C15G-0877 - Observations of depth, SWE, and stratigraphy using FMCW radar and machine learning, during the NASA SnowEx 2020 Grand Mesa Campaign

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Abstract

Snow properties can vary significantly over distances of 50-200 meters, and therefore rapid techniques for measuring bulk snow properties are valuable for calibration and validation of snow remote sensing efforts. We developed and deployed a ground-based microwave radar from a snowmobile, during a large NASA snow remote sensing campaign. These observations provide information about the spatial distribution of snow depth, snow water equivalent, and stratigraphy, and were performed coincident with many different airborne snow remote sensing observations.

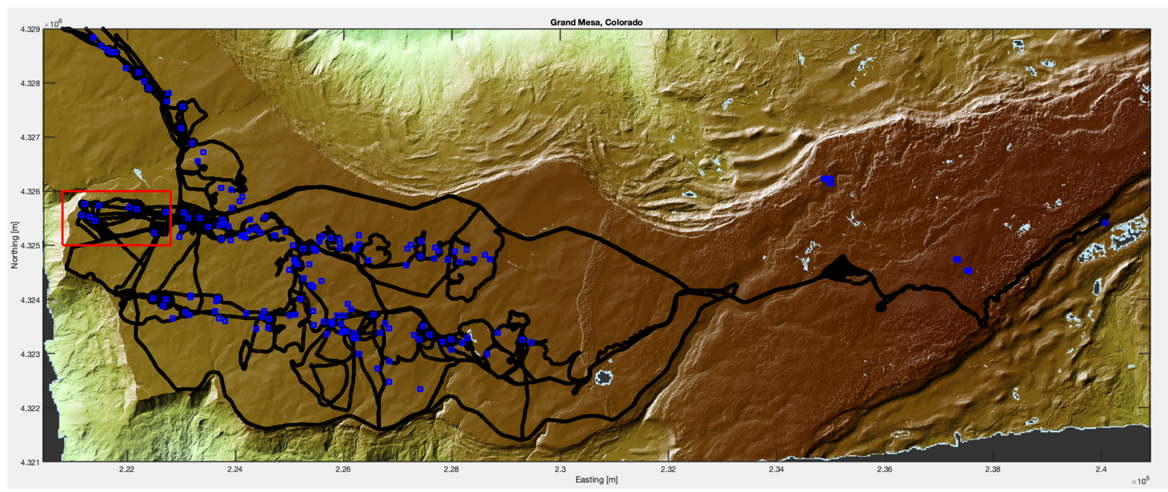

Figure 1: Map of Grand Mesa with radar profiles (black), and snowpits (blue), over a 20km x 8km region. Red box shows 2km x 1km area below.

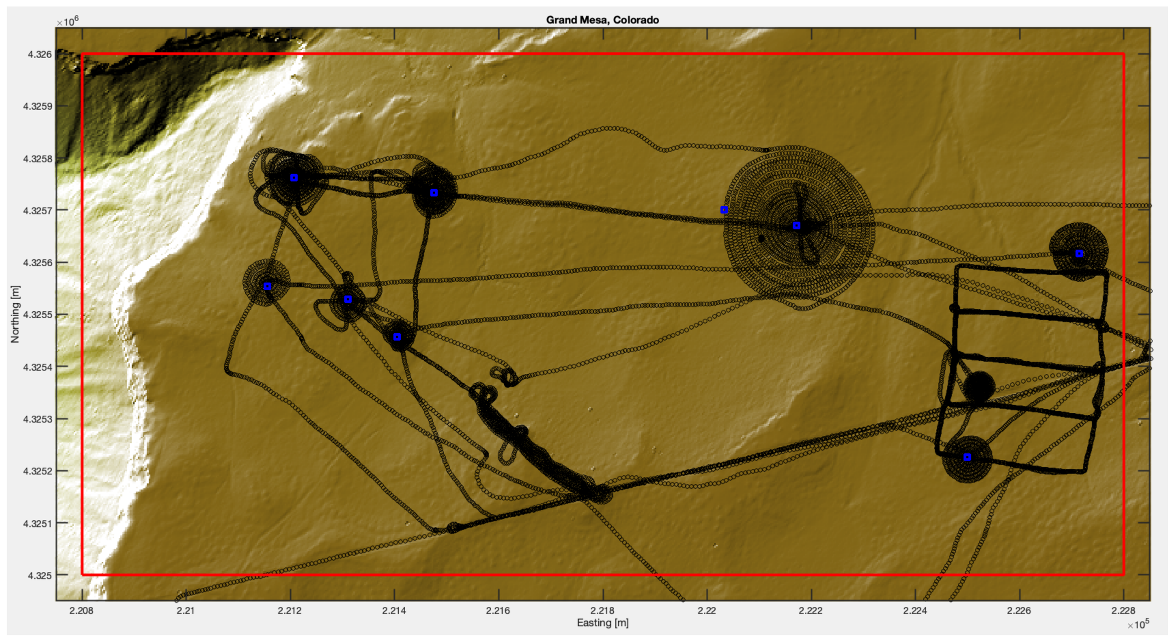

Figure 2: Grand Mesa map zoomed in to red box (2km x 1km) in figure above, to show different radar sampling strategies.

Introduction

- FMCW radar profiles during nearly all field sampling days of the SnowEx 2020 Grand Mesa IOP (e.g. *Marshall and Koh*, 2008)
- FMCW radar surveys sampled snow conditions near almost all 150+ SnowEx pits
- Manual layer picking of surface and ground returns represents the bottleneck in this massive dataset

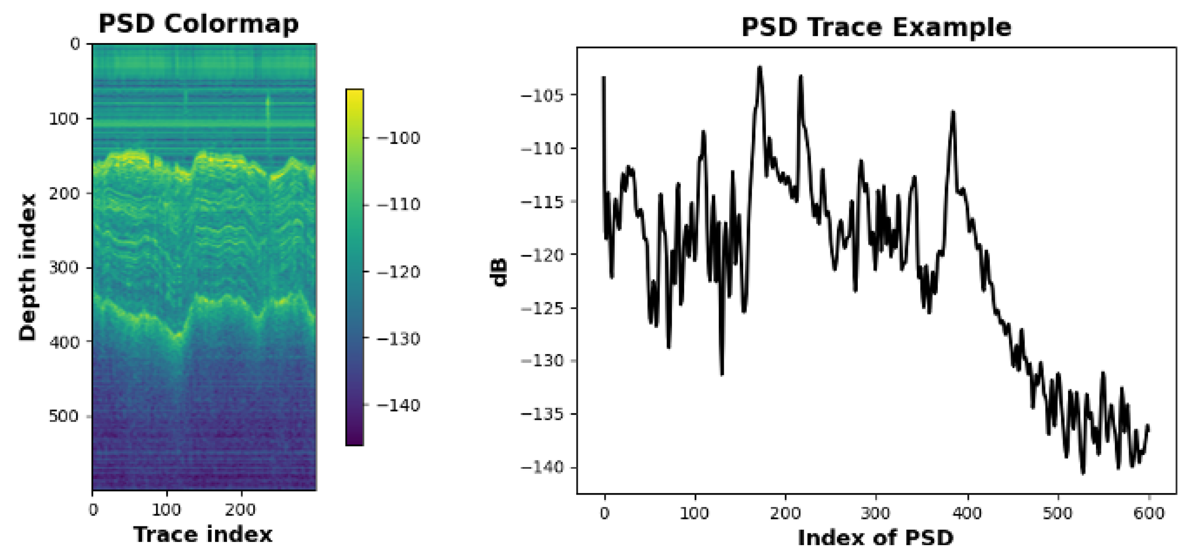

Figure 3: Example FMCW profile (left) and an individual trace (right)

Radar processing

- Time domain signal is converted to frequency domain using FFT and Kaiser-Bessel window
- Frequent sky calibration measurements used to remove instrumentation noise

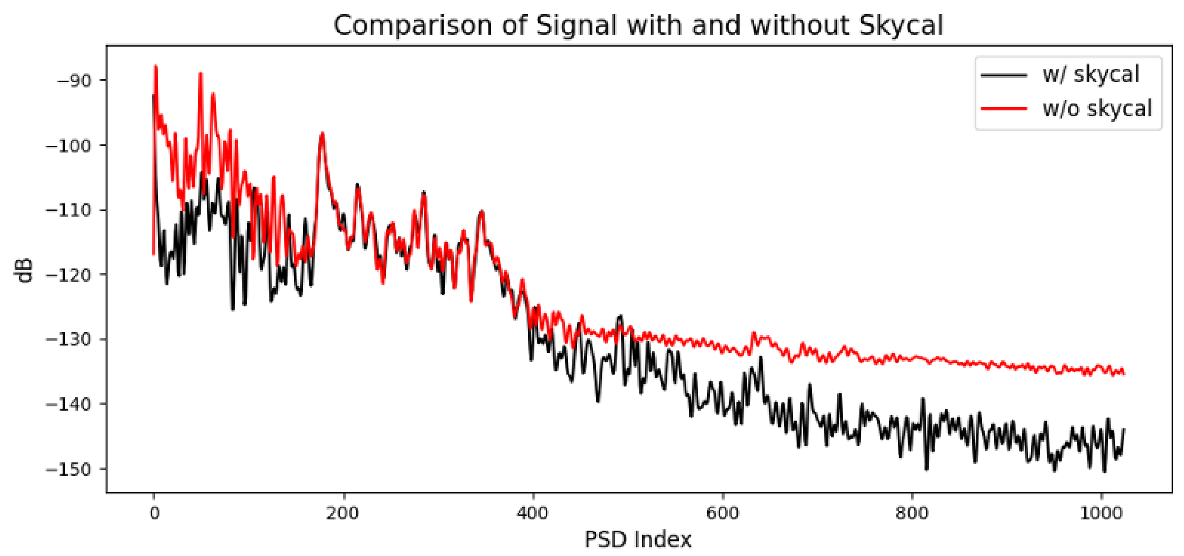

Figure 4: Frequency domain radar trace (black), with sky calibration (red).

Automatic layer picking: Genetic Algorithm

- Sky calibration used to define solution space, shown in gray in Fig. 5
- Genetic algorithm (GA) used as a first guess at snow-ground interface
- Uses 6 features from each trace, in groups of 1000 traces (about 1 minute of data)
- Output becomes training data for Neural Network

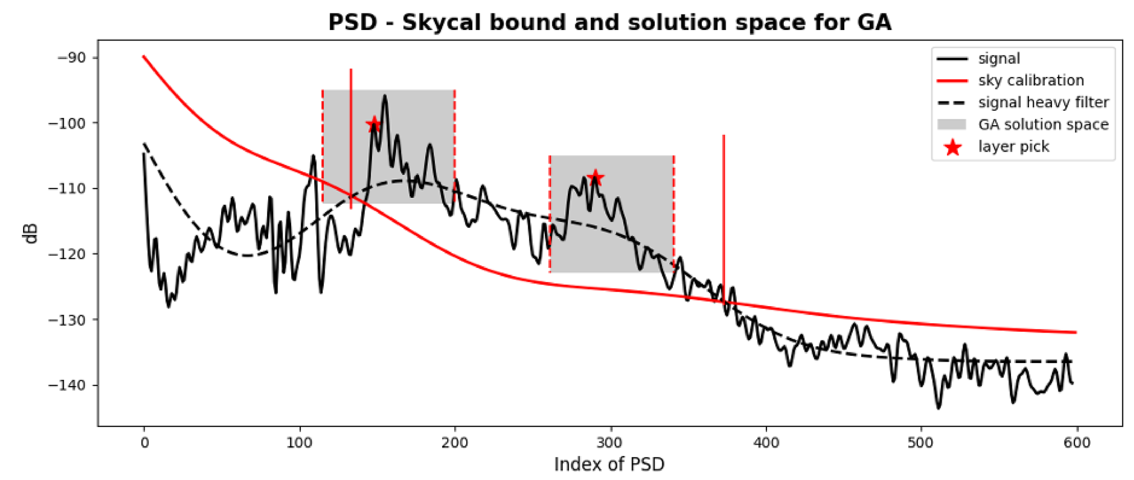

Figure 5: Sky calibration is used to define solution space for genetic algorithm.

Automatic layer picking: Neural Network

- Similar to recognition of handwritten numbers
- NN is a multilayer perceptron, has two hidden layer, uses 30 traces centered on trace to pick
- Uses output of genetic algorithm to train, avoiding the need for manually picking layers in training data

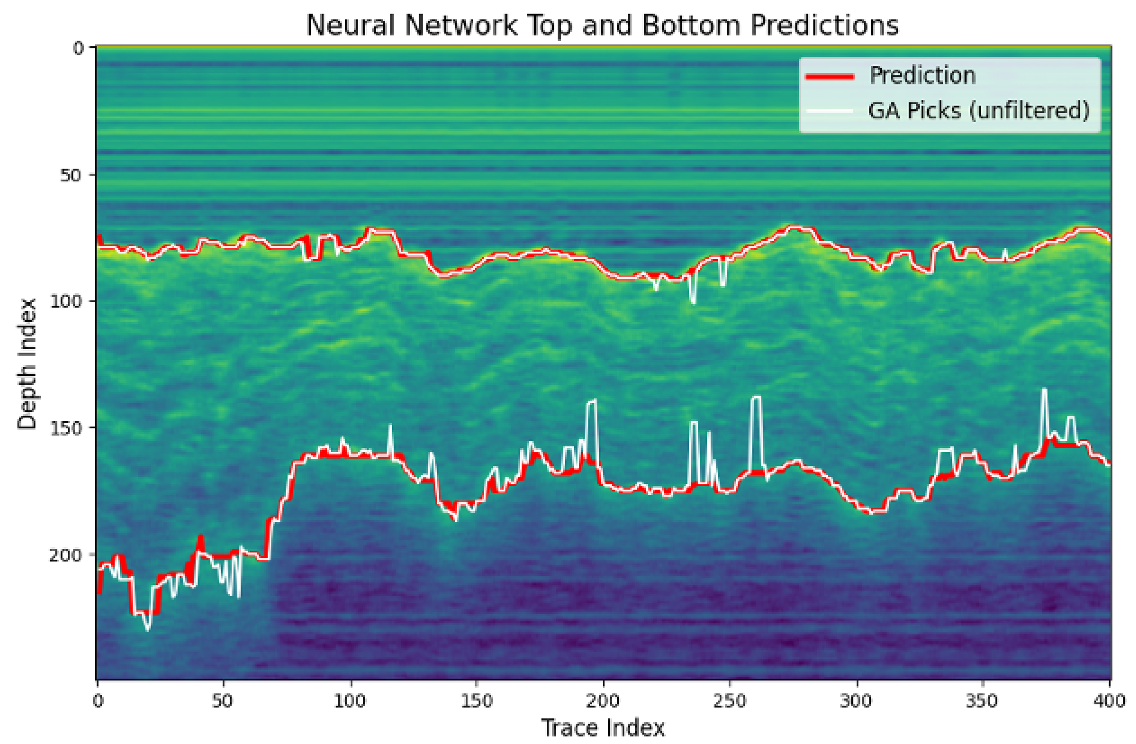

Figure 6: Genetic algorithm picks (white), used as training for neural network (picks shown in red).

Validation: Comparison to manual probe depth

- Comparisons made at 24 pits where radar drove same spiral coincident with manual probe measurements
- Similar to previous studies (*McGrath et al.*, 2019; *Webb et al.*, 2020), manual probes are deeper, likely due to over probing
- Comparison of mean depth across 24 pit sites, not used for training, shows good agreement (r=0.95, RMSE<5cm) with automatic picking

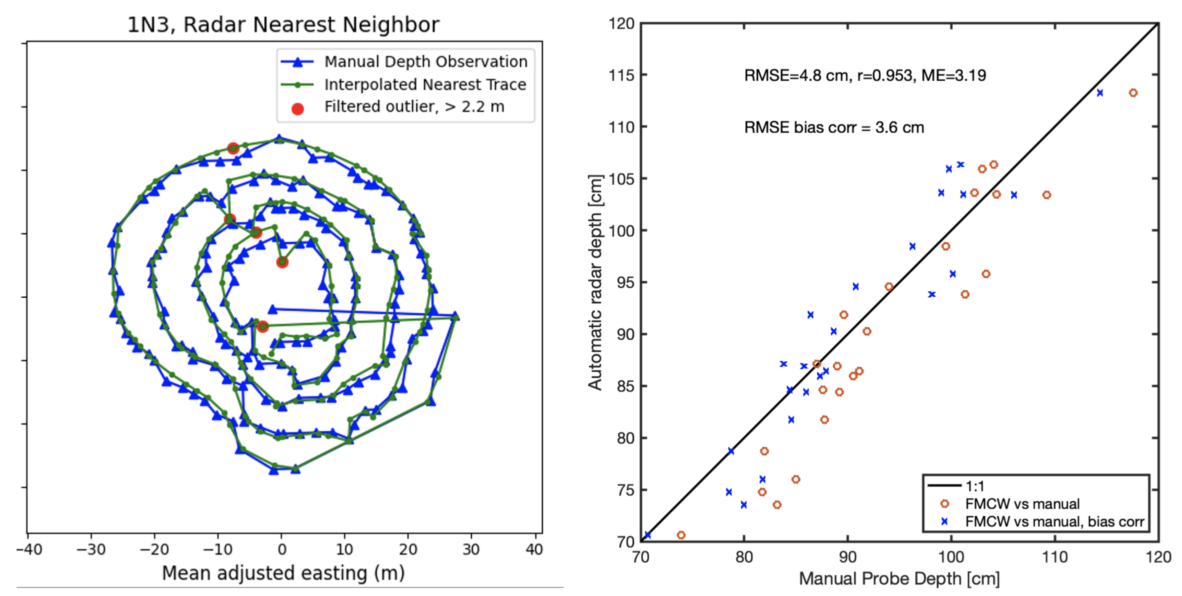

Figure 7: Example spiral around snowpit, showing location of manual depth observations and radar transects (left), and a comparison of mean manual depth observations and automatic radar results at 24 test pits.

Stratigraphy Information

- Stratigraphy can cause challenges for active and passive microwave retrievals of snow
- Random forest used to classify radar profiles into high stratigraphy and low stratigraphy regions

Figure 8: Random forest classified radar transects as either low stratigraphy (left) or high stratigraphy (right).

Acknowledgments

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