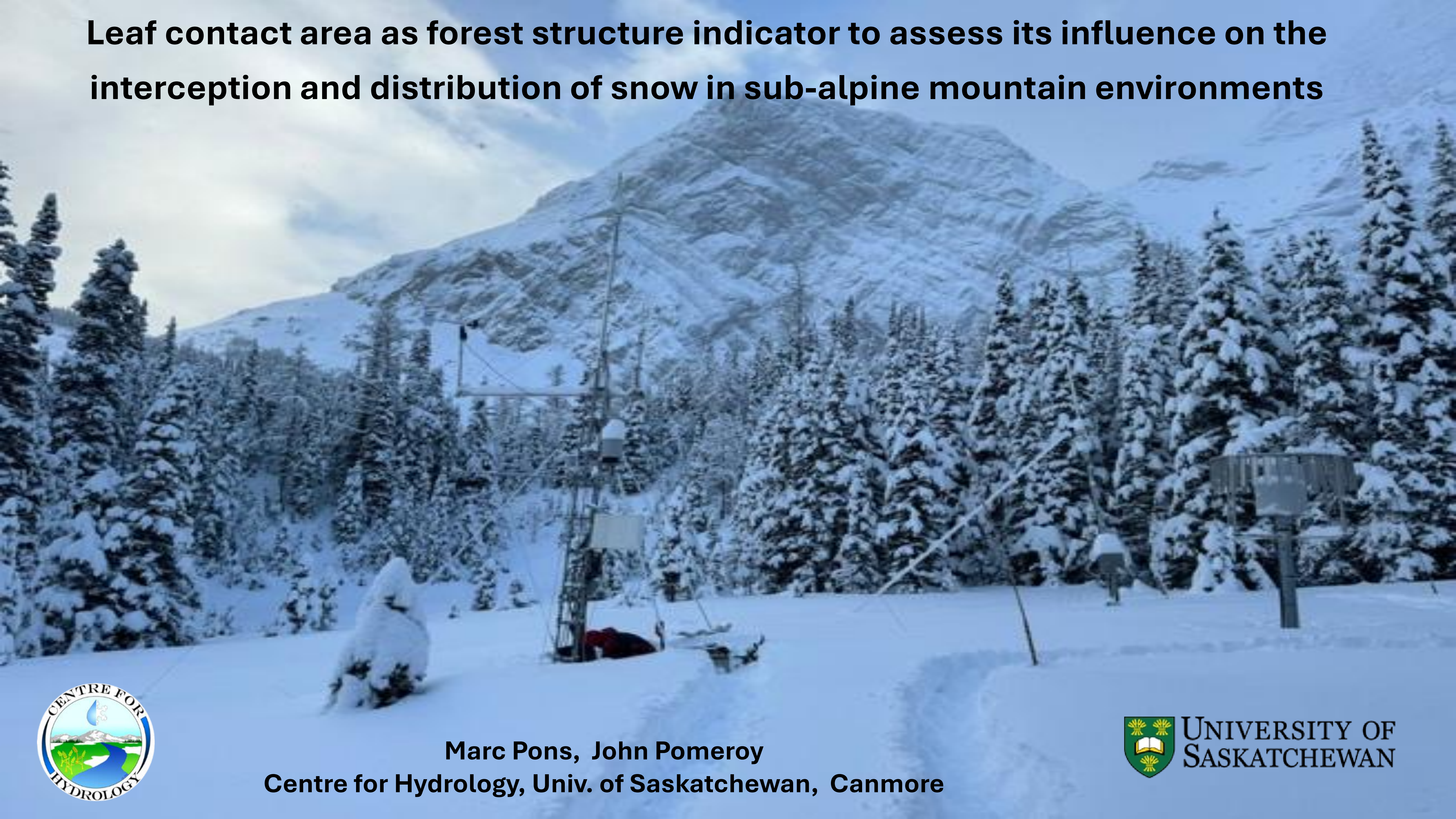
Leaf contact area as forest structure indicator to assess its influence on the interception and distribution of snow in sub-alpine mountain environments



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Background

- Snow in forested mountain headwaters is vital for downstream water supply
- Vegetation structure significantly influences spatial variability of snow accumulation and redistribution within forested areas
- Quantifying snow accumulation beneath needleleaf canopies and in forest gaps remains a persistent challenge for remote sensing.

Background

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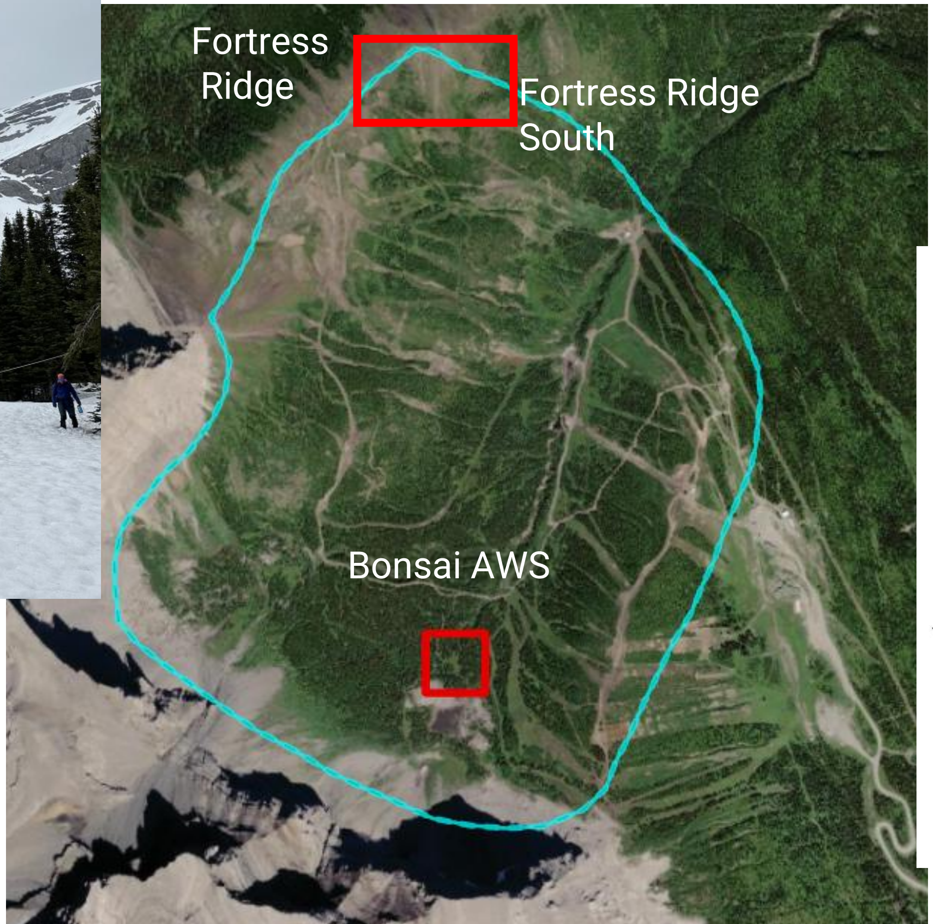
How does canopy interception of snow results in snow redistribution in complex mountain forests?

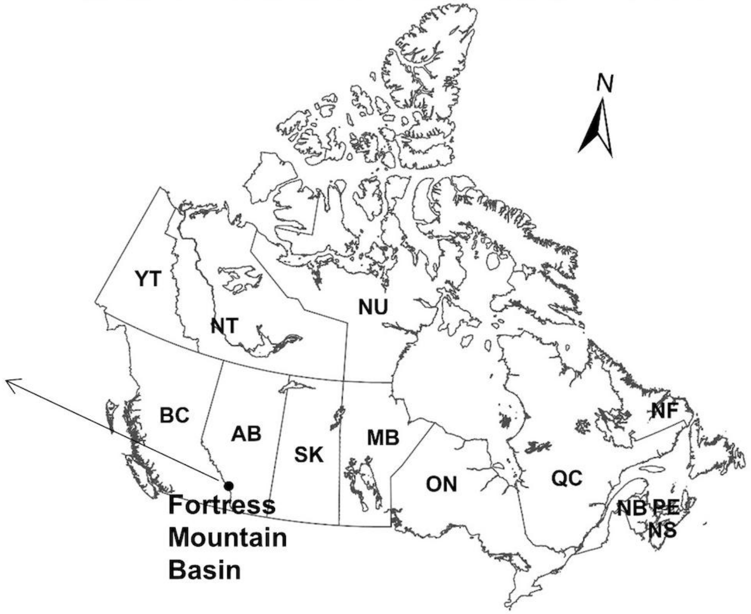
Objectives

- Analyse the relationship between forest structure indicators and snow depth and snow redistribution dynamics in a sheltered, heterogeneous, subalpine needleleaf forest

Study Area

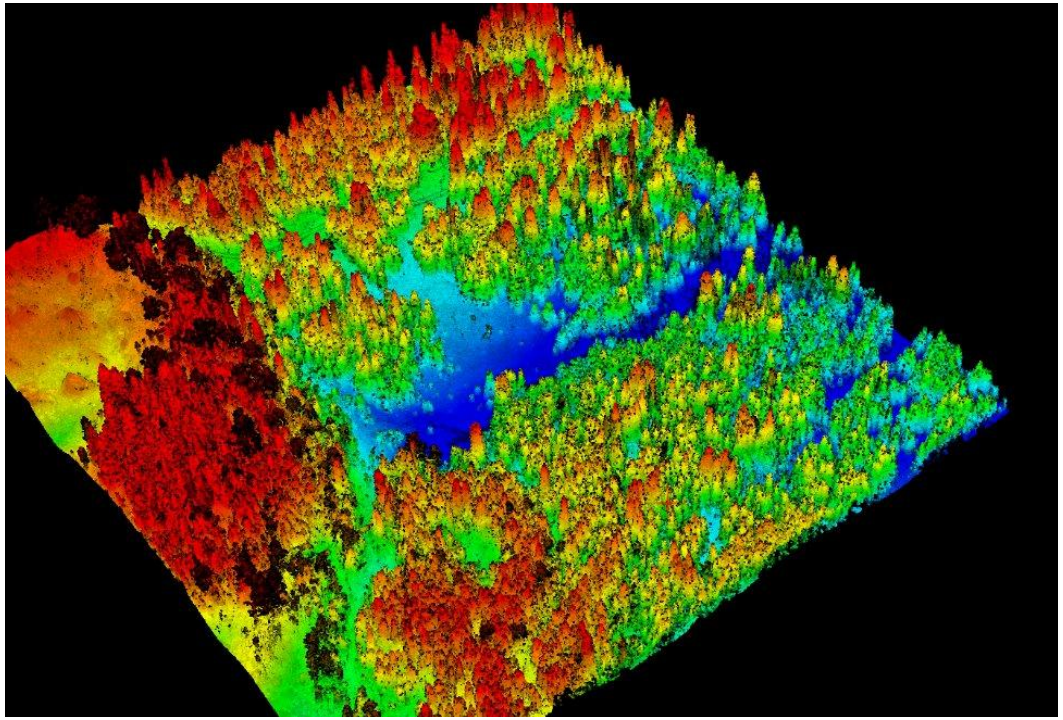
Fortress Mountain Research Basin, Alberta, Canada





Data Collection

Platform – ALTA X
Lidar - Minivux2-UAV Lidar (200Khz)
IMU - APX20 (type IMU82 – 200hz)

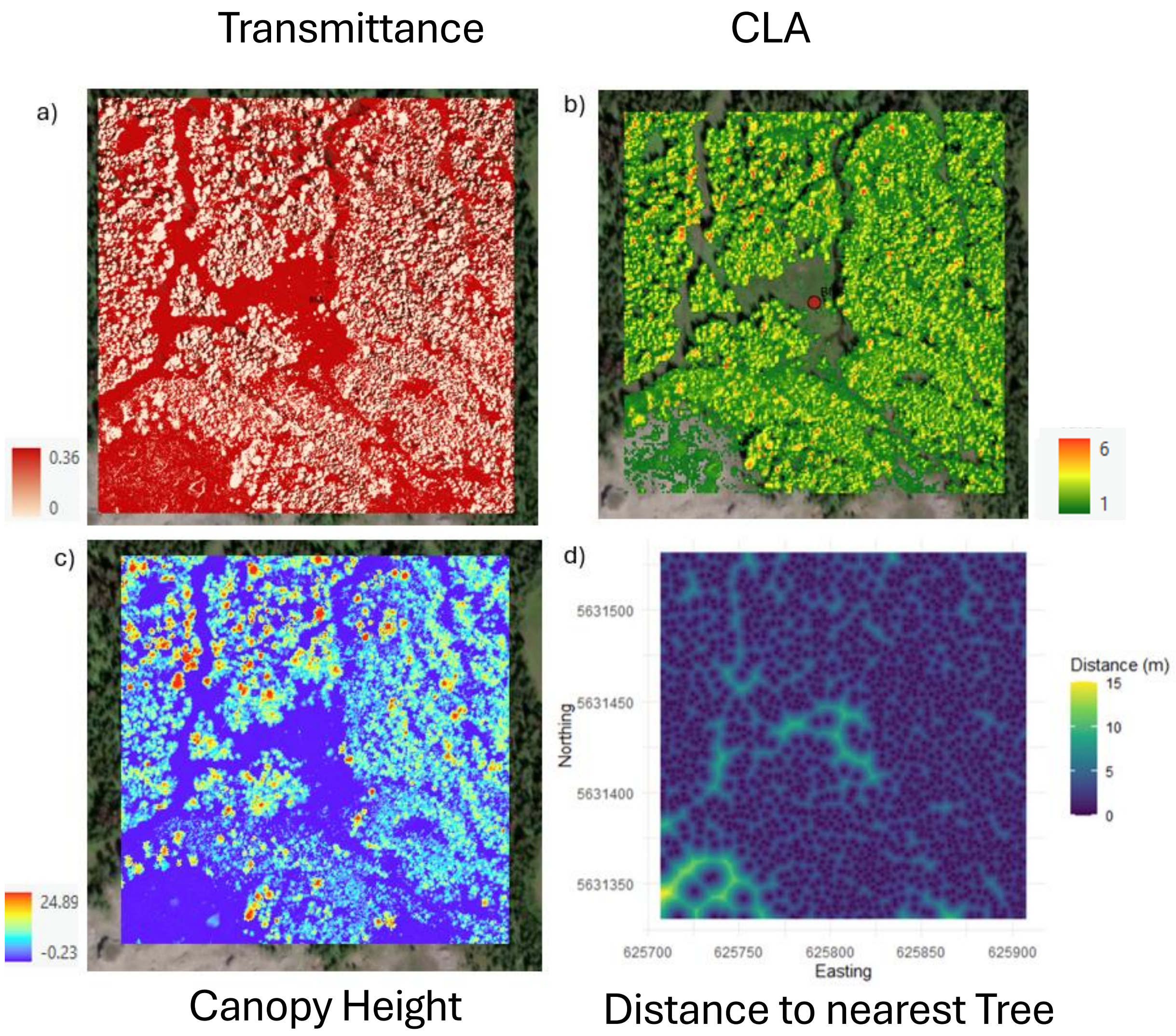


Flight Dates

- Bare ground: October 18,2022
- Snow depth on the ground - storm period:
  - March 15, 2023
  - March 29, 2023

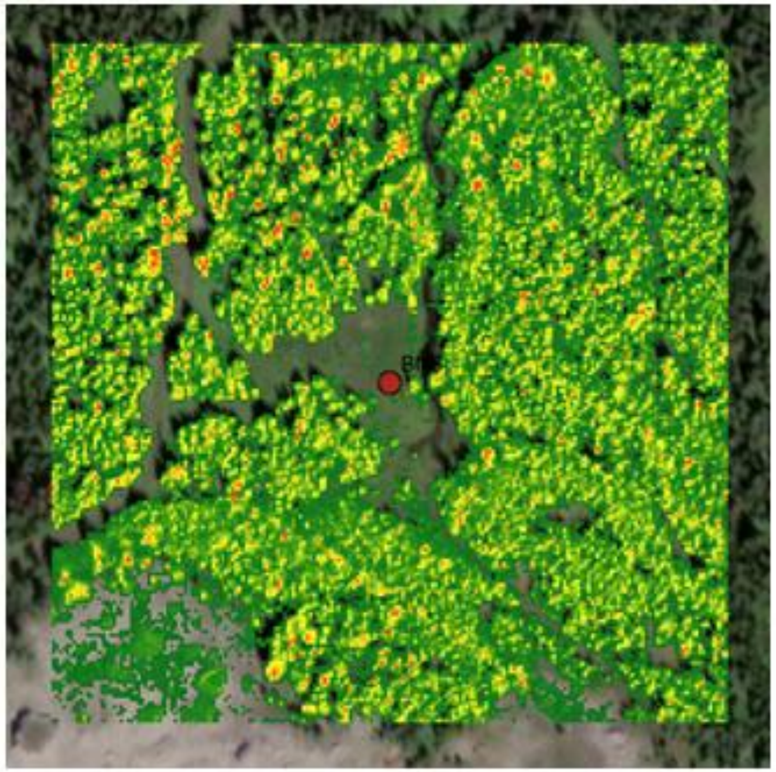
Forest Structure

Canopy metrics at 0.25m resolution :



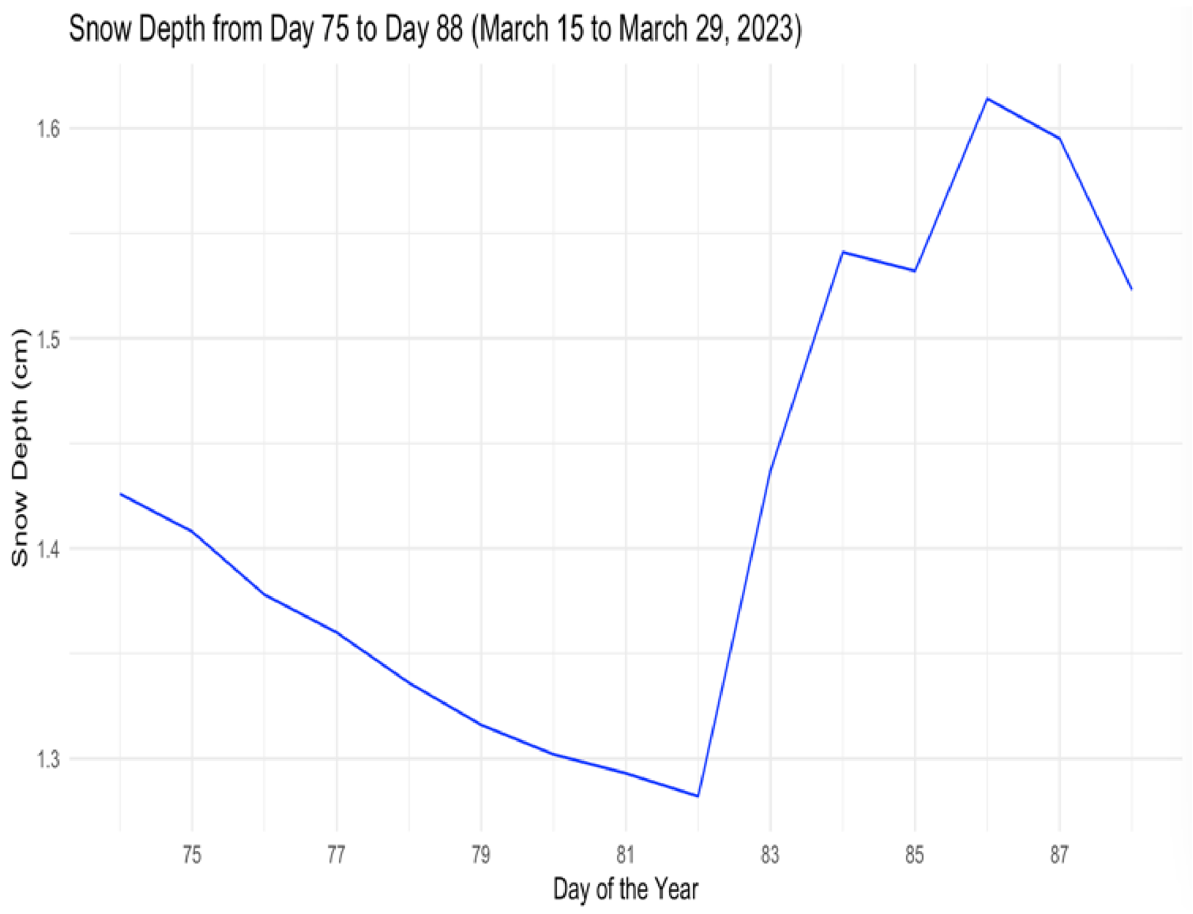
Forest Structure

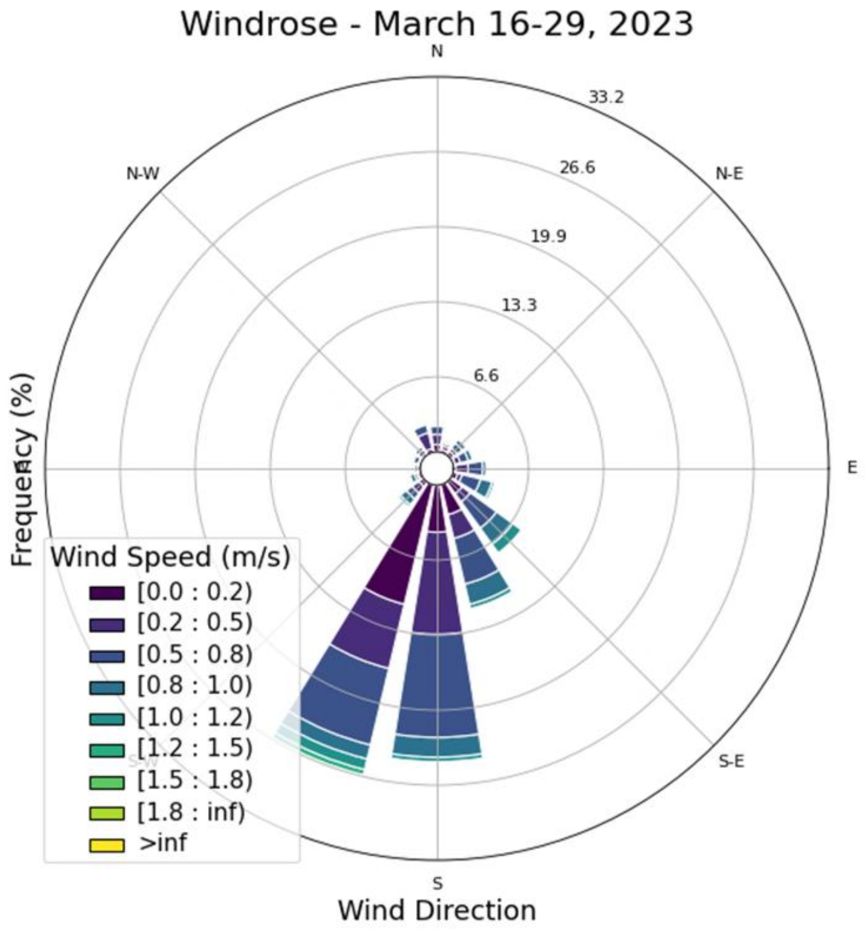
Characterised using CLA (Contact Leaf Area), that measures the leaf area per unit area of the ground in direct contact with the vector of falling snow particles. It can be estimated using light beams from airborne LiDAR



Voxelization resampling and trajectory bias correction process before computing canopy metrics to solve uneven point densities

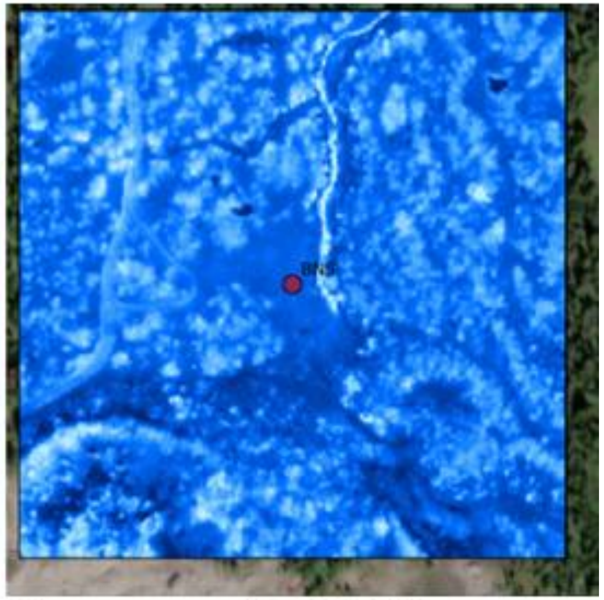
Snow fall and wind event



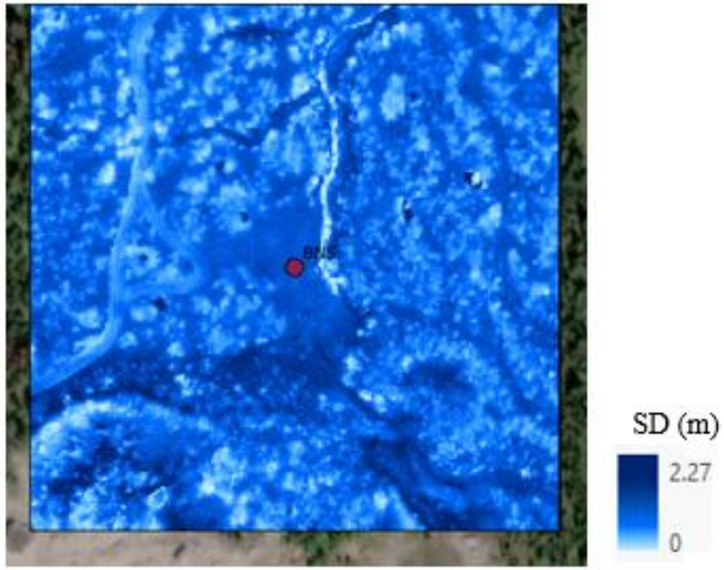


Storm event used for the analysis

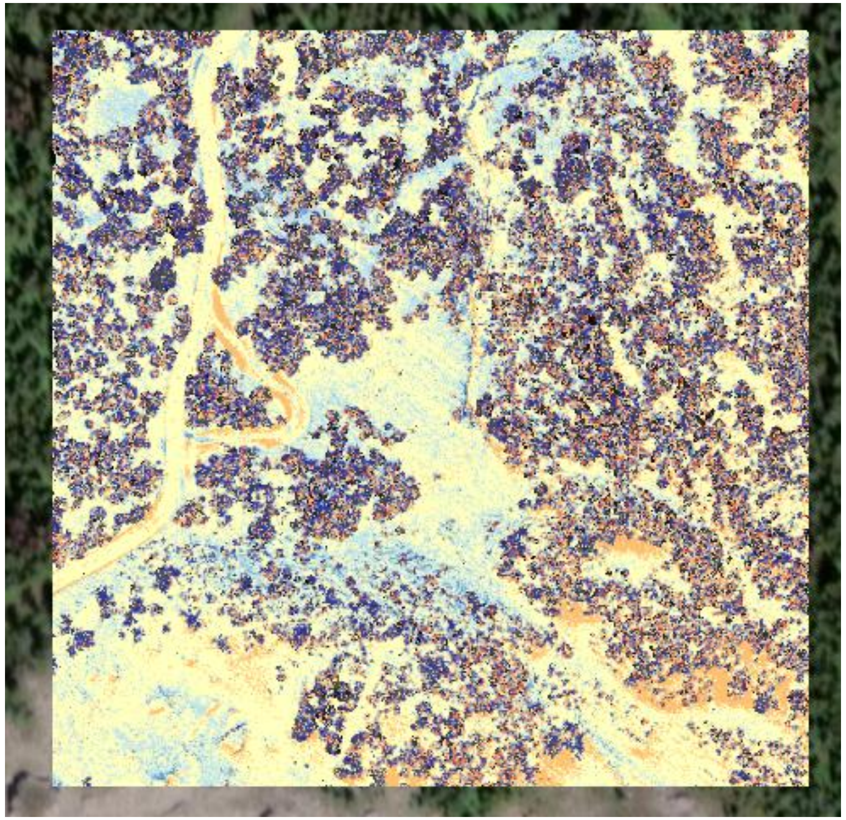
Snow depth and change maps at 0.25 m

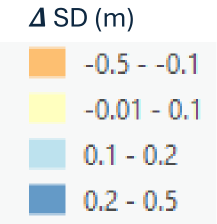


a) March 15 (77)



b) March 29 (88)





Snow Depth change (m)

	DOY	Max	Min	Mean	CV
Snow Depth March 19	77	2.14	0	1.28	0.26
Snow Depth March 29	88	2.27	0	1.37	0.25

Correlation CLA vs Snow Depth Change maps

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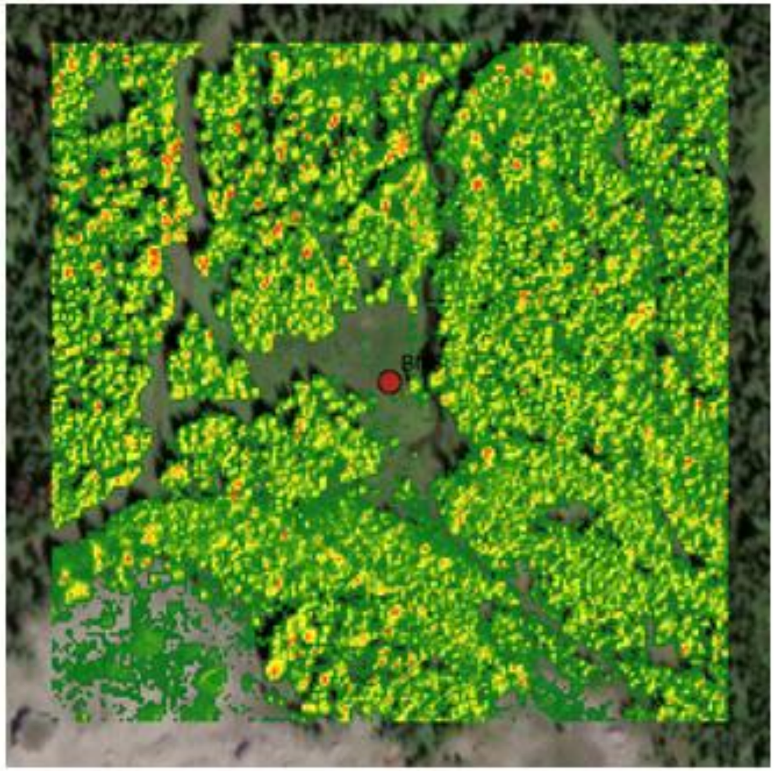
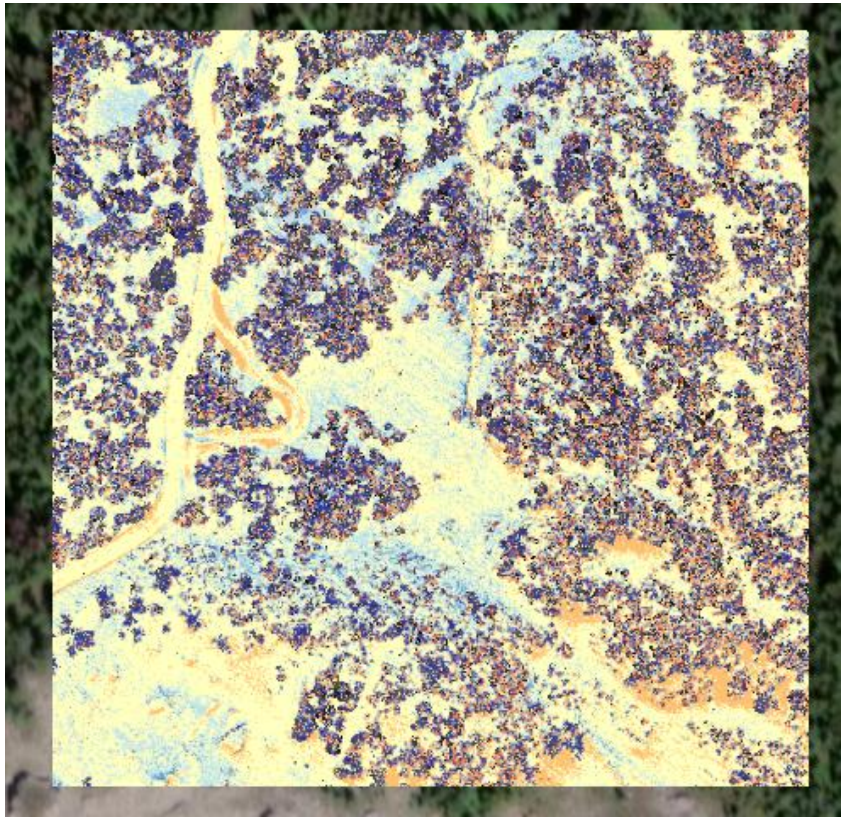


CLA



Snow Depth Change (m)

Spearman Cor.	R^2
-0.55	0.3

CLA – Snow depth change correlation in different forest structures

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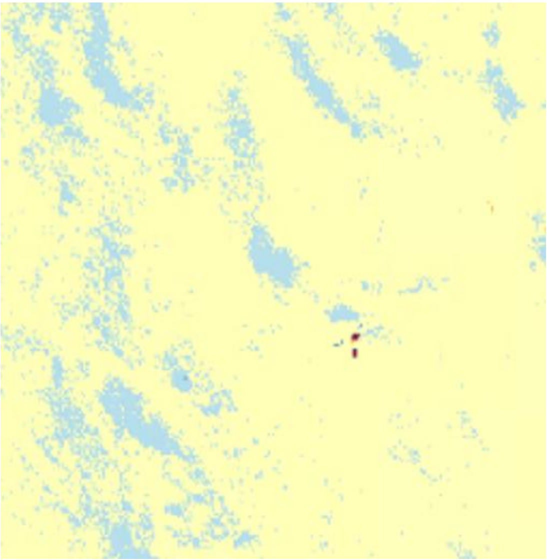
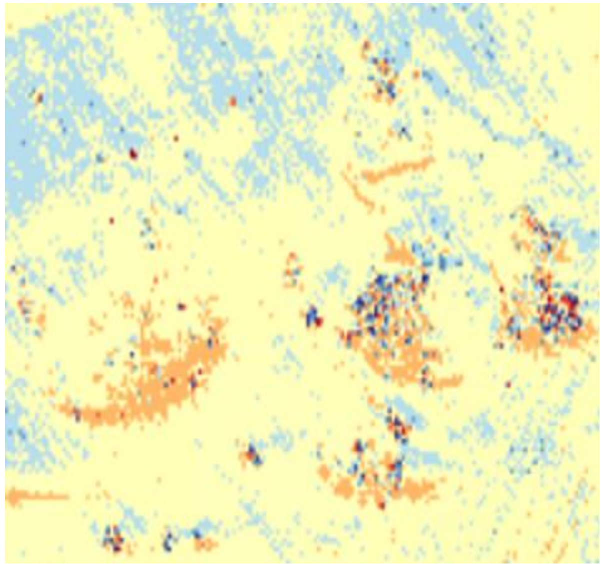
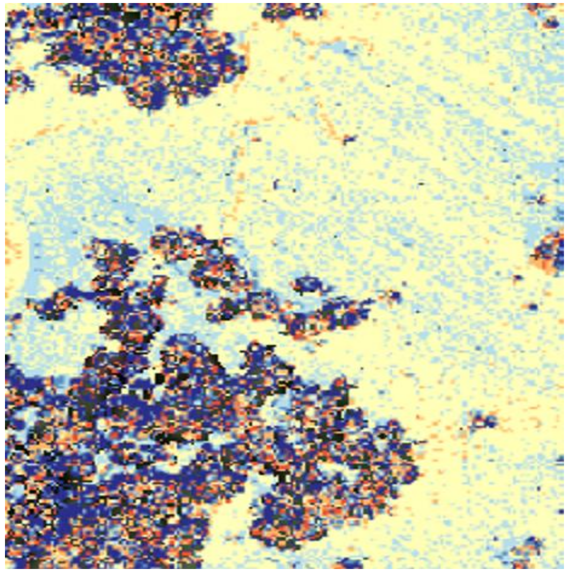


Δ SD (m)
- -0.5 - -0.1
- -0.01 - 0.1
- 0.1 - 0.2
- 0.2 - 0.5

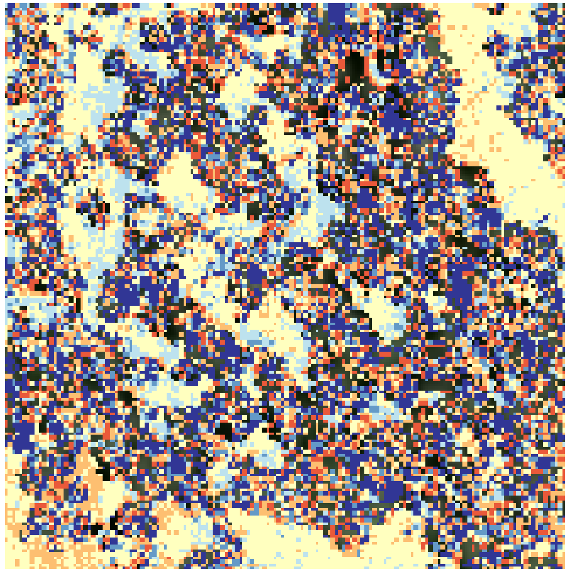
Open Forest



Sparse Forest



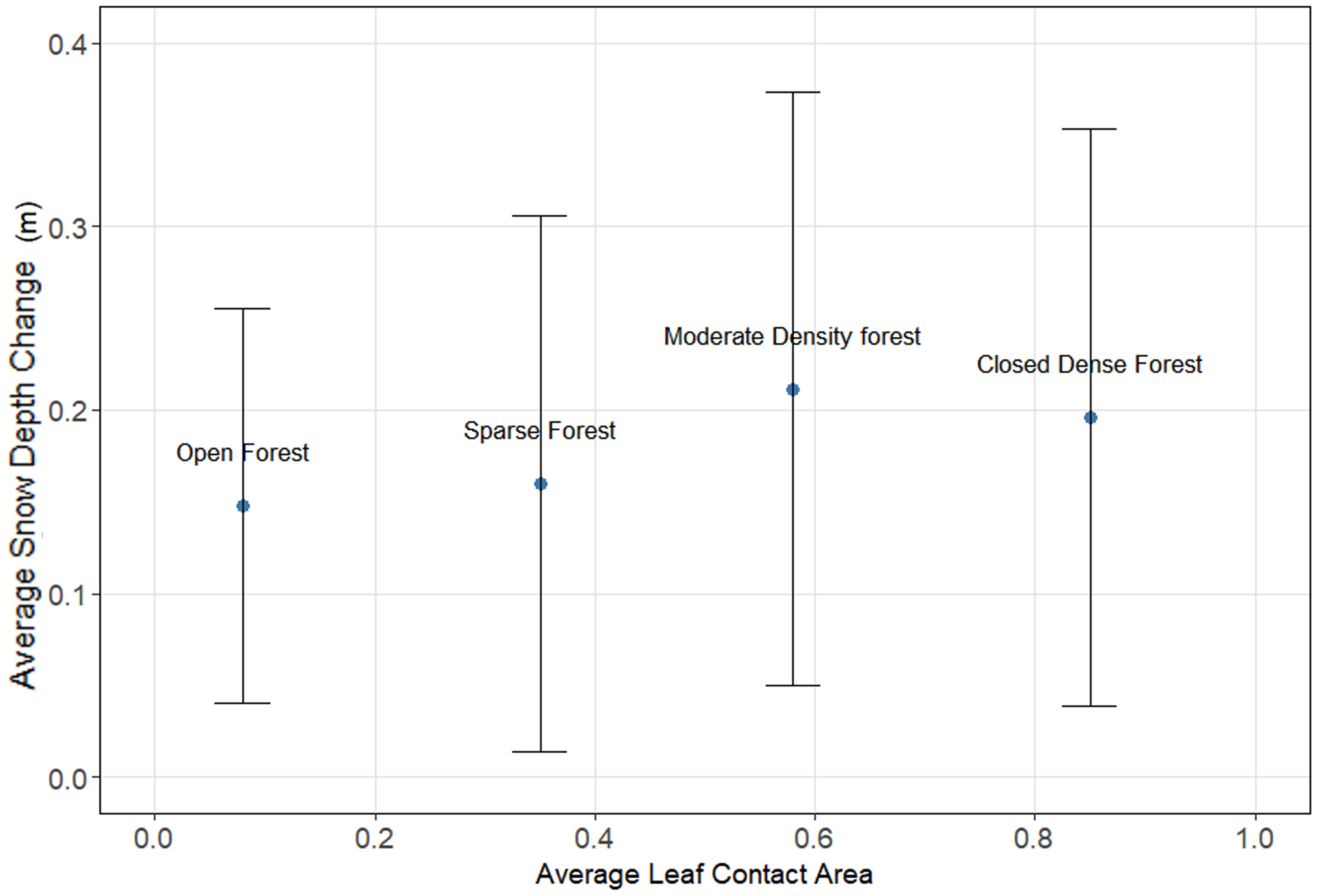
Moderate density Forest



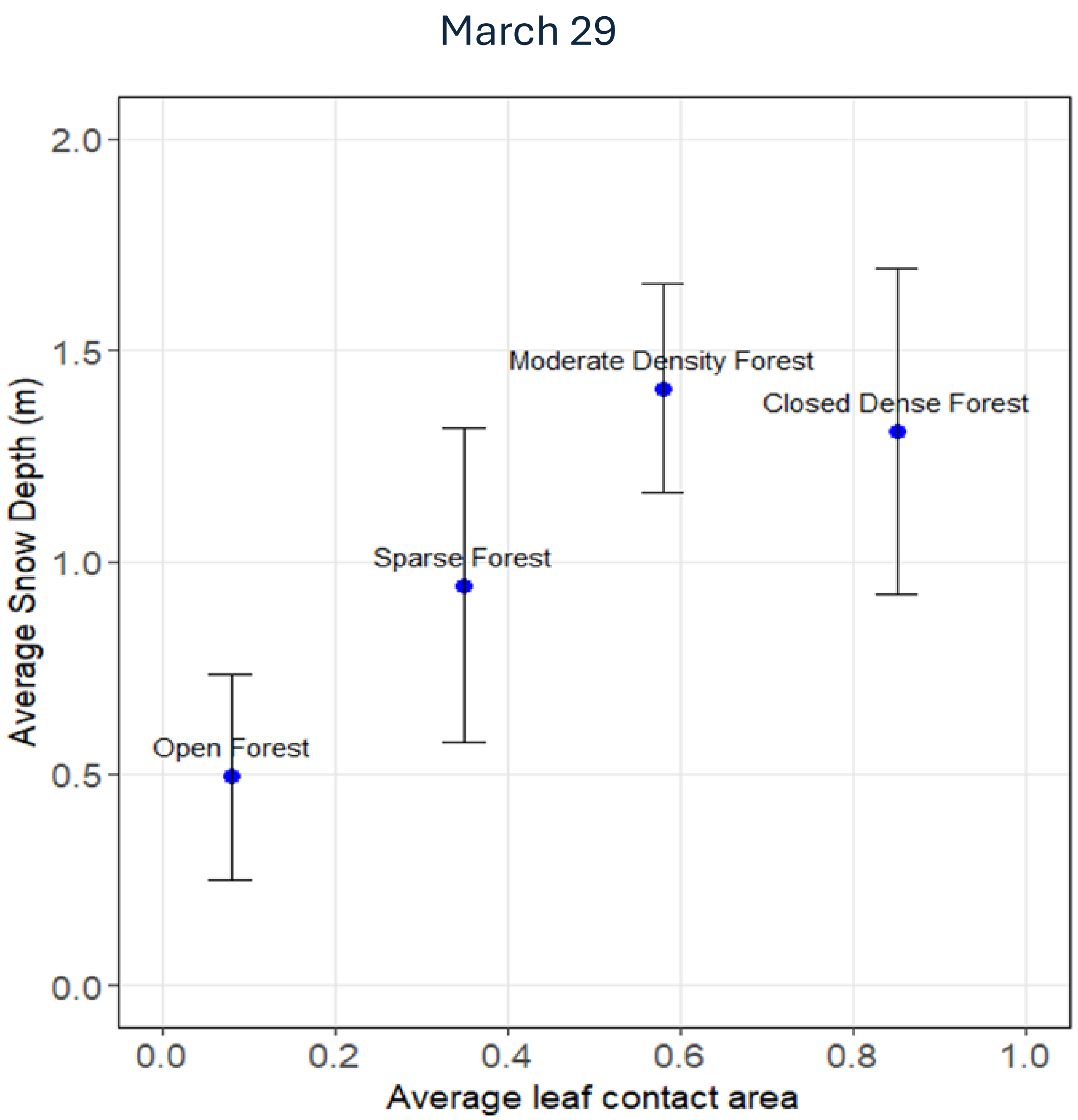
Closed Forest

	Fraction Cover	Average CLA	Spearman Cor.
Open Forest	<2%	0.08	-0.01
Sparse Forest	27%	0.35	-0.04
Moderate density Forest	77%	0.58	*-0.55*
Closed Forest	91%	0.85	-0.15

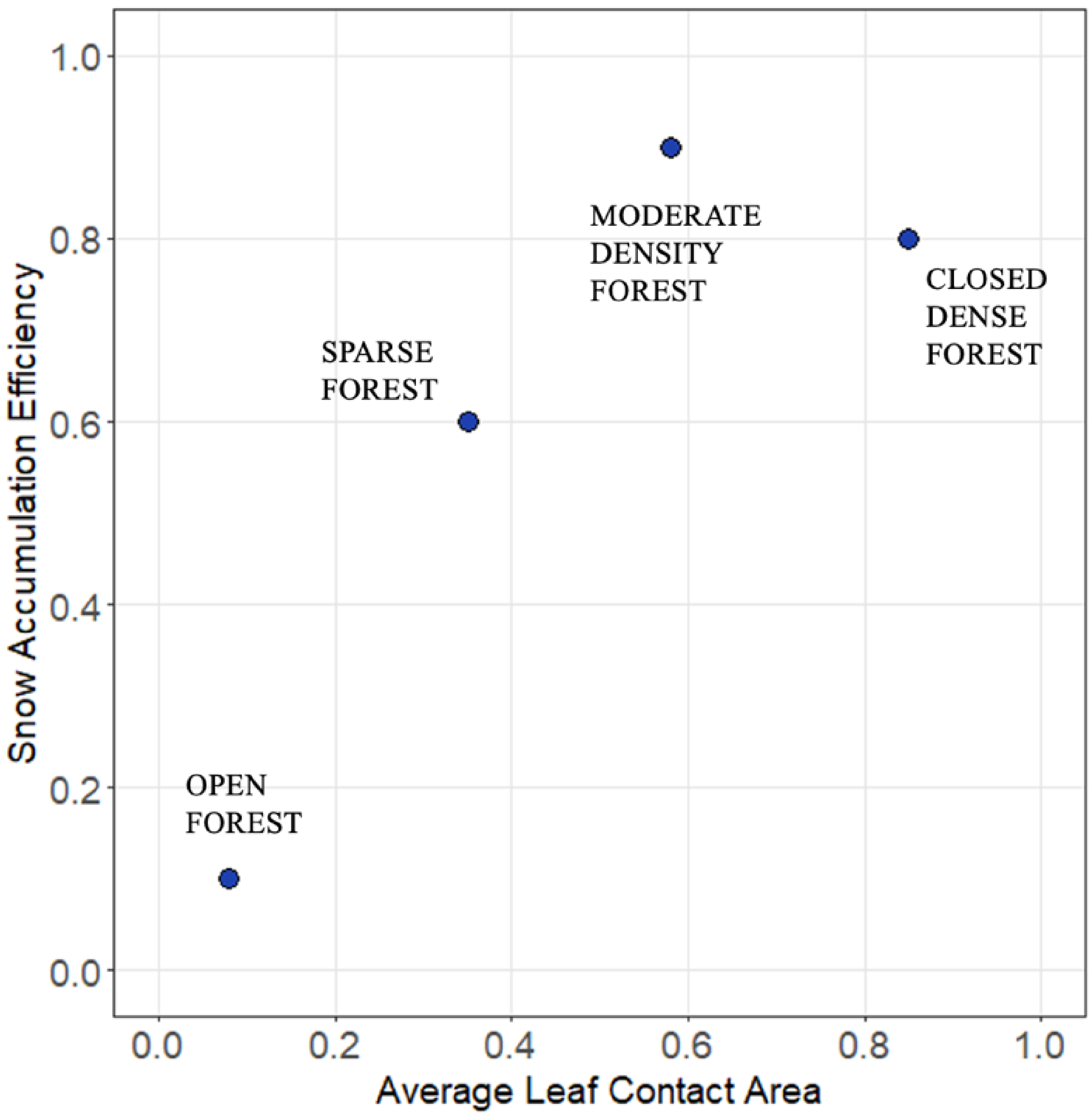
Average Snow Depth change and StDev in different forest structures



Average Snow Depth change and StDev in different forest structures 29 MARCH



CLA and Snow accumulation efficiency in different forest structures



Snow Accumulation Efficiency = ΔSWE / P

DISCUSSION

- **A statistically significant, negative correlation was found between CLA and snow depth change in the moderate density forest but not the dense forest**. However, snow depth change declined with CLA between moderate and dense forest stands.

- **No correlation** between CLA and snow depth change was found **in open and sparse forested** areas where wind-driven ablation, transport and redistribution process are predominant.

- **Sparse forest showed the highest standard deviation** in snow depth and snow depth change due to operation of both wind redistribution and interception processes.

- **From moderate density to closed/high density forest there is a decline in snow accumulation with increasing CLA** following the interception theory of Hedstrom and Pomeroy (1998) and congruent with Pomeroy et al. (2002) and Cebulski and Pomeroy (2025).

MAIN TAKEAWAYS

- **CLA can be a good indicator to estimate snow depth and SWE accumulation within moderate density forests** (including clearings) and between moderate and dense forest stands where depth and accumulation decline with CLA.

- **A nonlinear relationship was found between snow accumulation efficiency and CLA**, with the mixed forest being the most efficient in accumulating snow.

- In **open or sparse forest areas where wind redistribution** processes are more prominent, CLA **does not describe the small-scale variability of snow depth change** well, but there is a strong positive relationship between CLA and snow accumulation at larger scales.

- The mixed snow accumulation regimes – due to wind redistribution in more open environments and snow interception in more forested environments mean that **there is no simple relationship between vegetation density and snow accumulation efficiency** – processes need to be considered.

Assessing the Impact of Snow Interception on Fine-scale Sub-alpine Snow Accumulation Patterns

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