PROGRESS IN THE ANALYSIS OF ANTARCTICA AS A TARGET FOR MULTIFREQUENCY CROSS-CALIBRATION BETWEEN ASCAT AND NSCAT

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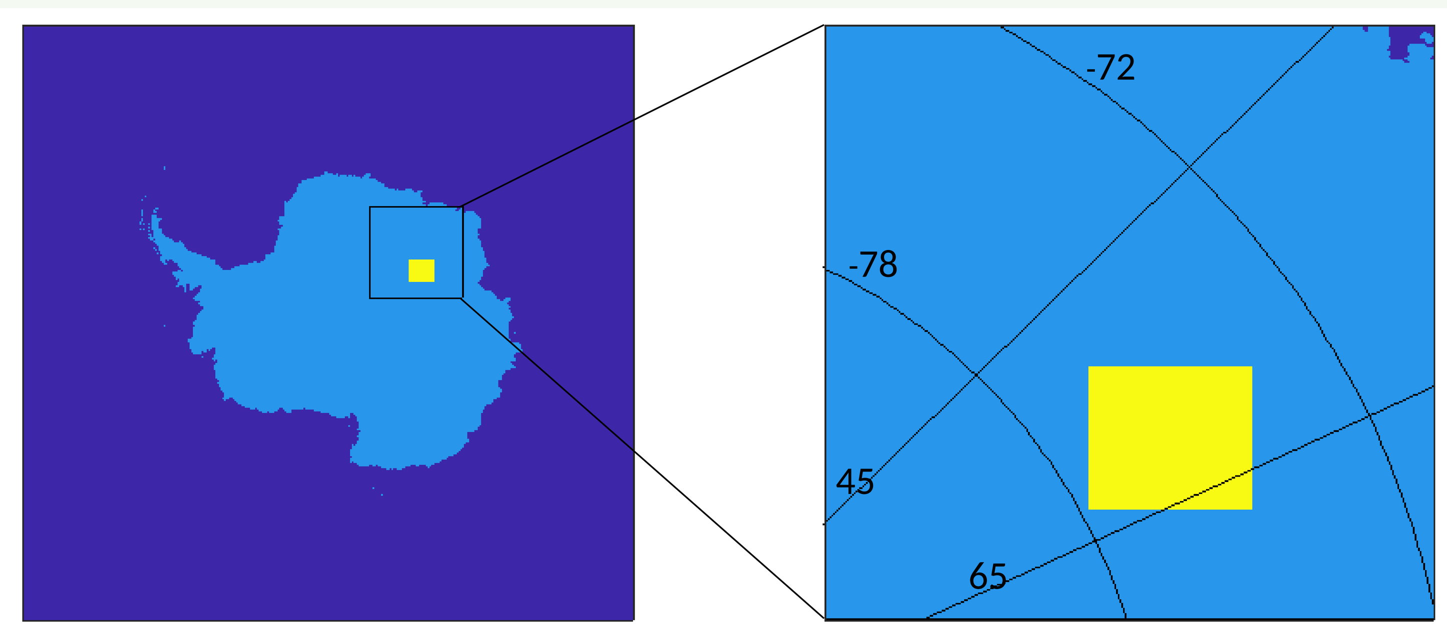
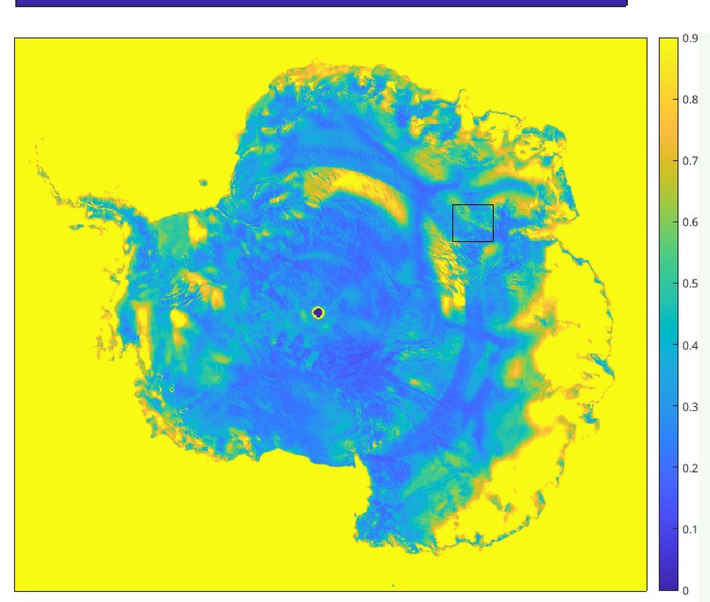
Summary

Variations in incidence angle, frequency, beam pattern, and time periods complicate efforts to cross-calibrate data from different sensors and make it difficult to create a homogenous data set to support long-term studies. Land calibration targets with little seasonal variation and significant volume scattering characteristics help to mitigate some of these differences, thus enabling cross-calibration of the various sensors [1][2][3]. Having shown that regions of Antarctica exhibit long-term stability and volume scattering effects we examine the characteristics of a study area near the Amery ice shelf in what is known as a 'wind glaze' region, an area characterized by near-zero snow deposition rate and an ice surface layer over coarse refrozen ice grains [4], as a calibration target. A simultaneous azimuth and incidence angle correction is used to predict and remove azimuth modulation [5]. The correction model assumes that the calibration offset is multiplicative to the sum of the volume and surface components. We predict the volume scattered component with a single scattering model, the surface scattering with the I2EM model, and subtract those values from the azimuth corrected measured backscatter to get the calibration offset [6]. Parameters in the models include particle size, surface RMS height, surface correlation length, and dielectric constant, which should all either remain constant for each scatterometer or vary predictably with frequency [6]. Data from SMAP (1.4 GHz), ASCAT (5.3 GHz) and NSCAT (13.995 GHz) are used in the model to evaluate the scattering behavior of the region. Because different frequencies exhibit different levels of volume and surface backscatter, using data from the two instruments enables better parameter estimates and a more accurate model. Figure 1 shows the fit of the model to ASCAT and NSCAT data with respect to incidence angle. The modeled fit follows the mean of the data to within 0.5 dB

We outline the use of a surface and volume scattering model to find this offset, and potential methods for and limitations of using this region-specific, first-order offset to cross-calibrate NSCAT and ASCAT scatterometer data. It also presents estimates of the physical characteristics of the area that allows us to estimate the calibration offset between scatterometers along with data that supports the estimates.

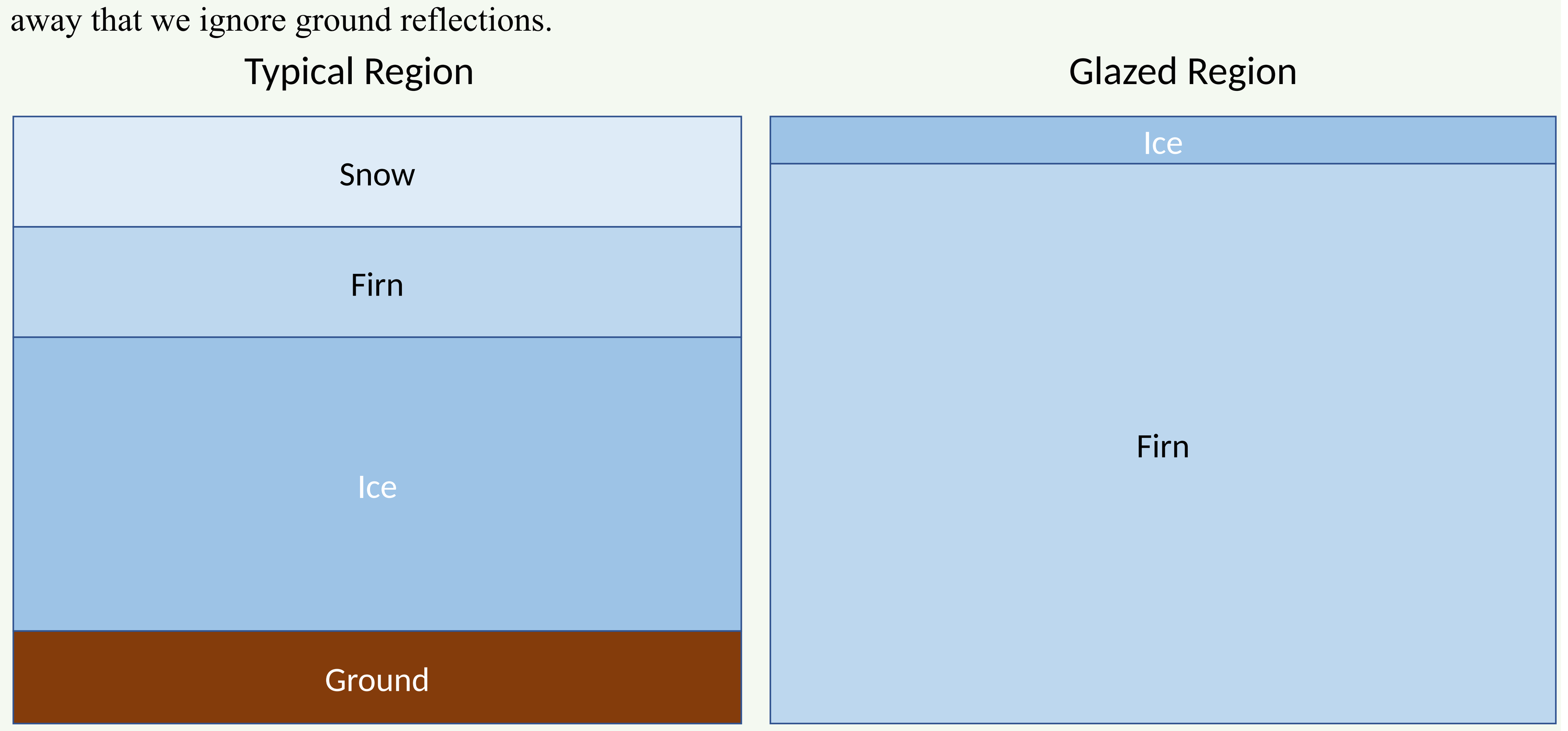




Study Region

(top row) Study region location inland of the Amery Ice Shelf. This region was chosen because of its location inside the section of Antarctica with coverage from all beams of the fan beam scatterometers and the consistency of its backscatter at 5.3 GHz and 13.5 GHz. (left) map of the 3-year standard deviation in the daily pixelwise mean difference between ASCAT and QuikSCAT SIR σ_0 data (in dB). The region of interest outlined in black, has low standard deviation

The backscattering consistency of this and similar areas is likely due to the areas being low accumulation regions known as glaze regions. These regions have a different layered structure than most snow-covered regions as outlined in the figure below. The main takeaway from a backscattering perspective is that glazed regions have fewer layering effects that complicate modeling of the backscatter, and the ground is far enough away that we ignore ground reflections.



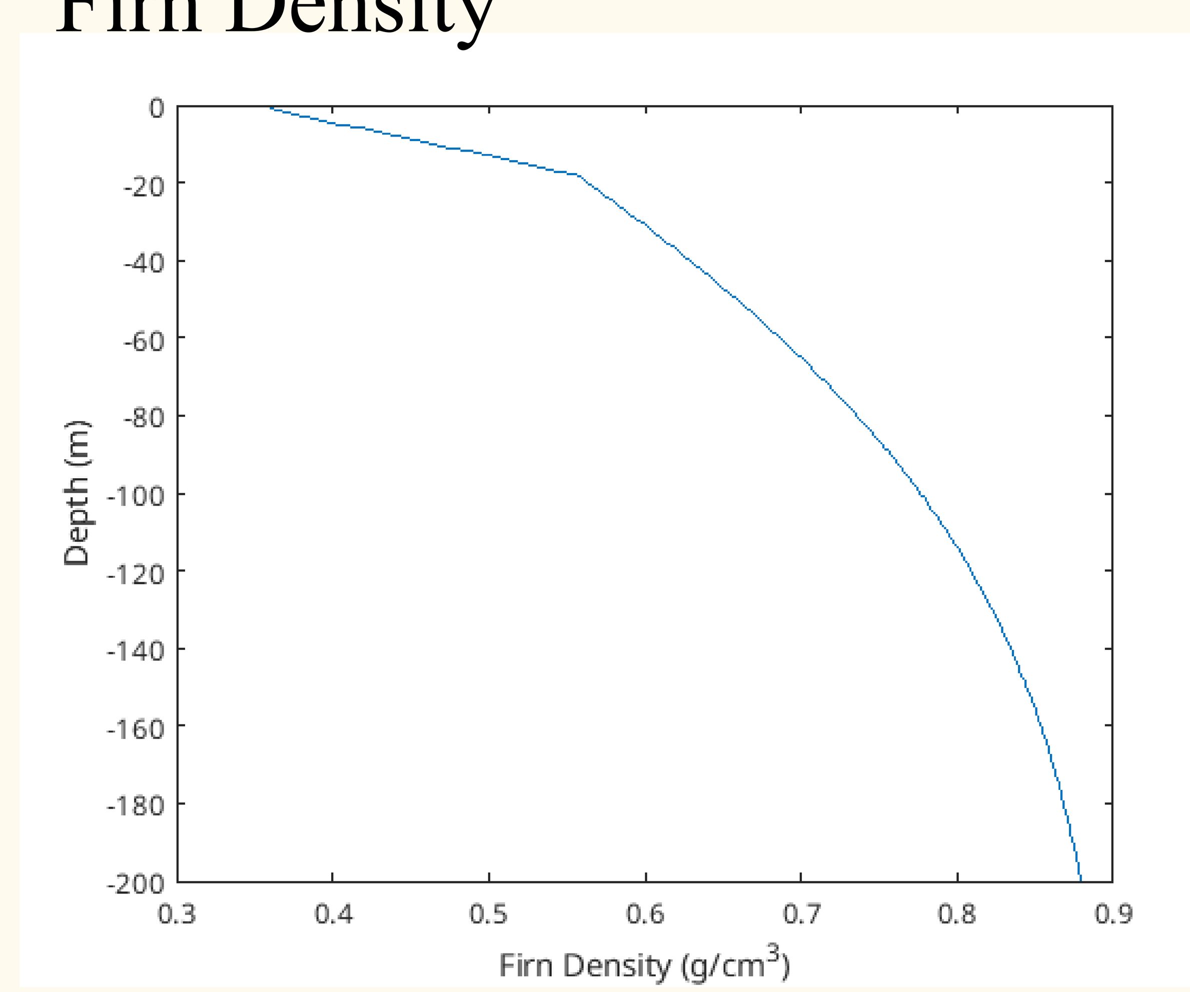
Glaze Region Backscatter Model

$$\sigma_0 = 10\log_{10}[\underbrace{\sigma_v(\theta_i)M_v(\theta_a)}_{\text{Volume Component}} + \underbrace{\sigma_s(\theta_i)M_s(\theta_a)}_{\text{Surface Component}}] + C$$

- σ_0 : Reported measurement
- σ_v : Volume return
- θ_i : Incidence angle
- θ_a : Azimuth angle
- σ_s : Surface return
- M_v : Volume azimuth modulation
- M_s : Surface azimuth modulation
- C : Calibration offset

The semi-empirical calibration model equation consists of three parts: volume and surface backscatter, volume and surface modulation, and a calibration constant, C. It estimates the azimuth modulations using an approximation from the data but predicts the volume backscatter using a single scattering physics model, and the surface backscatter using the I2EM model. The surface component in high incidence NSCAT and ASCAT data is negligible, so this data is used to estimate the volume scattering variables, and low incidence data is used to estimate the surface scattering variables. SMAP data is only taken at a narrow range of incidence angles and has significant contribution from both surface and volume scattering, so this data is only used to confirm the other estimates.

Firn Density



The volume model uses particle size and dielectric constant to estimate the volume contribution to σ_0. The dielectric constant is determined by the density of the firn. Because the firn density changes with depth, a densification gradient is used to predict the dielectric constant at a given depth. The formula used is the Herron and Langway firn densification model and is given as

$$\rho(z) = \rho_i \frac{\frac{\rho_0}{\rho_i - \rho_0}\exp\left(\frac{\rho_i}{\rho_w}k_0 z\right)}{1 + \frac{\rho_0}{\rho_i - \rho_0}\exp\left(\frac{\rho_i}{\rho_w}k_0 z\right)}$$

After the pore close-off depth ($\rho > 550$ kg/m^3)

$$\rho(z) = \rho_i \frac{\frac{\rho_{550}}{\rho_i - \rho_{550}}\exp\left(\frac{\rho_i k_1}{\rho_w b}(z - z_{550})\right)}{1 + \frac{\rho_{550}}{\rho_i - \rho_{550}}\exp\left(\frac{\rho_i k_1}{\rho_w b}(z - z_{550})\right)}$$

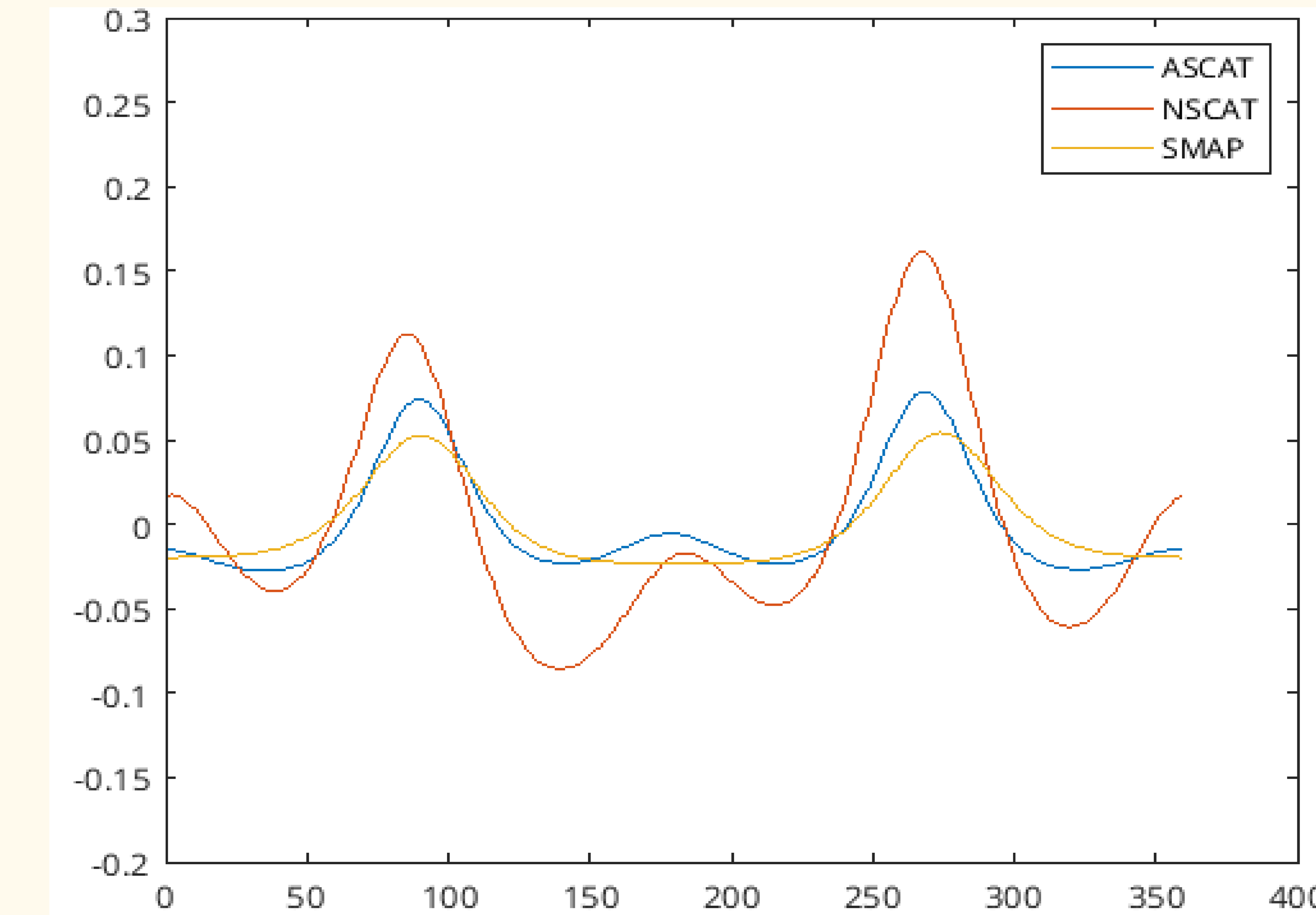
The figure shows the density of the firn as depth increases. Density increases steeply in the first 20 meters and then approaches 0.91 g/cm^3.

Volume Scattering

$$\sigma_v = \int_{-d}^{0} \sigma_v^{back} e^{2\kappa_e z \sec(\theta_i)} dz$$

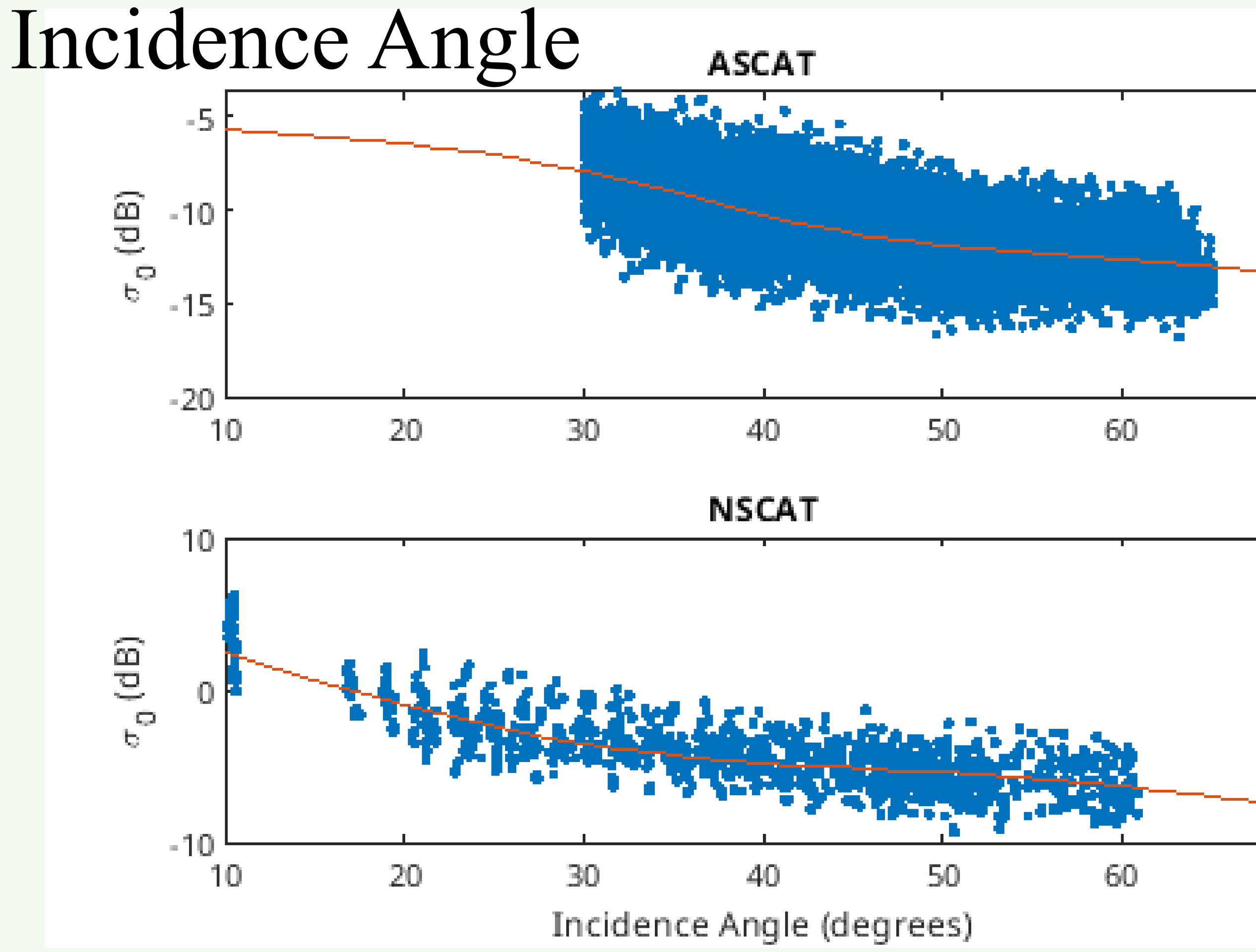
The volume model employs a single scattering method to predict the volume contribution. The single scattering equation is used in its integral form so that the appropriate dielectric constant can be applied at every depth increment. This leads to a volume calculation that is very similar at high frequencies but differs by up to 2 dB from the non-gradient model method at lower frequencies. This matches with expectations because lower frequencies penetrate deeper into the ice and thus interacting with a greater range of firn densities.

Azimuth Modulation



Azimuth modulation for ASCAT (blue), NSCAT (orange), and SMAP (yellow). Note that the main peaks are aligned with each other within 3 degrees. The data shown is adjusted to have zero mean and is displayed in normal space to more accurately compare examples of modulation that occur with a separation of several dB in dB space. Because the modulations are similar, we conclude that the cause of azimuth modulation in the glaze region is not sensitive to frequency.

Incidence Angle



ASCAT (top) and NSCAT (bottom) backscatter data points with respect to incidence angle with the respective modeled fit lines. The fit lines agree to within 0.5 dB of the data's mean line for both scatterometers. Predicted particle size from the model is also consistent with expectations from the literature.

References

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