Comparing Firn Densification Layers Simulated through Regional Climate Models and those Tracked through Radargrams

Debvrat Varshney[1], Nicole Schlegel[2], Alex Gardner[2], and Maryam Rahnemoonfar[3]

[1]Computer Vision and Remote Sensing Laboratory, University of Maryland Baltimore County
[2]NASA Jet Propulsion Laboratory
[3]Computer Vision and Remote Sensing Laboratory

November 22, 2022

Abstract

The Glacier Energy and Mass Balance (GEMB) module of NASA's Ice-sheet and Sea-level System Model (ISSM) can simulate the evolution of firn density profiles in the ice sheet snowpack. It is a column model that can give detailed subsurface parameters such as layer depth, snow grain growth, depth dependent albedo, layer density etc. These parameters are model simulation outputs, and lack of observations makes them difficult to evaluate on a broader scale. In this work, we take advantage of remotely-sensed snow conditions in the top ˜15m of the firn; more specifically, the layer depth vs density profiles, measured through the Snow Radar sensor from NASA's Operation IceBridge mission. We use these observations to calibrate the GEMB module over the Greenland Ice Sheet. The module optimized with the help of actual observations will become more reliable for predicting glacial mass loss and associated global sea level rise over time.

COMPARING FIRN DENSIFICATION LAYERS SIMULATED THROUGH REGIONAL CLIMATE MODELS AND THOSE TRACKED THROUGH RADARGRAMS

Debvrat Varshney [1], Nicole-Jeanne Schlegel [2],
Alex S. Gardner [2], Maryam Rahnemoonfar [1]

[1] University of Maryland Baltimore County, MD, USA

[2] NASA Jet Propulsion Laboratory, CA, USA

AGU FALL MEETING

15th December 2021

OVERVIEW

- Introduction and Background
- Background on climate models and radar observations
- Comparing firn layer profiles from climate models and radar
- Layer tracking from radargrams
- Integration and future scope

INTRODUCTION

- Global warming is rapidly reducing the polar ice caps and contributing to sea level rise
- Simulating the ice melt accurately is necessary to project global natural disasters

Greenland 100 years ago (top) and now (bottom)

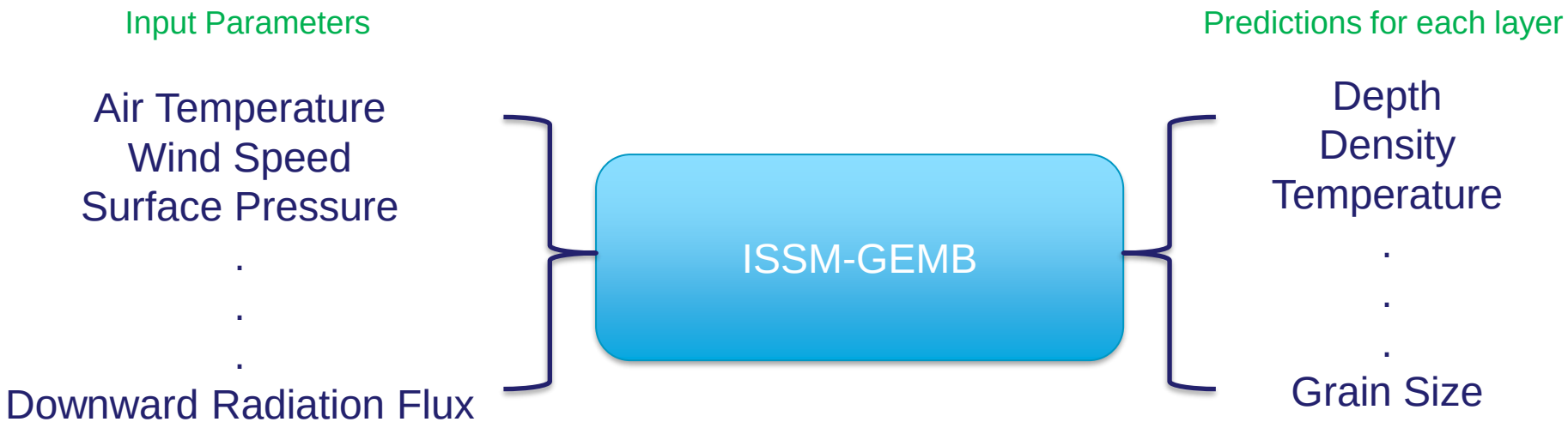
BACKGROUND

- State-of-the-art climate models make accurate predictions of firn layer characteristics at very-low resolution, whereas radar sensors can make high resolution observations which are somewhat noisy
- Intern firn layers simulated through climate models need to be validated with actual observations made through airborne sensors

CLIMATE MODEL: ISSM-GEMB

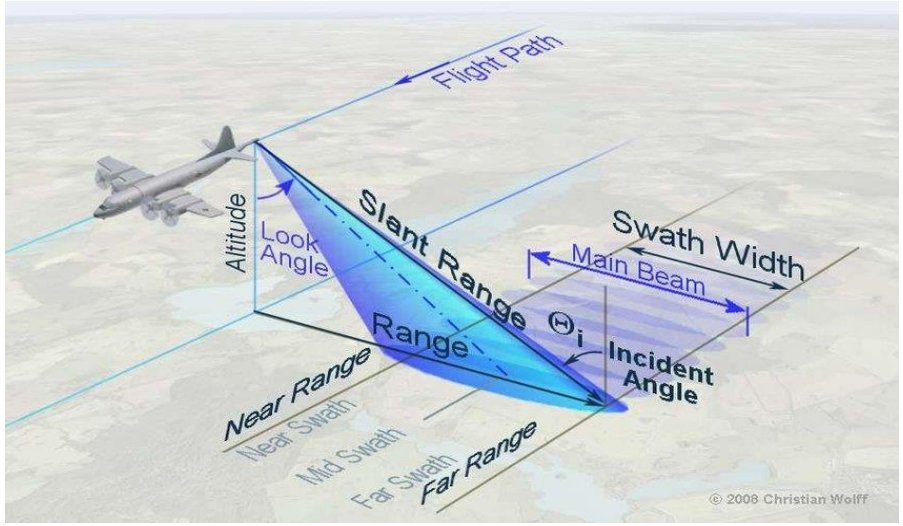
- The Glacier Energy and Mass Balance (GEMB) module of the Ice-Sheet and Sea-Level System Model (ISSM) can simulate the temporal evolution of the icesheet snow pack.
- GEMB is a column model (1-D) which simulates parameterized snow grain growth, depth-dependent albedo based on grain-size, thermal diffusion, depth-dependent calculation of temperature, melt, meltwater percolation and refreeze etc.
- It takes a 3-hourly input of ambient variables such as air temperature, wind speed, downward radiation flux, surface pressure etc.
- Gives a daily estimate of density, temperature, depth, grain size, water content etc. of each snowpack layer

CLIMATE MODEL: ISSM-GEMB

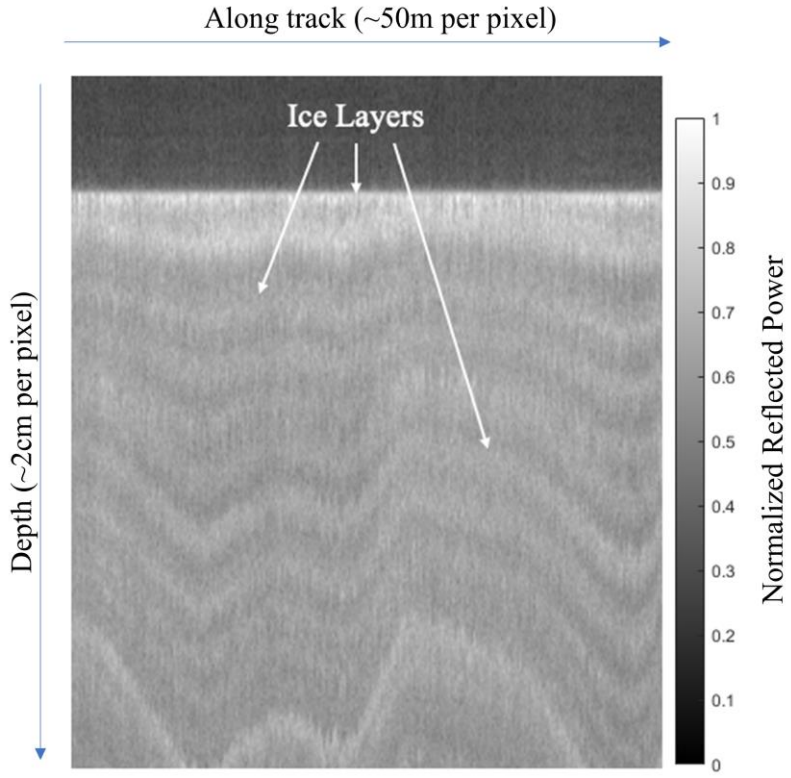


Model can make daily predictions for a given coordinate

OBSERVATIONS: AIRBORNE SNOW RADAR



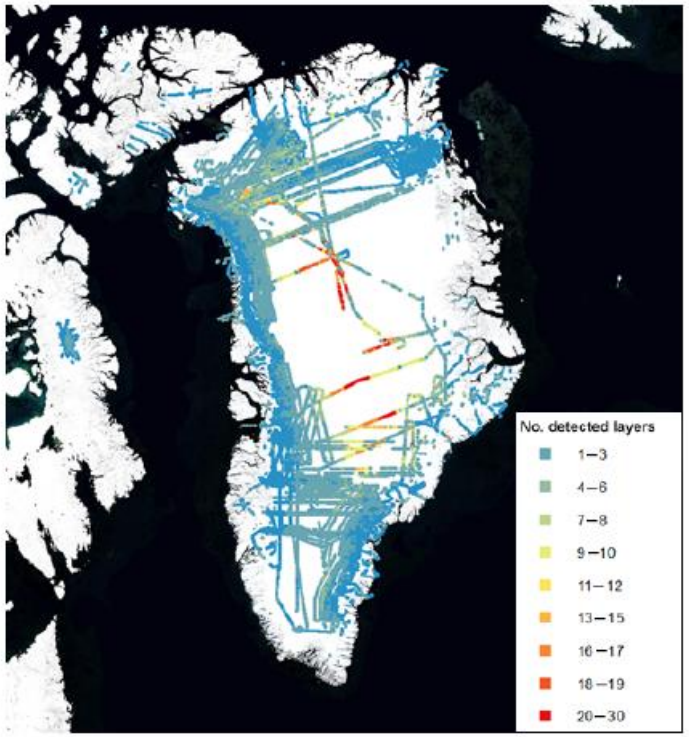
Dataset Details
Campaign: NASA Operation IceBridge 2009-2012
Sensor: Ultra wide-band (2-6.5GHz) Airborne Snow Radar sensor
Timespan: 2009-2012
Resolution: ~2cm per pixel in the vertical direction



A Snow Radar echogram showing multiple internal layers. [1]

OBSERVATIONS: AIRBORNE SNOW RADAR

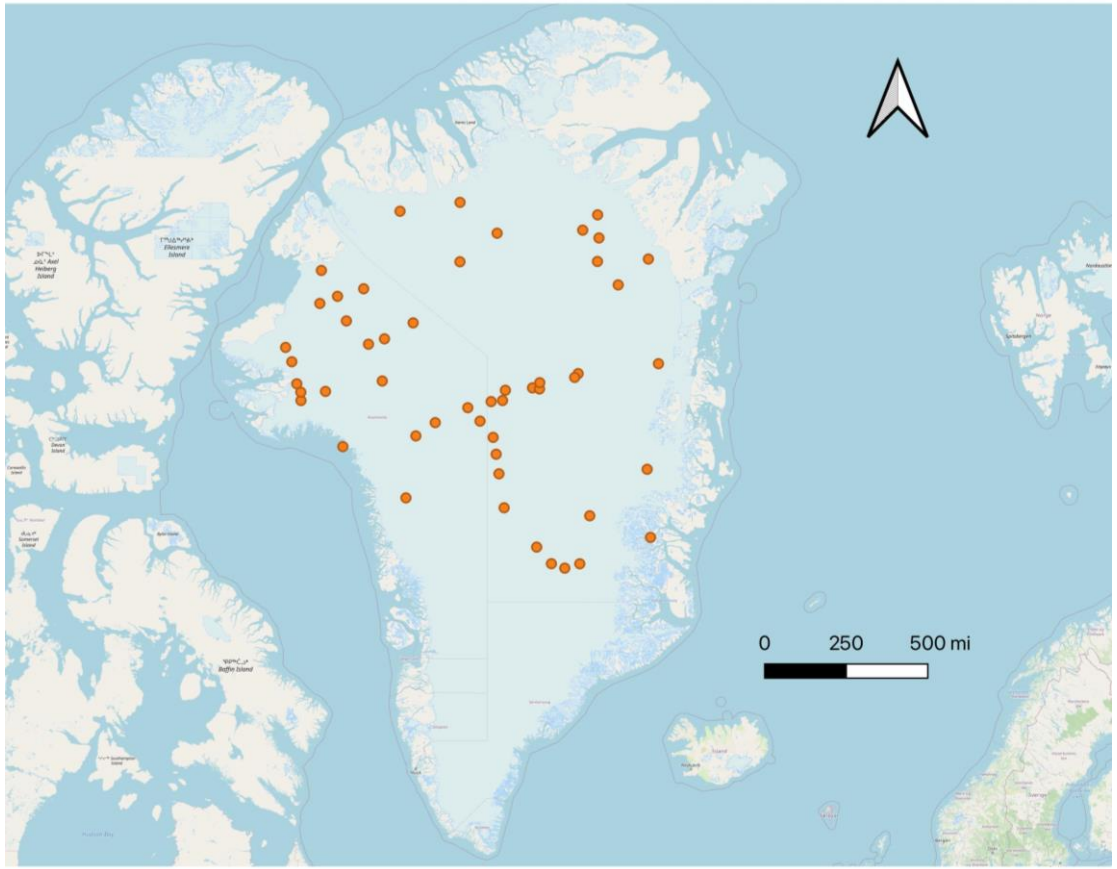
Flight map of Snow Radar



Number of detected annual layers from 2009 through 2012 across the Greenland Ice Sheet [1]

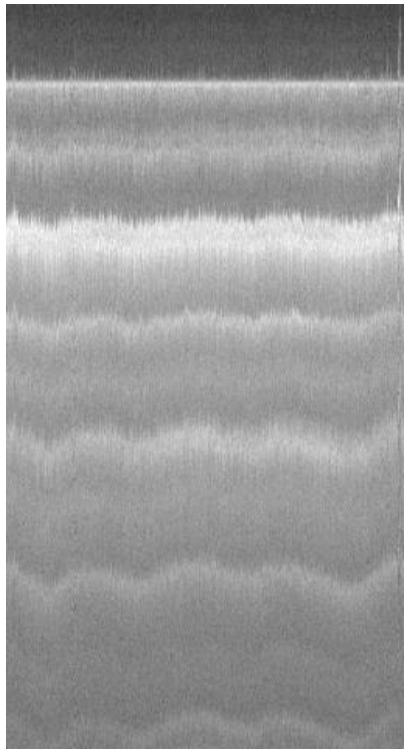
STUDY LOCATIONS

Locations where both radar observations and model simulations are taken into consideration

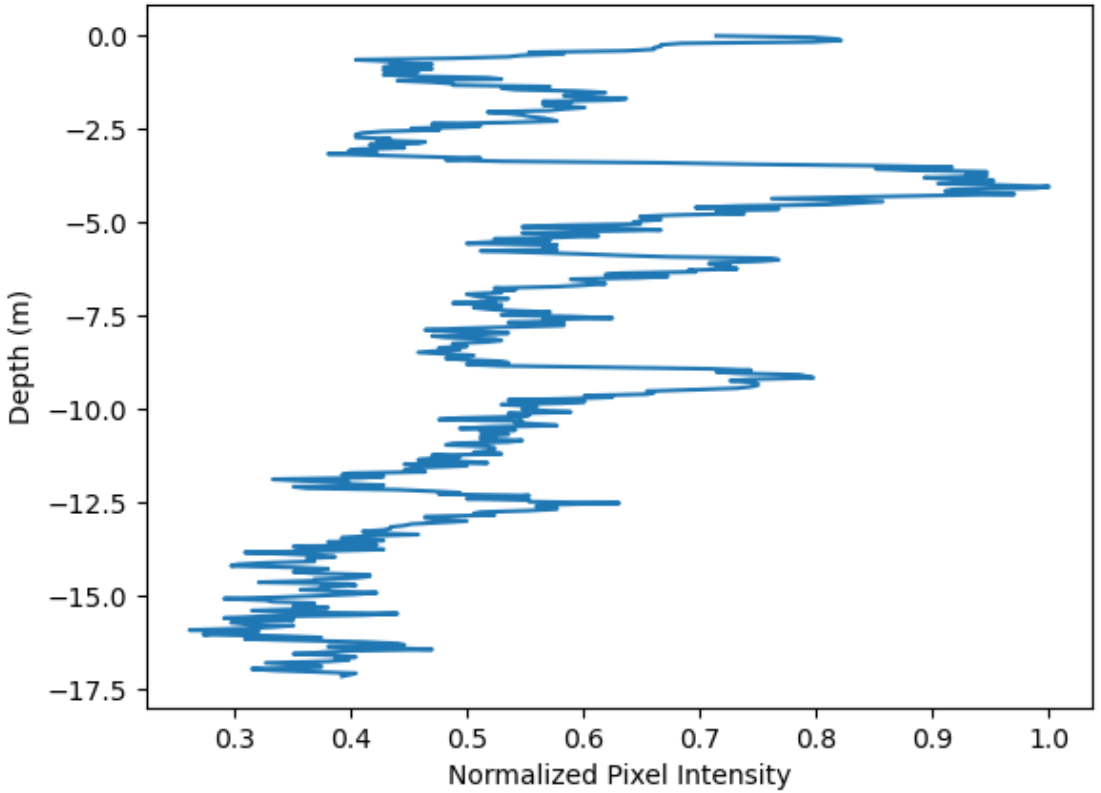


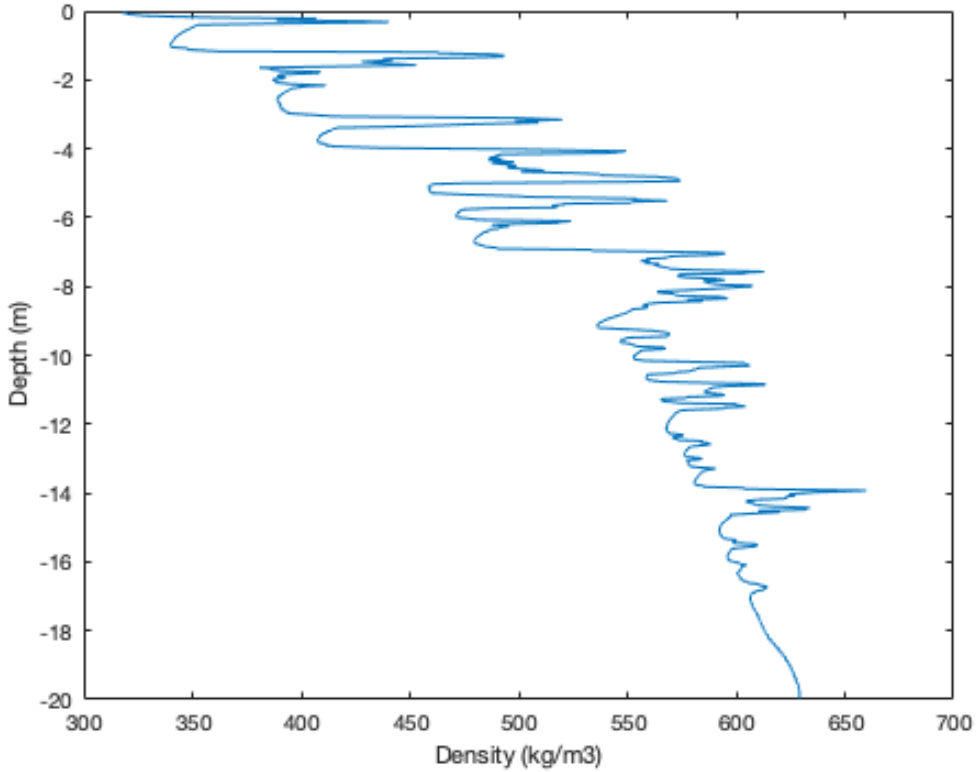
~50 coordinates randomly chosen across Greenland

ANALYSIS

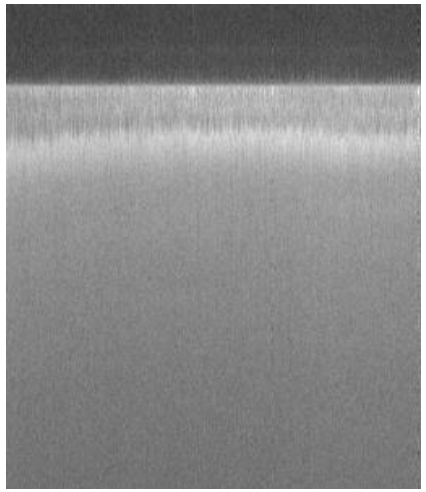


Radargram

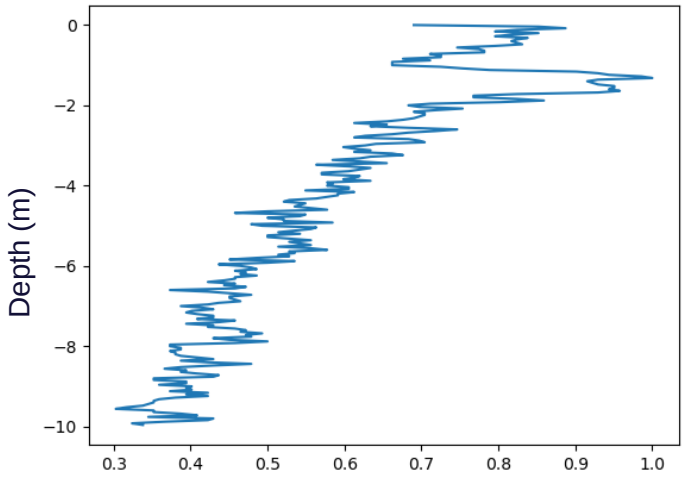




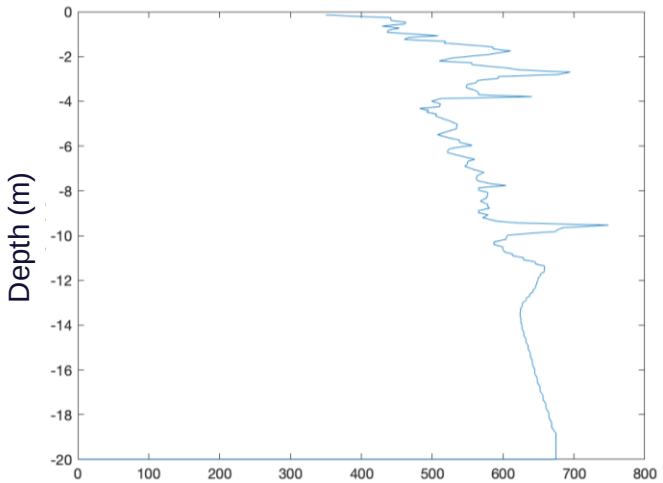
ANALYSIS



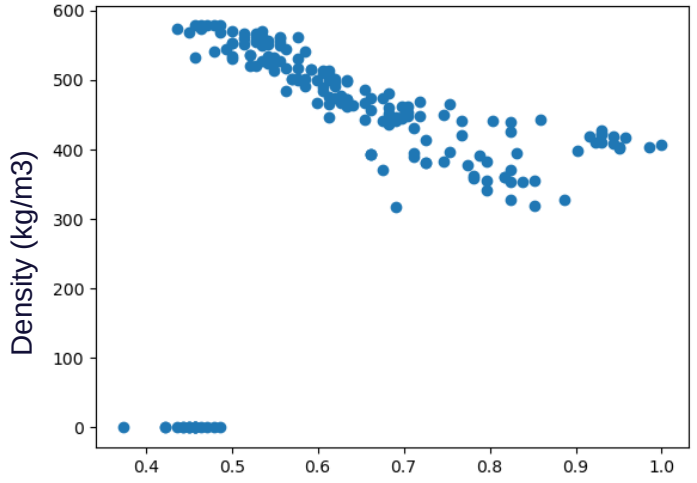
Radargram



Normalized Pixel Intensity of Radargram

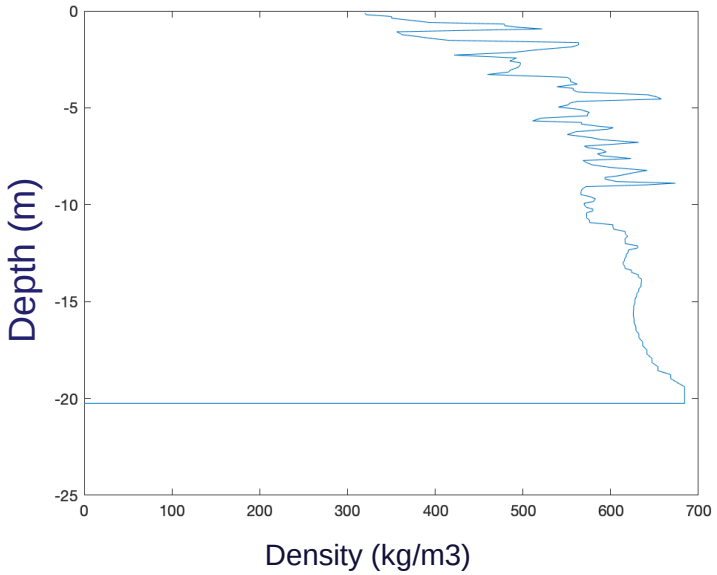


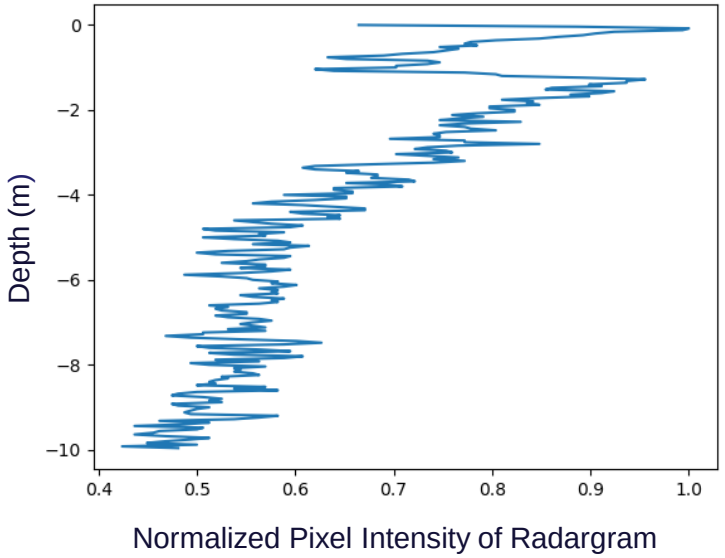
Density (kg/m3)

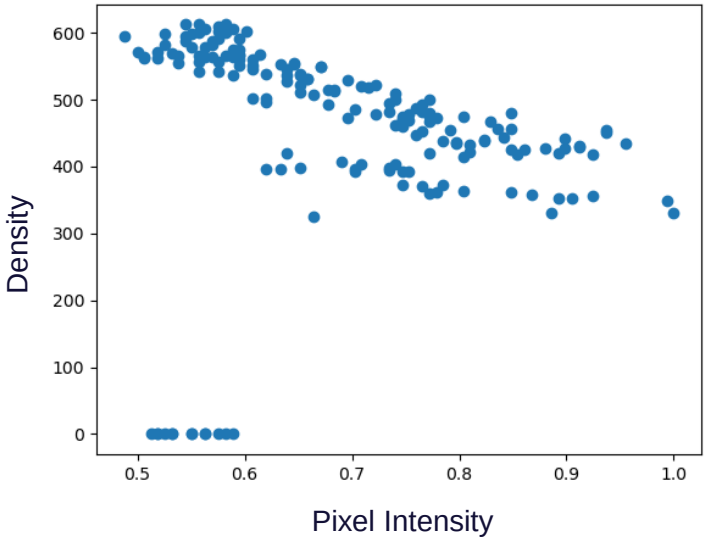


Pixel Intensity

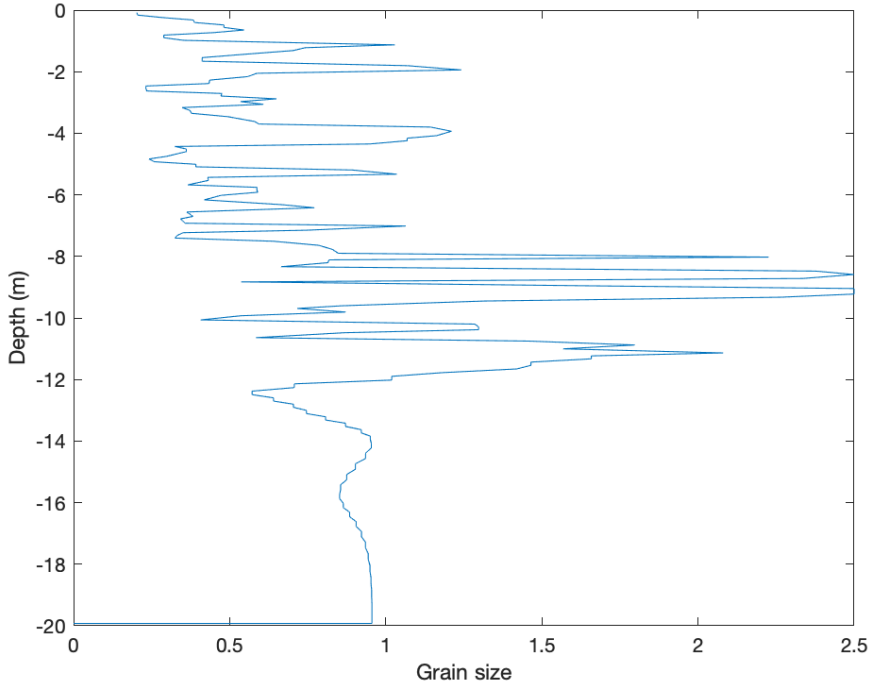
ANALYSIS

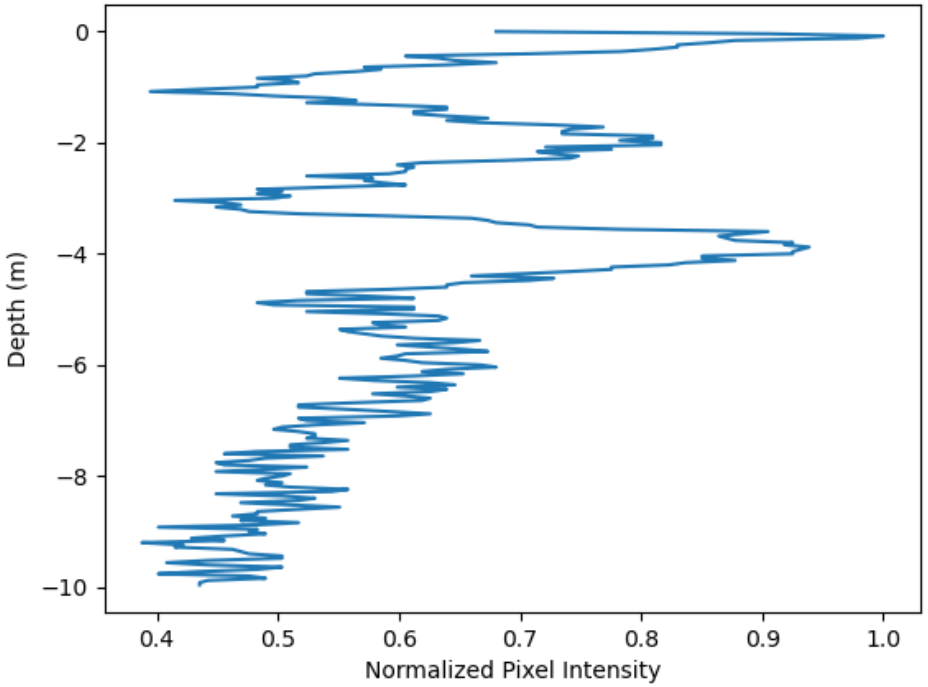




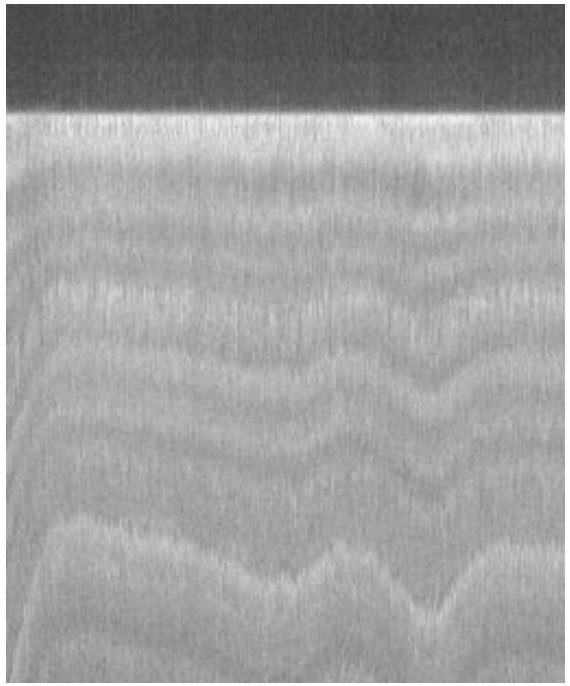


ANALYSIS

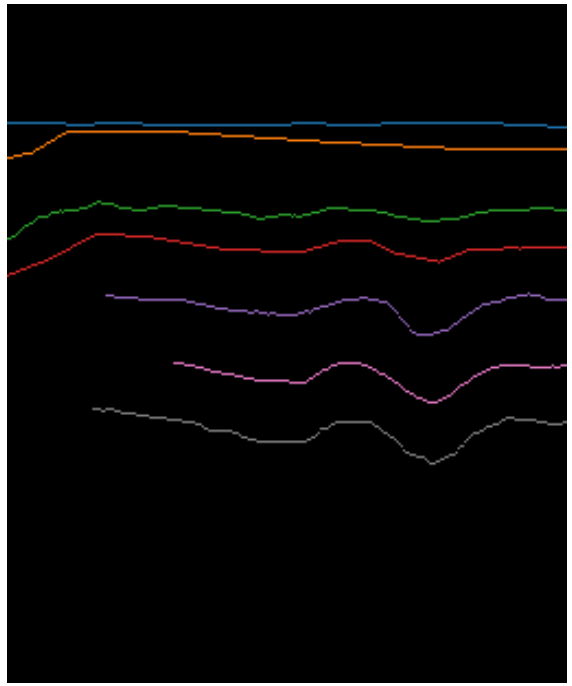

Depth (m)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
0
0.5
1
1.5
2
2.5
Grain size


Depth (m)
0
−2
−4
−6
−8
−10
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Normalized Pixel Intensity

ICE LAYER TRACKING THROUGH FCN



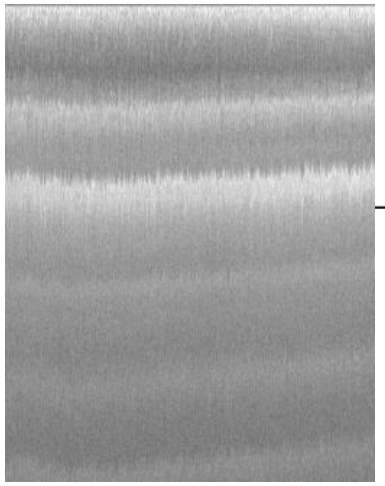
Radargram

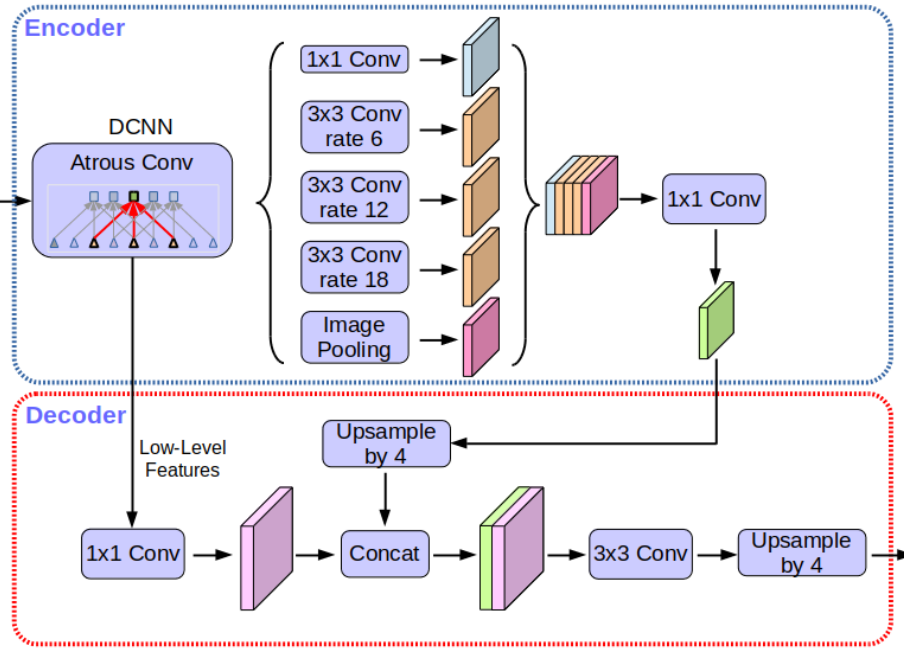


Manual annotations
(Ground Truth)

ICE LAYER TRACKING THROUGH FCN

Input Radargram

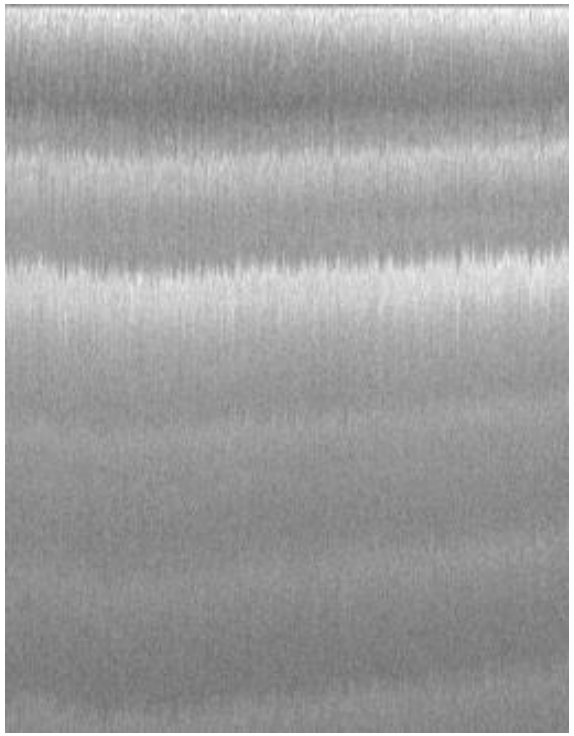




Prediction

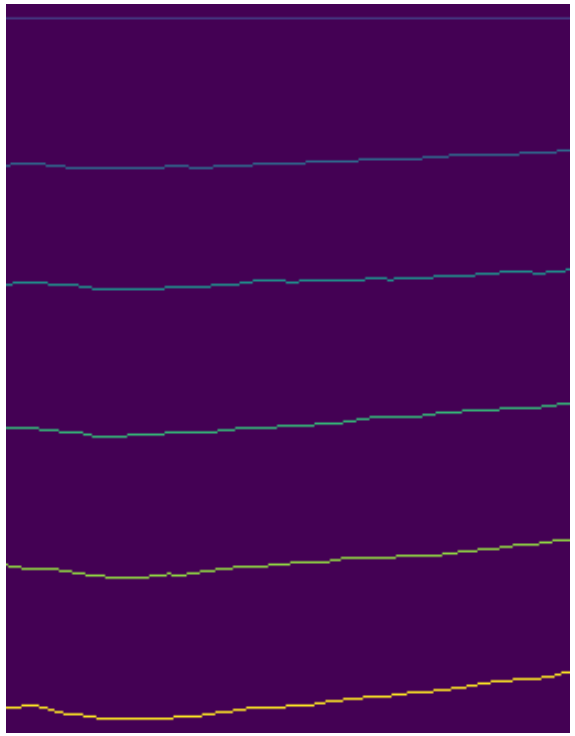
DeepLab v3+ FCN

ICE LAYER TRACKING THROUGH FCN



Test Radargram

Prediction



Converted to Layers

CONCLUSION AND FUTURE SCOPE

- Density variation vs depth for both radar observations and GEMB simulations are *similar* for most sample points.
- Layers detected in high resolution radar observations can be used to re-parameterize surface mass balance models with the help of machine learning.
- This would improve the models' prediction of ice melt and subsequent sea level rise.

THANK YOU

For queries, please reach out to ***dvarshney@umbc.edu***

AGU FALL MEETING

NSF

JPL