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Vertical mixing and horizontal transport determine bloom dynamics in a large riverine reservoir

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Phytoplankton blooms in lakes and reservoirs are sensitive to hydrodynamics. Bulk metrics of hydrodynamics are often used to investigate bloom formation, but they may not adequately represent the synergistic hydrodynamic processes in large riverine reservoirs caused by dam operation. Here we examine how complex three-dimensional hydrodynamic processes trigger blooms in Xiangxi Bay, a typical tributary bay of the Three Gorges Reservoir, China, which has suffered phytoplankton blooms of different scales in recent years. We used a 3D ecological-hydrodynamic model, which integrated hydrodynamics with the abiotic factors that limit phytoplankton growth to simulate one whole year (2010). By implementing a scaling criterion, we quantified the contribution of local phytoplankton growth and hydrodynamic processes, including advection transport and vertical mixing, on bloom dynamics. Results indicated vertical mixing was the main process inhibiting blooms in colder months (from October to February) but horizontal advection, which flushed and diluted blooms, was dominant in warmer months (from May to July) when stratification was intense and nutrients were replete. Accordingly, blooms occurred when both vertical mixing and horizontal advection were low. We suggested a potential dam operation strategy to mitigate blooms during stratification, which involves withdrawing the warm surface water from upstream reservoirs to increase horizontal flows in the surface layer. Extending the critical turbulence model, our study shows that not only the rate of vertical mixing, but also horizontal advection controls blooms in highly dynamic riverine systems.