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Interactive comment on "Abyssal plain hills and internal wave turbulence" *by* Hans van Haren

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»>I thank the reviewer for the time taken to comment my ms. Replies are behind »>

The author uses a line of high-resolution temperature sensors to find the interaction between small scale internal waves and large-scale shear near the bottom. Owing to the existence of internal waves and their breaking the stratification exists in thin stratified sheets and thicker layers between them. A highly variable near-bottom turbulent zone was found. Occasional solitary waves uplift the isotherms.

I know from the publications by van Haren that the NIOZ temperature sensors (many of them in a vertical line) are an important tool to study small scale processes in the ocean (line 169). »>Thank you for the appreciation, indeed the near-bottom zone is highly variable in turbulence.

Thank you for reporting on this interesting data set. The paper deals with an observed high-resolution temperature timeseries above an abyssal hill region. It describes internal wave, stratification, overturn, and estimated mixing aspects, as derived by frequency spectra, Thorpe scales, and exemplary showcases. Important points of outcome are a diagnosed relatively intense mixing, particularly in the bottom boundary layer (BBL), as well as a proposed mechanism causing this (internal waves propagating from above into a marginal stable bottom boundary layer and triggering instability).

The data set is unique and from an interesting setting between steep and smooth topography, and away from mainstream focus. It merits to be publicly visible, although in the present form I would not recommend to publish the paper. The two main reasons for that are reproducibility, and a possible flaw in the Thorpe scale analysis that would depreciate major results of the paper. »>Indeed, the abyssal hills areas are not generally studied. What does the reviewer mean by 'reproducibility'? As outlined in the previous version, and below, there is no flaw in the analysis as the reviewer suggests. It is stressed that the moored chain of high-resolution T-sensors is not the same as 'standard' shipborne CTD profiling.

Reproducibility: a range of results which are specified in the abstract and conclusions sections are not based on data analysis by objective methods or are not treated in the results or discussion sections (a methods part is entirely missing). E.g.: - The coupling mechanism/interaction/interplay between internal waves above the bottom boundary layer and their effects within the BBL. - Sediment resuspension. - Internal wave breaking to be the dominant cause for forming the BBL. - Evidence for the occurrence of fronts and solitary internal waves. - Asymmetric turbulent erosion of stratified layers. - Abundances of overturns. - Turbulence to be caused by both shear instability and convection alike. »>I am puzzled what is meant here. A methods part is not at all missing! Yes, a section named 'Methods' did not exist in the previous version, but data handling was (and is) described: Section 2 Data, and Appendices A and B gave/give instrumental and methods details. Section 2 is now elaborated somewhat (re. the comment below) and it is now called 'Methods and data handling'. I refute that specifications in abstract and conclusions are not treated in the results and discussion sections. I do not recognize the general summing up given by the reviewer. It would have been helpful if clear examples from the manuscript were given (e.g., by indicating line-numbers). Nevertheless, I have reread the manuscript and (tried to) clarify where necessary. It is noted that this is an observational paper that hopefully triggers analytic and numerical modelling to better understand the relevant processes.

Thorpe scale analysis: There is a striking pattern in the calculated Thorpe displacements, indicating a very frequent and long-lasting 50m overturn at the lowest 50m. I assume this is an artefact, because the temperature gradient is often at or below 0.5mK/50m, and sensor noise and uncertainty are comparatively high. In such a constellation of a very low density gradient like in the BBL, noise/uncertainty will cause spurious overturns and overestimated displacements, leading to overestimated mixing through Thorpe scale analysis [Piera et al., 2002; Johnson and Garrett, 2004]. The diagnosed intense mixing in the bottom 50m is at the base of major results of the paper: the increasing turbulence with depth, intense near-bottom mixing, and the explanation for the intense near-bottom mixing by internal waves which trigger overturns in a marginal stable regime. Given the importance of the intense bottom boundary layer mixing for the paper, a critical review of the appropriateness of the used Thorpe scale processing should be a central part of the methods. If the existence of a quasipermanently overturning 50m-bottom-layer should prove true, this as well should be a central part of the discussions. »>I like to stress that the string of T-sensors is not a shipborne CTD, for many reasons. The mooring hardly moves, the 400 m profile is made within 0.02 s (instead of lowering a CTD-package at a speed of 0.8-1 m/s never making a correct vertical profile), such 400 m profile is made every 1 s providing many profiles to average over the buoyancy scale of one hour or more instead of a single CTD-cast, the observations are generally made in relatively high Reynolds number areas where the temperature density relationship is tight, and the NIOZ T-sensor have very low noise level about one-third of that of SeaBird 911 T-sensor. The two quoted papers focus on noise by shipborne CTD, a completely different way of measuring than moored NIOZ-T (as Johnson and Garrett 2004 indeed indicate in their concluding remarks: noise problems may be very minor compared to other problems with shipborne CTD-data; Re: J&G2004 indicate underestimating of turbulence by noise, not overestimating). Ii is reminded (as was indicated in the text) that the resolvable dissipation rates by the moored T-sensors averaged over a 100-m vertical range is approximately 3ïĆť10-12 m2 s-3, much lower than resolvable by CTD (and generally much lower than dissipation rates observed in the lower 50 m of the range). This all is now made more explicit in Section 2, and with noise level panel added to Fig. B1. As for the turbulence in the lower 50 m of the range: no it is not quasi permanently, but slowly varying with time, dominantly on half the inertial period and on sub-inertial periodicities and sometimes on shorter timescales, as indeed indicated by this reviewer in the top-paragraph of this review. The text on this is all reread now and made more explicit where necessary.

Further remarks: - Given the reported numbers N = 5.5 * 10 ËĘ -4, S = 1.6 * 10 ËĘ -4 (lines 254 to 258), the average Richardson number in the BBL seems rather 10 than unity. This would not support the assumption of the BBL being systematically marginally stable. »>In the mean yes, but not in variability. It would have been better if current/shear observations were available over length scales of the thin layer stratification, but no such instrumentation was available. It was not clearly stated it was not to be systematically marginally stable ‘to occur regularly’ (now added ‘in bursts’).

- Can you make clearly understandable why the given arguments (lines 189 to 192) allow to choose a mixing efficiency parameter m of 0.2? »>It is following the works of Osborn, Dillon and Oakey (and many thereafter): after averaging over suitable number of profiles, length and time scales, this is the mean value to be found for mixing efficiency. Internal waves not only induce turbulent mixing by their breaking but also allow for rapid restratification making the mixing rather efficient.

- I’d propose to more prominently place the particular results for the abyssal hill region in the larger context of the limiting cases ’steep topography’ and ’smooth abyssal plain’

»>OK, done now, with the restriction that in my view a smooth abyssal plain hardly exists: there are always topographic features; it's merely a matter of scale.

- data availability is not stated »>Done now

References: Piera, Roget, Catalan (2002): Turbulent patch identification in microstructure profiles: a method based on wavelet denoising and Thorpe displacement analysis, J. Atm. Oceanic Tech., 19, 1390-1402 Johnson and Garrett (2004): Effects of noise on Thorpe scales and run lengths, J. Phys. Oceanogr., 34, 2359-2372

Please also note the supplement to this comment:
https://www.biogeosciences-discuss.net/bg-2018-142/bg-2018-142-AC2-supplement.pdf

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