Dynamics of phytoplankton blooms in turbulent vortex cells

Turbulence and coherent circulation structures, such as submesoscale and mesoscale eddies, convective plumes and Langmuir cells, play a critical role in shaping phytoplankton spatial distribution and population dynamics. We use a framework of advection-reaction-diffusion equations to investigate the effects of turbulent transport on the phytoplankton population growth and its spatial structure in a vertical two-dimensional vortex flow field. In particular, we focus on how turbulent flow velocities and sinking influence phytoplankton growth and biomass aggregation. Our results indicate that conditions in mixing and growth of phytoplankton can drive different vertical spatial structures in the mixed layer, with the depth of the mixed layer being a critical factor to allow coexistence of populations with different sinking speed. With increasing mixed layer depth, positive growth for sinking phytoplankton can be maintained with increasing turbulent flow velocities, allowing the apparently counter-intuitive persistence of fast sinking phytoplankton populations in highly turbulent and deep mixed layers. These dynamics demonstrate the role of considering advective transport within a turbulent vortex and can help to explain observed phytoplankton biomass during winter in the North Atlantic, where the overturn of deep convection has been suggested to play a critical role in phytoplankton survival.

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