Jet Propulsion Laboratory
California Institute of Technology

Preliminary Results from Fielding an In Situ Three-Frequency Tomographic Radar on Snowpack

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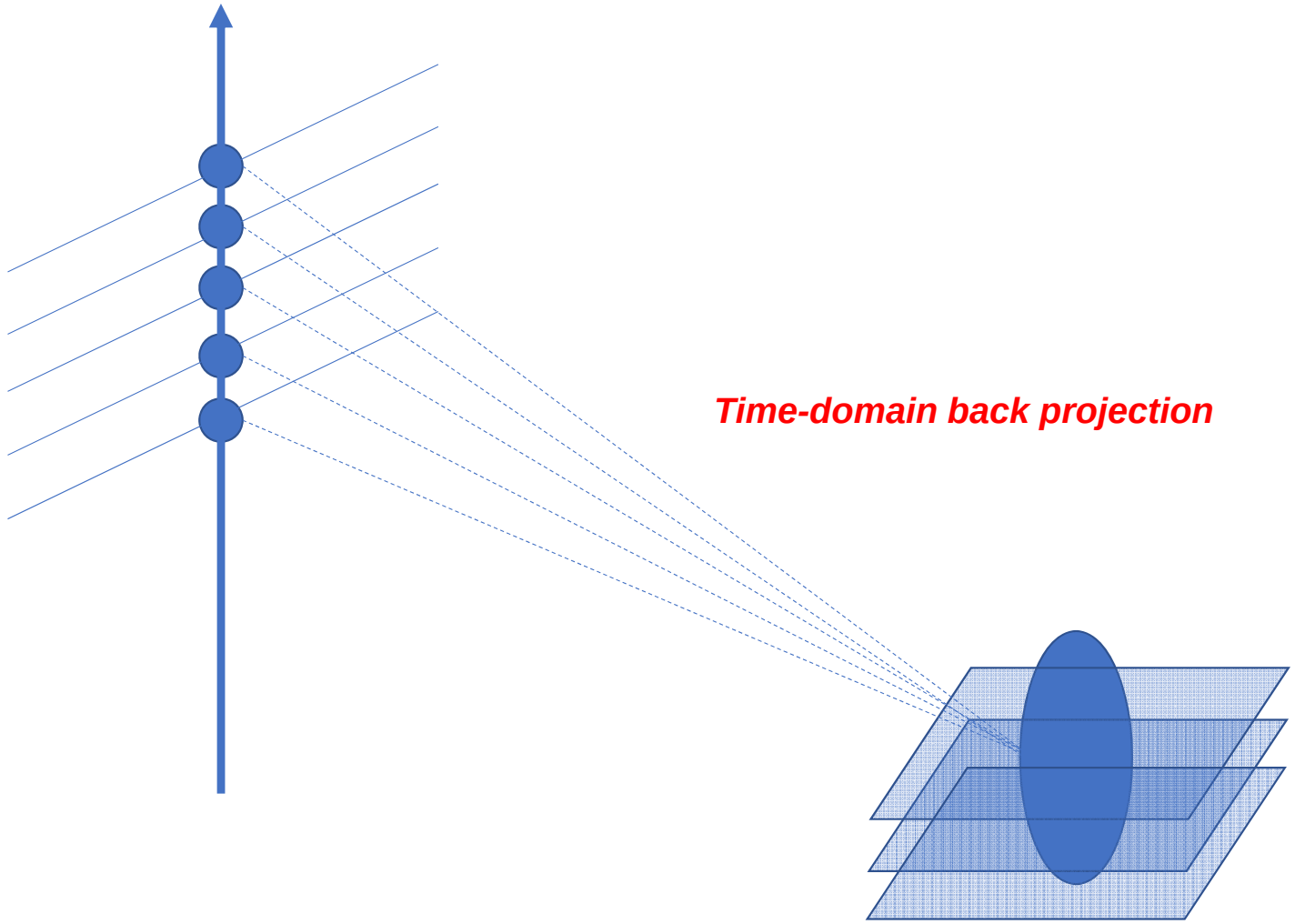
Motivation

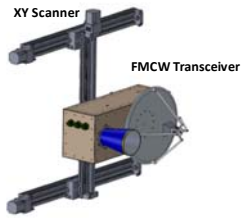
- Test different SAR-based techniques for snow parameter retrieval
  - SAR tomography
  - SAR interferometry or InSAR
  - Polarimetric SAR interferometry or PolInSAR
- Monitor snowpack diurnal change and melting process
- Cross-validate other types of field & remote sensing data

Synthetic Aperture Radar (SAR) tomography

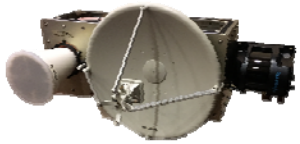


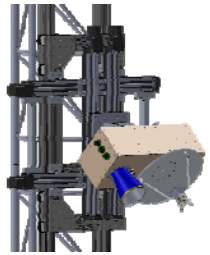
Snowpack Radar Tomographer (SRT-3)

X (9.65 GHz), Ku (13.5 GHz), K (17.2 GHz)
HH, HV, VH, VV

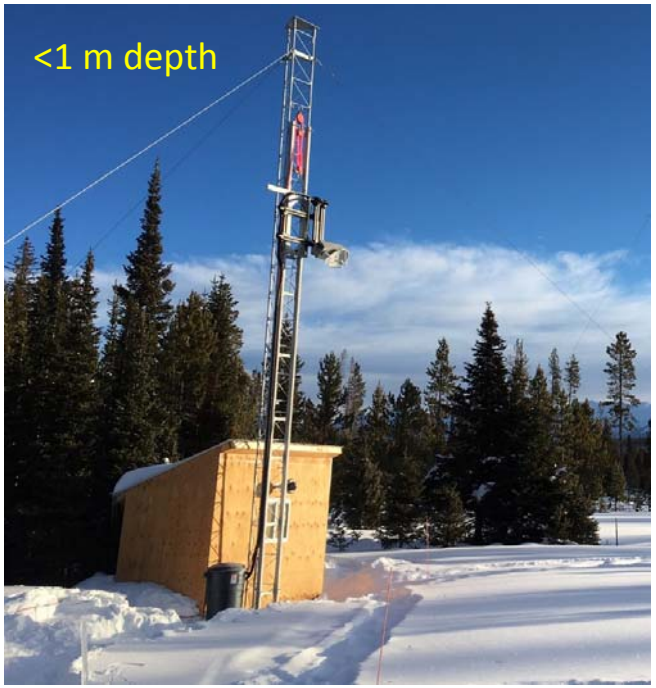


Mammoth Lakes,

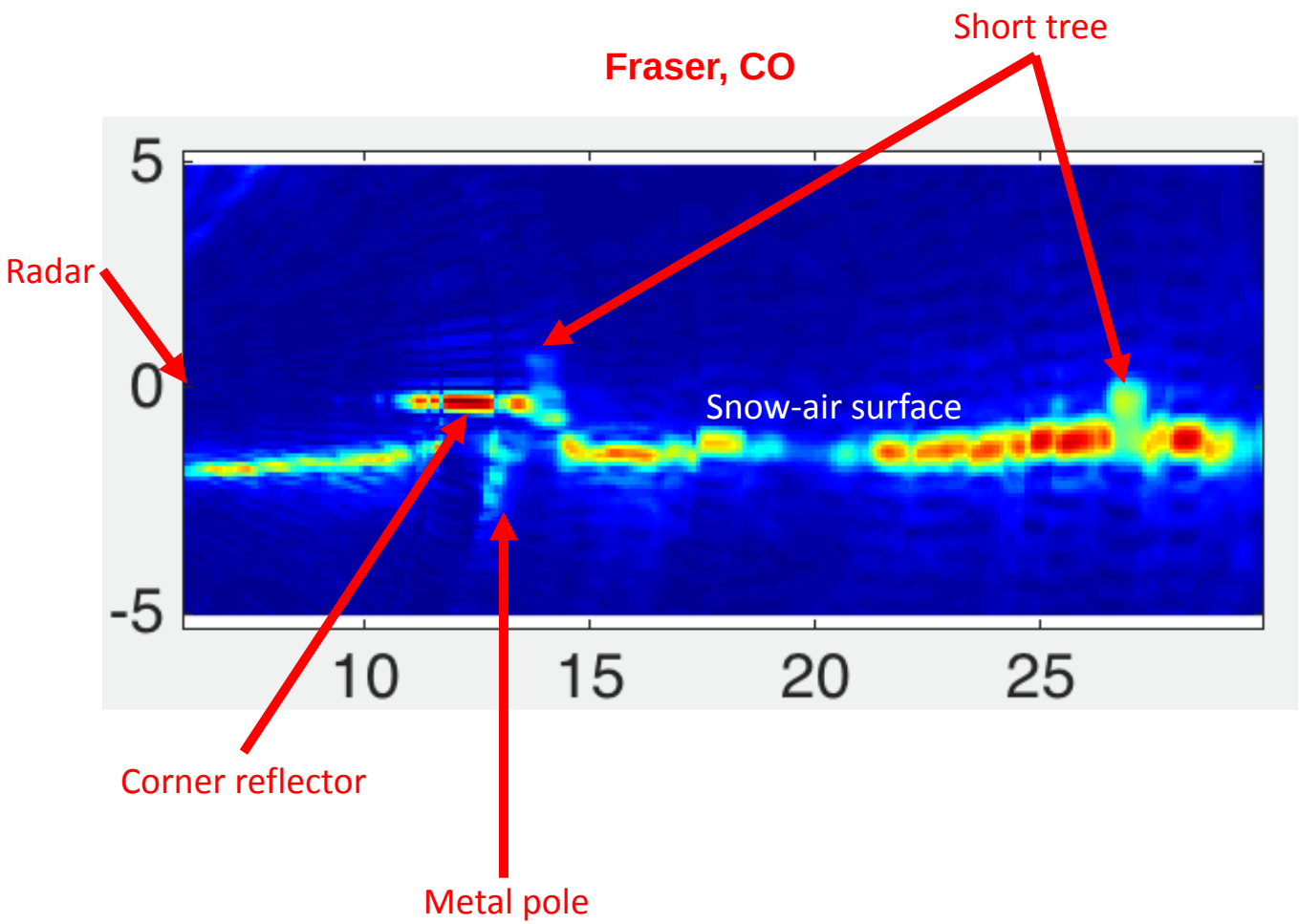




Fraser, CO

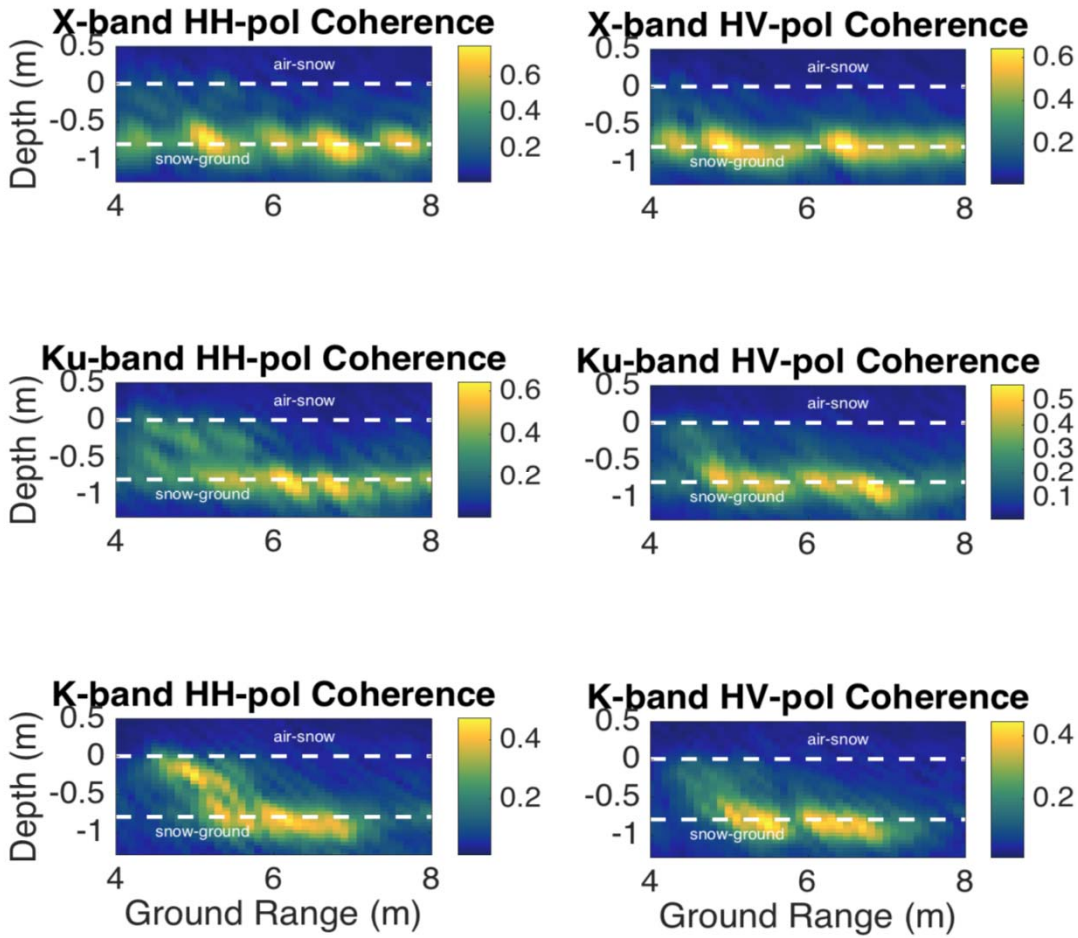


First tomogram (calibration purpose)



Three-frequency & full-polarized capabilities

Fraser, CO

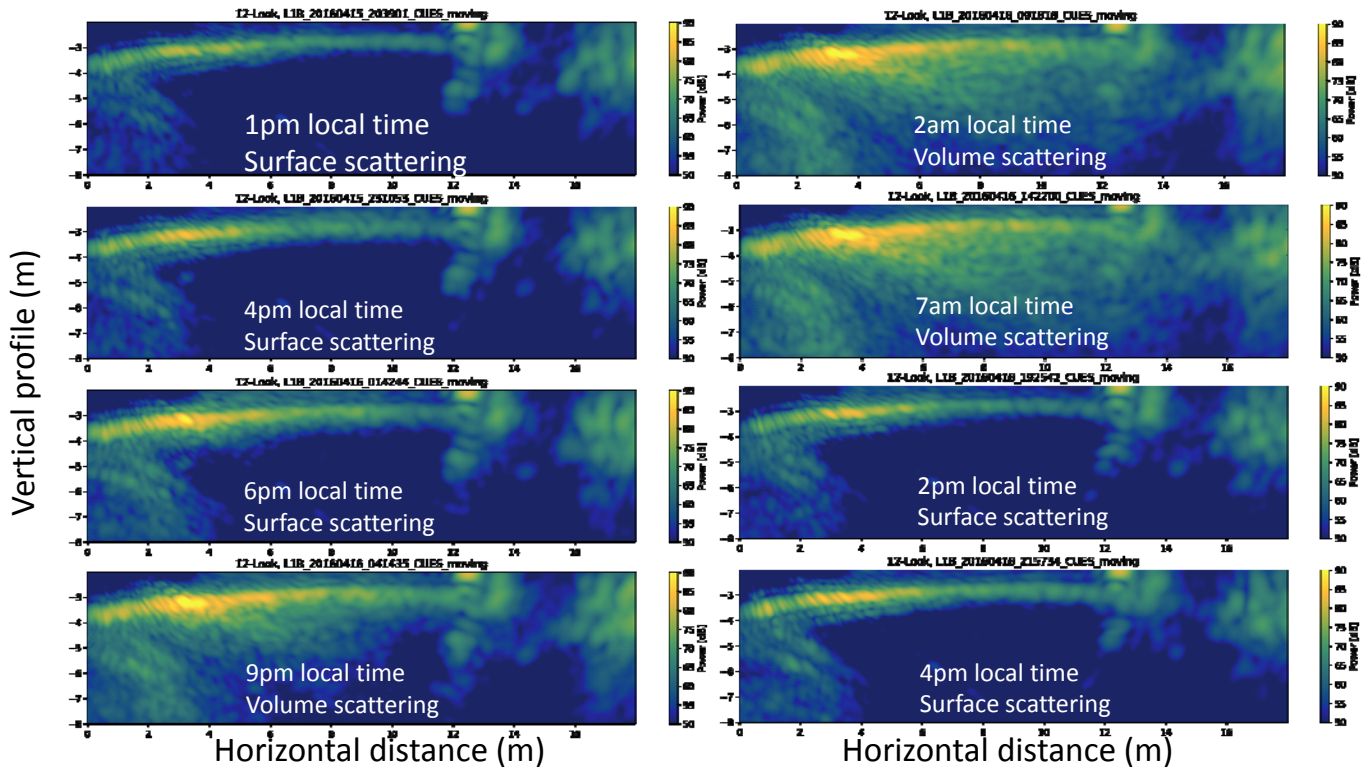


Time-series analysis

Diurnal change

2016/04/15

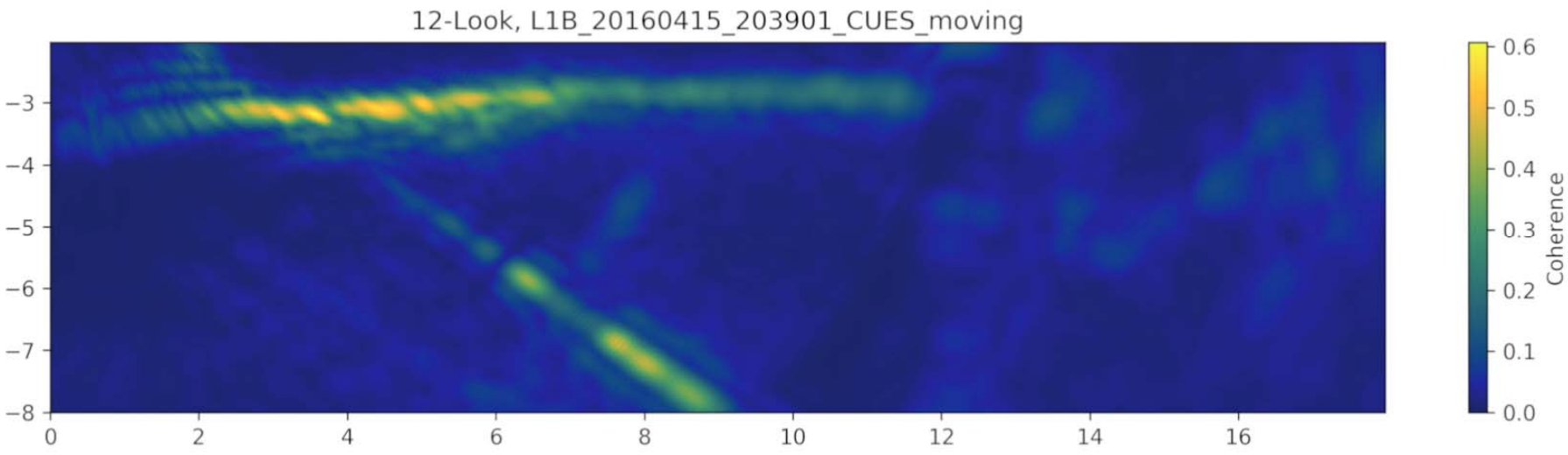
2016/04/16



Mammoth Lakes, CA

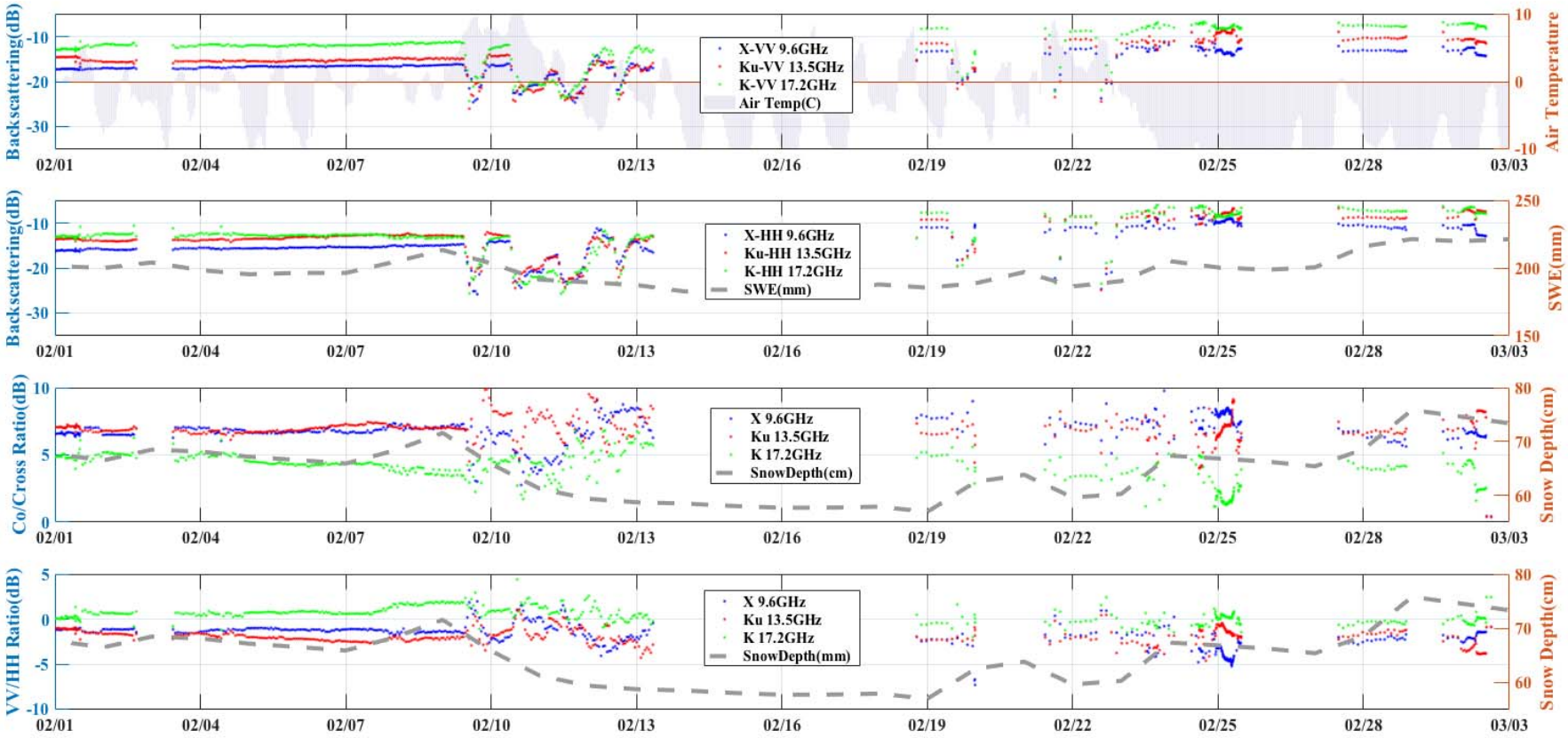
Time-series analysis

Melting Process

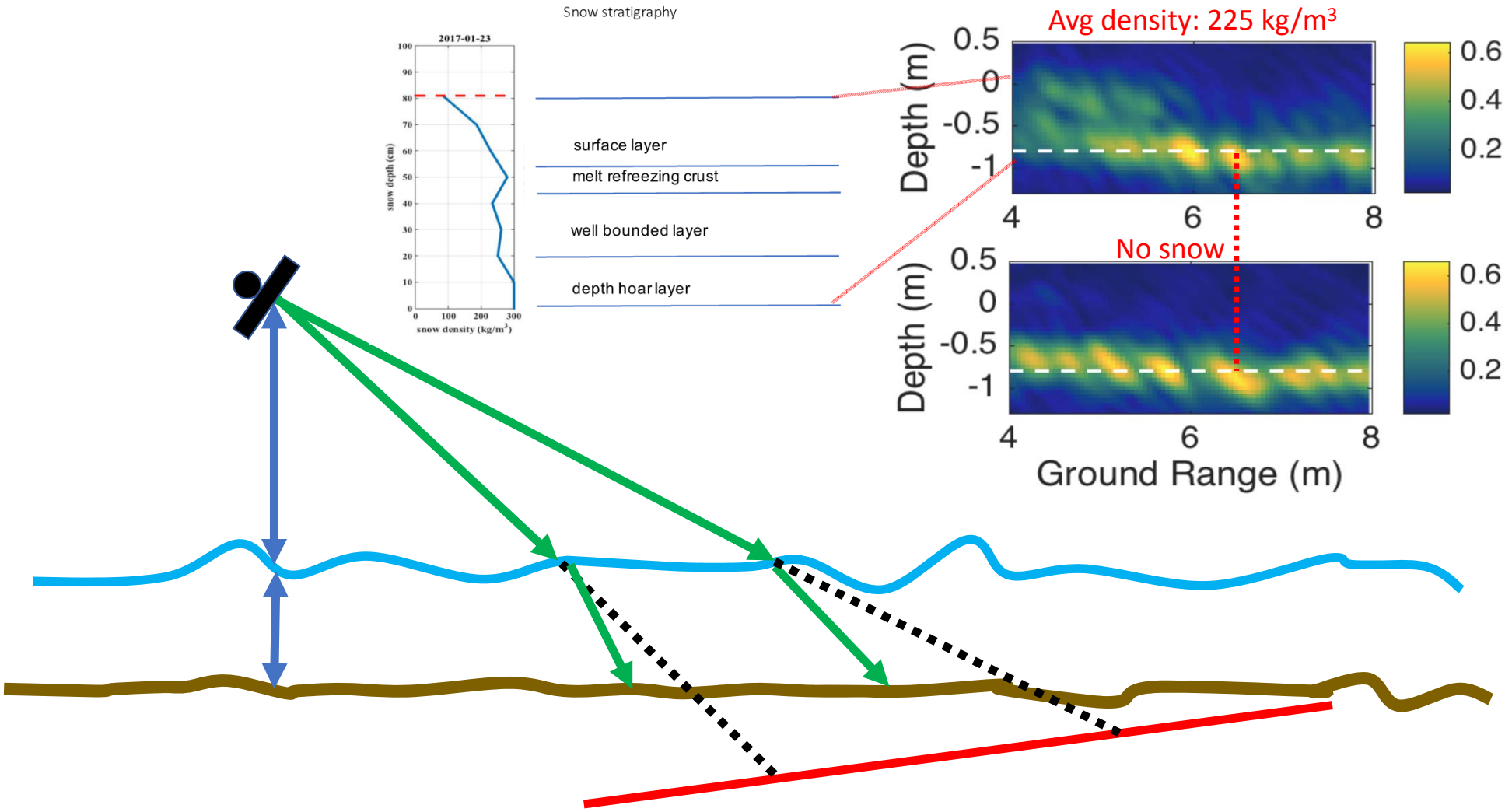


Mammoth Lakes, CA

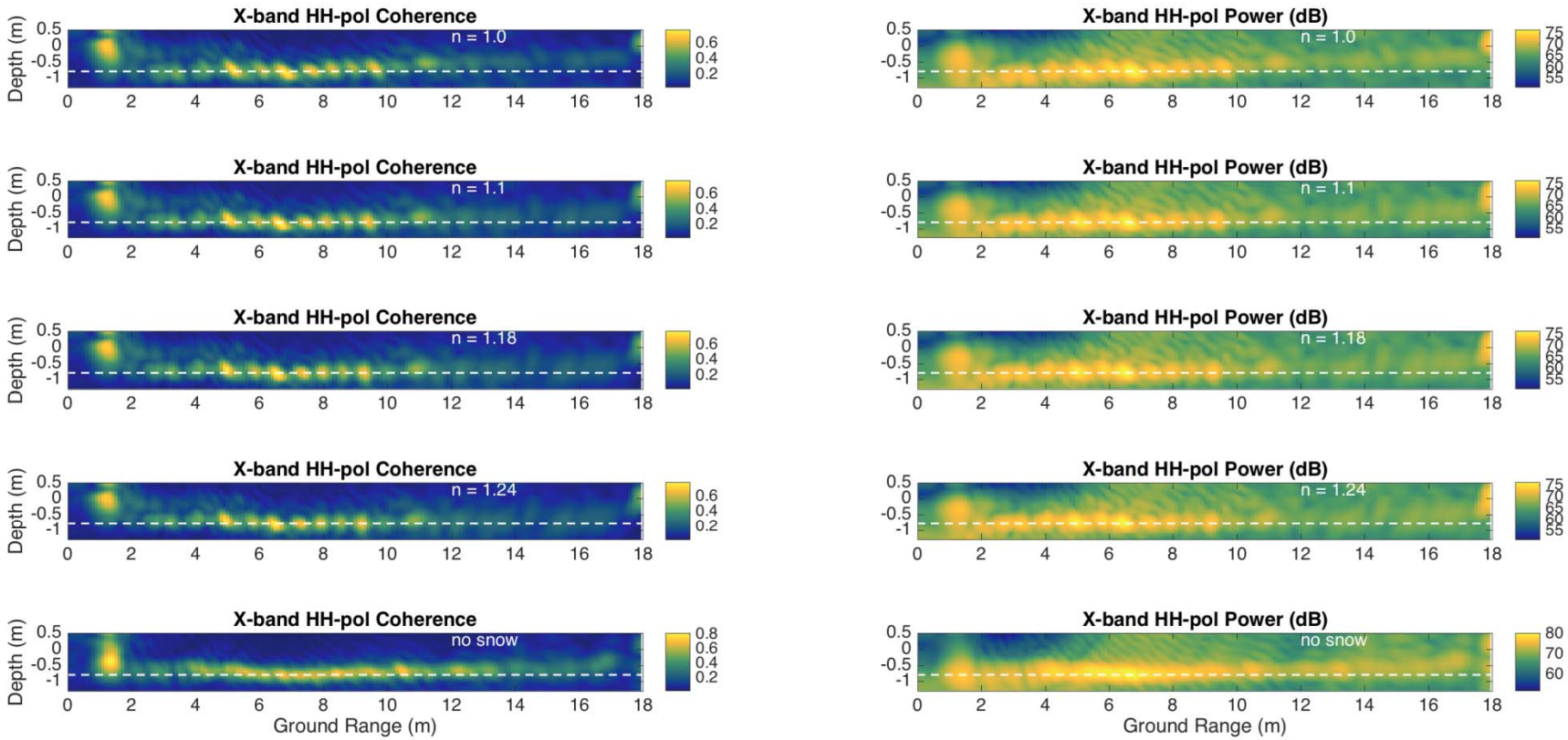
Time-series analysis



Snow Water Equivalent (SWE) retrieval



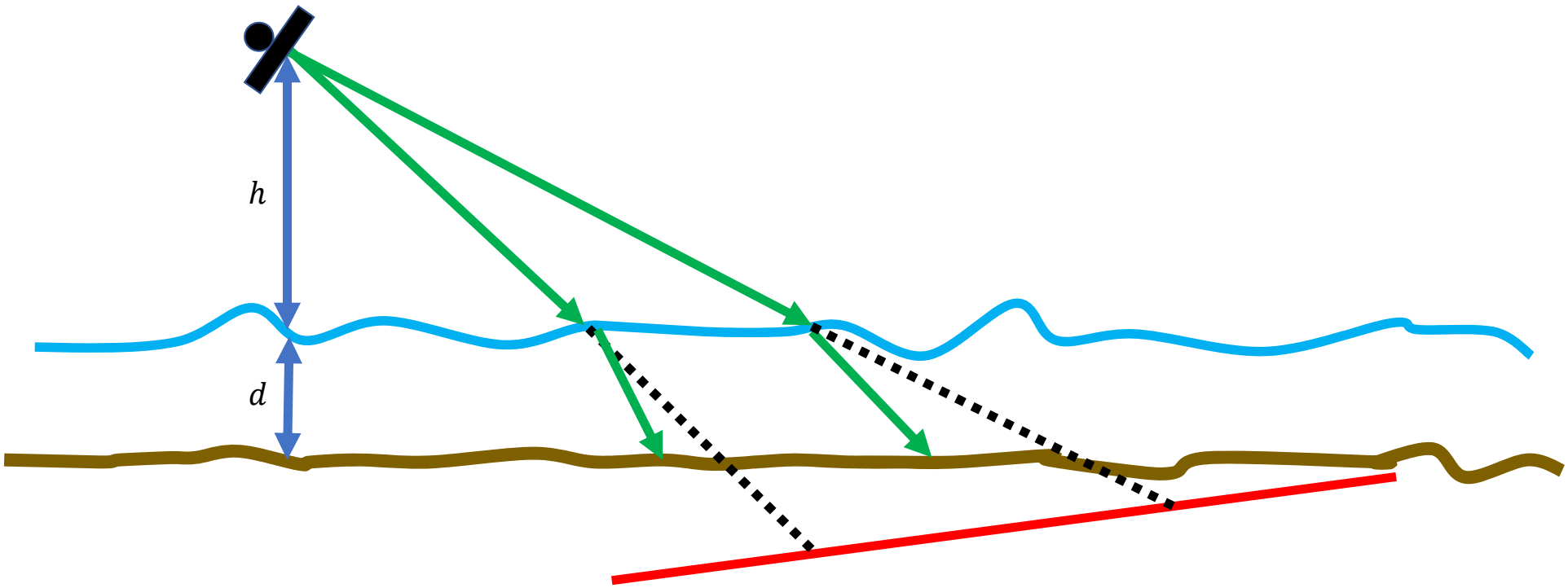
Snow Water Equivalent (SWE) retrieval

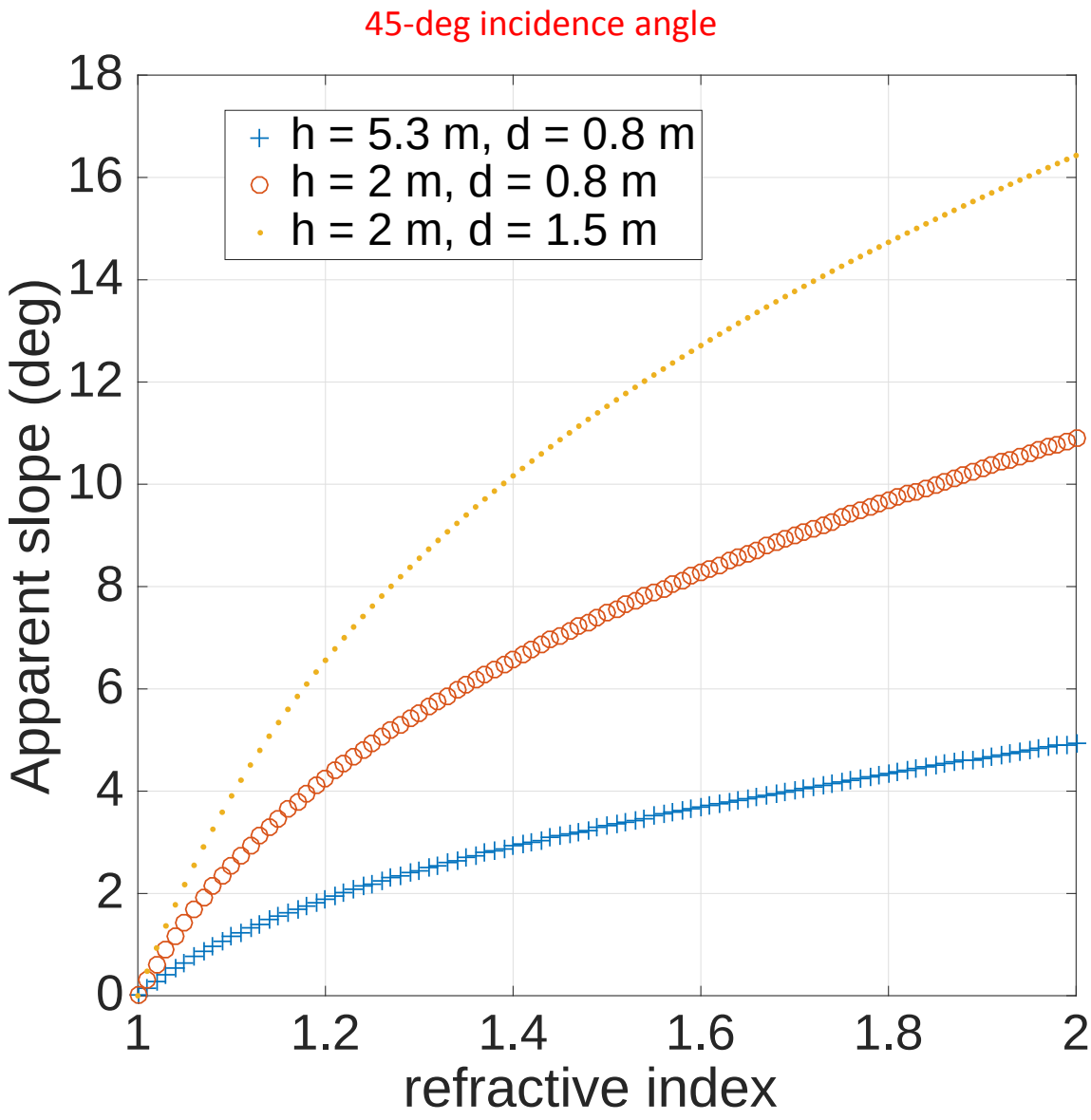


Slope-refractive index model

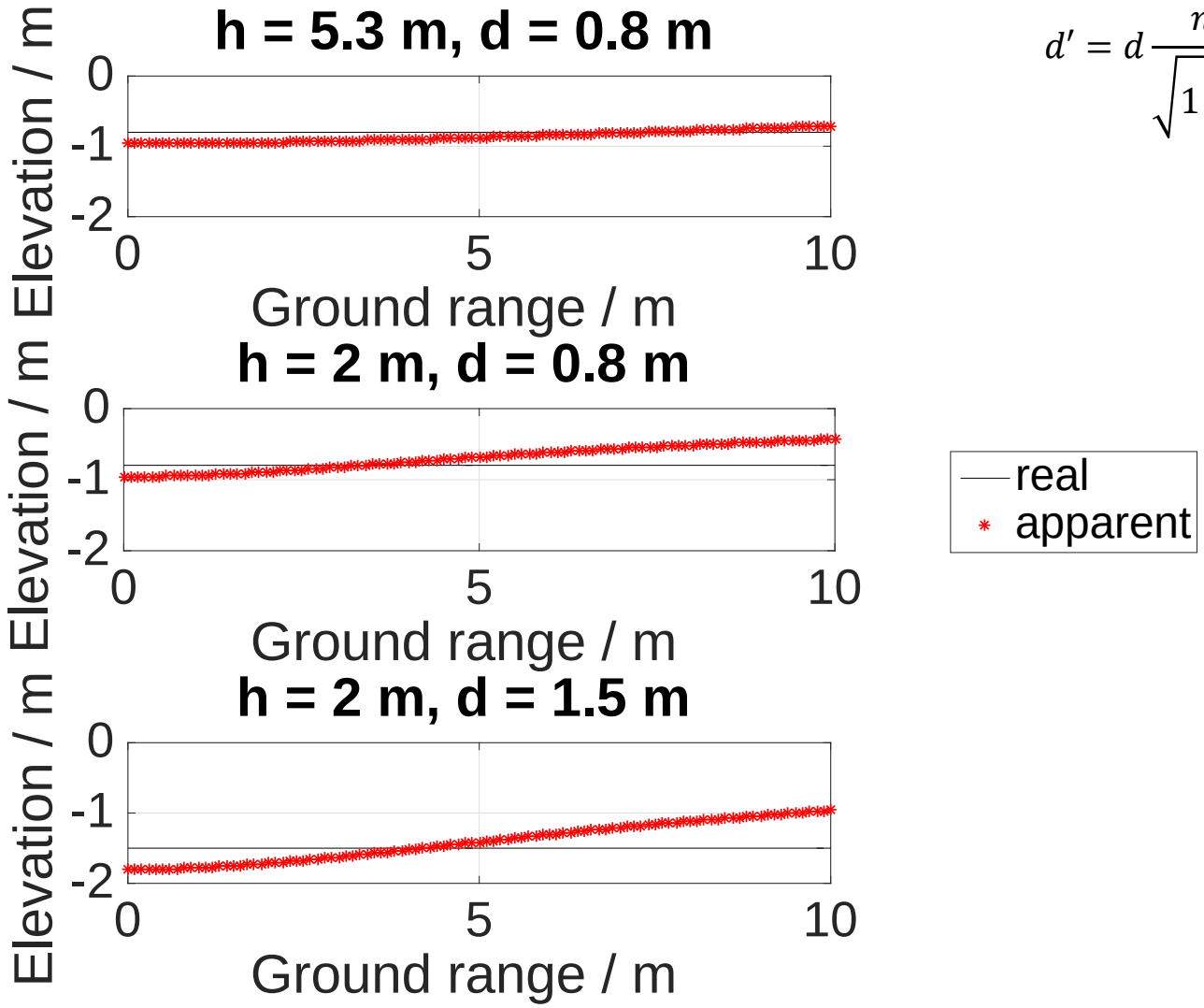
$$s = \frac{n \sin\theta_i \left(1 - \frac{1}{n^2}\right)}{n \cos\theta_i + \delta \left(1 - \frac{\sin\theta_i{}^2}{n^2}\right)^{3/2} / \cos\theta_i{}^2}$$

$$\delta = \frac{h}{d}$$

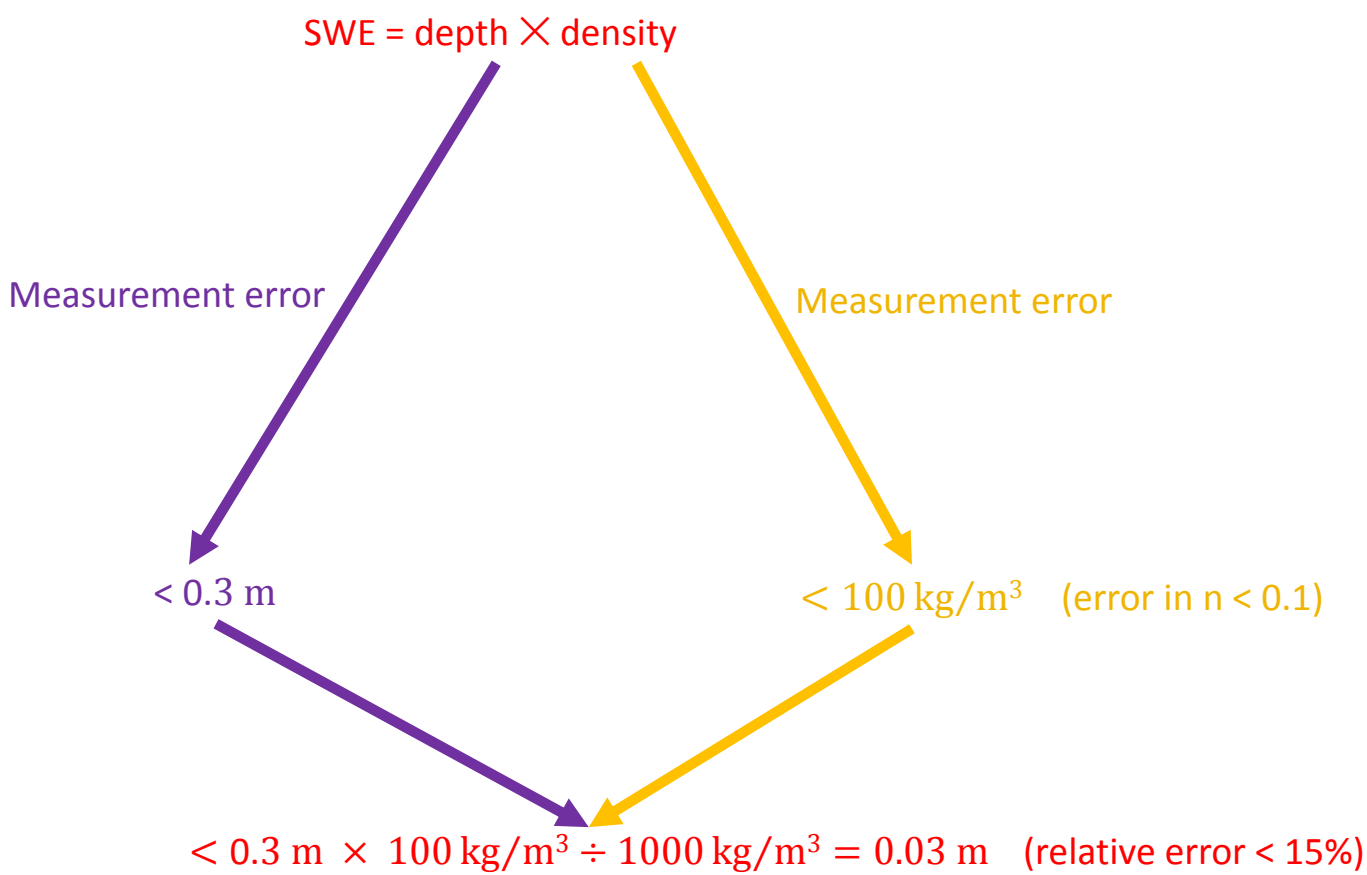



45-deg incidence angle
h = 5.3 m, d = 0.8 m
h = 2 m, d = 0.8 m
h = 2 m, d = 1.5 m
Apparent slope (deg)
refractive index
0
2
4
6
8
10
12
14
16
18
1
1.2
1.4
1.6
1.8
2

Current configuration

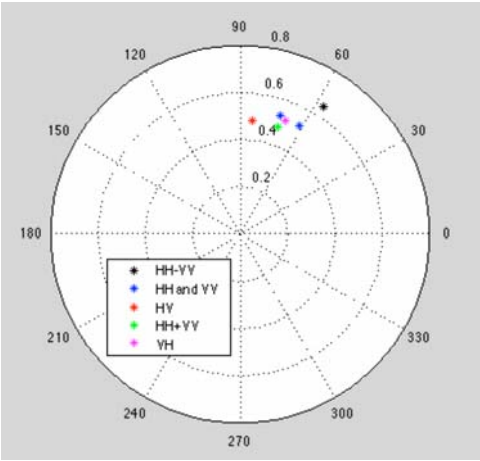


$$d' = d\frac{n\cos\theta_i}{\sqrt{1-\frac{\sin\theta_i{}^2}{n^2}}}$$


SWE = depth × density
Measurement error
Measurement error
< 0.3 m
< 100 kg/m³
(error in n < 0.1)
< 0.3 m × 100 kg/m³ ÷ 1000 kg/m³ = 0.03 m
(relative error < 15%)

Summary

- SAR tomography (or InSAR) allows the tracking of diurnal change process
- Surface scattering dominates during melting season and allows the tracking of snow depth
- Volume scattering noticeable in dry snow condition and allows the retrieval of snow depth
- Snow density can be retrieved by comparing the snow-on and snow-free tomograms

Future Work

- Enhance the resolution from 30 cm to 10 cm for better accuracy of SWE retrieval
- Deploy calibration targets in the test site
- Test various radar techniques for SWE retrieval: SAR tomography, InSAR/PolInSAR, etc
- Temporal change monitoring through the whole winter using various radar measurements
- Cross-validate other field & remote sensing data at the Fraser site