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Does turbulence help sinking phytoplankton species to survive?

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A long-standing issue of biological oceanography is the question as to how sinking phytoplankton species manage to persist. The present study focuses on one of the numerous aspects of this puzzle, i.e. the role of turbulent mixing. In this respect, under the assumption that hydrodynamics is horizontally homogeneous and time-independent, we consider the downward flux of particles with negative buoyancy leaving the upper mixed layer. The direct or forward mathematical model thereof is believed to admit no closed-form solution. However, the adjoint problem allows for various timescales to be derived rather easily. The latter depend on the vertical coordinate only. Two of them may be interpreted as residence times, i.e. the time needed to hit for the first time the boundary of the domain of interest. A third timescale, termed "exposure time", is a measure of the time spent in the upper mixed layer. The relevance of these timescales for addressing the abovementioned issue is discussed in detail, leading to the conclusion that estimating the exposure time is probably the best approach. Interestingly, the exposure time increases if the eddy diffusivity increases, indicating that turbulence causes settling particles to stay longer in the upper mixed layer. Finally, it is argued that it is even more appropriate to evaluate the amount of light that sinking particles are exposed to. This may be achieved through a slight modification of the adjoint problem from which the residence and exposure times are obtained. Analytical solutions are established, showing that the radiative energy increases as turbulence intensity is enhanced. Therefore, it is believed that turbulence definitely helps sinking phytoplankton species to survive.