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First Order Surface Roughness Correction of Active Microwave Observations for Estimating Soil Moisture

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Abstract—**Surface roughness has a significant effect on the relationship between radar backscatter and soil moisture. In order to use existing radar satellite data for soil moisture, roughness effects must be corrected. A technique is presented that utilizes the data bases from soil erosion studies and soil moisture remote sensing investigations to provide first order estimates of the roughness parameters.**

I. Introduction

Since initial experimentation began in the 1970's to measure soil moisture using microwave remote sensing, it has been recognized that the soil surface roughness has an effect on the relationship [1]. The theory that explains why this should be expected is well established for ideal conditions. Soils, especially under natural conditions, are very difficult to represent in these models due to three-dimensional (3-D) variability in their basic properties.

There have been several recent advances that have isolated and quantified roughness effects for bare soil conditions [1]–[10]. These results suggest that i) classical solutions to modeling the backscattering coefficient (σ°) based on the soil properties are valid when the physical system can be described and satisfies the model constraints; ii) three soil parameters are needed for these models: the dielectric constant, surface soil height random roughness (s), and the correlation length (l); iii) of the geometric parameters, surface soil height random roughness appears to be the most important; iv) using multipolarization radar data, it may be possible to determine the dielectric constant as well as the roughness parameters.

The multipolarization work [4], [5] may prove useful but does not provide answers for current satellite radar systems that have a single frequency and polarization. Therefore, it will be necessary to provide an independent estimate of surface roughness if we want to estimate soil moisture using radar data. There are several approaches that might be used: ancillary data bases, multiple angle viewing, and multitemporal observations. Multitemporal methods are based on change detection. If one assumes that surface roughness does not change, then the change in the σ° is due to the change in soil moisture. This approach may prove useful under the right conditions, however, it does not provide a direct estimate of surface soil moisture. Isolating soil moisture changes from other factors such as vegetation growth would be difficult. Alternatively, multiple angle observations of the same target might prove useful if they can be performed simultaneously. Since this is unlikely, the approach would be limited because the soil moisture most likely will have changed between observations.

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TABLE I
Average Random Roughness (s) Values Based on Single Tillage Operations [12].

Tillage Operation	s (cm)
Large offset disk	5.0
Moldboard plow	3.2
Lister	2.5
Chisel plow	2.3
Disk	1.8
Field cultivator	1.5
Row cultivator	1.5
Rotary tillage	1.5
Harrow	1.5
Anhydrous applicator	1.3
Rod weeder	1.0
Planter	1.0
No till	0.7
Smooth	0.6

There has been extensive research conducted primarily in the field of soil erosion to relate soil roughness to more readily available information. Most of this has been in agriculture with tillage practice and rainfall being the most important information. If one could associate the roughness with land cover/use variables derived using other remote sensing techniques, it should be possible to develop global roughness data that could provide a first order correction in soil moisture estimation algorithms. In this paper, the feasibility of this approach is explored.

II. Models and Sensitivity to Surface Roughness

The basic theory and the relationships between microwave backscatter and soil properties has been extensively described in works such as [1]–[3]. Recognizing that there may be uncertainties in the roughness parameter estimates and models, it is useful to briefly review some approaches to minimizing the impact of this uncertainty.

An optimal approach to estimating surface soil moisture using a single frequency polarization-look angle radar was developed and verified using ground-based scatterometers at the University of Kansas in the 1970's and 1980's [1]. If the goal is to minimize the sensitivity to surface roughness, a look angle close to 10° regardless of frequency will achieve this. Schanda [11] notes that this is a crossover point between angular regions in which the radar response is dominated by coherent and incoherent reflection. Results presented in [1] also suggested that C band is the optimal choice because the sensitivity to the surface roughness remains small at least up to 30°. Minimizing roughness sensitivity is the first step in reducing the impact of errors or uncertainties in the parameter estimates.

we described a procedure that could provide a first order correction for surface roughness. The procedure described would utilize land cover, rainfall, and associated parameter data bases. This method will provide an estimate of surface roughness; however, due to the high sensitivity of the soil moisture models to surface roughness, it is strongly suggested that the impact of uncertainty be minimized by selecting the best observing system parameters (primarily viewing angle).

The examples presented here for utilizing the roughness correction factor for an agricultural and rangeland surface have demonstrated that parameters can be estimated with a reasonable level of accuracy. However, errors can be further reduced by improving estimates of s through increased precision of roughness measurements in the fields. In addition, further work needs to be completed to populate the roughness archive and to ensure that s estimates for all tillage practices and rangeland conditions are included.

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