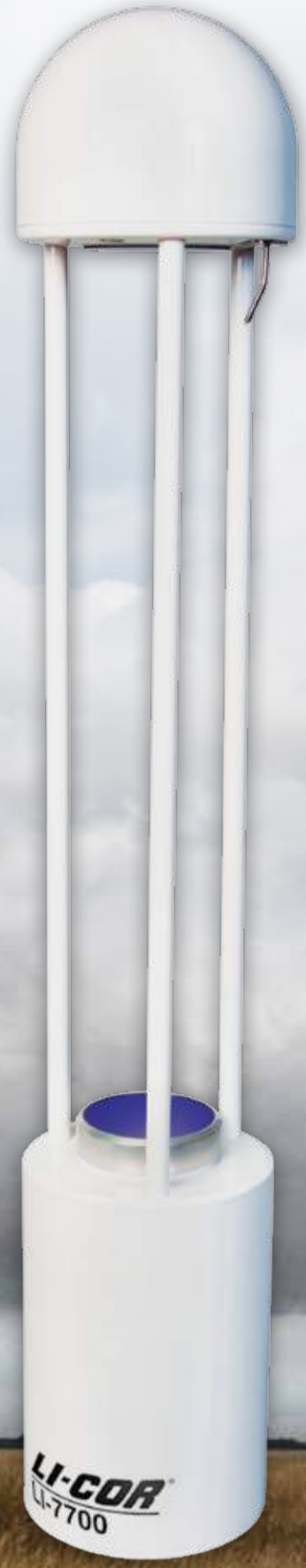
LI-7700

Open Path CH_4 Analyzer

Fast Atmospheric Methane Measurements

Designed for the Eddy Covariance Method

LI-COR®
Biosciences



Innovative Solutions

Remote Field Deployment

- Low power (8 W during normal operation)
- Light weight (5.2 kg)
- Low maintenance
- Designed for long-term, unattended, continuous operation

Open Path

- *In-situ* methane density measurement using laser spectroscopy
- Enables low power system operation
- No time delays or attenuation from tubing
- No pump required

Eddy Covariance

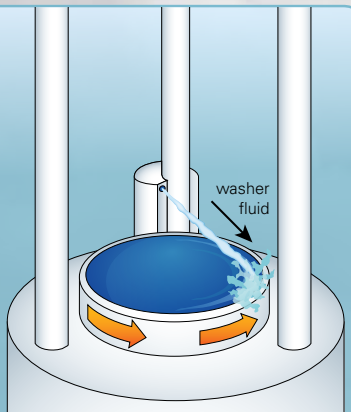
- High precision (5 ppb RMS noise @ 10 Hz, 2000 ppb CH_4)
- High-speed data output (up to 40 Hz)
- Simplified data integration
- Analog inputs for sonic anemometer data

Designed for Field Use

- Radiation shield minimizes condensation on the upper mirror
- Carbon fiber spars minimize thermal expansion of the optical path
- Heaters keep mirrors near ambient temperature to prevent condensation

Self-Cleaning Lower Mirror

- Decreases maintenance requirements
- Ensures more robust, continuous data sets
- Cleaning is initiated at user-specified time intervals or a signal strength threshold



▶ Go to www.licor.com/mirror to watch a video of the LI-7700's self-cleaning mirror

The LI-7700 Open Path CH_4 Analyzer

The LI-7700 makes *in-situ* measurement of methane density with the resolution, speed, and stability required for the eddy covariance technique.

Previously, measuring methane flux was difficult because of instrument limitations, including high power demands, heavy pumps, and the need for instrument enclosures. The LI-7700 overcomes all of these limitations.

The LI-7700 is light weight, has low power requirements, and provides high frequency response. The LI-7700 is designed to measure methane density at frequencies that are necessary to quantify ecosystem methane flux.

Why the LI-7700?

- High precision and accuracy
- Low power
- Long-term, low maintenance operation
- Easily integrates into flux towers
- Simplified data integration
- Light weight

Measure CH_4 Everywhere

Rice paddies, bogs, wetlands, and other methane-producing ecosystems are unforgiving places for scientific instrumentation. The LI-7700 Open Path CH_4 Analyzer is designed for use in these remote environments.

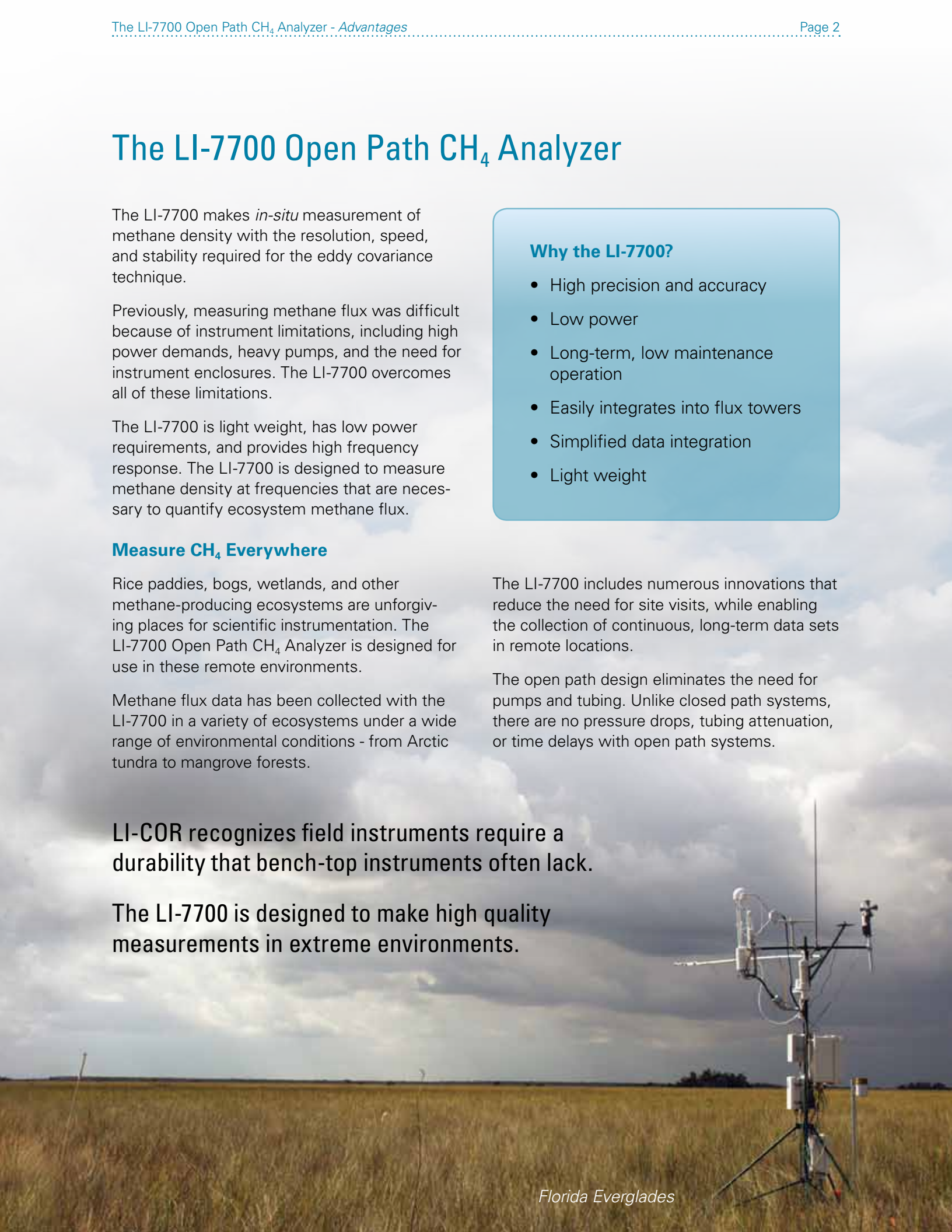
Methane flux data has been collected with the LI-7700 in a variety of ecosystems under a wide range of environmental conditions - from Arctic tundra to mangrove forests.

The LI-7700 includes numerous innovations that reduce the need for site visits, while enabling the collection of continuous, long-term data sets in remote locations.

The open path design eliminates the need for pumps and tubing. Unlike closed path systems, there are no pressure drops, tubing attenuation, or time delays with open path systems.

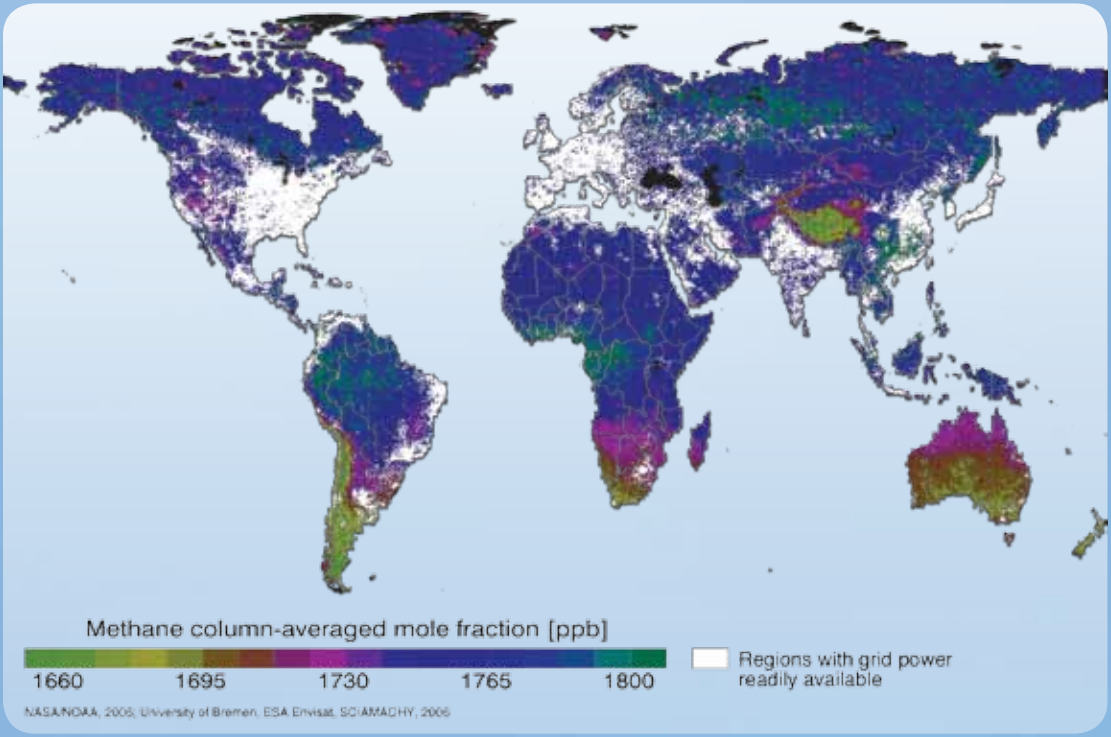
LI-COR recognizes field instruments require a durability that bench-top instruments often lack.

The LI-7700 is designed to make high quality measurements in extreme environments.



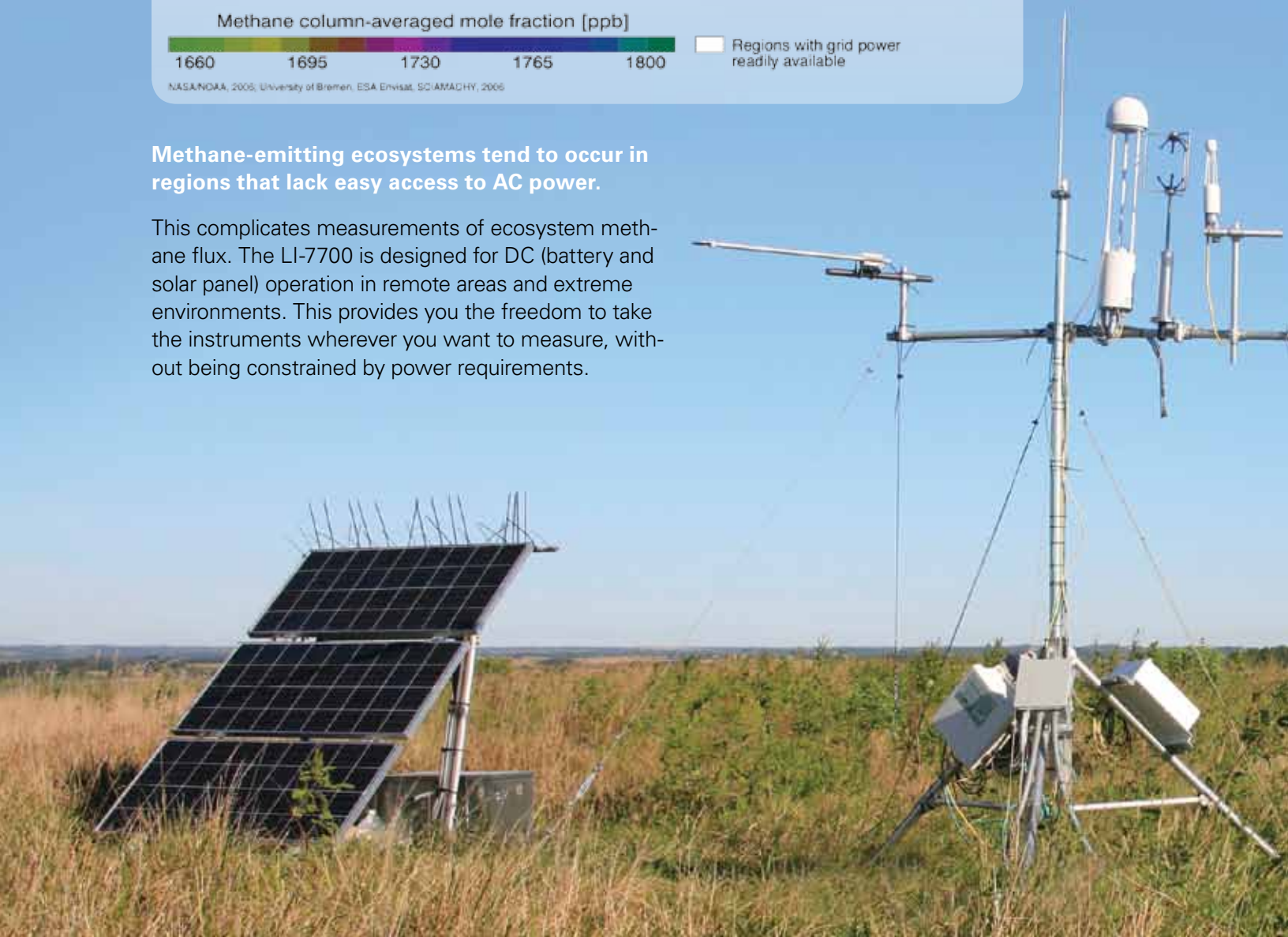
Florida Everglades

Low Power… to go where you need to go.



Methane-emitting ecosystems tend to occur in regions that lack easy access to AC power.

This complicates measurements of ecosystem methane flux. The LI-7700 is designed for DC (battery and solar panel) operation in remote areas and extreme environments. This provides you the freedom to take the instruments wherever you want to measure, without being constrained by power requirements.



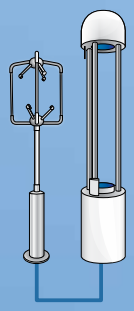
Enhanced Ethernet Capabilities

The LI-7700 provides Ethernet data output that allows for quick, easy connectivity to a computer or network. Ethernet connectivity allows you to monitor your instruments remotely, adjust instrument settings, and transfer data files over network connections when configured with LI-COR's CO_2/H_2O analyzers in GHG packages. Ethernet also facilitates remote data links through cellular modems which brings a new level of connection to remote field sites.

Simplified Data Collection

The LI-7700 accepts four analog input channels for sonic anemometer data, and outputs a single data stream via the Ethernet connection.

With the LI-7550 Analyzer Interface Unit data is stored on a removable, industrial-grade USB flash drive (4 GB drive included with LI-7550).



Time	Methane Density (mmol m^{-3})	Sonic Anemometer u ($m\ s^{-1}$)	v ($m\ s^{-1}$)	w ($m\ s^{-1}$)	T (°C)
14:22:15.4	0.08293	-0.87	-1.08	-0.11	22.97
14:22:15.5	0.08433	-0.86	-1.08	-0.01	22.90
14:22:15.6	0.08436	-0.82	-1.01	0.00	22.87
14:22:15.7	0.08386	-0.86	-0.94	0.18	22.88
14:22:15.8	0.08326	-0.91	-0.96	0.17	22.91
14:22:15.9	0.08458	-0.86	-1.11	0.16	22.88
14:22:16.0	0.08289	-0.72	-1.26	-0.01	22.85
14:22:16.1	0.08275	-0.70	-1.17	-0.02	22.82
14:22:16.2	0.08296	-0.79	-0.98	0.14	22.91

Signal from sonic anemometer is merged with methane data.

Intuitive Windows Interface

The Windows® interface software (included) makes set-up and configuration as simple as possible. It provides full control over logging configuration options, auxiliary inputs, and data output. Configuration of mirror heaters and cleaning settings is made easy with the graphical controls. The auto-scaling interface window is designed for viewing on netbook computer displays as well as desktop monitors.

Using the LI-7700's Ethernet capabilities, a LI-COR scientist monitors real-time data from instruments set up at the Bluff Road Municipal Solid Waste Landfill near Lincoln, NE.

Innovative Technology

Recent advances in laser technology and advanced engineering enabled LI-COR Biosciences to develop the LI-7700 Open Path CH_4 Analyzer. The LI-7700 uses a single-mode tunable near-infrared laser source, operating at ambient temperature, which greatly reduces power consumption and eliminates the need for cryogenic cooling systems.

Using Wavelength Modulation Spectroscopy (WMS), the laser scans across a single feature in the $2\nu_3$ absorption band of methane near 1.6 microns with high resolution and at a high repetition rate. The wavelength is modulated at sub-MHz frequency, virtually eliminating 1/f noise of the laser source and allowing detection of fractional absorption (smaller than 10^{-5}). The LI-7700 demodulates the resulting signal at twice the modulation frequency, and then compares it to a reference signal shape to determine CH_4 concentration. Pressure and temperature induced changes in line shape and population distribution, as well as changes in laser power and mirror reflectivity are compensated for using computational fitting algorithms. This ensures measurements remain accurate over a wide range of pressure and temperature conditions.

This combination of innovative technologies allows for an open path measurement with the speed and resolution required for eddy covariance measurements of methane.

Wavelength Modulation Spectroscopy

Wavelength Modulation Spectroscopy has distinct advantages over other spectroscopic techniques used for trace gas measurements. It provides a strong signal with very low noise. This enables the use of a shorter optical path-length with fewer reflections and reduces sensitivity to contamination of mirrors.

A multi-pass Herriott cell with off-axis alignment allows for a short physical path length (0.5 m) but a 30 m total optical path length. Other laser spectroscopy techniques require optical paths up to several kilometers in length to make a comparable measurement.

The 0.5 m optical cell enables the methane density measurement with relatively few reflections. With fewer reflections, the mirrors in the optical path are less vulnerable to contamination than mirrors used in other spectroscopic instruments. Instruments that use Cavity Ring-Down Spectroscopy (CRDS) and Integrated Cavity Output Spectroscopy (ICOS) require mirrors with 99.99% or higher reflectivity.

The LI-7700 makes *in-situ* methane density measurements at ambient pressure. CRDS and ICOS rely upon vacuum pumps to draw down pressure in the optical cell which sharpens absorption lines.

Advantages of WMS

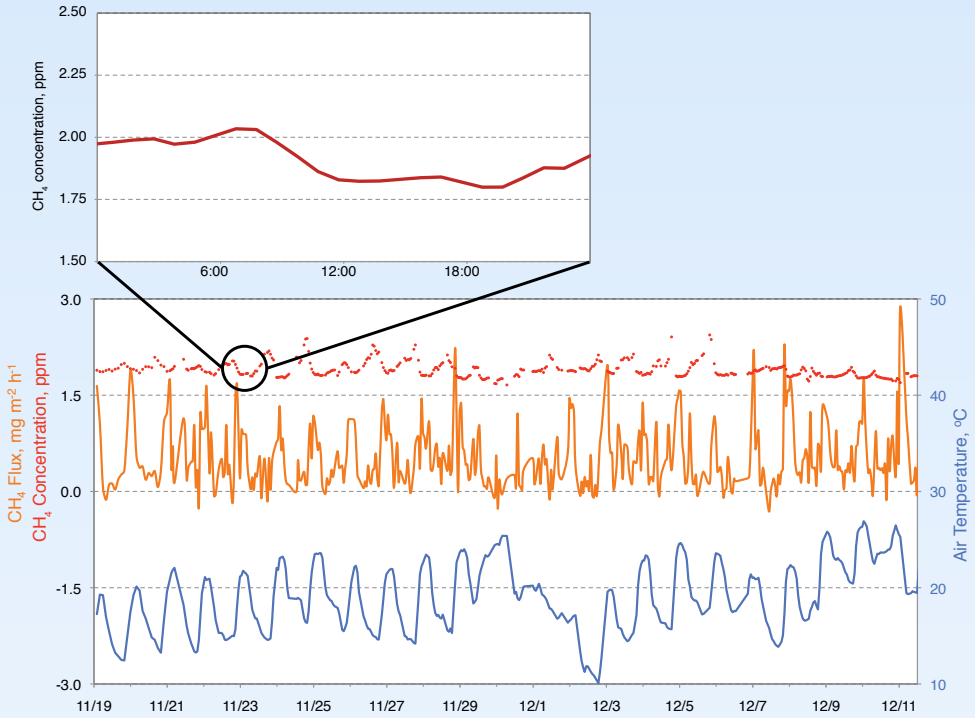
- Strong signal with low noise
- Reduced sensitivity to contamination of mirrors
- Short physical path length
- Operation at ambient pressure

The green laser shown at the right is for the purpose of illustration only. The LI-7700 uses a near-infrared laser source that is invisible to the human eye.

The LI-7700 was selected by R&D Magazine as one of the 100 most innovative, technologically significant products of 2010.

Field Data

The figure below shows an example of methane flux data from a 23-day period over the Florida Everglades at a height of 3.15 m. Under high humidity conditions, the LI-7700 collected data continuously with very little user-intervention. Fluxes were obtained with the eddy covariance method using the LI-7700 and a sonic anemometer. The inset shows hourly averages of data collected over a single 24-hour period. In this example, reduced wind speeds in the evenings led to lower turbulent exchange and allowed methane to accumulate in the canopy. Each morning, the build-up was eliminated as wind speeds increased.



Publications which include the LI-7700 :

McDermitt, D., G. Burba, L. Xu, T. Anderson, A. Komissarov, J. Schedlbauer, D. Zona , W. Oechel, S. Oberbauer, G. Starr, and S. Hastings, 2010. A New Low-Power, Open Path Instrument for Measuring Methane Flux by Eddy Covariance. Applied Physics B: Lasers and Optics. Accepted.

Burba, G., L. Xu, J. Schedlbauer, D. Zona, T. Anderson, D.K. McDermitt, S. Oberbauer, W. Oechel, A. Komissarov, and B. Riensche, 2010. Eddy Covariance Measurements of Methane Flux at Remote Sites with New Low-Power Lightweight Fast Gas Analyzer. European Geosciences Union General Assembly, Vienna, Austria, 02 – 07 May.

Pages 46-52 in the following publication:

Burba, G.G., and D.J. Anderson, 2010. A Brief Practical Guide to Eddy Covariance Flux Measurements: Principles and Workflow Examples for Scientific and Industrial Applications. LI-COR Biosciences, Lincoln, USA, Hardbound and Softbound Editions, 212 pp.

Go online for more publications: www.licor.com/7700publications

Co-spectra

Co-spectral analysis provides a powerful tool to evaluate the capability of the analyzer to detect gas fluctuations over a range of frequencies (Kaimal et al., 1972). It is important to validate frequency response of any new analyzer, open-path or closed-path, using actual field data, and compare it to co-located references such as a sonic anemometer or an open-path gas analyzer (e.g., LI-7500).

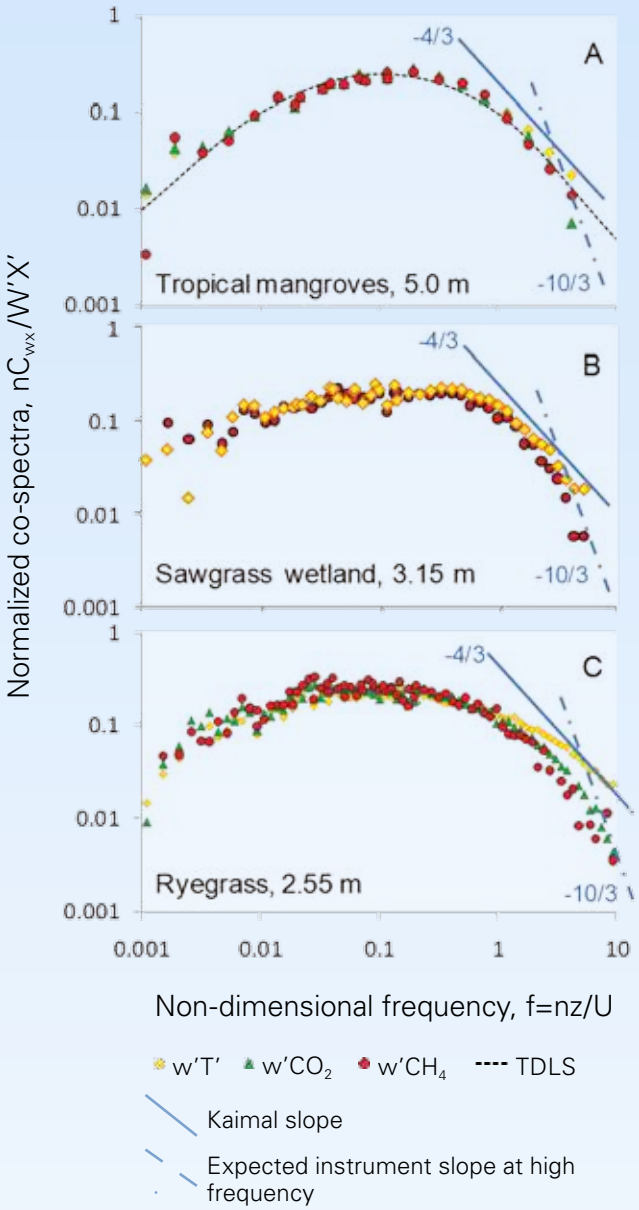
Sometimes it is also useful to compare the actual co-spectral shapes to ideal ones from a model. However, the modeled shapes may not always account for specificities and imperfections of study site topography and airflows, while sonic anemometer temperature flux co-spectra generally do account for these and are a practical reference of nearly-perfect frequency response.

The figures to the right show ensemble averages of normalized daytime co-spectra plotted versus non-dimensional frequency for contrasting ecosystems and measurement heights at a 10 Hz sampling rate.

In all cases, methane co-spectra behaved similarly to the co-spectra of CO_2, H_2O, and air temperature. This demonstrates that the LI-7700 configuration is suitable for measuring fluctuations in CH_4 concentration across the whole spectrum of frequencies that contributed to turbulent transport at these measurement heights.

All the co-spectra followed the Kaimal model (Kaimal et al., 1972).

Kaimal J., J. Wyngaard, U. Izui, and O. Cote. 1972. Spectral characteristics of surface-layer turbulence. Quart. J. Roy. Meteor. Soc, 98: 563-589.

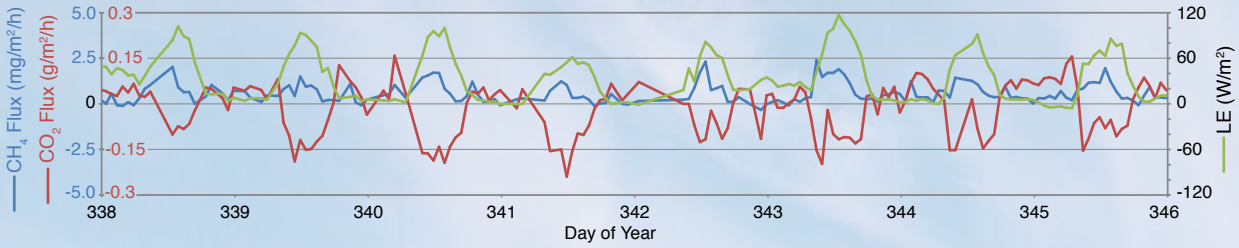


Field data illustrate that the LI-7700 has the frequency response required to sample the range of eddy frequencies that contribute to methane flux.

3-Gas Eddy Covariance System

For a multi-gas system, the LI-7550 Analyzer Interface Unit can be used to integrate an LI-7700, a CO_2/H_2O analyzer such as the LI-7500A Open Path CO_2/H_2O Analyzer or LI-7200 Enclosed CO_2/H_2O Analyzer and a sonic anemometer. When using the LI-7700 to calculate methane flux, it is critical that a high speed H_2O analyzer be used for water vapor correction.

The figure below shows methane, carbon dioxide, and latent heat fluxes measured with the eddy covariance technique over the Florida Everglades. These data are a subset of a 6-week data set collected during the winter of 2008-09, at 3.15 m above the canopy, using an LI-7500 Open Path CO_2/H_2O Analyzer and an LI-7700 Open Path CH_4 Analyzer. They show a net negative flux of CO_2, but positive CH_4 and LE fluxes for the measurement period, indicating that this ecosystem was a sink of carbon dioxide and a source of methane and water vapor.



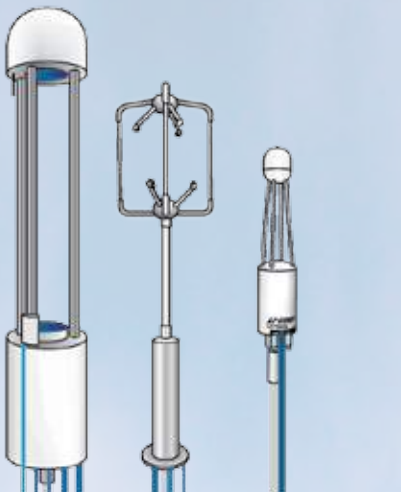
Both the LI-7700 Open Path CH_4 Analyzer and the LI-7550 Analyzer Interface Unit provide four general ±5 V inputs for analog data from any fast sonic anemometer. The LI-7700 also provides three type E thermocouple inputs for recording additional temperature data if desired. LI-COR sonic anemometer cables (optional) allow you to easily integrate analog data from Gill WindMaster™/Pro or Campbell® Scientific CSAT-3 sonic anemometers with the LI-7700 data stream. Weatherproof cable terminals provide simple and reliable electrical connections.

Greenhouse Gas Packages from LI-COR:

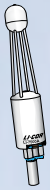
Greenhouse gas analyzer systems from LI-COR Biosciences facilitate the collection of eddy covariance data sets by logging CH_4, CO_2, and H_2O density data, along with wind speed, direction, and temperature data (u, v, w, and T_s) to a removable USB data storage device. Data can also be transferred via Ethernet to an external data storage device or computer network.

LI-COR offers two Greenhouse Gas Packages which include the LI-7700 CH_4 Analyzer with either the LI-7500A Open Path CO_2/H_2O Analyzer or LI-7200 Enclosed CO_2/H_2O Analyzer. Sonic anemometers can also be purchased from LI-COR.

Typical Eddy Covariance Configuration



CH_4 Analyzer
Integrates easily into new or existing towers.



CO_2/H_2O Analyzer
LI-COR's LI-7500A Open Path Analyzer (shown in the diagram) and LI-7200 Enclosed Analyzer make precise, accurate, and fast measurements. A CO_2/H_2O analyzer is a core component of a flux tower.

Sonic Anemometer
Measures wind speed and direction. LI-COR's flexible system allows for the integration of any sonic anemometer that has analog outputs.

The LI-7550 Analyzer Interface Unit
Used for data acquisition from the LI-7700, as well as data acquisition and control of the sonic anemometer and CO_2/H_2O analyzer. Data can be output through Ethernet, or stored internally on a removable industrial-grade USB drive.

7700-101 Washer Assembly (included)
Supplies washer fluid for automated washing of lower mirror surface.

Solar Panels
With low power requirements (nominally 8W for LI-7700, 20W for LI-7700 and LI-7500A), LI-COR's system can be easily operated on solar panels and batteries.

LI-7700 Open Path CH_4 Analyzer Specifications

Resolution (RMS noise): 5 ppb @ 10 Hz and 2000 ppb CH_4

Measurement Range:
0 to 25 ppm @ -25 °C, 0 to 40 ppm @ 50 °C

Accuracy at constant temperature:
typically < 1%, maximum < 2%

Drift from -25 °C to +45 °C: 0.05% per degree C

Bandwidth: 1,2,5,10, or 20 Hz

Operating Pressure Range: 50 to 110 kPa

Operating Relative Humidity Range: 0 to 100%

Operating Temperature Range: -25 to 50 °C

Data Communication: Ethernet (up to 40 Hz)

Detection method:
Wavelength Modulation Spectroscopy 2f detection

Power Requirements: 10.5 to 30 VDC

Power Consumption:
8 W nominal, 16 W during cleaning cycle

Dimensions:

Sensor: 14.33 cm dia (5.64 in), 82.8 cm height (32.6 in.)

Optical Path: 0.5 m physical path (1.65 ft), 30 m measurement path (98.4 ft)

Weight: 5.2 kg (11.5 lbs)

User Interface: Windows® based software supports all setup, configuration, and calibration functions through Ethernet connection

Acknowledgements

LI-COR has licensed certain aspects of the LI-7700 that were developed with expertise from Southwest Sciences, Inc. (Santa Fe, NM). This project was funded in part by the US Department of Energy through a Small Business Innovation Research grant (DE-FG02-05ER84283).

LI-7550 Analyzer Interface Unit Specifications

Data Storage: Removable USB Storage Device. 4 Gigabyte Provided (expandable with user supplied Industrial Grade USB Flash Drive)

Data Communication: Ethernet, Synchronous Devices for Measurement (SDM), RS-232 (57,600 baud), DAC Outputs (6)

Inputs: Ethernet, 4 analog input channels

Operating Temperature Range: -25 °C to 50 °C

Power Requirements: 10.5 to 30 VDC

Power Consumption: 10 W nominal

Dimensions: 35 cm × 30 cm × 15 cm (13.8 in x 12 in x 6 in) external dimensions

Weight: 4.4 kg (10 lbs)

Specifications subject to change without notice.

Ordering Information

LI-7700 Open Path CH_4 Analyzer:
Includes power and Ethernet cables, calibration fixture, washer assembly, mounting hardware, instruction manual, spares kit, carrying case, and software CD.

LI-7550 Analyzer Interface Unit (optional):
Provides data storage with a removable USB flash drive, and data output via Ethernet, SDM, RS-232, six DAC outputs for connecting to a data logger. Also includes four additional differential voltage inputs.

7550-101 Auxiliary Sensor Interface (optional):
Seven auxiliary inputs (four general ±5 V and three type E thermocouple channels).

LI-COR®
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The LI-COR board of directors would like to take this opportunity to return thanks to God for His merciful providence in allowing LI-COR to develop and commercialize products, through the collective effort of dedicated employees, that enable the examination of the wonders of His works.

"Trust in the LORD with all your heart and do not lean on your own understanding. In all your ways acknowledge Him, and He will make your paths straight."

—Proverbs 3:5,6