CARBON DIOXIDE AND METHANE FLUXES OVER A BOREAL RIVER MEASURED WITH EDDY COVARIANCE

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INTRODUCTION

Rivers have a significant role in the lateral transport of carbon from terrestrial ecosystems to the ocean. As rivers are generally supersaturated with CO_2 with respect to the atmospheric concentration (Raymond et al. 2013), their turbulent nature may make them effective emitters of carbon into the atmosphere (Allen and Pavelsky 2018). Rivers cover a varying fraction of the total land area. The largest coverages of up to 2% are found in the boreal zone, Southeast Asia and the Amazon (Allen and Pavelsky 2018). The flux of carbon from boreal rivers into the atmosphere is therefore potentially large.

The eddy covariance (EC) technique enables the direct measurement of turbulent fluxes within the flux source area. EC is a robust and widely used method for measuring trace gas and energy fluxes between land ecosystems and the atmosphere (Baldocchi 2014). More recently, advances have been made in applying EC over lakes but the methodology is not yet as established as on land (Mammarella et al. 2015). For rivers however, there exists only one previous campaign where greenhouse gas fluxes were measured using the EC method (Huotari et al. 2013). In addition, most of the earlier riverine flux studies, mainly conducted with flux chambers, have been carried out in temperate or tropical regions. Consequently, fluxes from the boreal rivers form a considerable knowledge gap.

From June to October 2018, the international KITEX campaign on the river Kitinen was arranged. The aim of the campaign was to measure the turbulent greenhouse gas and energy fluxes over a boreal river with an EC system throughout the growing season as well as all the essential supporting variables, so that a comprehensive view of the river–atmosphere greenhouse gas fluxes and their physical rivers could be formed.

METHODS

The boreal river Kitinen is located in northern Finland. It is 235 km long and its catchment area is 7 672 km^2. The catchment area comprises mostly of coniferous forest, wetlands and a few low fells. An EC system as well as several other instruments were set up on a floating platform, anchored in the middle of the river next to the Tähtelä research station of the Finnish Meteorological Institute (coordinates: 67.37° N, 26.62° E). The river is 180 m wide at the experiment site and approximately straight for 0.7 km upstream (north-northwest) and 1.1 km downstream (south-southeast).

On the platform, the turbulent carbon dioxide (CO_2) and methane (CH_4) fluxes above the river were measured. The EC system consisted of a METEK uSonic-3 sonic anemometer, a LI-COR LI-7200 gas analyser for measuring the CO_2 and H_2O concentration and a Picarro G-1301f gas analyser for measuring the CH_4 concentration. The system was set up at a height of approximately 2 m above the river surface. Additionally, the carbon dioxide concentration in the river surface water was measured with Los Gatos UGGA and CONTROS HydroC gas analysers, making it possible to calculate the gas exchange coefficient for CO_2. Other measured parameters included flow velocity, river temperature profile, river oxygen concentration, meteorological variables and several others.

The campaign provided with EC flux data from the 15th of June to the 2nd of October of 2018. The data were quality-flagged and wind direction-flagged so that only the good-quality fluxes that originated from the river were included in the data analysis. The accepted wind sectors were determined using flux footprint analysis. The temporal coverage of the quality and wind direction-flagged data was 34% for the CO_2 flux and 26% for the CH_4 flux.

RESULTS

Throughout the campaign, the river was supersaturated with CO_2. The aqueous CO_2 concentration varied between 550 and 1320 ppm. The wind was channeled along the river during approximately half of the campaign, making it possible to measure fluxes from the river with EC.

The mean carbon dioxide flux during the campaign was 0.8 µmol m^{-2} s^{-1}.The monthly mean flux was highest in July. The CO_2 flux had a diurnal variation such that the daytime fluxes were smaller than the nighttime fluxes. In June, the CO_2 flux at around the local noon was slightly negative, or from the atmosphere into the river. Apart from that however, the river was a source of carbon dioxide during the campaign.

The mean methane flux during the campaign was 5 nmol m^{-2} s^{-1}. The monthly mean CH_4 flux was also highest in July. Unlike the CO_2 flux, the CH_4 showed no diurnal cycle and the river was a constantly a source, although small, of CH_4. Both the CO_2 and CH_4 flux had significant variation, the standard deviation being 2.2 µmol m^{-2} s^{-1} for the CO_2 flux and 15 nmol m^{-2} s^{-1} for the CH_4 flux. The variability of fluxes was higher during nighttime than during daytime.

The mean gas exchange coefficient k_{600} was 19 cm h^{-1}. This value is comparable to the one determined by Huotari et al. (2013) and the ones revised by Lauerwald et al. (2015). Although there was much scatter in the values, the coefficient was slightly and positively correlated with the wind speed except for small wind speeds (< 1 m s^{-1}). The gas exchange between the river and the atmosphere therefore increases with an increasing wind speed.

CONCLUSIONS

The turbulent carbon dioxide and methane fluxes were measured with eddy covariance on the boreal river Kitinen during four months of summer and autumn in 2018. The river emitted both CO_2 and CH_4 throughout the campaign, except during daytime in June when the river was absorbing CO_2. The CO_2 flux had a diurnal pattern of higher nighttime fluxes whereas the CH_4 had no diurnal variation. The gas exchange between the river and the atmosphere was increased by increasing wind speed. The measured fluxes were generally small and the variability was high, which is a sign of the many challenges in applying the eddy covariance method over water bodies.

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