Assessing the effects of numerical diffusion in a three-dimensional unstructured-grid model of a periodically-stratified estuary

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Three-dimensional simulations of flow in San Francisco Bay are performed with the unstructured-grid SUNTANS model in order to assess the relative importance of using a high-resolution, second-order scalar transport scheme over the first-order upwind scheme. We devise a method to evaluate the effective numerical diffusion of each scheme which leads to a quantative measure of the spatial accuracy of the scheme as well as a means of understanding the relationship between the dynamics of scalar transport and the numerical diffusion. The results show that the effective numerical diffusion is lower for the high-resolution scheme only in regions where tidal straining is relatively low. In regions of high tidal straining, strong stirring of the scalar field leads to grid-scale variability that produces equivalent numerical diffusion for both the high-resolution and first-order schemes. In the presence of periodic stratification, the effect of the high-resolution scheme is compounded due to its indirect effect on the stratification dynamics. We show that, although vertical numerical diffusion is weak relative to vertical turbulent diffusion for both schemes, high horizontal numerical diffusion for the first-order scheme leads to a weaker horizontal salinity gradient which leads to weaker baroclinic circulation. The effect is a weaker vertical salinity gradient due to weaker tidal straining (due both to weaker currents and weaker horizontal salinity gradients) and due to increased vertical mixing which results from less supression of turbulence by stratification. The resulting indirect effect on the vertical stratification leads to substantially better results compared to the observations for the high-resolution scheme.

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