Dependence of Altimeter Sea-State Bias Coefficient on the Shape of the Wave Spectrum

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1. Introduction

Altimeter sea-state bias (SSB) is the overestimation in altimeter range measurements caused by nonlinearity of sea surface waves.

Current corrections rely on empirical algorithms:

$$SSB = -\varepsilon\, SWH$$

where the SSB coefficient ε is traditionally parameterised in terms of altimeter SWH and wind speed (U_{10}). Uncertainties remain at around 1% of SWH.

From the Srokosz (1986) SSB theory in 1D, Janssen (2000) derives a formula for the electromagnetic bias in terms of the Phillip's parameter β:

$$\varepsilon \approx -(7/12)\sqrt{2\beta}$$

This formulation will be tested to see whether the Phillips parameter could be used to better parameterise the SSB coefficient.

2. Dataset & Method

Directional wave spectra were obtained from National Buoy Data Centre (NDBC) moored buoys, collocated with Topex altimeter data in three geographical regions characterised by very different wave climates (see Table 1).

The directional wave spectra cover a frequency range of 0.04 to 0.4 Hz in 24 directions. For full integration the spectra were extended to higher frequencies using a Phillips (1958) spectrum (Figure 1). For fitting the tail, spectra were integrated over all directions.

Table 1: Geographical location of buoys.

Location	Buoy ID	# Spectra	Conditions
Gulf of Mexico	42002	185	Enclosed sea
Virginia Beach	44014	134	Mixed seas
Hawaii	51026	64	Open ocean

Dataset was also divided into two subsets:

1. 'Simple' spectra – well-defined spectral peak and high frequency tail
2. 'Complex' spectra – multiple peaks and/or no tail

The tail-fitting method is most consistent for the 'simple' spectra, so that results obtained with these spectra are more reliable that those obtained with the 'complex' spectra.

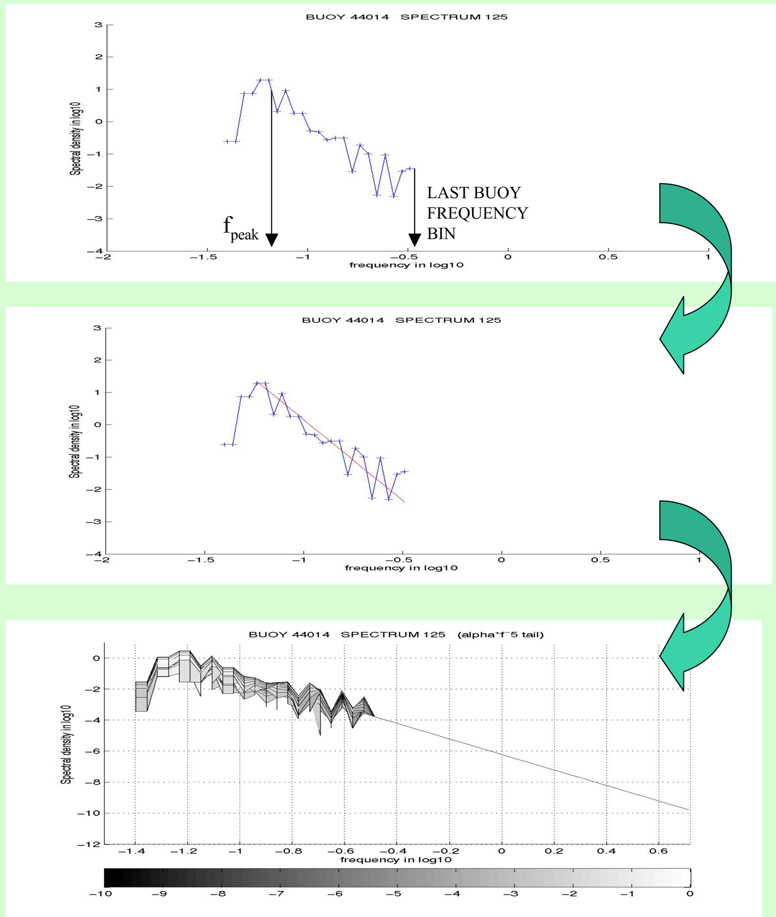

Figure 1. High frequency tail-fitting method.

3. Results

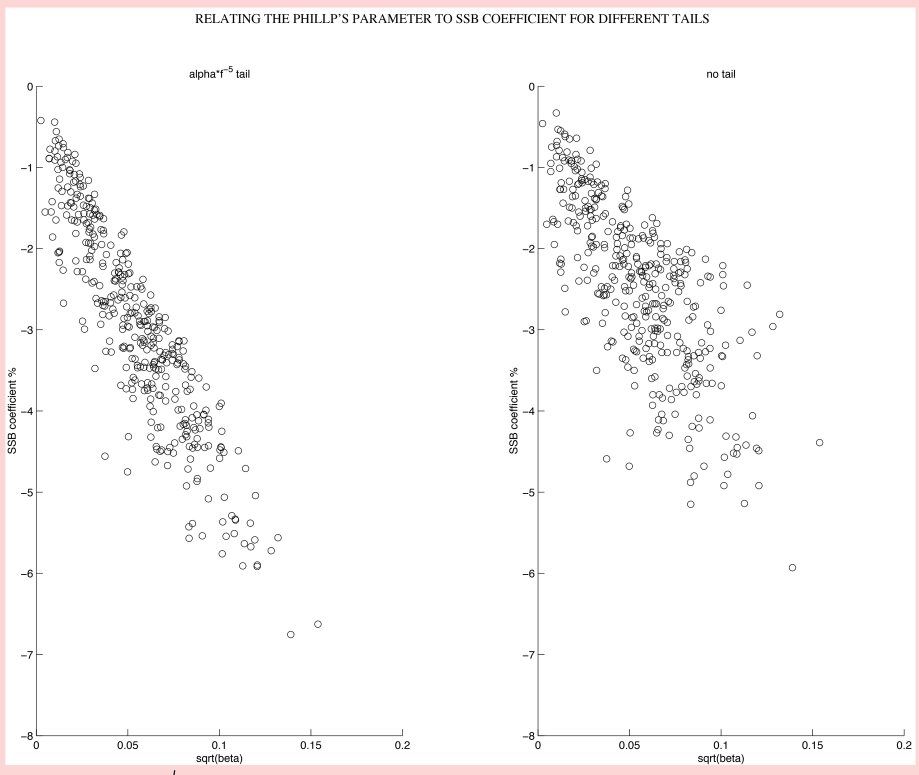

Figure 2. √(Beta) plotted against Srokosz (1986) SSB coefficient for all spectra fitted with (i) Phillips spectrum high frequency extension (ii) no tail extension.

The prediction by Janssen of a linear relationship between √β and the SSB coefficient is correct (Figure 2). However, the 1D Janssen theory overestimates the magnitude of the 2D Srokosz SSB coefficient by almost an order of 2 for high values of β (Figure 3). This is true for all locations and for both sets of spectra.

There is a linear relationship between rms slope and the SSB coefficient, with no difference between buoys in the slope or strength of the relationship (Figure 4).

Figure 5 compares this relationship with that found by Gommenginger *et al.* (2003) and the relationship between rms slope and the SSB coefficient calculated in the no tail case. The amount of scatter and gradient of the relationship differs between tail choices and fitting methods, but the relationship still holds in the no tail case. The tail-fitting method used here is more consistent than that employed by Gommenginger *et al.* (2003), leading to reduced scatter.

A linear relationship is evident between √β and rms slope (Figure 6). There is no difference between locations in the slope of the relationship or amount of scatter.

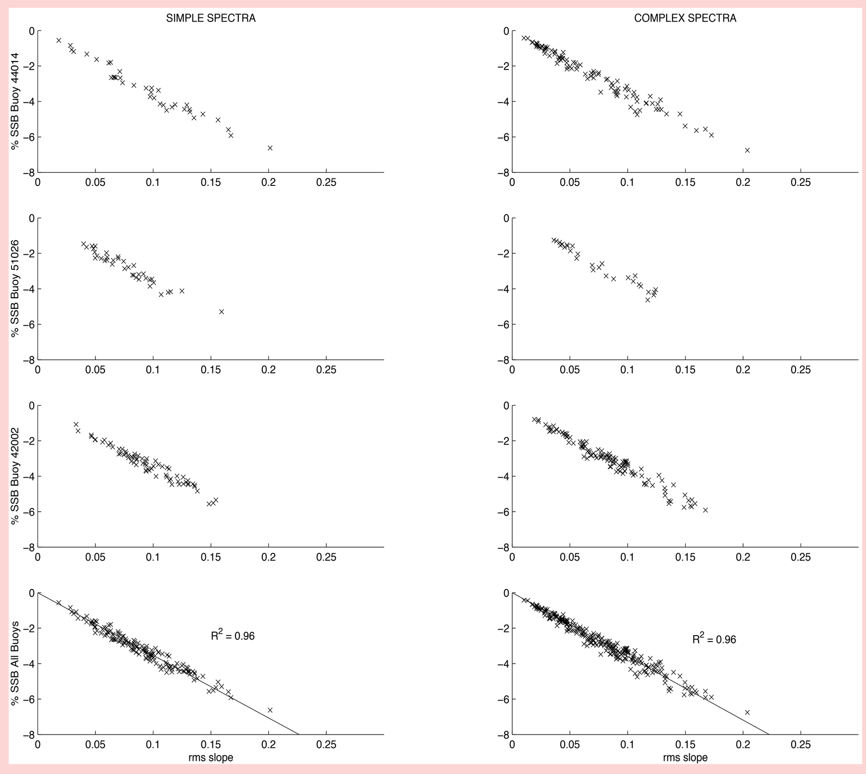

Figure 4. SSB coefficient against rms slope for each buoy for 'simple' and 'complex' spectra fitted with Phillips (1958) spectrum tail.

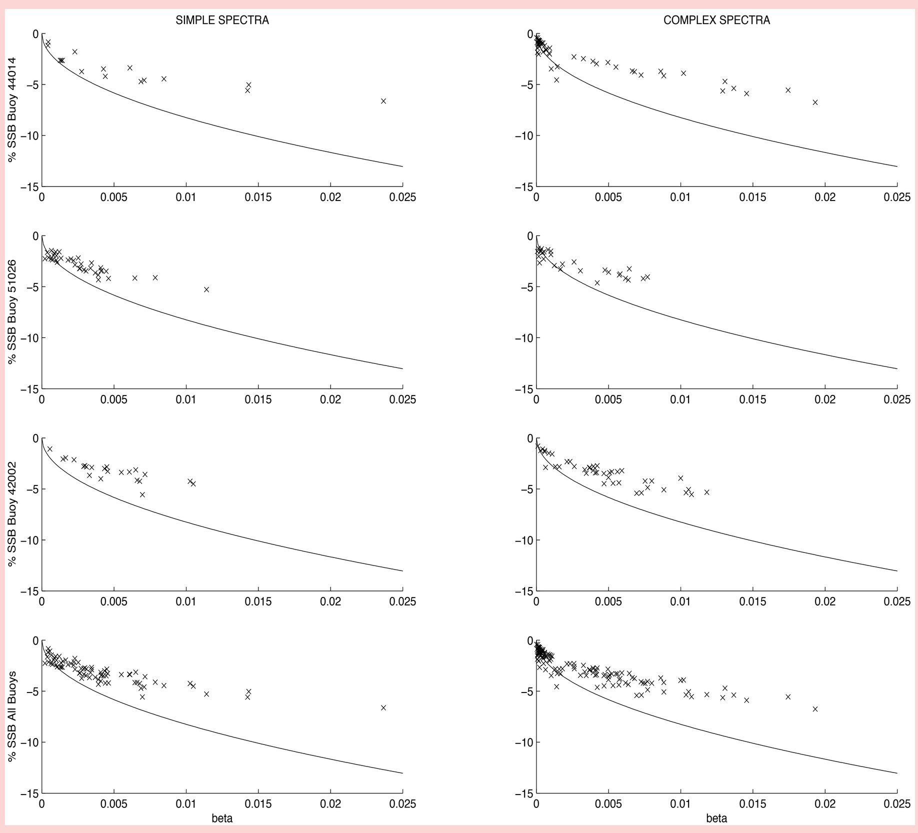

Figure 3. Phillips parameter plotted against SSB coefficient for each buoy for 'simple' and 'complex' spectra fitted with Phillips spectrum tail. Solid line indicates Janssen theory.

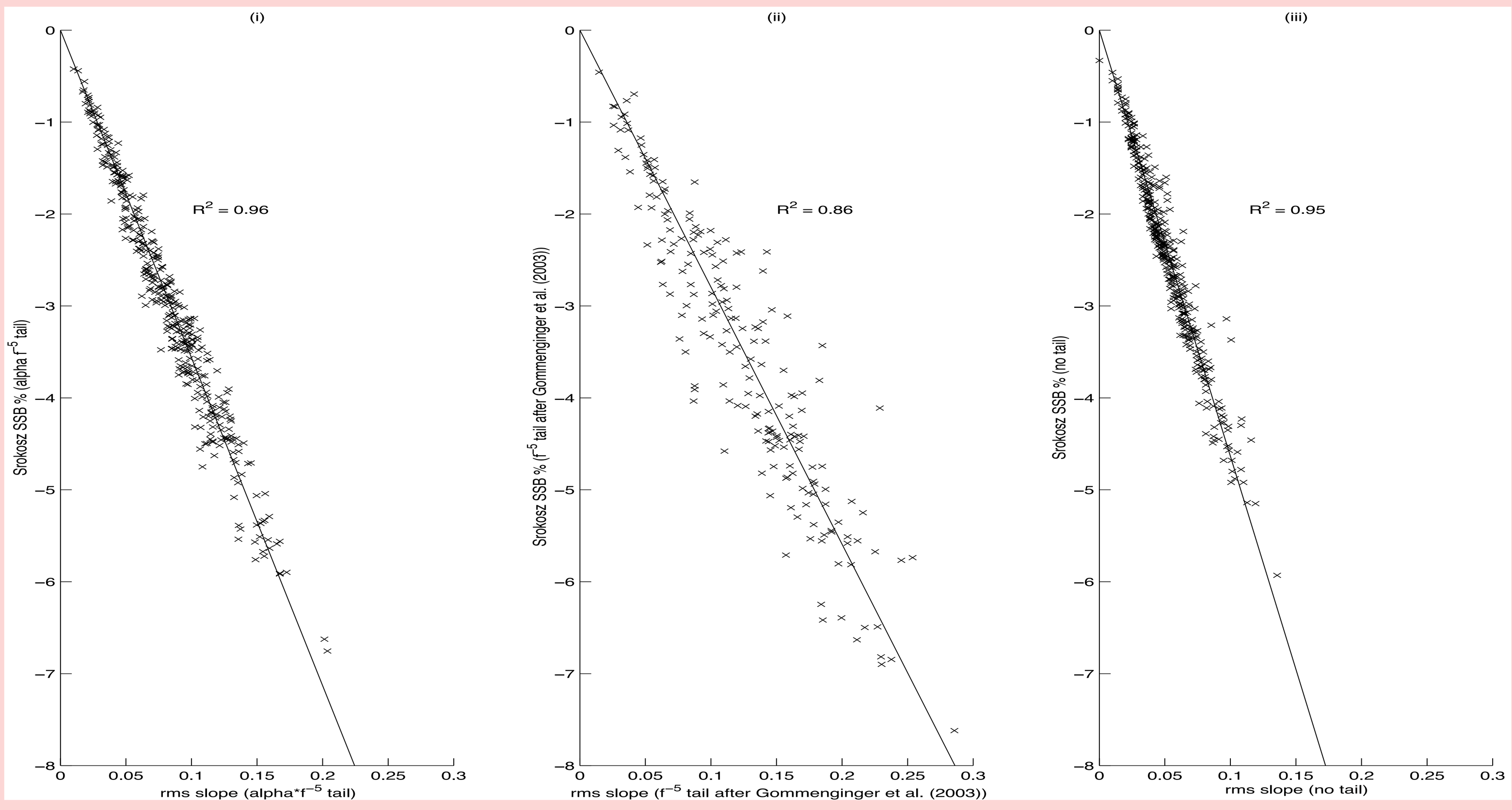

Figure 5. Plot of rms slope against Srokosz SSB coefficient for full dataset for spectra fitted with (i) Phillips (1958) spectrum tail, (ii) f^{-5} tail after Gommenginger *et al*. (2003) and (iii) no tail.

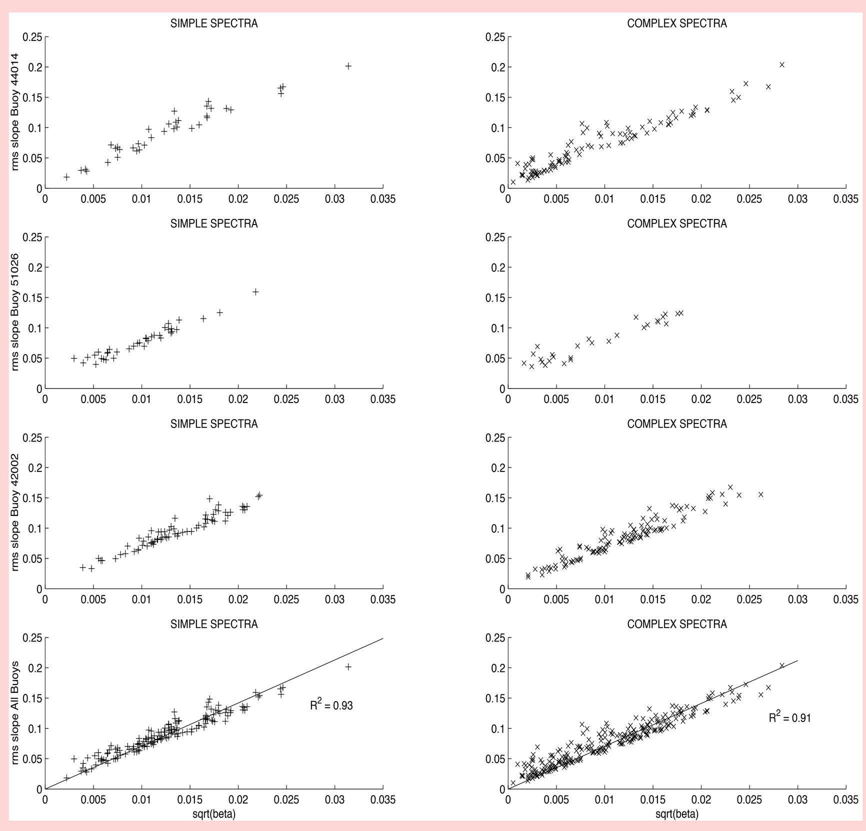

Figure 6. Square root of Phillips parameter plotted against rms slope for each buoy for 'simple' and 'complex' spectra fitted with Phillips (1958) spectrum tail.

4. Discussion

SSB coefficient is proportional to √β:

- As predicted by Janssen (2000).
- Magnitude of the SSB coefficient was overestimated by the Janssen theory. Since the SSB coefficient was calculated from the 2D SSB theory of Srokosz (1986), the difference must result from the reduction to the 1D case in the derivation of the Janssen theory.

SSB coefficient is proportional to rms slope:

- Linear relationship held for all tail choices, probably because the Srokosz (1986) SSB theory is essentially a long-waves theory (Gommenginger *et al.*, 2003), so that changes in energy in the short waves domain have minimal effect.
- The gradient of the relationship is different for each tail choice. This is because the tail choice and fitting method have a large effect on the rms slope calculations, since the k^2 term in the integration required for rms slope emphasises the contribution from large wave numbers (high frequencies).

The rms slope is proportional to √β implying that parameterisation of the SSB coefficient in terms of either would be equivalent.

Greater scatter for the 'complex' than 'simple' spectra. This results from the tail-fitting process being less suitable for the 'complex' spectra and so introducing more noise, rather than because the 'complex' spectra represent some sea state for which the relationships are less valid.

5. Conclusions

Either the Phillips parameter or rms slope could form the basis of future SSB correction algorithms.

Both parameters capture the bias well over a full range of sea states, whereas U_{10} and SWH, which are used in current corrections, fail to do this.

References

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