Monte Carlo Simulations of Altimeter Pulse Returns and the Electromagnetic Bias

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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 studies are based on low-order hydrodynamic and electromagnetic models. This study proposes an alternate approach for electromagnetic bias studies by employing a Monte Carlo procedure with numerical non-linear hydrodynamic simulations coupled with numerical methods for electromagnetic scattering from the sea surface. A deterministic set of sea surface profiles and the corresponding altimeter pulse returns are produced in the simulation. The approach allows studies of the impact of various physical effects on the electromagnetic bias including long wave and short wave effects.

Altimeter pulse return simulations involve generation of a set of nonlinear sea surfaces, computation of the near-normal incidence backscattering for each surface profile over a range of frequencies, and transformation of backscattered fields versus frequency into the time domain. Surfaces to be used in the Monte Carlo simulation are generated by two hydrodynamic models: a linear Gaussian random rough surface with an ocean-like Pierson-Moskowitz power spectrum, and a nonlinear surface generated by the "improved linear representation" (ILR) of ocean waves by Creamer et al (1989). The surfaces are assumed to be long-crested and perfectly conducting in order to reduce computational requirements. For the electromagnetic model, the physical optics approximate theory of rough surface scattering is used to compute backscattered fields in the frequency domain. It is expected to provide high accuracy for near normal incidence altimetry studies. The antenna pattern is also accounted for in the computations.

The altimeter time domain returns along with the corresponding surface profiles are examined to study the electromagnetic bias. Clear evidence of the electromagnetic bias (i.e. a shift in the pulse return time) can be observed with the non-linear surfaces apparently originating from a surface shifted lower with respect to the true sea surface. The simulated pulse returns are also in good agreement with the convolution (Brown) model. The electromagnetic bias can be estimated and is found to change with the radar frequency and length scales included in the generated sea surfaces. Studies with varying length scales in particular show the importance of "cutoff" effects in modeling the electromagnetic bias and its variation with altimeter frequency.