Vertical mixing schemes in the coastal ocean: Comparison of the level 2.5 Mellor-Yamada scheme with an enhanced version of the K profile parameterization

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[1] The performance of two vertical mixing parameterizations in idealized continental shelf settings is analyzed to assess in what aspects and under what conditions they differ. The level 2.5 Mellor-Yamada turbulence closure (M-Y) is compared with an enhanced version of the K profile parameterization (KPP), which has been appended to include a representation of the bottom boundary layer. The two schemes are compared in wind-driven one- and two-dimensional shallow ocean settings to examine differences in (1) the surface boundary layer response, (2) the response when surface and bottom boundary layers are in close proximity, and (3) the response when the horizontal advective effects of a coastal upwelling circulation compete with the vertical mixing processes. The surface boundary layer experiments reveal that M-Y mixes deeper and entrains more than KPP when the pycnocline beneath the wind-mixed layer is highly stratified and mixes less when it is weaker. This is related to the role of vertical diffusion of turbulent kinetic energy in M-Y and the nature of the interior shear mixing parameterization of KPP. In shallow water when surface and bottom boundary layers impinge on each other, the stronger mixing at the interface produced by KPP can lead to much more rapid disintegration of the pycnocline. The two-dimensional upwelling circulation experiments show that the two schemes can produce quite similar or significantly different solutions in the nearshore region dependent on the initial stratification. The differences relate to the stronger suppression of turbulence by M-Y under the restratifying influence of horizontal advection of denser water in the bottom boundary layer. *INDEX TERMS:* 4255 Oceanography: General: Numerical modeling; 4279 Oceanography: General: Upwelling and convergences; 4568 Oceanography: Physical: Turbulence, diffusion, and mixing processes; *KEYWORDS:* vertical mixing parameterizations, wind-driven mixing

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1. Introduction

[2] Accurate parameterization of vertical mixing processes has been a long-standing issue in ocean circulation modeling. A variety of schemes have been developed to face this challenge; however, very much is expected of them. Wind-driven turbulent boundary layer mixing, convection forced from the surface or at an overturning front, internal wave breaking and Kelvin-Helmholtz instabilities at the pycnocline are several of the typically unresolved mechanisms which contribute significantly to the vertical redistribution of both momentum and scalars. Numerical models focused on the mesoscale offer spatial information on scales of a kilometer in the horizontal and 1–10 m in the vertical. The fields at these resolutions may correlate strongly, weakly or not at all with the dynamics of small-scale processes. Nonetheless, vertical mixing parameterizations based on the values of the variables at the resolved scales have been shown to represent some mixing processes rather well and improve the accuracy of circulation models in general. As the demand for more accurate, higher-resolution real ocean simulations increases it is important to continue to assess the performance of currently available parameterizations to determine what can be done to improve their quality.

[3] Numerous comparisons between vertical mixing parameterizations have been undertaken [*Price et al.*, 1986; *Large et al.*, 1994; *Kantha and Clayson*, 1994; *Large and Gent*, 1999; *Burchard and Bolding*, 2001; *Wijesekera et al.*, 2003]. Often they focus on open ocean settings because

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