

Modeling of Mima Mounds in Bistatic Radar Scattering

Erik Hodges⁽¹⁾, James D. Campbell⁽¹⁾, Amer Melebari⁽¹⁾, Tianlin Wang⁽²⁾, Joel T. Johnson⁽³⁾,
and Mahta Moghaddam⁽¹⁾

⁽¹⁾ The University of Southern California, Los Angeles, CA 90089, USA, <http://www.usc.edu>

⁽²⁾ Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109,
<http://www.jpl.nasa.gov>

⁽³⁾ The Ohio State University, Columbus, OH 43210, USA, <http://www.osu.edu>

Global navigation satellite system reflectometry (GNSS-R) is a promising technique for retrieval of land surface parameters such as soil moisture. Through comparing results from the improved geometric optics with topography (IGOT) scattering model (A. Melebari et al., *Remote Sens.* 2023, 15, 1880.) with measurements from the Cyclone Global Navigation Satellite System (CYGNSS), it has been observed that mima mounds, such as those found in the Jornada Experimental Range (JER) in southeastern New Mexico, USA, produce signatures that cannot be explained using the standard version of IGOT. The mima mounds in this region range in height from 0.5 to 1.5 meters and in diameter from 2 to 20 meters. Mima mounds present a challenge in electromagnetic forward modeling because they are significantly larger than the wavelengths of L-band and P-band signals commonly used in land remote sensing, but they are too small to be detected with available digital elevation models (DEMs) such as those from the Shuttle Radar Topography Mission (SRTM). In this work, we present an enhanced version of the IGOT model for mima mound surfaces and validate the model using high-resolution lidar elevation data over JER.

The mima mounds are modeled as radially symmetric 2D raised-cosine functions with Gaussian surface roughness. For this work, the SRTM 1-Arcsecond Global DEM, which has a horizontal resolution of roughly 30 meters, is used. Therefore, the pixel size is much larger than the mima mounds present in the JER site in New Mexico. To solve this issue, mounds are treated as part of the intermediate scale roughness, which is the roughness of scale smaller than the DEM resolution but larger than the wavelength. In the IGOT model, this roughness is modeled using the probability density function (pdf) of the intermediate-scale slopes. To model mima mounds this way, we derive the pdf of mound slopes by defining a random variable with a uniform pdf over the area of the mound. The pdf of the raised-cosine slope is obtained by defining the gradient of the raised-cosine function as a function of the uniform random variable. Then, the pdf of raised-cosine slopes is convolved with a 2D Gaussian distribution to obtain the pdf of mound slopes. This convolution yields the pdf of the sum of the mound slope and an additional Gaussian slope. This is done because it was empirically observed that the mounds are roughly raised-cosine shaped with additional surface undulations. Because each 30-meter SRTM pixel is comprised of both mounds and sections of flatter ground between the mounds, both surface types must be modeled within each pixel. The pdf of intermediate-scale gradients for the ground between the mounds is a 2D Gaussian distribution. The scattering from this duality of surfaces is modeled as a binomial random process with the incident wave having a probability of scattering from either the mounds or the flat section based on their respective fractional areas. This technique has a significant advantage in computational efficiency over modeling the mounds as discrete scatterers because it eliminates the need to perform complex integrals and to perform Monte Carlo simulations.

High-resolution lidar elevation data are used to validate the model. An airborne survey with a horizontal resolution of 0.3 meters was conducted over the JER. First, sections of lidar data are cropped to match the extent of single pixels of SRTM data. Then, a dynamic thresholding algorithm is used to find the number of mounds in the tile, the mound heights, and the spatial extent of each mound. These data are then used to set parameters in the mound slope pdf of IGOT. Preliminary work has shown promising results in forward modeling predicting CYGNSS observations at a significantly higher fidelity.