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Measuring lake-air CH_4, CO_2 and H_2O fluxes with the gradient diffusion method

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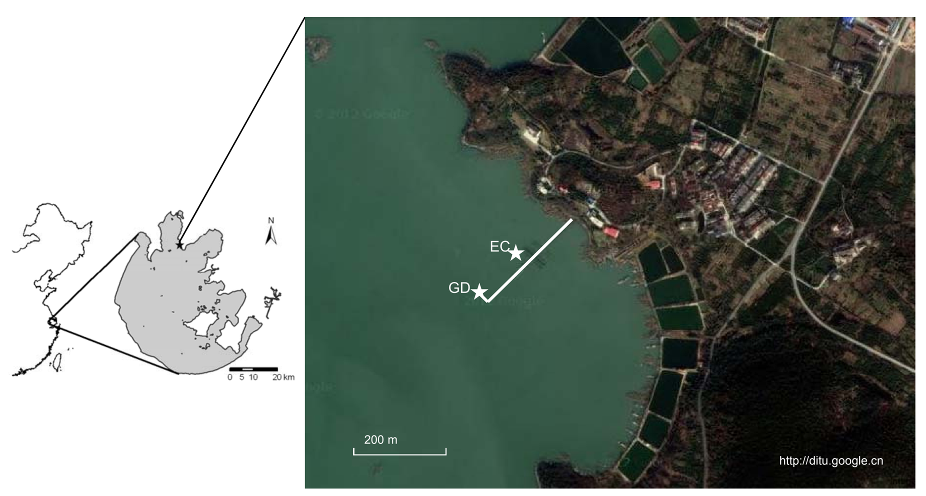
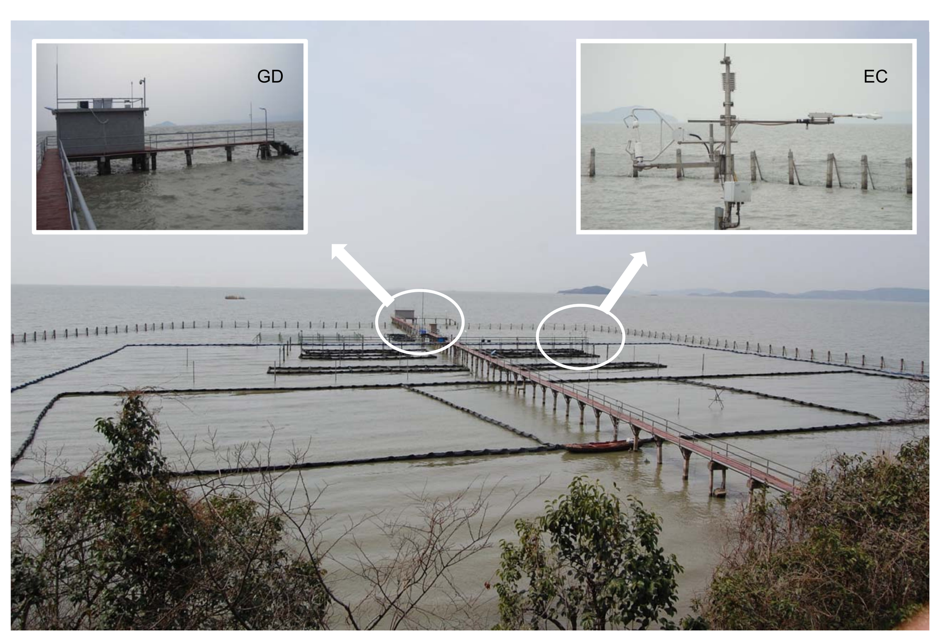
Introduction

- Lakes are an important component of the global greenhouse gas cycles. Several methods are available for the measurement of lake-air fluxes of greenhouse gases, such as floating static chamber, water equilibrium method, eddy covariance (EC) and gradient diffusion (GD).
- Measuring the lake-air greenhouse gas fluxes is challenging for several reasons, including small signal to noise ratios, bubble ebullition that evades equilibrium method detection, large density corrections on the EC flux, and wave interference with the chamber method.
- In this study, a trace gas analyzer based on the cavity ring-down spectroscopy (CRDS) was employed in the GD mode to measure the H_2O, CO_2 and CH_4 fluxes at a lake-atmosphere interface.
- Our study appears to be the first attempt at measuring these fluxes simultaneously using one instrument and in a long-term uninterrupted operation.
- The goal of this paper is to present a performance evaluation of this measurement system at Lake Taihu from May 11 to August 31, 2012

Site and Instruments

The experiment site (31°24′N, 120°13′E) was in the north part of Lake Taihu, which is the third largest freshwater lake in China, with a water surface area of 2400 km^2 and a mean water depth of 1.9 m.

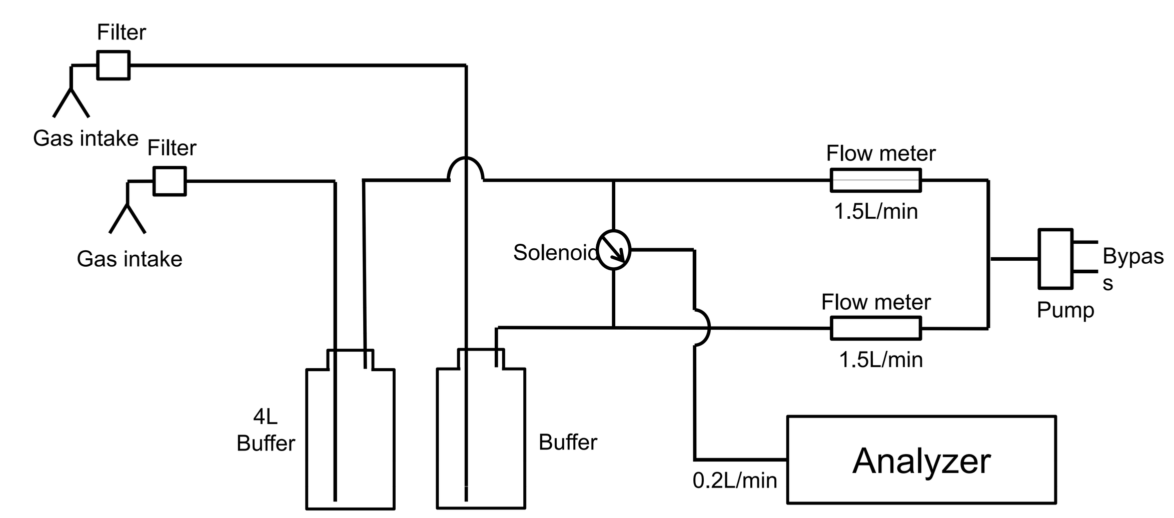




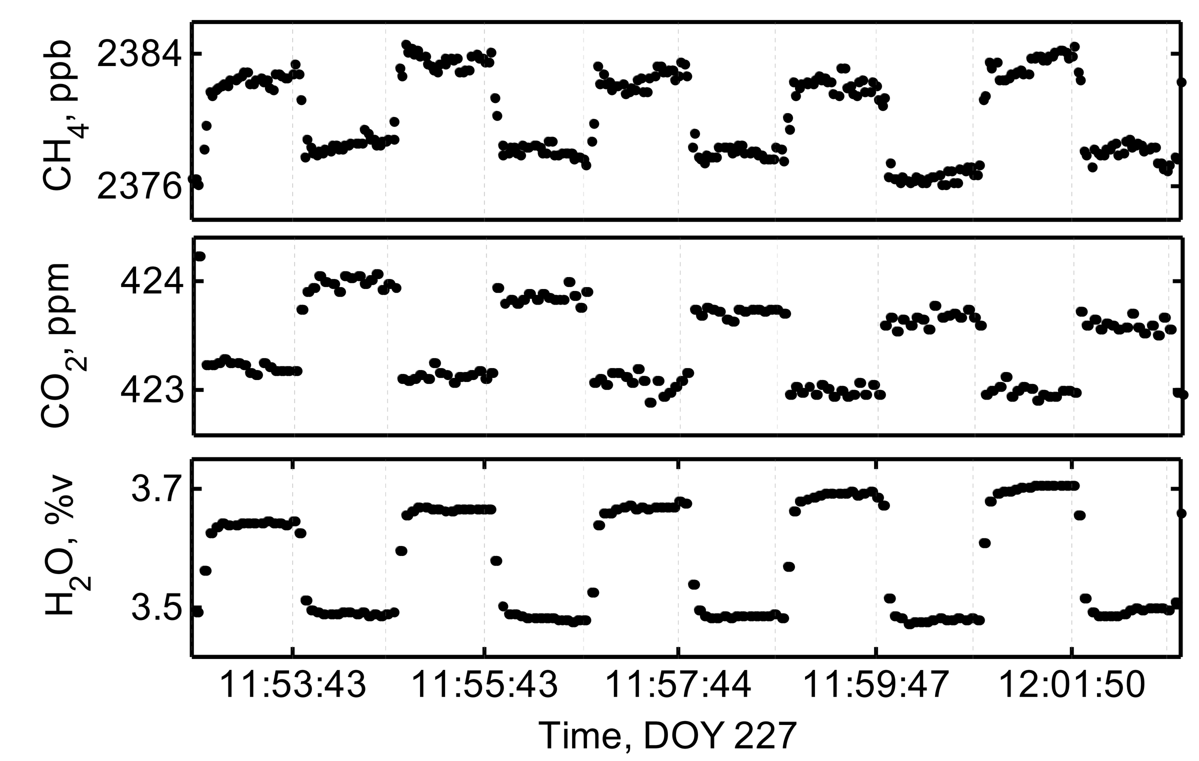
A CRDS analyzer (Model G1301, Picarro Inc., CA, USA) was used to simultaneously measure the mixing ratio of CO_2, CH_4 and H_2O. Air was drawn from two intakes at the heights of 1.1 m and 3.5 m above the water surface, and measurement time was 1 min on each intake.

An eddy covariance system was installed at the same site, with a distance of 100 m from the GD intakes.

Gradient measurement



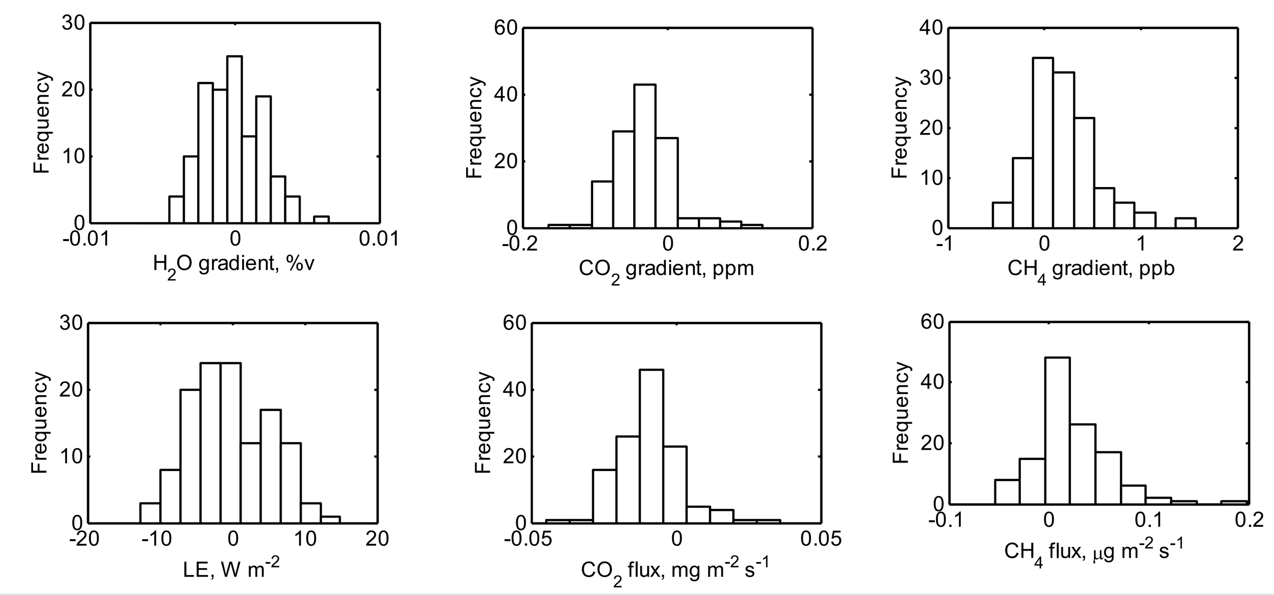
Schematic design diagram of the gradient measurement system



Step changes in the CO_2, CH_4 and H_2O mixing ratios in response to valve switching

- In order to measure the small flux at the lake-atmosphere interface using the GD method, we reduced turbulent fluctuations with buffer volumes and minimized the transient time between valve switching using small and short tubes.
- A 3-way valve switched between the two intakes every 60 s and the measurement approached steady state in less than 10 s after each switching.

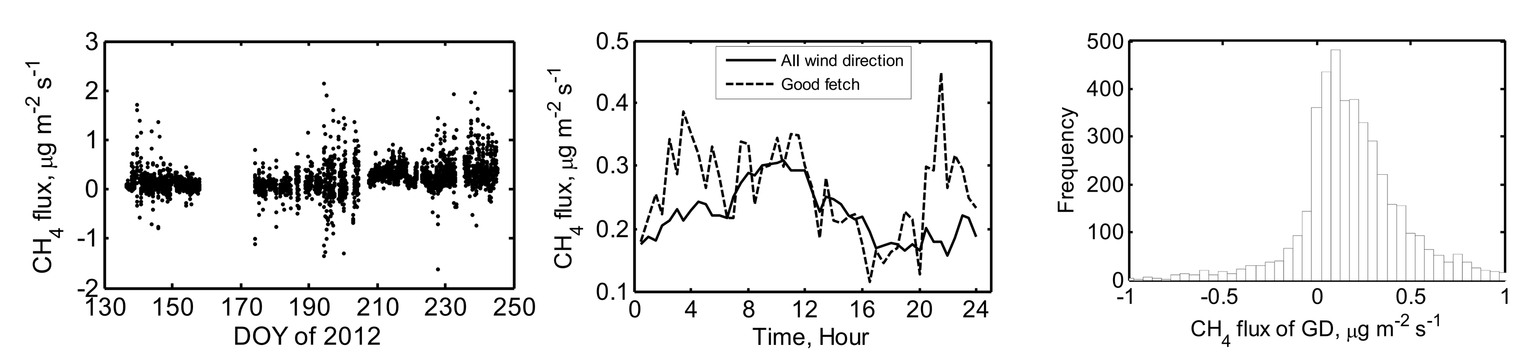
Zero-gradient test



	Mixing ratio gradient			30-min Flux		
	H_2O %v	CO_2 ppm	CH_4 ppb	*LE* W m^{-2}	CO_2 flux mg m^{-2} s^{-1}	CH_4 flux μg m^{-2} s^{-1}
Mean value	-7.36×10^{-5}	-0.0332	0.203	-0.231	-0.00914	0.0214
Standard deviation	0.00202	0.0410	0.356	5.496	0.0113	0.0379

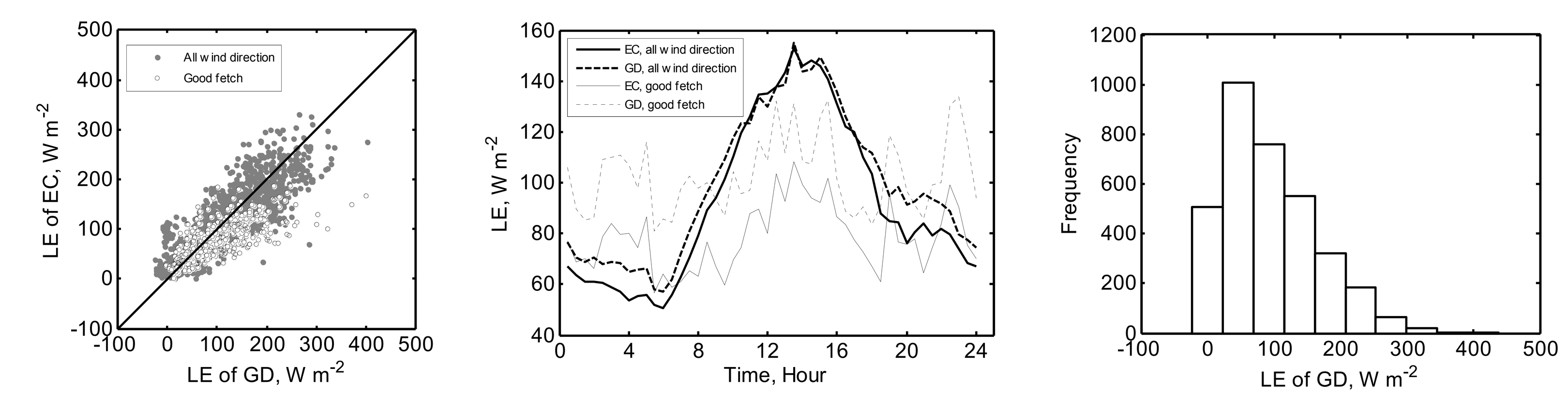
A zero-gradient test, performed with the two intakes positioned next to each other, indicates very small bias errors.

CH_4 flux

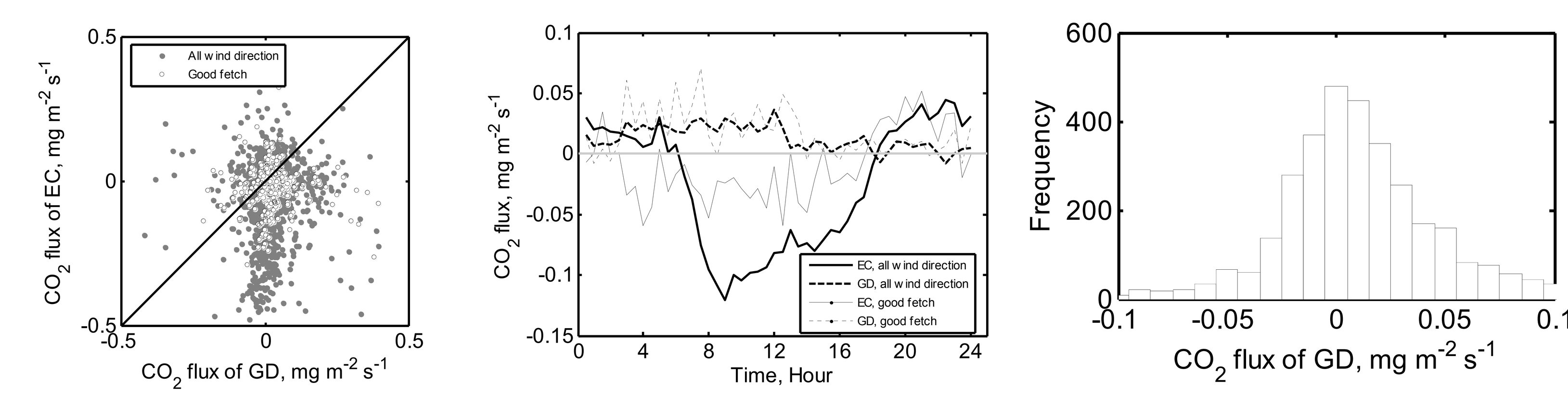


CH_4 flux was positive most of the time except for occasional negative values at night.

Latent heat and CO_2 flux comparison



- Wind direction falling in the range of 180-345° was considered as good fetch, wherein the signal was least interfered by land ecosystems.
- In comparison to the EC measurement, the GD method recorded higher *LE* values under good fetch conditions, indicating possible bias errors in the Monin-Obukhov turbulent diffusivity formulation.



- For the CO_2 flux, obvious difference exists between the GD and the EC method. The EC system recorded negative flux in the daytime, while the GD method shows a weak positive flux.
- The difference in the CO_2 flux may have been caused by errors in the density corrections to the EC flux and by different algal activities within their respective source footprints.

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