Effects of surface light modulation on vertical phytoplankton flow dynamics

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Phytoplankton growth in oceans and lakes is known to depend in a complex manner on a variety of physical phenomena according to both experimental measurements and numerical models. Experimental studies have put in evidence the relation between planktonic population survival and turbulent upwelling and downwelling flow motions from thermal convection. Recent works have shown the importance of accounting for advective transport in phytoplankton numerical models [1]. In addition, phytoplankton blooms in nutrient-rich polar marine ecosystems are limited by light availability under ice-covered waters . These ecosystems present non-trivial heterogeneous light-limited growth dynamics in the presence of advective transport [2]. In this work we extend a previous advection-reaction-diffusion model [1] accounting for phytoplankton light-limited growth vertical dynamic in the presence of fluid transport. Specifically, we account for horizontally heterogeneous light conditions through the use of two regions with different production regimes, modelling the absence (presence) of light under (in between) obstacles (see Fig. 1). Such a model is intended as an idealized representation of ice-covered waters in polar environments. Results show that the main role of advective transport is to hinder phytoplankton growth, but also that such effect depends on the obstacle positions with respect to the upwelling and downwelling regions of fluid motion. Furthermore, we argue that the sinking speed due to the density difference between phytoplankton organisms and water, while small, plays an important role, which depends on how it sums to the flow. These findings indicate the importance of advective transport for the survival of different phytoplankton species in heterogeneous light-limited polar environments.

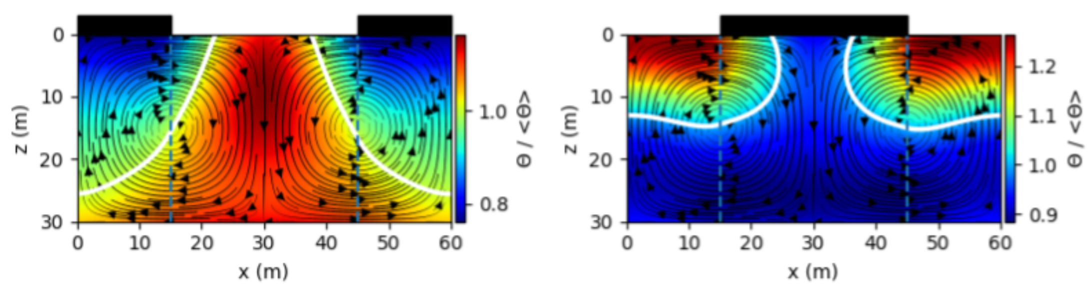

Figure 1. Instantaneous normalized population density field $\theta(x, z, t^*)/<\theta>$ at a fixed instant of time t^*. The white line is the isoline $\theta/<\theta>=1$. The solid black lines represent flow streamlines, with arrows indicating the circulation direction. The black rectangles indicate obstacle positions below which production is not possible due to the absence of light.

References

1. V. B. Tergolina *et al.*, Effects of large-scale advection and small-scale turbulent diffusion on vertical phytoplankton dynamics, *Phys. Rev. E*, **104**, 065106 (2021).
2. K. E. Lowry *et al.*, Under-ice phytoplankton blooms inhibited by spring convective mixing in refreezing leads, *J. Geophys. Res. Oceans*, **123**, 90 (2018).