Flux measurements of CH_4 and N_2O exchanges

P.S. Kroon[a]

T. Vesala[b]

J. Grace[c]

[a]Energy research Centre of the Netherlands (ECN), Petten, The Netherlands
[b]University of Helsinki, Helsinki, Finland
[c]University of Edinburgh, Edinburgh, UK

Published in Agricultural and Forest Meteorology 150 (2010) 745–747

ECN-W--10-028 March 2010

Agricultural and Forest Meteorology 150 (2010) 745–747

Contents lists available at ScienceDirect

Agricultural and Forest Meteorology

journal homepage: www.elsevier.com/locate/agrformet

Flux measurements of CH_4 and N_2O exchanges

ARTICLE INFO

Keywords:
Data processing
Ecosystem
Eddy covariance
Instruments

1. Foreword to the special issue

This special issue is the result of a workshop about eddy covariance (EC) flux measurements of CH_4 and N_2O held at the Hyytiälä Forestry Field station in Finland in April 2008 in relation to NitroEurope IP and ICOS (Integrated Carbon Observation System) ESFRI preparatory phase project. The topic is important in the greenhouse gas (GHG) evaluation community, and it also has policy implications in relation to managing land for reduced emissions. EC flux measurements of CO_2 have been performed successfully since the early 1990s; however, field-portable and rapidly responding instrumentation for CH_4 and N_2O measurement became a commercial reality only a few years before the workshop. Consequently, the annual estimates of CH_4 and N_2O emissions from ecosystems are predominantly based on studies using manual chamber measurement which give information at plot scale covering about 0.5 m^2 per measurement (e.g., Nykänen et al., 1995; Pilegaard et al., 2006; Schrier-Uijl et al., 2009) These annual estimates have large uncertainties, even larger than 50% (e.g., Flechard et al., 2007), due to the complexity of the sources and sinks (i.e. spatial and temporal variation) which are difficult to detect accurately using chamber measurements. Many researchers have suggested that continuous measurements at hectare scale could be the solution to obtain more accurate estimates (e.g., Flechard et al., 2005). This spatial resolution can be achieved by high-frequency micrometeorological techniques, like EC flux technique.

This workshop aimed at reviewing the current knowledge about EC flux measurements of CH_4 and N_2O exchange. Five topics were addressed:

1. Overview of available instruments;
2. Field set-up;
3. Data processing;
4. Determination of annual emission values;
5. Processes of CH_4 and N_2O emissions.

Scientists came from 19 different countries distributed over four continents, i.e., USA, Europe, Asia and Oceania. The workshop was funded by iLEAPS (http://www.ileaps.org/), ICOS (http://www.icos-infrastructure.eu/), NitroEurope (http://www.nitroeurope.eu/) and Vaisala Ltd. The organizing committee came from Finland (Timo Vesala, University of Helsinki), United Kingdom (John Grace, University of Edinburgh) and the Netherlands (Petra Kroon, Energy research Centre of the Netherlands).

At the time of the workshop some instruments were available for performing EC flux measurements of CH_4 and N_2O. For example, a limited number of EC flux measurements had been published using tunable diode laser (TDL) spectrometers and quantum cascade laser (QCL) spectrometers (e.g., Rinne et al., 2005; Eugster et al., 2007; Kroon et al., 2007; Lohila et al., 2007; Neftel et al., 2007). Hendriks et al. (2008) investigated the suitability of a fast methane analyzer (FMA) for EC flux measurements of CH_4. These complex measurement devices can probably not yet be considered as ideal, as there are issues of portability, stability and response time. Drift characterization is an issue and atmospheric data may at times be affected by sensor drift. Werle (2010) developed practical guidelines how to use EC flux measurements by laser-optical instruments suffering from signal instability.

We also discussed whether the commonly used Euroflux methodology for CO_2 EC flux measurements given in Aubinet et al. (2000) could also be used for EC flux measurements of CH_4 and N_2O. Some differences in data evaluation were identified. In addition, possible improvements were given for some parts of the Euroflux methodology. For example: Eugster and Plüss (2010) evaluated the data acquisition procedure in detail. They stated that experimentalists working in the field of EC flux measurements should switch to fully digital acquisition. Moreover, an overview of possible systematic errors by EC flux measurements of CH_4 and N_2O has been given in Kroon et al. (2010-b). The effect of high-frequency losses and the effect of cross-talk of water vapor on the trace gas concentration measured by a QCL have been evaluated in Kroon et al. (2010-a) and Neftel et al. (2010), respectively.

Next to the data procedures, the uncertainty in EC flux measurements was a crucial topic. The question was addressed whether the uncertainty in EC flux measurements of CO_2 was equal to the uncertainty of the other two greenhouse gases measured by EC flux technique. The uncertainty in CO_2 measurements has been discussed previously e.g., Moncrieff et al. (1996). Kroon et al. (2010-b) estimated the uncertainty in 30 min EC fluxes of CH_4 and N_2O and the uncertainty over longer time periods. The uncertainty in a 30 min EC flux value of CH_4 and N_2O can be much larger than the uncertainty of CO_2. This is partly due to the relative small flux values of CH_4 and N_2O.

The importance of comparing different independent measurement methods was also indicated. There were only a few

0168-1923/$ – see front matter
doi:10.1016/j.agrformet.2009.11.017

published articles available concerning comparisons of EC flux measurements to chamber measurements (e.g., Laville et al., 1999; Pihlatie et al., 2005). In this issue, EC flux measurements are compared to static chamber measurements as well to the soil gradient method by Schrier-Uijl et al. (2010) and Hendriks et al. (2010). In addition, Desjardins et al. (2010) compared N_2O emission estimated from tower, air-craft and a process-based model.

The magnitude of CH_4 and N_2O emissions and their underlying processes were the last topics of the workshop. We concluded that there is still a lack of knowledge for interpreting the global CH_4 and N_2O emissions from different land types. Therefore, we encouraged performing measurements over long time periods using micrometeorological techniques. Denmead et al. (2010) investigated the emissions of both gases from sugarcane soils in Australia and Tseng et al. (submitted for publication) determined the emissions of CH_4 from a rice paddy in Taiwan.

Finally, Famulari et al. (2010) showed how EC flux measurements could not only be used for natural or semi-natural ecosystem exchange, but also for urban surface and for urban air quality. This group investigated urban N_2O from a 65 m tower above the street level of Edinburgh in Scotland.

In summary, the present volume forms a collection of eleven papers discussing several aspects concerning EC flux measurements of CH_4 and N_2O. Even since this workshop, new sensors have been introduced, and clearly this is an exciting and rapidly-expanding field of enquiry; we hope this special issue will serve to guide new entrants into the field of EC flux measurements.

Workshop participants

Aaltonen, Miska; Acosta, Manuel; Ambus, Per; Aurela, Mika; Bonal, Damien; Carrara, Arnoud; Chojnicki, Bogdan; Denmead, Tom; Di Tomassi, Paul; Drewer, Julia; Dusek, Jiri; Elbers, Jan; Emmenegger, Lukas; Eugster, Werner; Falcimagne, Robert; Famulari, Daniela; Forbrich, Inki; Grace, John; Grover, Samantha; Haapanala, Sami; Hansen, Georg; Hendriks, Dimmie; Hensen, Arjan; Herbst, Mathias; Järvi, Leena; Jackowica-Korczynski, Marcin; Johansson, Torbjörn; Juszczak, Radoslaw; Kieloaho, Antti-Jussi; Kiese, Ralf; Klemedtsson, Leif; Klumpp, Katja; Korhonen, Janne; Kroon, Petra; Lindroth, Anders; Mammarella, Ivan; McDermitt, Dayle; Michala, Maria; Neftel, Albrecht; Nikinmaa, Eero; Nordstroem, Claus; Olejnik, Janusz; Papale, Dario; Pihlatie, Mari; Rinne, Janne; Diedlecki, Pawel; Survo, Hannu; Taufarova, Klara; Tsuang, Ben; Urbaniak, Marek; Vesala, Timo; Weidmann, Damien; Werle, Peter; Xu, Liukang; Yamulki, Sirwan; Zahniser, Mark and Zwitowska-Blacha, Olga.

Acknowledgements

We would like to thank the reviewers for their critical remarks and suggestions, the authors for preparing their manuscripts and all workshop participants for their contributions to the discussions. In particular, we would like to thank the representatives of the commercial companies who were able to attend and share us with their ideas: Mark Zahniser from Aerodyne Research, Inc., and Dayle McDermitt and Liukang Xu from LI-COR Biogeosciences. We are also very grateful to the editors of agricultural and forest meteorology for the editorial work. Finally, we owe a special debt of gratitude to the sponsors of this workshop which gave rise to this special issue.

References

Aubinet, M., Grelle, A., Ibrom, A., Rannik, Ü., Moncrieff, J., Foken, T., Kowalski, A.S., Martin, P.H., Berbigier, P., Bernhoffer, C., Clement, R., Elbers, J., Granier, A., Grünwald, T., Morgenstern, K., Pilegaard, K., Rebmann, C., Snijders, W., Valentini, R., Vesala, T., 2000. Estimates of the annual net carbon and water exchange of forests: The EUROFLUX methodology. Adv. Ecol. Res. 30, 113–175.

Denmead, O.T., MacDonald, B.C.T., Bryant, G., Naylor, T., Wilson, S., Griffith, D.W.T., Wang, W.J., Salter, B., White, I., Moody, P.W., 2010. Emissions of methane and nitrous oxide from Australian sugarcane soils. Agric. For. Meteorol. 150, 748–756.

Desjardins, R.L., Pattey, E., Smith, W.N., Worth, D., Grant, B., Srinivasan, R., MacPherson, J.I., Mauder, M., 2010. Multiscale estimates of N_2O emissions from agricultural lands. Agric. For. Meteorol. 150, 817–824.

Eugster, W., Zeyer, K., Zeeman, M., Michna, P., Zingg, A., Buchmann, N., Emmenegger, L., 2007. Methodical study of nitrous oxide eddy covariance measurements using quantum cascade laser spectrometery over a Swiss forest. Biogeosciences 4, 927–939.

Eugster, W., Plüss, P., 2010. A fault-tolerant eddy covariance system for measuring CH_4 fluxes. Agric. For. Meteorol. 150, 841–851.

Famulari, D., Nemitz, E., Di Marco, C., Philips, G.J., Thomas, R., House, E., Fowler, D., 2010. Eddy-covariance measurements of nitrous oxide fluxes above a city. Agirc. For. Meteorol. 150, 786–793.

Flechard, C.R., Neftel, A., Jocher, M., Ammann, C., Fuhrer, J., 2005. Bi-directional soil/atmosphere N_2O exchange over two mown grassland systems with contrasting management practices. Global Change Biol. 11, 2114–2127, doi:10.1111/j.1365-2486.2005.01056.x.

Flechard, C.R., Ambus, P., Skiba, U., Rees, R.M., Hensen, A., Van Amstel, A.E.A., 2007. Effects of climate and management intensity on nitrous oxide emissions in grassland systems across Europe. Agric. Ecosyst. Environ. 121, 135–152.

Hendriks, D.M.D., Dolman, A.J., Van der Molen, M.K., Van Huissteden, J., 2008. A compact and stable eddy covariance set-up for methane measurements using off-axis integrated cavity output spectroscopy. Atmos. Chem. Phys. 8 (2), 431–443.

Hendriks, D.M.D., Van Huissteden, J., Dolman, A.J., 2010. Multi-technique assessment of spatial and temporal variability of methane fluxes in a peat meadow. Agric. For. Meteorol. 150, 757–774.

Kroon, P.S., Hensen, A., Jonker, H.J.J., Zahniser, M.S., Van't Veen, W.H., Vermeulen, A.T., 2007. Suitability of quantum cascade laser spectroscopy for CH_4 and N_2O eddy covariance flux measurements. Biogeosciences 4, 715–728.

Kroon, P.S., Schuitmaker, A., Jonker, H.J.J., Tummers, M.J., Hensen, A., Bosveld, F.C., 2010-a. An evaluation by laser Doppler anemometry of the correction algorithm based on Kaimal co-spectra for high frequency losses of EC flux measurements of CH_4 and N_2O. Agric. For. Meteorol. 150, 794–805.

Kroon, P.S., Hensen, A., Jonker, H.J.J., Ouwersloot, H.G., Vermeulen, A.T., Bosveld, F.C., 2010-b. Uncertainties in eddy covariance flux measurements assessed from CH_4 and N_2O observations. Agric. For. Meteorol. 150, 806–816.

Laville, P., Jambert, C., Cellier, P., Delmas, R., 1999. Nitrous oxide fluxes from a fertilized maize crop using micrometeorological and chamber methods. Agric. For. Meteorol. 96, 19–38.

Lohila, A., Laurila, T., Tuovinen, J., Aurela, M., Hatakka, J., Thum, T., Pihlatie, M., Rinne, J., Vesala, T., 2007. Micrometeorological measurements of methane and carbon dioxide fluxes at a municipall landfill. Environ. Sci. Technol. 41, 2717–2722.

Moncrieff, J.B., Malhi, Y., Leuning, R.R., 1996. The propagation of errors in longterm measurements of land-atmosphere fluxes of carbon and water. Global Change Biol. 2, 231–240.

Neftel, A., Flechard, C., Ammann, C., Conen, F., Emmenegger, L., Zeyer, K., 2007. Experimental assessment of N_2O background fluxes in grassland systems. Tellus B 59, 470–482.

Neftel, A., Ammann, C., Fischer, C., Spirig, C., Conen, F., Emmenegger, L., Tuzson, B., Wahlen, S., 2010. N_2O exchange over managed grassland: Application of a quantum cascade laser spectrometer for micrometeorological flux measurements. Agric. For. Meteorol. 150, 775–785.

Nykänen, H., Alm, J.J., Lang, K., Silvola, J., Martikainen, P.J., 1995. Emissions of CH_4, N_2O and CO_2 from a virgin fen and a fen drained for grassland in Finland. J. Biogeography 22, 351–357.

Pihlatie, M., Rinne, J., Ambus, P.E.A., 2005. Nitrous oxide emissions from a beech forest floor measured by eddy covariance and soil enclosure techniques. Biogeosciences 2, 377–387.

Pilegaard, K., Skiba, U., Ambus, P., Beier, C., Brüggemann, N., Butterbach-Bahl, K., Dick, J., Dorsey, J., Duyzer, J., Gallagher, M., Gasche, R., Horvath, L., Kitzler, B., Leip, A., Pihlatie, M., Rosenkranz, P., Seufert, G., Vesala, T., Westrate, H., Zechmeister-Boltenstern, S., 2006. Factors controlling regional differences in forest soil emission of nitrogen oxides (NO and N_2O). Biogeosciences 3, 651–661.

Rinne, J., Pihlatie, M., Lohila, A., Thum, T., Aurela, M., Tuovinen, J., Laurila, T., Vesala, T., 2005. Nitrous oxide emissions from a municipal landfill. Environ. Sci. Technol. 39, 7790–7793.

Schrier-Uijl, A.P., Kroon, P.S., Leffelaar, P.A., Van Huissteden, J.C., Berendse, F., Veenendaal, E.M., 2009. Methane emissions in two drained peat agro-ecosystems with high and low agricultural intensity. Plant Soil, doi:10.1007/s11104-009-0180-1.

Schrier-Uijl, A.P., Kroon, P.S., Hensen, A., Leffelaar, P.A., Berendse, F., Veenendaal, E.M., 2010. Comparison of chamber and eddy covariance based CO_2 and CH_4 emission estimates in a heterogeneous grass ecosystem on peat. Agric. For. Meteorol. 150, 825–831.

Tseng, K., Alagesan, A., Tsai, J., Tsuang, B., Yao, M., submitted for publication. Methane and CO_2 flux measurement during rice paddy maturity period by integrating profile and eddy covariance system in Taiwan. Agric. For. Meteorol.

Werle, P., 2010. Time domain characterization of micrometeorological data based on a two sample variance. Agric. For. Meteorol. 150, 832–840.

P.S. Kroon[a,*]
T. Vesala[b]
J. Grace[c]
[a] *Energy research Centre of the Netherlands (ECN), Department of Air Quality and Climate Change, Westerduinweg 3, 1755 ZG Petten, The Netherlands*
[b] *University of Helsinki, Department of Physics, P.O. Box 48, FI-00014 Helsinki, Finland*
[c] *University of Edinburgh, School of GeoSciences, West Mains Road, Edinburgh EH9 3JN, UK*

[*] Corresponding author.
Tel.: +31 224 564062; fax: +31 224 56 8488
E-mail address: p.kroon@ecn.nl (P.S. Kroon).