The Airborne CryoSAR: Season-long Airborne and Ground-based Observations of Terrestrial Snow and Lake Ice During Fall 2022 and Winter 2023

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Outline

- Motivation
- The CryoSAR system
- Field sites
- Field snow and soil surveys
- Airborne SAR observations
- Current status

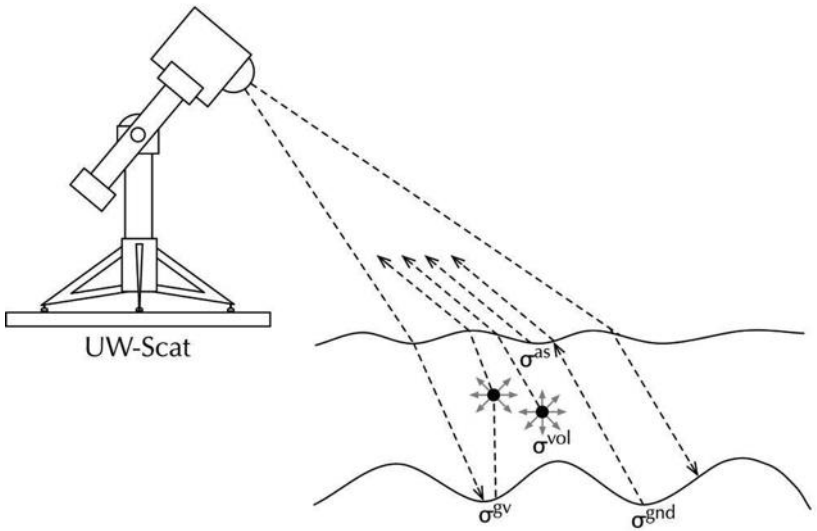


Motivation

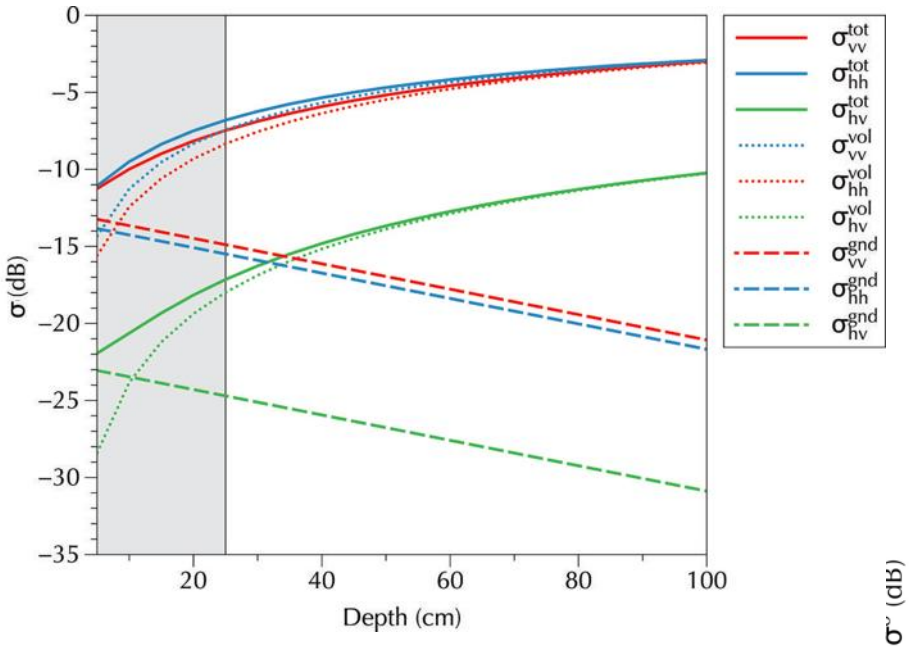
Ku-band (17.5 GHz) radar remote sensing of snow: signatures

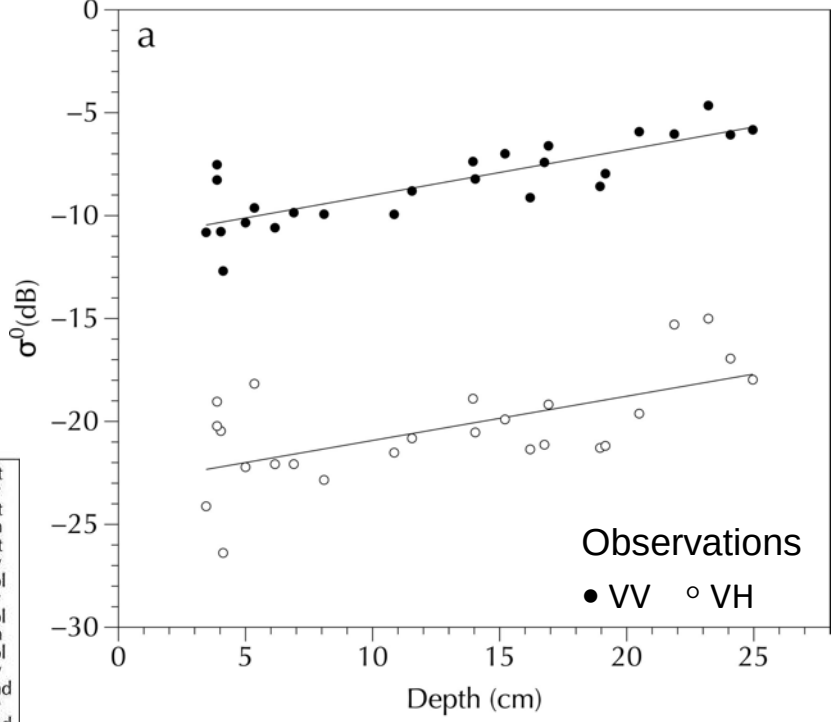
$$\sigma_{pq}^{tot} = \sigma_{pq}^{as} + \sigma_{pq}^{vol} + \sigma_{pq}^{gv} + \sigma_{pq}^{gnd}$$

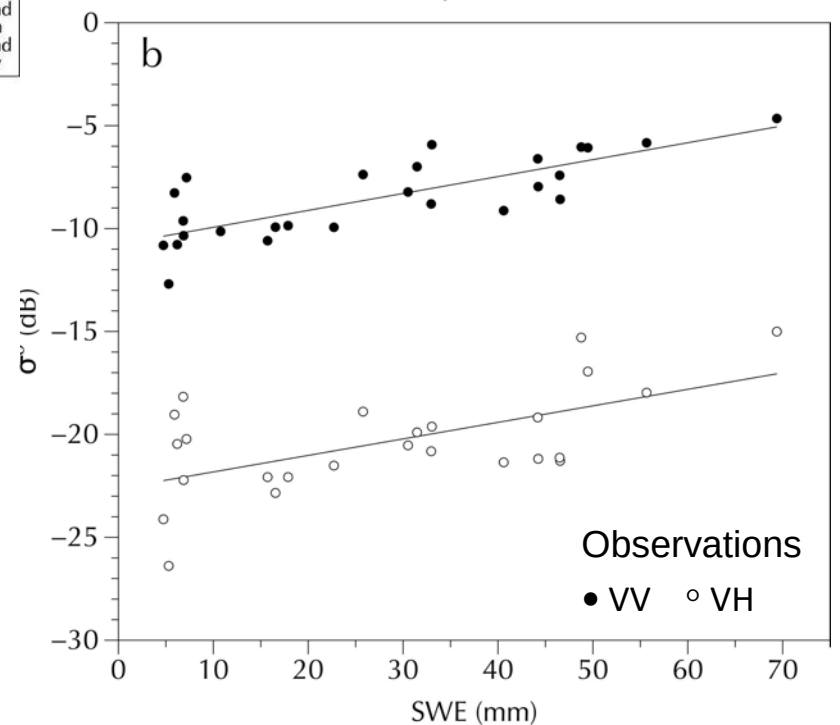
From Rott et al., 2010.



DMRT



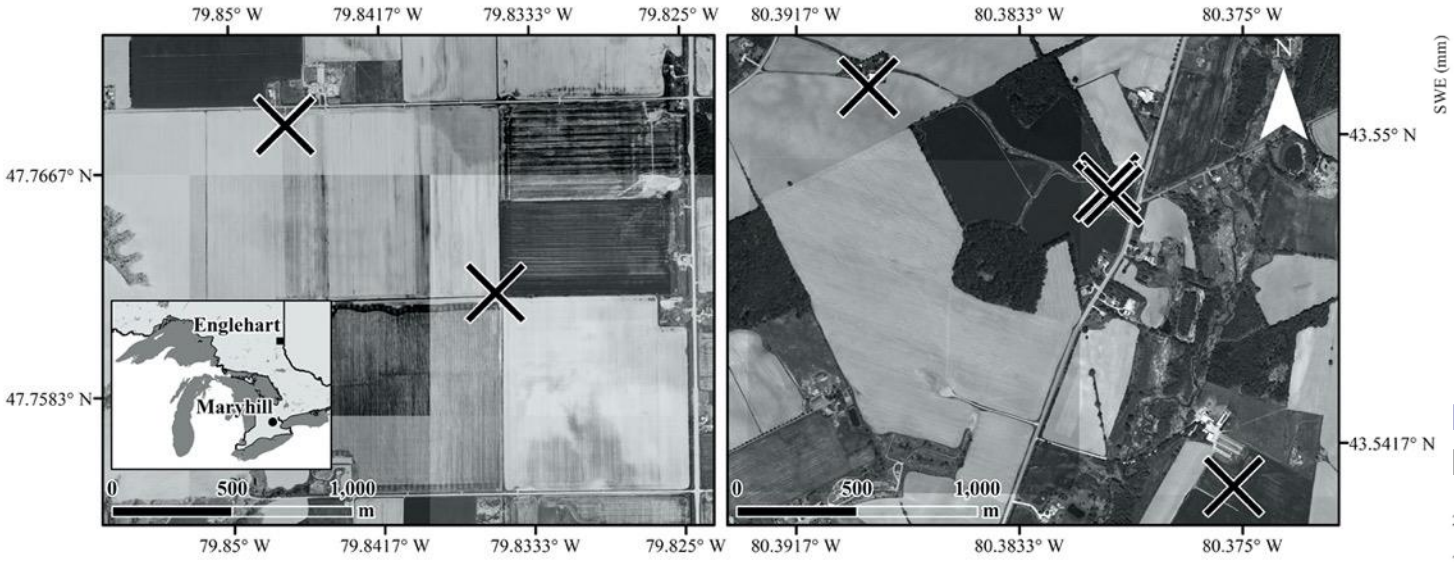




King, JM.L., R.E.J. Kelly, A. Kasurak, C. Duguay, G. Gunn, N. Rutter, T. Watts, and C. Derksen (2015) Spatiotemporal influence of tundra snow properties on Ku-band (17.2 GHz) backscatter, *Journal of Glaciology*, 61(226), doi: 10.3189/2015JoG14J020

Motivation

S. Ontario example





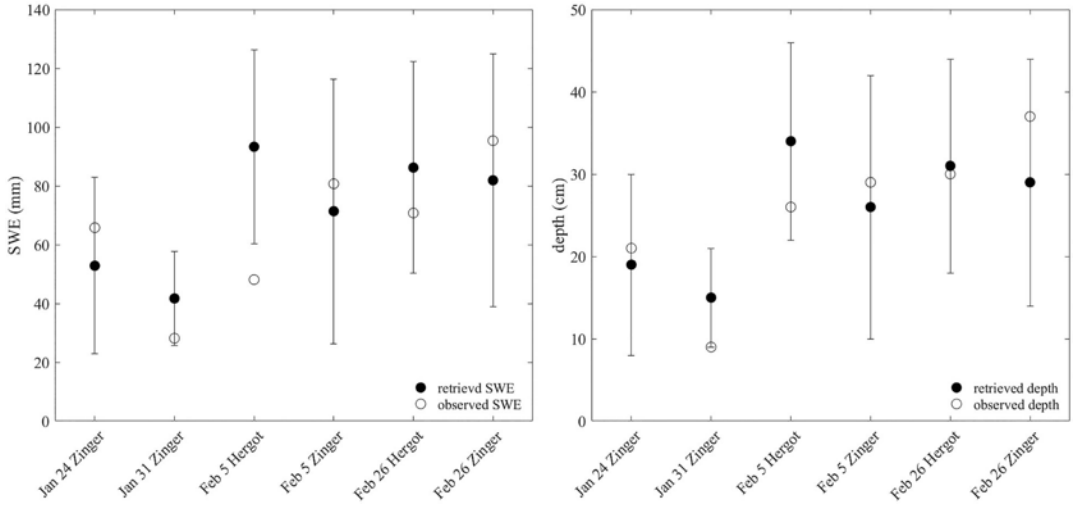
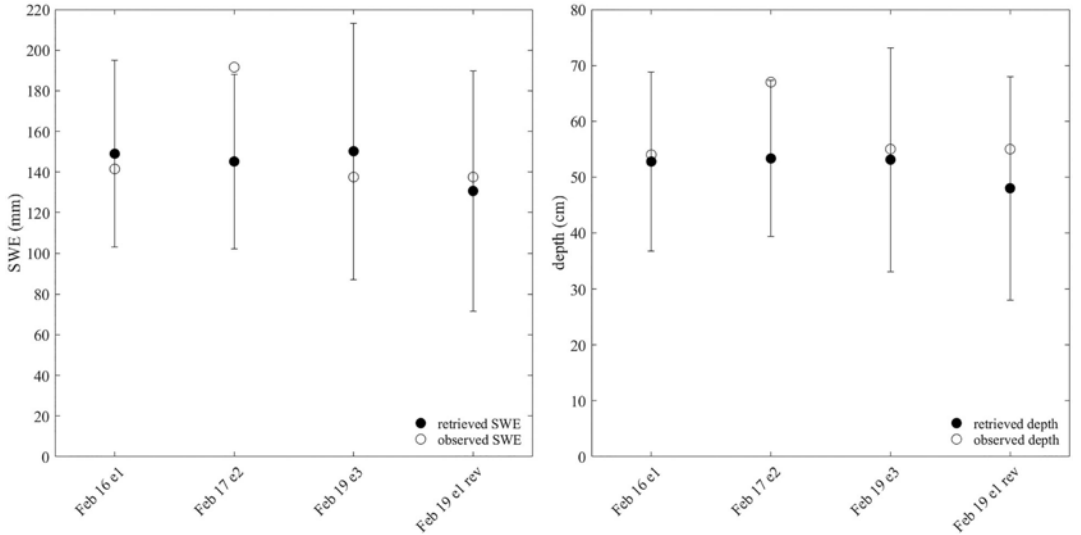


Figure 8. Maryhill SWE (left) and snow depth (right) retrieval results Error bars represent one standard deviation.



Englehart SWE (left) and snow depth (right) retrieval results. Error bars represent one standard deviation

Thompson, A. and R.E.J. Kelly (2021). https://doi.org/10.1080/07038992.2021.1898938
Thompson, A, R.E.J. Kelly and J.M.L. King (2019) doi: 10.1080/07038992.2019.1704621

In 2017 we went shopping for:



An airborne Ku- and L-band SAR that we could use for observing snow accumulation, sea/lake ice, glaciers/ice sheets, soil moisture content and state.

An “agile” system that could be “easily” deployed on a “common” platform.

- Cessna 208/208B Caravan. “*A utility aircraft used for flight training, commuter airlines, VIP transport, air cargo and humanitarian missions*.” And jumping out of.

A community instrument to support remote sensing cryospheric research and capacity building.

MetaSensing BV (manufacturers of the SnowSAR system).

(Funding: Canadian Foundation for Innovation, Ontario Research Fund)

The CryoSAR System

Instrument parameters - Ku-band (13.5 GHz) & L-band (1.3 GHz)

Parameter	L-band	Ku-band
Waveform modulation (*)	*Pulsed*	FMCW
Bandwidth (max)	200 MHz	600 MHz
Transmitting channels	2 (alternating)	2 (alternating)
Receiving channels	2 (simultaneous)	2 (simultaneous)
Acquisition modes	Interferometry (repeat-pass), Polarimetry	Interferometry (single-pass), Polarimetry
Azimuth resolution (max)	25 cm	25 cm
Transmit power (max)	10 W	10 W
Antenna type	Microstrip Patch Array	Microstrip Patch Array
Antenna polarization	Dual Linear (H & V)	Dual Linear (H & V)
Cross-pol isolation	< -28 dB	< -28 dB

Parameter	L-band	Ku-band
Antenna gain	13 dB	18 dB
HPBW (El x Az)	40° x 40°	40° x 5°
Antenna bandwidth	200 MHz	600 MHz
Sampling rate (max)	100 MHz	100 MHz
PRF (max)	20 kHz	20 kHz
Data Storage	2 TB SSD (replaceable during flight)	
Sensor weight	< 20 kg (without antenna mounting frame)	
DC power	18 - 32 VDC	
Power consumption	< 400 W	
Operating temperature	-20° – 60° C	
Antenna Mounting Structure	< 10 kg	
Status monitoring	Internal health status monitoring, log of configuration and transmitted power, log of errors and warnings	
Onboard verification	AirGUI provides a tool to read and plot raw data and range-Doppler data for onboard data verification	

The CryoSAR System

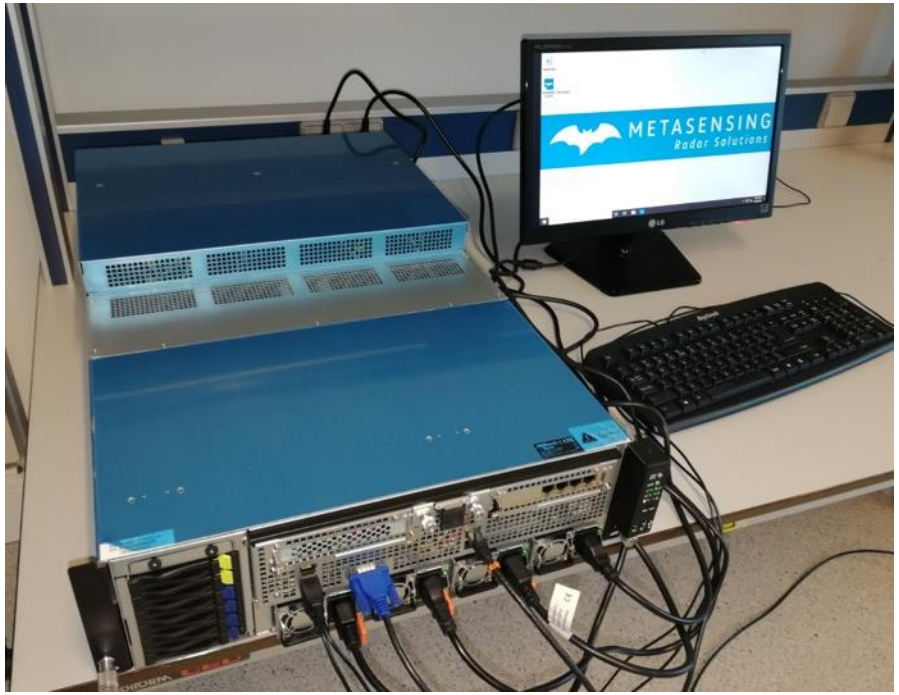
RF Units



Antennas (Ku[2], L[1])



SAR Processor



System package

The CryoSAR System: Installation modifications at Lake Central Air Services

Manufacturer's installation



https://blogs.esa.int/campaignearth/2022/03/15/flying-over-the-wadden-sea-for-harmony/



UW's installation



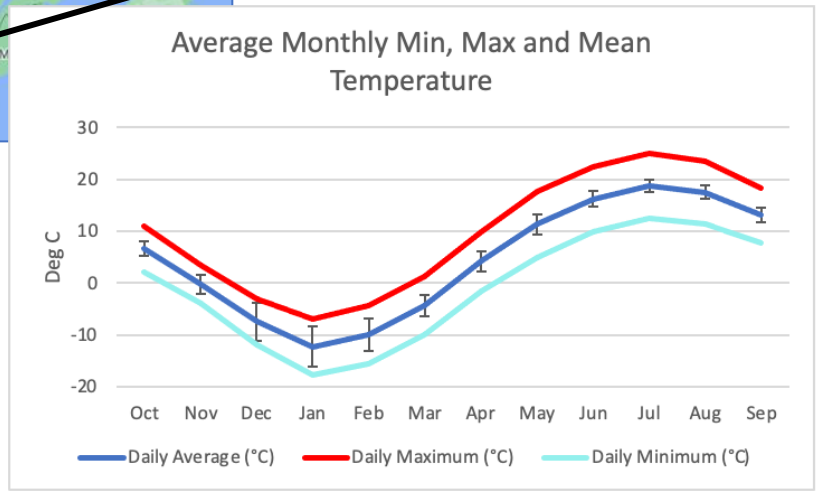
Project goals

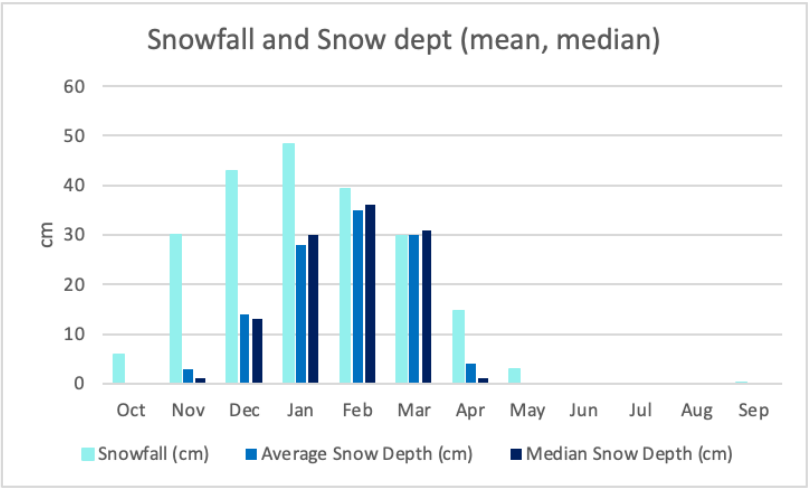
- Combine Ku observations with land surface models as a simulator for Terrestrial Snow Mass Mission science development
- Season-long field experiment to test Ku-band (and L-band) SAR observations of a site in Ontario.
- Instrumented field sites in **Powassan (terrestrial snow)** and Haliburton (lake ice and snow).
- Overfly with Ku and L-band SAR observations
  - Polarimetric response
  - InSAR (L-band) opportunity
- Multiple partners (University, ECCC, LCAS, SkyDive Toronto, Metasensing)
- Canadian Space Agency Funding

Field sites


Baffin Bay
Northwestern Passages
NU
NT
YT
Canada
Hudson Bay
Labrad
AB
BC
SK
MB
ON
QC
NL
WA
MT
ND
MN
OR
ID
SD
WI
MI
WY
NY
VT
NH
MA
CT
NE
IA
IL
IN
OH
PA
NJ
NV
United States


North Bay
Powasan Field Site
Algonquin Provincial Park
Haliburton Field Site
Parry Sound
Huntsville
Muskoka Airport (YQA)
Orillia
Image NOAA
Image Landsat / Copernicus


Average Monthly Min, Max and Mean Temperature
30
20
10
0
-10
-20
Deg C
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Daily Average (°C)
Daily Maximum (°C)
Daily Minimum (°C)


Snowfall and Snow dept (mean, median)
60
50
40
30
20
10
0
cm
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Snowfall (cm)
Average Snow Depth (cm)
Median Snow Depth (cm)

Field sites: Powassan







December 2nd 2022



January 14th 2023



Field soil and snow surveys: Powassan

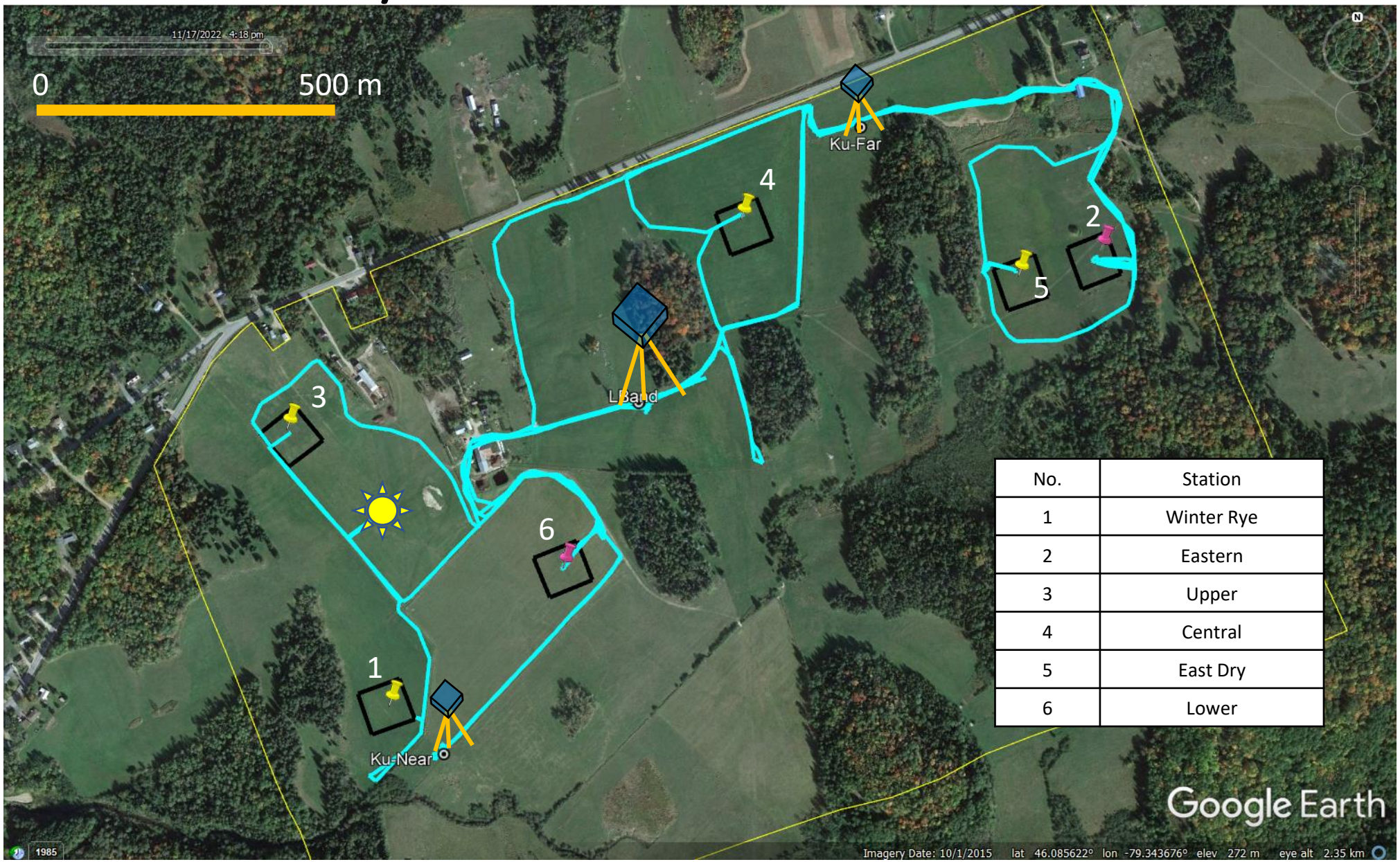
Undisturbed site

Soil Moisture
- 2x HydraProbes

Wx Station

Corner Reflector
- Ku and L-band

Access tracks



No.	Station
1	Winter Rye
2	Eastern
3	Upper
4	Central
5	East Dry
6	Lower

Field snow surveys: Powassan



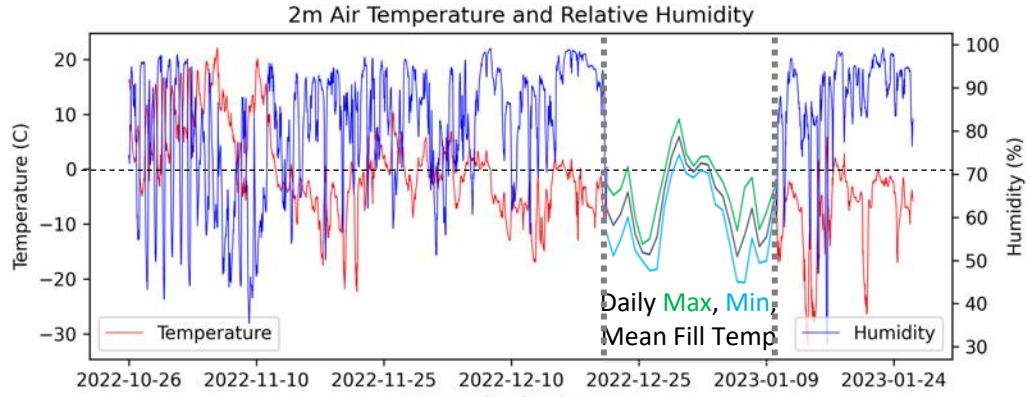


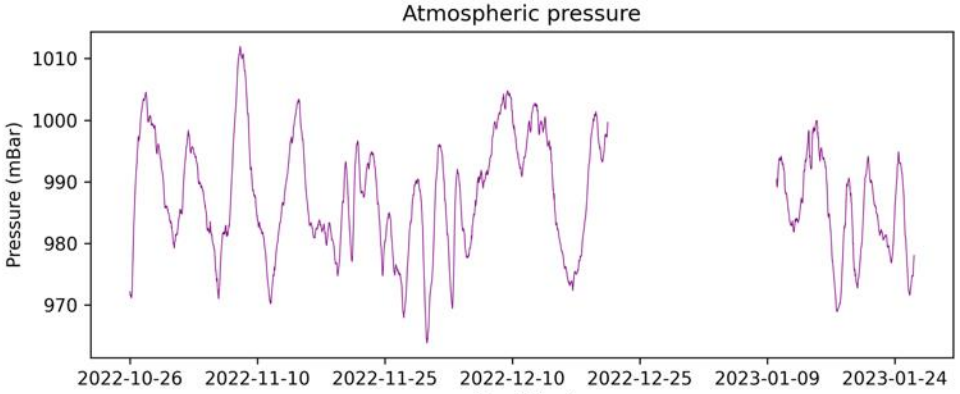


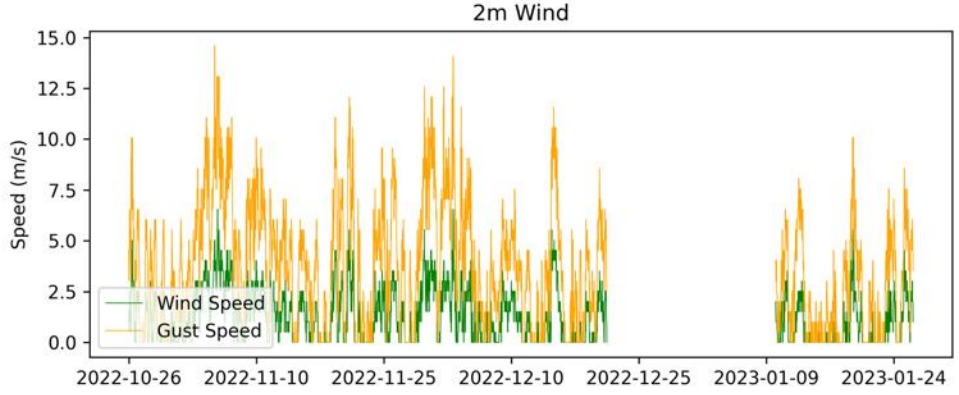

Adjacent to undisturbed sites

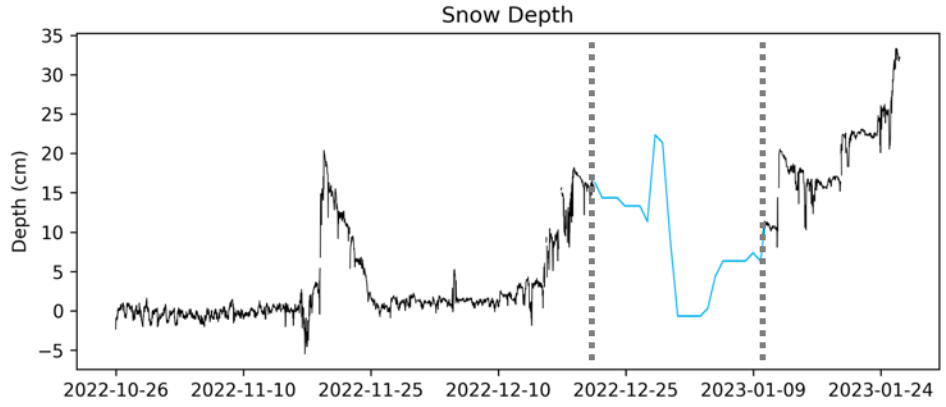
- SMP profiles
- IceCube
- Pit characterization
- Density
- MP Transects

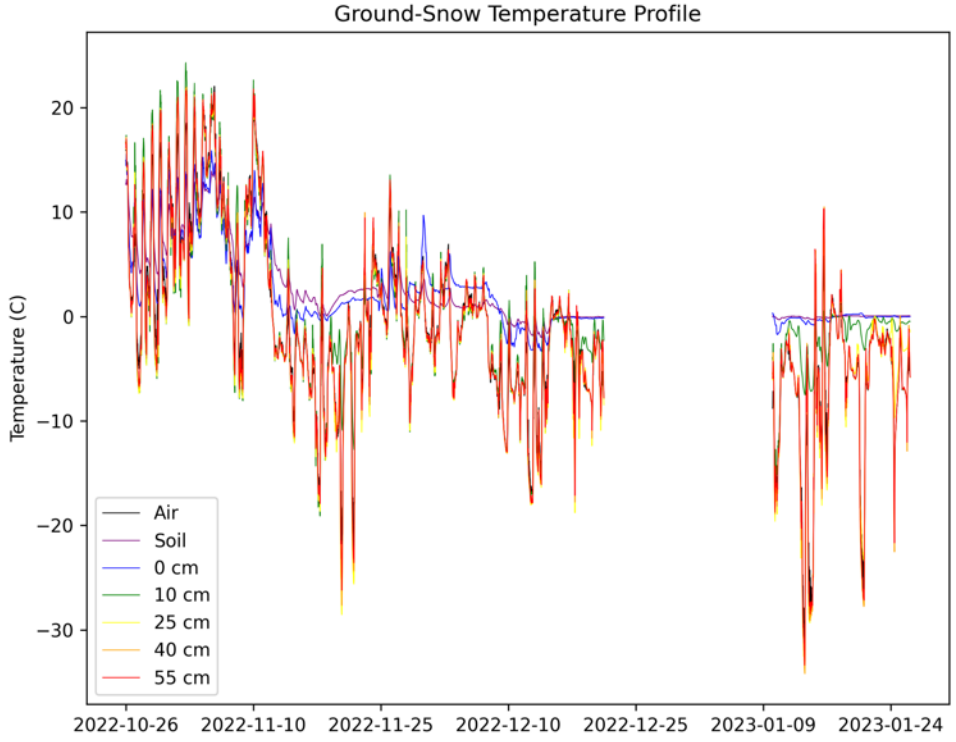
Weather station observations: Powassan



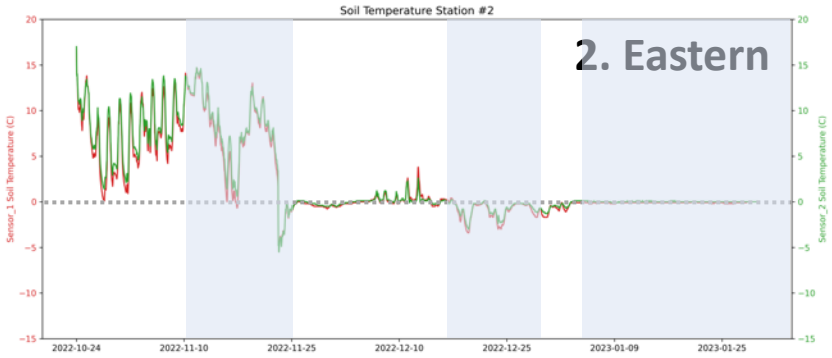


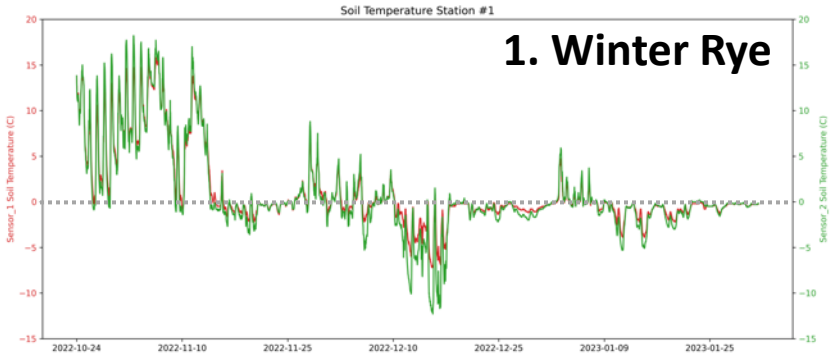


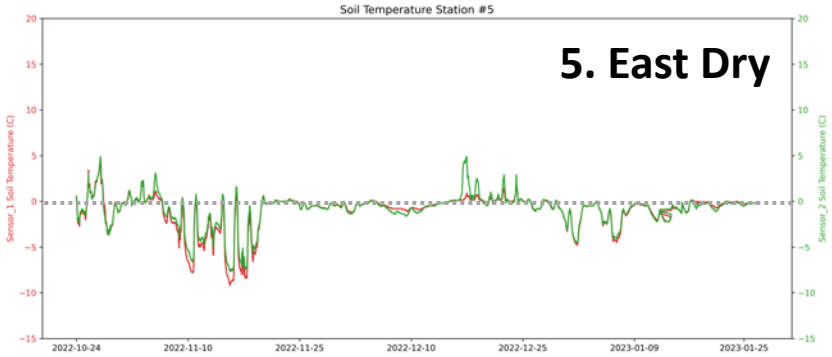


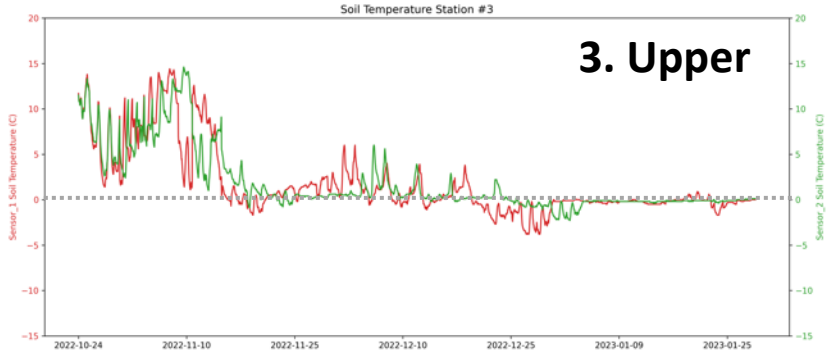


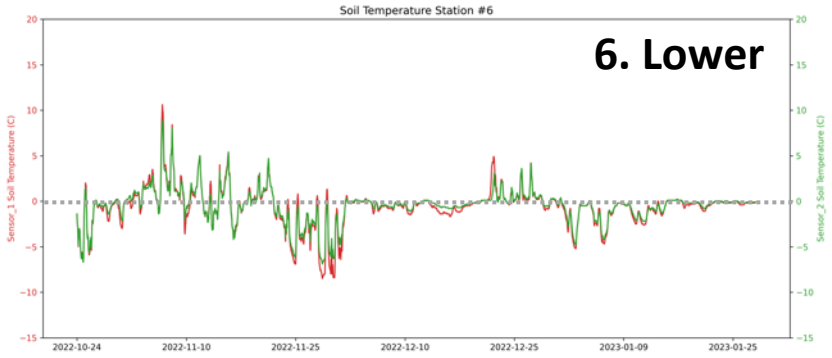
Field soil temperature logging: Powassan

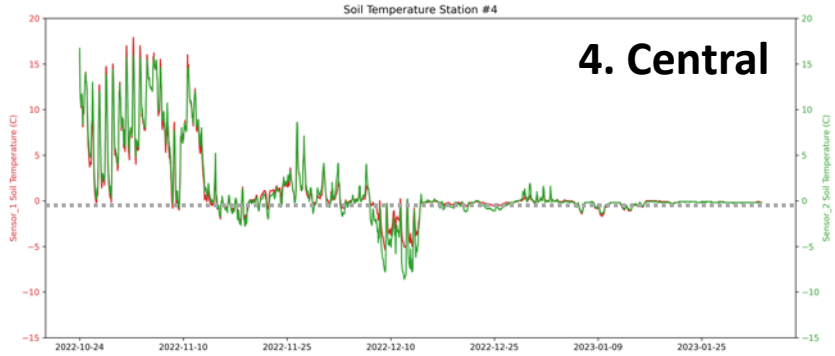








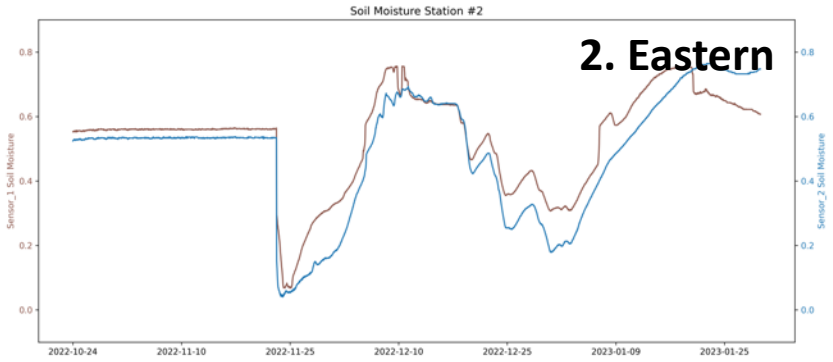


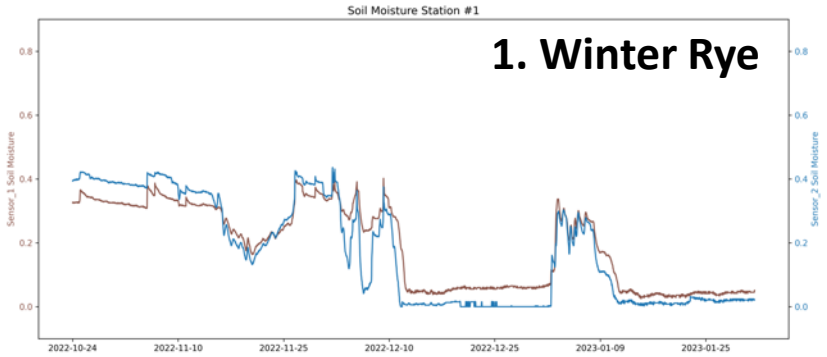


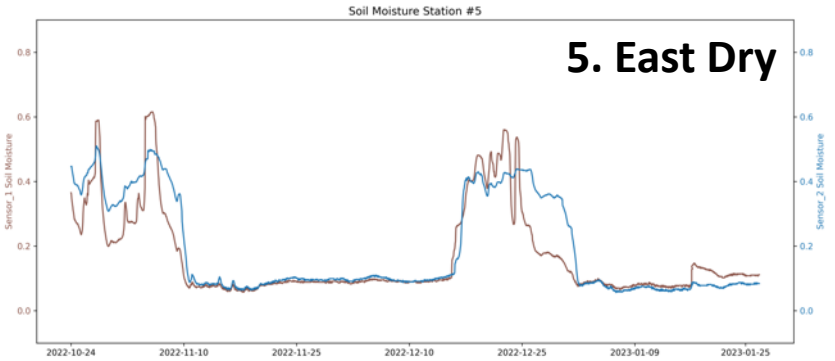


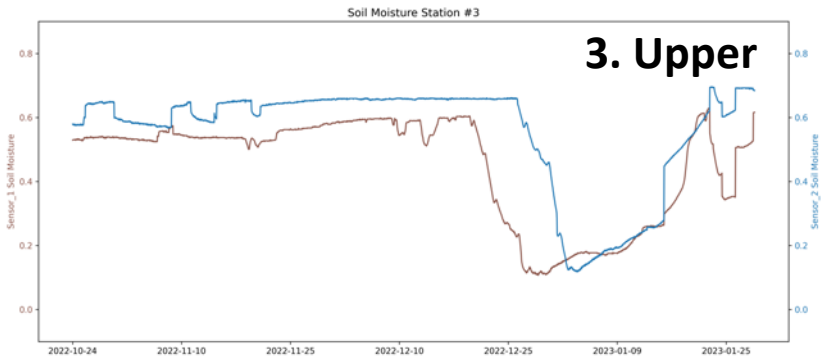
- Soil moisture HydraProbe installation: two probes per logger
- Two iButtons installed for each station at the depth of 2.5 cm and 5 cm

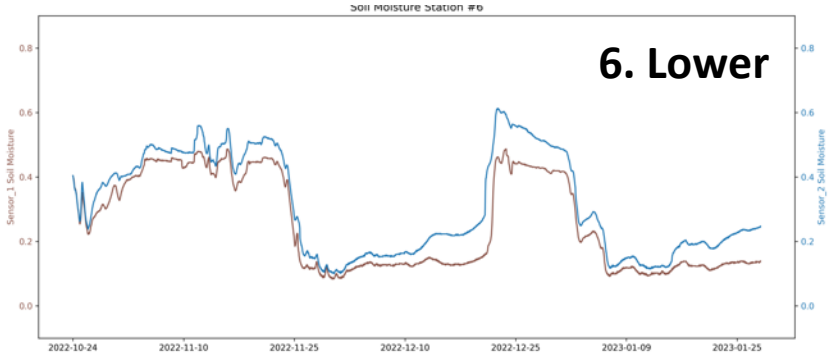
Field soil moisture (uncalibrated) logging: Powassan

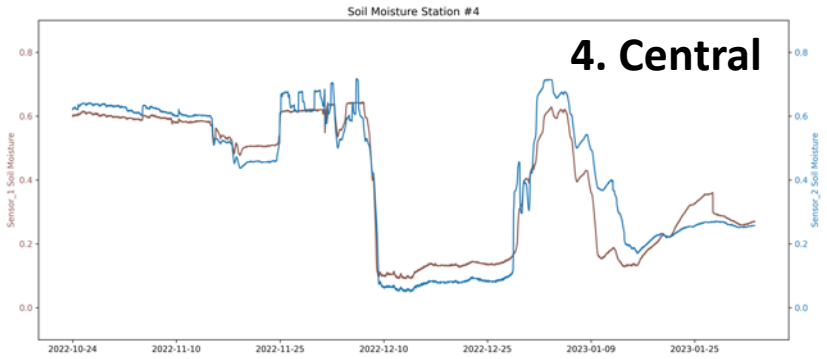






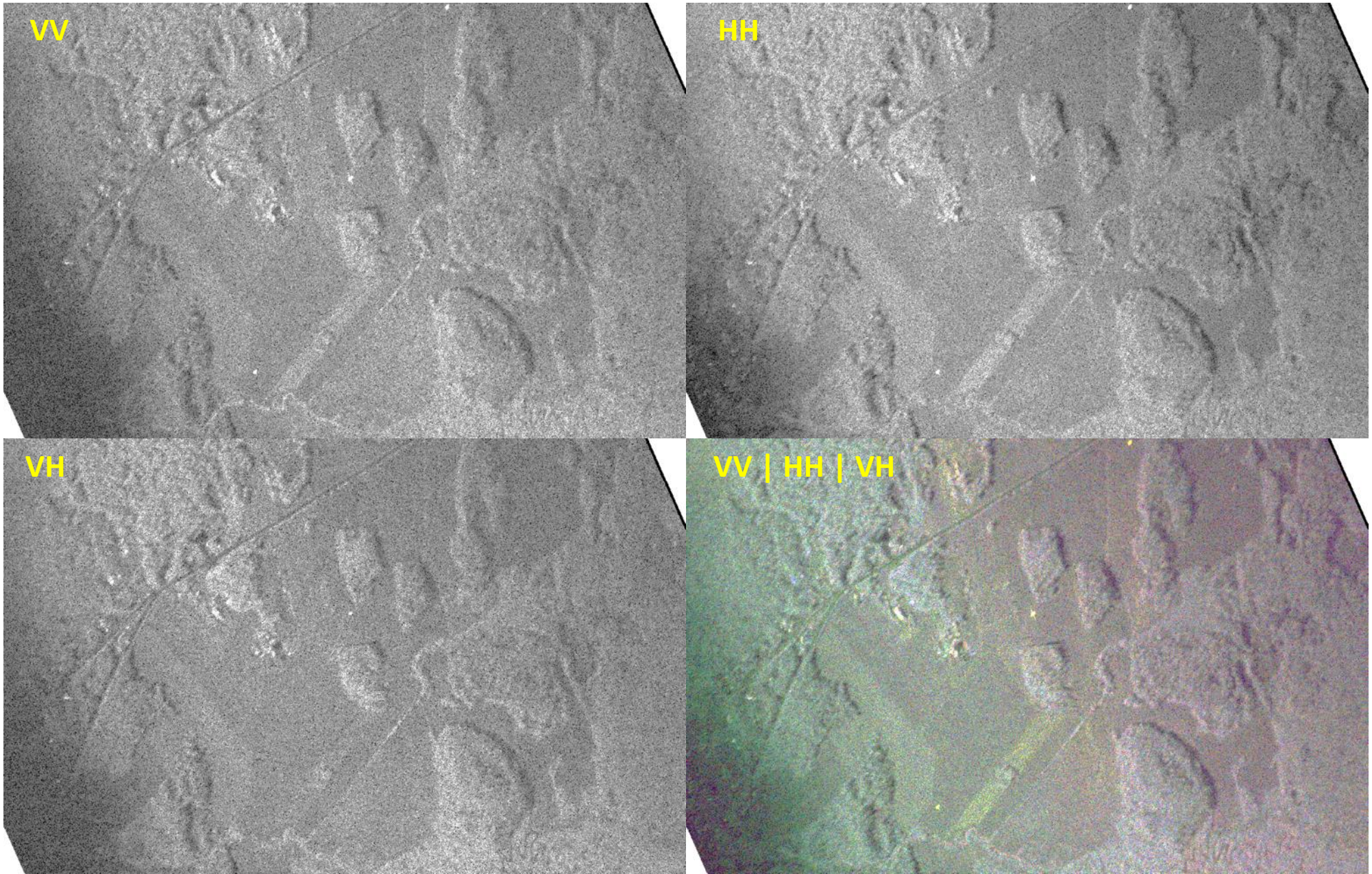






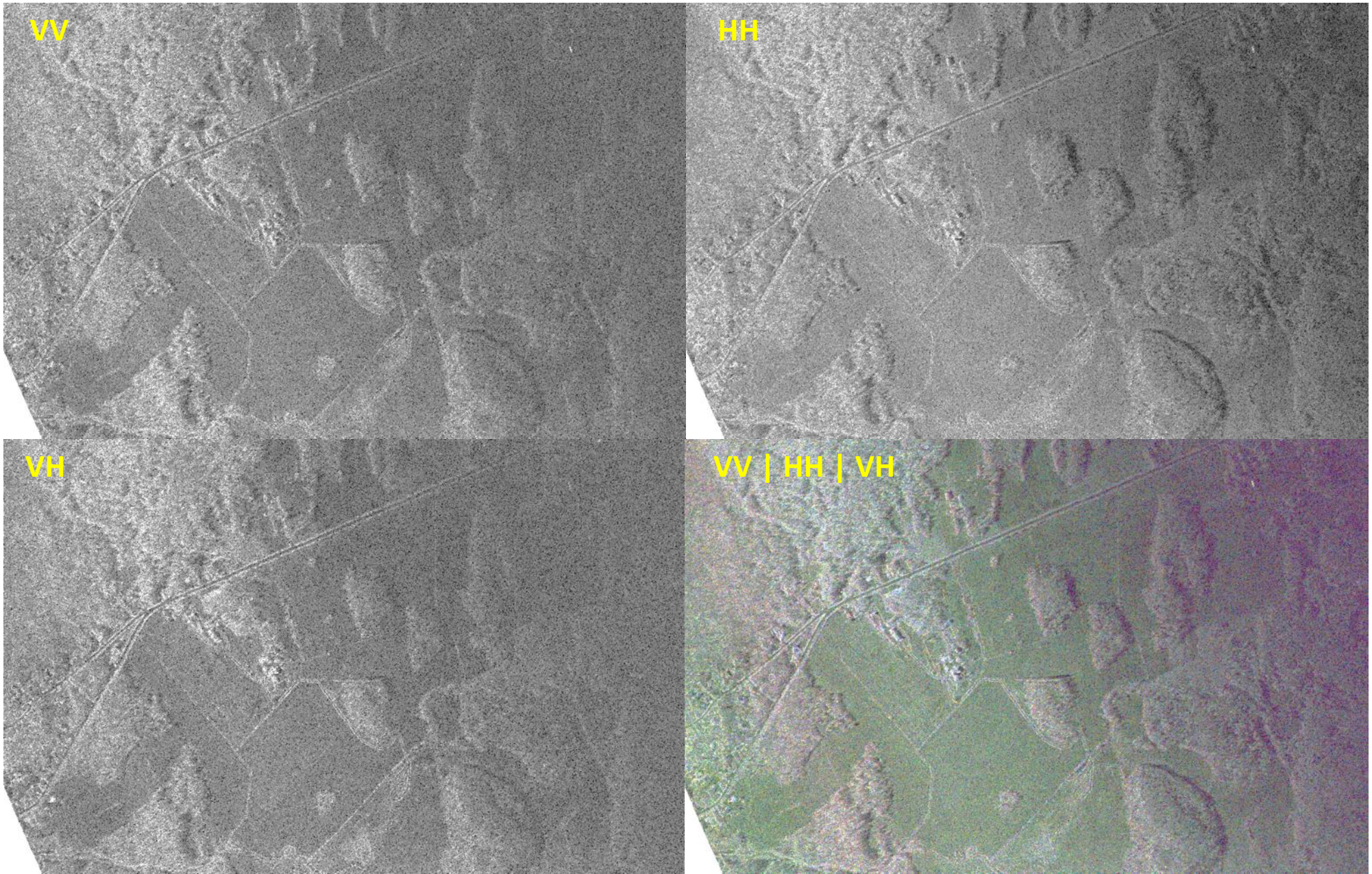
Ku-band SAR Observations (0 cm snow thickness) 2/Dec/2022

Note: Uncalibrated



Ku-band SAR Observations (33 cm snow thickness) 31/Jan/2023

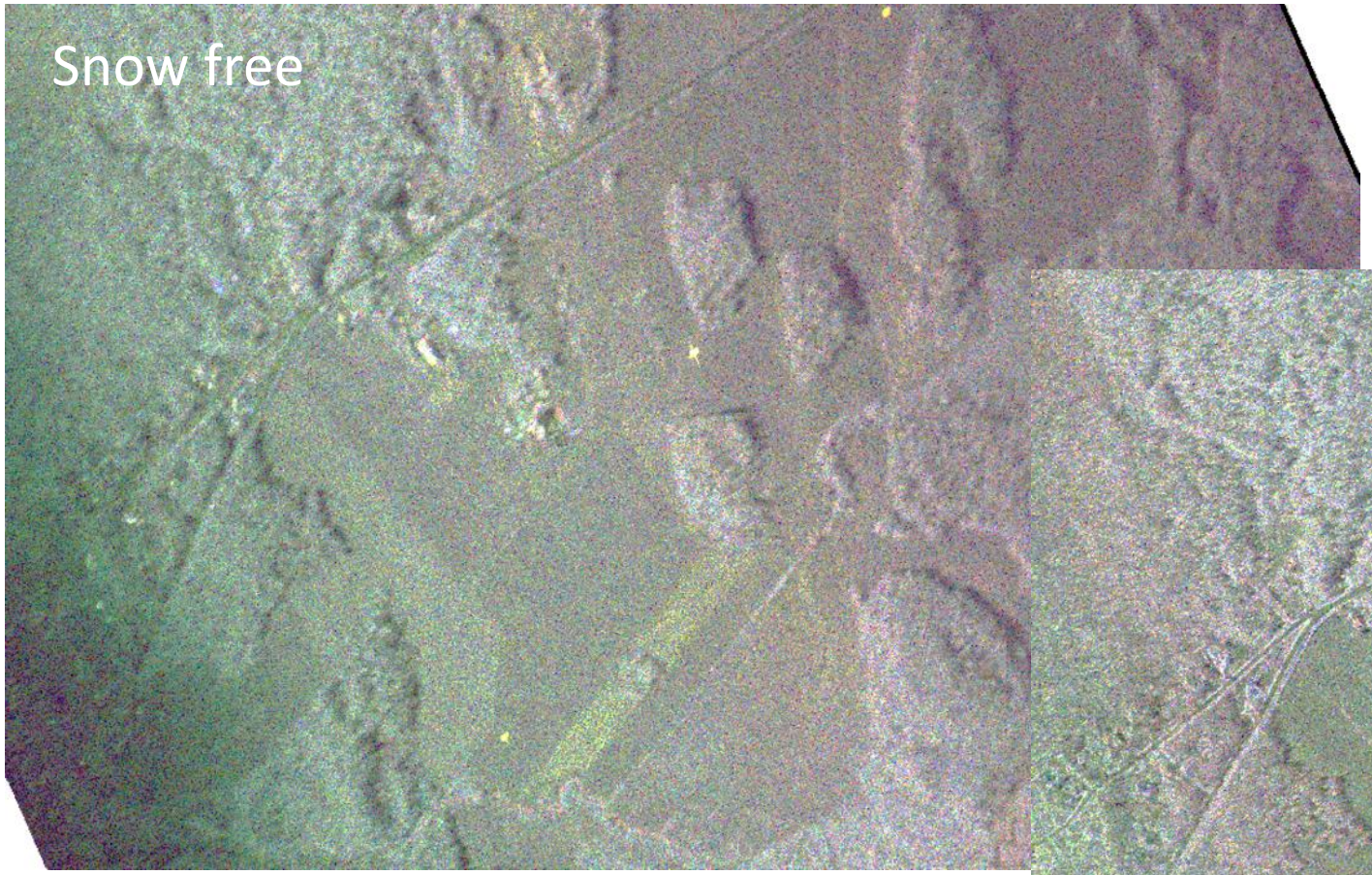
Note: Uncalibrated



Airborne CryoSAR Ku Observations

I. Ku band observations: VV | HH | VH [RGB]

Note: Uncalibrated

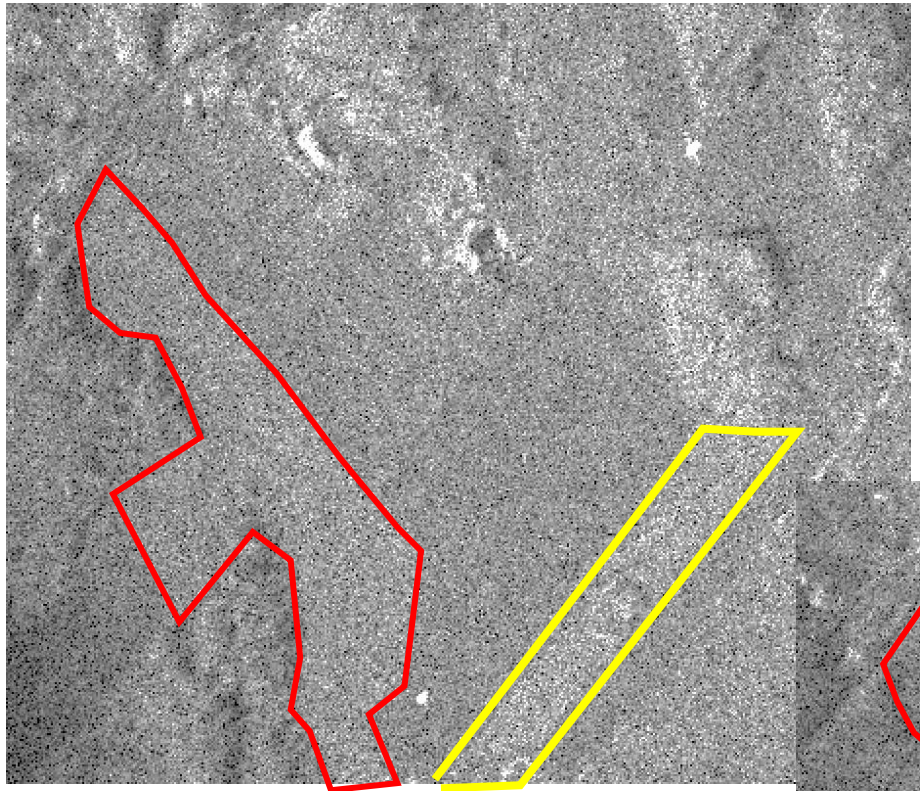


2/Dec/2022

31/Jan/2023



Ku-band SAR Observations (VV)



2/Dec/2022



14/Jan/2023

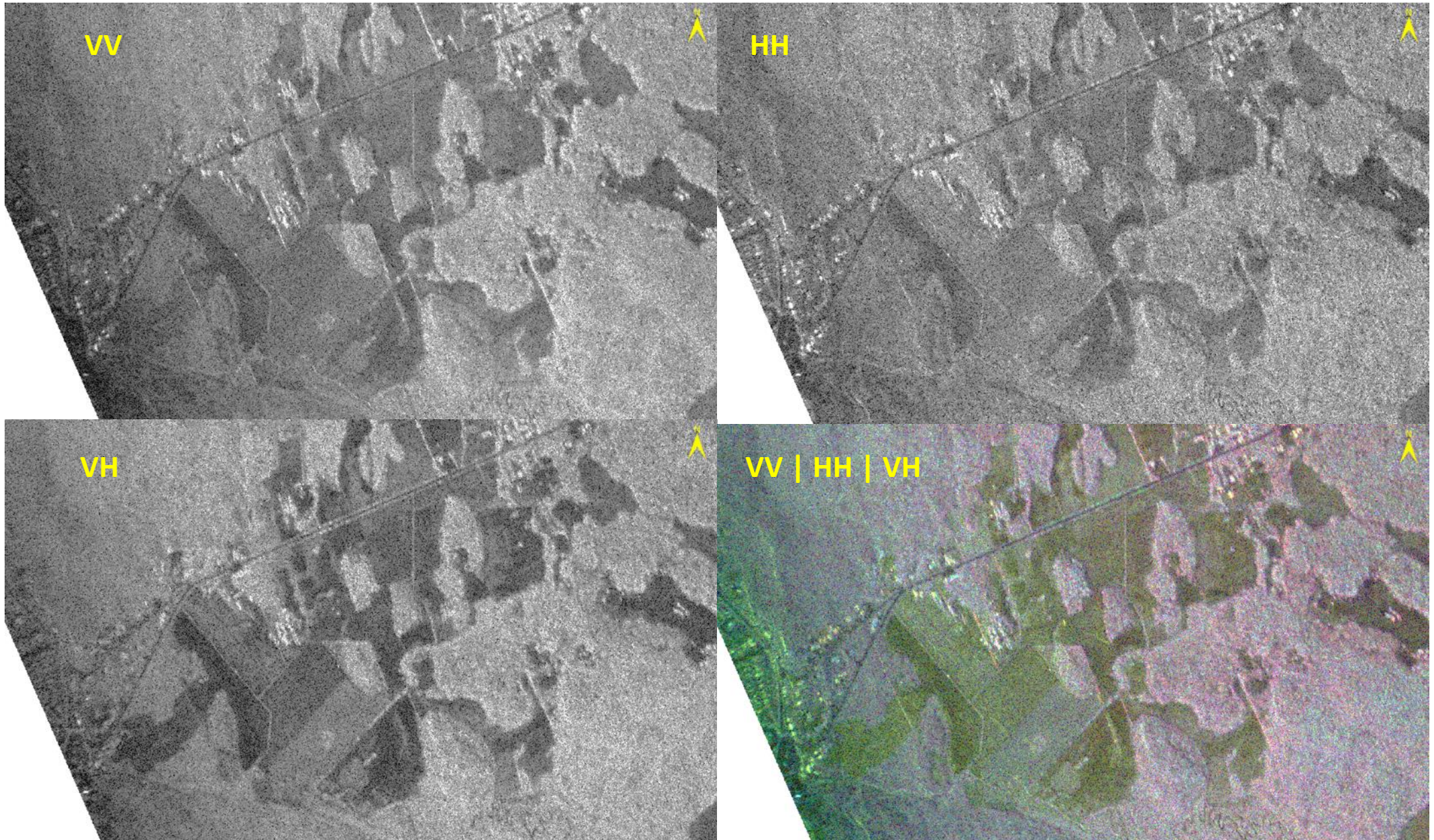


31/Jan/2023

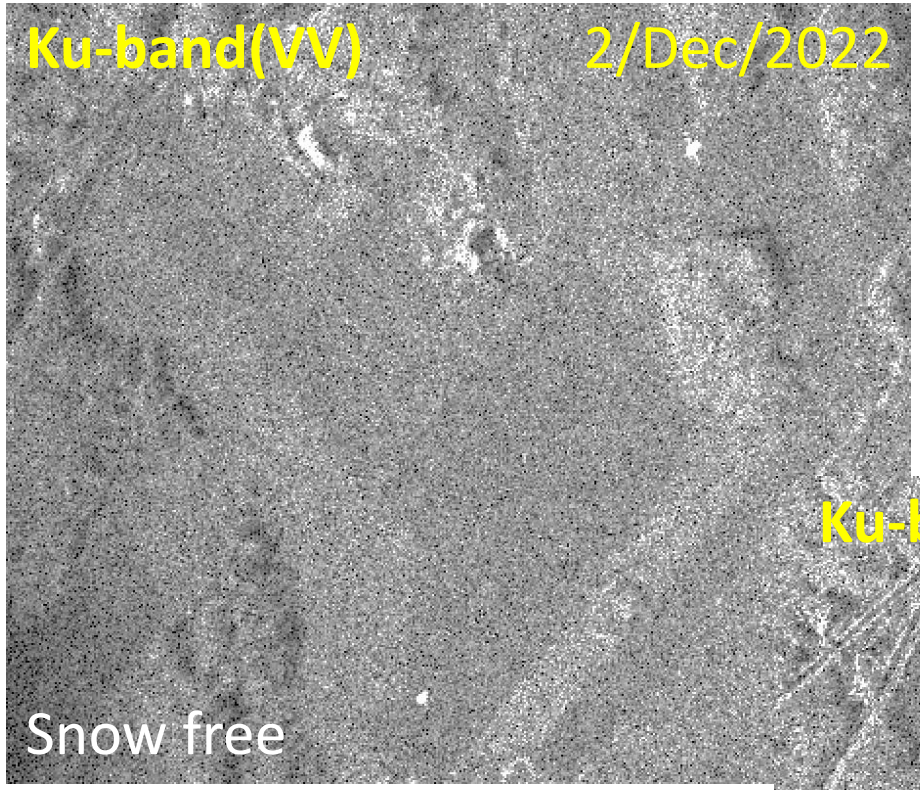
Note: Uncalibrated

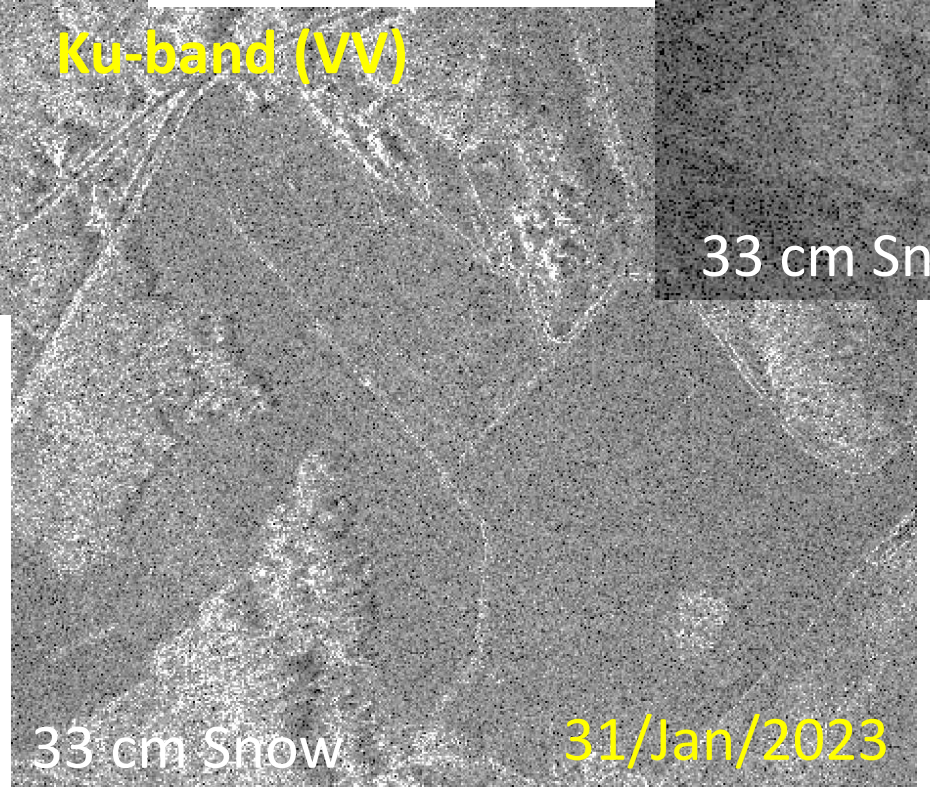
L-band SAR Observations (33 cm snow) 31/Jan/2023

Note: Uncalibrated



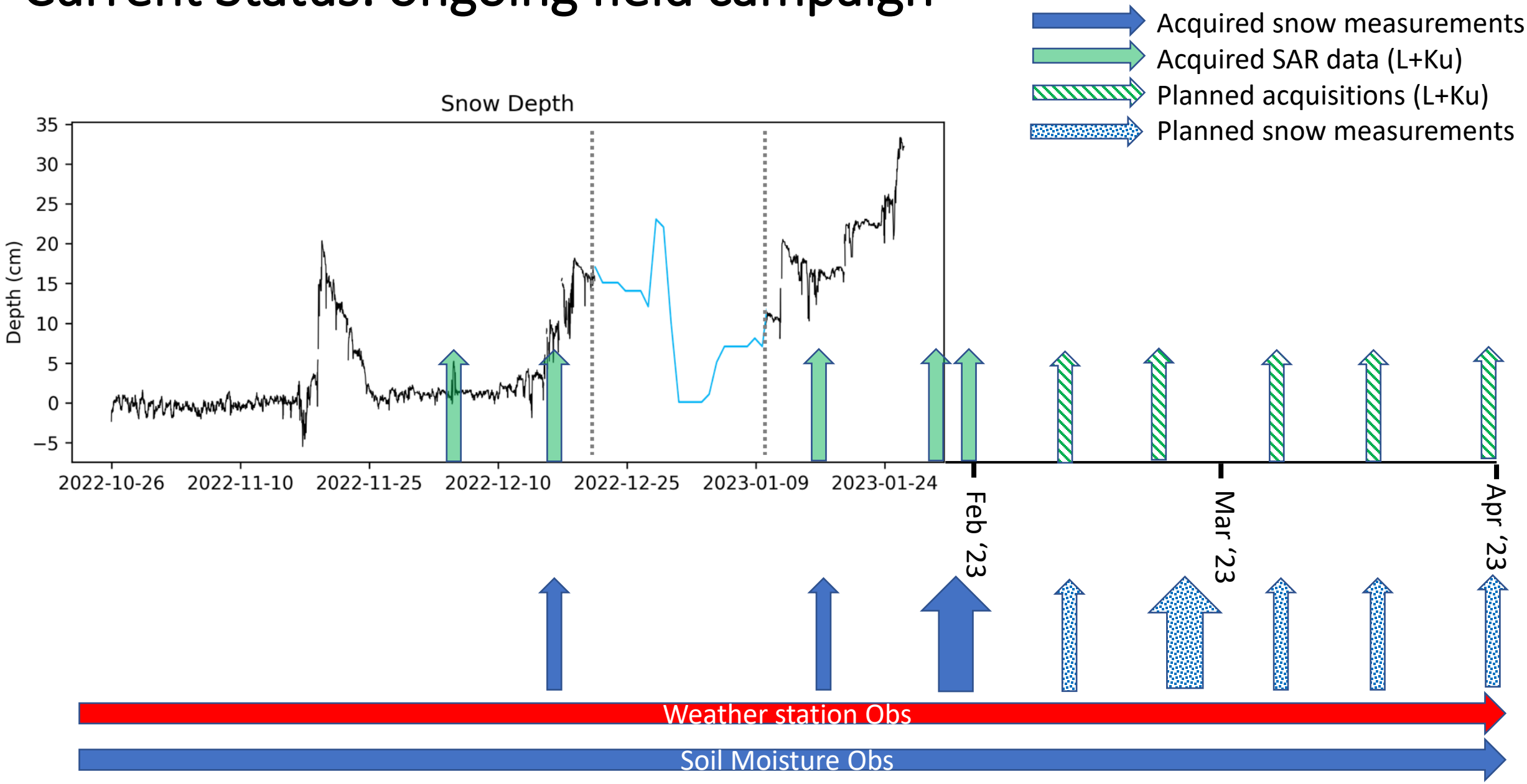
Ku- and L-band comparisons







Current Status: ongoing field campaign



THANK YOU!

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Environment and Climate Change Canada

UdS Université de Sherbrooke

UQTR Université du Québec à Trois-Rivières

UNIVERSITY OF TORONTO

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Radar Solutions