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Non-breaking wave induced ocean mixing

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Mixing of the upper ocean affects the sea surface temperature by bringing deeper, colder water to the surface. Even small changes in the surface temperature can have a large impact on global weather and climate, so it is critical to determine it accurately for forecasting. Although there are several mechanisms that can lead to mixing, one that has until recently been overlooked is the effect of non-breaking, wind-generated surface waves.

In most theoretical models, ocean surface waves are presumed to be irrotational, since the viscosity of water is small and their motion is not greatly affected. However this overlooks two important aspects of the motion: the first is that however small the viscosity, it is not zero; secondly, even potential wave motion can interact with pre-existing vorticity in the water. The consequences of this are clear: given large enough waves, the non-irrotational motion can generate turbulence, and given pre-existing turbulence, the waves, even when considered as irrotational, transfer their own energy to the turbulence. Aside from dissipating the waves, this enhancement of the background turbulence can lead to deeper and more rapid mixing than might otherwise occur.

Other mechanisms of turbulence generation by surface waves that have been studied include the interaction of Stokes drift with the turbulence, Langmuir circulation, and wave breaking. Experimental, observational, modelling and theoretical work indicates that the last of these only has a very shallow effect, and the other two are either too weak or too infrequent to account for the observed mixing. All have to be artificially enhanced in models to account for the mixing observed. By parameterising the effect of the turbulence directly generated by the orbital particle motion due to the waves, the correct rate and depth of mixing can be calculated. Various models incorporating such a parameterisation have shown closer agreement with observation than previously achieved, however the parameterisations still need refinement. We propose one based closely on the physics of the motion, deriving results from a wave model coupled to a large eddy simulation turbulence model.