A REVIEW OF MODELS FOR POLARIMETRIC THERMAL EMISSION FROM THE SEA SURFACE

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ABSTRACT

Current models for the microwave polarimetric brightness temperature of the sea surface are reviewed. Results from the physical optics (PO), composite surface, and small slope approximation (SSA) theories are illustrated and compared with an empirical model. All models are shown to predict both first and second harmonic azimuthal variations of sea brightnesses, but the physical effects captured are distinct for each model. Both the composite surface and small slope theories are found to show reasonable agreement with empirical results, although some discrepancies exist, while the physical optics model tends to under-predict empirical results.

INTRODUCTION

Polarimetric radiometry has been proposed as an effective means for retrieving wind speed and direction over the sea surface from spaceborne sensors, and plans to include polarimetric radiometers in future satellite systems are in progress [1]. Several models have been proposed for predicting polarimetric emission from the rough sea surface, although these models are all based on approximations in the solution of the electromagnetic boundary value problem. Solutions based on geometrical or physical optics capture emission from surface features which have small slopes and which are large compared to the electromagnetic wavelength [2]-[3], while composite surface (or “two-scale”) [4] and small slope approximate theories [5]-[9] include both long and short wave effects. Higher order implementations of both the small slope and optical theories can be developed and would provide information on convergence of these methods, but the resulting expressions are typically difficult to evaluate for a multi-scale sea surface. Note it has been shown that both the composite and small slope theories provide predictions similar to those of physical optics for long wave features [9].

MODELS

The JPL WindRAD empirical model [10] predicts first and second azimuthal harmonic coefficients of sea polarimetric brightness temperatures as a function of wind speed. The model applies to frequencies 19.35 and 37 GHz, and polar observation angles of 45, 55, and 65 degrees. The 55 degree results are focused on in this paper due to their importance for space-borne sensors.

In the results to be shown, physical optics predictions were obtained by integrating over the Cox and Munk slope distribution for the sea surface [11], and shadowing and multiple scattering effects are neglected. Composite surface model predictions follow the formulation of [4], including the use of a doubled “Durden-Vesecky” spectrum [12], and model the long wave slope distribution as Gaussian. Integrations over the long wave slope distribution were performed using Gauss-Hermite quadrature with 4 x 4 points. Small slope approximation predictions used the second order theory [5]-[6] for second azimuthal harmonic predictions, and the third order theory [8] for first azimuthal harmonic predictions. The doubled “Durden-Vesecky” spectrum was again used, and the long-short wave modulation process described in [4] applied. Of course, all of these predictions are sensitive to the sea surface models included, and continued research in improving these descriptions is of great importance.
RESULTS

Figures 1 through 4 illustrate the comparison of results from the PO, composite surface, and SSA models with the WindRAD model, in all four polarimetric brightnesses. First azimuthal harmonics in Figures 1 (19.35 GHz) and 2 (37 GHz) show that the third-order small slope theory appears to provide the highest level of agreement with the empirical data, but composite surface results are similar. PO predictions under-predict the empirical data, particularly at low wind speeds, suggesting that short wave effects may be important contributors to these results. An asymmetric foam coverage (not modeled here) has also been proposed as an additional source of up-downwind brightness asymmetry [3]. Second azimuthal harmonic results in Figures 3 (19.35 GHz) and 4 (37 GHz) show composite surface and second order small slope theory results are more similar, indicating that “tilting” effects have little influence in the composite model. PO results again underpredict the empirical model. The over-prediction of second azimuthal harmonics at high wind speeds by both the composite and small slope theories is related to the fact that Durden-Vesecky spectral amplitudes do not saturate at high wind speeds.

The results of this paper suggest that short wave effects can be important contributors to sea emission signatures, given the difference between the composite/SSA and PO results. While the comparison with the WindRAD model showed a reasonable level of agreement, continued investigation of the accuracy of all sea emission models is warranted. Higher-order implementations of the SSA are currently under development, and should provide a more rigorous means for evaluating the accuracy of composite and lower-order SSA predictions. Some results with higher order implementations of the SSA and PO theories are available in [13].

REFERENCES


Figure 1: First azimuthal harmonics versus windspeed: 19 GHz, 55 degrees (a) PO (b) Composite (c) SSA

Figure 2: First azimuthal harmonics versus windspeed: 37 GHz, 55 degrees (a) PO (b) Composite (c) SSA
Figure 3: Second azimuthal harmonics versus windspeed: 19 GHz, 55 degrees (a) PO (b) Composite (c) SSA

Figure 4: Second azimuthal harmonics versus windspeed: 37 GHz, 55 degrees (a) PO (b) Composite (c) SSA