SEA STATE BIAS IN SATELLITE RADAR ALTIMETRY - REVISITED

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MOTIVATION

There are non zero correlations, with distinct geographical patterns, between SWH and SSH-<SSH>, where <> is a two year mean (fig. 1). Correlations between SWH2-SWH1 and SSH2-SSH1 (1 and 2 indicating differences in time) show no regional correlations (fig. 2). This raises the question, when using SSH-<SSH> to calculate SSB, does this method affect the results?

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 instrumental properties ('tracker 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 solve for SSB is

$$SSH'2 - SSH'1 = (SSB2 - SSB1) + \varepsilon, \quad (1)$$

where 1 and 2 indicate measurements taken at time t1 and t2 at the same geographical location. SSH' is the sea surface height above the ellipsoid that has not been corrected for SSB and ε is an error term that includes residual geophysical correction errors, altimetric measurement errors and dynamic topography variation between times (Gaspar et al. 2002). Equation 1 can be solved parametrically (Gaspar et al. 1994) or nonparametrically (Gaspar and Florens 1998, Gaspar et al. 2002, Labroue et al. 2004). Here we are using the Kronecker Delta as the kernel function. In most studies SSB is solved as SSH'2 - <SSH'>, where <> is a long term time mean.

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 2003-2004) and SSH from ECCO2 (http://ecco2.org), a high-resolution ocean general circulation (numerical) model and ran with no data assimilation. ECCO2 SSH comes from a model so it 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 collinear 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 SSH'2-SSH'1, the Direct method assumes these signals will cancel out in the mean. Next we added SSB into <SSH'> 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.

FIGURES

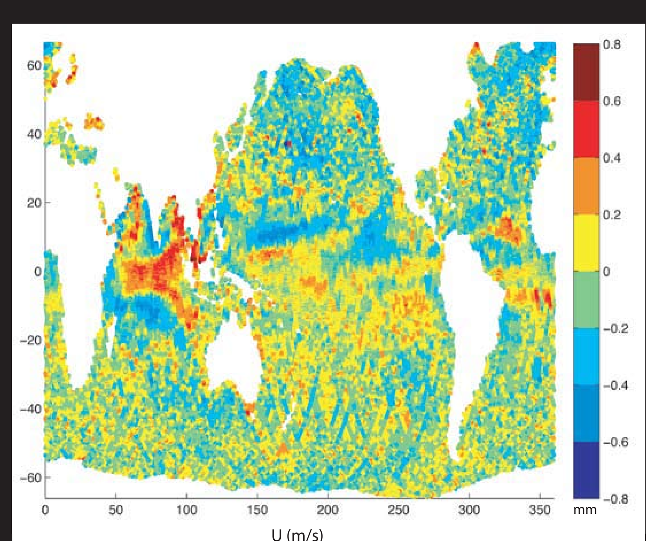

Figure 1. Correlation of SWH vs. SSH for Direct.

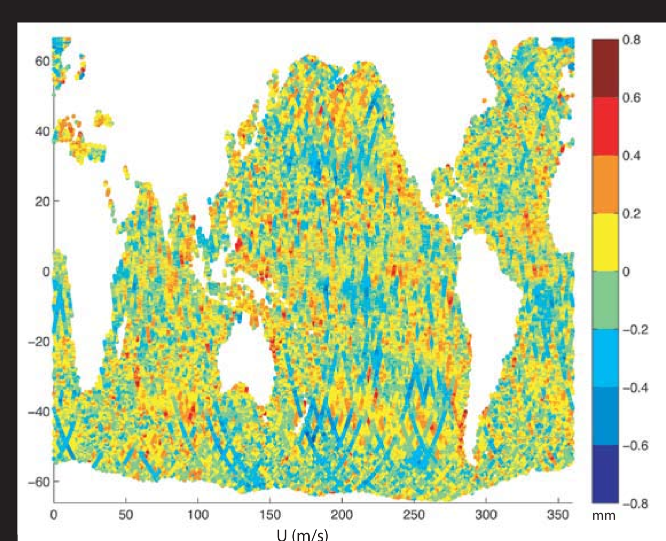

Figure 2. Correlation of SWH vs. SSH for CCD.

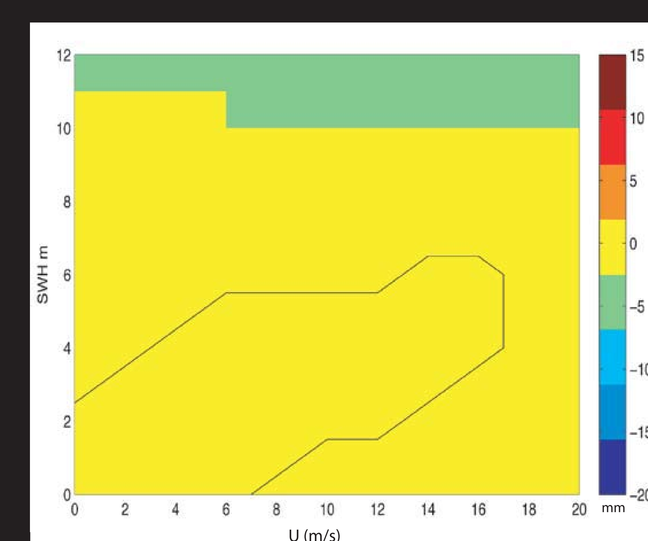

Figure 3a. SSB CCD parametric solution in millimeters. Outlined region is the data rich region for NP Direct.

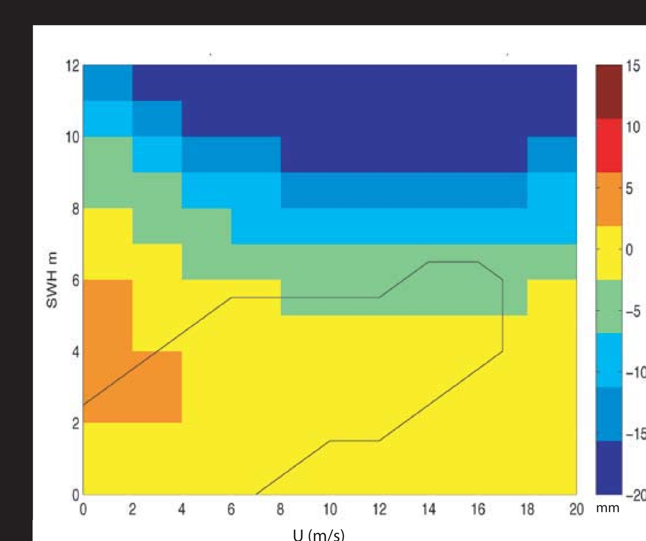

Figure 3b. SSB Direct parametric solution in millimeters.

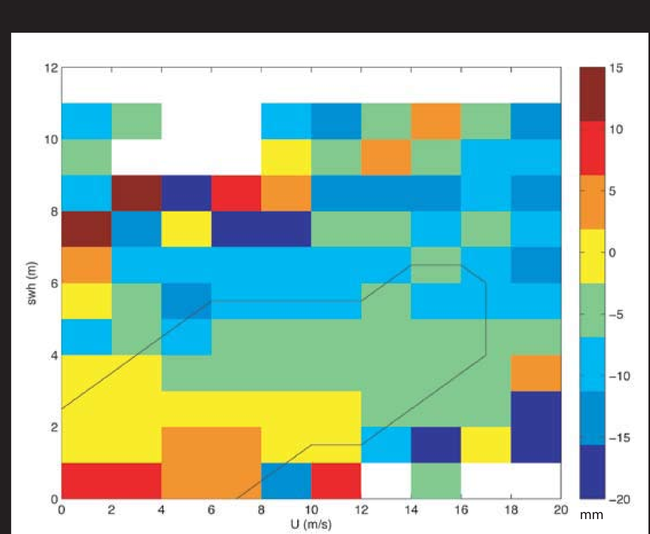

Figure 4a. CCD nonparametric solution in millimeters for SSB.

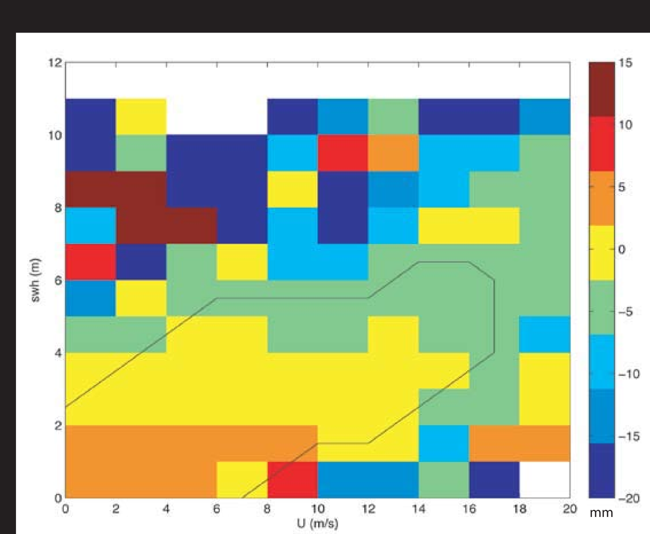

Figure 4b. Direct, 2 year mean nonparametric solution in millimeters for SSB.

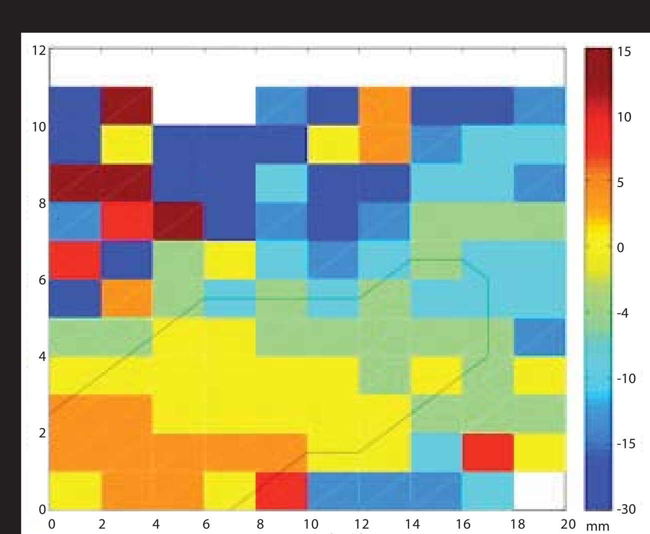

Figure 4c. Direct, 10 year mean nonparametric solution in millimeters for SSB.

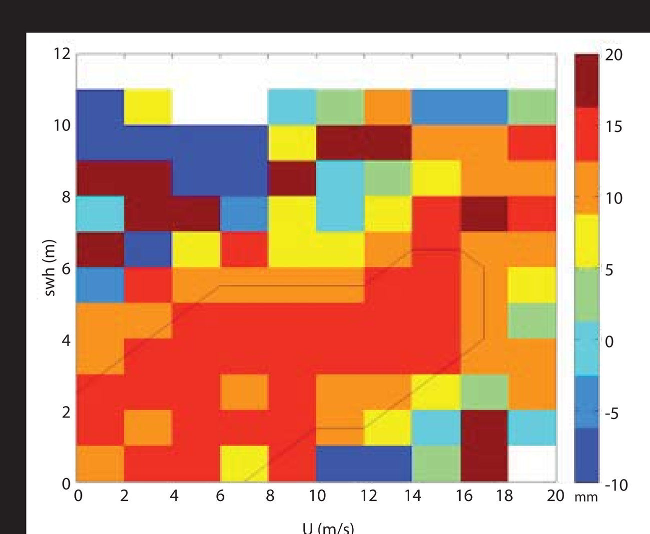

Figure 4d. Direct, 2 year mean, with added error, nonparametric solution in millimeters for SSB.

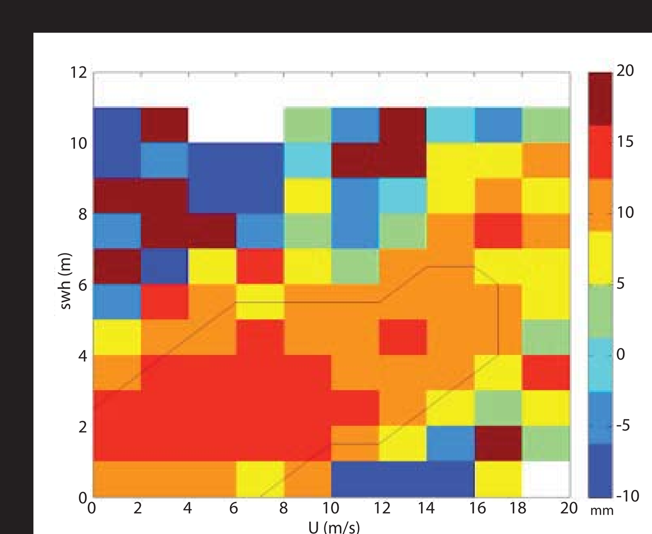

Figure 4e. Direct, 10 year mean, with added error, nonparametric solution in millimeters for SSB.

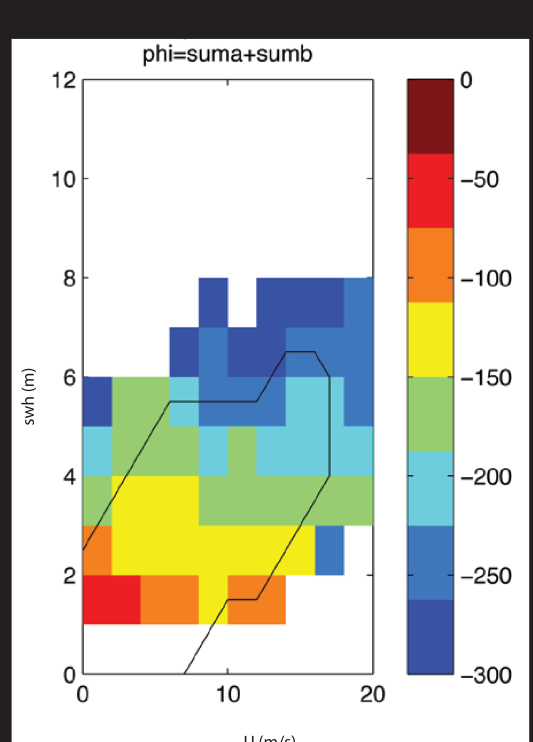

Figure 5a. CCD nonparametric for ACC 2003.

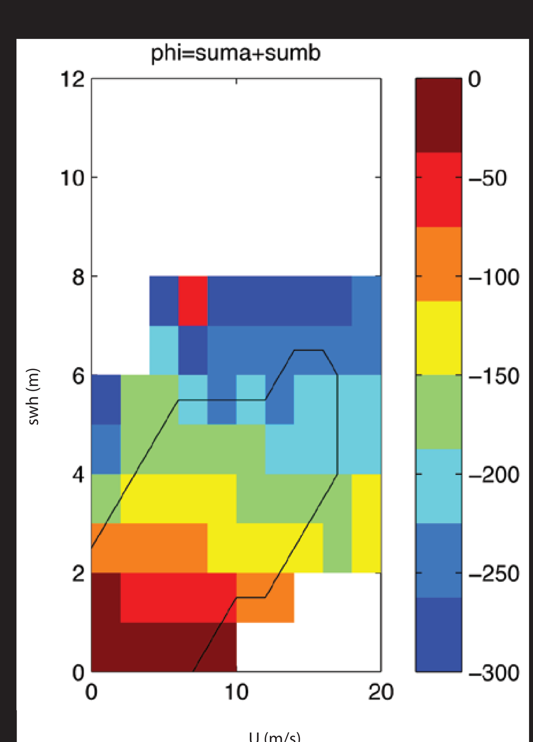

Figure 5b. CCD nonparametric for ACC 2002-2006.

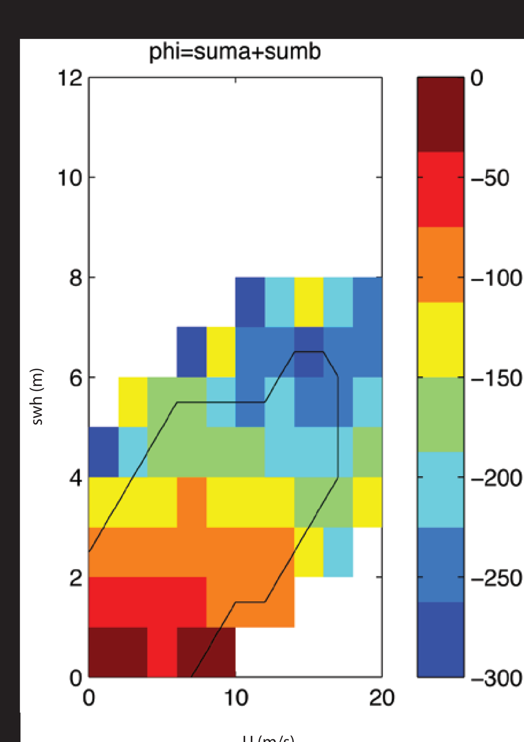

Figure 5c. CCD nonparametric for N. Pacific 2003.

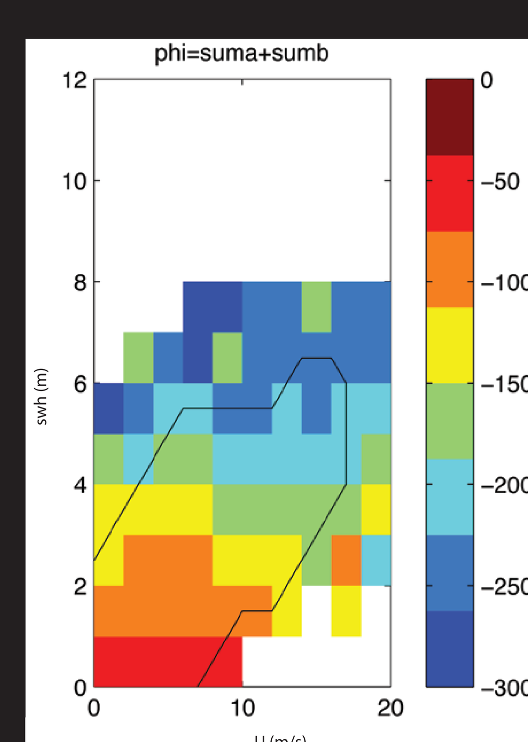

Figure 5d. CCD nonparametric for N. Pacific 2002-2006.

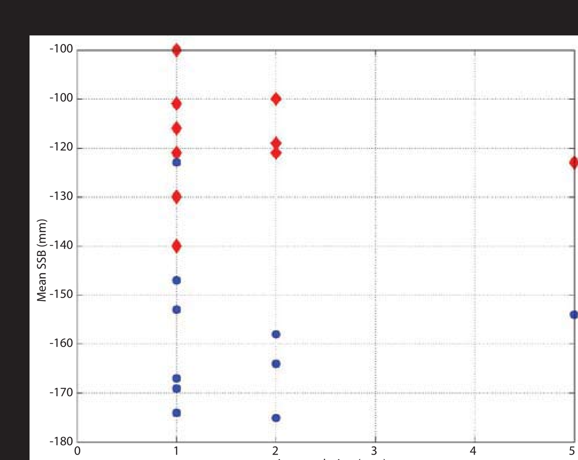

Figure 6a. Mean SSB in mm for ACC (blue dots and N. Pacific (red dots) for 2002-2007, with different temporal scales.

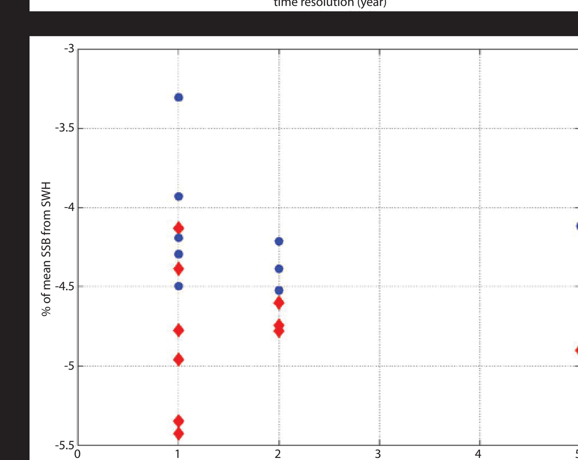

Figure 6b. Percentage of mean SSB from mean SWH for ACC and N. Pacific for 2002-2007, with different temporal scales.

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, 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=12.98 mm, std=74 mm
Direct, 10 yr mean +error (fig. 4c): 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 closest 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.

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 SSB 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 180 to 210 (North Pacific, red diamonds) and calculated the nonparametric solutions (fig. 5). 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 unreliable. The SSB will need to be recomputed whenever new data is available to make a more reliable solution.

ACKNOWLEDGEMENTS

Dimitris Menemenlis provided ECCO2 output, software and various other ECCO2 expertise. Akiko Hayashi provided an along-track grid for the data and helped with Jason-1 data. Monika Kessling made this poster pretty.