The effect of ultraviolet radiation on freshwater planktonic primary production: The role of recovery and mixing processes

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ABSTRACT: We used a spectrally resolved kinetic model to calculate ultraviolet radiation (UVR) and photosynthetic active radiation (PAR)-dependent photoinhibitory losses in planktonic primary production in a large lake (Lake Erie) under mixing and water transparency scenarios typical of current and possible future environmental conditions. The model, previously calibrated for Lake Erie phytoplankton, also provided estimates of photoinhibition recovery rates under high irradiance conditions that were compared against direct measurements of recovery rates under lower irradiance. Extensive recovery of photosynthesis, even after severe (80%) inhibition, occurred after transfer to benign, low irradiance conditions. Measured recovery rate constants were independent of preexposure treatment (median of $1.70 \times 10^{-4}\ s^{-1}$) and were comparable to modeled rates under higher radiation fluxes ($2.10 \times 10^{-4}\ s^{-1}$). Recovery rates were sufficient to allow near-full recovery within one photoperiod, even after severe inhibition (<6 h). Estimates of the photoinhibitory loss of primary production, integrated through the mixed layer, were not greatly affected by mixing rate variations but were higher in all scenarios with finite mixing rates than in those with no mixing. Modeled 20% stratospheric ozone reductions resulted in small increases in integrated UVR photoinhibition (<1%), as did 20% and 50% changes in dissolved organic carbon (DOC) concentration, whereas increased maximum water clarity scenarios decreased integrated photoinhibition estimates. While UVA, not UVB or PAR, caused most of the photoinhibition in Lake Erie phytoplankton, the extent of integrated photoinhibition is likely to depend mostly on algal physiological parameters of UVR susceptibility (sensitivity and recovery) and the ratio of mixing depth to PAR and UVR photic depths.

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