2023 SnowEx field campaign in Alaska, U.S.

Presented by Svetlana Stuefer, University of Alaska Fairbanks

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Toolik All Scientists Meeting, Santa Barbara, CA, January 19, 2023

Photo by Alicia Pouw

SnowEx Alaska Organizing Team:

Carrie Vuyovich, Sveta Stuefer, HP Marshall, Mike Durand, Kelly Elder, Dragos Vas, Art Gelvin, Batu Osmanoglu, Chris Larsen, Stine Pedersen, Dan Hodkinson, Eli Deeb

WHAT IS SNOWEX?

Snow Experiment (SnowEx)
A series of field and airborne campaigns designed to test out different remote sensing techniques to measure snow

SnowEx Science Plan:
https://snow.nasa.gov/sites/default/files/SnowEx_Science_Plan_v1.6.pdf

Website:
https://snow.nasa.gov/campaigns/snowex/2023/overview

NASA SnowEx

Designed to prepare for snow satellite missions to observe global snow water equivalent and albedo

Includes extensive airborne and surface-based observations to evaluate different snow remote sensing technologies throughout the season in various landscapes

Help address key issues impacting snow remote sensing and algorithm development

SnowEx 2017 – Colorado, focused on multiple instruments in forest gradient

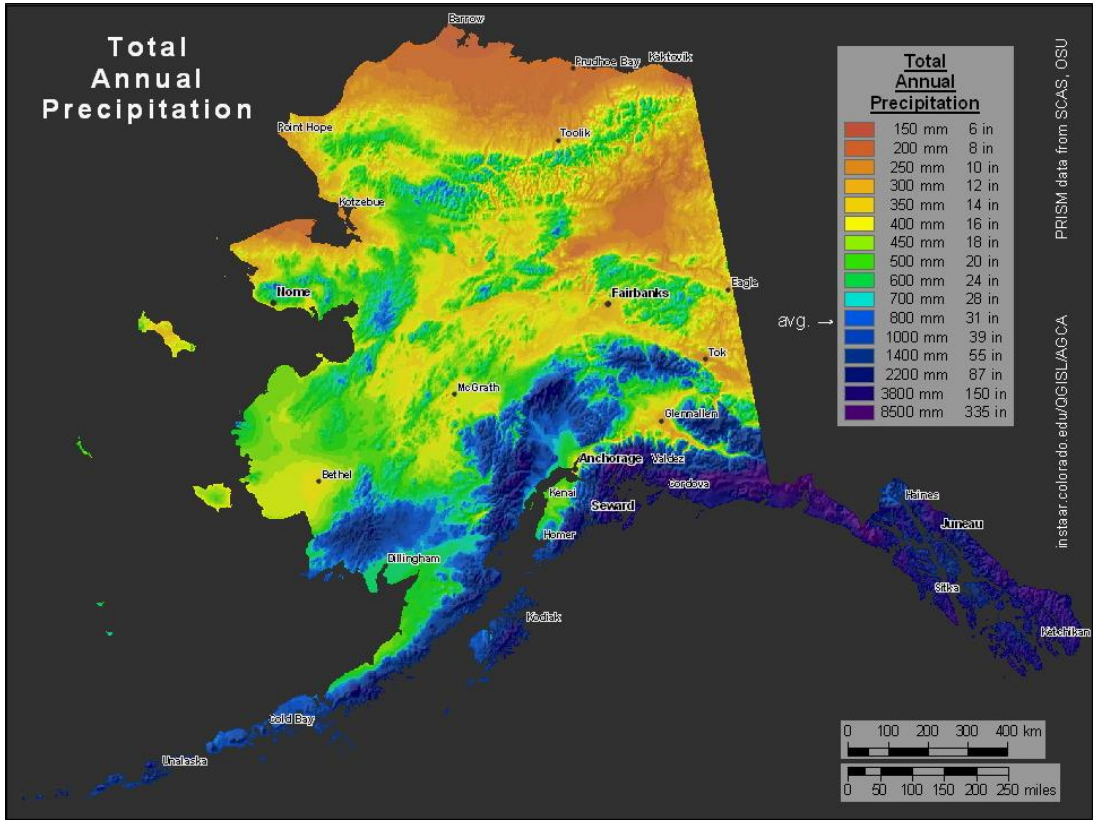
SnowEx 2020 – Western US, focused on Time Series of L-band InSAR, Active/passive microwave for SWE and Thermal IR for snow surface temp

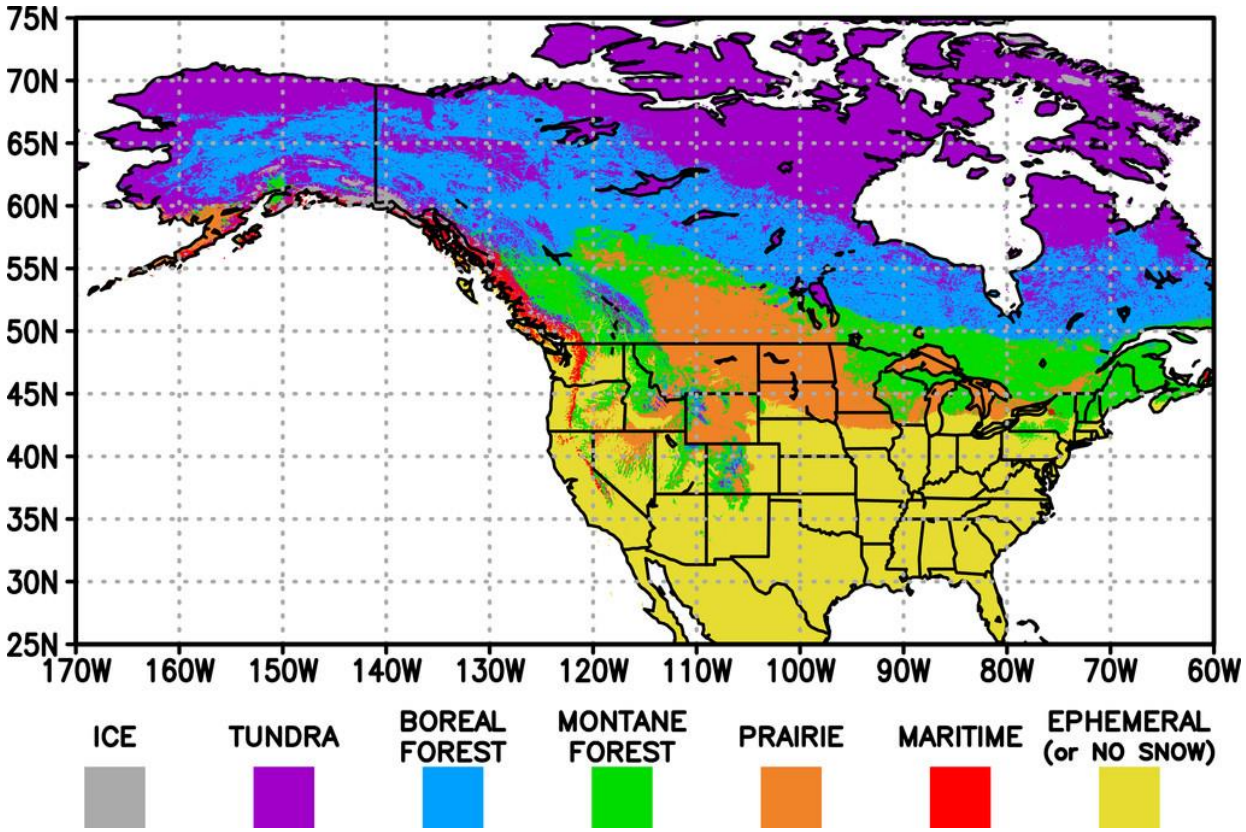
SnowEx 2021 – Western US, Continue Time Series, L-band InSAR, also address Prairie & Albedo questions

SnowEx 2023 – Northern Alaska, Tundra/Boreal forest focus; plans developed to address SWE/snow depth and albedo objectives

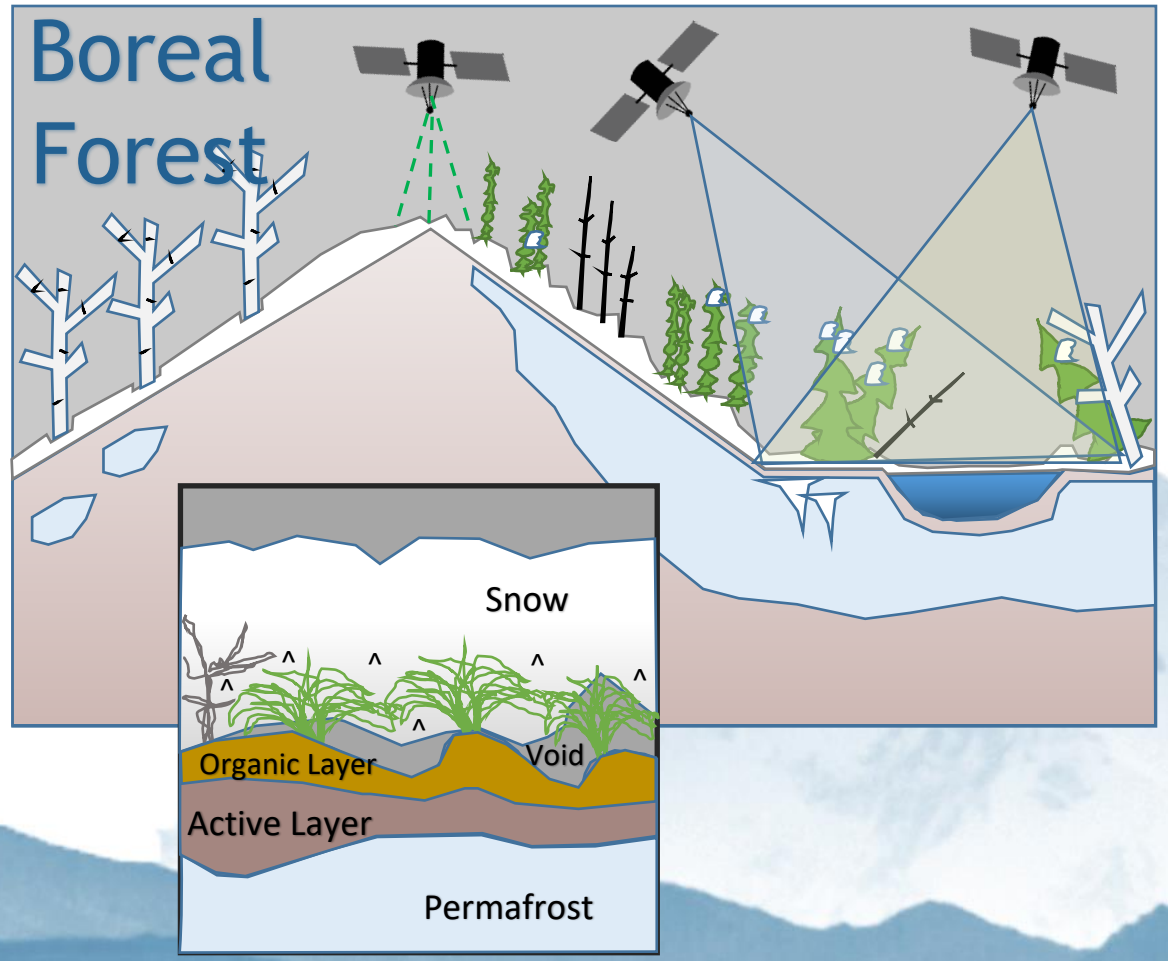
Why Alaska?

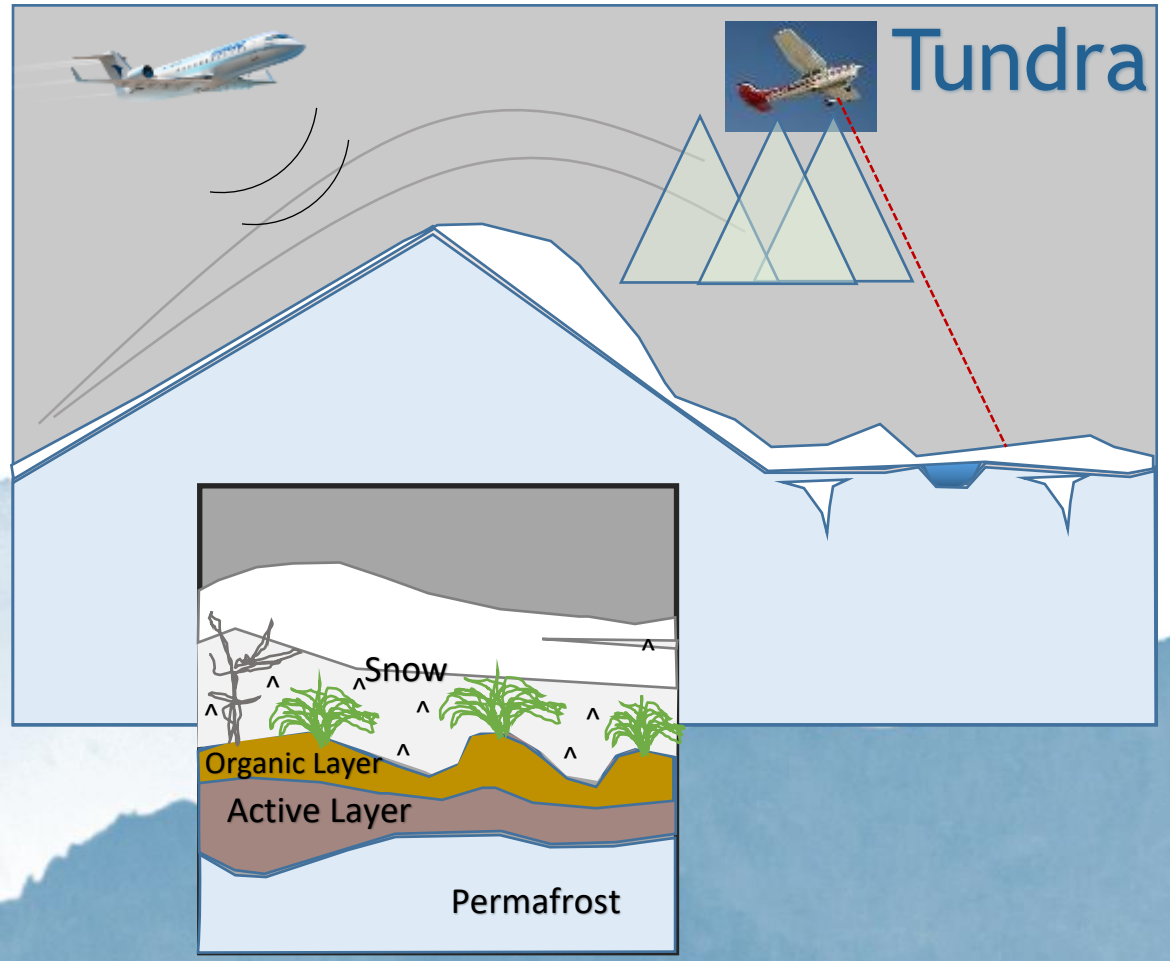
Snow in Alaska





Source: Sturm and Liston 2021, Revisiting the Global Seasonal Snow Classification: An Updated Dataset for Earth System Applications





Tundra and Boreal Forest Snow represent unique and significant remote sensing challenges:

- The permafrost and active layer impacts altimetry methods when “bare earth” changes
- Strong temperature and humidity gradients modify snow characteristics
- Forest cover obscures snow from remote sensing measurements or impacts the signal

Graphics by C. Hiemstra

SnowEx Tundra/Boreal Forest Science Objectives:

Three classes of objectives/questions: **Measurement Science**, **Snow Science**, **Information Science**

1. Snow depth/SWE: How does microstructure model accuracy and scaling issues impact use of models to inform microwave retrievals in tundra snow? Taiga snow: How much do microwave signals penetrate forest canopies in boreal forests?

2. Snow depth/SWE: How well do snow depth retrieval methods (e.g., lidar and SfM) work where in the variable permafrost, water, and vegetation characteristics ubiquitous at high latitudes?

3. Snow depth/SWE: How does the L-band interferometric SAR approach perform where "bare earth" surfaces change?

4. Snow albedo: What is the nature of spatial variability of snow reflectance/albedo and physical properties in the Boreal/taiga/ tundra regions of North America?

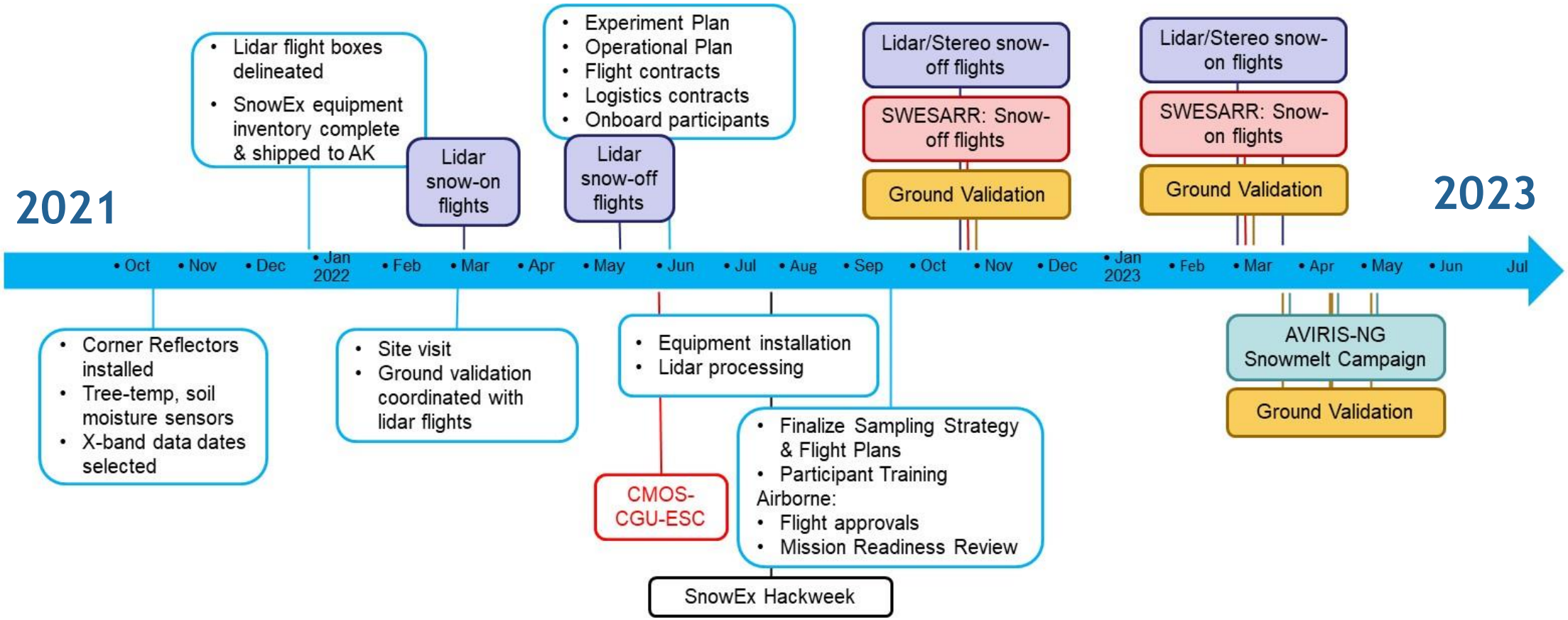
5. Snow albedo: How does the spatial variability of snow reflectance/albedo change with scale?

6. Snow process: How do vegetation and snow cover processes impact the "zero curtain" or freeze-thaw status of the surface layer and active layer transitions over seasonal time scales, and how does this affect remote sensing?

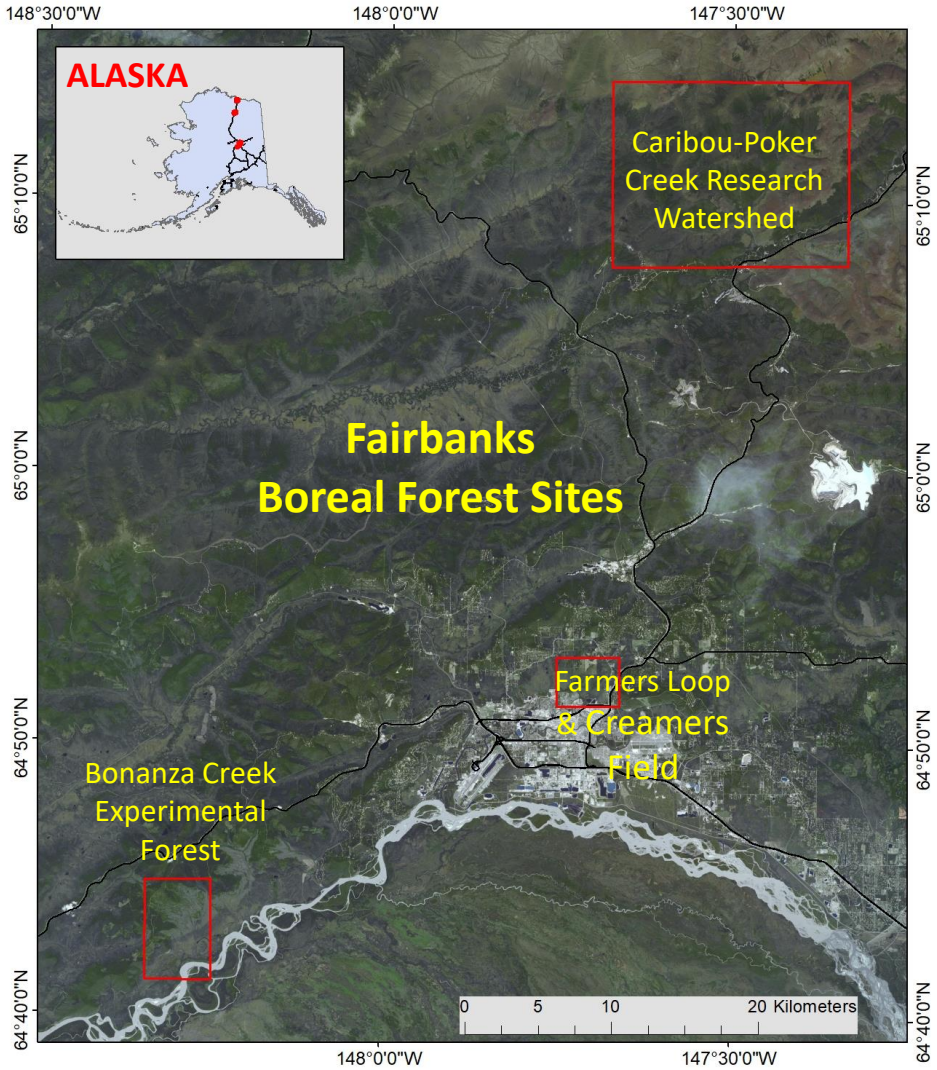
7. Snow process: What factors control variability in snow cover and physical properties across latitudinal, topographic, vegetation and disturbance gradients during the accumulation and melt seasons?

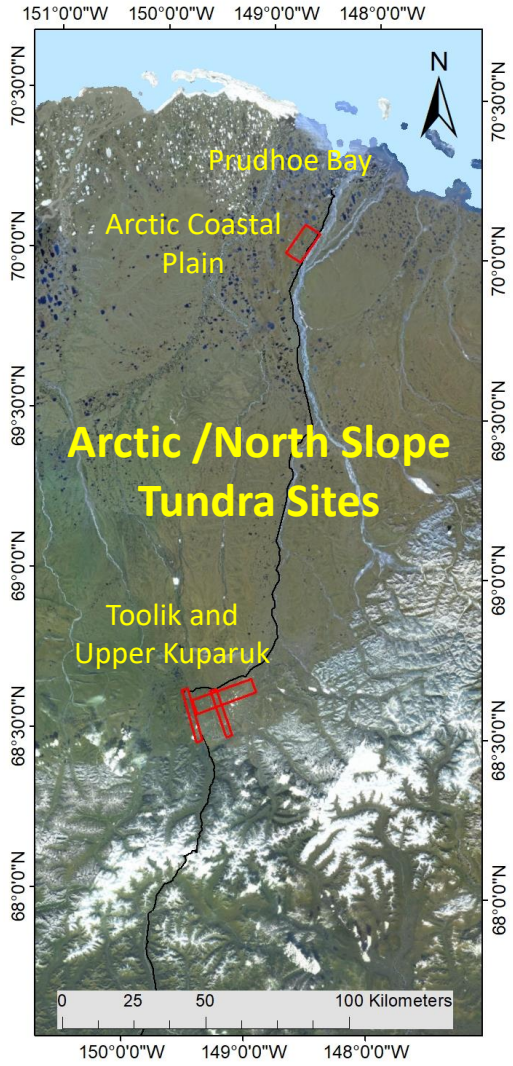
8. Data assimilation: How well do methods that integrate multiple types of data with process-based models help to fill in observational gaps given the uncertainties with bare earth elevations and other factors?

SnowEx 2023 timeline



Study Sites





Diverse boreal forest and Arctic sites to span conditions

Site Criteria:

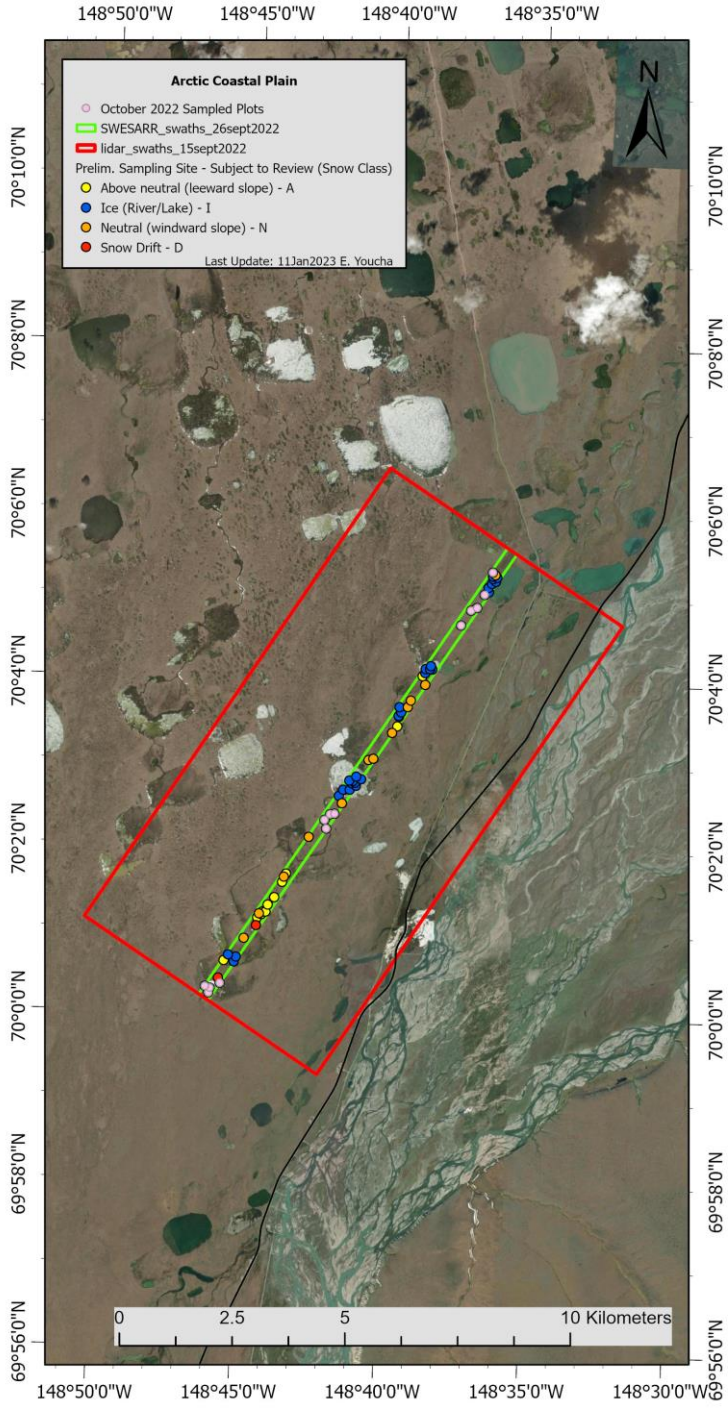
1. Access
2. Existing instrumentation/infrastructure
3. Long-term meteorological, snow and soil data records
4. Substrate/vegetation characterization
5. Permissions

Science criteria:

1. Sites with variable snow characteristics, vegetation, permafrost and disturbance
2. Vegetation (tundra & boreal forest)
3. Forest diversity – range of cover fraction & density (boreal)

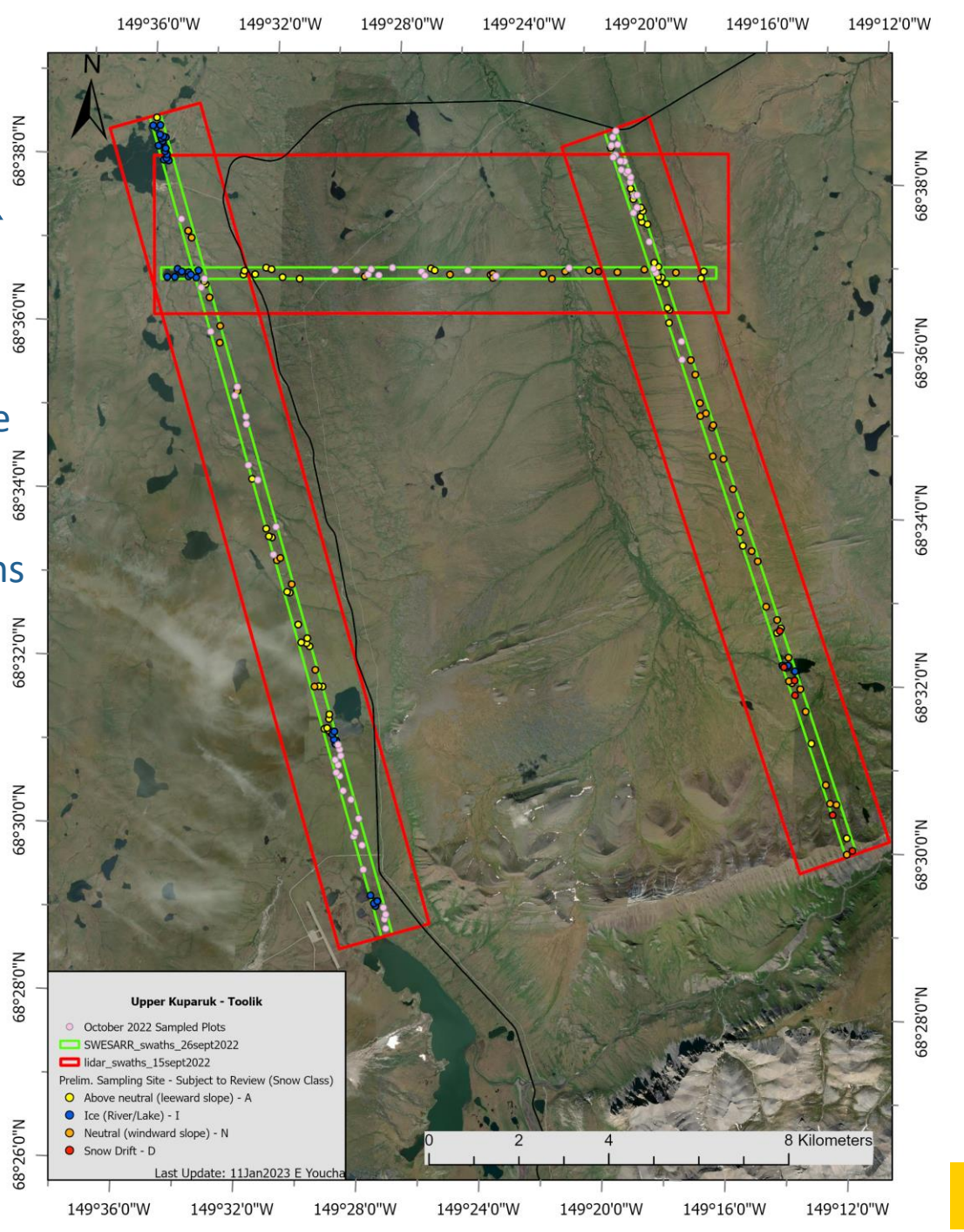
Arctic Coastal Plain

- Polygonal tundra, lakes, wetlands
- Elevation range 20 m – 45 m
- Continuous permafrost
- Shallow tundra snow with deep snow drifts
- Different ratio and characteristics of wind slab and depth hoar layers
- SNOTEL weather station
- Base out of Prudhoe Bay/Deadhorse



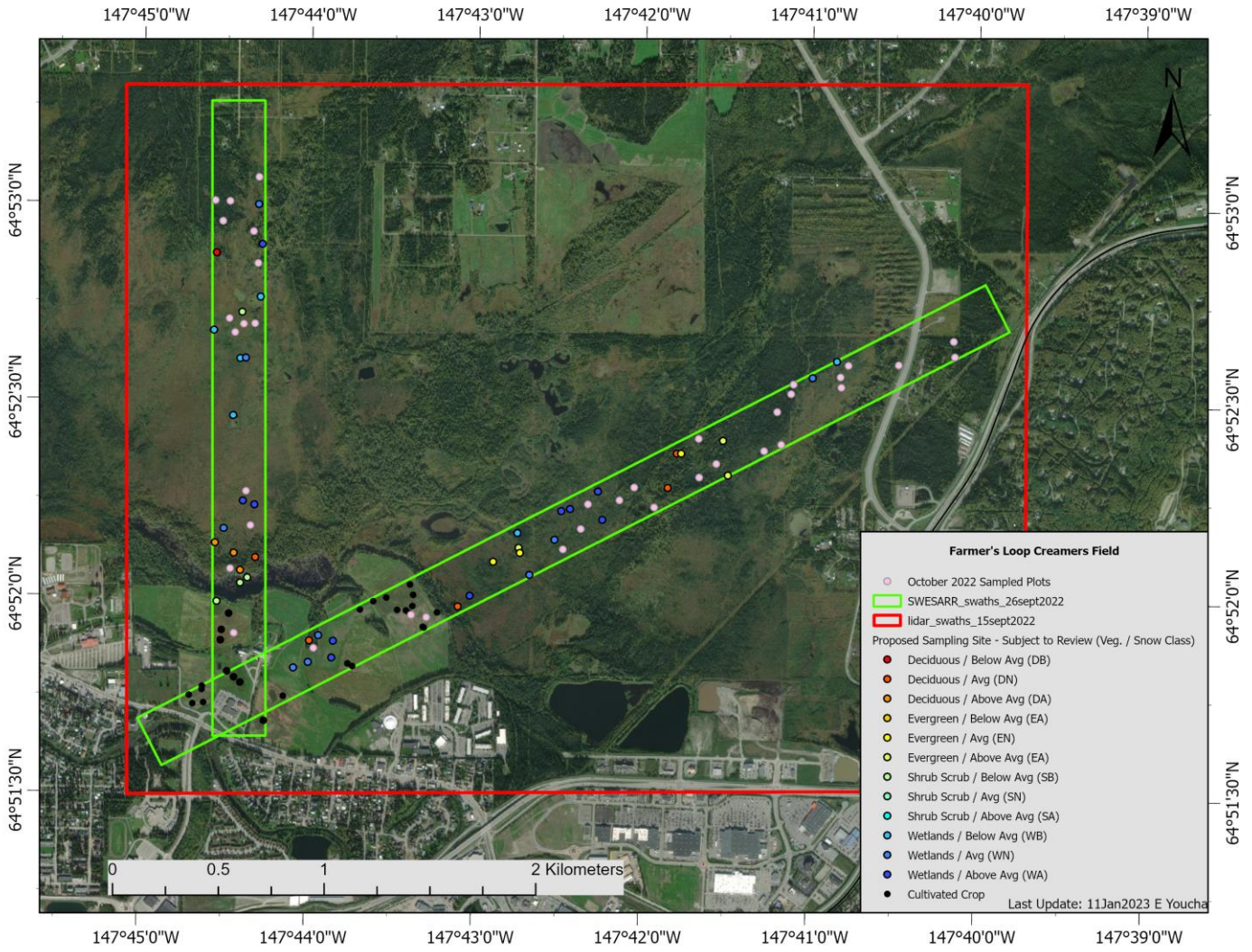
Toolik - Upper Kuparuk

- Tundra, riparian shrubland, shrub tundra, wetland, barren
- Elevation range 700 m – 1500 m; foothills of the Brooks Range
- Continuous permafrost
- Shallow tundra snow with deep snow drifts
- Long-term research site with weather and hydrological stations
- SNOTEL site
- CLPX (2007) & CoReH20 (2013) observations
- Base out of Toolik Field Station



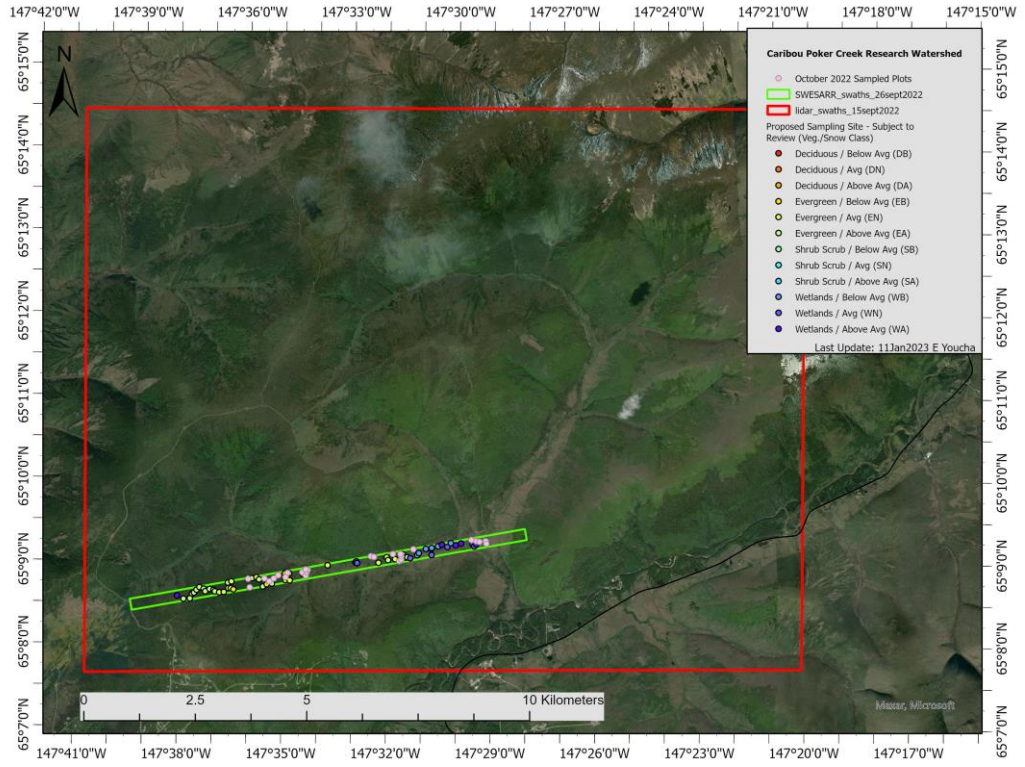
Farmers Loop and Creamer's Field

- Variable landscape conditions: Black spruce, mixed forest, shrubs, wetlands
- Elevation range 130 m – 165 m
- Discontinuous permafrost
- Taiga / boreal forest snow
- Easily accessible from lodging; trail access
- Long-term CRREL observations, met station and line power at Farmers Loop
- SNOTEL site at Creamer's Field
- Large open areas, opportunity to test SWE retrievals in varying forest densities



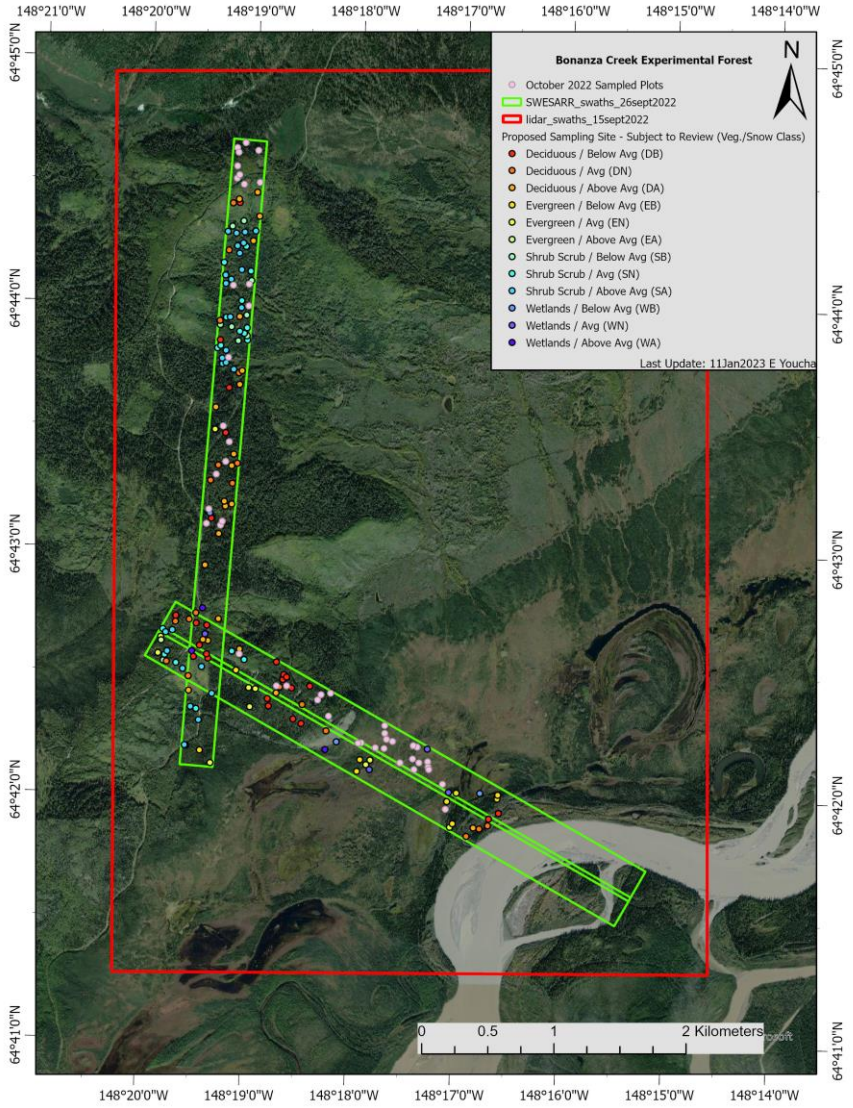
Caribou Poker Creek Research Watershed

- Variable landscape conditions: black spruce, mixed forest, wetlands
- Elevation range 200 m – 800 m
- Discontinuous permafrost
- Taiga / boreal forest snow
- Fire disturbance to the landscape (i.e. Haystack Fire, June 2021)
- Ongoing research project focused on boreal forests & water use
- NEON site, line power
- Challenging for SWE retrievals
- Existing snow-free lidar data



Bonanza Creek Experimental Forest

- Focus on black spruce area with variable forest density
- Elevation range 120 m – 400 m
- Discontinuous permafrost
- Taiga / boreal forest snow
- Corner reflector experiment to measure X- and Ku-band penetration in forests
- Road access between lines
- Weather stations
- CRREL snow survey lines
- Overlaps with AirSWOT/SWOT cal/val site (future effort)



October 2022 IOP measurements:

Ground:

- Plots - 186
  - Snow pits or SWE
  - Snow stratigraphy
  - Snow depth
  - Weather conditions
  - Vegetation characteristics
  - Substrate characteristics
- Terrestrial Laser Scanner (TLS) - 10 sites
- SfM for surface roughness
- Specific Surface Area (SSA)
- Time lapse cameras deployed
  - 9 at CPC
  - 11 at BCEF

Airborne:

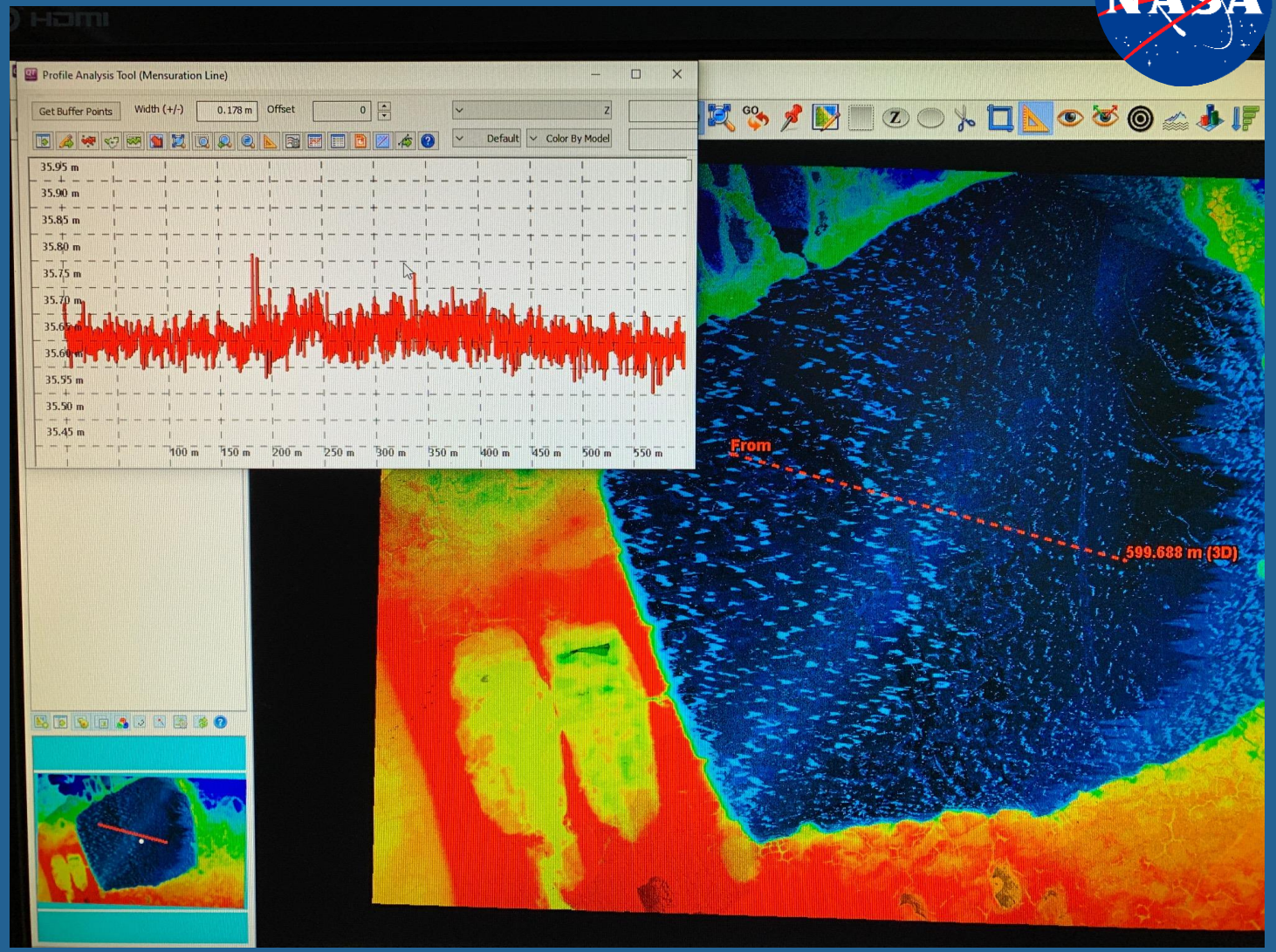
- Lidar
- Stereo Optical Imager
- Flights at all 5 sites

Satellite:

- ICESat-2 (lidar)
- Worldview (optical stereo)
- Pleaides-HR (optical)
- BlackSky (optical stereo)
- Planet SkySat-C (optical triplet stereo)
- Capella (x-band)
- ICEYE (x-band)
- Sentinel 1A (c-band)

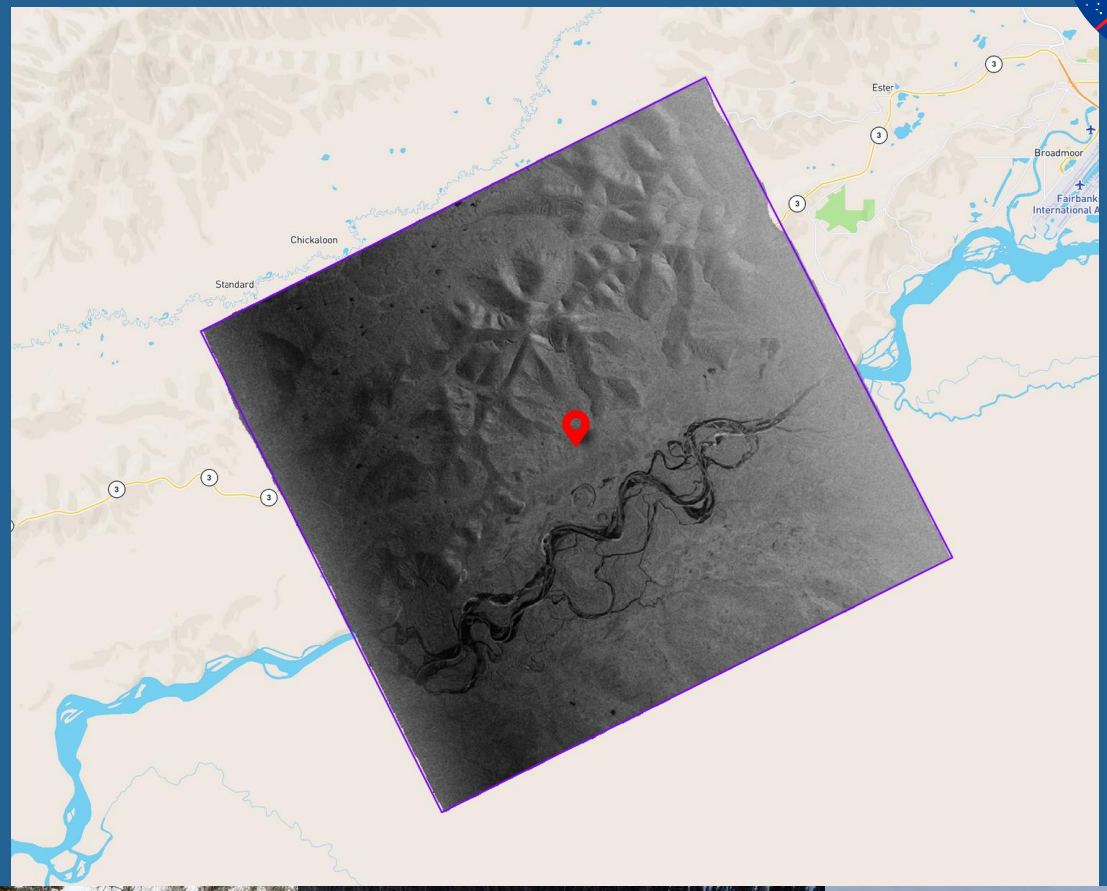
Airborne Lidar/Stereo

Point of contact: Chris Larsen, UAF



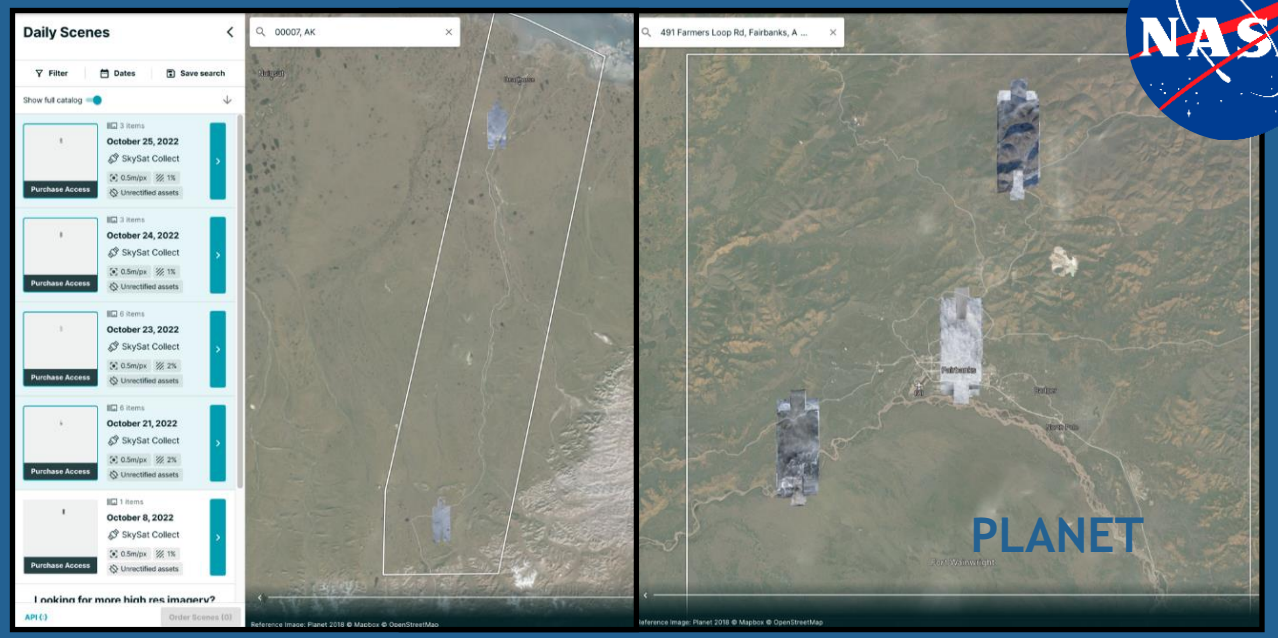
CAPELLA
ICEYE

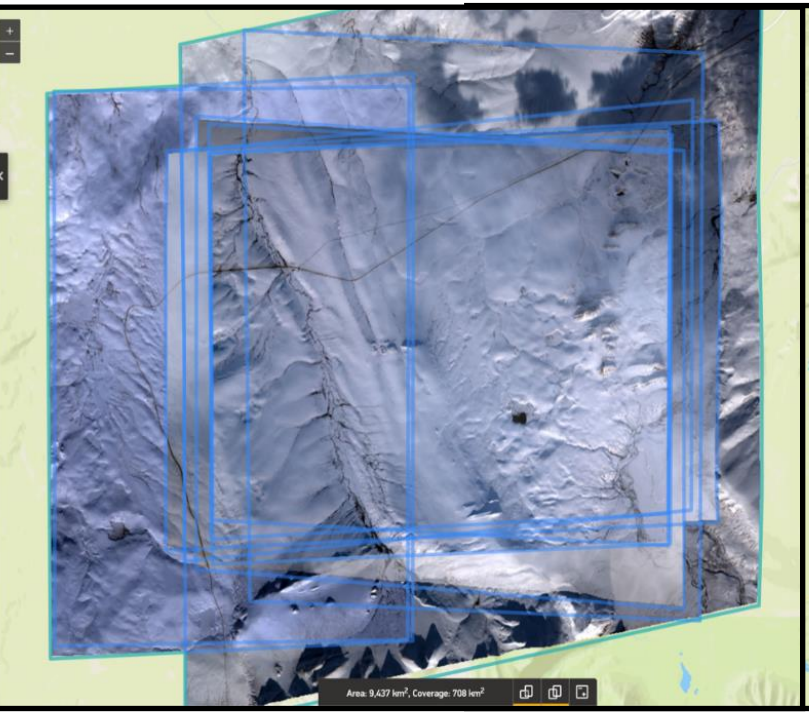
Point of contact: Mike Durand, OSU and Batu Osmanoglu, GSFC.

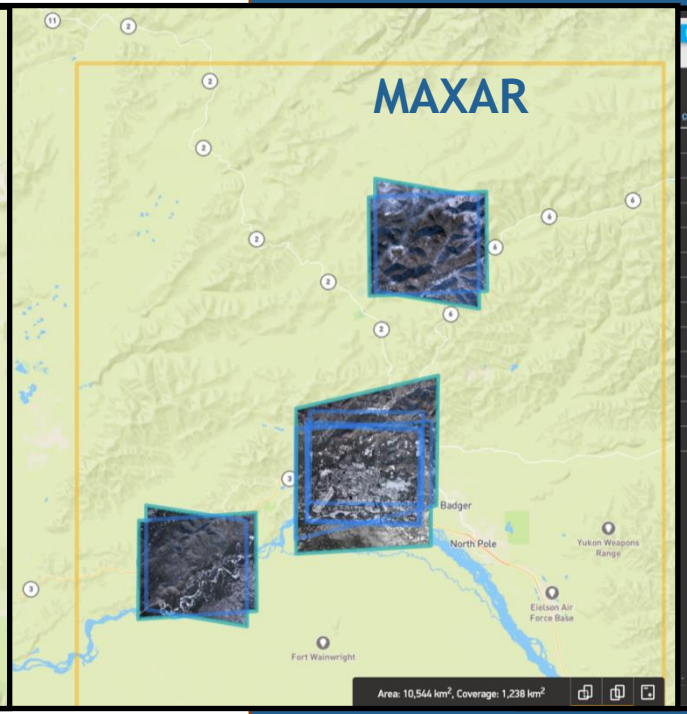


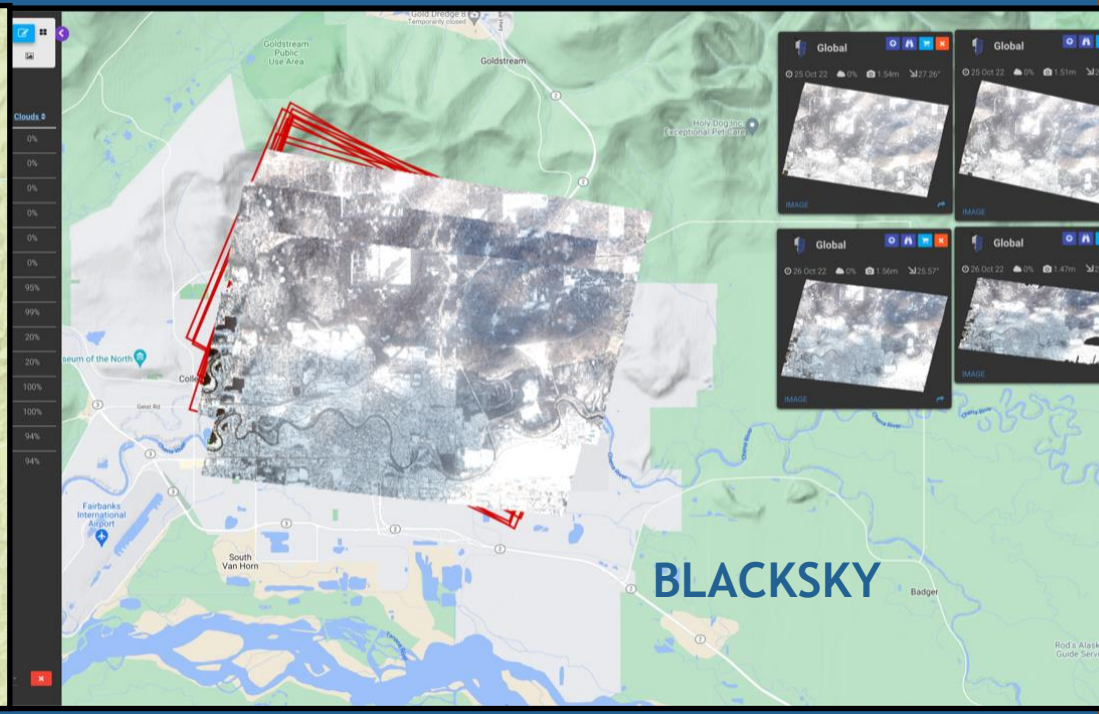
Optical imagery

Point of contact: David Shean, UW



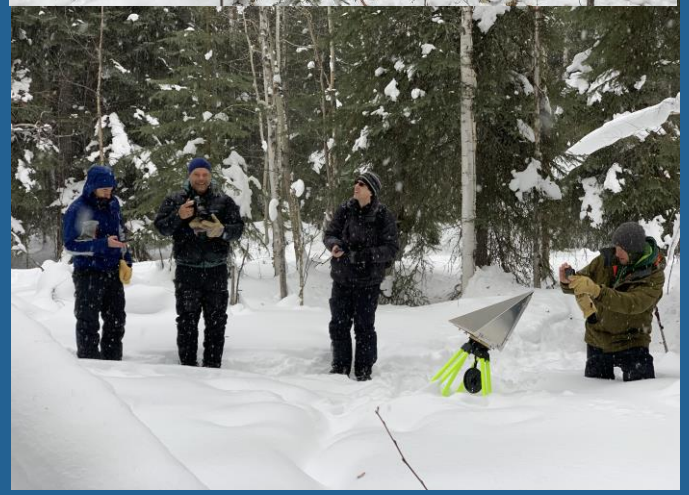






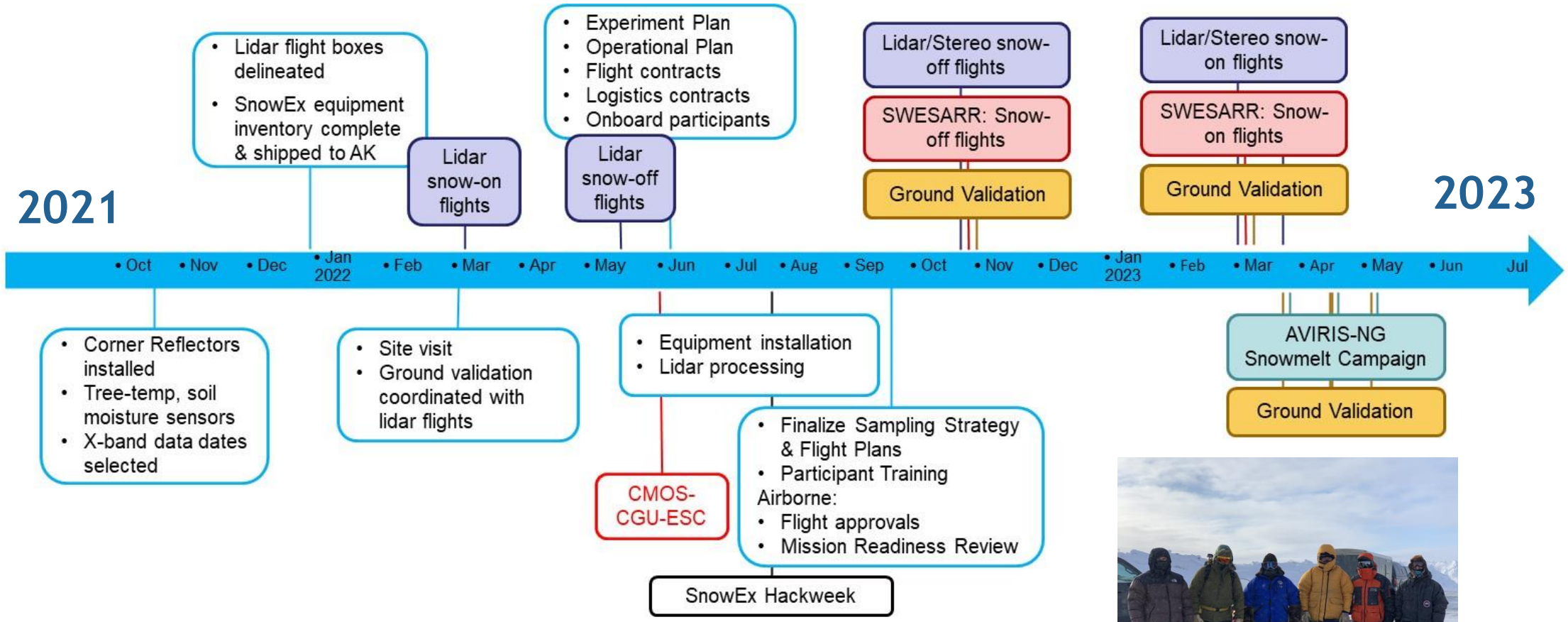
Corner Reflectors

Point of contact: Mike Durand, OSU



Naturally Inspiring. UAF UNIVERSITY OF ALASKA FAIRBANKS

March 2023 campaign



Thank you!

Toolik Field Station; UAF LTER; NOAA NWS, Fairbanks office

Photos by Alicia Pouw

Extra slides

Measurement Strategy

Ground Measurements

- Ground conditions: soil moisture and F/T state
- TLS (Bonanza): Characterize under/within canopy snow & no-snow conditions
- Snow Conditions:
  - Snow pits – selected with input from models, 2022 lidar data
  - Snow depth transects or spirals (magnaprobe, GPR)
  - Mini-pits/SMP – variability in stratigraphy
  - SWE tubes – snow density variability
  - Microstructure (SSA, SMP, Casting)

Airborne Measurements

- Active/passive microwave (SWESARR) during no/low-snow and snow-on conditions
- Lidar & stereoimagery during no/low-snow and snow-on conditions
- Hyperspectral (AVIRIS-NG) during melt period at boreal forest sites

Coincident satellite observations

Photos by Alicia Pouw

Thank you!

- Toolik Field Station
- UAF LTER
- NOAA NWS, Fairbanks office