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Seasonal dynamics of greenhouse gases in a large river

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Rivers represent a significant source of greenhouse gases (GHGs), with the three main gases emitted being carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). To comprehend the spatio-temporal variability of these gases, it is essential to consider the regulating factors that influence their concentration. In larger rivers GHG concentrations are mostly regulated by in-river processes. Thus, the concentration of all these GHGs is supposed to be governed by the trophic state and the activity of phytoplankton.

We performed a monthly monitoring for the three GHGs at the river Elbe (Germany) over 5 years (2020-2024); together with chlorophyll concentrations and other basic water chemical variables.

CO_2 concentrations showed a clear seasonal pattern with minimum values in summer, mainly driven by light availability and chlorophyll concentration (photosynthesis). CH_4 concentrations showed an opposite seasonal dynamic with maximum values in summer, as indicated by its dependence on temperature and particulate organic carbon (POC). N_2O concentrations were mostly near saturation and mainly determined by temperature dependent solubility. The total GHG-potential of the three gases in terms of CO_2 equivalents was dominated by CO_2 and its seasonal cycle. We successfully used this comprehensive dataset to develop data-driven models based on machine-learning methods, reaching coefficients of determination greater than 0.75. Looking ahead to subsequent research these models enable predictions of GHG concentrations and emissions under potential future climate scenarios.