Large-Scale Inverse Modeling of Microwave Backscatter from Sea Ice

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Abstract

Many forward electromagnetic scattering models have been proposed to predict the normalized radar cross section, $\sigma$, from sea ice characteristics. In this paper, we apply scatterometer data to large scale inverse modeling. Given the limited resolution, we adopt a simple geometric optics forward scattering model to analyze surface and volume scattering contributions to observed Ku-band signatures. A model inversion technique based on recursive optimization of an objective function is developed. Simulations demonstrate the performance of the method in the presence of noise. The inverse model is implemented using Ku-band image reconstructed data collected by the NASA scatterometer. The results are used to analyze and interpret phenomena occurring in the Arctic.

Forward Modeling of Microwave Backscatter

Data from the NASA scatterometer (NSCAT) are used in an inversion study. To improve the nominal resolution of NSCAT measurements, resolution enhancement algorithms can be applied to generate images. These methods rely upon a simple parameterization of the dependence of $\sigma$ on incidence angle. Various order models can be used with increasing sensitivity to noise as order is increased. In general, $\sigma$ (in dB) can be modeled by

$$\sigma(b) = A + B \cdot \cos(b) + C \cdot \cos^2(b) + D \cdot \cos^4(b) + \ldots$$

where $b$ is the incidence angle, $A$ is a normalized to 40°, $B$ is the linear incidence angle dependence of $\sigma$, $C$ is the quadratic incidence angle dependence of $\sigma$, and so forth to the $n$th model order.

Swift [1] proposed a simple forward scattering model applicable to NSCAT. The model assumes that sea ice scattering consists of incoherently summed surface and volume scattering responses

$$\sigma = \sigma_s + \sigma_v$$

where $\sigma_s$ is the modeled $\sigma$, $\sigma_v$ is the surface scattering $\sigma$, and $\sigma_v$ is the volume scattering $\sigma$. The model is defined by three basic large-scale parameters: the nadir reflectivity, $\rho_0$, the RMS surface slope, $\delta$, and the volume scattering albedo. For convenience, $25^\circ$ is used in the model inversions discussed below.

Inversion Methodology

The theoretical scattering model proposed by Swift is defined by three basic parameters, $\rho_0$, $\delta$, and $\sigma_v$. These values can be estimated from observed NSCAT $\sigma$ signatures given sufficient incidence angle sampling.

The inversion approach consists of the automated steepest descent optimization of an objective function. The objective function provides a measure of the error between observed signatures and estimated model parameters,

$$J(\mathbf{\hat{A}}) = \frac{1}{\nu} \sum_{i=1}^{\nu} \left( \frac{\sigma(i) - \sigma_v(i)}{\sigma(i)} \right)^2$$

where $\mathbf{\hat{A}}$ is a vector containing $\rho_0$, $\delta$, and $\sigma_v$. The $\sigma_v(i)$ response is determined by $\sigma$ vs. from the polynomial fit coefficients in Eq. (2) for each pixel in the reconstructed imagery. The optimum $\mathbf{\hat{A}}$ yields the minimum $J(\mathbf{\hat{A}})$.

References