

# Automatic chamber measurements of Net Ecosystem (CO<sub>2</sub>) Exchange at a Subarctic Mire in Northern Sweden

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**Abstract**— Permafrost stores 50% of the global soil organic carbon [1]. Increasing climate temperatures in the arctic region have given rise to permafrost thaw, exposing once stable organic carbon to decomposition, and potentially altering the global carbon budget. In this study, we present a secondary data analysis of high frequency net ecosystem (CO<sub>2</sub>) exchange measurements made using a quantum cascade laser spectrometer (Aerodyne Research Institute) connected to a nine member autochamber system positioned in the three dominant vegetation communities at Stordalen Mire in Northern Sweden (68° 21'N, 18° 49'E). Over DOY 121 - 260 during the year 2013, the magnitude of net ecosystem (CO<sub>2</sub>) exchanged followed the moisture gradient with increasing CO<sub>2</sub> uptake from the dry Palsa site (- 0.3 ± 1.6 mg C m<sup>-2</sup> h<sup>-1</sup>), to the wet intermediate melt feature with Sphagnum spp. (- 22.1 ± 0.9 mg C m<sup>-2</sup> h<sup>-1</sup>), to the fully wet Eriophorum spp. site (- 49.9 ± 4.2 mg C m<sup>-2</sup> h<sup>-1</sup>), with highest uptake occurring in the fully thawed Eriophorum/Sphagnum (Ch. 9) collar (- 87.2 ± 6.0 mg C m<sup>-2</sup> h<sup>-1</sup>) (overall mean ±1 SE, n = 1267, 2334, 1211, 772). All mean fluxes were statistically different from each other (p < 0.0001). At all sites, PAR was the best environmental predictor of NEE. Although increased warming has resulted in permafrost thaw, any possible loss of old carbon in the form of CO<sub>2</sub> from thawing or thawed sites was more than offset by a greater net uptake of CO<sub>2</sub> occurring in the wetter sites.

**Index Terms**— Permafrost, wetland, bog, fen net ecosystem (CO<sub>2</sub>) exchange, diurnal, peatland, peat, respiration, thaw gradient

## I. INTRODUCTION

Northern latitude (>~50°N) wetlands are characterized by cold, wet conditions that result in low decomposition rates for plant litter. These conditions promote the sequestration of carbon (C) in the form of organic matter (i.e. peat) and result in the development of widespread peatlands, wetlands thick with water-logged organic soil layer (peat) made up of decomposing plant material. Peatlands in the Northern Hemisphere have removed atmospheric CO<sub>2</sub> for

the past 10,000 years [2]. Approximately twenty-four percent (24%) of the Northern Hemisphere contains permafrost, which has accumulated 1700 Petagrams (Pg) of organic C, which is more than double the size of the whole atmospheric carbon pool and more than twice the amount of previous estimates in high latitude [3, 4, 5].

As of 2000, average temperature levels in the Swedish sub-arctic region have reached a point where statistical data shows the temperature has crossed the 0°C mean annual threshold for permafrost stability [6]. With the temperature increase in arctic regions, the result is permafrost thaw. Peatlands in the Northern permafrost regions have been currently experiencing increased thaw rates [6, 8, 9]. The recession of permafrost has been the subject of observation in prior studies of arctic and subarctic regions [10]. Large scale permafrost degradation has been predicted for the 21st century in models by the Arctic Climate Impact Assessment [11].

A more prevalent concern is the environmental and physical changes that would occur from positive or negative feedback of accelerated climate change. Changes in vegetation could include increased plant growth and vegetation decomposition [9]. In correlation with the decomposition of vegetation, carbon released into the atmosphere has the potential to turn into carbon dioxide (CO<sub>2</sub>) or methane (CH<sub>4</sub>). The addition of carbon dioxide and methane to the atmosphere will create positive feedback to global warming [6, 7]. Scientists question whether the northern peatlands will remain an overall carbon sink or if they will shift to a carbon source.

A site of interest to help understand the effects that climate change has had on arctic wetlands is the Stordalen Mire located in northern Sweden. The mire is a heterogeneous landscape, where the vegetation varies due to the site being in a zone of discontinuous permafrost, which creates differences in plant life, moisture, nutrient and permafrost statuses [9]. The hydrological component and climate temperature have

impacting effects on the environment and the atmospheric sink function of the peatlands [9]. The thawing of permafrost increases the hydrologic levels which produce more pond-like areas [6]. It has been shown that moisture impacts microbial activity [12]. The increase in moisture and nutrients due to the degradation of permafrost enhance conditions for CO<sub>2</sub> and CH<sub>4</sub> to be emitted in the atmosphere [16].

In this study, we performed a secondary data analysis of net ecosystem (CO<sub>2</sub>) exchange (NEE) measurements and environmental conditions (i.e. PAR, air and ground temperature) collected along a natural permafrost thaw gradient from DOY 121 - 260, year 2013.

## II. METHODOLOGY

### A. Site Description

Stordalen Mire (10 km east of Abisko of northern Sweden (68° 21'N, 18° 49'E, altitude 363 m above sea level) has been the focus of many investigations and research concerning decadal vegetation, trace gas emissions, and climate change due to its location within the Arctic circle [6, 9, 12, 13, 14, 15]. Stordalen is characterized as a palsa mire underlain with patchy, sporadic permafrost. The areas within the mire nearby each other have a variety of moisture and nutrient status ranges [9].

The annual temperature at Abisko Scientific Research Station of 0.07°C with 308 mm of accumulated precipitation (1986-2006 20 year mean) [15]. The research focused on three different sub-habitats that have the most dominant presence in Stordalen and common to northern wetlands. The three communities are i) drained palsa underneath woody herbaceous (permafrost), ii) intermediate permafrost sites where the water table fluctuates close to the ground, dominated by Sphagnum, and iii) wet sites where the ground completely thawed in the summer, wet areas containing Eriophorum. For the sake of this research we will refer to the three sites as the palsa site, Sphagnum site, and Eriophorum site. Together, the three vegetation communities cover 98% of Stordalen Mire. The palsa site coverage extends 49% of Stordalen, the Sphagnum site expands over 37%, and Eriophorum reach 12% of the mire [14]. The fourth site is a transition collar between the Eriophorum and Sphagnum sites [10].

### B. Automatic Chamber System and Quantum Cascade Laser Spectrometer Measurements

The automatic chamber system has been fully described in earlier papers [15, 17]. The chamber system was updated in 2011 with the addition of a ninth chamber [(n = 3 each at the Palsa and Sphagnum site, n = 2 Eriophorum site, n = 1 at the Eriophorum/Sphagnum collar, designated as Ch. 9). The chambers are closed every 3 hours for 5 minutes, approximately 3% of everyday.

### C. Measurements of Net Ecosystem (CO<sub>2</sub>) Exchange

The NEE between an ecosystem and the atmosphere is the net result of the competing flux processes of gross primary

production (GPP, photosynthetic CO<sub>2</sub> uptake) and total ecosystem respiration (TER, autotrophic and heterotrophic CO<sub>2</sub> production). Net uptake of CO<sub>2</sub> fluxes were calculated using the standard procedure. All fluxes (positive or negative; n = 13,527) with r<sup>2</sup> < 0.87 (minimum necessary for 95% confidence limits) were eliminated, resulting in 47% of the data being discarded (n = 6,411).

### D. Environmental Variables

In addition to the trace gas data, ground and air temperature were recorded within each chamber, while photosynthetically active radiation (PAR) was measured at the top of the automatic chamber system shelter. The data was continuously logged by the automatic chamber system previously described.

### E. Data Analysis

We distinguished day and night CO<sub>2</sub> fluxes to account for diurnal fluctuations. The sun does not set during this time of year in areas located 180 km above the Arctic Circle, but during the period where the sun is at its lowest angle, calm cool periods are induced due to surface cooling. Based on light and temperature variability during 24 hour periods, daytime was determined to be from 10:30 am to 3:30 pm and night time was from 9:30 pm to 2:30 am [10]. For this study, CO<sub>2</sub> uptake by the ecosystem is negative and emitted CO<sub>2</sub> is positive.

## III. CONCLUSION

The purpose of this research was to determine whether or not the Stordalen Mire would maintain the status of an atmospheric C sink or become an atmospheric C source after the effects of climate change. In conclusion, the data for the green season of 2013 revealed that the entire Stordalen Mire site remained a carbon sink. The calculated mean of NEE was recorded as -32.207 mgCm-2h-1 for the whole peatland showing consistent uptake during the green season. The same can be concluded for each individual site within mire. The palsa site recorded -0.394 mgCm-2h-1 which was the lowest atmospheric sink site. Next came the Sphagnum site with -22.12 mgCm-2h-1. The highest average C uptake present in the mire was found at the Eriophorum site with -49.935 mgCm-2h-1 and the Eriophorum/Sphagnum (Ch.9) site with -87.196 mgCm-2h-1. The Eriophorum and Ch.9 sites were the largest carbon sinks of the mire, with the transition collar, Ch. 9, having the largest uptake of CO<sub>2</sub>. The regression analysis performed showed that out of the three environmental variables tested, PAR explained most of the data with the highest r<sup>2</sup> value for the whole mire and each individual site. This could be due to the strong impact photosynthesis has on the uptake of carbon.

## IV. FUTURE WORKS

For the future work we plan to study the water table depth to have an understanding of the hydrology of the sites. Hydrological functions influence microbial communities that can have an effect on the production either CO<sub>2</sub> or CH<sub>4</sub>. The water table depth also provides clarity to the extent of the

permafrost thaw. In addition to the water table depth, we also plan to look at measurements of the active layer. The active layer depth increases as the permafrost thaws. Documentation of the changes in the active layer on an extensive period of time can indicate the amount of permafrost that is lost. Both of these would be used as environmental variables to further develop insight on their effect on NEE.

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