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The basin-scale effect of shear-induced stratification in bottom boundary layers on slopes : A modeling study

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Recent studies have shown evidence for inverse density-stratification in turbulent bottom boundary layers (BBLs) on the slopes of stratified basins. These data suggest that the near-bottom vertical current shear acting on the upslope buoyancy gradient may create unstable stratification with considerable implications for turbulence and mixing in the BBL. In addition to shear production, this mechanism provides an additional source for turbulent kinetic energy with a yet unknown impact on the basin-scale mixing. Here, we present results from a process-oriented modeling study investigating this effect in lakes, where periodic near-bottom shear and turbulence result from internal seiching motions. The three-dimensional simulations have been performed with a high-resolution hydrostatic numerical model using topography-following coordinates and a state-of-the-art second-moment turbulence model. In agreement with available data our results suggest that mixing occurs in a BBL of a few meters thickness, and dominates the basin-scale mixing for the systems we have investigated (Lake Constance, Lake Alpnach). Turbulence during BBL convection was found to be strong with diffusivities approximately one order of magnitude larger than during stable stratification. However, because of the weak stratification, the contribution of unstable boundary layers to overall mixing was found to be small. Conversely, during periods of downwelling, the stabilizing effect of the shear strongly enhances the mixing efficiency thus leading to strong mixing in spite of the comparatively small diffusivities.