Simple mixing criteria for the growth of negatively buoyant phytoplankton

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ABSTRACT: Phytoplankton population dynamics are controlled by the relative rather than absolute timescales of mixing, growth, and loss processes such as sedimentation, grazing, and so on. Here, the vertical distribution and biomass of phytoplankton populations are quantified by two timescale ratios: the Peclet number Pe[]the ratio of mixing and sedimentation timescales[]and the growth number G[]the ratio of sedimentation and net growth timescales. Three mixing regimes are defined for phytoplankton and other particles. For Pe $\geqslant$ 100, the population is translated linearly down the water column over time and will leave the surface mixing layer completely after sedimentation time πt_z. For 0.1 < Pe < 100, the population distribution depends on the relative magnitude of Pe and G. Finally, for Pe $\geqslant$ 0.1, the population will be vertically uniform, and biomass changes exponentially over time with characteristic timescale $\tau_c = \tau_z/(G - 1)$. This analysis is valid for negatively buoyant phytoplankton, except when mixing time is much longer than growth time and Pe $\geqslant$ 0.1, which can occur for very slow sinking species. These regimes can be used for assessing the effect of changes in the mixing, growth, or sedimentation conditions on population dynamics. Published data from a lake and diurnally stratified river weir pool are used here to verify a minimum thermocline depth hypothesis proposed by others. Mixing and growth regimes are used to calculate minimum mixing depth h_{min} and to determine phytoplankton sinking rates from published sediment trap data.