EPA Climate Change Research Programme 2007-2013

Field campaign at Dripsey, Cork for inter-comparison of eddy covariance instrumentation for N_2O, CO_2 and CH_4 measurements

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CCRP Report

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by

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DISCLAIMER

The EPA CCRP Programme addresses the need for research in Ireland to inform policymakers and other stakeholders on a range of questions in relation to environmental protection. These reports are intended as contributions to the necessary debate on the protection of the environment.

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Details of Project Partners

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Executive Summary

Europe-wide efforts are underway to improve accuracy of the eddy-covariance measurements that are used as a basis for estimating national and regional inventories of the greenhouse gases. It is, therefore, important to assess performance of existing micro-meteorological observations systems in Ireland against the most advanced eddy covariance equipment.

During a month of field inter-comparison study at the grassland site in Dripsey, two sets of eddy-covariance equipment were used to estimate ecosystem fluxes of carbon dioxide, nitrous oxide and methane. One of them was an 8-year old system equipped with tuneable-diode laser (for N_2O) and open-path infrared analyser (for CO_2) and operated by the UCC's Hydromet group. The second system included closed-path quantum-cascade laser analyser (for both N_2O and CO_2) acquired in 2009 by the UK's Forestry Research.

Both systems performed equally well when estimating carbon dioxide fluxes. The employment of the open-path (UCC) systems is known to be associated with higher rate of the data loss under adverse weather conditions. This difference was not significant, however, during our field campaign.

The differences between N_2O measurements were greater, mostly due to the intermittent nature of the nitrous oxide fluxes and the configuration of the FR setup.

An abstract entitled "*Inter-comparison of field methods for measurement of nitrous oxide emission*" for the upcoming NitroEurope meeting was submitted by authors.

1. Introduction

1.1. Background

Monitoring and accounting of the greenhouse gas fluxes (CO_2, N_2O, CH_4) is a critical step in fulfilling Ireland's obligations under the Kyoto Protocol. In recent decades near-continuous measurements of ecosystem fluxes became possible with introduction of advanced micrometeorological techniques, such as eddy covariance (EC) (Baldocchi 2003). The development of the eddy covariance equipment is ongoing with the major progress seen in the area of trace gas analysers.

Carbon dioxide (CO_2) is the major and the most studied green house gas. It has minimal global warming potential (GWP), however, as primary element of Earth's carbon cycle it is a dominant greenhouse in the atmosphere. Such importance of the CO_2 is acknowledged in the high quality of equipment available for monitoring tasks.

Development of the equipment for other trace gases, such as N_2O and CH_4, is on-going and the improvements are still being made. Our existing N_2O analyser (tuneable diode laser, http://www.campbellsci.com) has been in service for over 8 years and while a number of peer-reviewed publications were produced (Leahy et al. 2004; Hsieh et al. 2005; Kim et al. 2010; Mishurov and Kiely 2010), its measurements were not verified against another eddy-covariance system.

Since, our study site is located in the grassland area, we do not posses EC equipment for monitoring methane flux. However, availability of new equipment provides an opportunity to gain experience operating and maintaining it.

Due to the higher GWP values, 25 and 298 for CH_4 and N_2O, respectively, precision of non-CO_2 gas fluxes is a concern for the correct estimation of the greenhouse gas balance. To improve quality and decrease uncertainty of the eddy-covariance measurements, ongoing efforts are underway across a number of international projects. For example, the CarboEurope-IP project recently carried out a cross-site inter-comparison analysis of the data quality and calculation techniques to assess the most important steps in data manipulation (Göckede et al. 2008; Mauder et al. 2008). Similar steps with regard to methane and nitrous oxide are required to produce reliable balance of greenhouse gases.

1.2. Aims and objectives

The objectives of the EPA funded project were as follows:

1. Build network links with international researchers.
2. Gain experience with the technical and practical application of emerging state of the art instrumentation and data analysis methodology.

2. Materials and methods

2.1. Study site

The experimental site was located near village of Donoughmore, Co. Cork. Figure 1 demonstrates location of the study site within the Republic of Ireland. The existing eddy covariance tower is located in a middle of a grassland area on a privately-owned land. The primary land use in the adjacent area is typical for this region: dairy cattle grazing, and silage cutting. The field measurements were carried out in a month between 26th August and 26th September. A set of environmental variables was also observed: rainfall, top-soil moisture and temperature.

2.2. Eddy covariance methods

Eddy covariance is a micrometeorological technique that uses the properties of the atmospheric boundary layer (ABL) to calculate the fluxes of gas species and energy between an ecosystem and the atmosphere. This method is based on the ability to calculate the covariance of simultaneous fluctuations in the vertical component of the turbulent flow of air along with the fluctuations in the specific gas concentration (or density) for gas fluxes, temperature for sensible heat flux and horizontal wind speed for the flux of momentum. The nature of the turbulent flow requires high-frequency measurements at the scale of 10–20 Hz; precise measurements of the gas concentrations at such frequencies were until recently impossible (Kaimal and Finnigan 1994; Lee et al. 2004).

2.3. Eddy-covariance equipment and data processing

The existing equipment managed by our group includes: closed-path tuneable diode laser trace gas analyser (TDL TGA 100A, Campbell Sci., USA) for high-frequency measurements of nitrous oxide concentration; open-path CO_2/H_2O analyser Li-7500 (LI-COR Biosciences, USA) and the 3-D sonic anemometer (CSAT3, Campbell Sci., USA) installed at the 6 m height. The signals from these instruments are recorded with CR1000 data logger (Campbell Sci., USA) at the rate of 10 Hz. The data are further processed in-house to obtain the 30-min flux series.

The equipment owned by the Forestry Research (FR) includes quantum cascade laser gas analyser (QCL, Aerodyne Inc., USA) that is used for measuring N_2O, CO_2 and H_2O gases (Figure 2). The 20 Hz sonic anemometer (USA-1, Metek, Germany) was installed along side UCC anemometer and positioned to minimize the interference from pre-dominant wind direction. Additionally, the Fast Methane Analyser (FMA, Los Gatos, USA) was included in the setup. The data collection was performed on the desktop computer running Ubuntu Linux operating system, with the CO_2/H_2O and CH_4 data processing done by *eth-flux* program (by Werner Eugster, ETH Zurich). Since, no processing software existed for N_2O flux calculation; our own software was adapted to handle the output of the FR system. FR equipment was overall more compact and mobile than the UCC equipment. Particular to the nitrous oxide measurement, it did not require compressed reference gas and therefore, could be easily transported and operated even on mobile platforms. While such measurements are not done routinely in terrestrial ecosystems, it is helpful when a number of small-scale plots is being evaluated, since transportation and setup costs are minimal.

Since no methane analyser is owned by Hydromet group, it was not possible to conduct inter-comparison of CH_4 fluxes. Instead, the hands-on experience was gained operating and maintaining the instrumentation on site. Unlike the QCL, FMA analyser is capable of measuring gas concentration at variable rate between 1 and 20 Hz, for the duration of experiment it was run at 20 Hz. This sampling rate could be changed while instrument is online.

3. Results and Discussion

3.1. Environmental conditions

Cumulative daily rainfall and averaged daily soil moisture and soil temperature are presented in Figure 3. While soil temperature varied throughout the study period around 14 °C, levels of soil moisture were strongly affected by the rainfall. Before a heavy rainfall on 5th September WFPS was under 50%, its level increased up to around 65% and was maintained at that level until the end of experiment due to the intermittent rains of lower intensity. Because of the data logger downtime in early September some records of soil temperature and moisture were missing.

3.2. CO_2 fluxes

Daily time series of CO_2 fluxes is presented in Figures 6 and 7. The rainfall intensity during most of observation period was relatively low and as such open-path (UCC) system did not differ much from the closed-path (FR) system in the amount of obtained record. It is known, however, that an open-path system would be more prone to data loss under adverse weather condition.

Comparison of the results shows that both systems observed similar amounts of uptake (negative) flux of CO_2 during the first (dry) week of measurements. During the following period frequent rainfall events emission events dominated the time series, but the ecosystem returned to uptake mode when the rain shortly ceased on 22–24 days of measurement (15–17th September). This demonstrated quick response of the equipment to changing environmental conditions.

3.3. N_2O fluxes

The time series of daily N_2O fluxes between the two systems is presented in Figures 4 and 5. It is notable that the average magnitude of FR fluxes is somewhat smaller than that of UCC fluxes. We speculate that the reason behind it is the configuration of the FR setup, where FMA analyser is installed between the sample intake and the QCL. Further work is currently being done to investigate effects of such configuration on the concentration measurements in QCL. While both CO_2 and N_2O are measured at the same instrument, this phenomenon was only observed in case of N_2O, which in our opinion is due to the lower fluxes (that are the reason for lower variation in instantaneous concentration values).

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5. List of Figures

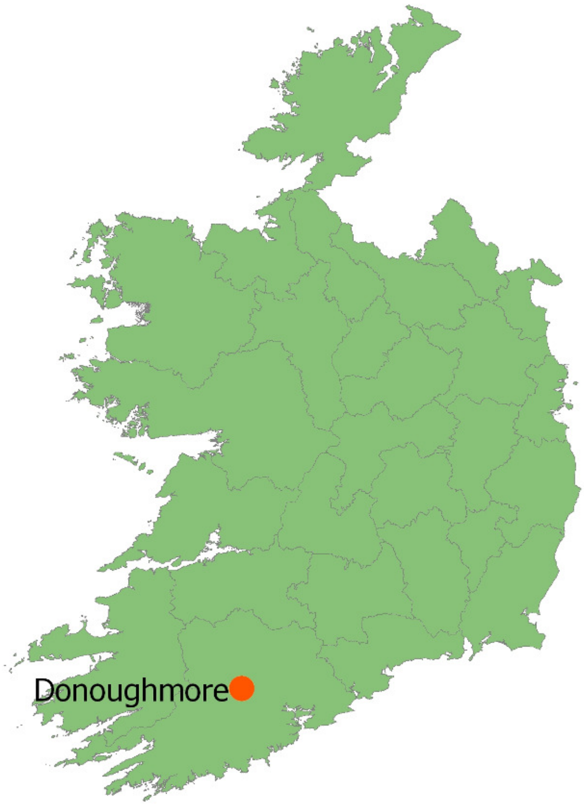

Figure 1: Geographic location of the study site within the Republic of Ireland.

Figure 2: FR equipment including FMA (on the left), QCL (top right), cryogen cooler and pump are on the ground.

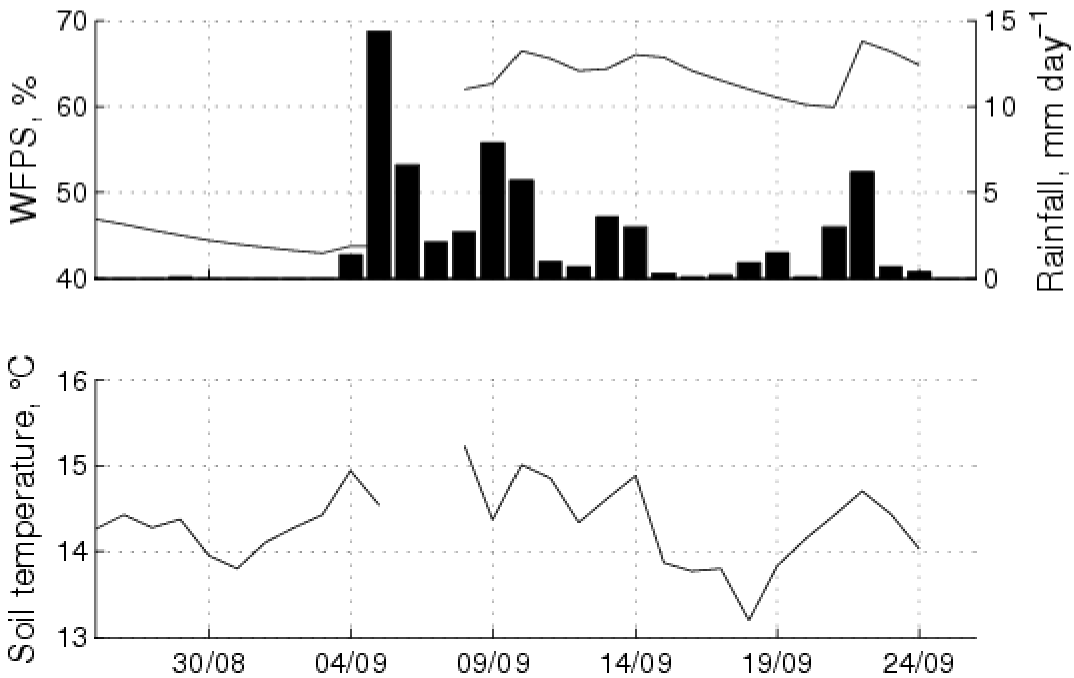

Figure 3. Soil moisture (WFPS), daily rainfall and soil temperature during the observation period.

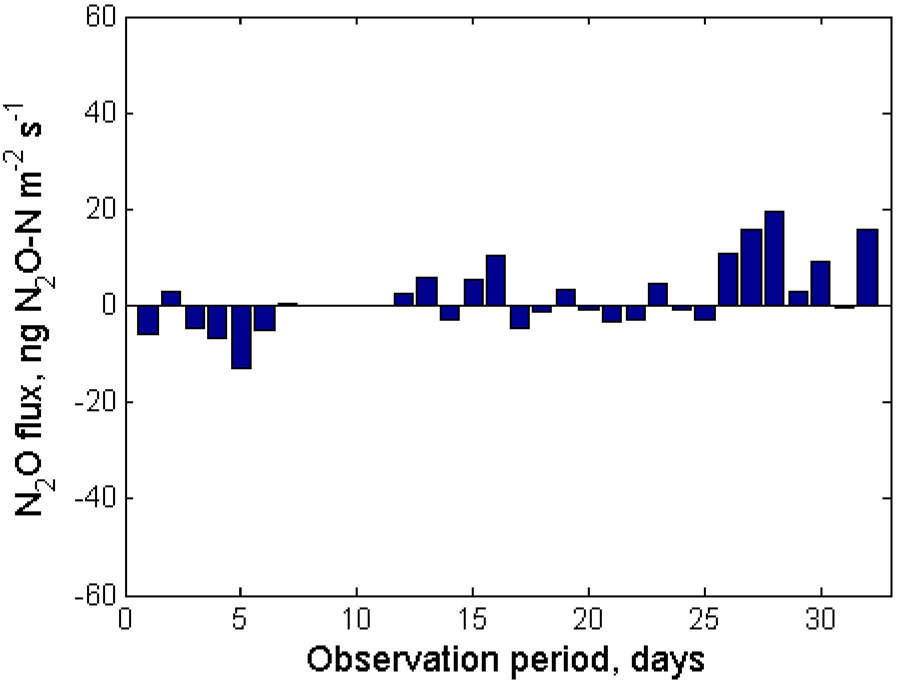

Figure 4. Daily averaged fluxes of nitrous oxide obtained from FR system.

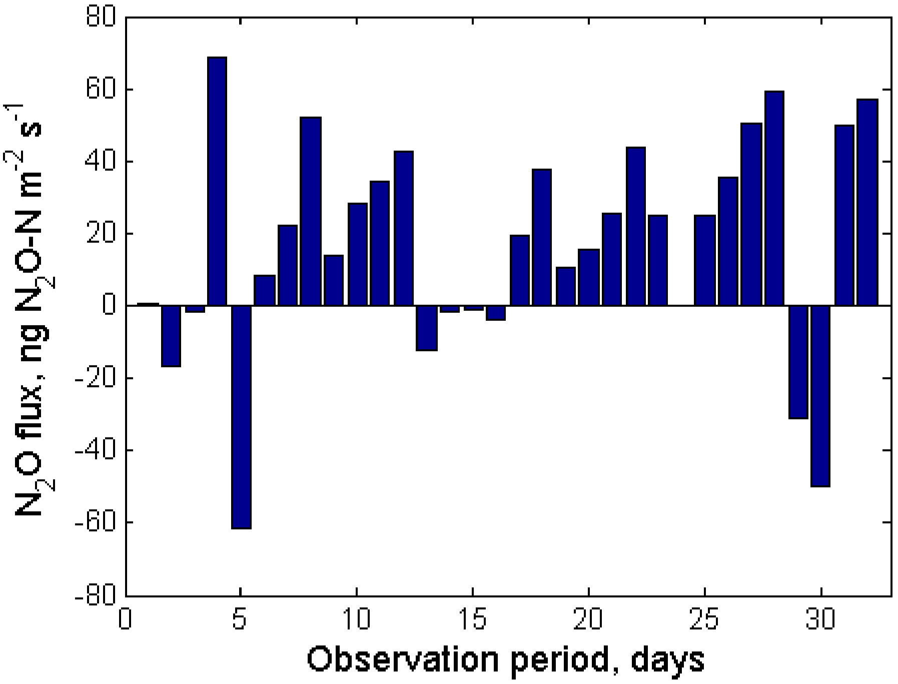

Figure 5. Daily averaged fluxes of nitrous oxide obtained from UCC system.

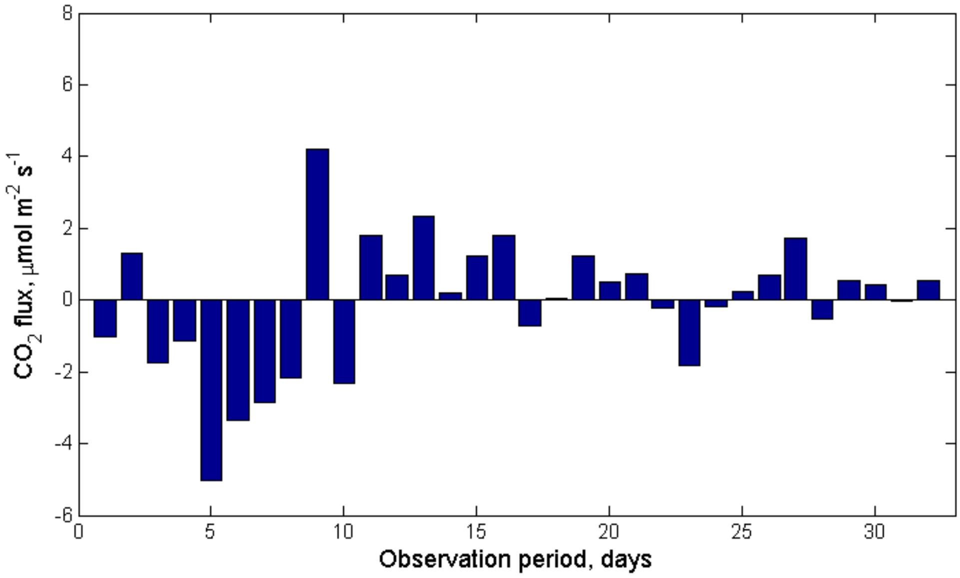

Figure 6. Daily averaged fluxes of carbon dioxide obtained from FR system.

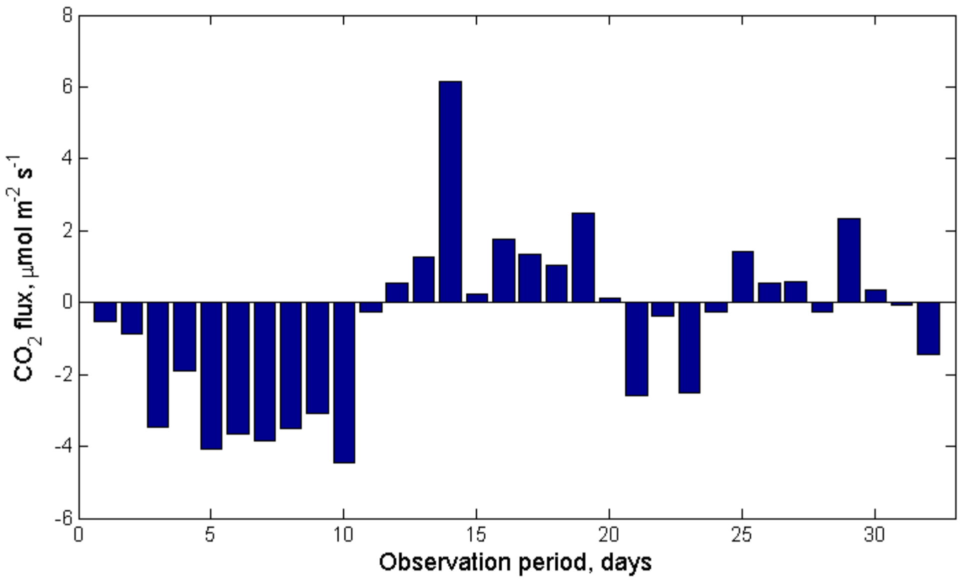

Figure 7. Daily averaged fluxes of carbon dioxide obtained from UCC system.