Stratification produced by surface cooling in lakes with significant shallow regions

Wells, Mathew Graeme, Bradford Sherman

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ABSTRACT: A reservoir with distinct shallow and deep regions can produce stratification in response to uniform surface heat loss. The shallow region cools more rapidly, and a cold dense gravity current forms that results in stratification at the base of the deep region and an upwelling of cold water. The surface mixed layer deepens by convective entrainment, and a steady mixed-layer depth can result when the cold upwelling balances the rate at which the mixed layer deepens. The steady depth of the mixed layer depends on the ratio of the area of the shallow region to the area of the deep region. Significant stratification only results when the reservoir has shallow regions that account for more than 50% of the surface area. The depth of the surface mixed layer also depends on the ratio of the depths of the shallow and deep regions, and no significant stratification can form if this ratio is greater than 0.5. For a wedge-shaped geometry, these observations can be generalized by considering the ratio of the average depth to the maximum depth in a reservoir; the gravity current can produce stratification in more than 50% of the depth when this ratio is less than 0.5. Results from a laboratory study and field data from Chaffey Reservoir, Australia, are presented on the surface mixed-layer depth, along with estimates of the time scales needed for atmospheric forcing to lead to the development of stratification.

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