# Shrub-associated thermokarst detection using high density UAV-based LiDAR

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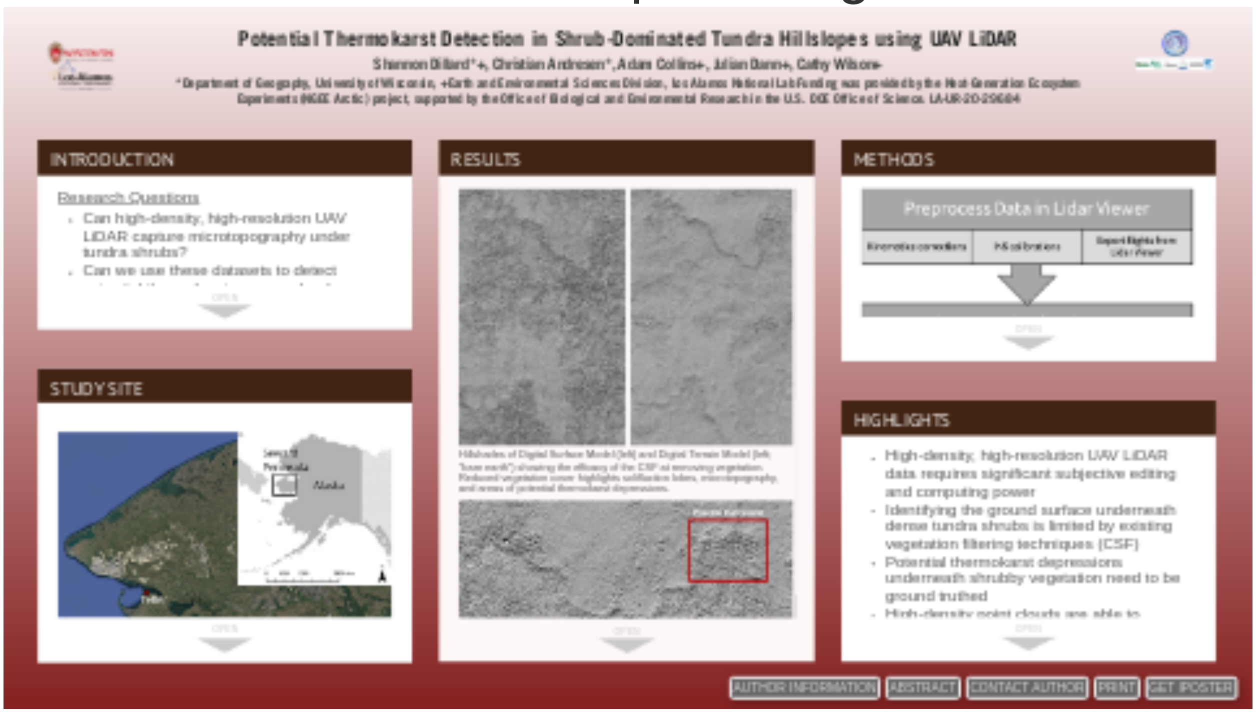
**Abstract**

Light detection and ranging (LiDAR) technologies are changing the ways in which scientists research the Arctic. Unmanned aerial vehicle (UAV)-based LiDAR collects detailed structural landscape data by returning high density point clouds. LiDAR systems are improving the quality and accuracy of data collection compared to field surveys and help to remove some of the logistical barriers of research in remote and complicated terrain. Our study mapped thermokarst depressions in a 3 km2 watershed on the Seward Peninsula near Nome, Alaska in 2017 and 2018. The watershed is characterized as tussock permafrost landscape consisting of grasses and mosses interspersed with patches of dense shrubs. By configuring the UAV with a 32 laser swath and flying slowly at low altitude, we collected high density point clouds of about 4,000 points m2, including high density terrain surface points underneath dense shrubby vegetation. We then modeled the sub-vegetation terrain surface at very fine detail to detect thermokarst depressions. Combining these high resolution data with vegetation surveys and topographic properties, we tested the relationship between permafrost subsidence, thermokarst depressions and vegetation type, specifically the relationships in shrub-associated thermokarst features. By coupling our LiDAR data and analysis with hydrologic models, climate variables (e.g., snow depth, soil moisture), and vegetation surveys, we can infer geospatial relationships between thermokarst development, vegetation, and landscape position throughout the watershed. The technologies used in our study have implications for predicting the development of future thermokarst features and permafrost thaw sites across the Arctic.

# Potential Thermokarst Detection in Shrub-Dominated Tundra Hillslopes using UAV LiDAR

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# INTRODUCTION

Research Questions

- Can high-density, high-resolution UAV LiDAR capture microtopography under tundra shrubs?
- Can we use these datasets to detect potential thermokarst areas under dense shrub cover?

Shrubs in discontinuous permafrost

↑ snow accumulation via drift

↑ ground surface insulation

↑ soil surface temperature

↓ intensity of deep freeze cycles

**↑ potential for thermokarst development?**

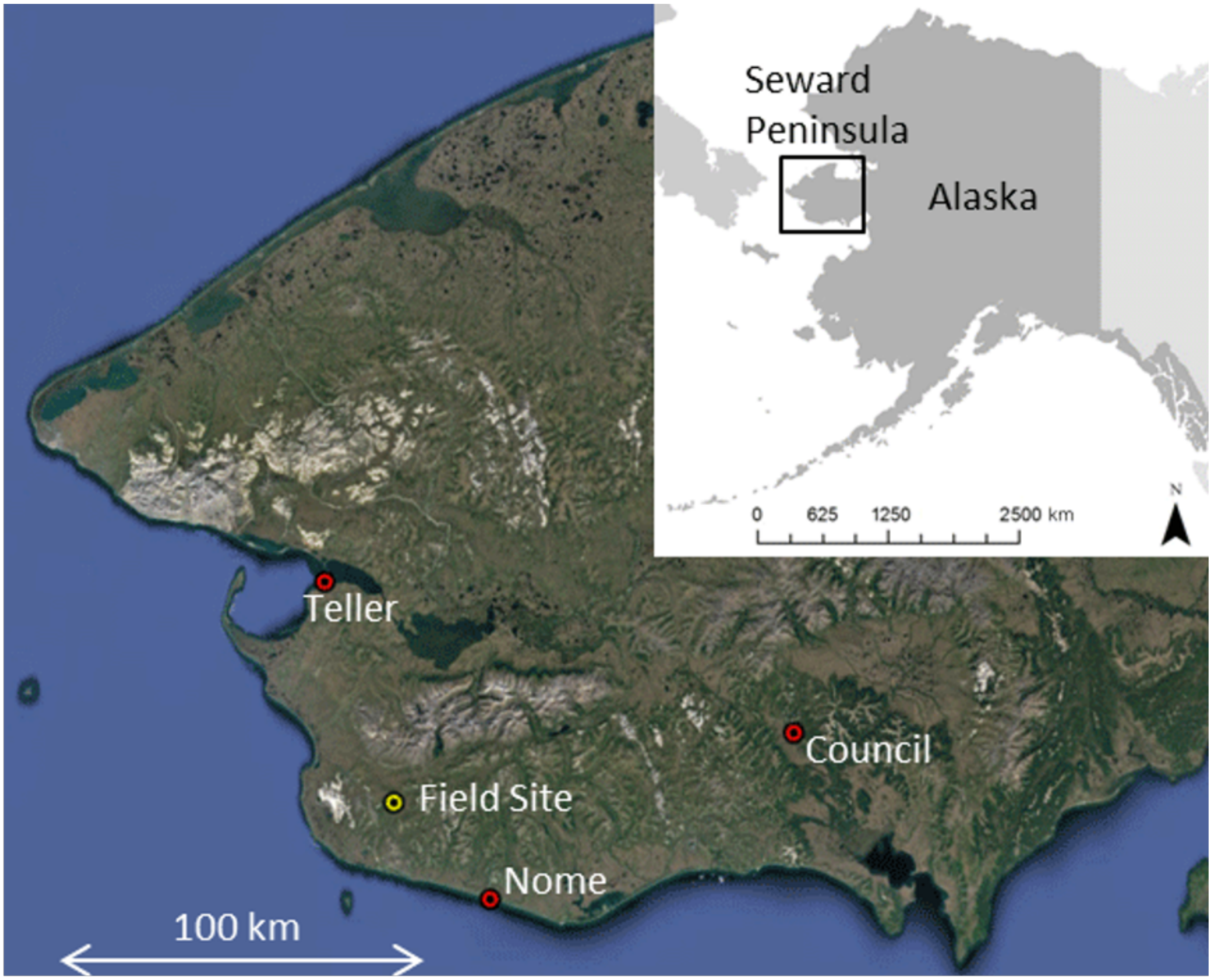
Data Collection: Next Generation Ecosystem Experiment (NGEE) Arctic project

2017: 34 UAV LiDAR flights of ~217 ha

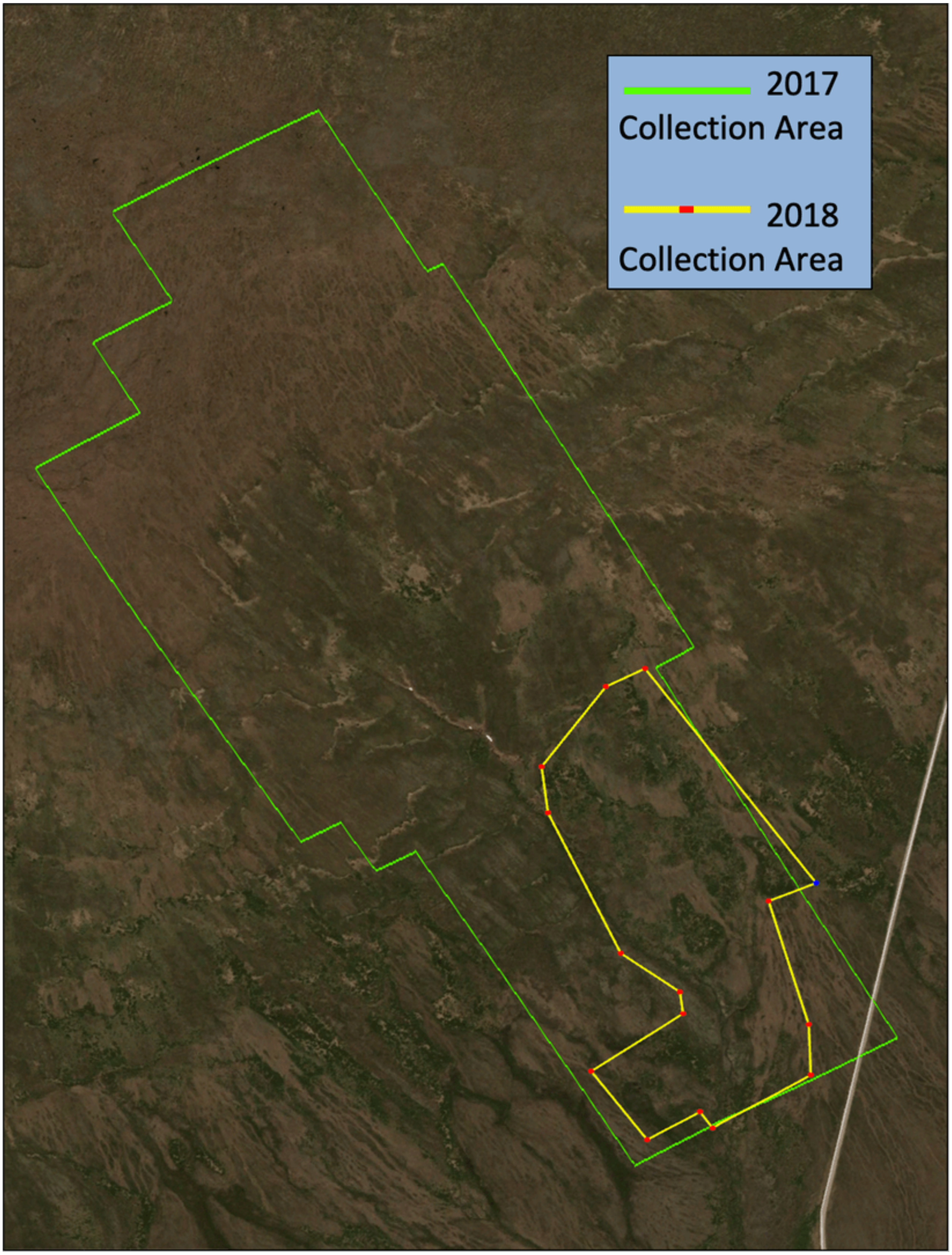
Watch campaign video

2018: 12 flights of ~46 ha of shrubby portions of the watershed with higher point density (higher resolution)

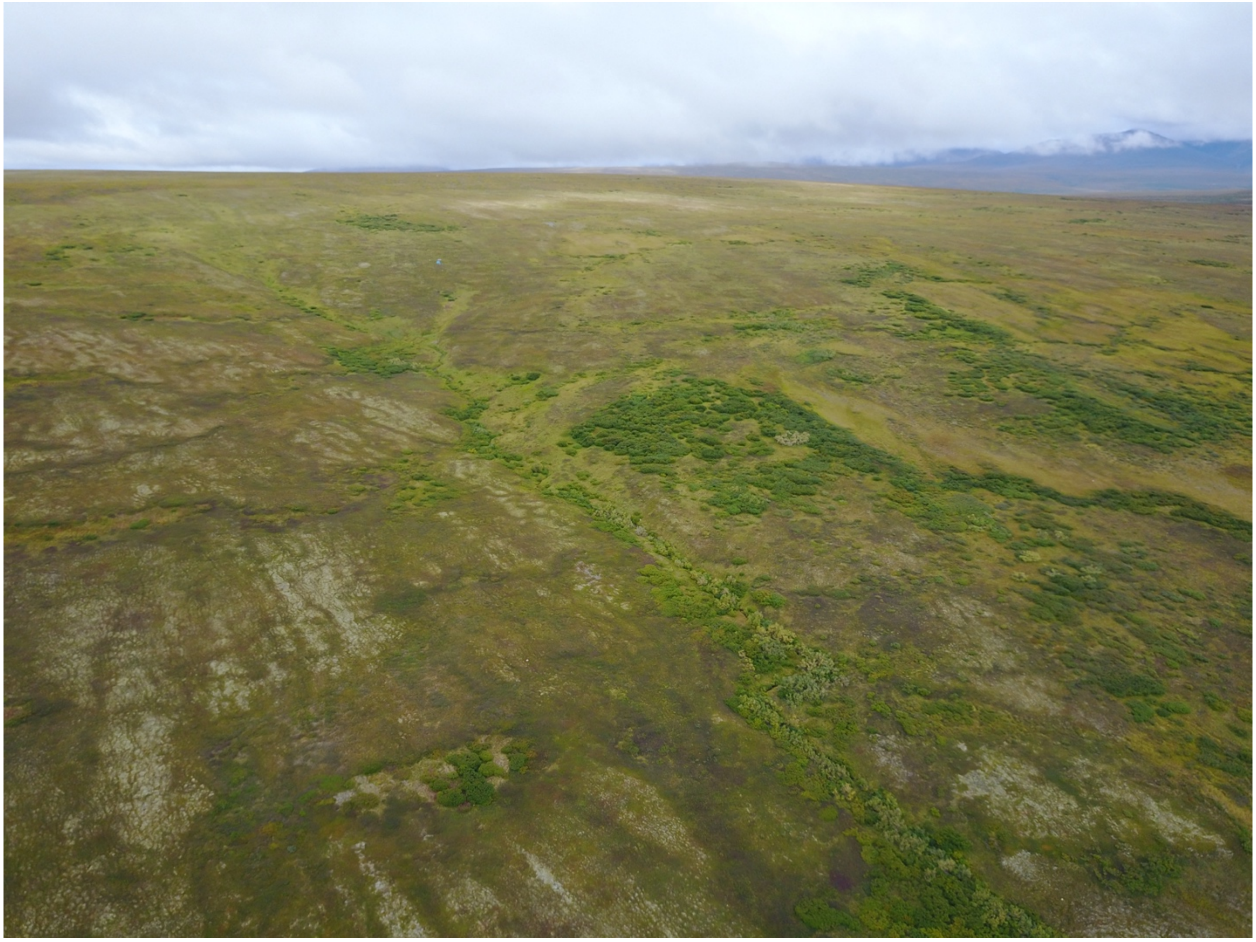
## STUDY SITE




Field sites on the Seward Peninsula, Alaska (Léger et al., 2019)

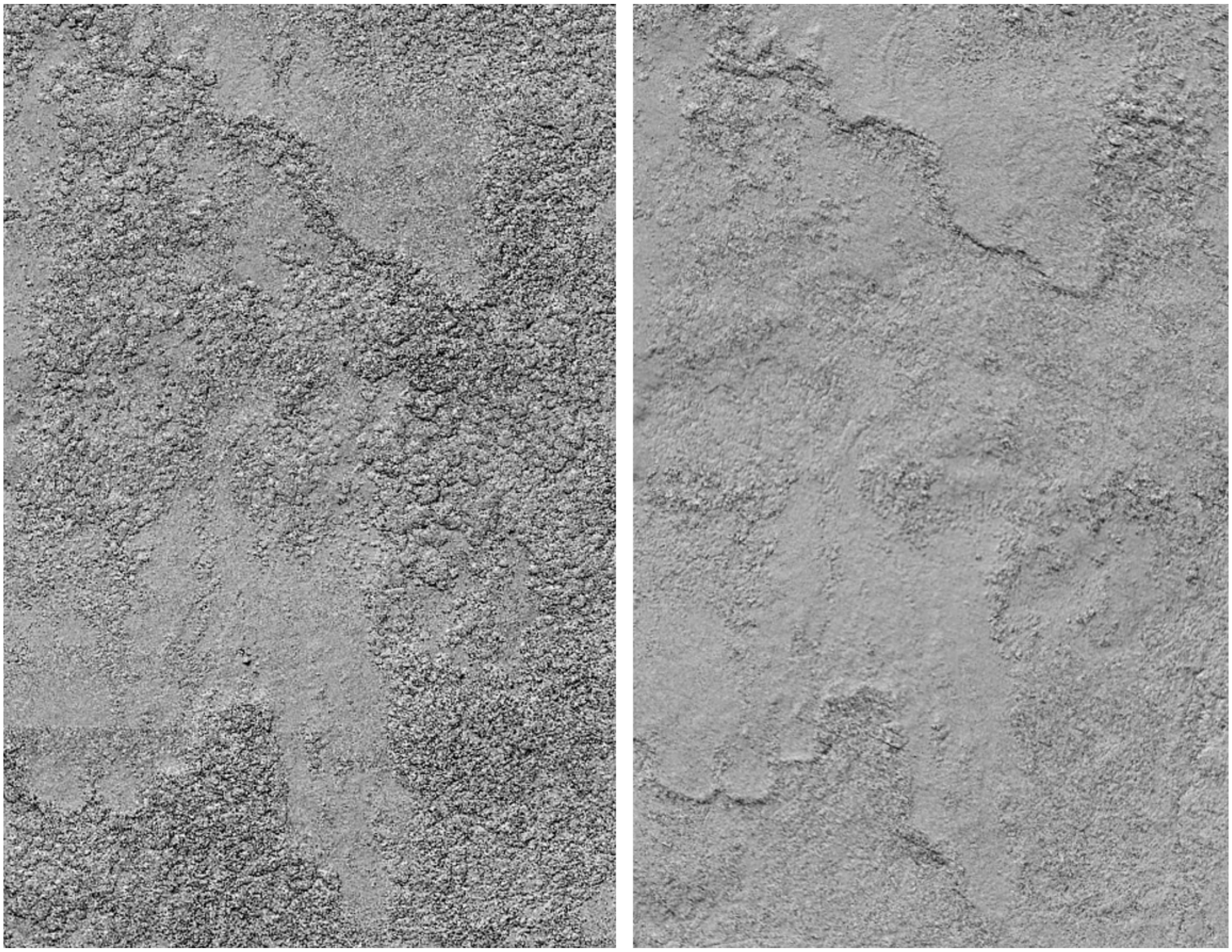



Teller Watershed data collection areas (Collins, 2019)

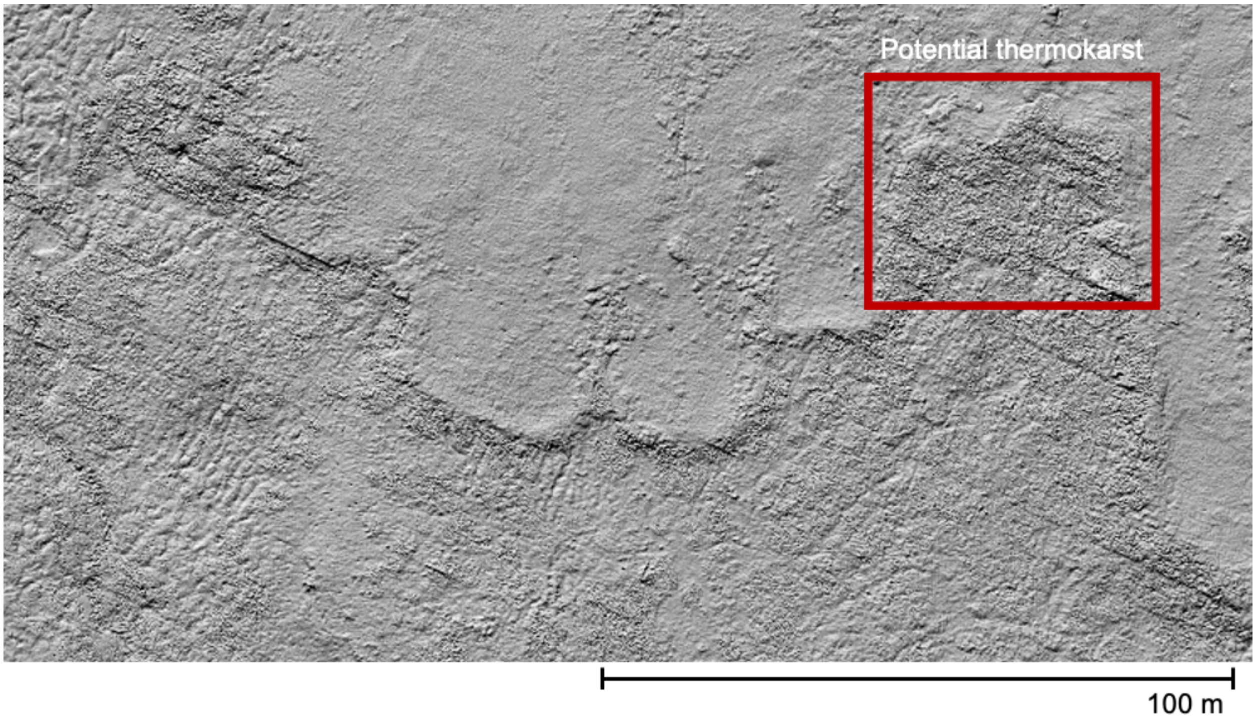


Patches of shrubs in the lower portion of the Teller Watershed

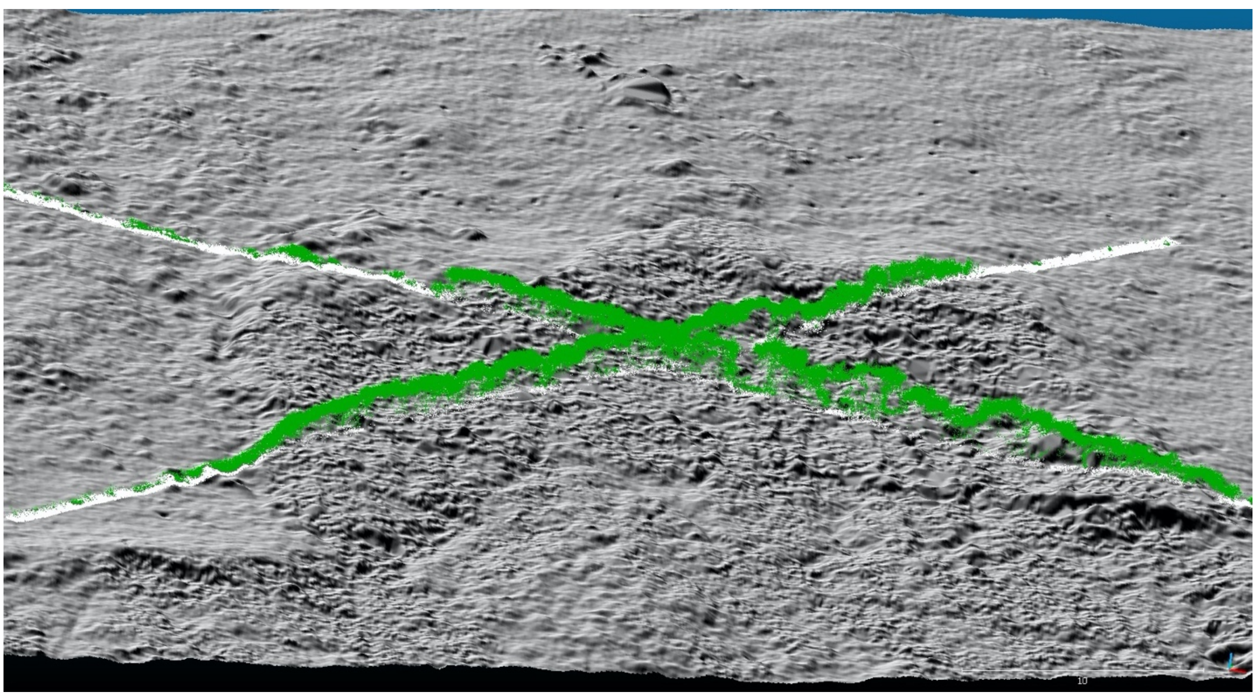
# RESULTS



Hillshades of Digital Surface Model (left) and Digital Terrain Model (left; "bare earth") showing the efficacy of the CSF at removing vegetation. Reduced vegetation cover highlights solifluction lobes, microtopography, and areas of potential thermokarst depressions.




Potential thermokarst area identified in Digital Surface Model



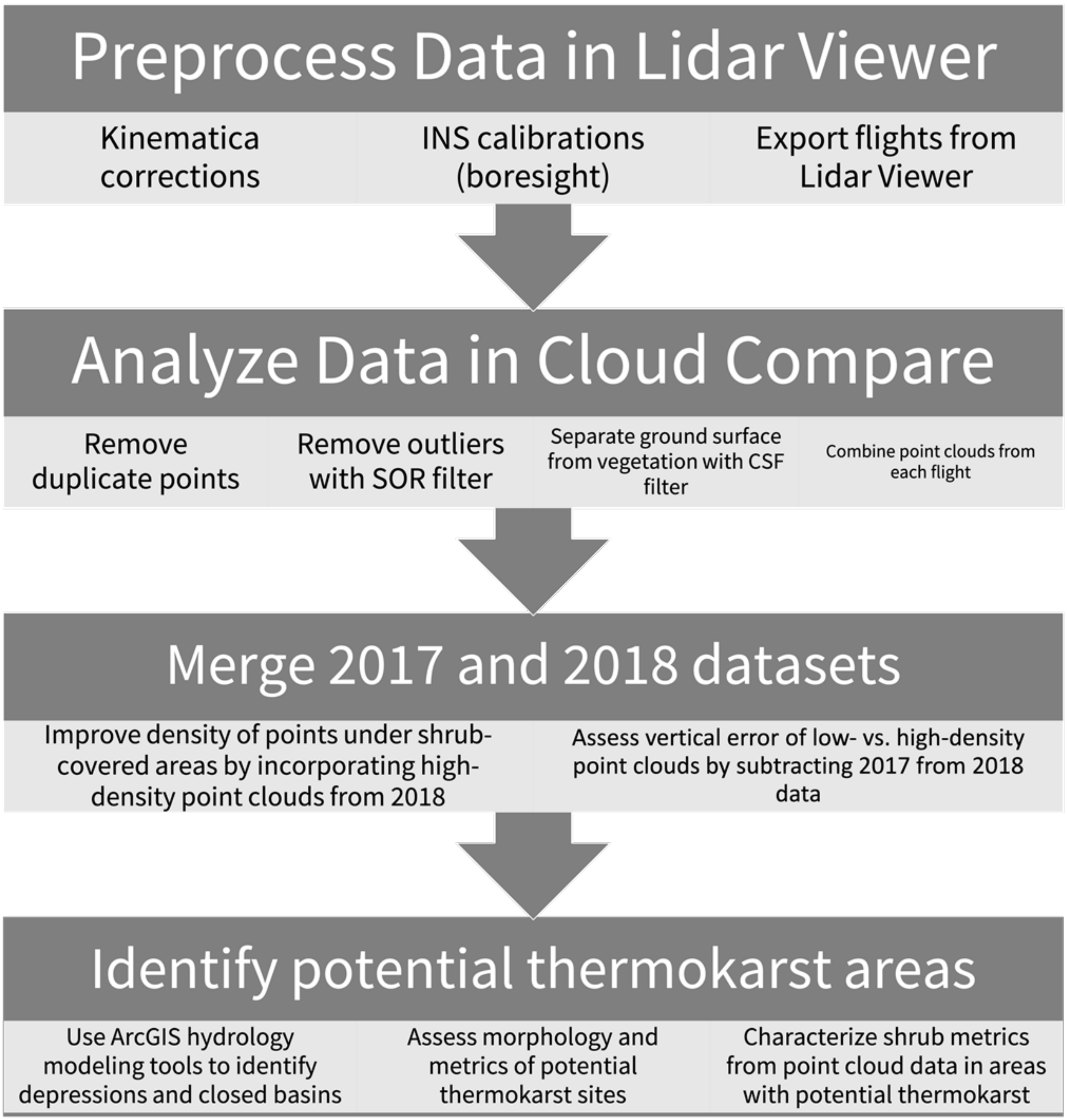
CSF filter separating ground points (white) from vegetation (green) superimposed on a hillshade of the ground points in a potential thermokarst area. [Watch the point cloud move.]

Ground Point Comparison

2017 (UAV collection at 6 m $s^{-2}$, 35 AGL): ~150 points $m^{-2}$

2018 (UAV collection at 2 m $s^{-2}$, 15 AGL; high-density LiDAR): ~2,750 points $m^{-2}$

# METHODS



Lidar Viewer

- Geographic coordinate system (UTM Zone 3N)
- Corrective files from Kinematica to increase position accuracy with GNSS (Advanced Navigation, 2020)
- Calibrated unique pitch, yaw, and roll boresight of the LiDAR instrument
- Trimmed the laser scan to 60 m

CloudCompare

- Eliminated duplicate points
- Removed outliers ≥10 standard deviations with the Statistical Outlier Removal tool
- Cut the files into four roughly equal quadrants
- Applied Cloth Simulation Filter (CSF; Zhang et al, 2016) to remove vegetation
- Recombined the ground points with ≥10 m overlap
- Visually identified problem areas where the CSF did not remove ground surface vegetation, re-ran the CSF with altered classification threshold and cloth resolution parameters
- Patched the files where improvement occurred

# HIGHLIGHTS

- High-density, high-resolution UAV LiDAR data requires significant subjective editing and computing power
- Identifying the ground surface underneath dense tundra shrubs is limited by existing vegetation filtering techniques (CSF)
- Potential thermokarst depressions underneath shrubby vegetation need to be ground truthed
- High-density point clouds are able to characterize in detail the ground surface under shrub-covered areas in tundra hillslopes

# AUTHOR INFORMATION

Shannon Dillard's Curriculum Vitae

# ABSTRACT

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surveys and topographic properties, we tested the relationship between permafrost subsidence, thermokarst depressions and vegetation type, specifically the relationships in shrub-associated thermokarst features.

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