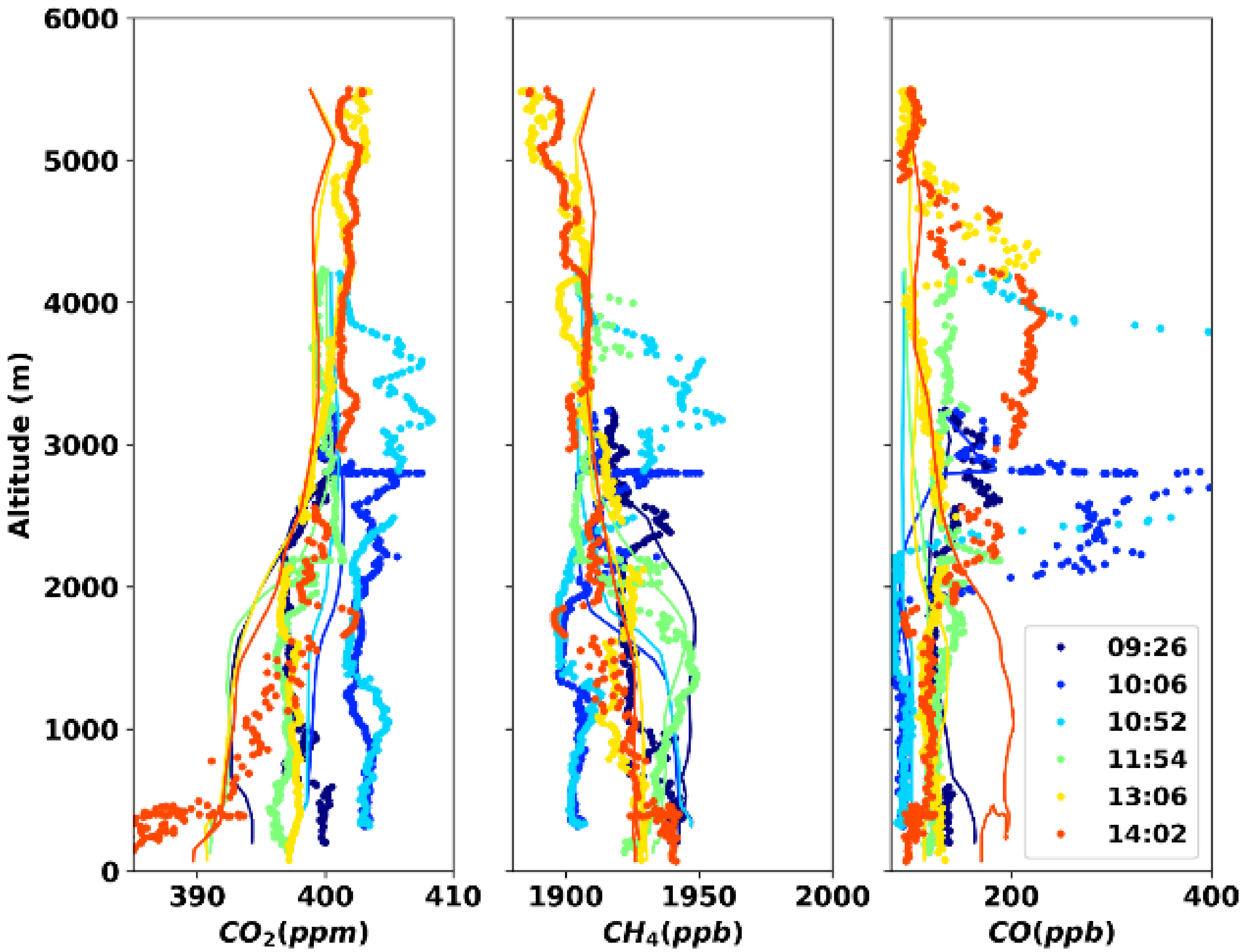


Sweeney 2020

ArctiCAP Vertical Profiles Reveal Local (PBL) vs Regional (FT) Influences

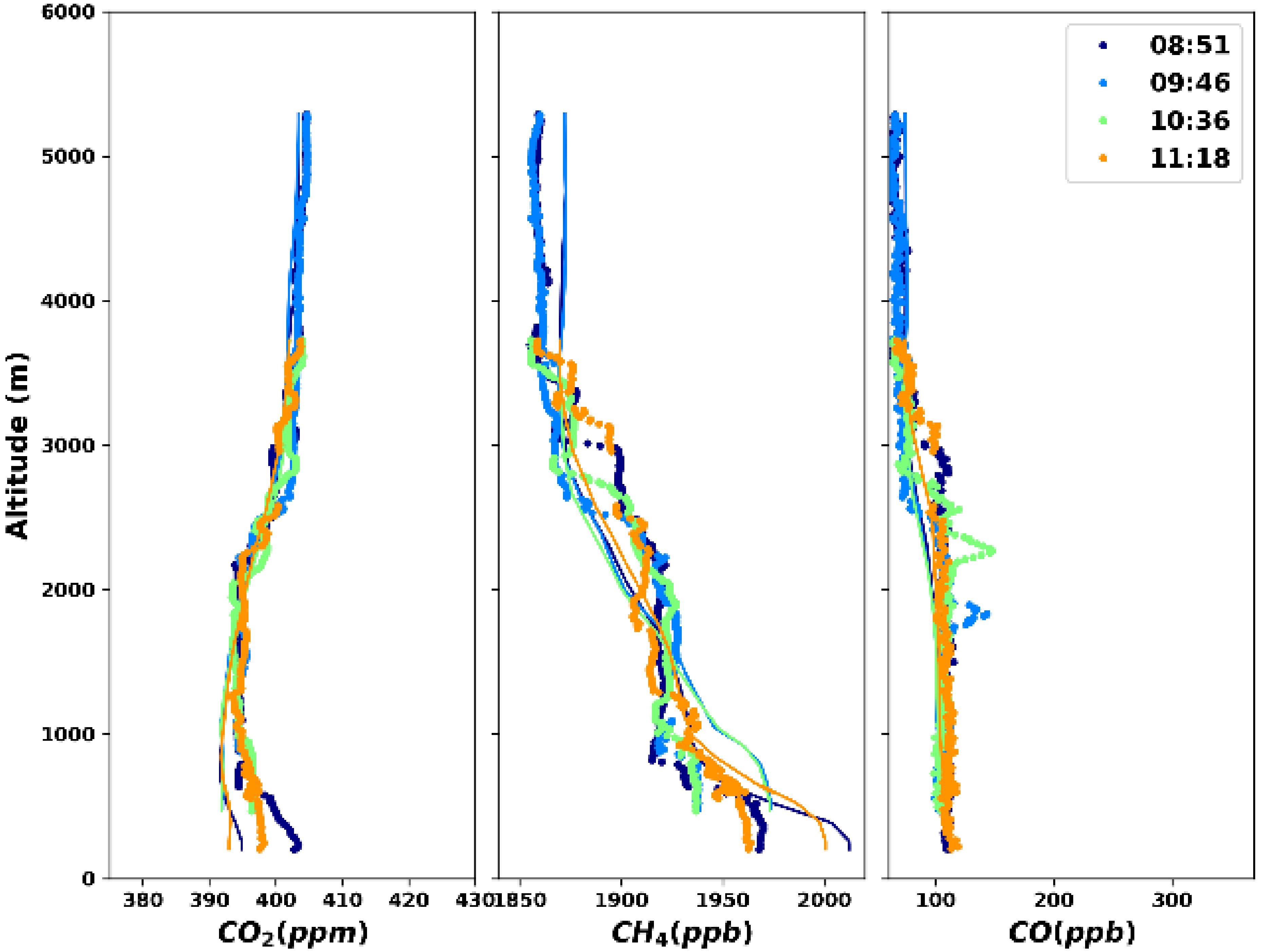


Mackenzie River Transect Observation and model estimates of profiles
July 10, 2017



ABoVE Arctic-Boreal Vulnerability Experiment

Mackenzie River Transect Observation and model estimates of profiles August 30, 2017



GEOS-GCM CO2 and CH4 Flux Estimates

GEOS-GCM CO_2 Flux Estimates (PgC yr^{-1}) for 2017

ABoVE Domain		pan-Arctic (>48 N)		Global	
Land Sink	Fuel Source	Land Sink	Fuel Sources	Land Sink	Fuel Sources
-0.32	0.11	-1.84	1.37	-3.28	11.08

GEOS-GCM CH_4 Flux Estimates (TgCH4 yr^{-1}) for 2017

ABoVE Domain		**pan-Arctic (>48 N)**		**Global**	
Wetland	All Sources	Wetland	All Sources	Wetland	All Sources
9.01	11.64	21.74	52.03	187.39	536.01

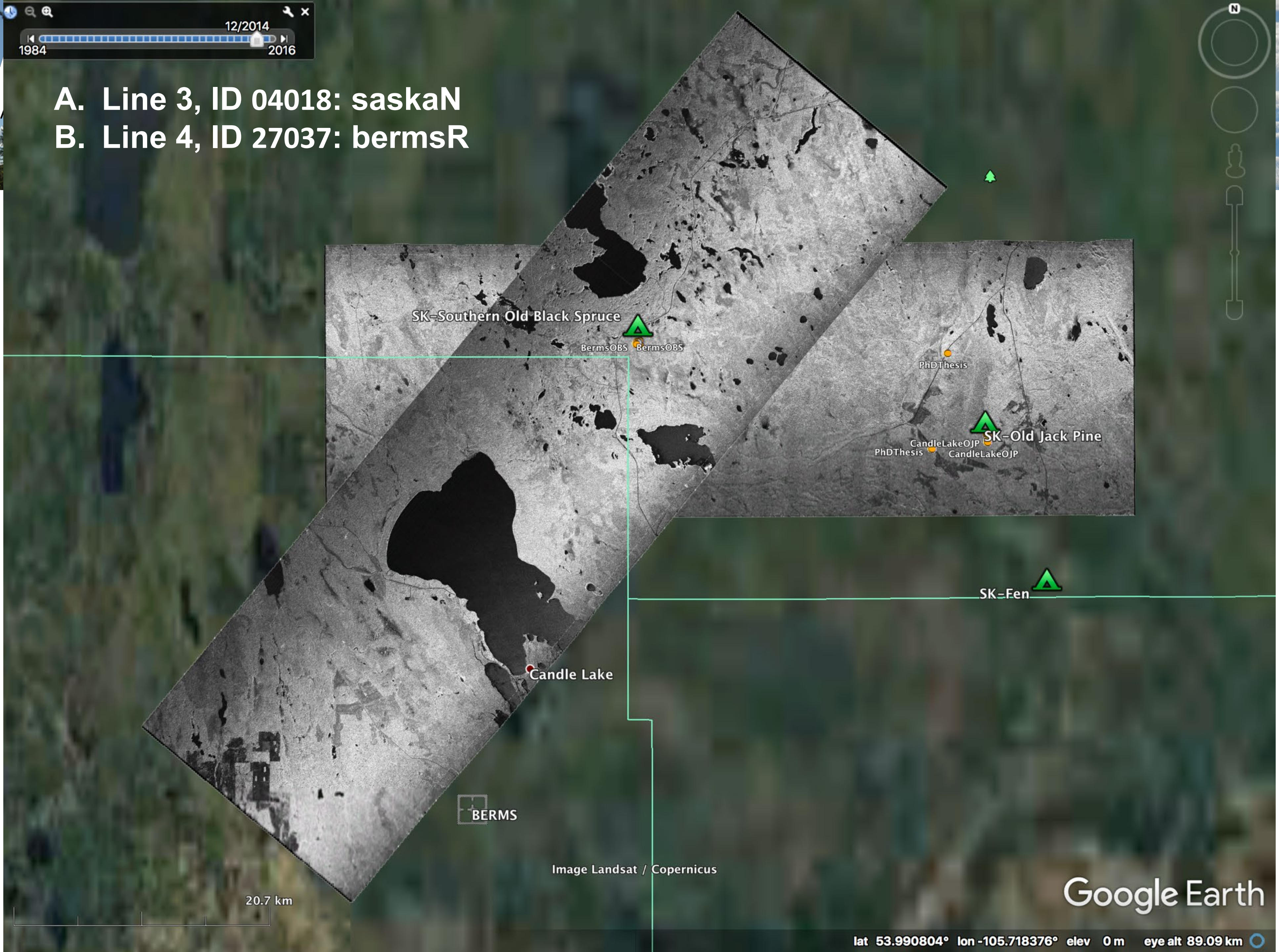
Chatterjee, in prep

ABoVE Arctic-Boreal Vulnerability Experiment

2019 L-Band SAR Updates


16 August 2019/DOY 228
BERMS
Line 4, ID 27037: bermsR – screen shot

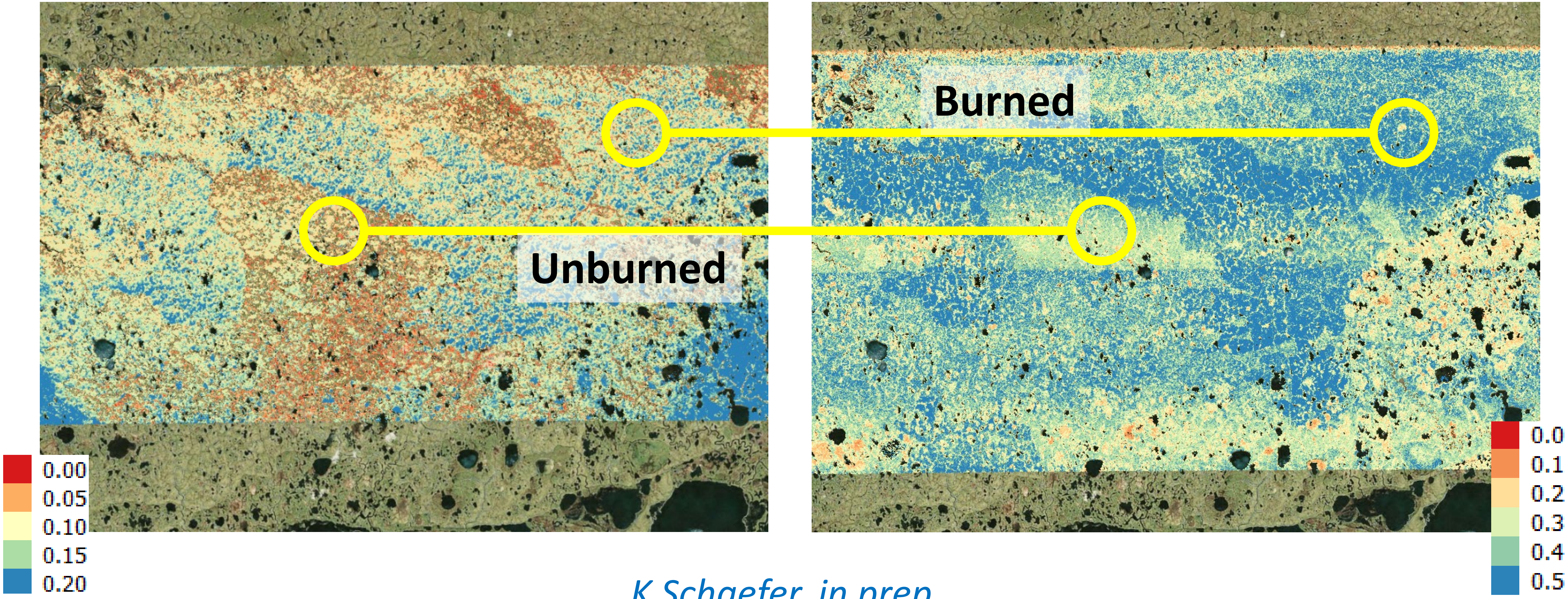
A. Line 3, ID 04018: saskaN
B. Line 4, ID 27037: bermsR



2015 YK Delta Burn Scars Show Deeper ALT and Wetter Soils

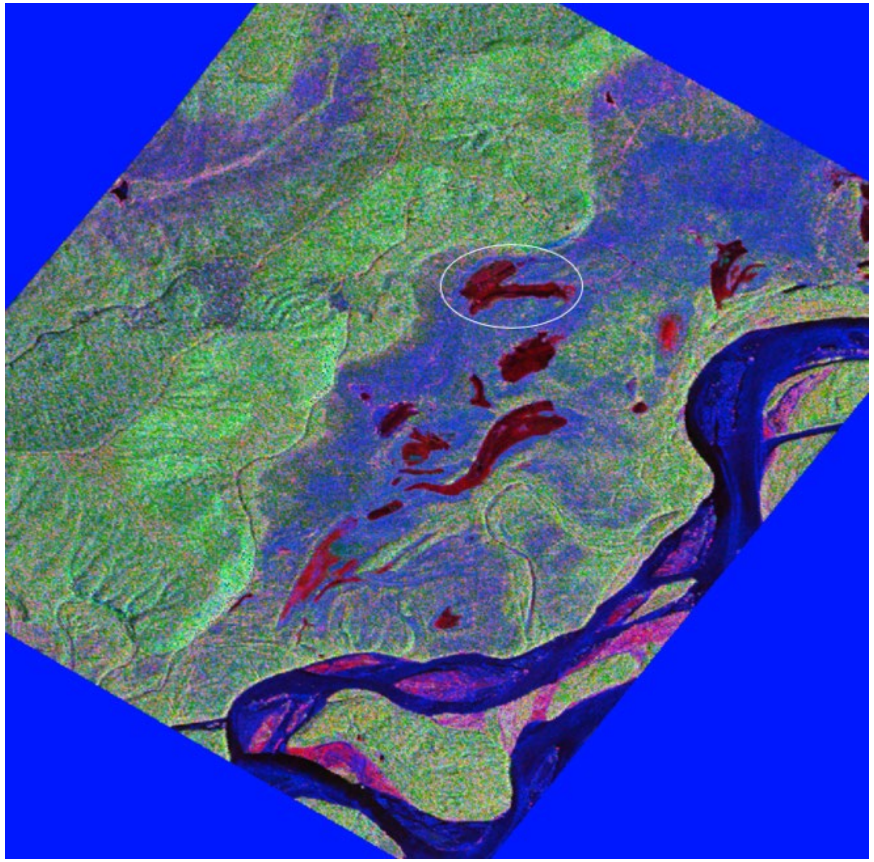
Active Layer Thickness (m)

Volumetric Water Content



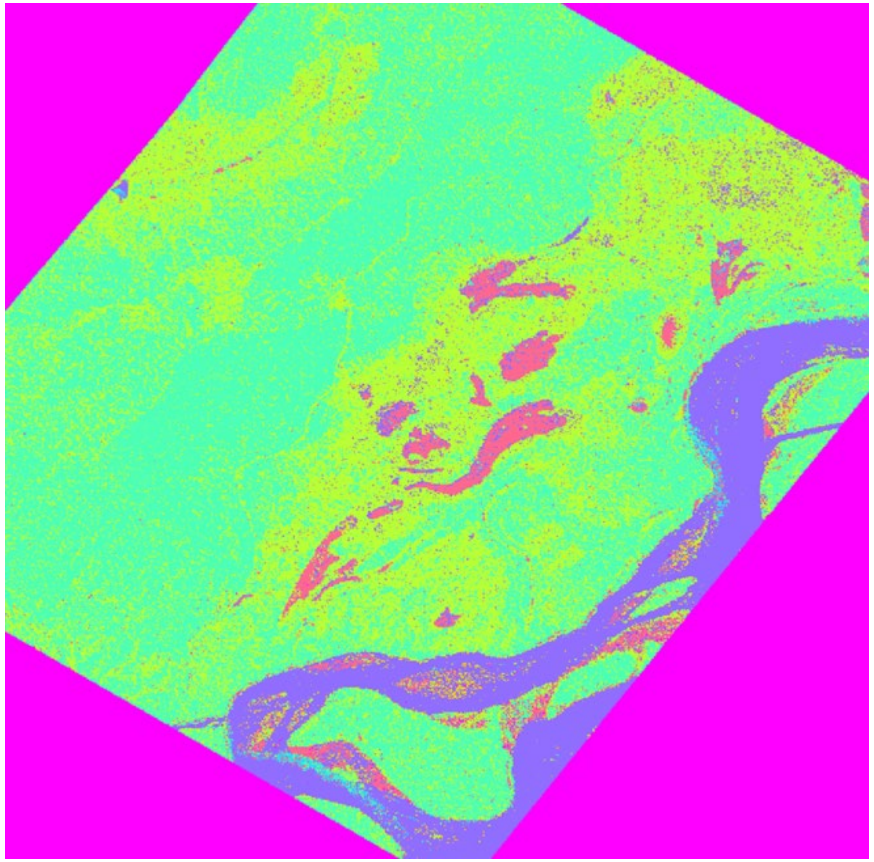
K Schaefer, in prep

Mapping Seasonal Inundation at Bonanza Creek with L-band SAR



Freeman-Durden(F-D) polarimetric decomposition of UAVSAR _band SAR data collected over the Bonanza Creek Apex site on June 16, 2017.

Red indicates dominated by double bounce scattering
Green indicated dominated by volume scattering
Blue indicates dominated by surface scattering



Classification of UAVSAR F-D values from UAVSAR /June 16, 2017.

Flooded grass-like vegetation/sedges (red)
Dry low vegetation (yellow)
Open water (blue)
Forest (green)

B Chapman, ES. Kasischke, N French, D Rupp, E Kane, IGARSS, July 2020.

Arctic-Boreal Vulnerability Experiment

Mapping Permafrost Active Layer Properties Using P-Band SAR

Background

- Long wavelength radar enables direct retrieval of permafrost soil properties and dynamics due to ability to penetrate soils. We developed a retrieval algorithm for permafrost active layer thickness (ALT) and soil moisture profiles from AirMOSS time-series P-band polarimetric SAR (PolSAR).

Analysis

- The dielectric contrast between the thawed active layer and the frozen soil provides the signature in radar backscatter for ALT and soil moisture retrieval.

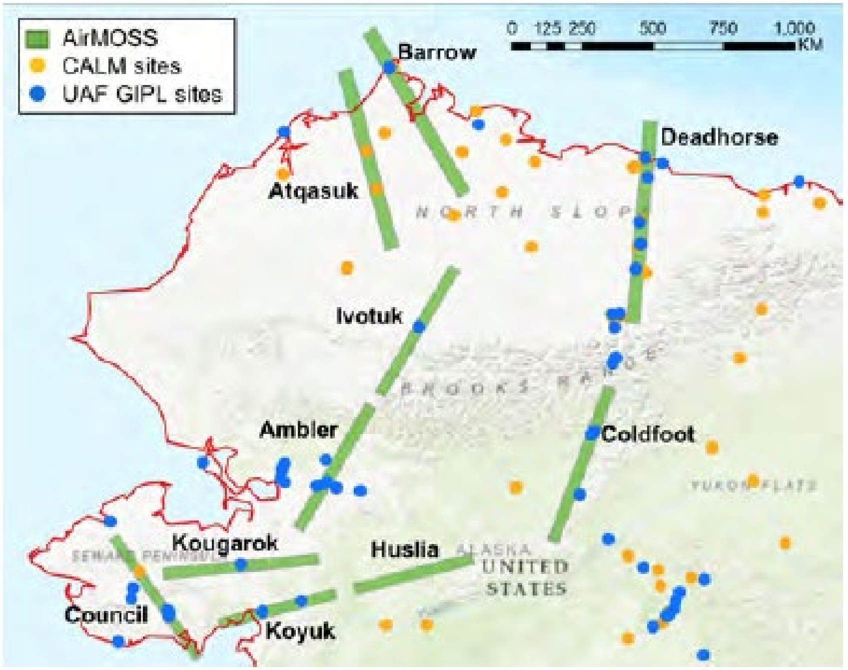
Findings

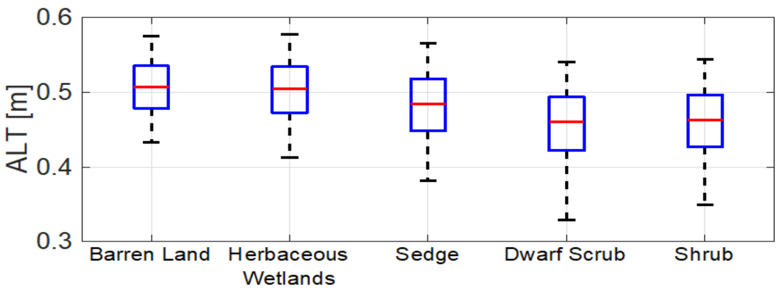
- ALT retrieval error is <10 cm for sites where in-situ ALT is within the AirMOSS sensing depth (~0.55 m).
- Retrieved dielectric profiles also provide soil moisture and F/T state and can inform organic matter content calculation.

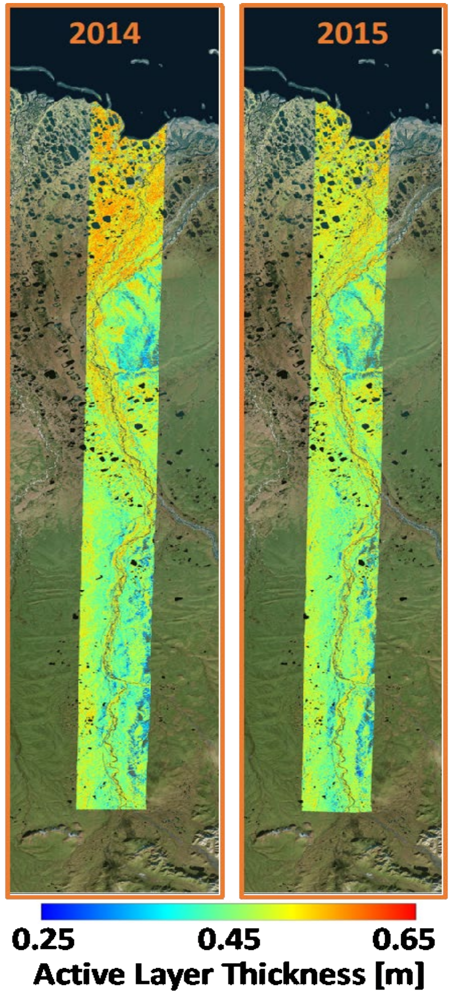
Significance

- Results show the capability of P-band radar for direct retrieval of active layer soil properties, including ALT, soil moisture, and F/T profiles. This approach provides insights into regional high-resolution active layer variability and can help improve soil process modeling for assessing the vulnerability of permafrost.

RH Chen et al., IEEE TGRS (2019)



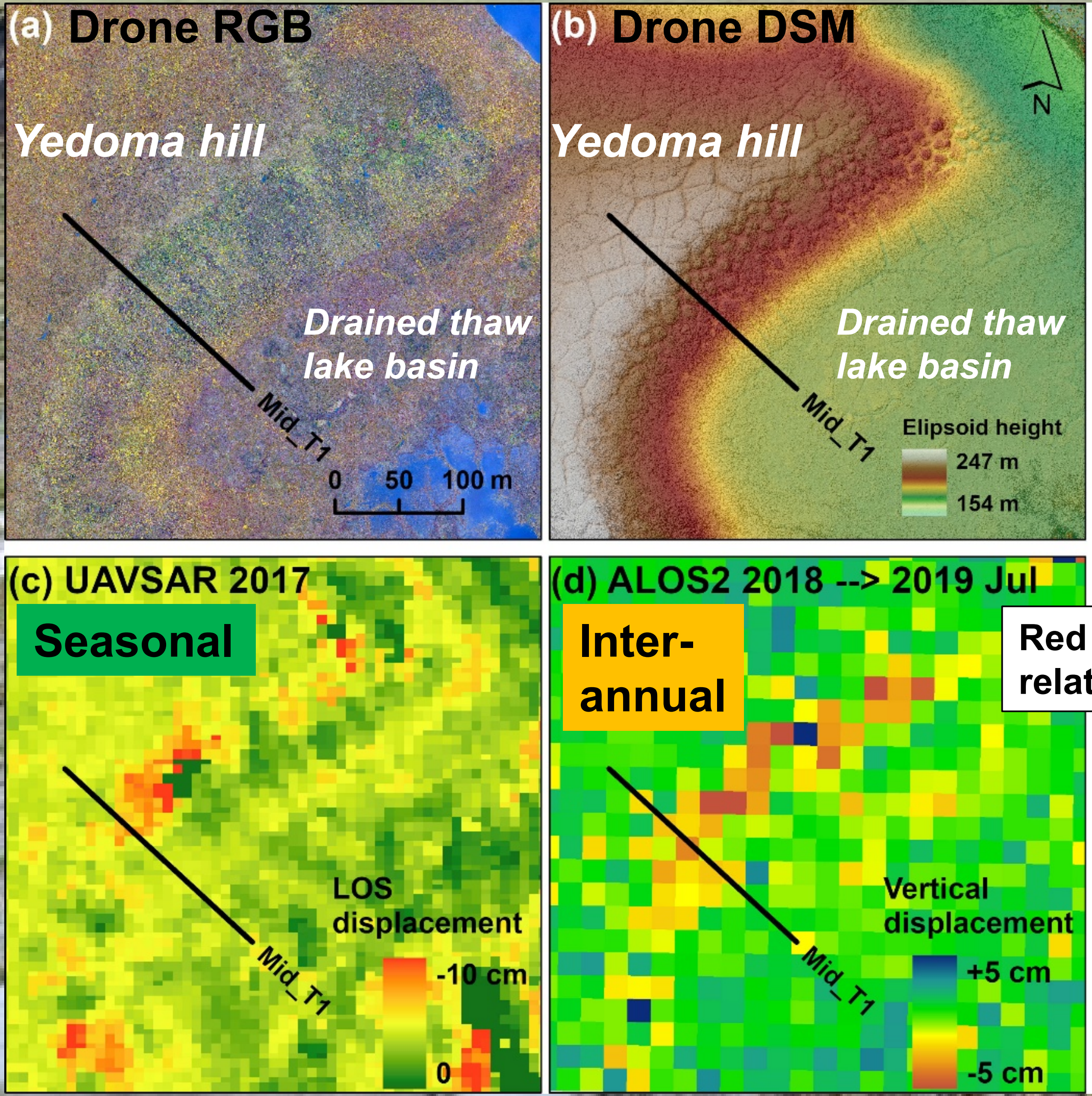


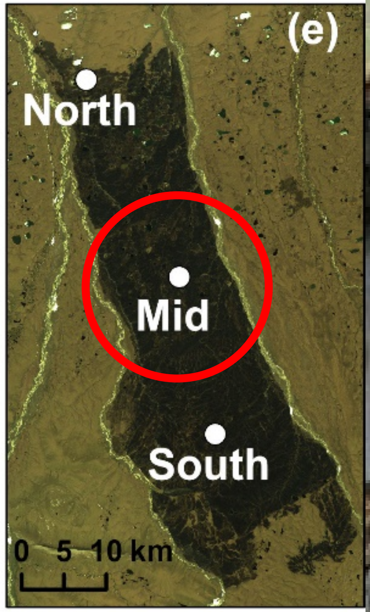


ALT is shown on right for the Deadhorse flight line. Bottom left panel shows retrieved ALT spatial distributions across different land covers.

High subsidence rates along the edges of Yedoma hills

(Iwahana et al., in prep.)

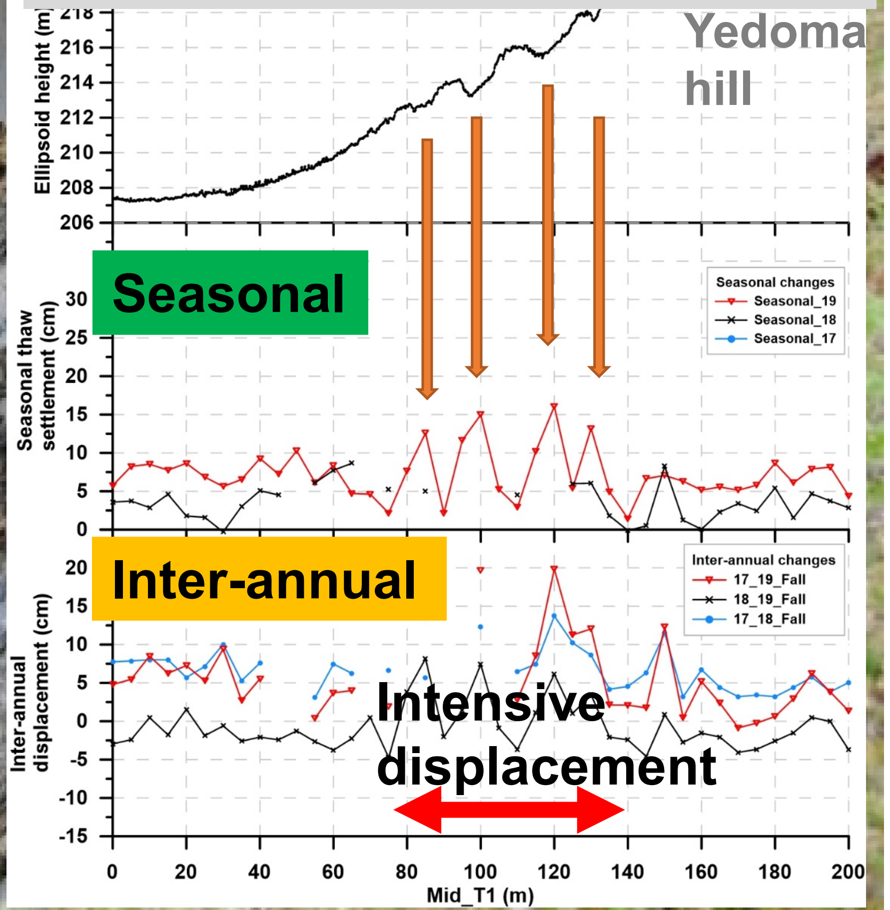




Red pixels indicate relative subsidence

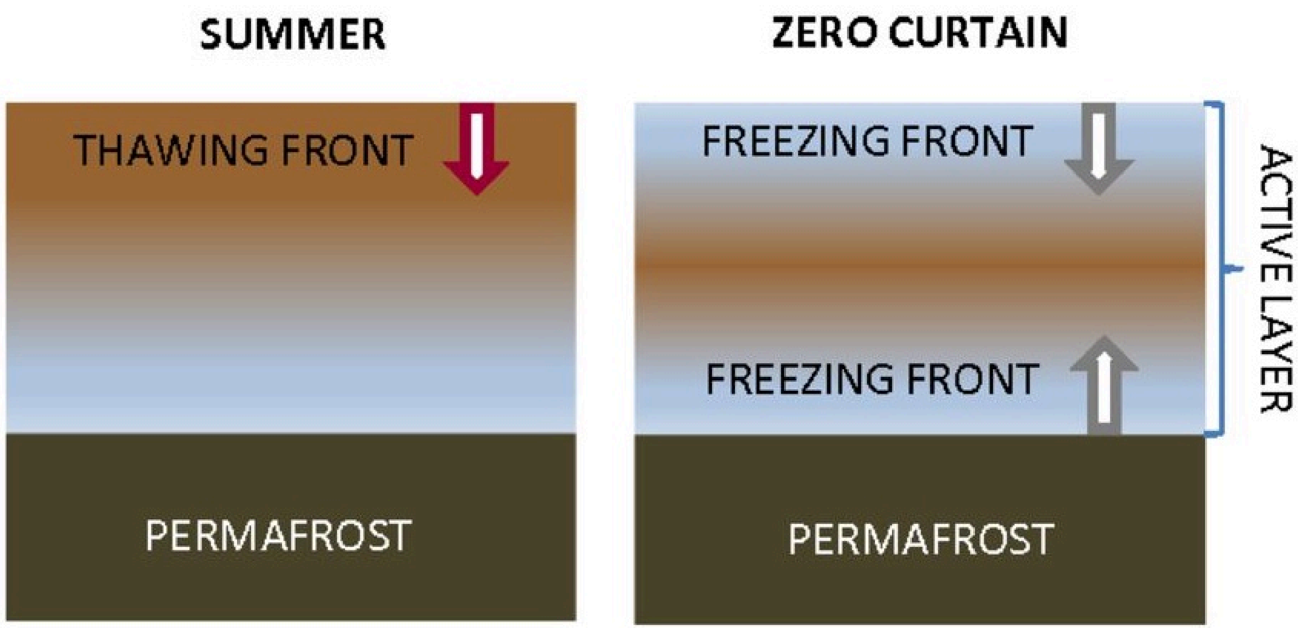
Freeze/thaw-related subsidence measured by UAVSA/ALOS2 InSAR was confirmed by field survey

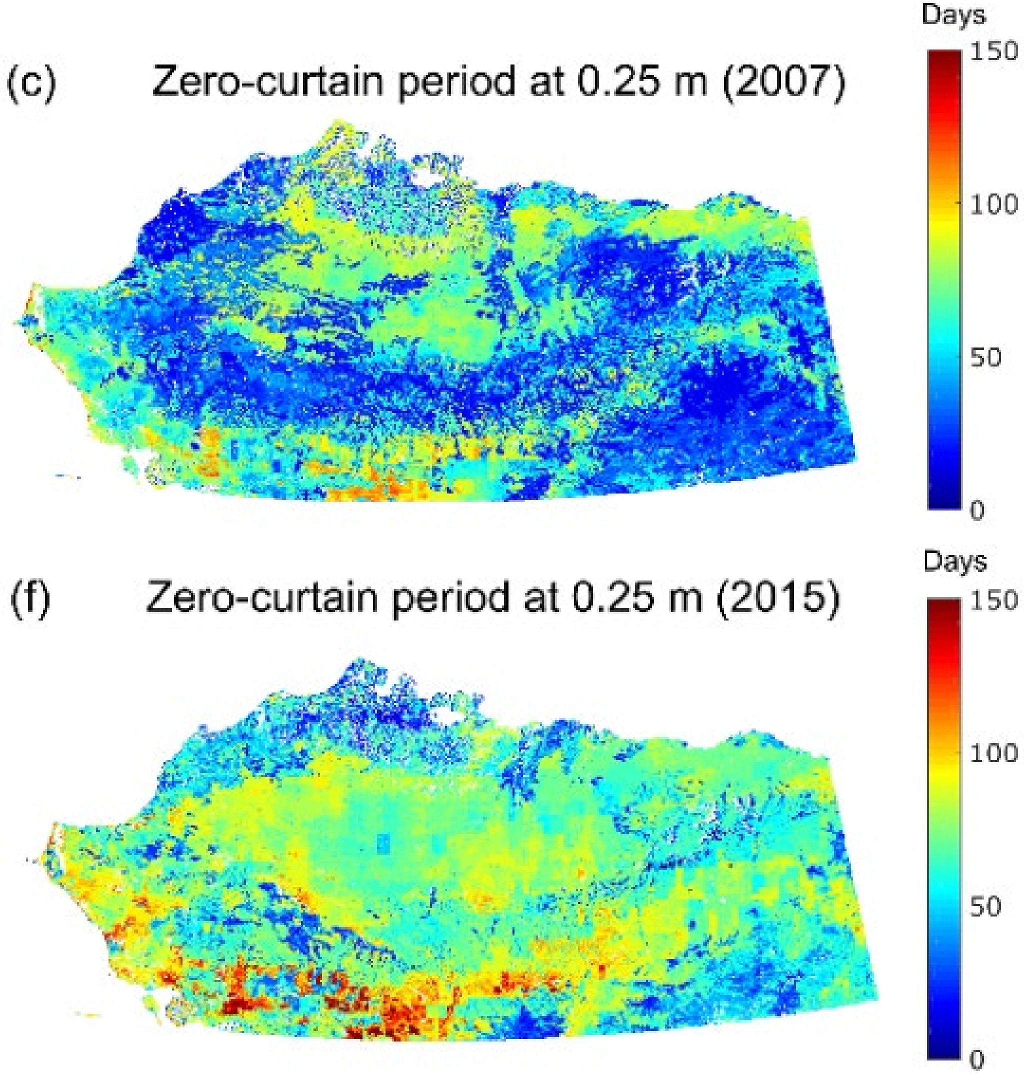
Field survey of surface displacement



- Difference in seasonal and inter-annual subsidence zones
- Spatial resolution matters for field-scale interpretations

Challenge: SAR Mapping of Pan-Arctic Permafrost Zero Curtain Period





Y Yi et al., The Cryosphere (2019)

Measurement Challenge:
Quantify the depth, thickness, and duration of subsurface thawed soils under a surface ice layer

D Zona et al., PNAS (2016)

Questions

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https://above.nasa.gov/airborne/index.html