

Summary of Previous Research

During the last five years, I have conducted research as a Ph.D. candidate and post-doctoral research fellow in the areas of remote sensing, wireless communications, and mathematical modeling.

My doctoral dissertation research was conducted at Microwave Earth Remote Sensing Laboratory, Brigham Young University, Provo, Utah, until August 2006, under the supervision of Dr. David Long. I used spaceborne microwave remote sensing observations made by scatterometers and radiometers to study sand bedforms (ergs) and vegetation. The principals of electromagnetic scattering, emission, and signal processing applied to the observed microwave data provided new insights into the surface characterization and understanding of geophysical phenomena over sand and vegetation. I showed the potential of scatterometers and radiometers to infer long-term average near-surface-wind behavior from erg geomorphology. Over the vegetation, the multi-frequency and multi-temporal radar backscatter (σ°) and radiometric temperature (Tb) responses were related to the vegetation density; and long-term changes in the σ° were used to identify the tense ecologies of the Amazon basin. The key observations of this research include the effects of spatial and temporal variations of surface geophysical characteristics on σ° and Tb measurements as functions of observation geometry; the inference of the factors governing variations of geophysical characteristics; and an analysis of the consistency, quality, and fusibility of data from multiple microwave instruments.

Over ergs, σ° directional modulation is studied and related to the surface geometrical characteristics. The electromagnetic scattering from erg surfaces is modeled as composed of scattering from large- and small-scale sand bedform features. Large-scale dunes are modeled as composed of tilted rough facets. The total scattering from dunes is the sum of scattering from all of the rough facets in the footprint weighted by the fraction of their area in the footprint. Longitudinal and transverse dune fields are modeled as composed of rough facets. The proposed rough facet model is applied to the modeled dune fields. The results indicate a strong signature of the rough facets in the σ° response. The look directions at which the peak value occurs give the mean tilt of the facet. Small-scale ripples are modeled as cosinusoidal ripples that scatter the incident electromagnetic waves in discrete directions called Floquet modes. The backscattering from the cosinusoidal ripples occurs in the directions that have Floquet modes directed towards the sensor.

The σ° incidence angle (θ) modulation reflects the presence of slip-sides on the surface in the form of a slight rise in σ° at the incidence angle equal to the angle of repose of sand. At these incidence angles, the azimuth angle (ϕ) modulation indicates the number of slip-sides present that can be used to identify the transverse and longitudinal dunes. The ϕ -modulation of σ° measurements at $\theta=33^\circ$ is used to compute the dune slip-side orientations, which are almost equal to the dominant average wind directions over erg bedforms. Over the areas with simple dunes and less variable wind, the σ° -inferred wind is spatially and temporally similar to the wind directions provided by European Centre for Medium-Range Weather Forecasts. The model accuracy reduces over the areas with complex bedforms and high wind variability.

The σ° measurements over ergs are influenced by the ergs' general topography and dune geometry, and are a function of sensor view angles and footprint centroid location. A new model is proposed that includes coupled dependence on ϕ -modulation and spatial inhomogeneity. The σ° spatial inhomogeneity has highest magnitudes at the erg boundaries consistent with a change of terrain

from sandy surface to Hamadas. The high inhomogeneity magnitudes mark the boundaries of major bowl-like erg basins. The new model improves the estimation of θ dependent σ° ϕ -modulation, which carries useful information about dominant facets' slopes and orientations in the antenna footprint.

In the passive microwave remote sensing, dual polarization 19 GHz and 37 GHz Tb observations of spaceborne radiometers are used to analyze emission from erg surfaces. The observed Tb versus ϕ is modulated by the surface geometrical characteristics and reflects the presence of dominant dune facets. The Tb polarization difference (Δ Tb) has negligible dependence on the thermal characteristics of the surface and its ϕ -modulation varies with changes in the surface geometrical characteristics. The ϕ -modulation of Δ Tb depends upon the tilts and orientation of the facets in the footprint of the sensor. The tilted rough facet model is used to model the Tb response from the erg surface. The total Tb from dunes is the weighted sum of Tb response from its dominant facets. When modeled as surfaces composed of multiple rough facets, longitudinal and transverse dunes exhibit significant differences in their Tb and Δ Tb ϕ -modulation: Δ Tb decreases whereas Tb increases due to a decrease in local incidence angle. Thus, a tilted facet reveals its presence as a minimum in Δ Tb ϕ -response, where the magnitude of the Δ Tb reflects the tilt of the facet. The model simulation results are consistent with the satellite observations over areas of known dune types.

Over vegetation, σ° versus θ response shows distinctive behavior for different vegetation densities. Different scatterometers provide similar σ° incidence angle response. Different land cover types exhibit unique frequency responses of σ° and Tb. The spatial inhomogeneity model parameters provide additional information about spatial geophysical characteristics of Amazon basin. C-band and Ku-band σ° measurements are generally found to be consistent. The σ° time series indicates a general decrease in σ° with time. This trend is used to identify areas of significant σ° reduction possibly caused by geophysical changes. Such areas are found mostly at the southern boundary of the Amazon forest that could be a result of deforestation.