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Comment on: "The spatial extent of the Deep Western Boundary Current into the Bounty Trough: new evidence from parasound sub-bottom profiling" by Horn and Uenzelmann-Neben

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Horn and Uenzelmann-Neben (2016) have described computing power spectra from sediment profiler data collected over the Bounty Trough from which they inferred Milankovic cycles. Sediment profiler records are routinely acquired on research vessels, so the method presented is interesting if it can help to resolve different influences on sediment deposits from such data. A significant concern, however, is that attenuation dominates the amplitude variation in profiler data, distorting power spectra computed over the sediment age intervals of interest. In the case of the

Bounty Trough data shown, attenuation appears to have strongly varied amplitudes over the depth range commensurate with the first 41 ky Milankovic cycle, so the article's result is less certain than claimed. Attenuation rates can vary spatially (both along track and with depth) so evaluating cycles will not be straightforward without ground truth from boreholes, which potentially diminishes the utility of remote-sensing data. Nevertheless, while not separating attenuation and reflectivity unequivocally, alternative displays of such data as explained below can help to suggest the relative importance of attenuation and reflectivity on amplitude variations.

The frequency analysis software of Schulz and Stattegger (1997) used by Horn and Uenzelmann-Neben (2016) was originally designed to find periodic variations in data series in the presence of noise. Aside from a single peak at ~14.5 m, the amplitudes shown in Figure 5a of Horn and Uenzelmann-Neben (2016) decline sharply within the first 13 m below seabed. Amplitudes below 13 m are generally less than 10% of the maximum amplitude. Figure 1 shows a compilation of attenuation measurements, updated with data from Tyce (1981), who derived sediment attenuation rates at 4 kHz (the frequency of the data of Horn and Uenzelmann-Neben (2016)). He measured attenuation rates of 0.19 to 0.63 dB m^{-1} in hemipelagic turbidites and other layered sediments broadly comparable with those of the Bounty Trough. To illustrate how reflection data would be affected, at 0.2 dB m^{-1}, a halving of amplitude (a change of 6 dB) occurs over 30 m. At 0.6 dB m^{-1}, a halving of amplitude would occur over 10 m. Given the decline in the Bounty Trough data to only 10% of peak amplitude within 13 m, the attenuation coefficient may be locally extreme, perhaps even >2 dB m^{-1} (this is itself interesting as such high attenuation rates at 4 kHz would commonly be associated with sands, not the silty clays mainly found at Ocean Drilling Program

Site 1122 within the study area of Horn and Uenzelmann-Neben (2016), although turbidites within these units contain some sand and the laminated structure may cause unusually high transmission loss).

An effect of attenuation can be observed in Figure 2, which shows the average of six traces of Chirp sediment profiler data collected in the central Red Sea (Mitchell et al. 2015). These data were collected with a system with frequency swept over 2-7 kHz. They reveal prominent reflections in an area known to have climatically modulated sediment properties (during sea level lowstands of the late Pleistocene, the sea became more isolated and saline, leading to deposition of rigid aragonite-rich layers (Gevirtz and Friedman 1966; Milliman et al. 1969; Stoffers and Ross 1974)). The pair of reflections within R1 was produced by the surface of the Last Glacial Maximum sediments and by overlying Holocene sediments, while R2 to R5 represent reflections from deeper lowstand deposits.

The data have been plotted in Figure 2 with amplitude on a logarithmic scale. Attenuation reduces amplitudes exponentially with propagation distance if attenuation coefficient is uniform, so the logarithm of amplitude would be expected to be linear with depth. Here, these data indeed show, below R1 (which has exaggerated amplitudes because of contrast of sediments with low-impedance water), a systematic variation with further two-way time. The straight dashed regression line fitted to the data shown implies an attenuation coefficient of 0.34 dB m^{-1}, assuming sediment velocity of 1500 m s^{-1}. This coefficient is potentially over-estimated because progressive compaction with depth tends to reduce density and velocity contrasts (reducing reflection amplitudes with depth), although 0.34 dB m^{-1} is compatible with other attenuation data on similar sediments for this 2-7 kHz frequency band (Figure 1).

The red line in Figure 3 shows the amplitude data superimposed with the attenuation trend (dashed red line). The blue line shows the effect of de-trending the data using the regression line in Figure 2 and converting the logarithmic de-trended data back into amplitudes. The principal trend in the red data is caused by the attenuation, while the de-trended data have a more episodic variation more likely to reveal periodicities if the data two-way times were transformed to sediment age. The corresponding power spectra computed using the "spectrum1d" module of the Wessel and Smith (1991) software shown in Figure 4 illustrate how dramatically spectra can sometimes differ when computed with and without de-trending.

A preferable analysis procedure would therefore be to plot log(amplitude) versus two-way time or depth. If such plots are linear, this may imply a uniform attenuation rate, which can be evaluated against other attenuation measurements as above. Even if plots are not linear, the attenuation component of any variation could be assessed knowing the range of attenuation coefficients to be expected of the target sediments. Where de-trending appears worthwhile, it also unfortunately enlarges noise with increasing two-way travel time, which produces unwanted effects on power spectra. However, noise effects could potentially be reduced by fitting periodic functions to the data series (Fourier transforming) with weighting to account for signal-to-noise ratio varying with two-way time. Interpreting sediment profiler records in terms of Milankovic cycles is likely to be complicated, but the basic step of plotting the data logarithmically as in Figure 2 may help to reveal whether variations in profiler data along tracks are genuine variations in reflectivity or are artifacts of varied attenuation.

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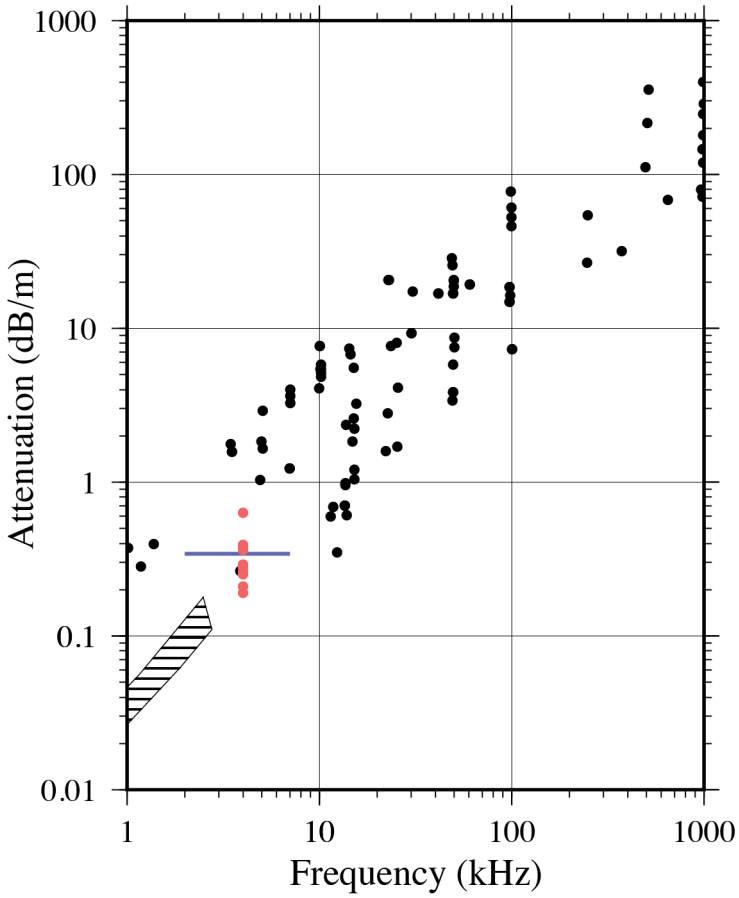

Figure 1. Attenuation coefficients of marine sediments from Mitchell (1993), with data originally from Hamilton (1980). Attenuation values for finer grained sediments tend to be smaller and values for sand grade sediment higher at a given frequency. Blue bar represents attenuation coefficient of 0.34 dB m^{-1} over 2-7 kHz range for the Chirp data in Figure 2. Red circles represent attenuation measurements made by Tyce (1981) at 4 kHz using data collected with the Scripps Deep Tow over the Southern California Borderland (terrigenous sandy silt to clayey silt) and Rockall Trough (hemipelagic turbidites with silty clay with silt and sand layers).

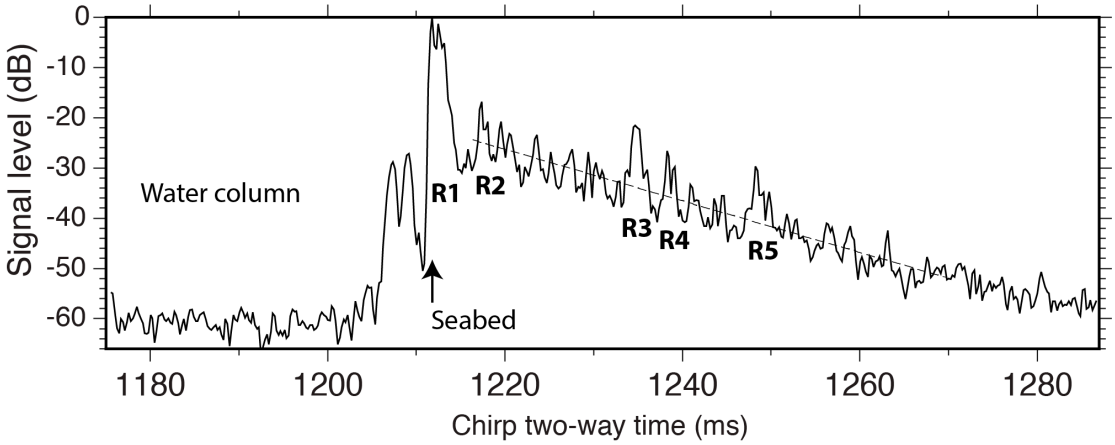

Figure 2. Chirp data amplitudes (average of 6 traces) collected in the central Red Sea (data corresponding to Figure 9 of Mitchell et al. (2015)). Amplitudes are plotted in decibels relative to the seabed reflection amplitude (i.e., $20\log_{10}(A/A_0)$, where A is the data amplitude and A_0 is the seabed reflection amplitude). Dashed line is simple least squares regression used to quantify the systematic trend in the data over the extent of two-way time covered by the dashed line. R1 to R5 are prominent reflections referred to in the text.

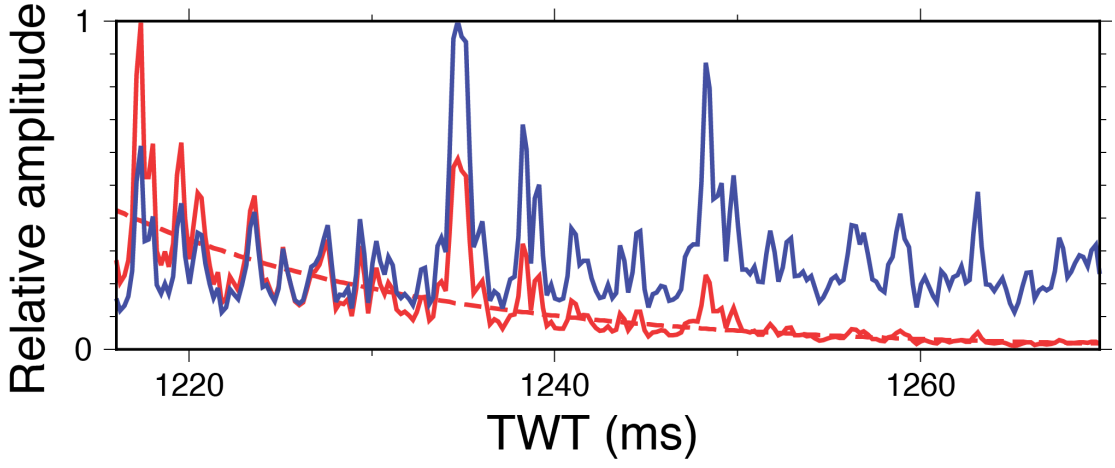

Figure 3. The data of Figure 2 plotted as linear amplitudes (red) and the result of de-trending (blue). Dashed red curve shows the regression line of Figure 2. Amplitudes are shown relative to maximum amplitude.

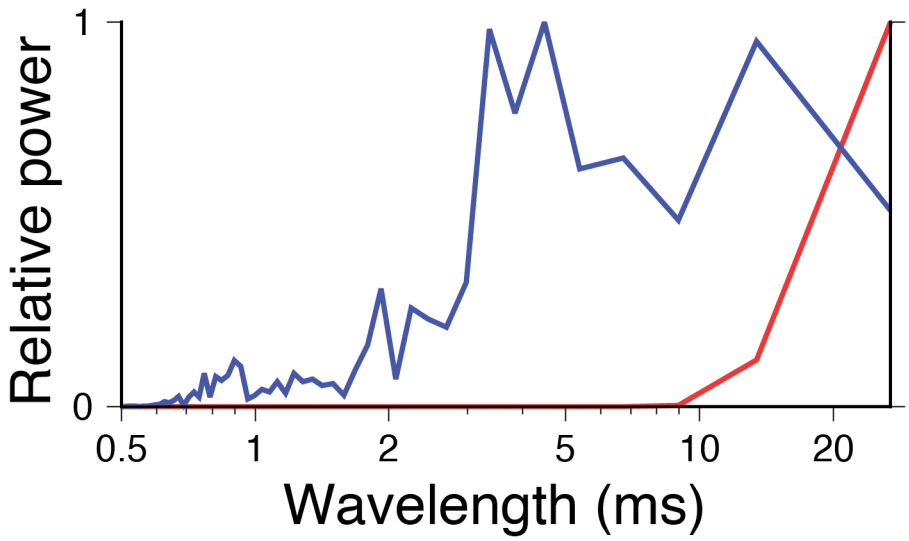

Figure 4. Power spectra computed from the data in Figure 3 (line colours correspond with those in Figure 3).