the significant level of horizontal homogeneity these environments offer facilitates model-data comparisons by alleviating the need to consider lateral advective effects. It is arguably in these settings that the models have achieved their greatest success; however, for general use the parameterizations must perform reasonably in a much broader range of settings. A particularly challenging environment for comparison of vertical mixing parameterizations is that of the coastal ocean. There the water column can range from well-mixed surface-to-bottom to highly stratified over a few kilometers and the strong horizontal velocities and shallowness of the water column can lead to interaction between surface-forced and bottom-forced boundary layers which come in close proximity to each other. In such complex environments, where the performance of the vertical mixing parameterization is most dubious, comparison with observations is most difficult to achieve. Coastal circulation models have improved to the point that they can capture many of the features of mesoscale coastal processes but rarely with the accuracy necessary for vertical mixing estimates to be directly compared with small-scale turbulent measurements in the field.

[4] In lieu of model-data comparison a great deal can still be learned about the relative performance of vertical mixing parameterizations through sensitivity tests in idealized coastal ocean settings. By developing a detailed understanding of why parameterizations give different solutions one can better determine what attributes are critical to obtaining a certain response. Although this paper does not promote one parameterization as superior, by clarifying the nature and causes for differences, it can suggest how future theoretical, laboratory, high-resolution numerical or field work can most profitably advance our understanding of vertical mixing processes and lead to improvement in parameterizations.

[5] The approach of this study is to compare two mixing schemes in a series of idealized coastal ocean settings. The study is limited to purely wind driven systems to isolate specific aspects of their response. Three characteristics of the coastal ocean are considered specifically: (1) the potential for the stratification to range over several orders of magnitude, (2) the potential for surface/bottom turbulent boundary layers to interact in shallow water, and (3) the potential for horizontal density gradients to interact with vertical mixing in association with such phenomena as coastal upwelling fronts.

[6] The two parameterizations that will be considered are the K profile parameterization of *Large et al.* [1994] (referred to as KPP) and the Mellor and Yamada level 2.5 closure scheme *Mellor and Yamada* [1982] (referred to as M-Y). Whereas the Mellor-Yamada scheme has become something of the "industry standard" for coastal ocean application, the KPP scheme has gained respect as an alternative in deep ocean applications and has been shown to compare favorably to M-Y in such situations [*Large and Gent*, 1999; *Large et al.*, 1994]. There are numerous other parameterizations that could be included in a sensitivity study such as this [*Canuto et al.*, 2001; *Burchard and Baumert*, 1995; *Price et al.*, 1986; *Pacanowski and Philander*, 1981]. These two were chosen because they represent popular members of two different classes of parameterization. The estimates of vertical mixing coefficients made by the KPP scheme are based on the surface boundary forcing and the state of the resolved velocity and potential density fields instantaneously in a vertical column of water. M-Y, on the other hand, considers the energetics of the mixing explicitly by solving prognostic equations for turbulent kinetic energy and length scale. In doing so, the mixing estimates carry information about the time history of the flow and can effectively both advect and diffuse.

[7] The KPP scheme was primarily designed as an advanced surface boundary layer approximation coupled at its base with simple parameterizations to represent a range of mixing processes in the ocean interior. Consequently, it takes no special consideration for the presence of a lower boundary and can produce erroneous mixing as a result in shallow water. As part of this study, the original scheme is appended to include a representation for the turbulent bottom boundary layer. This improvement gives the model general applicability to continental shelf and estaurine flows.

[8] Three model setups will be discussed. These are (1) a simple one-dimensional wind driven surface boundary layer over a range of stratifications, (2) interacting surface and bottom boundary layers in a one-dimensional setting over a range of stratification intensities and water depths, and (3) a two-dimensional coastal upwelling on a gently sloping continental shelf.

[9] After a discussion of the vertical mixing parameterizations in the next section the circulation model and the three simulation setups will be presented. This will be followed by results and analysis of each case and a final discussion.

2. Vertical Mixing Parameterizations

[10] In the published literature one can find a variety of alterations, adjustments and "corrections" associated with the parameterization being examined here. Thus it is important to present some details of their specific implementations in this study as some results may depend on the particulars of these formulations. A variety of alternatives are offered for coefficient values and functional representations, particularly for the Mellor-Yamada scheme [*Mellor and Yamada*, 1974, 1982; *Galperin et al.*, 1988; *Blumberg et al.*, 1992; *Kantha and Clayson*, 1994; *Mellor*, 2001], but also for KPP [*Large and Gent*, 1999]. In this section the addition of a bottom boundary layer to the KPP scheme will also be discussed.

2.1. Mellor-Yamada Parameterization

[11] The formulation for the Mellor-Yamada level 2.5 closure presented here is based on *Mellor and Yamada* [1982] with the modifications suggested by *Galperin et al.* [1988] and the parameter adjustments presented by *Kantha and Clayson* [1994]. Coefficients for vertical eddy viscosity and diffusivity are estimated as

$$K_v = q\tilde{l}S_M \tag{1}$$

$$K_\rho = q\tilde{l}S_H \tag{2}$$

where $0.5q^2$ is the turbulent kinetic energy, $\tilde{l}$ is a limited turbulent length scale, ρ denotes potential density, and S_M