Image: http://ais.wetter.de/masters/514430/switzerland-snowfarming.jpg

Feasibility of Over-Summer Snow Storage in Craftsbury, VT

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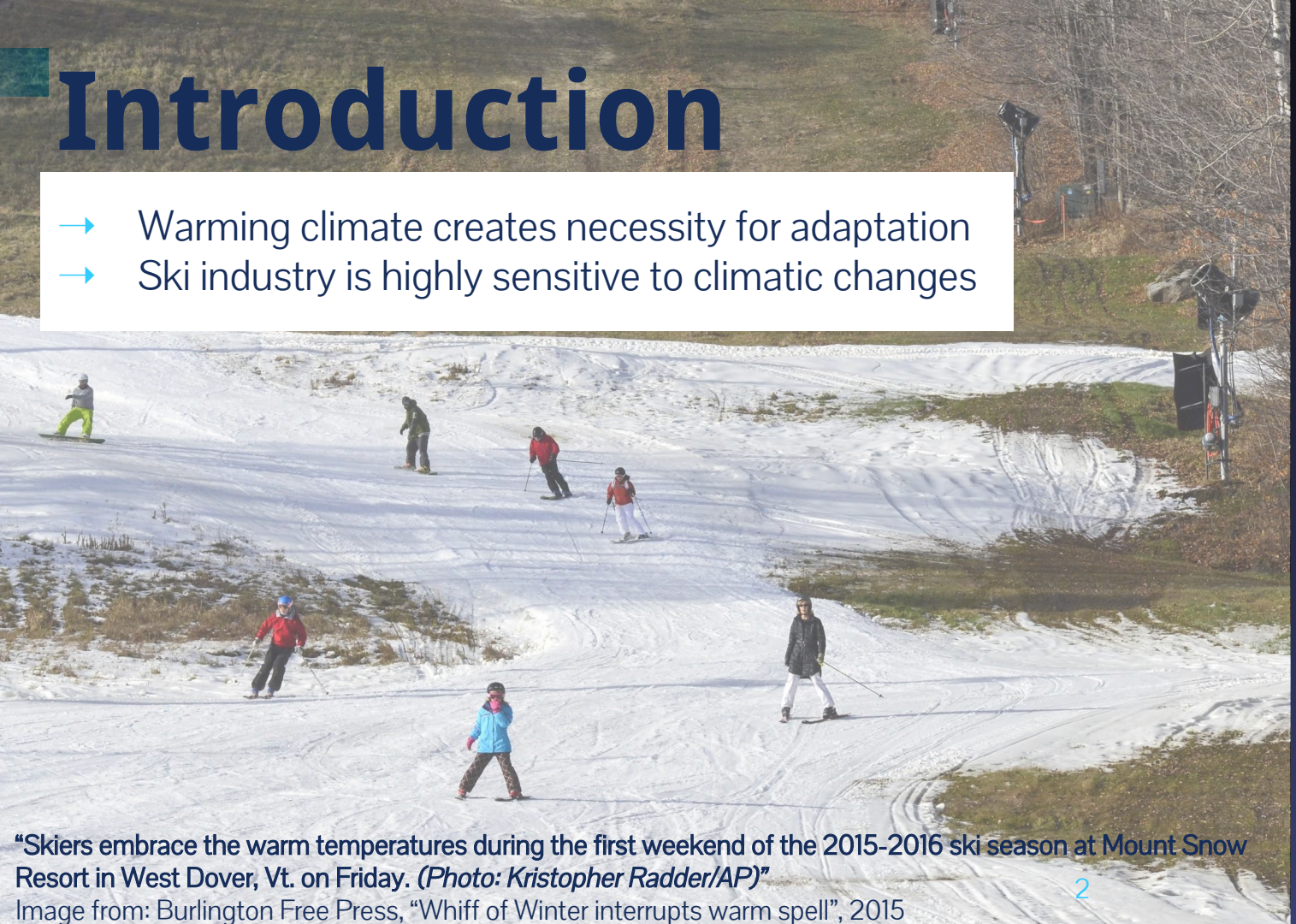
The University of Vermont

Craftsbury OUTDOOR CENTER

Introduction

- Warming climate creates necessity for adaptation
- Ski industry is highly sensitive to climatic changes

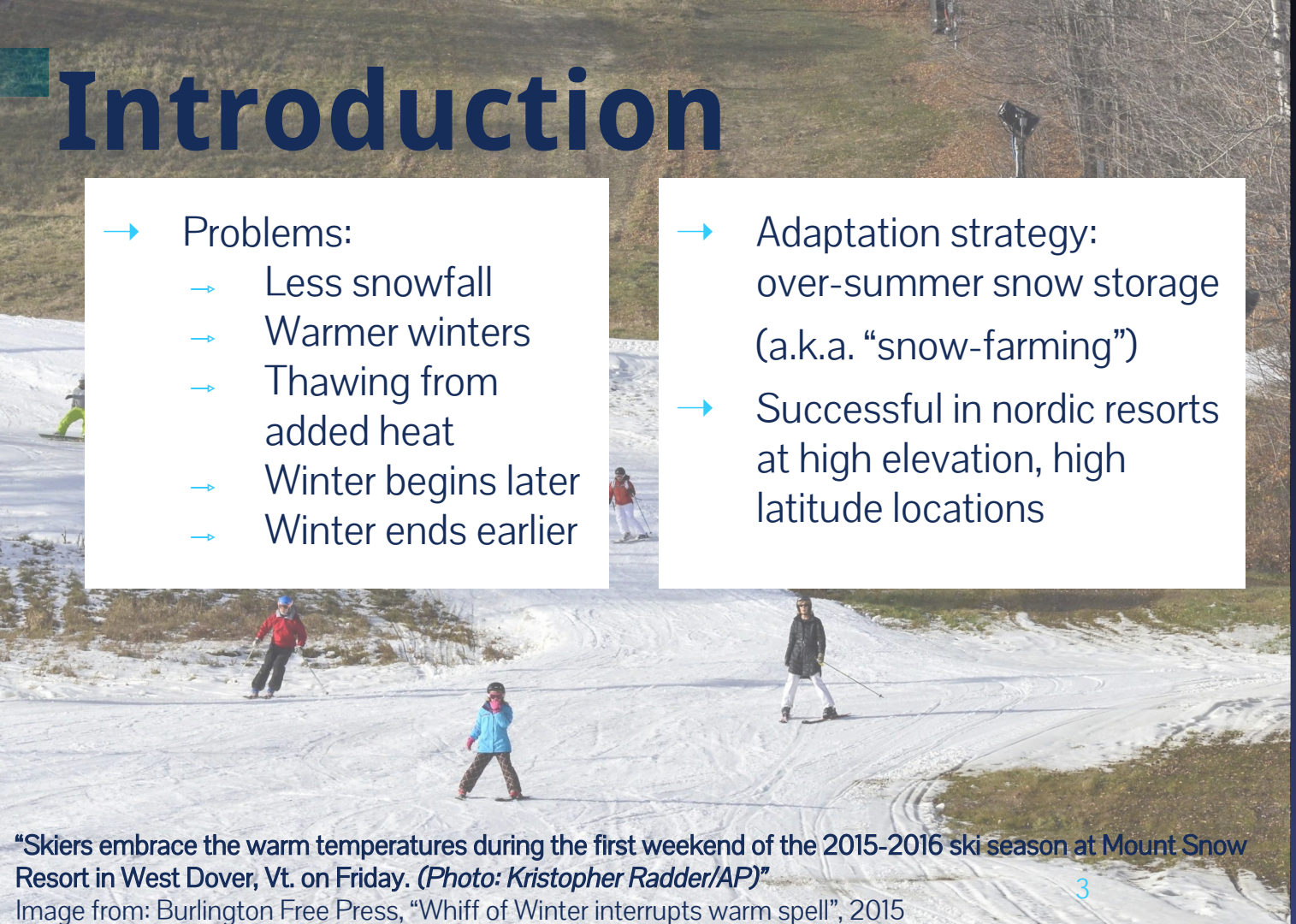


"Skiers embrace the warm temperatures during the first weekend of the 2015-2016 ski season at Mount Snow Resort in West Dover, Vt. on Friday. *(Photo: Kristopher Radder/AP)*"
Image from: Burlington Free Press, "Whiff of Winter interrupts warm spell", 2015

Introduction

- Problems:
  - Less snowfall
  - Warmer winters
  - Thawing from added heat
  - Winter begins later
  - Winter ends earlier

- Adaptation strategy: over-summer snow storage (a.k.a. “snow-farming”)
- Successful in nordic resorts at high elevation, high latitude locations



“Skiers embrace the warm temperatures during the first weekend of the 2015-2016 ski season at Mount Snow Resort in West Dover, Vt. on Friday. *(Photo: Kristopher Radder/AP)*”
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Snow-storage

- Traditional approach:

  Make snow at beginning of season

- Snow-storage approach:

  1) Make large pile of snow in late winter

  2) Store beneath insulating layers (ie. woodchips) throughout summer

  3) Uncover in late fall, spread along trails

Image from: "Snowfarming – weisse Weihnachten auch ohne Schneefall", 2014, www.srf.ch

The Craftsbury Outdoor Center

Craftsbury
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The Craftsbury Outdoors Center


From: frozen-1920s-version.html

From: http://www.mooseriverhandcrafts.com/

Goal: Can we keep snow over the summer at Craftsbury?

Duration of project: June, 2017 through May, 2020

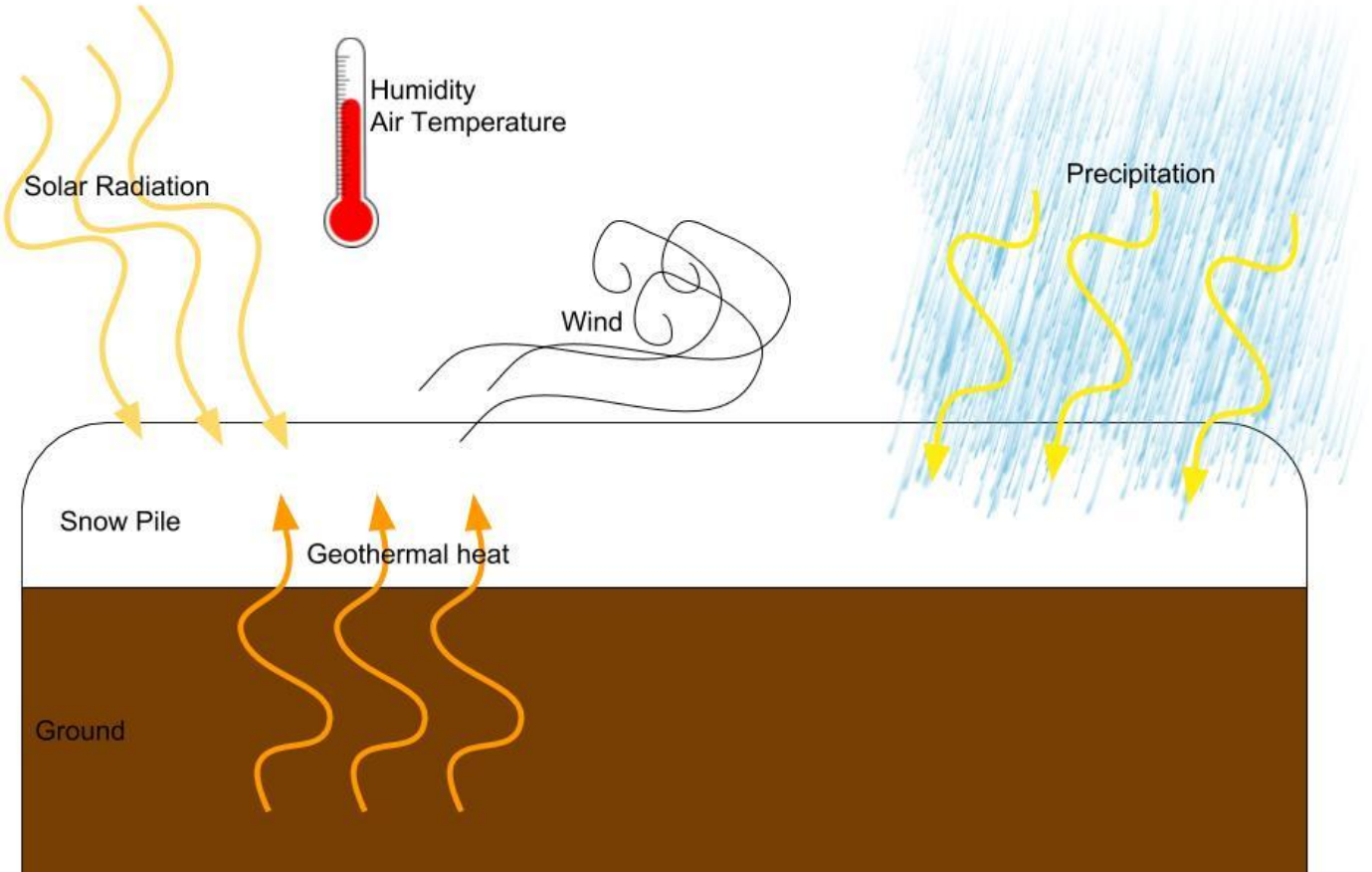
Long-Term Objectives

1. **Gather current, local weather and soil temperature data at the Craftsbury Center for undergraduate research**

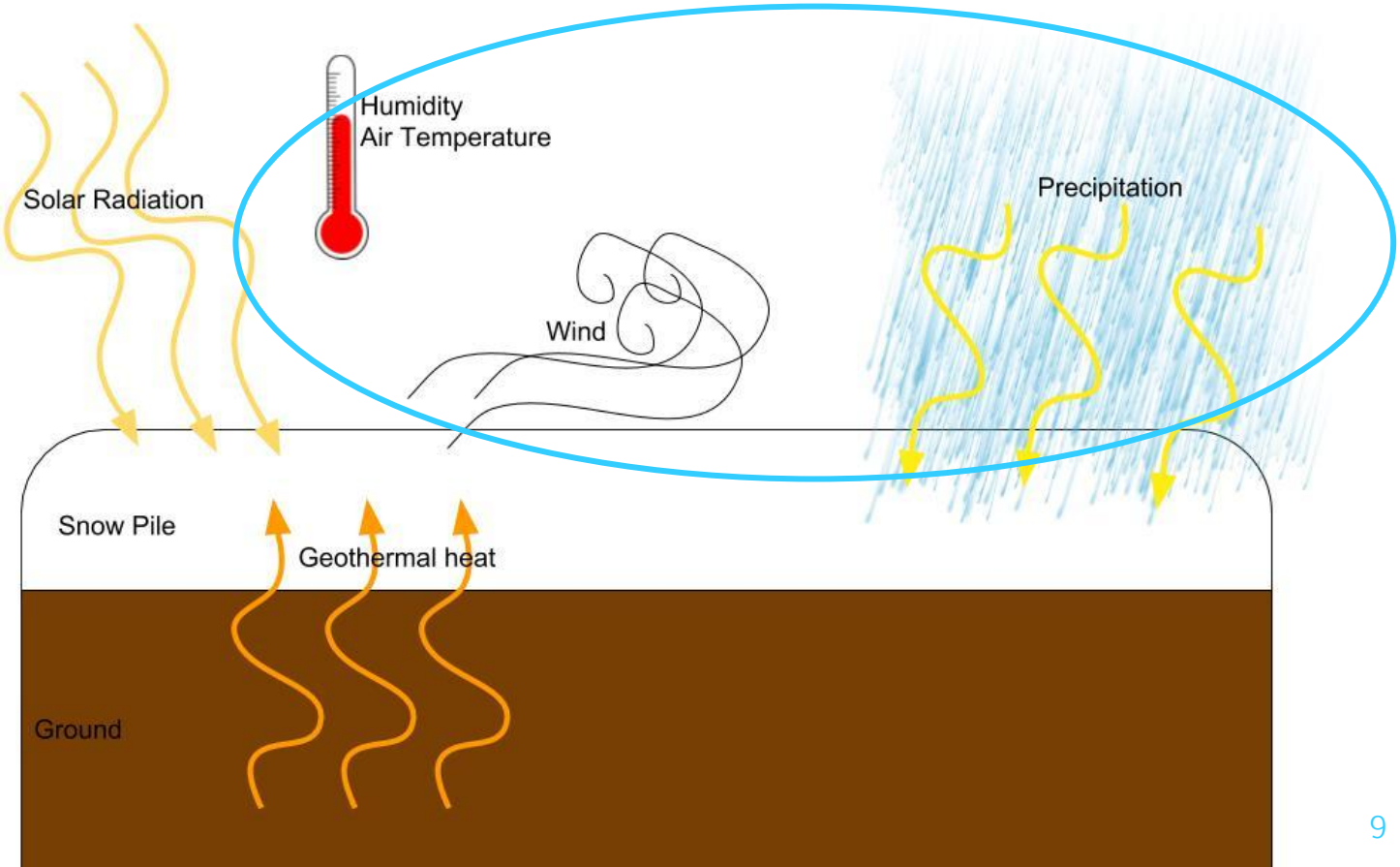
MASTER'S THESIS WORK

2. Use data to create computer models of summer snow-melt
3. Use models and previous century's climate data to predict snow melt rate in varying conditions
4. Run cost/energy analysis based on melt-rate to determine feasibility of snow-farming

What affects snowmelt?



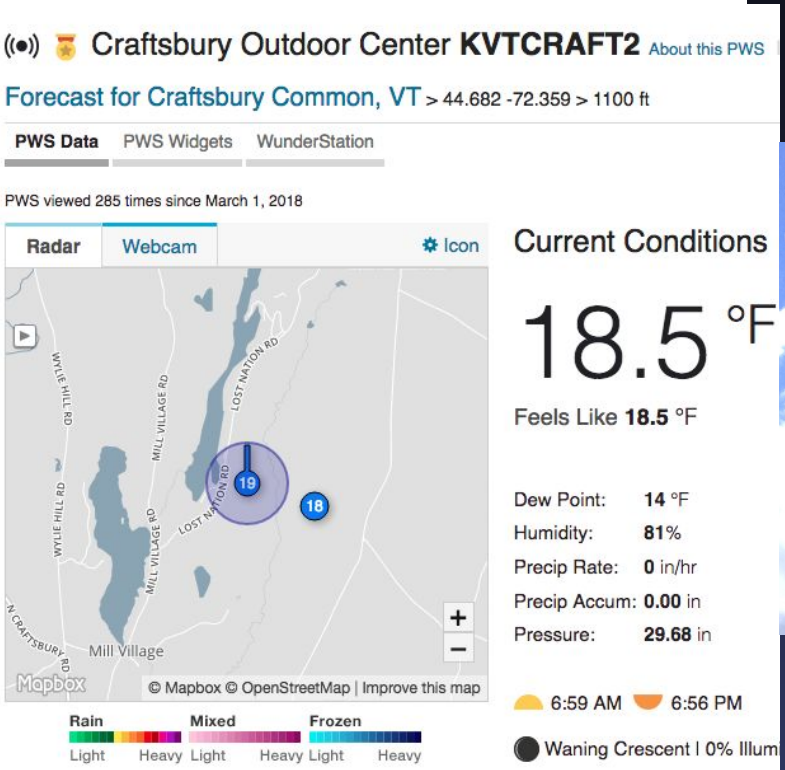
What affects snowmelt?



Methods

- Local past decade of weather conditions:
  a. Weather station at Craftsbury Outdoors Center monitors:
     i. Air Temp
     ii. Precipitation
     iii. Humidity
     iv. Wind Speed

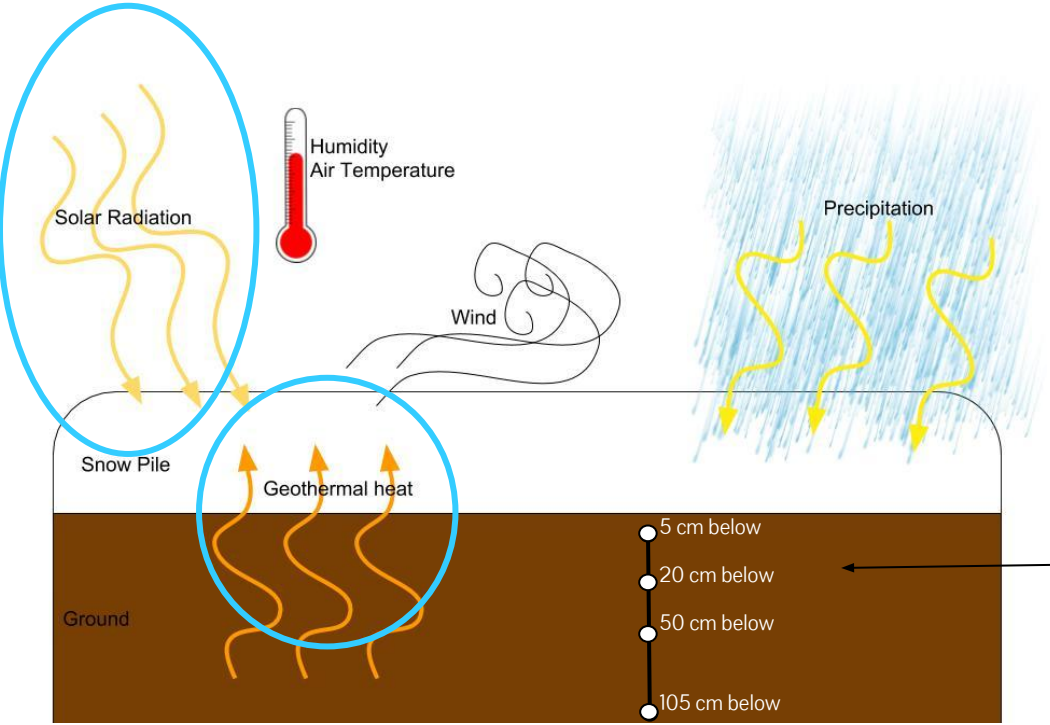
- Statewide past 134 years of weather conditions:
  a. Fairbanks Museum's "The Northern New England Weather Center Records, 1894 - 1997, ongoing"



FAIRBANKS MUSEUM & planetarium

Methods

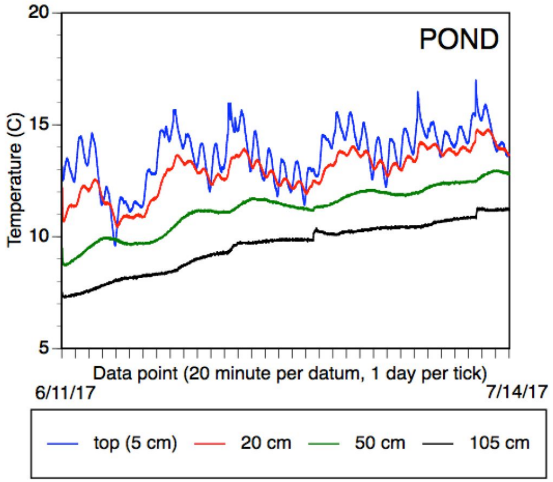
→ How to measure Solar Radiation?



→ How to measure Ground Temperature?

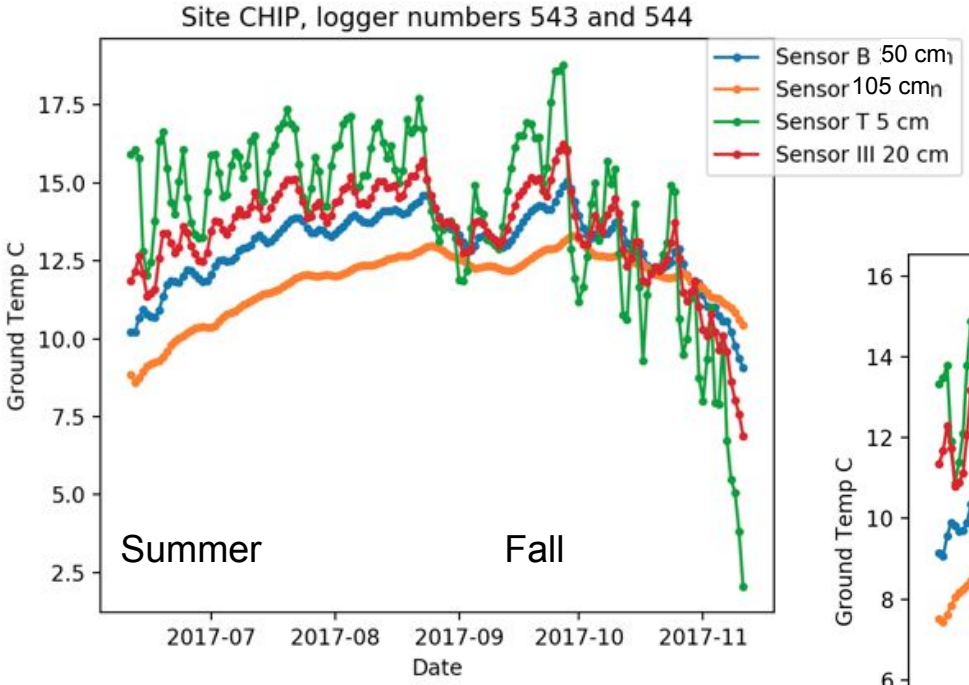
Ground Temperature

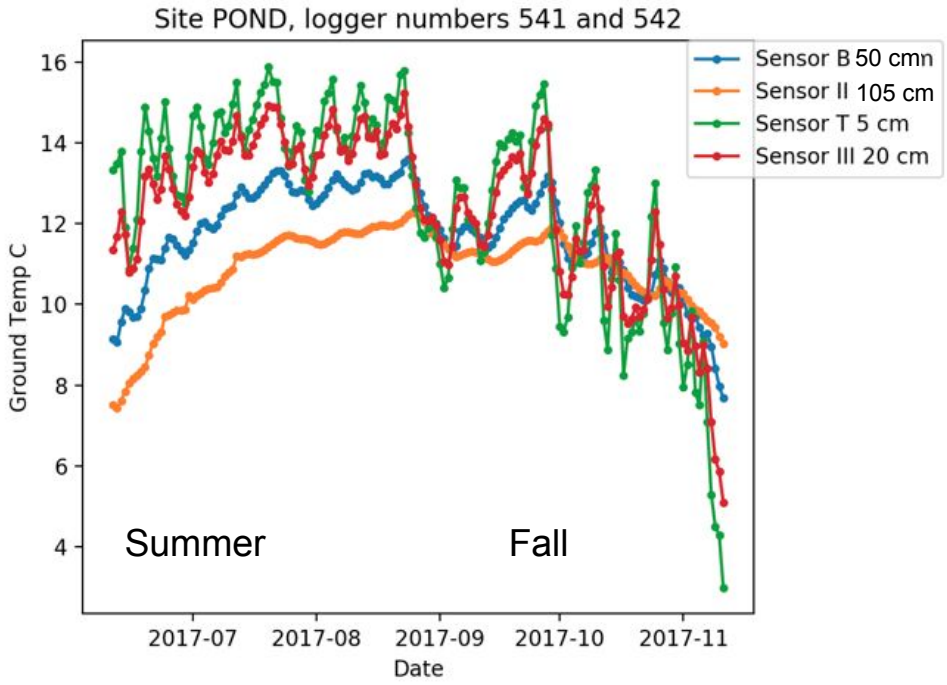
- June, 2017 to present:



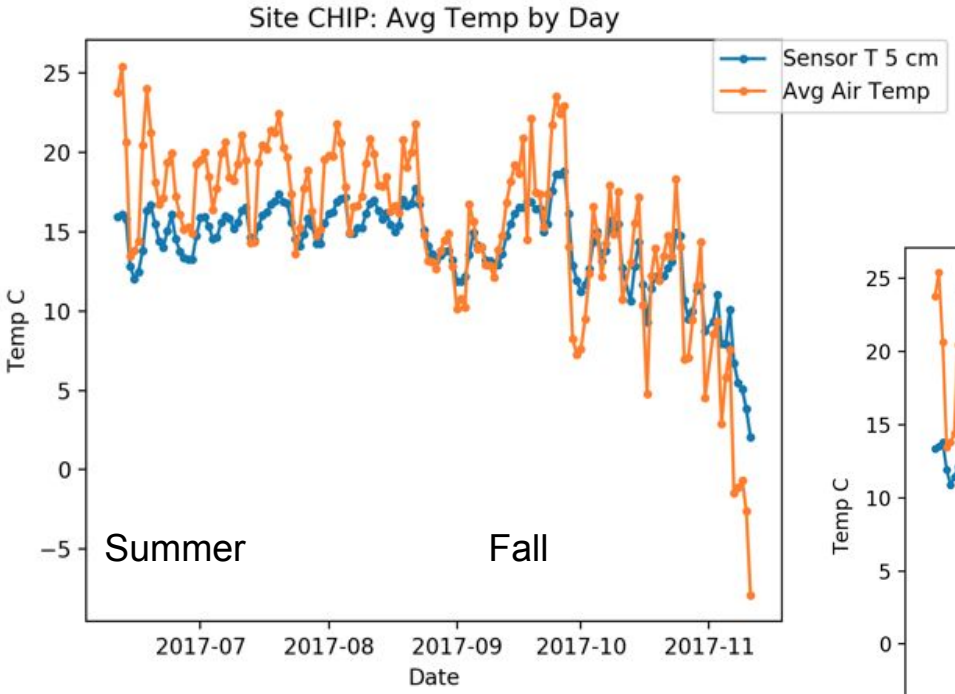
- 5 cm below surface
- 20 cm below surface
- 50 cm below surface
- 105 cm below surface

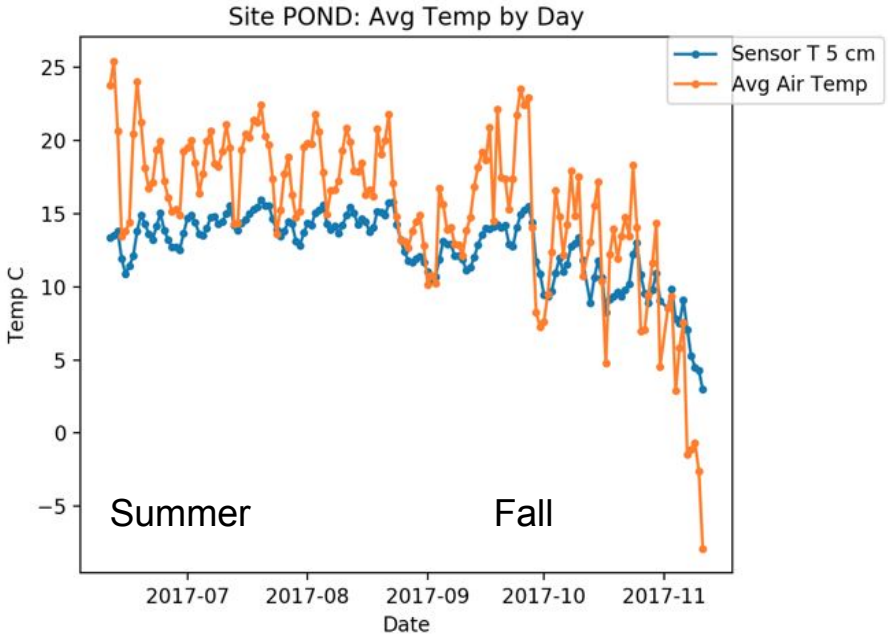
Results - Ground Temperature





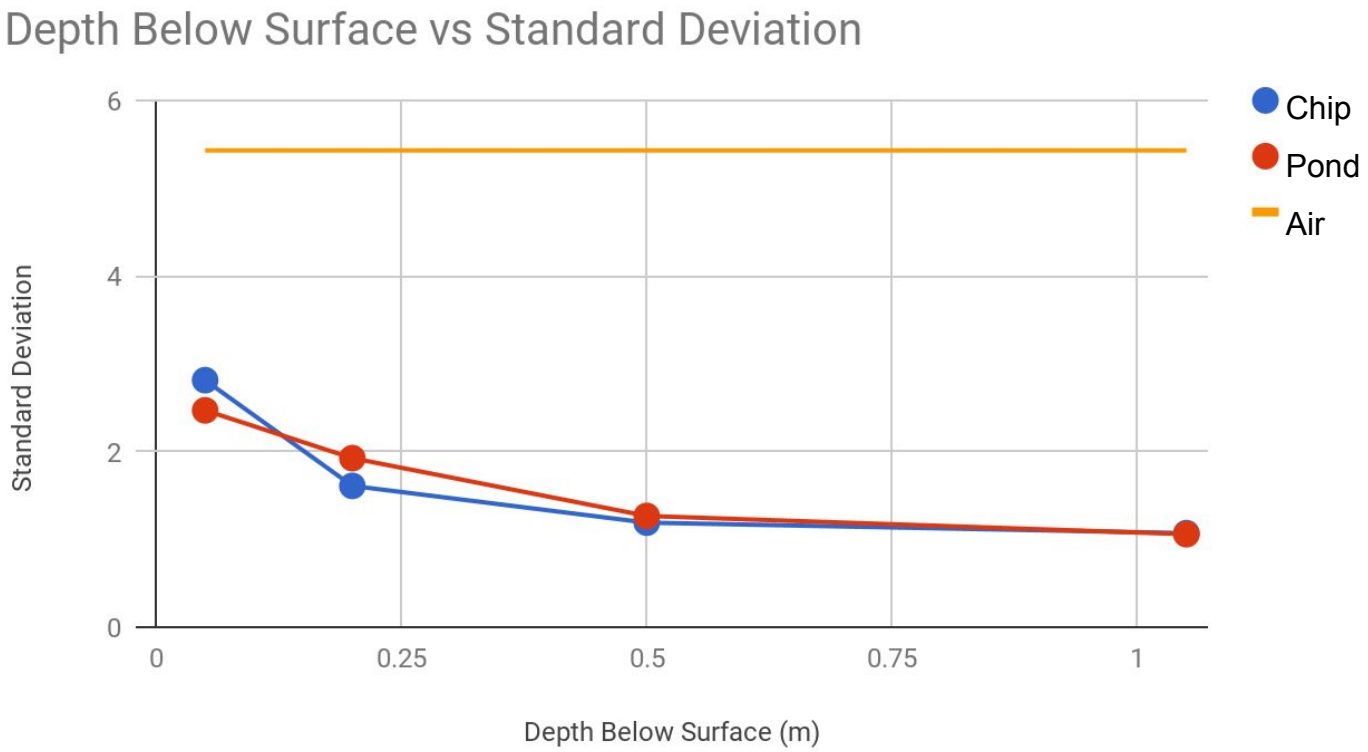
Results - Air vs Ground Temp



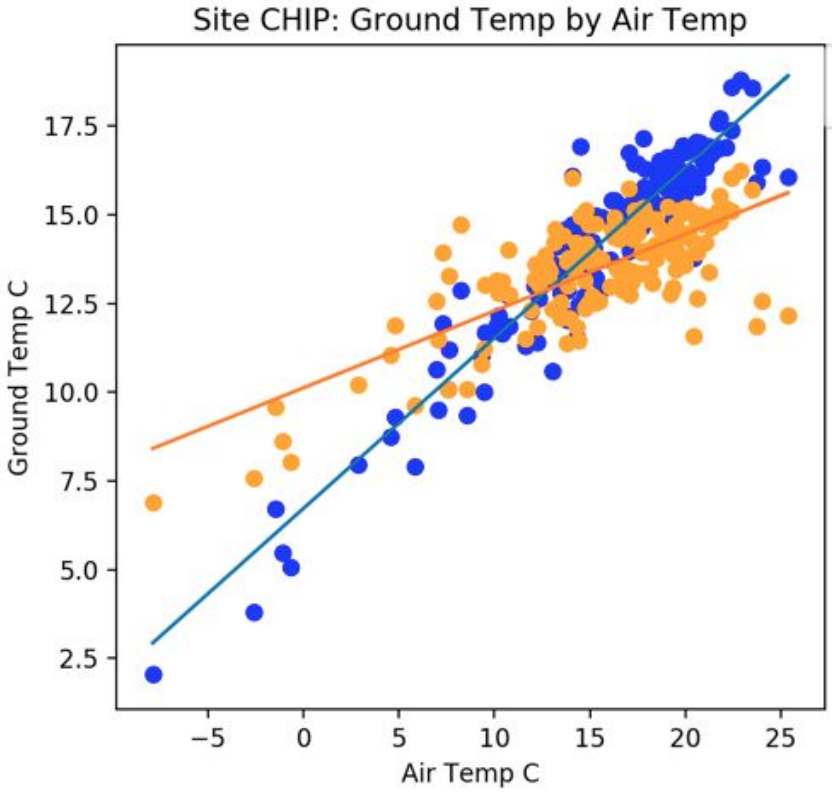


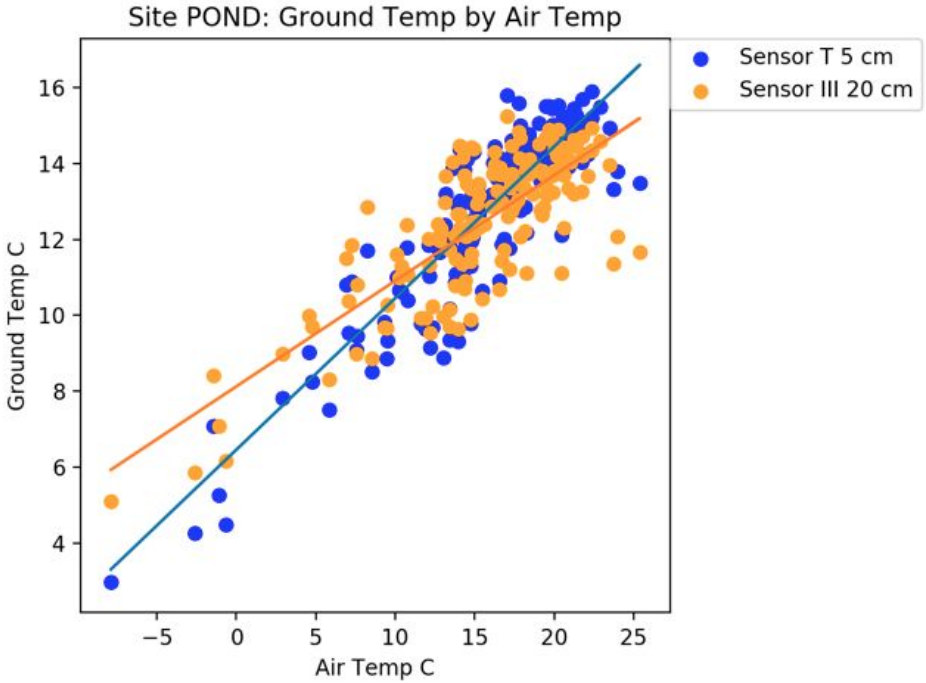
Results

- SD of air is twice as large as SD for shallowest sensors
- SD similar for both sites
- SD decreases with soil depth



Results - Air vs. Ground Temp





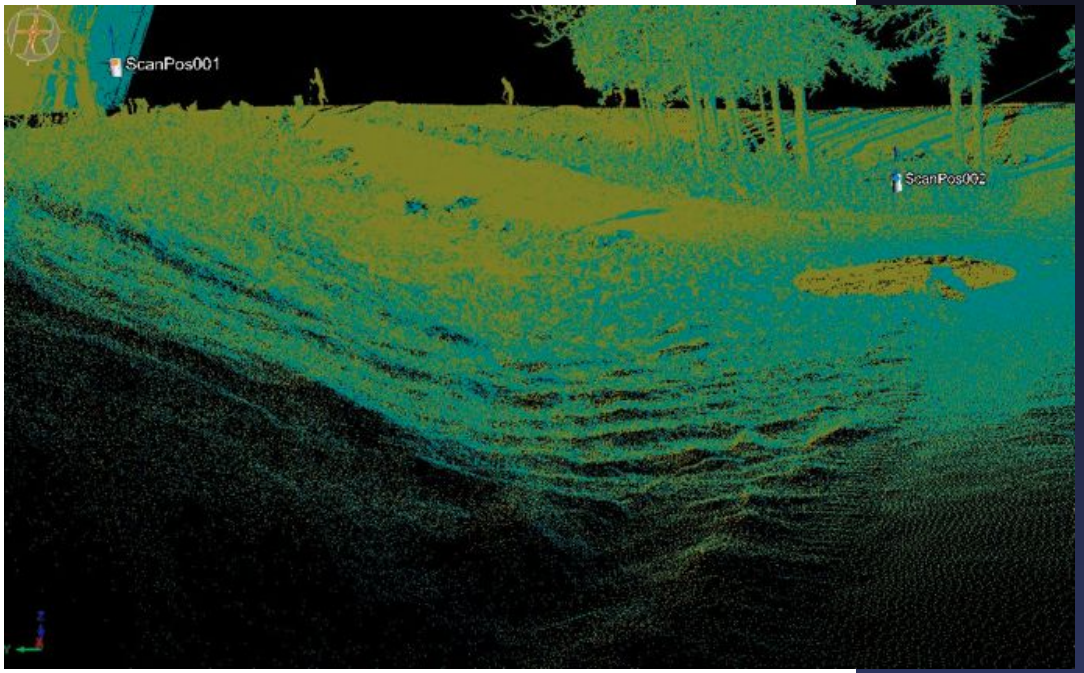
Results

- Strong correlation between air temp and shallowest sensor
- Lesser correlation between air temp and 20 cm below surface sensor

Identification	Value
CHIP: 5cm Slope	0.48
CHIP: 5cm R^2-value	0.88
CHIP: 20 cm Slope	0.22
CHIP: 20 cm R^2-value	0.55
POND: 5cm Slope	0.40
POND: 5cm R^2-value	0.79
POND: 20cm Slope	0.28
POND: 20cm R^2-value	0.62

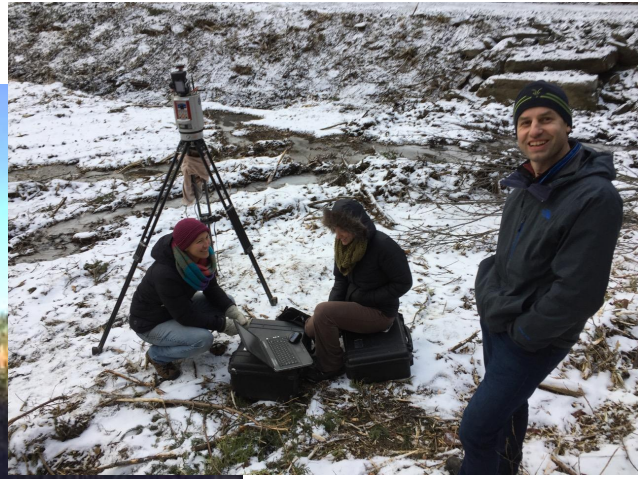
Methods

- Fall 2017: LiDAR

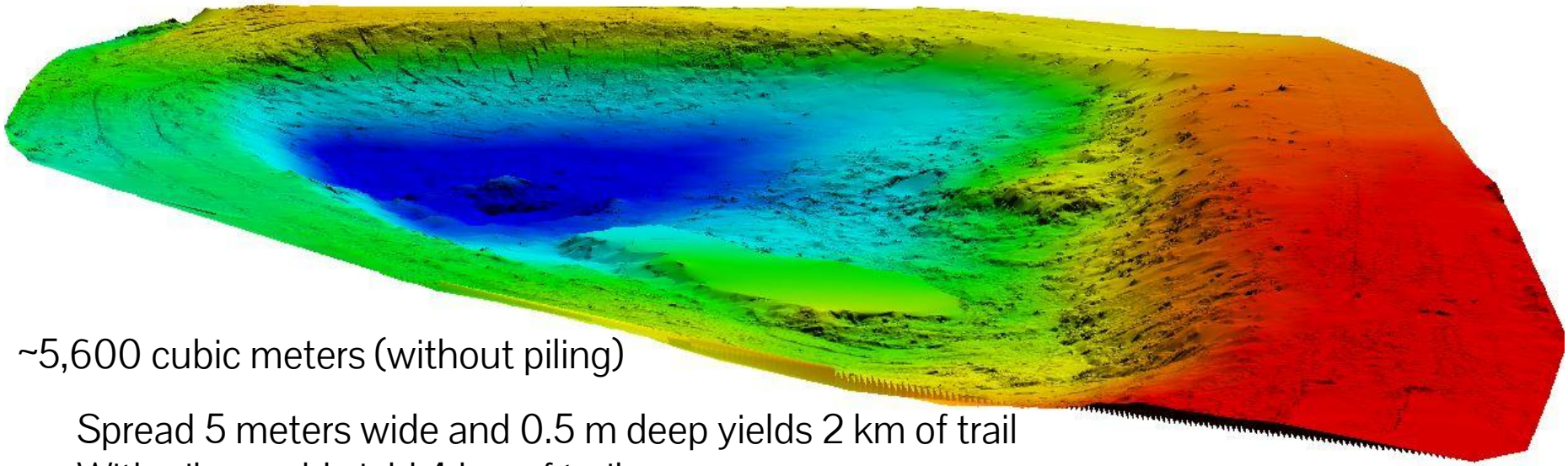


- Used to measure snowpile volume
- Collects 80,000 survey points in 3 minutes

Results - LiDAR POND Site



Results - LiDAR POND Site



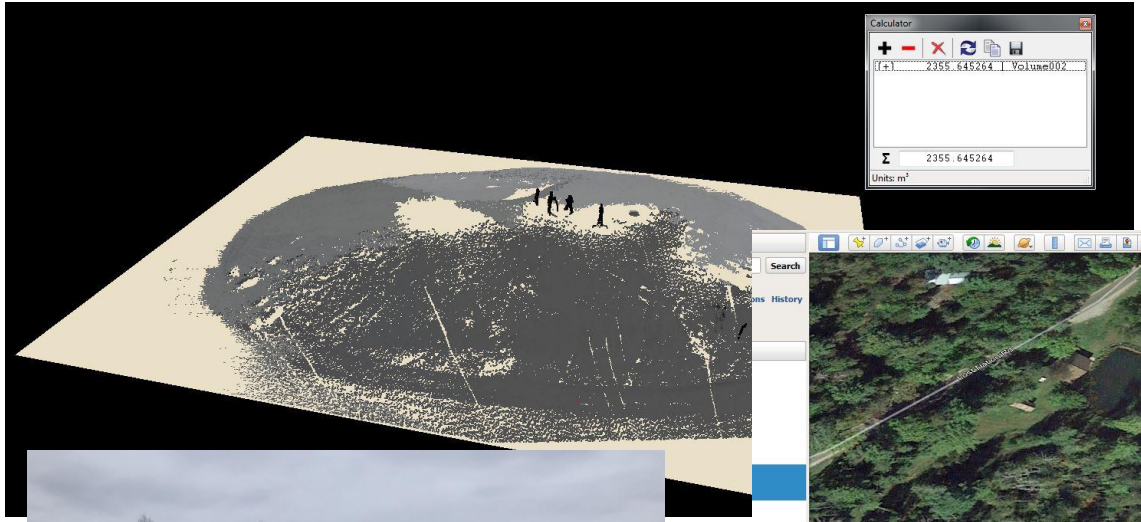
~5,600 cubic meters (without piling)

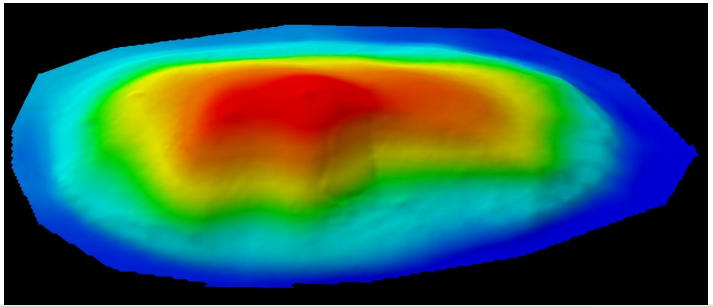
Spread 5 meters wide and 0.5 m deep yields 2 km of trail
With pile, could yield 4 km of trail

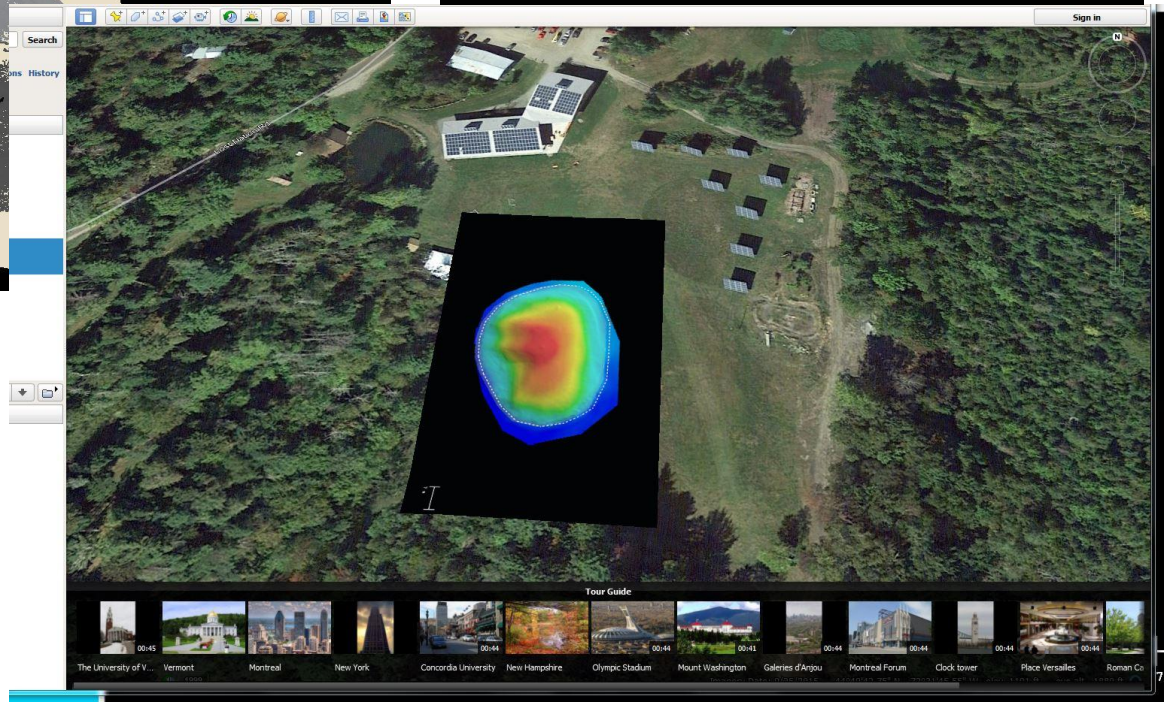
4 km of trail is enough for major races

Q: How much will melt?

Snow pile imaging







Conclusions

- We have the first year-long soil temperature data collection in New England
- We have data to model snowmelt over summer in piles and will test model against reality in summer 2018

Thank you to:

- UVM Geology Department
- UVM Engineering Department
- UVM Spatial Analysis Lab
- UVM Office of Undergraduate Research
- Craftsbury Outdoors Center