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Ocean Science Discussions

Interactive comment on "Wave-turbulence scaling in the ocean mixed layer" *by* G. Sutherland et al.

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Reviewer Comments

The paper would need some efforts. I am quite sure the data and exposition of the results are of interest for the community. Yet, the abstract and conclusions are quite misleading. As it is mentioned turbulent kinetic energy dissipation rate is analyzed to be quite consistent with a wind shear-driven wall layer, but also that many profiles rather scale with a Stokes-driven shear. After reading the analysis, it is clear that the experiment spanned a period of veering wind and waves, and it is certainly a bit delicate to conclude without properly trying to separate the residual sea from the local wind-driven sea. I would suggest to try to possibly use numerical directional wave spectra, constrained by the 1D-spectral measurements. The authors further seem to avoid to analyze the fact that the mixed layer is rapidly evolving. It would be very in-

teresting to study and test in more details the consistency between the time evolution and levels of wind, waves, and measured TKE with the observed mixed-layer erosion and deepening. Accordingly, and given the apparent high quality data sets, this more thorough analysis would possibly help to more quantitatively assess the role of variable atmopheric forcing, waves and related Langmuir circulation, compared to standard parameterization, in such a rapid and well observed deepening process. Finally, the authors state that integrating the TKE over the mixed layer yields results that 1% of the wind power referenced to 10m is being locally dissipated. Again, given the rapid time evolution of wind, TKE, and mixed-layer depth, idealized models can be used and questions be addressed concerning the overall transfer of momentum (and possibly heat) to erode the base of the mixed-layer.

Author Response:

The authors would like to thank the reviewer for his careful and insightful comments, and for making it clear the necessity to clarify the results in our manuscript. We have used this input to improve the manuscript significantly.

The main result from our article is that dissipation measurements with our ASIP profiler are largely consistent with a shear-driven wall layer (to within an order of magnitude) in the mixed layer. Considering that air-foil type shear probes can resolve turbulent dissipation (at best) to a factor of 2 (Oakey and Eliot, 1982), we believe that the results here represent a very good agreement. It also needs to be considered that given the intermittent nature of turbulence adding to the uncertainty when profiling, an order of magnitude is a very good agreement.

However, when wavenumbers of energetic portions of the wave spectrum were chosen to estimate the depth dependence (assuming dissipation scales with the shear of the Stokes drift), it was found that dissipation not only scaled as the sum of the Stokes shear from the wind and the swell, but that this extended deeper than the observed mixed layer.

Further Reviewer Clarification:

1-At least to try, given a first guess spectrum from NWP, the given local wind speed and direction, to evaluate partition, and to use the 1D spectrum to distribute the wave energy.

Basically, Stokes term will weight the energy distribution as funnction of wavelength and direction: if you put everything in the same direction, as using the 1D, or if you have crossing seas, results will be different.

Under veering wind conditions, this can especially affect the results.

Author Response:

As part of the analysis for this article, we attempted to partition the wave spectra into wind and swell components using various methods. First, we applied the method of Hwang et al. (2012) to our spectra but results were inconsistent and often separation frequencies were at a peak in the spectrum. We also tried calculating the separation frequency by using the 10 m wind velocity such that the phase speed of the wind waves would be less than $0.83U_{10}$ (the value 0.83 is taken from the lower range of values for U_{10}/c_p from Donelan et al. (1985), where c_p is the phase velocity of the peak of the wave spectrum). We also tried this with a value of 1.00, similar to Wang and Hwang (2001)However, Hwang et al. (2012) method grossly overestimated the separation frequency during lower winds. In the end we decided that the best approach for this paper was to choose sections of the wave spectrum which corresponded to more typical values for wind and swell frequencies. Admittedly the magnitude and horizontal direction of the Stokes drift will be less if the waves are not aligned with the wind, but this should have little affect on the depth dependence (unless their directions are 90 degrees apart).
This depth dependence is what we find of interest because even though the dissipation profile does not appear to vary exponentially with depth, it does resemble the sum of two exponential profiles with the e-folding depth for each exponential equal to $1/(2k)$

where k is the mean wave number for either of the selected swell or wind portion of the spectrum.
We have considered using NWP models and investigated spectra from archived data. The wave model products for the region (e.g. ERA Interim) only have 6-hourly output of spectra. Comparing with ERAI we noted that the reanalysis does not capture rapid transitions very well. The overall agreement between model and measurements is good, but at the peak of the rise in wind speed towards the end of the period, model winds are almost 50% lower than measured winds. It is thus likely that the swell/wind sea energy ratios in the model spectra are inaccurate for the period we are interested in. It would be interesting to make a hindcast for this period with higher temporal and spatial resolution, and also more frequent output, but that is beyond the scope of this paper.

Further Reviewer Clarification:

2-Given the evaluated wind/wave conditions, the observed rate of change of the mixed layer can be be used and compared to standard 1D model? This shall help to constrain the TKE evaluation made by the authors.

Author Response:

Unfortunately there are no measurements during the entire duration of the deepening of the mixed layer which makes any analysis of the evolution of the mixed layer depth crude at best. In addition, the authors feel it is beyond the scope of the current paper to delve into a numerical simulation of the event and instead to present the observations to aid other researchers in modelling the response of the upper ocean. As stated in the manuscript, our result of 1% of E_{10} is dissipated in the mixed layer is consistent with some observations from microstructure profilers, but is slightly lower than other studies which found 4-10% of E10 is dissipated in the mixed layer.
It is left to future studies to expand on what ratio of the wind power is dissipated in the mixed layer.

References

Donelan, M. A., J. Hamilton, and W. H. Hui, 1985: Directional spectra of wind-generated waves. Philos. Trans. Roy. Soc. London, 315A, 509–562.

Hwang, P. A., F. J. Ocampo-Torres, and H. Garcia-Nava, 2012: Wind sea and swell separation of 1D wave spectrum by a specgtrum integration method. J. Atmos. Oceanic Technol., 29, 116-128.

Oakey, N. S. and J. A. Elliott (1982). Dissipation within the surface mixed layer. J. Phys. Oceanogr. 12, 171–185.

Wang, D. W., and P. A. Hwang, 2001: An operational method for separating wind sea and swell from ocean wave spectra. J. Atmos. Oceanic Technol., 18, 2052–2062.

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