Solving the "electromagnetic bias" problem

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The electromagnetic bias, or difference between the mean sea surface height measured by an altimeter and the actual mean surface height, is among the largest sources of error in satellite altimetry. Our research project aims to understand the relationship between the bias and properties of wind waves, and identify parameters which allow more accurate modeling of the bias, so that it can be subtracted from altimeter data.

The goal of ocean satellite altimetry is to provide the sea surface height over the oceans of the earth.
Of course, the sea surface height varies on the scales of centimetres and meters, due to wind driven waves and ripples. It is less well known that the mean surface height (if one were to smooth over the waves) also varies, over tens or hundreds of kilometres. This gentle sloping of the surface is produced by tides, seamounts, and currents. It is these larger scale effects that users of altimeter data would like to study. The problem is, how do we average out the small-scale waves and ripples to obtain the mean sea surface level?

The good news is that some of this averaging is done automatically. The footprint, or illuminated area, seen by the altimeter signal on the sea surface, is much larger than surface undulations due to wind-driven waves. Some of the altimeter's signal arrives a bit early, due to the wave crests, and some arrives later, due to the troughs. By adjusting the instrument to average these arrival times, we can determine the mean surface height over the footprint area.

The bad news is that wind waves are not symmetric: if we compare the surface height to a "sine wave" profile, the crests are sharper, and troughs longer (figure 1).
This makes the altimeter's measured height a few centimetres lower than the height actually obtained if the wind stopped and the waves died out to leave a glassy smooth surface. This error is the "electromagnetic (EM) bias."

Our research project is to understand the physical cause of this bias, and to model it in terms of measurable properties of the ocean surface, such as wind speed and height of the largest waves (the waves a surfer would ride on, also known as "swell", as opposed to smaller ripples). A good bias model would allow altimeter data to be corrected, so that geoscientists would have more accurate surface height information.

There are two approaches to modeling the EM bias. The first, empirical methods, compares results from measurements and experiments to estimate the EM bias for given wind and sea conditions. Empirical models using the wave height and wind speed are the most common models currently in use. The other approach is to create mathematical models using electromagnetic theory.
These theoretical models are improving, but as yet have not been able to be widely applied.

One result of our work so far is that by including a new parameter of the surface waves, the slope of the swell, much more accurate models for the bias are obtained. For altimeter data collected from altimeters mounted on towers, together with surface height data from wave gauges, the bias can be estimated to less than a centimetre. Previous models also work better for some regions of the ocean, and worse for others. Including the slope reduces the error from region to region.

The drawback of this new model is that the slope parameter is not directly available from the altimeter data. We are working on better surface models, which relate wind to waves, and improved electromagnetic models, which relate the altimeter's received signal to the surface height, which will help us learn how to use the data that is available to better estimate the bias. We plan to use computer simulation of the altimeter signal to model the bias without actually having to mount a radar on a tower and collect data. Most bias models are based on the assumption that the ocean surface only varies in one direction. We are investigating two dimensional surface models as well.

Hopefully, with the progress that has been made so far, and a bit more effort, the bias problem can be reduced so that instead of being the largest source of error in altimeter measurements, the bias will become only a minor part of the overall system error budget.

Figure 1: The sea surface profile has sharper crests and deeper troughs than the dashed sine curve. This causes an altimeter to measure a mean surface height that is lower than the actual mean, shown as a horizontal solid line.

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