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Photoproduction of dissolved inorganic carbon in Swedish lakes

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A substantial fraction of the dissolved organic carbon (DOC) in inland waters is mineralized to dissolved inorganic carbon (DIC) during passage towards the sea. Both microbial and photochemical mineralization have a share but there is currently no landscape-scale estimate of the contribution of photomineralization to total lake carbon dioxide emissions, restricting our understanding of inland-water C cycling. We use 1) DOC absorbance spectra measured during autumn 2009 in water samples from 1074 lakes distributed across Sweden, 2) light attenuation coefficients estimated based on correlations with absorption coefficients as established from literature data, 3) cloud-corrected, below-water-surface downwelling scalar irradiance spectra derived by modeling radiative transfer in the atmosphere and transmission into the water and 4) an apparent quantum yield spectrum determined in a humic lake, to calculate spectra of DIC photoproduction from 280 to 600 nm and from the water surface down to the mean lake depths. For each lake, we calculate DIC photoproduction rates on a daily base and integrate to obtain yearly flux estimates. Preliminary model results calculated for July 2009 show that, even though water color differed largely (25%- and 75%-quantiles of specific UV absorption coefficients at 254 nm ($SUVA_{254}$) of 6.4 and 9.6 $L\ mg\ C^{-1}\ m^{-1}$, respectively), depth-integrated DIC photoproduction rates showed a relatively small variation with a 25%-quantile of 12.0 and a 75%-quantile of 13.1 $mg\ C\ m^{-2}\ day^{-1}$. These rather similar DIC photoproduction rates are explained by their different depth distributions: The brownest lake with a $SUVA_{254}$ of 12.9 $L\ mg\ C^{-1}\ m^{-1}$ had large surface DIC photoproduction rates of 887.9 $mg\ C\ m^{-3}\ day^{-1}$ but photons were quickly attenuated with depth, with DIC photoproduction rates falling below 1 $mg\ C\ m^{-3}\ day^{-1}$ already at ˜ 0.2 m depth (depth-integrated rate of 14.2 $mg\ C\ m^{-2}\ day^{-1}$). The clearest lake with a $SUVA_{254}$ of 1.4 $L\ mg\ C^{-1}\ m^{-1}$ had nearly 100-fold smaller surface DIC production rates of 9.4 $mg\ C\ m^{-3}\ day^{-1}$ but rates still reached ˜ 1 $mg\ C\ m^{-3}\ day^{-1}$ at 2 m depth (depth-integrated rate of 8.4 $mg\ C\ m^{-2}\ day^{-1}$). Across lakes, DIC photoproduction rates correlated positively with specific absorption coefficients at 420 nm (SA_{420}) (y = 10.3 + 3.1 * x, R^2 = 0.76, P < 0.0001). Using this relationship we predict DIC photoproduction rates for a larger data set of 3853 Swedish lakes for which SA_{420} has been determined in further recent sampling campaigns. Assuming that the combined data set (n = 4927) is representative for the total population of Swedish lakes, we upscale the flux by multiplying the mean DIC photoproduction rate with the overall lake area to obtain a country-wide, annual DIC flux estimate. DIC-fluxes from photomineralization are compared to total carbon dioxide emissions from Swedish lakes available from earlier studies.