AN ANALYSIS OF ANTARCTICA AS A TARGET FOR FIRST ORDER CROSS-CALIBRATION BETWEEN NSCAT, SMAP, AND ASCAT

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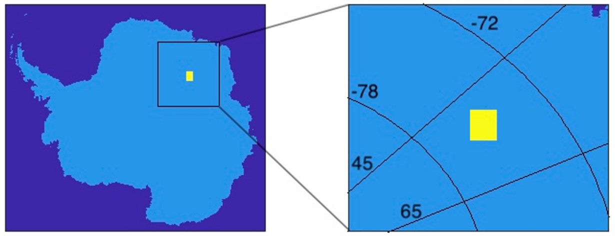
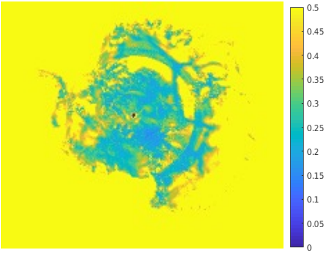
Abstract

While scatterometers have been measuring the radar cross-section of the surface of the earth for decades, differences in the way scatterometers measure backscatter are significant. 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 climate 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. The Amazon is a traditional calibration target because it comprises a large, homogenous region with backscatter dominated by volume scattering. Unfortunately, resonant behavior with leaves in the Amazonian canopy at Ku band frequencies and the diurnal dew cycle reduce the effectiveness of the Amazon as a target for cross-calibration of scatterometers at multiple frequencies. We show that regions of Antarctica exhibit long-term stability and volume scattering effects that make them favorable calibration targets. We examine the characteristics of a study area near the South Pole 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.

A simultaneous azimuth and incidence angle correction is used to predict and remove azimuth modulation. The correction model assumes the backscatter is composed of a linear combination of volume scattered return, surface scattered return, and a calibration offset. We predict magnitude of 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. 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. Data from ASCAT (5.3 GHz), NSCAT (13.995 GHz), and SMAP (1.41 GHz) are used in the model to evaluate the scattering behavior of the region. Figure 1 shows the normalized fit with respect to azimuth modulation in normal (not dB) space. It shows that trends in C-band ASCAT data with respect to azimuth angle are repeated nearly exactly by the trends in Ku-band NSCAT data and in L-band SMAP data. This implies that over the area, the calibration differences between Ku-band, C-band, and L-band backscatter measurements can be accurately described by first-order offsets.

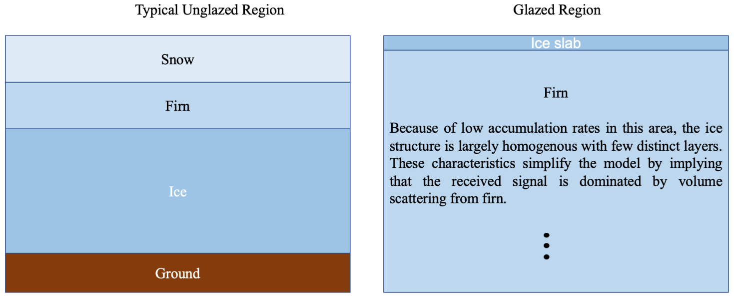
This poster outlines the use of a surface and volume scattering model to find this offset, and potential methods for and limitations of using this region-specific, first-order offset to cross-calibrate NSCAT, ASCAT, and SMAP scatterometer data. It also presents estimates of the physical characteristics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





As depicted in the above figures, the study region is located inland of the Amery Ice Shelf. This region was chosen because of the consistency of its backscatter at 5.3 GHz and 13.5 GHz. The figure to the left shows a 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 is shown as a low point in the standard deviation, implying that the relationship between the backscatter at the two frequencies can be represented well by a simple first order offset.

The consistency of this and similar areas is likely due to them being low accumulation regions known as glaze regions. These regions have a different structure than most snow-covered regions as outlined in the figure below. The main takeaway from a backscattering perspective is that this region does not have the layering effects that make modeling difficult in other areas.

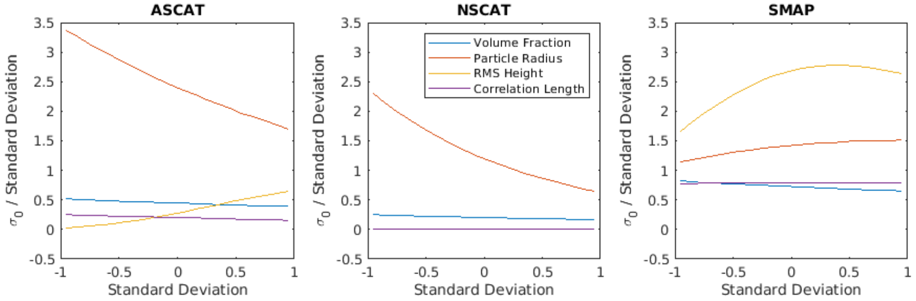


Because of low accumulation rates in this area, the ice structure is largely homogenous with few distinct layers. These characteristics simplify the model by implying that the received signal is dominated by volume scattering from firn.

$$\sigma_0(\theta_i,H,L,f) = \overbrace{\underbrace{A\,T(\theta_i)^2\cos(\theta_i)}_{\text{Volume Scattering}} + \underbrace{S(\theta_i,H,L,f,e)}_{\text{Surface Scattering}}}^{\text{Scattering Model}} + \overset{\text{calibration offset}}{\downarrow \atop C} + \underset{\text{Azimuth Modulation}}{M(\theta_a)}$$

- A : constant to be solved for
- θ_i : incidence angle
- θ_a : Azimuth angle
- M : Azimuth modulation
- H : RMS height
- L : correlation length
- f : frequency
- e : dielectric constant

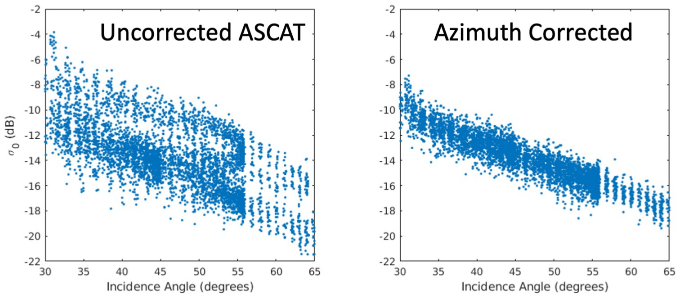
The model equation is shown above and consists of four terms: a volume component, a surface component, the calibration offset, and an azimuth modulation term. The data is first corrected for azimuth modulation. Because the remaining components have different relationships with frequency and incidence angle, which are known, we use these properties to isolate the various variables and determine a best estimate for each. The surface component of NSCAT and high incidence angle ASCAT is negligible, so this data can be used to estimate the volume scattering variables, and high incidence ASCAT is used to estimate the surface scattering variables. SMAP data is only taken at a narrow range of incidence angles, so this data is only used to confirm the other estimates. These estimated parameter values are shown in a table below, and are reasonable values based on data found in the literature.



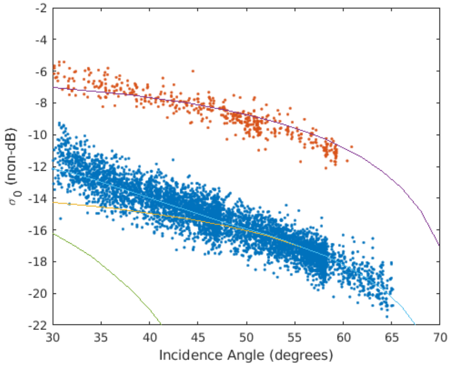
Parameter Estimates

Variable	Mean	Standard Deviation
Particle Radius (mm.)	0.41	0.097
Ice Volume Fraction (%)	66%	8.3%
Correlation Length (m.)	0.25	0.014
RMS Height (cm.)	5.26	1.07

The above figures show the model sensitivity to the four main parameters at NSCAT, ASCAT and SMAP frequencies up to ±1 standard deviation away from the estimated value for the parameter. The plots show that the model is sensitive to particle radius at all frequencies, though at low frequency surface RMS height dominates. The values used in the model for each of these parameters are estimates, so this sensitivity analysis is an important tool for evaluating the model's accuracy. The table to the left shows the estimated value and standard deviation for each parameter that were used to make the above figure.



We use a simultaneous incidence/azimuth fit to remove the azimuth modulation. The fit approximates the azimuth modulation as a 4th order trigonometric polynomial, and the incidence angle variation as linear. Though the backscatters relationship to incidence angle is closer to a cosine, the linear approximation works reasonably well, as can be seen in the above figure.



The above plot shows ASCAT (blue) and NSCAT (red) data points with the modeled NSCAT (purple) and ASCAT (light blue) fit lines. ASCAT surface (green) and volume (yellow) components are also depicted. The modeled surface component for NSCAT is below -40 dB at the measured incidence ranges, so is not depicted. The fit lines generally agree with the data, although with this set of parameters the NSCAT fit is slightly off.

Bibliography and References

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