ANALYTICAL MODEL OF THE ELECTROMAGNETIC BIAS USING THE PHYSICAL OPTICS SCATTERING THEORY

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1. INTRODUCTION

The electromagnetic bias (EM) is a critical error term in sea surface height estimation from satellite radar altimetry. At present the EM bias models used in current altimetry missions are empirically based and globally-averaged functions of the altimeter-measured significant wave height and wind speed alone. Recent studies have shown that a reduction in the EM bias error variance can be achieved by incorporating ancillary wave model data into the EM bias model. This motivates an improved understanding of the physical mechanisms of the EM bias, so that an optimal means for incorporating ancillary data can be developed.

While the electromagnetic bias has been studied extensively, most previous studies (e.g. [1],[2]) have resorted to low-order hydrodynamic and electromagnetic models in order to express the backscattering radar cross section as a function of surface height. Recently, an alternate approach for EM bias studies has been proposed by Naenna and Johnson based on Monte Carlo simulations of altimeter pulse returns [4]. It has shown that, under the Brown model [3], the EM bias as obtained by Jackson [1] can also be expressed in terms of the normalized first moment of the altimeter time-domain pulse return. The simulation produces a deterministic set of sea surface profiles and the corresponding altimeter pulse returns, thus allows the impact of various physical effects to be investigated by varying the method used to produce the sea surfaces simulated. The Monte Carlo results are reasonable, but hard to interpret. This is because the EM bias is so small that a large number of surface realizations are required for good convergence. As a result, an analytical model is is developed in this presentation to provide physical insight into the EM bias mechanism.

2. ANALYTICAL EM BIAS MODEL

The analytical model utilizes the same formulation as used in the computation of pulse returns in the previous Monte Carlo simulation. Sea surfaces are assumed to be long-crested. The pulse return in the time domain is derived using the physical optics scattering model, and given by [4]

$$P_R = P_T \left\langle \psi_R^*(t)\psi_R(t) \right\rangle \qquad \text{where} \qquad \psi_R(t) = \int_S dS \cos\theta_l \, \frac{G(\theta)}{2\pi\rho} \, e^{-i\omega_0\left(t-\frac{2\rho}{c}\right)} w\left(t-\frac{2\rho}{c}\right) \tag{1}$$

This shows that the received voltage waveform is a sum of individual returns from infinitesimal segments of the surface. Each return waveform has the shape $w(t)$ delayed by the two-way travel time from the antenna to the point on the surface $(2\rho/c)$. The amplitude of each individual return depends on the antenna gain pattern $G(\theta)$ and the cosine of local incidence angle $\cos\theta_l$.

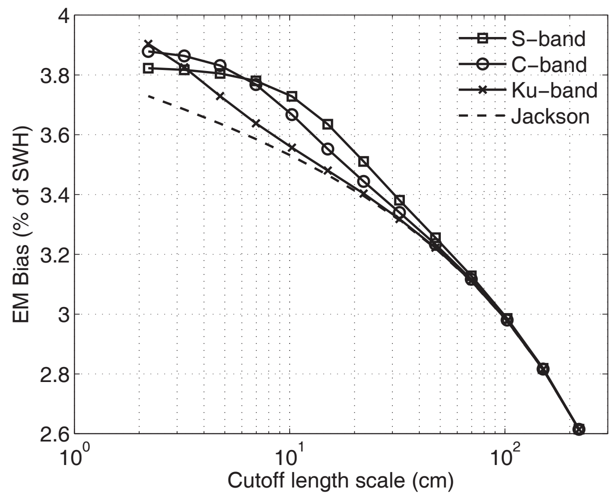

Fig. 1. The EM bias at 8 m/s wind speed as more short waves are included in the surface profiles.

Averaging the pulse returns analytically requires the two-point joint probability density function (pdf). The joint pdf for linear sea surfaces is Gaussian with the rms height and the correlation function as the parameters. For nonlinear sea surfaces, a weakly non-Gaussian random process is assumed, i.e. the joint pdf of two surface points is given by a second-order bivariate Edgeworth series that involves the correlation function and the reduced bicorrelation function of the sea surface:

Under the Brown model, it is possible to express the Jackson's EM bias [1] in terms of the difference between normalized first moment of the average pulse return waveforms from linear and nonlinear sea surfaces [4]. Using this definition with the expression for the altimeter pulse return and the two-point joint pdf, the resulting EM bias involves an integral that contains both the correlation function and the reduced bicorrelation function. It can also be shown that asymptotic evaluation of the integral yields Jackson's EM bias in terms of the height-slope skewness of the sea surface.

3. RESULTS

An examination of short wave effects on the EM bias is provided in Figure 1, where the EM bias in three radar frequency bands is plotted as a function of short scale roughness (i.e. the horizontal axis denotes the shortest sea length scale included in the surface profile). The results show the developed analytical model gives the EM bias that varies with the EM frequency and the short wave surface content. As the radar frequency increases, the EM bias becomes closer to the Jackson's theory.

4. REFERENCES

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