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Intra-1 Hz Correlations

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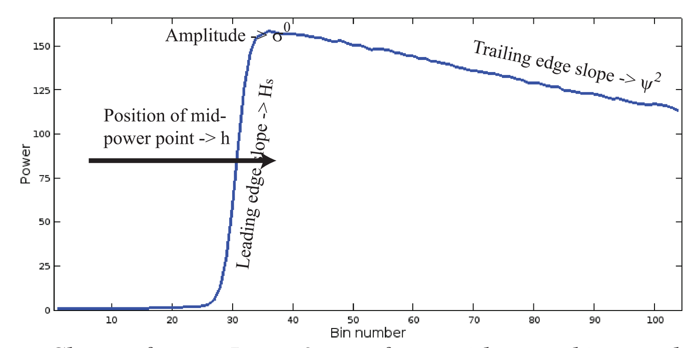
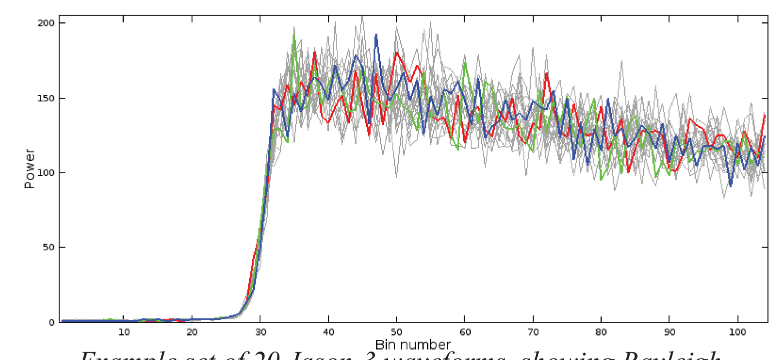
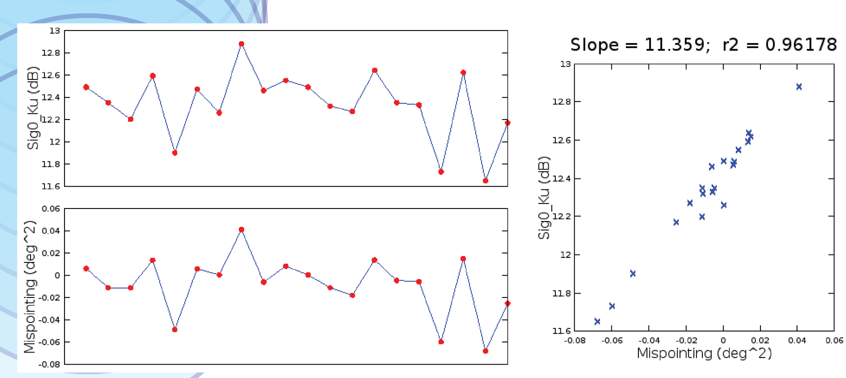
1 - PML ; 2 - NOAA ; 3 - DGFI-TUM



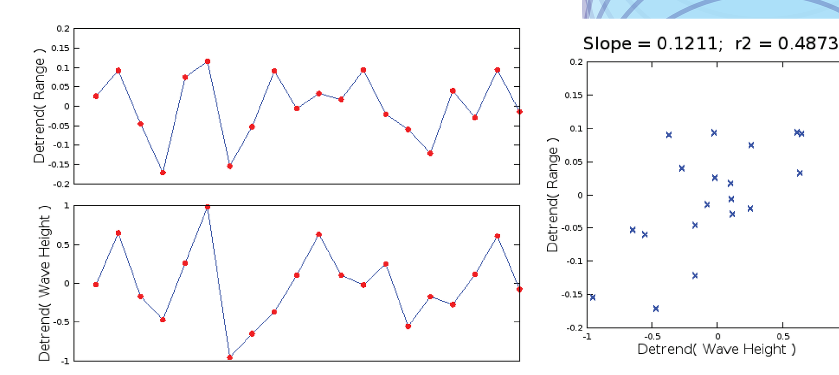
Shape of mean Jason-3 waveform, with retracking used to estimate geophysical parameters.



Example set of 20 Jason-3 waveforms, showing Rayleigh noise (random variations about the mean).



Example of 20 Jason-3 estimates in a 1 Hz record, and a scatter plot of those observations.



Example of 20 Jason-3 estimates in a 1 Hz record, and a scatter plot of those observations. (Note range had to be detrended otherwise it is dominated by an orbit term.)

Introduction

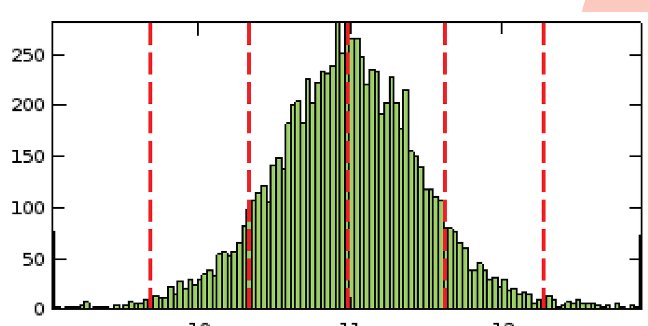
For a conventional radar altimeter operating over a homogeneous surface, the expected shape of a waveform is well known, with various models and numerical algorithms being used to extract the geophysical parameter of interest: epoch (giving range and thus SSH), wave height (H_s), amplitude (σ^0), and, for some, a mispointing angle (termed ψ^2). However, the echo from a single pulse suffers from incoherent summation of reflections from different facets; on-board averaging in groups of 90 produces a shape akin to the Brown model, but with clearly visible Rayleigh (fading) noise. Provided the on-board retracker kept the reception window in exactly the right place, averaging hundreds of these together would give a shape close to the ideal.

However, in many cases, we are interested in the small scale variations of the parameters, e.g. to look at coastal currents, to infer bathymetry, or to study SSH spectra. Consequently all high-resolution geophysical estimates are affected by the Rayleigh noise on the waveforms.

As a number of parameters are determined from the same noisy data, there can be correlations in the biases of these estimates. This poster investigates these correlations and suggests how they may be used to provide better estimates

Improving Sigma0

For the MLE-4 processing algorithm, there is a strong correlation between σ^0 and ψ^2. Quartly (2009) showed that for the initial processing of Jason-2 data, the proportionality constant, α, was 11.34. Thus, a more even series of σ^0 values was given by defining an "adjusted value", $\sigma^0_{adj} = \sigma^0_{MLE4} - \alpha\,\psi^2$. We would normally expect the along-track σ^0 variation to be smooth, as 20 Hz values are spaced every 330 m and correspond to a measurement over a disk ~8km across.

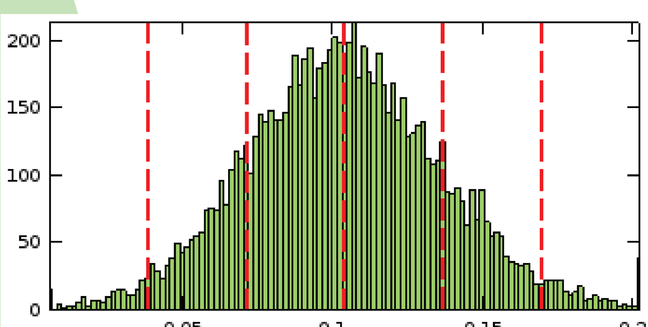


Histogram of proportionality constant for many 1 Hz ensembles.

However, the appropriate value for the current Jason-2 processing, and for Jason-3 is α=11.0. This probably reflects a change in the fitted model e.g. a more realistic representation of the PTR (point target response). Segmenting a according to different wind-wave conditions, we find that it varies slightly with σ^0, being a little higher in very calm conditions.

Improving SSH ?

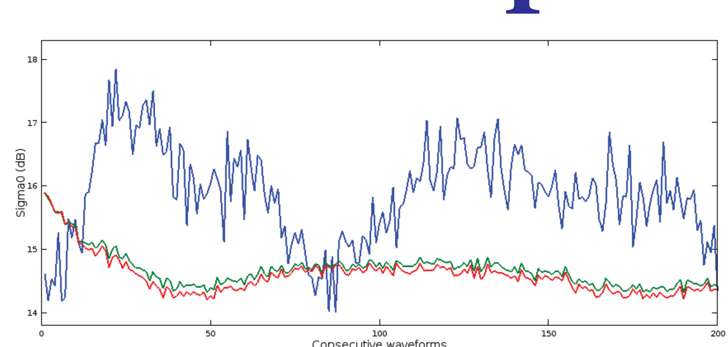
Sandwell & Smith (2005) had shown that retrackers such as MLE-4 produce correlated errors in range and H_s. Both range and Hs are estimated principally from the bins on the leading edge. The range term is rapidly changing, as the altimeter is approaching to or receding from the Earth; thus the correlation is better shown using detrended values. Processing a large number of 1 Hz data shows the constant of proportionality to have a mean (β) of 0.099, but with a wide interquartile range.



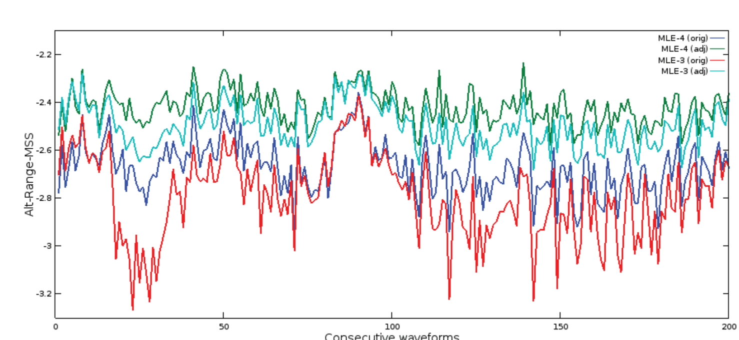
Histogram of proportionality constant for many 1 Hz ensembles. [Note the spread is much wider than for sigma0]

Actually, β varies with the slope of the leading edge, with slightly lower values at low H_s. We can produce an adjusted value for SSH using a variable value for β: $h_{adj} = h_{MLE4} + \beta(Hs).Hs$

Implementation

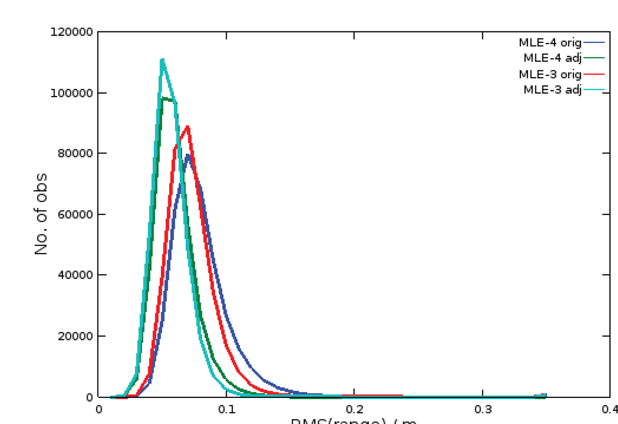


Series of 200 consecutive estimates of σ^0 (blue - MLE-4 ; green - adj. ; red - MLE-3) .

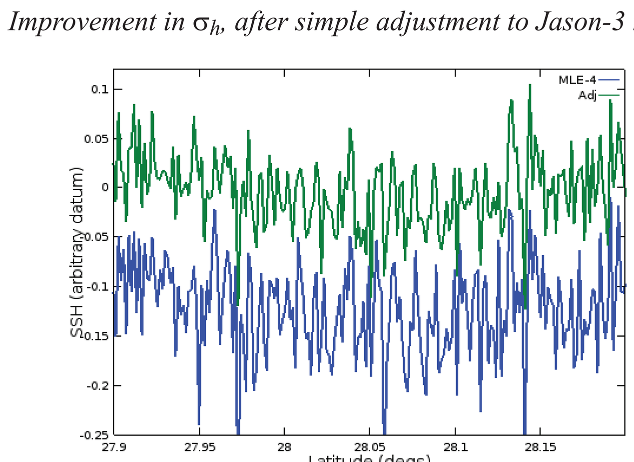


Series of 200 consecutive estimates of pseudo-SSH (blue - MLE-4 ; green - adj. ; red - MLE-3 ; cyan - MLE3 (adj)) .

In the above plots a simple global adjustment is applied -- $\alpha.\psi^2$ or $\beta.H_s$ respectively, leading to smoother more realistic along-track profiles, with absolutely no filtering. In the case of σ^0, the result is almost akin to the output of the MLE-3 retracker, which has a preset value for ψ^2, whereas for range, dependencies are noted for both MLE-4 and MLE-3, and both can be separately corrected, leading to a clear reduction in the 1 Hz values of S.D. (range).



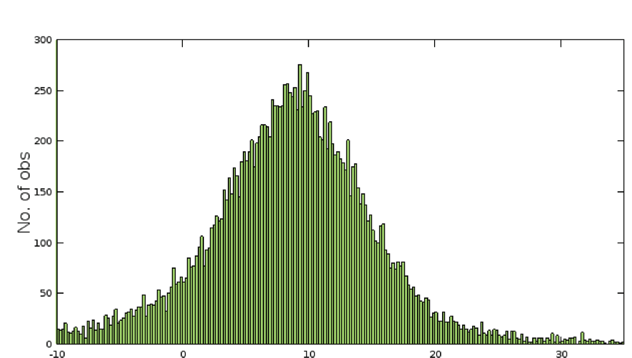
Improvement in σ_h, after simple adjustment to Jason-3 ranges.



Improvement in AltiKa range after simple adjustment. Lines are offset to show reduction in small-scale variability.

Different altimeters

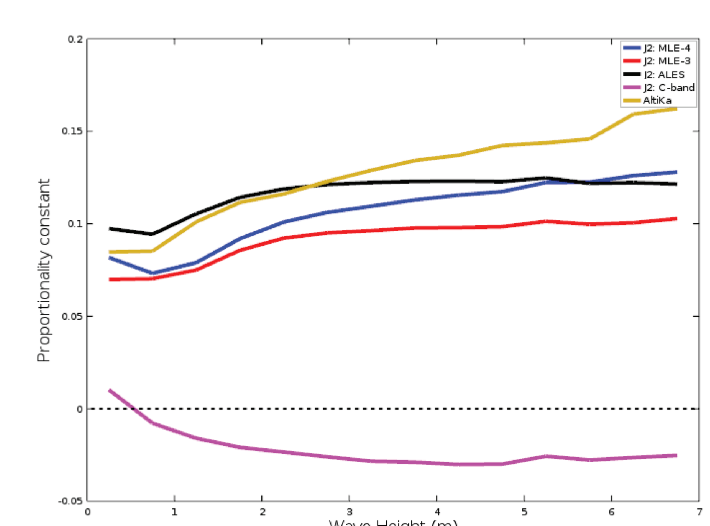
AltiKa, the first Ka-band altimeter, has a different shaped mean waveform, due to narrower antenna beamwidth and shorter reception bins. Unsurprisingly, use of an MLE-4 model shows strong correlations between σ^0 and ψ^2; in this case, α = 8.4. However the spread of values is much wider than for the Ku-band altimeters.



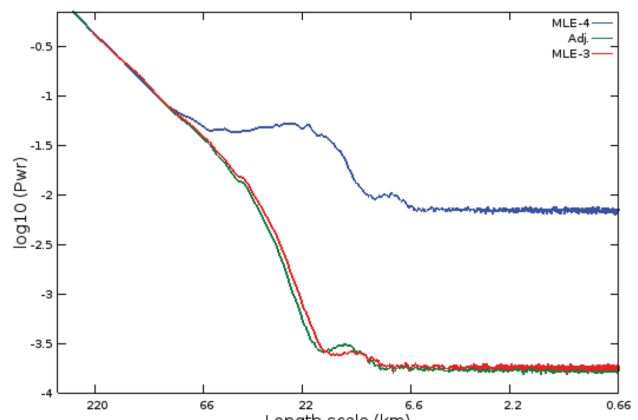
Histogram of proportionality constant for many 1 Hz ensembles.

Different altimeters & retrackers

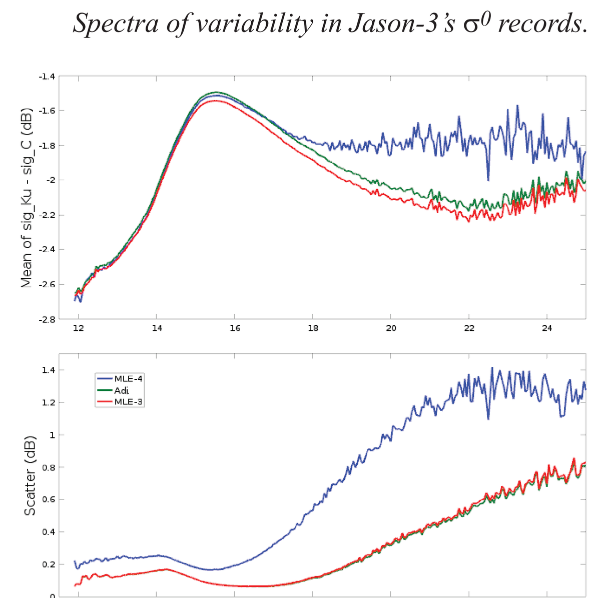
The GDRs for Jason-3 also provide estimates determined using an MLE-3 model. As a different overall set of free parameters is being used, the observed correlation between range and H_s is different (β_3=0.090). The procedure can be applied to other altimeters, different operating frequencies, and with the use of different retrackers. All yield different proportionality constants, showing that this relationship is dependent upon the instrument and the retracker.



Proportionality constant for different altimeter / retracker, shown as a function of H_s.



Spectra of variability in Jason-3's σ^0 records.



Relationship between Jason-3's Ku- and C-band values for σ^0. (top) Mean difference in narrow σ^0 bins (bottom) Scatter (i.e. S.D. about mean)

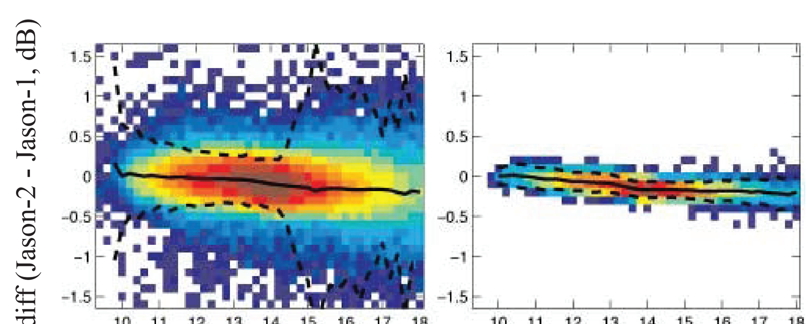
Application

There have been several applications of this adjustment, and it can be applied at 1 Hz, without the need to "correct" all the individual 20 Hz values.

1) Rain-flagging. The dual-frequency rain-flagging (based on the close connection of observations at Ku- and C-band) was unworkable with MLE-4 data. A much tighter relationship was found using σ^0_{adj}; results using σ^0 from the MLE-3 fitter (which does not allow ψ^2 to vary) were almost as good as for σ^0_{adj}.

2) Inter-calibration. Comparison of Jason-1 and Jason-2 altimeters was improved by a factor of 3 once σ^0 values were adjusted.

3) Improved spectra. Power spectra of σ^0 variations are much lower for σ^0_{adj} than σ^0_{MLE4} at short scales. This is achieved on the 20 Hz data without any along-track smoothing.

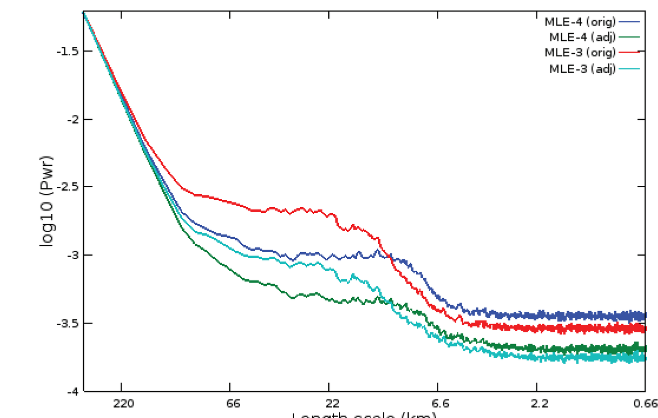


Comparison of Jason1 & Jason-2 σ^0_{Ku} measurements: (left) MLE-4 , (right) Adjusted values. The scatter for the latter is one third of that for MLE-4 values

Applications & Implications

The values for h_{adj} are more consistent than h_{MLE4} (σ_h), have less small-scale noise. What needs to be tested is whether this adjustment improves the agreement between Jason-2 and Jason-3 during their tandem phase. Also, does the reduction in σ_h lead to an increased ability to detect bathymetric features (obtained via double differentiating the SSH values along track)

This applied "correction" changes SSH values by tens of centimetres, depending upon H_s. This is very much a property of the retracking algorithm, and thus corresponds to the "tracker bias" component of SSB (sea state bias). Consequently, if applied for ocean studies, it would need a corresponding adjustment to be made to the SSB correction (which is an empirical adjustment at the large scale).



Improvement in Jason-3 range spectra after simple adjustment. (This corresponds to a redcution of the high-frequency noise component by a factor of 1.7)