SEA STATE BIAS IN SATELLITE RADAR ALTIMETRY - REVISITED

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INTRODUCTION & METHODS

Sea state bias (SSB) is an effect in radar altimetry that arises both from the fact that wave troughs are better reflectors than wave crests, and from atmospheric properties, ‘breaker bias’, with similar waveheight dependence, which results in an apparent lower instantaneous sea surface height (SSH) measurement instead of the true height. The classical way to SSB is

\[
\text{SSH}_2 - \text{SSH}_1 = \text{SSB} + \epsilon, \]

where 1 and 2 indicate measurements taken at time 1 and 2 at the same geographical location. SSB is the sea surface height above the ellipsoid that has not been corrected for SSB and is an error term that includes residual geophysical correction errors, altimetric measurement errors and dynamic topography variation between times. Equation 1 can be solved parametrically (Gaspar et al. 1994) or nonparametrically (Gaspar and Flores 1998, Gaspar et al. 2002, Labroue et al. 2004). Here we are using the Konecny Delta as the kernel function. In most studies SSB is solved as SSB = 1/2<SSH>, where 1 is a long term time mean.

RESULTS & CONCLUSIONS

Two key assumptions with this method is:
1. There are enough data that any oceanographic signals at all wave lengths and periods cancel out of the SSB estimate.
2. That <SSH> itself has no SSB in it. Here we explore the implications of the first assumption. To investigate this we calculate SSB parametrically and nonparametrically using significant wave height (SWH) and wind speed (U) from altimetric measurements (Jason-1 during 2001-2004) and SSH from ECCO2 (http://ecco2.org), a high resolution ocean general circulation (numerical) model and run with no data assimilation. ECCO2 SSB comes from a model so has no SSB except for random noise. We will estimate SSB by using the difference between SSH'2 from a time mean (“Direct” method), using a 2 year mean (2003-2004) and a 10 year mean (1997- 2006) and from colinear consecutive cycle differences (CCD). Since CCD has a short time period (<10 days, the time difference between cycles) most oceanographic signals (ENSO, etc.) cancel out of SSB =<SSH>’, the Direct method assumes those signals will cancel out in the mean. Next we added SSB’ by using the parametric coefficients found in Labroue et al. 2004 and added 10% of those results into the ECCO2 SSH’ to calculate the mean.

REGIONAL APPLICATION

The caveat with the CCD method is the loss of points due to the nonparametric method. This raises the question, is this method robust enough to handle small regions where there will be less data? We use SSH data from RADS with SWH still in the data for the regions Latitude -60 to -40 and Longitude 210 to 240 (ACC, blue dots) and Latitude 20 to 40 and Longitude 210 to 240 (ACC, blue dots) and Latitude 20 to 40 and Longitude 180 to 210 (North Pacific, red diamonds) and calculated the nonparametric solutions (fig. 4). We also look at what the SSB is for 1, 2 and 5 year’s worth of data (fig 6a & b). There is a much greater spread of values when only 1 years worth of data is used, making it unlikely that SSB will be recomputed whenever new data is available to make a more reliable solution.

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FIGURES

Figure 1. Correlation of SWH vs. SSH for Direct.
Figure 2. Correlation of SWH vs. SSH for CCD.
Figure 3a. SSB CCD parametric solution in millimeters. Outlined region is the data rich region for NP Direct.
Figure 3b. SSB Direct parametric solution in millimeters.
Figure 4a. Direct, 2 year mean nonparametric solution in millimeters for SSB.
Figure 4b. Direct, 2 year mean nonparametric solution in millimeters for SSB.
Figure 4c. Direct, 10 year mean nonparametric solution in millimeters for SSB.
Figure 4d. Direct, 10 year mean with added error, nonparametric solution in millimeters for SSB.
Figure 4e. Direct, 10 year mean, with added error, nonparametric solution in millimeters for SSB.
Figure 4f. Mean SSB in mm for ACC (blue data and N. Pacific, red data) for 2002-2007, with different temporal scales.
Figure 4g. Percentage of mean SSB from mean SWH for ACC and N. Pacific for 2002-2007, with different temporal scales.

RESULTS & CONCLUSIONS

Direct seems to be introducing SSB, more so with the 10 year mean than 2 year mean; while CCD gives results similar to those inputted.

Parametric Sea State Bias
Parametric solutions were calculated to check the results of the nonparametric solutions were reasonable or not (fig 3a & b).

Nonparametric Sea State Bias
Mean and std of outlined data rich region.
CCD (fig. 4a): mean=0.78 mm, std=53 mm
Direct, 10 yr mean +error (fig. 4c): mean=1.03 mm, std=79 mm
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CCD and Direct look similar to each other. Direct contains more data points so there is better resolution. However CCD is closer to 0 SSB and is the most stable when compared to the two direct methods. The 10 year mean produces the largest SSB and is the most unstable. When an error is introduced into the <SSH'>, it is carried into the SSB results.

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Parametric Sea State Bias
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Nonparametric Sea State Bias
Mean and std of outlined data rich region.
CCD (fig. 4a): mean=0.78 mm, std=53 mm
Direct, 2 yr mean (fig. 4b): mean=0.82 mm, std=74 mm
Direct, 10 yr mean (fig. 4c): mean=1.03 mm, std=79 mm
Direct, 2 yr mean +error (fig. 4d): mean=13.98 mm, std=74 mm
Direct, 10 yr mean +error (fig. 4e): mean=13.6 mm, std=79 mm
CCD and Direct look similar to each other. Direct contains more data points so there is better resolution. However CCD is closer to 0 SSB and is the most stable when compared to the two direct methods. The 10 year mean produces the largest SSB and is the most unstable. When an error is introduced into the <SSH'>, it is carried into the SSB results.