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MICROMETEOROLOGICAL MEASUREMENTS OF METHANE AND ENERGY FLUXES IN A MINNESOTA PEATLAND

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The micrometeorological eddy correlation technique was used to measure fluxes of methane and energy. Results from these measurements made in a Minnesota peatland are reviewed here. The field observations made in a pilot study (1990) demonstrated the utility of the eddy correlation technique for measuring surface fluxes of methane. Seasonal distribution of methane flux at the same site was obtained in a detailed study (May to October) in 1991. The evapotranspiration rates and other components of the surface energy budget were also quantified. The daily evapotranspiration during the measurement period (mid May to mid October) ranged from 0.9 to 6.0 mm day^{-1}, with a seasonal average of 3.6 mm day^{-1}.

Keywords: Eddy correlation technique, methane flux, peatlands

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INTRODUCTION

Recently, we have initiated a program of research to measure and analyze methane fluxes in northern wetlands, using the micrometeorological eddy correlation technique. A tunable diode laser spectrometer was employed to measure the fluctuations in methane concentration. Here we review the results on methane and energy fluxes measured in a Minnesota peatland in 1990 and 1991.

MATERIALS AND METHODS

The study site, referred to as the Bog Lake Peatland, is located in the Chippewa National Forest, adjacent to the Marcell Experimental Forest (47°32´N, 93°28´W) in north central Minnesota, U.S.A. The average annual precipitation is about 770 mm and the average annual temperature is 3°C. The eddy correlation instrumentation included one-dimensional sonic anemometers, a three-dimensional sonic anemometer, fine wire thermocouples, a krypton hygrometer and a methane sensor. The three-dimensional sonic anemometer, a fine wire thermocouple and a hygrometer were mounted at 3.5 m above the peat surface. The other sensors were mounted at 2.5 m. The methane sensor used in this study was a fast response, closed cell, tunable diode laser absorption spectrometer (TDLS). The description of these sensors are given in Verma (1990) and Verma et al. (1992). In order to minimize contamination due to low frequency oscillations and loss in flux due to somewhat imperfect sensor response at higher frequencies, a band-pass covariance technique (e.g., Hicks & McMillen 1988) was employed. Details on this technique and data acquisition information are included in Verma et al. (1992).

RESULTS AND DISCUSSION

Measurement of methane flux

In this section, we will first review the results of a pilot study conducted in 1990 (for details, see Verma et al. 1992). Then the results from a more extensive study in 1991 will be outlined (details are available in Shurpali et al. 1993, submitted).

Pilot study: 1990

Time domain signal traces

As seen in Fig. 1, the three scalars (methane concentration, humidity and air temperature) seem to fluctuate in a similar manner with a high degree of correlation, and are in phase. The positive fluctuations in these scalar signals are generally associated with updrafts (positive vertical velocity) and the negative scalar fluctuations correspond to downdrafts, as would be expected for fluxes directed away from the surface. The magnitude of the scalar fluctuations appears to depend on the direction of the vertical velocity. Relatively large positive fluctuations (with respect to the "means") of methane (≈ 45 ppb), water vapor (≈ 1.6 g m^{-3}) and air temperature (≈ 3.0°C) are observed. The negative fluctuations in s, q and T are moderate in magnitude (≈ 25 ppb, 0.6 g m^{-3} and 1.0°C, respectively).

These results are consistent with the previous observations of carbon dioxide and other scalar fluctuations (e.g. Ohtaki 1984). The similarity in the trace patterns of methane, water vapor and air temperature, and the relationship of these scalar fluctuations with respect to updrafts and downdrafts provided encouraging preliminary evidence of the TDLS sensor's performance under field conditions.

Cospectra

To evaluate the performance of the TDLS sensor, it is useful to examine the cospectrum of methane concentration and vertical velocity fluctuations. The peak of the methane cospectrum (Fig. 2A) occurs near f (dimensionless frequency) ≈ 0.10,

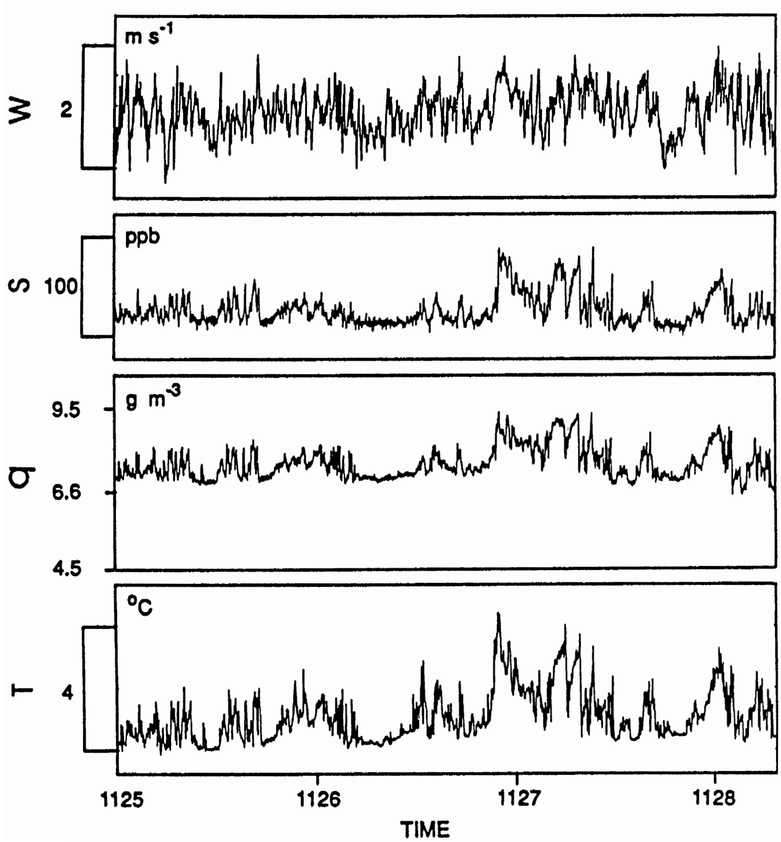


Fig. 1. Typical time traces of turbulent fluctuations of vertical velocity (w), methane concentration (s), humidity (q) and air temperature (T). August 12, 1990. (Adapted from Verma et al. 1992.)

with most of the contributions to the turbulent flux of methane taking place in the frequency interval of $f \approx 0.001$ to 5. This result is similar to the observations on carbon dioxide, sensible heat and water vapor transfers made by Ohtaki (1984) and others. In Fig. 2B, the normalized cospectra of methane, water vapor and sensible heat, measured concurrently, are plotted together. The three normalized cospectra are quite similar in shape. Methane and water vapor cospectra followed the –4/3 power slope over $f \approx 0.4$ to 2.5, whereas the temperature cospectrum followed the –4/3 slope over $f \approx 0.9$ to 10.

Comparison with results from previous studies

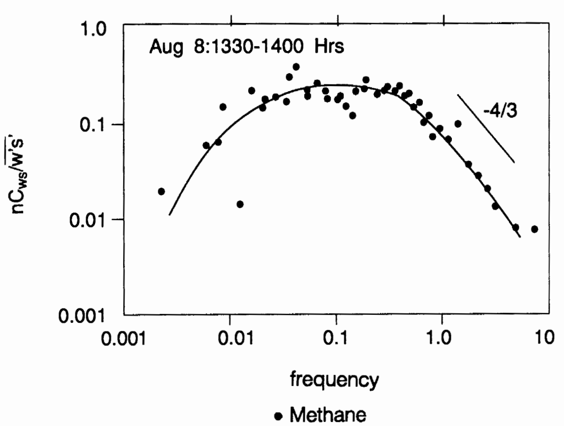
The methane flux from our study site, Bog Lake Peatland (open fen), should be comparable to fluxes from other (nonfloating) open fens and open bogs [e.g., S-4, (nonfloating), Bena Bog, Harriss et al. 1985, Crill et al. 1988] with a similar depth to water (aerated zone). The mean daily methane flux from our site during the second week of August was 177 (± 35) mg m^{-2} day^{-1}. The mean fluxes from other open fens and open bogs (nonfloating) with a similar depth to water ranged from 194 to 262 mg m^{-2} day^{-1} in August in previous studies (Table 1).

1991 Study (May to October)

Methane flux was measured at our site during mid May through mid October in the 1991 growing season. Two levels of variability were observed in the methane flux data. The first level represented a "gradual" seasonal pattern of methane flux, which appeared to be somewhat similar to the pattern of the peat temperature. In the early part of the season (late May to early July), the mean daytime (averaged during 1 000 to 1 700 hrs., local time) methane flux ranged from 45 to 120 mg $m^{-2}day^{-1}$. During mid July to mid August, the methane flux ranged from 125 to 160 mg $m^{-2}day^{-1}$. Later in the season (early September to mid October), the flux reduced to the range of 35 to 100 mg $m^{-2}day^{-1}$. Superimposed on the seasonal pattern are several episodic emissions of methane. These events generally spanned 4 to 5 days, and the methane flux was 2 to 3 times as large as the values in the general seasonal trends, discussed above. The episodic emissions were associated with substantial drops in atmospheric pressure and decline in water table (for details, see Shurpali et al. 1993, submitted).

Energy partitioning and evapotranspiration

The latent heat flux (LE) consumed 60 to 80% of net radiation (Rn) during May to August (daily mean air temperature varied from 15 to 25°C). The value of LE/Rn ranged from 0.4 to 0.6 during the senescence period (September to October) when air temperature fell below 10°C. During the measurement period (May to October), the daily ET ranged from 0.9 to 6.0 mm day^{-1}, with a seasonal average of 3.6 mm day^{-1}. The *Sphagnum* bog evapotranspired at near potential rate (within 15%) through most of the season, except during the senescence period (late September to October).



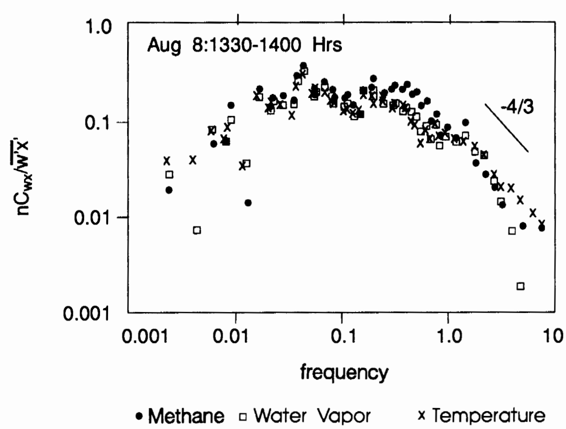


Fig. 2. Normalized logarithmic cospectra of methane, water vapor and temperature as functions of nondimensional frequency (f). (Adapted from Verma et al. 1992.)

Table 1. Comparison with previous studies in Minnesota Peatlands (mid summer data).

	Site	Study period	Methane flux, mg $m^{-2}day^{-1}$ Mean	Range	Reference
Open fen	Bog Lake	Aug. 7–14, 1990	177	142–212	This study
	Bena Bog	Aug. 1986	221	151–413	Crill et al. (1988)
Open bog	S-4	Aug. 1983	194	33–468	Harriss et al. (1985)
	S-4	June 1986	262	207–321	Crill et al. (1988)

SUMMARY AND CONCLUDING REMARKS

Examination of the time domain traces and cospectra of methane in relation to other scalars, and comparison of fluxes with previous measurements in Minnesota peatlands, provide substantial evidence that the micrometeorological eddy correlation technique can produce accurate measurements of methane fluxes.

Methane flux was measured during mid May through mid October, 1991, at a peatland site in north central Minnesota. The distribution of methane flux consisted of a general seasonal pattern (with low flux values in May and October and a maximum of about 160 mg $m^{-2}day^{-1}$ during July to August) with several episodic emissions superimposed.

The components of the surface energy budget were quantified at this peatland site. This bog evapotranspired at near potential rate through most of the measurement period, except during the senescence period (late September to mid October).

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