Variability in CO_2 Concentrations and Sources in a Peatland Stream during Storm-Flow Events

Kerry Dinsmore (kjdi@ceh.ac.uk) and Mike Billett

Centre for Ecology & Hydrology, Bush Estate, Penicuik, EH26 0QB

Background

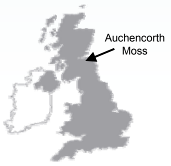
Peatland streams are known to be supersaturated in CO_2 with respect to the atmosphere. Through degassing at the water surface (evasion), streams have the potential to act as an important pathway directly linking the peatland carbon pool to the atmosphere.

The limitations of previous measurement techniques have meant that our understanding of stream water CO_2 dynamics has been patchy and of poor temporal resolution. Furthermore, periodic sampling regimes are unlikely to fully capture the importance of storm-flow extremes, possibly leading to error in estimating annual aquatic catchment carbon losses.

This study therefore aims to examine short-term temporal variability in CO_2 concentrations in response to the extreme hydrological events which make up a large proportion of the annual flow regime in UK peatland streams.

Auchencorth Moss, Scotland

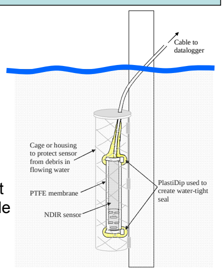
Auchencorth Moss is a relatively flat, low lying, 335 ha, ombrotrophic peatland, located approximately 17 km from Edinburgh, Scotland (55°47'34 N; 3°14'35 W). The catchment drains in a northeast direction via the Black Burn into the North Esk, aided by a series of overgrown drainage ditches. The stream hydrograph is characterized by a rapid (''flashy'') response to storm or snowmelt events producing high-flow events with high DOC concentrations.



Methods

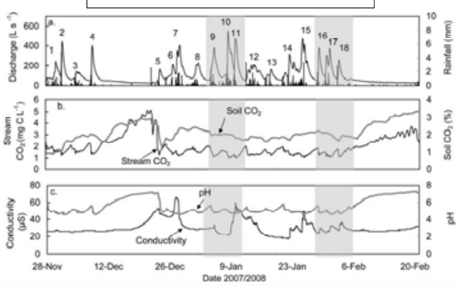
Measurements of dissolved aquatic CO_2 in the Black Burn and the adjacent peat were made continuously, alongside auxiliary measurements, from November 2007 - February 2008. CO_2 measurements were made using Vaisala CARBOCAP1 non-dispersive infrared absorption (NDIR) sensors (Johnson *et al*., in press)

'Excess CO_2' (the change in CO_2 concentration not explained by dilution) was calculated using a simple dilution model based on the increase in discharge over a time step

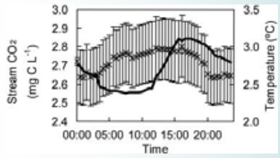


Results

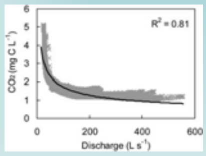
Stream hydrochemistry
(periods of catchment snow cover shown in grey)



Diurnal cycling



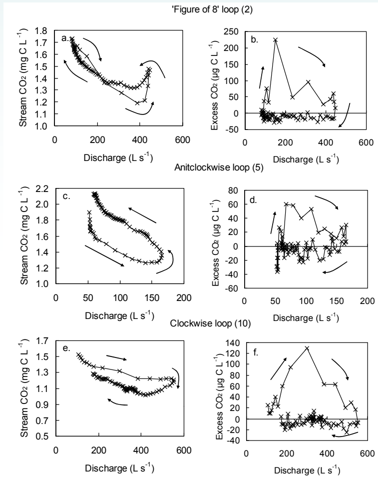
CO_2-Discharge relationship



- Off-set between CO_2 and temperature indicate that temperature dependent changes in gas solubility cannot fully explain the diurnal variation in CO_2.
- Negative curvilinear relationship between CO_2 and discharge typical of groundwater-derived solutes.
- The slope of the logarithmic plot was <1, indicates that whereas concentrations decrease with increasing discharge, total load actually increases

Concentration-Discharge (C-Q) Hysteresis loops

- Initial increase in excess CO_2 indicates an increase in input from the terrestrial system.
- Values of excess CO_2 become negative as a result of evasion.
- Anticlockwise C-Q loops produced with component concentrations: groundwater > soil water > event water (Evans and Davis, 1998).
- Reversal in rotational direction (clockwise loops) attributed to greater volume of soil water component – i.e. low water table preceding anticlockwise loops (Chanat *et al*., 2002).
- Figure-of-8 loops result of variable source area within catchment, i.e. late arrival of soil water from deep peat upstream of study site



Main Findings

- The total CO_2-C load transported downstream during the study period was 1.25 tons, 71% of which occurred during storm events which represented only 56% of the study time period.
- C-Q plots during individual storm events revealed the presence of 3 distinct hysteresis loop types, suggesting stream water CO_2 is influenced by changes in the relative dominance of different flow paths and variable source areas within the catchment.
- The strong dilutional effect indicates that deep peat/groundwater, which sustains base flow during the dry periods, is a major source of dissolved CO_2. By removing the effect of dilution and deriving ''excess CO_2'', we also show the importance of terrestrial CO_2 inputs during storm events.
- Modeled aquatic concentrations showed a greater correlation with terrestrial parameters during periods of storm-flow than base-flow, illustrating temporal variability in soil-stream connectivity.
- Discharge peak rather than total rainfall or total storm-related discharge correlated with excess stream CO_2. As peak discharge is a function of catchment hydrology and geomorphology, changes due to land management (e.g. drainage and drain-blocking) have the potential to significantly alter catchment CO_2 export.
- The correlation between soil and water CO_2 concentrations illustrates the close connectivity between the soil-stream system. This suggests that changes in the terrestrial carbon cycle will not only have a significant effect on DOC and POC, but also on CO_2 concentrations and fluxes in drainage systems.

References:
- Dinsmore, K. J. and Billett, M. F. (2008) Continuous measurement and modeling of CO_2 losses from a peatland stream during stormflow events, Water Resour. Res., doi:10.1029/2008WR007284
- Chanat, J. G., K. C. Rice, and G. M. Hornberger (2002), Consistency of patterns in concentration-discharge plots, Water Resour. Res., 38(8), 1147, doi:10.1029/2001WR000971.
- Evans, C., and T. D. Davies (1998), Causes of concentration/discharge hysteresis and its potential as a tool for analysis of episode hydrochemistry, Water Resour. Res., 34(1), 129– 138.
- Johnson, M. S., Billett, M. F., Dinsmore, K. J., Wallin, M., Dyson, K. E., Jassal, R. S. (in press), Direct and continuous measurement of dissolved carbon dioxide in freshwater aquatic systems – method and applications. Ecohydrology

SAC

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL