Geophysical Research Abstracts
Vol. 20, EGU2018-1888, 2018
EGU General Assembly 2018

Impact of climate change on CO_2 concentration and flux in a humic boreal lake

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The importance of freshwater lakes in carbon cycling is pronounced in the boreal zone as the lakes ventilate carbon originally fixed by the surrounding terrestrial system. The effect of climate change on lake ecosystems is most evident in high latitudes. Higher air temperature shortens the ice-covered period and accelerates biochemical processes. Modelling is an efficient tool for estimating the effects of climate change on freshwaters, and recent advances in the long-term high-frequency measurement of lake carbon dioxide (CO_2) concentration and air-water flux facilitate the development and the reliable validation of models. The purpose of our study was to estimate potential implications of higher air temperature and increased carbon loading on lacustrine carbon cycle.

We used a new one-dimensional process-based model for simulation of CO_2 dynamics in a lake. The model is an extension of a lake model MyLake, and it simulates lake thermodynamics, phosphorus, phytoplankton, dissolved oxygen, and inorganic and organic carbon species. We calibrated the model for Lake Kuivajärvi, a small, humic boreal lake, making use of comprehensive measurement data available on carbon inflow and the concentration of CO_2 in the lake. The lake is a constant source of CO_2 to the atmosphere in present climate. We studied potential effects of climate chance induced warming on the CO_2 dynamics of the lake between a control period 1980–2009 and a scenario period 2070–2099 using downscaled air temperature data from recent-generation global climate models with two alternative representative concentration pathway (RCP) forcing scenarios. Estimates for climate change impacts on lake inflow volume were obtained from the literature. In addition, we compared the effects of constant percentage increases in the inflow concentrations of CO_2 and dissolved organic carbon (DOC).

The concentrations of CO_2 near the surface were considerably higher in the scenario period, especially under the scenario with a high forcing. A higher wintertime inflow in the scenario period accumulated more CO_2-rich water in the surface layers under ice, but the maximum water-column average CO_2 concentration under ice was smaller and the spring peak in CO_2 air-water flux was lower in the scenario period because of a shorter ice-covered period. The simulations showed that warmer climate will result in a 20–35 percent increase in CO_2 efflux from the lake to the atmosphere in the scenario period compared to the control period, depending on the RCP used. A 40 percent increase in direct CO_2 loading raised the annual average water column concentration and flux of CO_2 more than a similar increase in DOC loading. Our study gives important insight on in-lake mechanisms related to possible climate induced changes in aquatic carbon cycling and enables further application of the new model as a part of a model chain for assessing the impact of climate change on the dynamics of greenhouse gases in boreal lakes.