

# Open-Path Measurements of CH<sub>4</sub> Flux Using Eddy Covariance Technique

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## INTRODUCTION

Methane is one of the most important greenhouse gases, and has a warming potential about 23 times that of CO<sub>2</sub> over 100-year cycle (Houghton *et al.*, 2001).

Prior measurements of CH<sub>4</sub> fluxes have mostly been made with chamber techniques, and with Eddy Covariance approach using closed-path analyzers.

Both chambers and closed-path analyzers have their advantages. However, chamber measurements are discrete in time and space, may disturb soil surface integrity and atmospheric pressure, and often are labor-intensive.

Present closed-path analyzers work under significantly reduced pressures, and require powerful pumps and grid power. Long intake tubes lead to frequency losses.

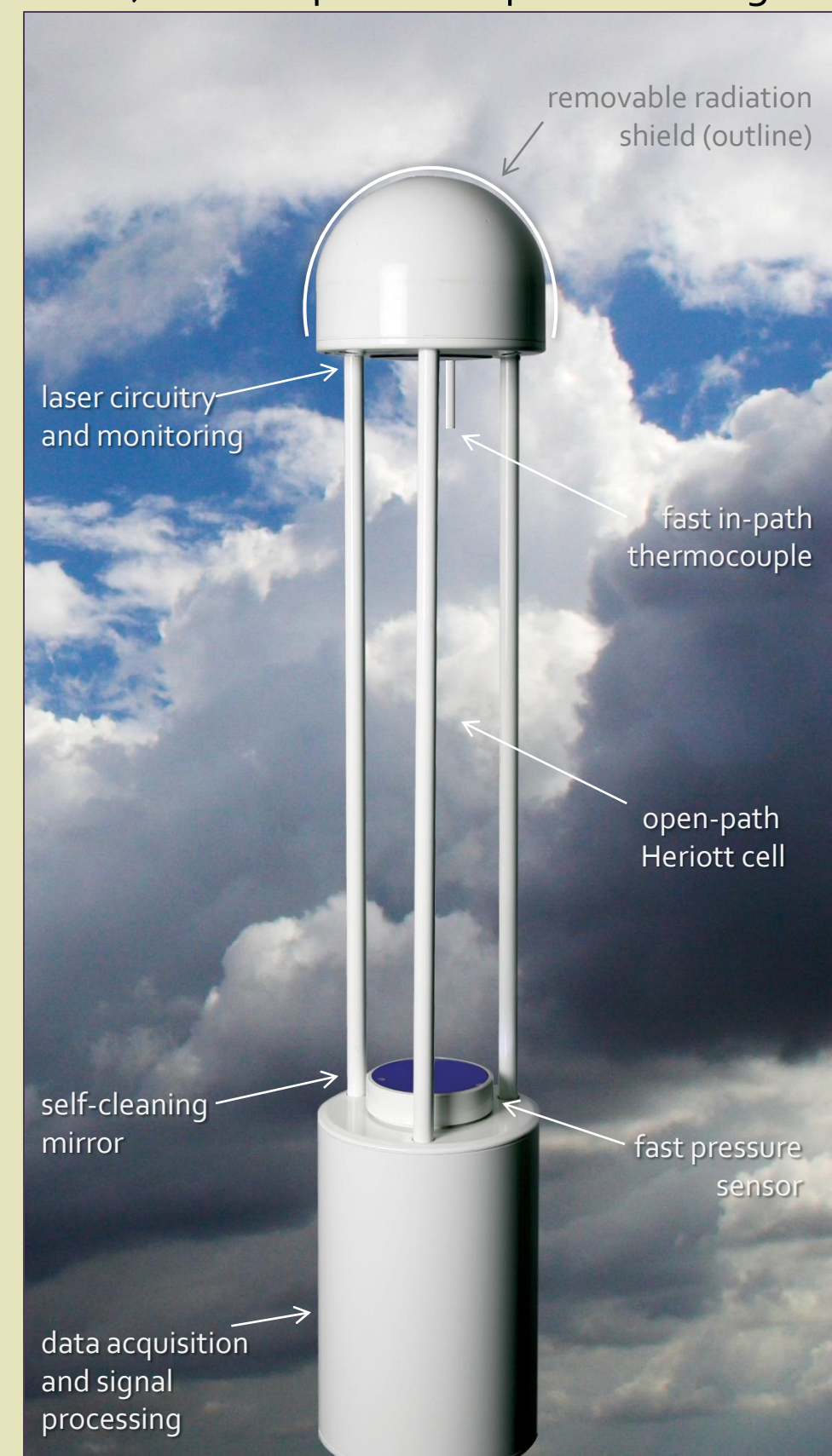
Power and labor demands may be reasons why CH<sub>4</sub> flux is often measured at locations with good infrastructure and grid power, and not with high CH<sub>4</sub> production.

Open-path measurements could provide significant advantages for CH<sub>4</sub> flux research:

- remote solar-powered deployment due to low power demand
- portable or mobile deployments due to light weight
- undisturbed *in-situ* spatially integrated flux measurements
- zero frequency response errors from tube attenuation
- confident WPL terms from co-located standard fast measurements
- can measure at locations of interest regardless of available infrastructure

## NEW INSTRUMENT

The LI-7700 fast open-path methane analyzer uses TDLS (tunable diode laser spectroscopy) technology that employs a VCSEL (vertical-cavity surface-emitting laser) and an open multi-pass cell design.



CH<sub>4</sub> is measured with a RMS noise below 5 ppb at 10 Hz sampling in controlled laboratory conditions.

LI-7700 can provide outputs with frequencies up to 40 Hz.

In addition to CH<sub>4</sub> density, the fast air temperature in sampling path and fast air pressure are also output.

Four fast auxiliary input channels are available for sonic anemometer outputs or for any other desired fast or slow data.

Seven additional fast channels and USB data logging are available with an optional analyzer interface unit.

Field maintenance is minimized by a fully-programmable self-cleaning mechanism for the lower mirror.

Dew formation on both mirrors solved by fully programmable heaters.

Radiation shield is provided to minimize power consumption.

The stand-alone power consumption of LI-7700 is <10 Watts in steady-state, and 12 Watts during warm-up.



Field maintenance is minimized by self-cleaning lower mirror to help keep it contamination-free

## EXPERIMENTS

Eddy Covariance measurements of CH<sub>4</sub> flux using the three prototypes of open-path methane analyzer were conducted in 2006-2009 during seven deployments covering four ecosystems with contrasting weather, moisture and CH<sub>4</sub> production:

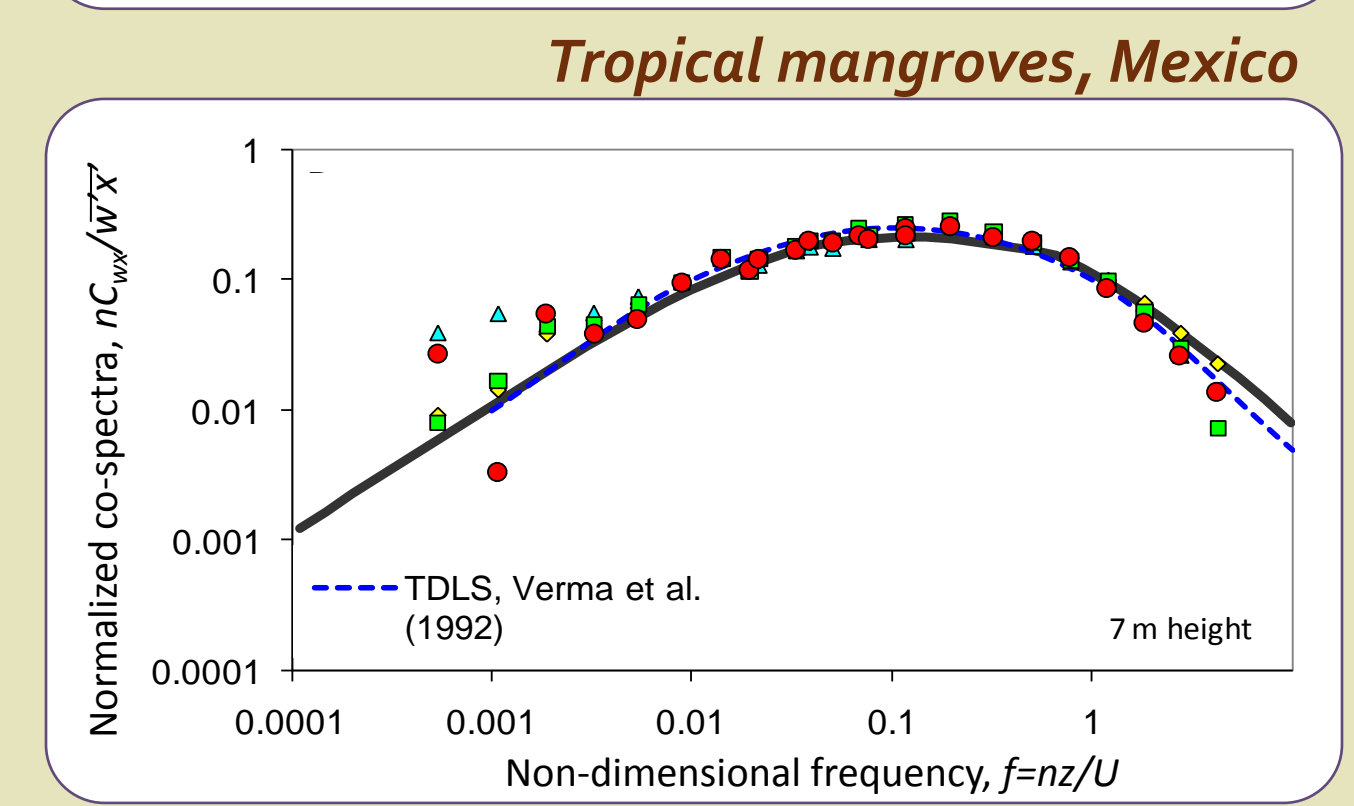
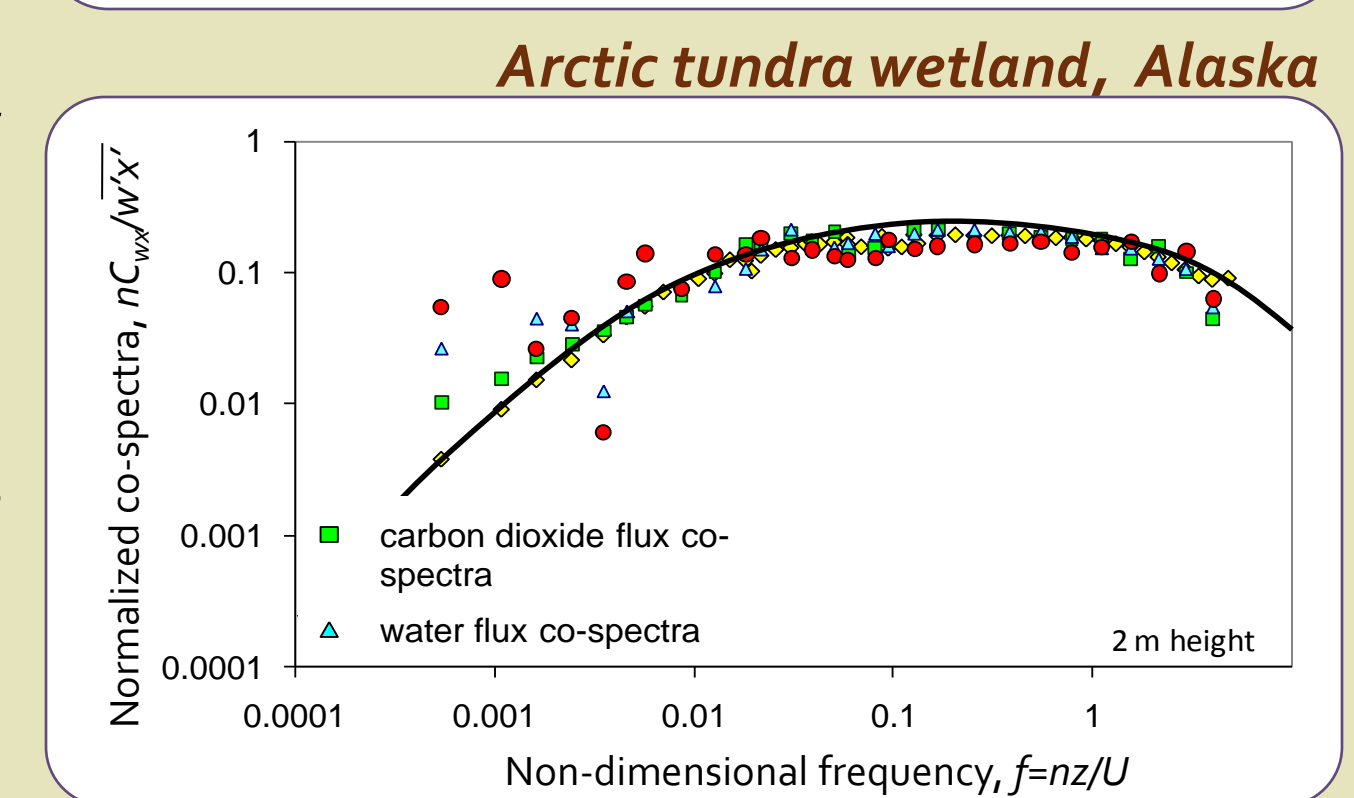
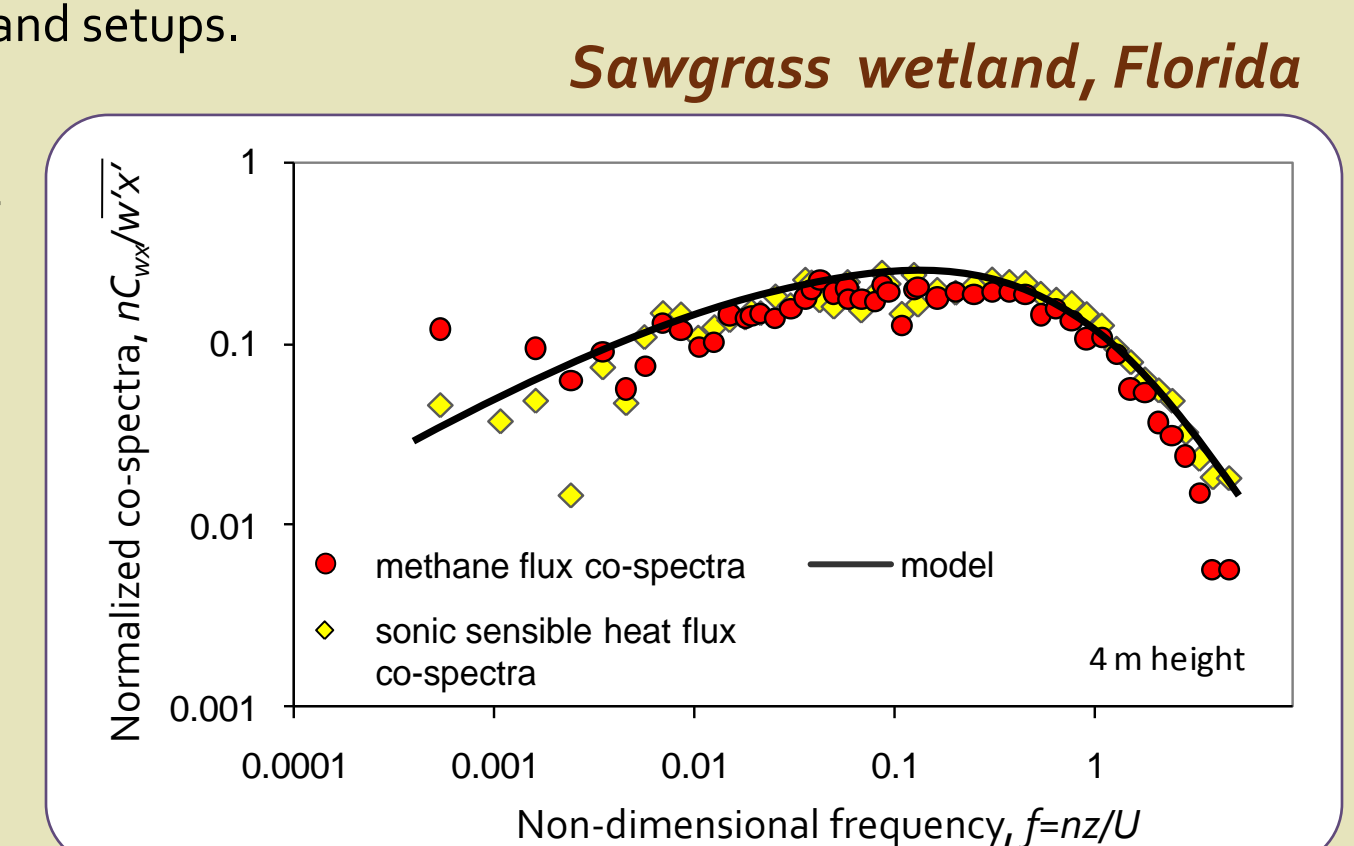
- Fluxes over short-hydroperiod sawgrass wetland in Florida Everglades were measured in warm and humid conditions with temperatures often exceeding 25°C
- Experiments in an arctic tundra described fluxes over coastal wetlands with frequent sub-zero temperatures, mist, and moderate winds
- Winter and spring experiments over bare agricultural field in Nebraska tested zero-flux measurements and computations in cold and moderate conditions
- Deployment over pacific mangroves in Mexico examined fluxes measured in conditions of high winds, sea spray, and moderate air temperatures

Florida and Nebraska experiments were conducted using portable light tower setup, with solar panel providing power in Florida and with grid power available in Nebraska. Tundra and mangroves experiments utilized permanent towers, and were powered by small portable generator in mangroves and larger generator in the tundra.

Eddy covariance flux data from a co-located open-path methane analyzer, LI-7500 and sonic anemometer were collected at a 10 Hz rate. Data were processed using EdiRe software following standard FluxNet methodology (Aubinet *et al.*, 2000).

## METHANE CO-SPECTRA

Ensemble averages of normalized midday co-spectra for the periods with sufficient wind and flux are plotted below versus non-dimensional frequency for the three contrasting ecosystems and setups.



In these and other experiments, CH<sub>4</sub> flux co-spectra behaved generally similar to the co-spectra of CO<sub>2</sub>, H<sub>2</sub>O, from LI-7500 and close to sonic air temperature.

The co-spectra from the LI-7700 measurements closely followed the Kaimal model (Kaimal *et al.*, 1972).

The methane co-spectra also demonstrated good agreement with another co-spectrum from TDLS (Unisearch Associates, Inc.) over peatland (Verma *et al.*, 1992).

The LI-7700 adequately measured fluctuations in methane concentration across the whole spectrum of frequencies which contributed to turbulent transport at different tower heights, surface roughness and atmospheric stabilities.

## METHANE FLUXES

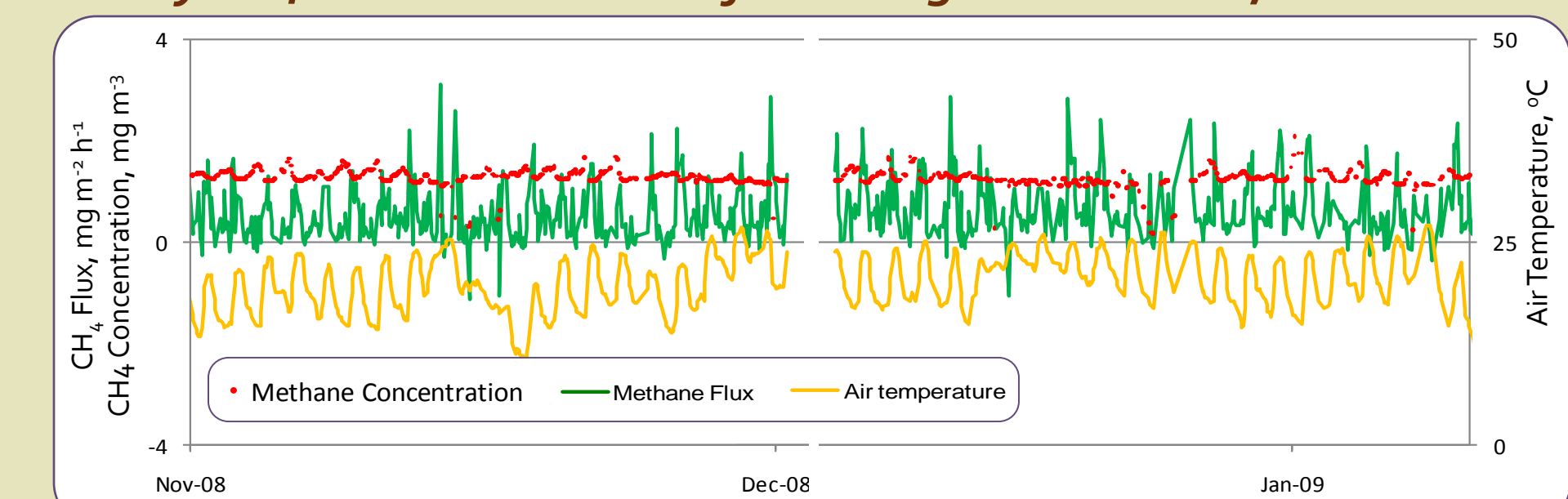
Examples of hourly CH<sub>4</sub> concentrations and fluxes are shown in the top two figures below.

The third figure demonstrates CH<sub>4</sub> emissions integrated over daytime from November, 2007, through January, 2008, in sawgrass wetland, alongside mean air temperature.

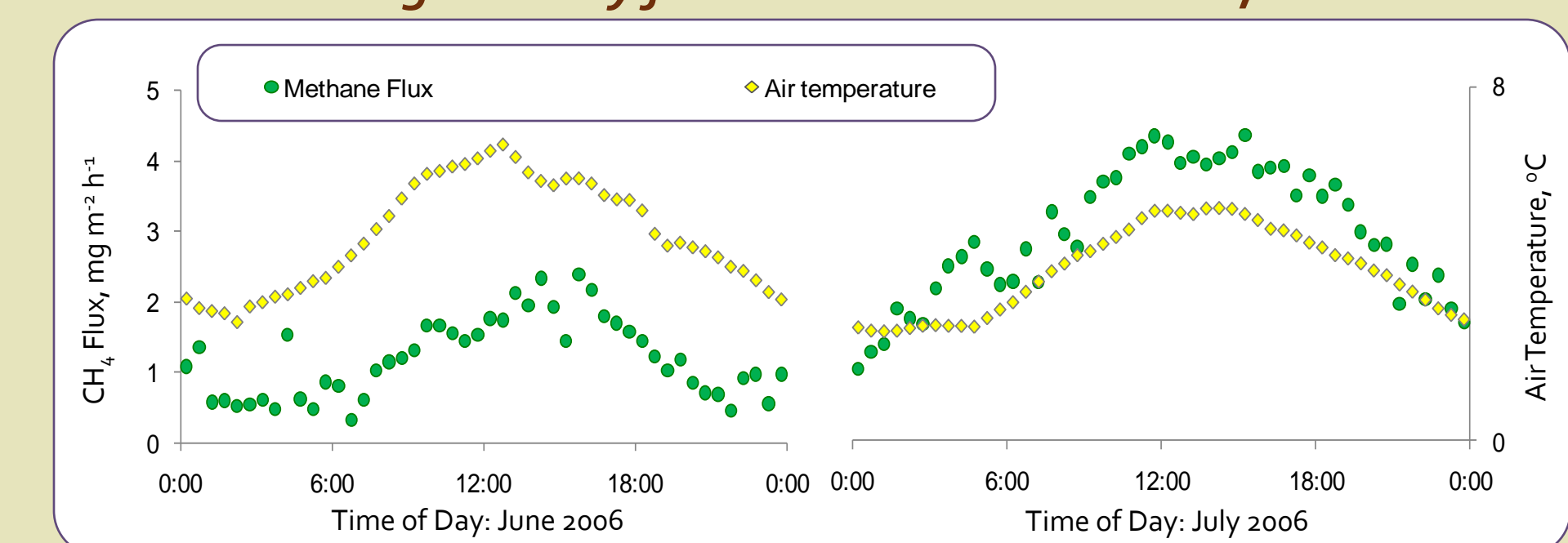
Overall, hourly CH<sub>4</sub> fluxes ranged from near-zero at night to 4 mg m<sup>-2</sup> h<sup>-1</sup> in arctic tundra (Zona *et al.*, 2008) and pacific mangroves (not shown), and to 3.5 mg m<sup>-2</sup> h<sup>-1</sup> in sawgrass wetland.

Observed fluxes were within the ranges reported in the literature for a number of wetlands in North America, including the Everglades wetlands in Florida (Harris *et al.*, 1988), fen in Canada (Bubier *et al.*, 1993), peatland in Minnesota (Shurpali and Verma, 1998) and bog in Alaska (Moosavi *et al.*, 1996).

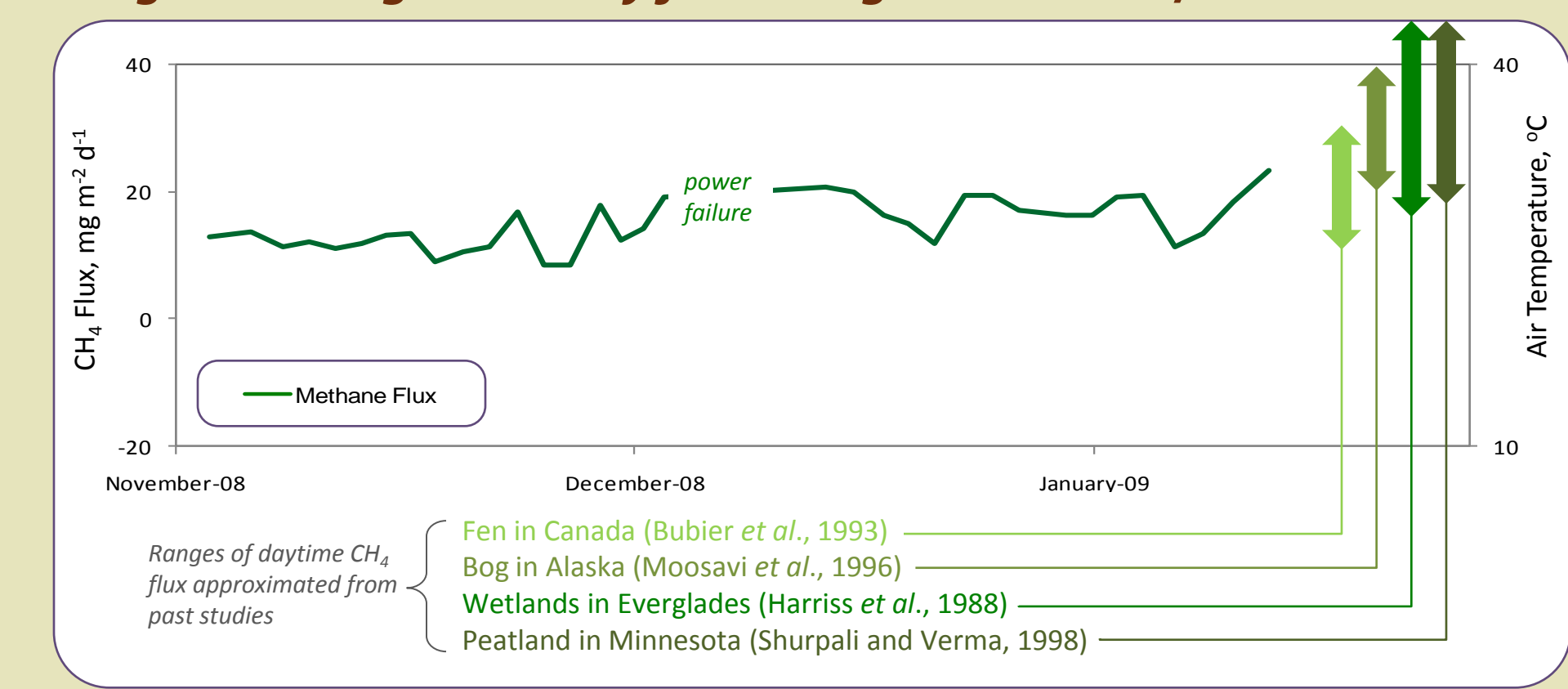
Hourly CH<sub>4</sub> concentration and flux: sawgrass wetland, Florida



Ensemble averaged hourly flux: arctic tundra wetland, Alaska

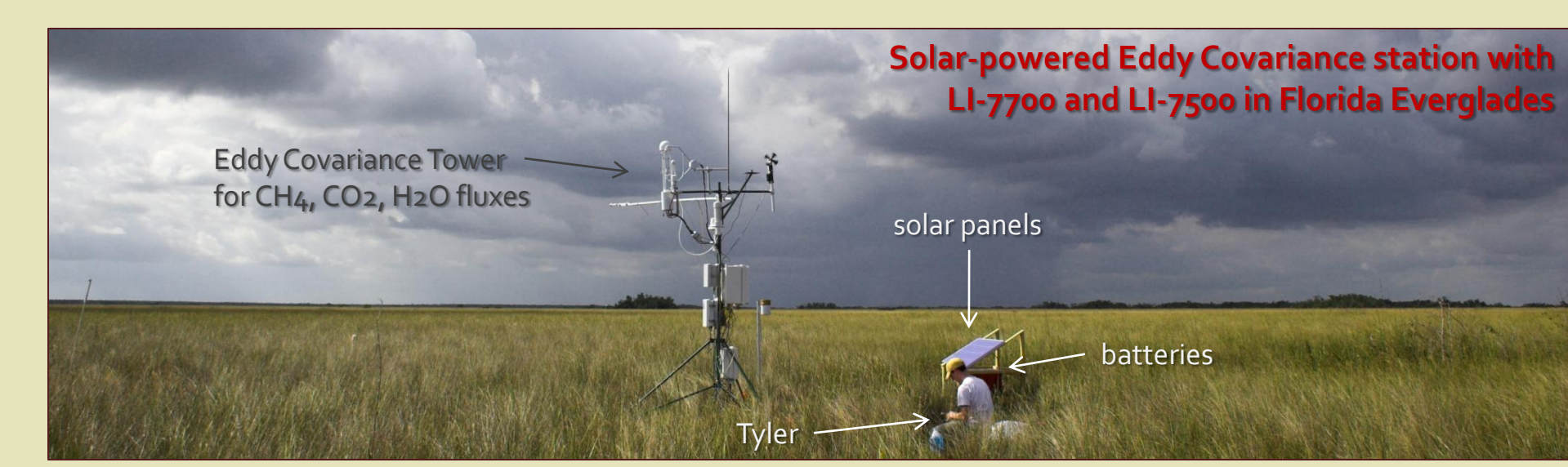


Long-term integrated daily flux: sawgrass wetland, Florida



## POWER CONSUMPTION

Approximate power consumption by solar-powered Eddy Covariance station in sawgrass wetland in Florida Everglades was 26 Watts. The station included LI-7700 for CH<sub>4</sub>, LI-7500 for CO<sub>2</sub> and H<sub>2</sub>O, sonic anemometer, and slow air temperature/relative humidity sensors and a barometer.



## CONCLUSIONS

- Open-path measurements of CH<sub>4</sub> flux using Eddy Covariance approach were conducted in seven experiments in four contrasting ecosystems
- The shape of CH<sub>4</sub> flux co-spectra was generally similar to those of CO<sub>2</sub> and H<sub>2</sub>O from LI-7500, close to sonic sensible heat co-spectra, and to a theoretical curve from Kaimal model
- Methane concentration ranged 1.1-1.7 mg m<sup>-3</sup>, with hourly variations close to those observed in similar ecosystems, and with nighttime build-ups at low winds
- Hourly fluxes ranged from near-zero at night to about 4 mg m<sup>-2</sup> h<sup>-1</sup> at midday in the arctic tundra
- Diurnal patterns were similar to those measured by closed-path sensors (Kim *et al.*, 1998; Hendriks *et al.*, etc.)
- LI-7700 open-path methane analyzer is a valuable tool for measuring long-term CH<sub>4</sub> fluxes in a wide range of ecosystems
- LI-7700 enables long-term deployment of permanent, portable or mobile CH<sub>4</sub> flux stations at remote locations with high CH<sub>4</sub> production or consumption, because it can be powered by a solar panels or a small generator

Setting up Eddy Covariance station with LI-7700 and LI-7500 in pacific mangroves, powered by portable generator



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