Comments on "Estimates of Kinetic Energy Dissipation under Breaking Waves"

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11 October 1996

ABSTRACT

It is noted that the results of recent experiments on the enhancement of turbulent kinetic energy (TKE) dissipation below surface waves can be stated as follows. TKE dissipation is enhanced by a factor $15H_{ws}/z$ at depths $0.5H_{ws} < z < 20H_{ws}$ with respect to the wall-layer result $\epsilon = u_{*w}^3/\kappa z$, where u_{*w} is the friction velocity in water and H_{ws} is the significant windsea wave height. For open ocean conditions, this reduces in most cases to an enhancement factor $10^6 u_{*w}^2/gz \approx u_{10}^2/gz$.

Recently, a group of experimentalists and theorists succeeded in measuring and interpreting how turbulent kinetic energy dissipation is much enhanced below surface waves in the WAVES experiment (Agrawal et al. 1992; Terray et al. 1996) and also in the SWADE experiment (Drennan et al. 1996).

In Fig. 1a, their results are shown for the enhancement of TKE dissipation ϵ with respect to the wall-layer result $\epsilon_{\mathrm{wall}} = u_{*w}^3/\kappa z$ as a function of dimensionless depth gz/u_{*w}^2. Here u_{*w} is the friction velocity in water. A general enhancement is clear, but there is no clear relationship between the enhancement factor and the dimensionless depth. Moreover, WAVES and SWADE data appear to be different.

Terray et al. (1996) point out that there are two important scaling variables for wave-enhanced TKE dissipation: windsea wave height H_{ws} and energy dissipation of surface waves. The latter will be equal to the energy input F from the wind to surface waves. Using these variables, they find a clear relation: $\epsilon H_{ws}/F = 0.3(H_{ws}/z)^2$ for WAVES. The SWADE data (Drennan et al. 1996) satisfy the very same relation as the WAVES data (Fig. 1b).

To estimate enhanced TKE dissipation, the relation of Terray et al. has the drawback that one has to estimate somehow the wind input F; but this is not really necessary. An equally good fit can be obtained by using u_{*w}^3 instead of F, with the added advantage that the result can be written as an enhancement factor times the wall-layer result. This is shown in Fig. 1c. The straight line corresponds to

$$\epsilon = 15\frac{H}{z}\frac{u_{*w}^3}{\kappa z}. \qquad (1)$$

Note that Fig. 1 is a log–log plot and that the uncertainty in the factor 15 is quite large. The fit of Fig. 1b is only slightly better than the fit of Fig. 1c; a slightly better fit than that of Fig. 1b can be obtained using $u_{*w}^2 c_p$ instead of F (not shown), with c_p the wave velocity at the windsea peak frequency.

Approaching the surface, TKE dissipation should not grow without bound. Using that TKE dissipation integrated over depth should equal the wind input F, Terray et al. (1996) arrived at a constant dissipation layer of a depth $0.6H_{ws}$. Assuming $F \approx 150u_{*w}^3$, the same reasoning applies here.

Finally, I note that the waves of WAVES were very little developed because they were only 1 km from the coast. In contrast, the waves of SWADE resembled much more those of the open ocean. In open ocean conditions, windsea is most of the time well developed, that is, $5 \times 10^4 < gH_{ws}/u_{*w}^2 < 10^5$, except in strong storms. So for open ocean conditions, Eq. (1) can be approximated by

$$\epsilon = 10^6 u_{*w}^2/(gz)\frac{u_{*w}^3}{\kappa z}. \qquad (2)$$

Note that this "open ocean" line does not go at all through the WAVES points in Fig. 1! To change in Eq. (2) from u_{*w} to U_{10}, the windspeed at 10-m height, one can use $10^6 u_{*w}^2/gz \approx U_{10}^2/gz$.

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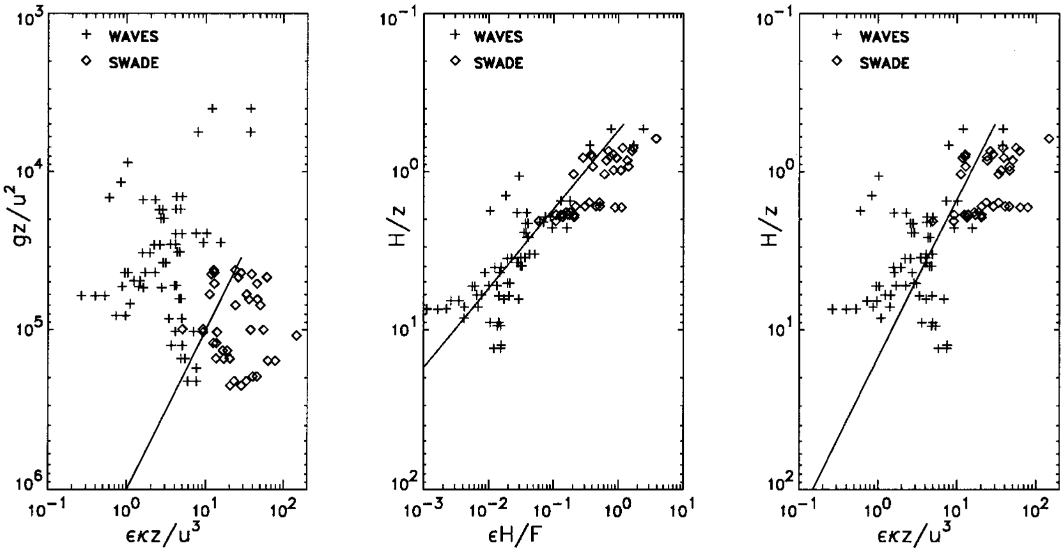

FIG. 1. Dissipation vs depth in WAVES (crosses) and SWADE (diamonds). In (a) $\epsilon\kappa z/u_{*w}^3$ vs gz/u_{*w}^2 is shown, together with the open ocean relation (2). In (b), the relation $\epsilon H_{ws}/F = 0.3(H_{ws}/z)^2$ of Terray et al. (1996) is shown. In (c), the fit of Eq. (1) $\epsilon = 15(H/z)u_{*w}^3/(\kappa z)$ is shown.

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