CAMPBELL® SCIENTIFIC
WHEN MEASUREMENTS MATTER

Gas Fluxes & Turbulence

Greenhouse gas fluxes

- CO_2, H_2O, N_2O, CH_4, or CO_2 isotopes
- Eddy covariance, profile (storage term), gradient, or chamber-compatible

Featuring the TGA200A Trace-Gas Analyzer, *p. 13*

Shown: N_2O, CO_2, & H_2O eddy-covariance system

Now with vortex intake technology!

With over 40 years of experience in micrometeorological measurements, Campbell Scientific provides the most advanced micrometeorological instrument solutions. This booklet includes two such solutions: the vortex intake for closed-path eddy-covariance systems, which revolutionizes the possibilities for long-term, low-maintenance operation; and the IRGASON, the only commercially available, co-located and aerodynamic combination of gas analyzer and 3D sonic anemometer.

This booklet also presents a variety of other micrometeorological solutions for measuring turbulence and fluxes of greenhouse gases (CO_2, H_2O, CH_4, N_2O, and CO_2 isotopes) and energy (sensible heat, latent heat, and momentum). Thanks to low power, ruggedized designs, and low-maintenance operation, our systems are ideal for sites in remote or challenging conditions.

We are unique among flux system providers in that we manufacture all key system components: 3D sonic anemometers, gas analyzers, sampling systems, and dataloggers. This enables us to make our systems much more highly integrated, taking into account important system-level considerations such as sensor co-location and mounting, high-speed measurement synchronization, sensor aerodynamics, and whole-system frequency response.

Please feel free to contact us for more information. We look forward to helping you make the best measurements possible.

Campbell Scientific Micrometeorology Group: 435-227-9120
info@campbellsci.com

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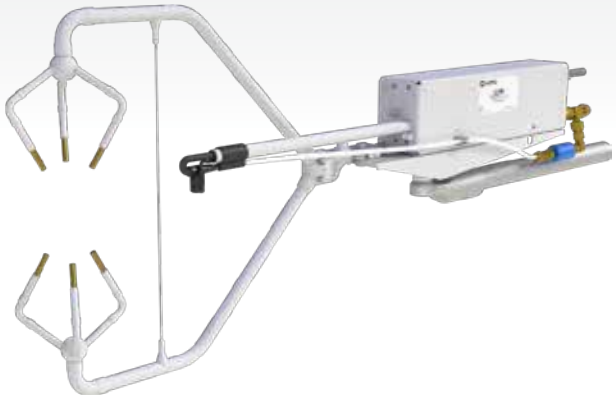
EC155

Closed-Path CO_2 /H_2O Gas Analyzer



Now with Vortex Technology

Use as part of closed-path eddy-covariance system

Overview

Campbell Scientific's EC155 closed-path analyzer now incorporates vortex intake technology for reduced maintenance, more accurate pressure measurements, and improved protection against corrosion. The EC155 can be combined with the CSAT3A sonic anemometer as shown above. The newly revised CSAT3A has a more aerodynamic and rigid design.

The EC155 is ordered as part of the CPEC200 system, which also includes the sample pump, datalogger, optional valve module, and optional scrub module to provide a zero air source. The EC155 with anemometer simultaneously measures absolute carbon dioxide and water vapor mixing ratio, sample cell temperature and pressure, and three-dimensional wind speed and sonic air temperature.

New Benefits and Features of Updated EC155 and CSAT3A

- Vortex Intake (U.S. Pat. No. 9,217,692) greatly reduces maintenance frequency compared to traditional in-line filters
- Heated inlet increases protection against condensation
- More accurate pressure measurements with the new sample cell absolute pressure sensor
- Fully integrated, detachable intake
- Improved corrosion protection with stainless steel sample cell
- Improved sonic temperature from more rigid CSAT3 geometry
- Stream-lined, aerodynamic CSAT3A mounting

Other Benefits and Features

- Slim aerodynamic shape with minimal wind distortion
- Analyzer, sample cell, and sonic anemometer measurements have matched bandwidths and are synchronized by a common set of electronics
- Low power consumption; suitable for solar power applications
- Low noise
- Small sample cell for excellent frequency response
- Integrated zero/span connection for simplified field zero/span
- Field rugged
- Field serviceable
- Factory calibrated over wide range of CO_2, H_2O, pressure and temperature in all combinations encountered in practice
- Extensive set of diagnostic parameters
- Fully compatible with Campbell Scientific dataloggers; field setup, configuration, and field zero and span can be accomplished directly from the datalogger
- Rain: Innovative signal processing and transducer wicks considerably improve performance of the anemometer during precipitation events

EC155 Outputs

- U_x (m/s)*
- U_y (m/s)*
- U_z (m/s)*
- Sonic Temperature (°C)*
- Sonic Diagnostic*
- CO_2 Mixing Ratio (µmol/mol)
- H_2O Mixing Ratio (mmol/mol)
- Gas Analyzer Diagnostic
- Cell Temperature (°C)
- Cell Pressure (kPa)
- CO_2 Signal Strength
- H_2O Signal Strength
- Differential Pressure (kPa)
- Source Temperature (°C)

**Requires a CSAT3A Sonic Anemometer Head.*

General Specifications[a]

- Operating Temperature: -30° to +50°C
- Operating Pressure: 70 to 106 kPa
- Input Voltage: 10 to 16 Vdc
- Power @ 25°C: 5 W (steady state and power up)
- Measurement Rate: 60 Hz
- Output Bandwidth: 5, 10, 12.5, or 20 Hz; user programmable
- Output Options: SDM, RS-485, USB, analog (CO_2 and H_2O only)
- Auxiliary Inputs: air temperature and pressure
- EC100 barometer accuracy
  Basic: ±1.5 kPa (> 0 °C), increasing linearly to ±.3.7 kPa at -30°C
  Enhanced: ±0.15 kPa (-30° to 50°C)
- Cable Length: 3 m (10 ft) from EC155/CSAT3A to EC100
- Sample Intake/Sonic Volume Separation: 15.4 cm (6.1 in)
- View EU Declaration of Conformity documentation at:
  www.campbellsci.com/ec155
- Warranty: 3 years or 17,500 hours of operation, whichever comes first
- Weight
  EC155 Head and Cables: 3.9 kg (8.5 lb)
  CSAT3A Head and Cables: 1.7 kg (3.7 lb)
  Mounting Hardware: 0.4 kg (0.9 lb)
  EC100 Electronics: 3.2 kg (7 lb)

Figure 1. Streamline flows through the vortex. Warmer colors represent higher speeds of dirty air to the right (towards bypass), and cooler colors represent higher speeds of clean air to the left (towards sample cell).

Gas Analyzer Specifications[a]

- Sample Cell Thermistor Accuracy: ± 0.15 °C (-30° to 50°C)
- Sample Cell Pressure Accuracy: ± 1.5 kPa (> 0 °C), increasing linearly to ±3.7 kPa at -30 °C

Performance

	CO_2	H_2O
Accuracy[b]	1%[c]	2%[c]
Precision RMS (maximum)[d]	0.15 µmol/mol	0.006 mmol/mol
Calibrated Range	0 to 1,000 µmol/mol[e]	0 to 72 mmol/mol (38°C dewpoint)
Zero Drift with Temperature (maximum)	±0.3 µmol/mol/°C	±0.05 mmol/mol/°C
Gain Drift with Temperature (maximum)	±0.1% of reading/°C	±0.3% of reading/°C
Cross Sensitivity (maximum)	±1.1 x 10^{-4} mol CO_2 /mol H_2O	±0.1 mol H_2O/mol CO_2

Sonic Anemometer Specifications[a]

Measurement Path

- Vertical: 10.0 cm (3.9 in)
- Horizontal: 5.8 cm (2.3 in)

Transducer Diameter

- 0.64 cm (0.25 in)

Range

- u_x: ±30 m s^{-1}
- u_y: ±60 m s^{-1}
- u_z: ±8 m s^{-1}
- T_s: -50° to +60°C
- Wind Direction: ±170°

Accuracy[f]

- Offset Error
  u_x, u_y: <±8.0 cm s^{-1}
  u_z: <±4.0 cm s^{-1}
  Wind Direction: ±0.7° while horizontal wind at 1 m s^{-1}
- Gain Error
  Wind Vector within ±5° of horizontal: <±2% of reading
  Wind Vector within ±10° of horizontal: <±3% of reading
  Wind Vector within ±20° of horizontal: <±6% of reading
- Measurement Precision RMS
  u_x, u_y: 1 mm s^{-1}
  u_z: 0.5 mm s^{-1}
  Sonic Temperature: 0.025°C
  Wind Direction: 0.6°

[a]*Subject to change without notice.*
[b]*Assumes the gas analyzer was properly zero and spanned using the appropriate standards; CO_2 span concentration was 400 ppm; H_2O span dewpoint was at 12°C (16.7 ppt); zero/span temperature was 25°C; zero/span pressure was 84 kPa; subsequent measurements made at or near the span concentration; temperature is not more than ±6°C from the zero/span temperature; and ambient temperature is within the gas analyzer operating temperature range.*
[c]*Standard deviation of calibration residuals.*
[d]*Nominal conditions for precision verification test: 25°C, 86 kPa, 400 µmol/mol CO_2, 12°C dewpoint, and 20 Hz bandwidth.*
[e]*0 to 3,000 µmol/mol available upon request.*
[f]*The accuracy specification for the sonic anemometer is for wind speeds <30 m s^{-1} and wind angles between ±170°.*

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CPEC300, CPEC306, and CPEC310

Closed-Path Eddy-Covariance Flux Systems


CPEC300


CPEC306


CPEC310

State of the Art

Systems ideal for top-level research

Overview

The CPEC300-series systems are turn-key, closed-path eddy-covariance (EC) flux systems for long-term monitoring of atmosphere-biosphere exchanges of carbon dioxide, water vapor, heat, and momentum. Three models are offered that support different applications:

- CPEC300—A basic, entry-level, closed-path eddy-covariance flux system that is a good solution for sites with fewer sensors and a short tower
- CPEC306—A mid-level, expandable, closed-path eddy-covariance system that is a good solution for sites with many sensors and either a short or tall tower
- CPEC310—A high-end, expandable, closed-path eddy-covariance system that is a good solution for sites with many sensors and either a short or tall tower, and that will use automatic zero and span

Each system typically includes an EC155 closed-path gas analyzer, CSAT3A sonic anemometer (ordered as an option), CR6 datalogger (ordered as an option), sample pump, and enclosures that house the electronics. The CPEC310 also has a valve module that provides automatic zero and span, and an optional scrub module that provides a convenient source of zero gas. Often the CDM-A116 16-channel analog input module is ordered with a CPEC306 or CPEC310 to connect additional energy-balance and meteorological sensors. The CDM-A116 fits inside the system enclosure.

The EC155 gas analyzer's intake design and small sample cell volume (5.9 mL) provide excellent frequency response (4.3 Hz cutoff frequency) with low total system power (12 W). Additionally, the now-available vortex intake greatly reduces maintenance and maintains frequency response compared to traditional inline filters.

Benefits and Features

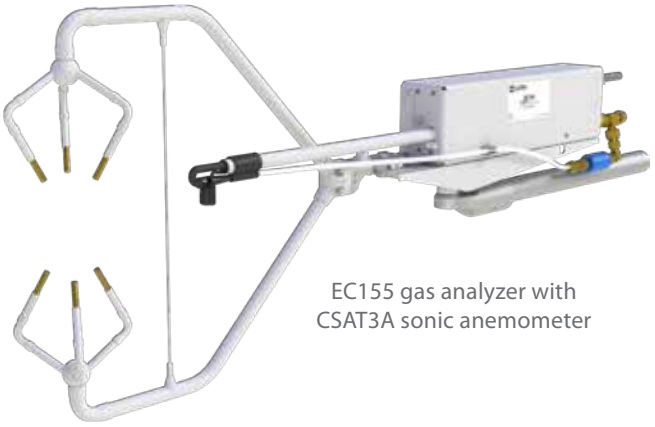
- Ease of use
  - Vortex intake greatly reduces maintenance compared to inline filters
  - EasyFlux™ datalogger program requires minimal input from station operator
  - Active system flow control; EC and zero/span flows set by datalogger program variables
  - System operates continuously during inclement weather
  - Heated sample intake prevents condensation
  - Installation requires minimal tools
- Excellent system frequency response (see graph on next page)
- Low power
- Onboard data storage available using microSD cards; maximum 8 GB or 8 months at 10 Hz measurement frequency
- Remote data collection, including direct (Ethernet, RS-232, short haul modem, landline[a]) and wireless (Wi-Fi, RF, cellular[a], satellite[b])

[a]Collecting high frequency time series is possible, but may be cost prohibitive.

[b]Only online statistics can be collected using satellite.

Science Measurements

CO_2 and H_2O are measured with an EC155 Closed-Path Gas Analyzer. Three-dimensional wind speed and sonic air temperature are measured with a CSAT3A sonic anemometer head.



EC155 gas analyzer with CSAT3A sonic anemometer

CPEC300-series System Enclosures

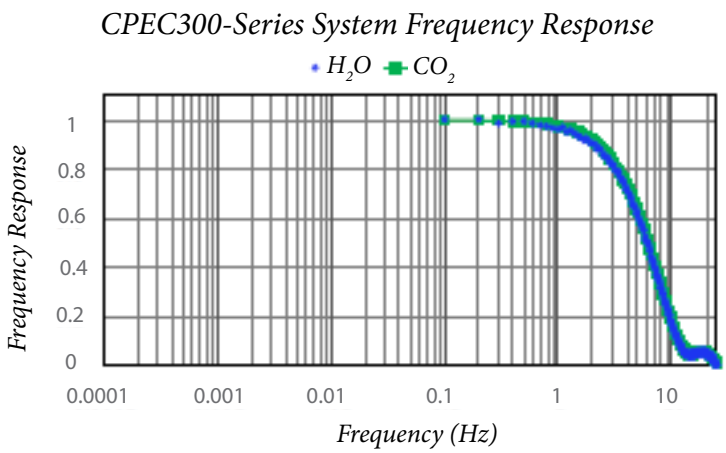
The CPEC300 series uses fewer enclosures than the previous system. The CPEC300 has only two enclosures: the EC100 enclosure of the CPEC300 that contains the CR6 datalogger, and the pump module enclosure. Both the CPEC306 and CPEC310 have two enclosures: a fiberglass enclosure that houses the CR6 datalogger, pump module, and optional CDM-A116, and the EC100 enclosure for data processing. The CPEC310 can also be equipped with a scrub module for automatic zeroing of the EC155. The CPEC300-series system enclosures can be mounted to a tripod mast, CM106B tripod leg base, tower legs, or a large-diameter pole.

CPEC300-series Pump Module

The pump module, a standard component of the CPEC300-series system, consists of a small dual-head diaphragm pump with a brushless dc motor mounted inside a fiberglass enclosure. An integral cable connects the pump module to the CPEC300 enclosure, which provides power, temperature measurement and control, pressure measurement, and pumping speed measurement and control. The CPEC306 and CPEC310 come with the pump module contained within the main fiberglass enclosure.

Valve Module

The CPEC310 comes with a three-valve module that enables the system to automatically perform zero, CO_2 span, and H_2O span measurements.



Specifications[c]

- Operating Temperature: -30° to +50°C
- Input Voltage: 10.5 to 16.0 Vdc
- Power: 12 W (typical); 35 W (maximum (at cold startup)
- View the EU Declaration of Conformity document at: www.campbellsci.com/cpec300, www.campbellsci.com/cpec306, or www.campbellsci.com/cpec310

System Enclosure

- Dimensions
  CPEC300: 34 x 25 x 13 cm (13.4 x 9.8 x 5.1 in)
  CPEC306/310: 54 x 44.5 x 29.7 cm (21.3 x 17.5 x 11.7 in)
- Weight
  CPEC300: 4.02 kg (8.85 lb)
  CPEC306: 13.72 kg (30.25 lb)
  CPEC310: 15.36 kg (33.85 lb)
  CDM-A116 Module: 0.88 kg (1.95 lb)

[c]Refer to the EC155 and CSAT3A product brochures for closed-path gas analyzer and sonic anemometer specifications.

Pump Module

- Cable Length for CPEC300: 3.0 m (10 ft)
- Inlet Connection for CPEC300: 3/8 inch Swagelok®
- Pressure Sensor Range: 15 to 115 kPa
- Pumping Speed: 3 to 9 LPM (automatically controlled at the set point, typically 8 LPM)
- Dimensions for CPEC300: 35.6 x 29.2 x 13.5 cm (14.0 x 11.5 x 5.3 in)
- Weight for CPEC300 without mounting bracket: 5.4 kg (11.8 lb)

CPEC310 Three-Valve Module

- Inlets: Zero, CO_2 span, and H_2O span
- Outlets: Analyzer and H_2O bypass
- Connections: 1/4 inch Swagelok®
- Flow Rate: 0.5 to 5 LPM (automatically controlled at user-entered set point)
- Dimensions: 14.0 x 12.7 x 14.0 cm (5.5 x 5.0 x 5.5 in)
- Weight: 1.5 kg (3.3 lb)

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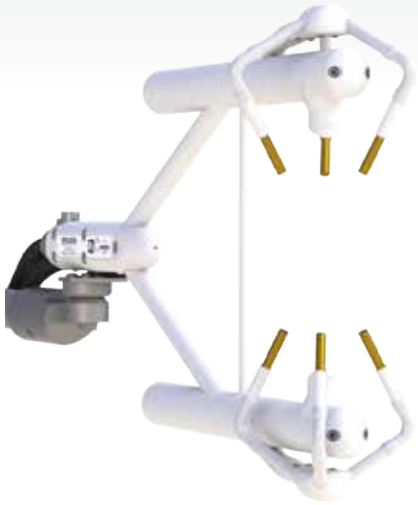
IRGASON

Integrated Open-Path CO_2/H_2O Gas Analyzer and 3D Sonic Anemometer



Patented Design[a]

Gas analyzer and sonic anemometer in one sensor

Overview

Campbell Scientific's IRGASON fully integrates the open-path analyzer and sonic anemometer. Designed specifically for eddy-covariance flux measurements, the patented design is easier to install and use than separate sensors and provides increased measurement accuracy. The IRGASON simultaneously measures absolute carbon dioxide and water vapor, air temperature, barometric pressure, and three-dimensional wind speed and sonic air temperature.

Benefits and Features

- Combined support structure causes less flow distortion than two separate sensors
- Truly colocated gas analyzer and sonic anemometer avoids flux loss due to sensor separation
- Synchronized gas analyzer and sonic anemometer measurements avoid the need to correct for time lag
- Low power consumption
- Measurements are temperature compensated without active heat control
- Low noise
- Maximum output rate of 50 Hz with 25 Hz bandwidth
- Angled windows to shed water and are less tolerant to window contamination
- Field rugged
- Field serviceable
- Factory calibrated over wide range of CO_2, H_2O, pressure, and temperature in all combinations encountered in practice
- Extensive set of diagnostic parameters
- Fully compatible with Campbell Scientific dataloggers; field set-up, configuration, and field zero and span can be accomplished directly from the datalogger
- Sonic Temperature: Determined from 3 acoustic paths; corrected for crosswind effects
- Rain: Innovative signal processing and transducer wicks considerably improves performance of the anemometer during precipitation events

IRGASON Outputs

- U_x (m/s)
- U_y (m/s)
- U_z (m/s)
- Sonic Temperature (°C)
- Sonic Diagnostic
- CO_2 Density (mg/m^3)
- H_2O Density (g/m^3)
- Gas Analyzer Diagnostic
- Ambient Temperature (°C)
- Atmospheric Pressure (kPa)
- CO_2 Signal Strength
- H_2O Signal Strength
- Source Temperature (°C)

The EC150 and CSAT3A combination is also available for applications requiring separate sensor heads. For more information, see www.campbellsci.com/ec150.

[a] *U.S. Patent No. D680455*

General Specifications[b]

- Operating Temperature Range: -30° to +50°C
- Calibrated Pressure Range: 70 to 106 kPa
- Input Voltage Range: 10 to 16 Vdc
- Power @ 25°C: 5 W (steady state and power up)
- Measurement Rate: 100 Hz
- Output Bandwidth: 5, 10, 12.5, 20, or 25 Hz; user programmable
- Output Options: SDM, RS-485, USB, analog
- Auxiliary Inputs: air temperature and pressure
- Weight
  IRGASON Head and Cables: 2.8 kg (6.1 lb)
  EC100 Electronics: 3.2 kg (7.1 lb)
- Cable Length: 3.0 m (10.0 ft) from IRGASON to EC100

Gas Analyzer Specifications[b,c]

- Path Length: 15.37 cm (6.05 in)

Performance

	CO_2	H_2O
Accuracy[d]	1%[e]	2%[e]
Precision RMS (maximum)[f]	0.2 mg/m³ (0.15 µmol/mol)	0.004 g/m³ (0.006 mmol/mol)
Calibrated Range	0 to 1000 µmol/mol[g]	0 to 72 mmol/mol (37°C dewpoint)
Zero Drift with Temperature (maximum)	±0.55 mg/m³/°C (±0.3 µmol/mol/°C)	±0.037 g/m³/°C (±0.05 mmol/mol/°C)
Gain Drift with Temperature (maximum)	±0.1% of reading/°C	±0.3% of reading/°C
Cross Sensitivity (maximum)	±1.1 x 10^{-4} mol CO_2 /mol H_2O	±0.1 mol H_2O/mol CO_2

Sonic Anemometer Specifications[b]

Measurement Path

- Vertical: 10.0 cm (3.9 in)
- Horizontal: 5.8 cm (2.3 in)

Transducer Diameter

- 0.64 cm (0.25 in)

Range

- u_x: ±30 m s^{-1}
- u_y: ±60 m s^{-1}
- u_z: ±8 m s^{-1}
- T_s: -50° to +60°C
- Wind Direction: ±170°

Accuracy[h]

- Offset Error
  u_x, u_y: <±8.0 cm s^{-1}
  u_z: <±4.0 cm s^{-1}
  Wind Direction: ±0.7° while horizontal wind at 1 m s^{-1}
- Gain Error
  Wind Vector within ±5° of horizontal: <±2% of reading
  Wind Vector within ±10° of horizontal: <±3% of reading
  Wind Vector within ±20° of horizontal: <±6% of reading
- Measurement Precision RMS
  u_x, u_y: 1 mm s^{-1}
  u_z: 0.5 mm s^{-1}
  Sonic Temperature: 0.025°C
  Wind Direction: 0.6°

Barometer Specifications[b]

	-BB Basic Barometer	-EB Enhanced Barometer (Vaisala PTB110)
Total Accuracy	±3.7 kPa at -30°C, falling linearly to ±1.5 kPa at 0°C (-30° to 0°C), ±1.5 kPa (0° to 50°C)	±0.15 kPa (-30° to +50°C)
Measurement Rate	10 Hz	1 Hz

Ambient Temperature Specifications[b]

- Manufacturer: BetaTherm 100K6A1IA
- Total Accuracy: ±0.15°C (-30° to +50°C)

[b]Subject to change without notice.

[c]A temperature of 20°C and pressure of 101.325 kPa was used to convert mass density to concentration.

[d]Assumes the gas analyzer was properly zero and spanned using the appropriate standards; CO_2 span concentration was 400 ppm; H_2O span dewpoint was at 12°C (16.7 ppt); zero/span temperature was 25°C; zero/span pressure was 84 kPa; subsequent measurements made at or near the span concentration; temperature is not more than ±6°C from the zero/span temperature; and ambient temperature is within the gas analyzer operating temperature range.

[e] Standard deviation of calibration residuals.

[f] Nominal conditions for precision verification test: 23°C, 86 kPa, 400 µmol/mol CO_2, 12°C dewpoint, and 20 Hz bandwidth.

[g] 0 to 3,000 µmol/mole available upon request.

[h]The accuracy specification for the sonic anemometer is for wind speeds <30 m s^{-1} and wind angles between ±170°.

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EasyFlux DL

Eddy-Covariance Datalogger Program

EASYFLUX DL

Overview

EasyFlux™ DL is a free CRBasic program that enables a datalogger to report fully corrected fluxes of CO_2, latent heat (H_2O), sensible heat, and momentum from a Campbell Scientific open-path eddy-covariance (EC) system. Final fluxes are processed from raw high frequency time series data by applying commonly used corrections found in scientific literature.

In the past, Campbell Scientific datalogger EC programs roughly estimated fluxes, and PC post-processing software was used to fully correct the flux measurements. Now with the EasyFlux DL program, fully corrected fluxes are processed by the datalogger and reported at the end of each EC averaging interval. Also provides many other variables of atmospheric properties, instrument diagnostics, intermediate correction, and other energy balance or biomet sensors

EasyFlux DL has been tested at several stations in various environments, including irrigated alfalfa, grassland, maize, open water, forest, and desert. The results have shown good agreement with fluxes processed using traditional PC-based software applications.

Benefits and Features

- Accesses final fluxes quickly without the burden of post-processing
- Produces flux output tables that are smaller than time series tables, which allows flux data to be frequently collected using cellular, radio, or other lower-bandwidth telemetry options
- Available, at no charge; see Downloads section on website
- Matches the fluxes provided by PC post-processing software packages (assuming same filtering of raw data and same selection of correction procedures)
- Saves high frequency time series to removable media in case reprocessing is later needed
- Includes data quality and footprint characteristics
- Reports uncorrected and intermediate values in an auxiliary output table for more detailed data inspection
- Provides for CR6 program fully processed data output in AmeriFlux format

Supported Sensors

Required

- IRGASON Integrated CO_2 and H_2O Open-Path Gas Analyzer and 3-D Sonic Anemometer
- EC150 CO_2 and H_2O Open-Path Gas Analyzer with CSAT3A 3-D Sonic Anemometer
- CR6 or CR3000 datalogger
- NL116 or CFM100 (CR3000 only)
- 27158 (2 GB) or 33288 (8 GB) microSD Flash SLC Memory Card (CR6); CFMC2G or CFMC16G CompactFlash Card (CR3000)

IRGASON

*Optional**

- CDM-A116 for CR6 with energy balance sensors
- FW05, FW1, or FW3 Fine-Wire Thermocouple
- HC2S3 or HMP155A Temperature and Relative Humidity Probe
- CNR4, NR01, or NR-LITE2 Net Radiometer
- CS300 or LI200RX Pyranometer
- LI190R Quantum Sensor
- SI-111 Infrared Radiometer
- TE525MM Tipping Bucket Rain Gage
- TCAV Averaging Soil Thermocouple Probe (quantity up to two)
- CS616 or CS650 Water Content Reflectometer (quantity up to two)
- HFP01 or HFP01SC Soil Heat Flux Plate (quantity up to four)

**It may be possible to add non-standard sensors to the program upon request and for a fee.*

Main Correction and Processing Procedures

- Despike and filter high frequency time series data using sonic anemometer and gas analyzer diagnostic codes, signal strengths, and measurement output range thresholds.
- Apply coordinate rotations with an option to use the double rotation method (Tanner and Thurtell, 1969) or planar fit method (Wilczak, et al., 2001).
- Lag CO_2 and H_2O measurements against sonic wind measurements for maximization of CO_2 and H_2O fluxes (Horst and Lenschow, 2009; Foken et al., 2012), with additional constraints to ensure lags are physically possible.
- Apply frequency corrections using commonly used cospectra (Moore, 1986; van Dijk, 2002; Moncrieff et al., 1997) and transfer functions for block averaging (Kaimal et al., 1989), line/volume averaging (Moore, 1986; Moncrieff et al., 1997; Foken et al., 2012; van Dijk, 2002), time constants (Montgomery, 1947; Shapland et al., 2014; Geankoplis, 1993), and sensor separation (Horst and Lenschow, 2009; Foken et al., 2012).
- Apply a modified SND correction (Schotanus et al., 1983) to derive sensible heat flux from sonic sensible heat flux following the implementation as outlined in van Dijk (2002). Additionally, fully corrected sensible heat flux computed from a fine-wire thermocouple is provided if our FW05, FW1, or FW3 is used.
- Apply correction for air density fluctuations using Webb et al., 1980.

Figure 1. Fully corrected fluxes are calculated using EasyFlux DL over a field of maize.

- Assign data quality classifications based on steady state conditions, surface layer turbulence characteristics, and wind direction following Foken et al., 2012.
- Calculate footprint characteristics using Kljun et al., 2004 or Kormann and Meixner, 2001.
- If energy balance sensors are used, calculate energy closure based on energy balance measurements and corrected sensible and latent heat fluxes.

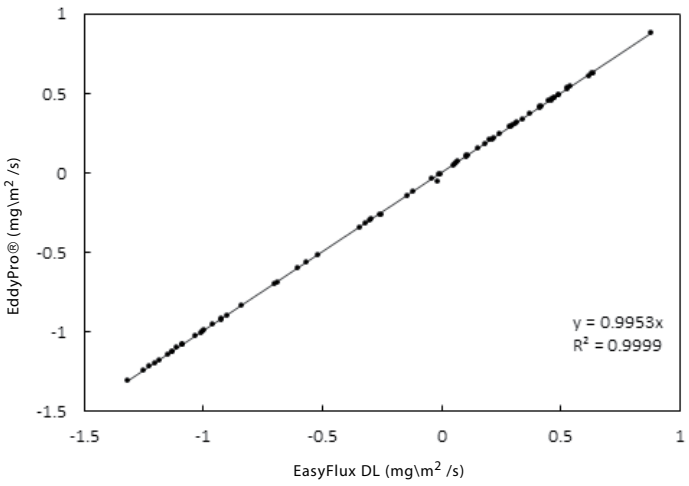

Figure 2. CO_2 fluxes over maize are calculated and compared using EasyFlux DL and EddyPro® (LI-COR, Inc., Lincoln, NE) after applying similar diagnostic and despiking filters to raw data. Data shown represent half-hour fluxes taken over a four-day period in August.

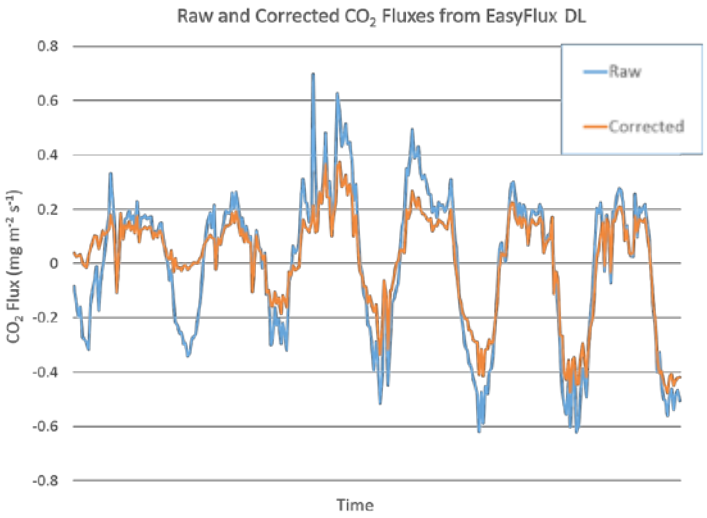

Figure 3. Corrected CO_2 fluxes from EasyFlux DL are compared to uncorrected CO_2 fluxes over a week period from an irrigated alfalfa field soon after the alfalfa was harvested.

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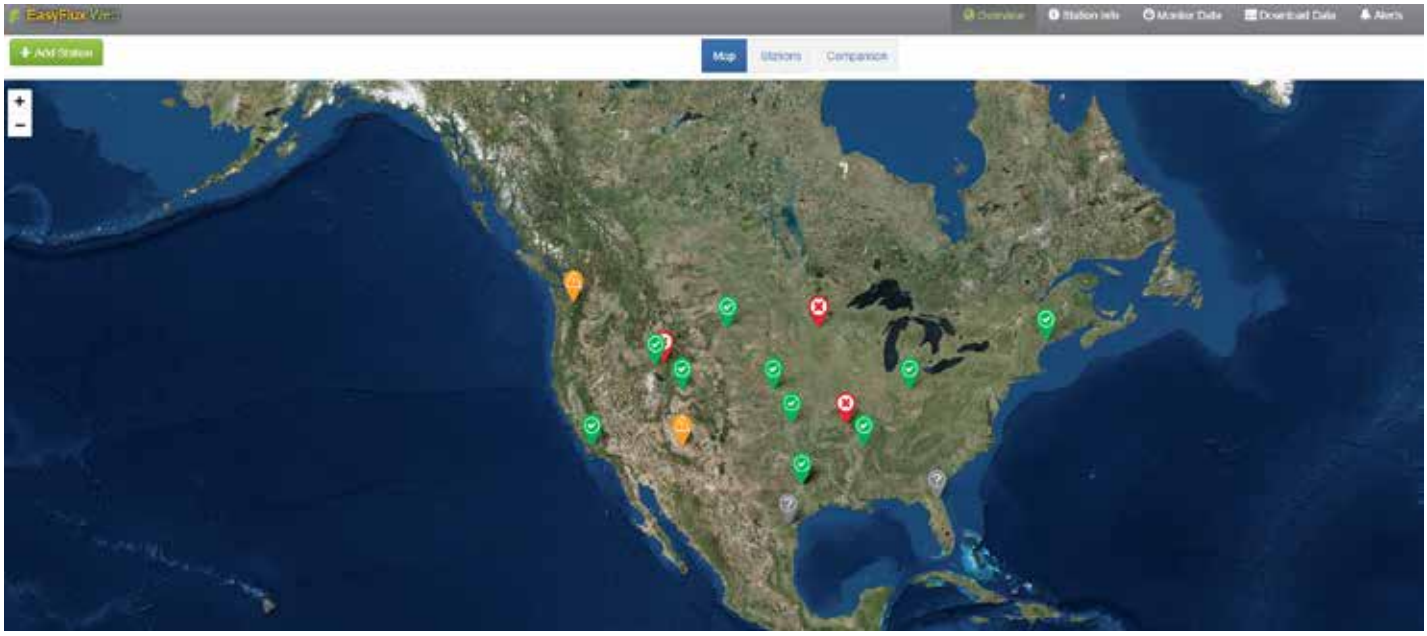
EasyFlux Web

Eddy-Covariance Browser-Based Software

EASYFLUX Web



Overview

EasyFlux™ Web is a web-based multi-user software system used for monitoring Internet-connected Campbell Scientific eddy-covariance stations. EasyFlux Web builds on our EasyFlux™ DL series for the IRGASON or EC150/CSAT3A and CPEC200/CPEC300 series to provide real-time display of fully corrected 30-minute fluxes, energy-balance sensors, and overall health of the network. EasyFlux Web gives you the ability to track your eddy-covariance systems in one easy-to-use interface.

EasyFlux Web functions with the EasyFlux DL program running on a Campbell Scientific CR6 or CR3000 datalogger. When a station is added, EasyFlux Web automatically pulls station information available from the program running in the datalogger (ecosystem, latitude, and longitude). After adding your stations, you can graphically monitor data including QA/QC values, download data, compare data between stations, and set up alerts to notify you by email of data values outside of user-entered thresholds.

An administrator can set up user accounts and control the rights of each user. The following installation options are offered for EasyFlux Web.

1. **EasyFlux™ Web Self-Hosted**: You install the software directly on your server, which also installs SQL Server Express. EasyFlux Web is then accessed by typing the IP address of the server into a web browser.
2. **EasyFlux™ Web CSI-Hosted:** Campbell Scientific installs the software and automatically updates the software for you in a Microsoft Azure-based environment and provides a link to access the software.

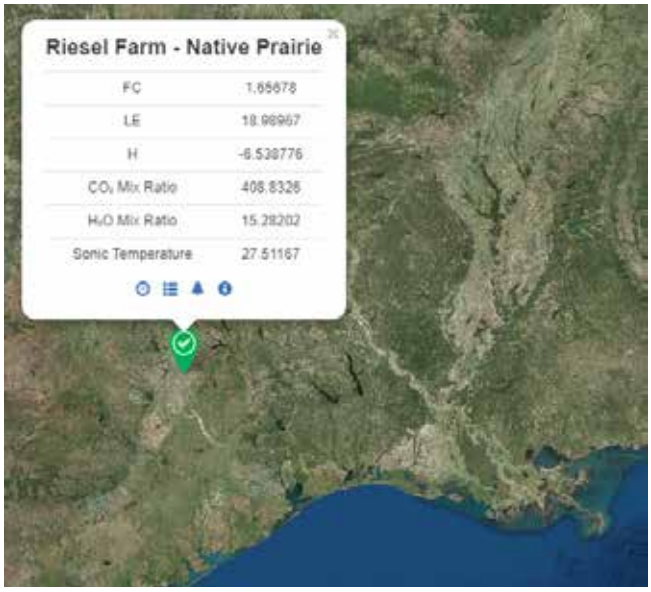
Benefits and Features

- Custom alerts with email notification
- Monitor flux instruments and energy balance sensors, letting you plan site visits more effectively
- Quickly reference metadata for each station
- Remotely download data
- Map view of all stations in network with quick view of critical data and alerts available on a computer, tablet, or smartphone device
- Flexible product offering with ability to purchase a local copy or a subscription to a cloud-based plan
- Administrator choices on read/write abilities of users
- Fully compatible with EasyFlux DL series for CR6 dataloggers

Station Setup

EasyFlux Web allows for users to add all of their stations within a network that has remote communication access. Adding your station's IP address to the program immediately adds your station to the interface. You can uniquely modify each station with site images, ecosystem type, and location information. Once added, your site will display on the interactive map, making your data one click away.

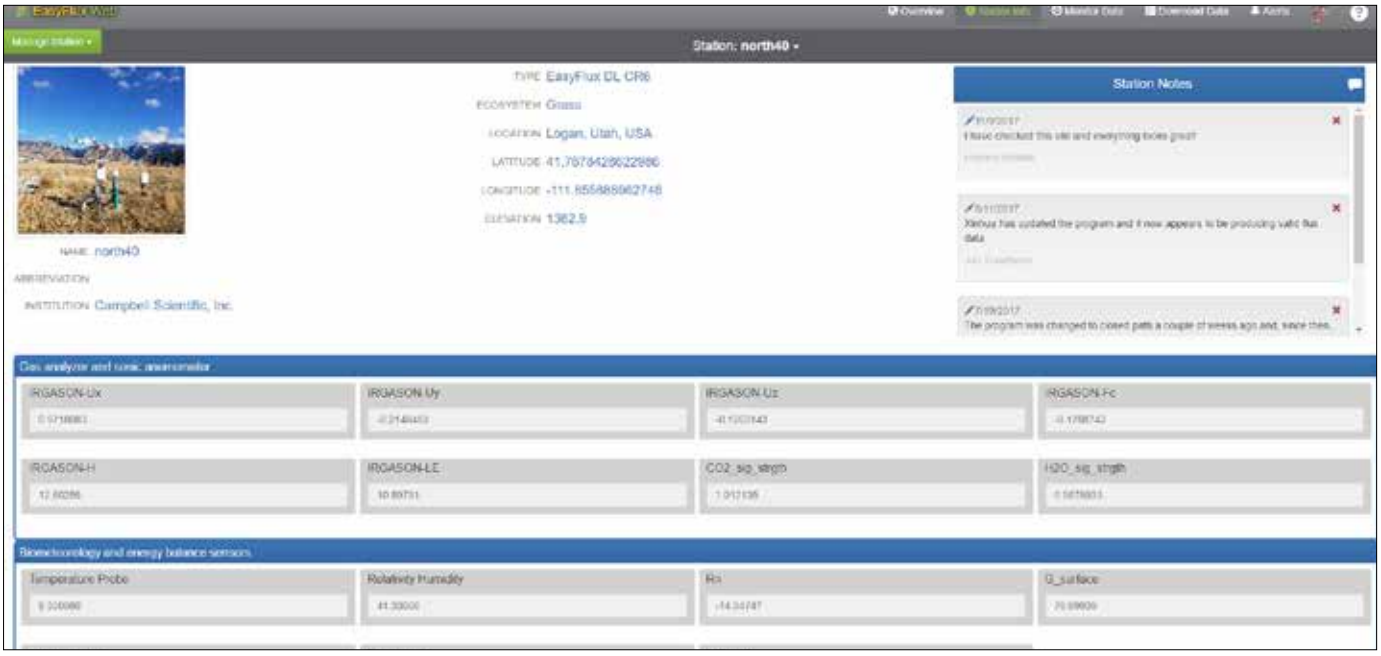
Adding a station is quick and easy. Just select ***Manage LoggerNet Dataloggers***, fill in your datalogger's information, and then customize your station using the ***New Station*** interface. Once you hit save, you're all done!



Once your site has been added, it will appear on the interactive ***Overview Map*** where you can see snapshots of data at your site for easy monitoring. For example,Texas Water Observatory at Riesel Farm – Native Prairie Site: http://two.tamu.edu/sites/primary/rfpr.aspx

Station Info

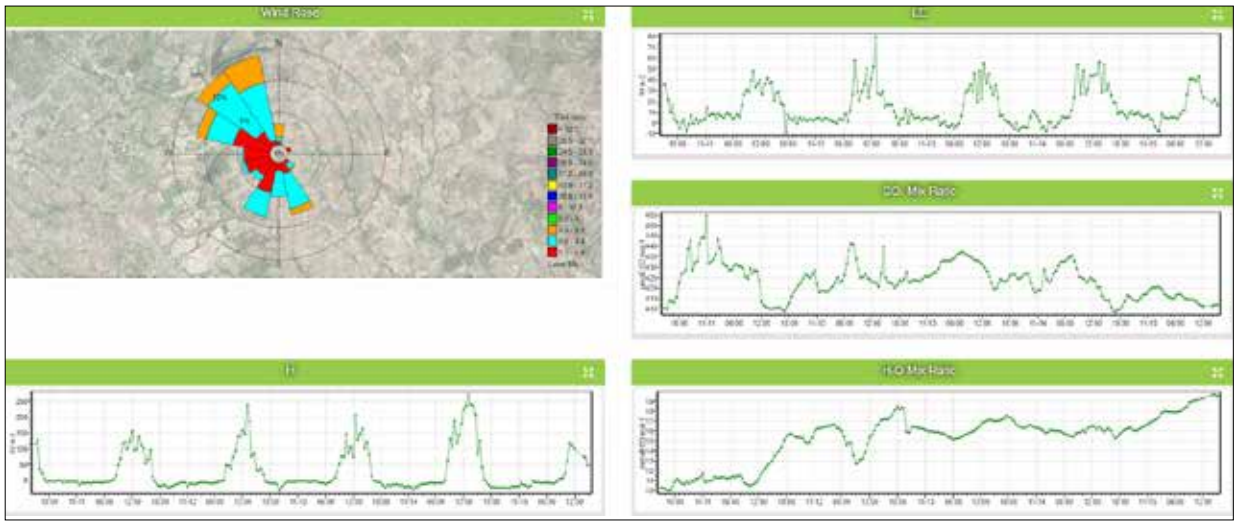
The ***Station Info*** section is a great tool for checking the status of important station data variables, metadata, and datalogger information. Station notes can be logged here after site visits to provide important information that you may need to be aware of for future reference.



The ***Station Info*** tab for your sites

Monitor Data

EasyFlux Web gives you the capability to monitor your fully corrected fluxes and other sensor data. The ***Monitor Data*** section allows you to add and customize which station variables are visible to you. This tool helps track your data over time to give you a better understanding of the important environmental processes that occur at your site.



Monitor Data section can be easily customized for your application.

Download Data

You can instantly download data in EasyFlux Web. Just specify what data tables to collect, what data format you would prefer, and how much data you need.

Alerts

EasyFlux Web helps notify you of potential problems with your eddy-covariance station. Customizable alerts help to inform you when system conditions have triggered a data flag. You can set thresholds to your station variables that will alert you when your data has fallen within these values. You can subscribe to those alerts for which you want to be notified by email.

Title	Status	Value	Threshold	Message	Subscribed	Actions
No Data				No data received for over one hour		
Skipped Scans		0	value > 0			
Watchdog Errors		0	value > 0			
Card Storage Running Low		0.8756945	value < 7	There are less than seven days of card storage on the datalogger.		
FC OK		NAN	value = NAN	Invalid value for FC		
LE OK		NAN	value = NAN	Invalid value for LE		
H OK		NAN	value = NAN	Invalid value for H		
TAU OK		NAN	value = NAN	Invalid value for TAU		
USTAR OK		0.2260097	value = NAN			

Alerts send you messages when your data has been flagged.

Compatibility

Required Campbell Systems

- Campbell Scientific CR6 datalogger running either the EasyFlux-CR6OP or EasyFlux-CR6CP program for closed-path eddy-covariance systems.
- Campbell Scientific CR3000 datalogger running the EasyFlux DL program for open-path, eddy-covariance systems.

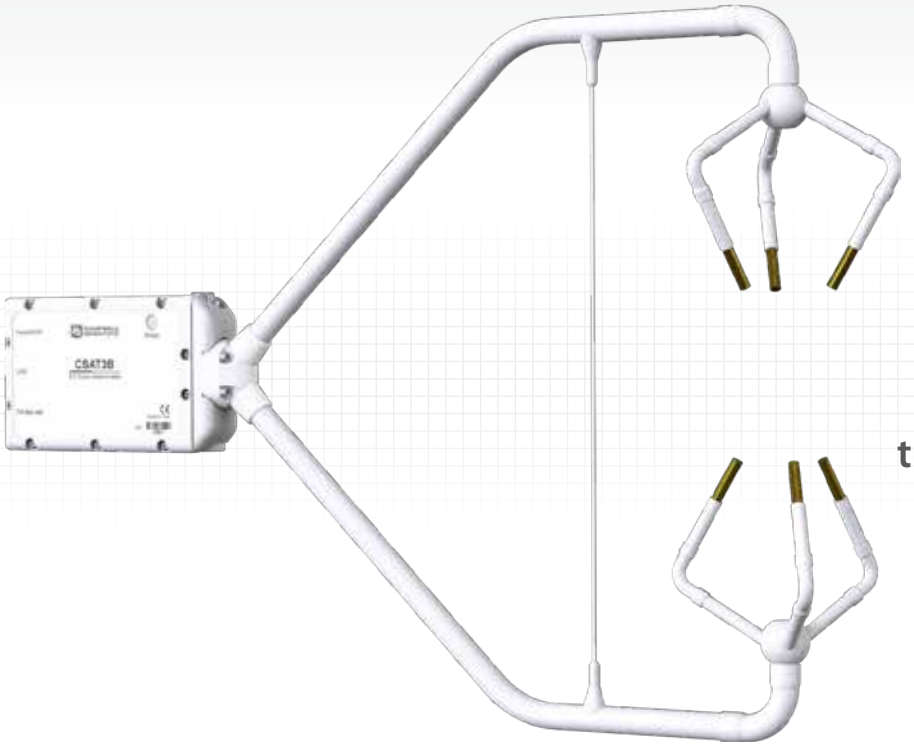
Required Computer Software

- Windows 8.1 or newer and Windows Server 2012 R2 or newer 64-bit only.
- 10 GB of hard-disk space
- 4 GB RAM
- 2.0 GHz or faster processor
- x64 processors only

CAMPBELL SCIENTIFIC®
WHEN MEASUREMENTS MATTER

CSAT3B

3D Sonic Anemometer



Precision Measurements

Designed for flux and other turbulence research projects

Overview

Campbell Scientific's CSAT3B 3D Sonic Anemometer is an update and replacement to the original CSAT3, and remains the 3D sonic anemometer of choice for eddy-covariance measurements. It has an aerodynamic design, a 10 cm vertical measurement path, operates in a pulsed acoustic mode, and withstands exposure to harsh weather conditions. Three orthogonal wind components (u_x, u_y, u_z) and the sonic temperature (T_s) are measured and output at a maximum rate of 100 Hz.

The most conspicuous innovation of the new design is the elimination of the electronics box. Instead, the electronics are packaged inside the mounting block of the CSAT3B head. This design feature makes installation easier and offers greater flexibility in instrument placement.

Measurements can be triggered from three sources:

- Datalogger SDM command
- Datalogger CPI command
- CSAT3B internal clock

The SDM and CPI protocols both support mechanisms for synchronizing multiple CSAT3Bs.

Benefits and Features

- Integrated electronics that provide easy mounting of a single piece of hardware
- Integrated inclinometer
- High-precision measurements ideal for turbulence and eddy covariance studies
- An improved design with a thin, aerodynamic support strut close to the ends of the sensor arms, creating greater rigidity and improved accuracy of sonic temperature
- Datalogger sampling supported for any frequency between 1 and 100 Hz
- New CPI communications for more robust, higher bandwidth measurements
- Multiple communication options including SDM, CPI, USB, and RS-485
- Internal temperature and humidity measurements with easily replaced desiccant
- Version 5 algorithm for calculating data outputs; combines the signal sensitivity of version 3 with the rain performance of version 4
- Includes options to filter high frequencies for applications requiring analysis of non-aliased spectra

Specifications

Measurements

- Operation temperature range: -30 to +50 °C, equivalent to 312 to 368 m s^{-1} in speed of sound
- Outputs: u_x, u_y, u_z, T_s (u_x, u_y, u_z are wind components referenced to the anemometer axes; T_s is sonic temperature in degrees Celsius)
- Speed of sound: Determined from three acoustic paths; corrected for crosswind effects
- Wind direction range: 2.5 to 357.5° in CSAT3B coordinate system; 0 to 360° customized
- Filter Bandwidths: 5, 10, 20, or 25 Hz

Wind Accuracy[b]

- Offset error (maximum): <±8.0 cm s^{-1} (u_x, u_y), <±4.0 cm s^{-1} (u_z)
- Gain error (maximum)
  Wind vector within ±5° of horizontal: <±2% of reading
  Wind vector within ±10° of horizontal: <±3% of reading
  Wind vector within ±20° of horizontal: <±6% of reading

Measurement Resolution

- u_x, u_y: 1 mm s^{-1} rms
- u_z: 0.5 mm s^{-1} rms
- T_s: ± 0.002 °C RMS at 25 °C
- Wind direction: < 0.058° ($u_x = u_y \leq 1$ m s^{-1})

Measurement Rates

- Datalogger Triggered: 1 to 100 Hz
- Unprompted Output (to PC): 10, 20, 50, or 100 Hz
- Internal Self-Trigger Rate: 100 Hz

Measurement Delay

- Datalogger-Triggered (no filter): 1 trigger period (1 scan interval)
- Unprompted Output (no filter): 10 ms
- Filtered Output (Datalogger-Prompted or Unprompted to PC):
  795 ms with 5 Hz bandwidth filter
  395 ms with 10 Hz bandwidth filter
  195 ms with 20 Hz bandwidth filter
  155 ms with 25 Hz bandwidth filter

Internal Monitor Measurements

- Update Rate: 2 Hz
- Inclinometer Accuracy: ± 1°
- Relative Humidity Accuracy:
  ± 3 % over 10 to 90% range
  ± 7 % over 0 to 10% range
  ± 7 % over 90 to 100 % range
- Board Temperature Accuracy: ± 2°C

Compliance Information

- View the EU Declaration of Conformity for the CSAT3B cables at: www.campbellsci.com/csat3bcbl1-l

Communications

SDM (use for datalogger-based data acquisition)

- Bit Period: 10 µs to 1 ms
- Cable Length:
  7.6 m (25 ft) max @ 10 µs bit period
  76 m (250 ft) max @ 1 ms bit period
- Address Range: 1 to 14
- Bus Clocks per Sample: ~200

CPI (Used for datalogger-based data acquisition)

- Baud Rate: 50 kbps to 1 Mbps
- Cable Length: 15 m (50 ft) max @ 1 Mbps
  122 m (400 ft) max @ 250 kbps
  853 m (2800 ft) max @ 50 kbps
- Address Range: 1 to 120
- Bus Clocks per Sample: ~300

RS-485 (used for configuration or PC-based data acquisition)

- Baud rate: 9.6 kbps to 115.2 kbps
- Cable Length: 305 m (1000 ft) max @ 115.2 kbps
  610 m (2000 ft) max @ 9.6 kbps
- Bus Clocks per Sample: ~500 (ASCII formatted)

USB (used for configuration or PC-based data acquisition)

- Connection Speed: USB 2.0 full speed 12 Mbps
- Cable Length: 5 m maximum

Power Requirements

- Voltage supply: 9.5 to 32 Vdc

Current

- 10 Hz Measurement Rate: 110 mA @ 12 Vdc; 65 mA @ 24 Vdc
- 100 Hz Measurement Rate: 145 mA @ 12 Vdc; 80 mA @ 24 Vdc

Physical Description

- Measurement path length: 10.0 cm (3.9 in) vertical; 5.8 cm (2.3 in) horizontal
- Transducer angle from horizontal: 60 degrees
- Transducer diameter: 0.64 cm (0.25 in)
- Transducer mounting arms diameter: 0.84 cm (0.33 in)
- Support arms diameter: 1.59 cm (0.63 in)
- Anemometer Head Weight: 1.45 kg (3.2 lb)

Anemometer Overall

- Length: 60.64 cm (23.87 in)
- Height: 43.0 cm (16.9 in)
- Width: 12.2 cm (4.8 in)

[a]Accuracy specifications assume -30° to +50°C operating range; wind speeds < 30 m s^{-1}; wind angles between ±170°.

CAMPBELL SCIENTIFIC
WHEN MEASUREMENTS MATTER

TGA200A
Trace Gas Analyzer

High Speed, Low Maintenance, Field Rugged

Measures CO_2 isotopes, N_2O, or CH_4

Overview

The TGA200A Trace Gas Analyzer measures trace gas concentrations in an air sample using tunable-diode laser absorption spectroscopy (TDLAS). This technique provides high sensitivity, speed, and selectivity. Its simple design allows it to measure one of many gases by choosing an appropriate laser source. The TGA200A features a 1.5 m single-pass optical measurement system that uses a thermoelectrically cooled laser.

The TGA200A is housed in a rugged environmental enclosure designed for use in demanding climates ranging from high-latitude boreal forests, permafrost, and tundra to agriculturally intensive mid-latitude regions and equatorial rainforests. Common applications include slow-gradient or high-speed eddy-covariance measurements of nitrous oxide fluxes or carbon fluxes in the form of methane, or isotopologs of carbon dioxide in all global ecosystems.

Campbell Scientific has been manufacturing TGAs since 1993, and the TGA200A is the result of over 20 years of research and development. Even though previous generations of the TGA (TGA100, TGA100A, and TGA200) have the same core technology, the TGA200A builds upon this succession with further improvements. For more information about the TGA200A, contact Campbell Scientific, Inc.

Benefits and Features

- Small sample cell volume that provides superior frequency response
- Thermoelectrically cooled laser; no cryogenic cooling required
- Laser upgrades available to existing TGA customers; contact Campbell Scientific for more information
- Choice of laser sources to measure CO_2 isotopes, N_2O, or CH_4
- Optically simple measurement system that does not require cleaning of the optical cell in the field
- 500 Hz measurement rate that supports excellent synchronization
- Rugged environmental enclosure that allows the TGA200A to be placed outside on the ground
- Simple Windows user interface for setup, configuration, and real-time monitoring
- Complete greenhouse gas measurement flux solution provided by combining one or more TGA200As with Campbell Scientific's sonic anemometers, dataloggers, gas analyzers, closed-path gas analyzers, or eddy-covariance system
- Advanced sampling systems also available for low-flow applications such as profile, gradient, or user-supplied chamber measurements

For comprehensive details, visit: www.campbellsci.com/tga200a

Specifications

Measurement Rate	500 Hz
Sample Cell Volume	200 mL
Dimensions	211 x 47 x 55 cm (83 x 18.5 x 21.5 in.)
Weight	› 5.4 kg (12.0 lb) for power module with cable › 62.8 kg (138.5 lb) for TGA200A

Typical Measurement Noise

-NOTE-	*Preliminary Results* *Allan deviation with 100 ms averaging time.*
Nitrous Oxide (N_2O) - Laser pn 30478	1.5 nmol mol^{-1}
Methane (CH_4) - Laser pn 30477	7.0 nmol mol^{-1}
Nitrous Oxide (N_2O) - Laser pn 31121	1.8 nmol mol^{-1}
Carbon Dioxide (CO_2) - Laser pn 31121	0.3 µmol mol^{-1} (based on the $^{13}C^{16}O^{16}O$ isotopolog)
Carbon Dioxide (CO_2) - Laser pn 31119	0.15 µmol mol^{-1}
$\delta^{13}C$ - Laser pn 31119	0.5 ‰
Carbon Dioxide (CO_2) - Laser pn 30877	0.5 µmol mol^{-1}
$\delta^{13}C$ - Laser pn 30877	2.0 ‰
$\delta^{18}O$ - Laser pn 30877	2.0 ‰

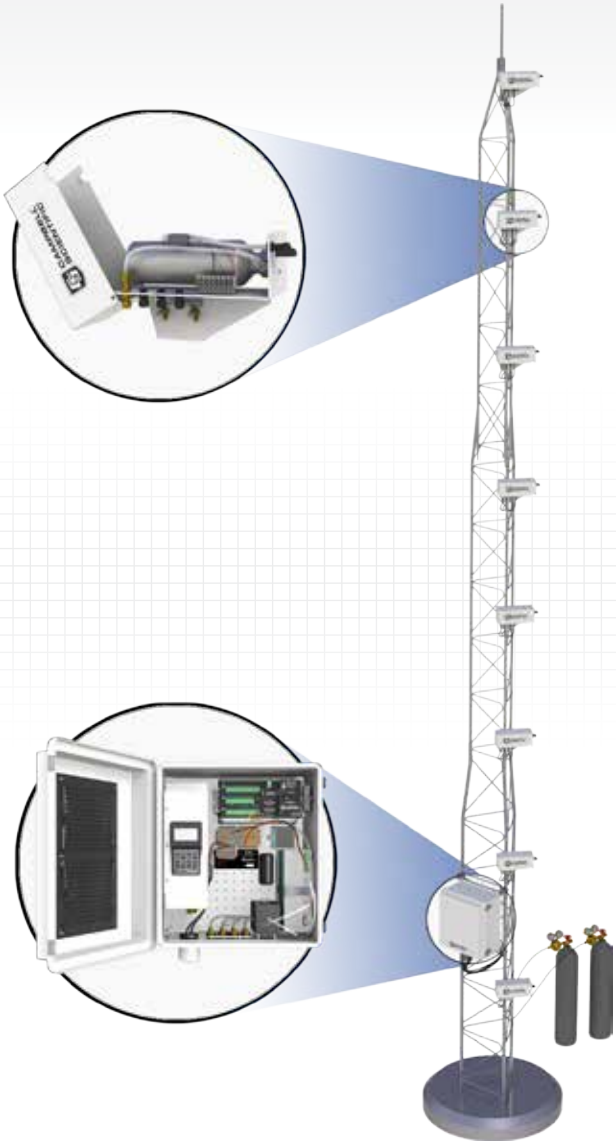
Power Requirements

Analyzer (TE-cooled laser)	90 to 264 Vac, 47 to 63 Hz, 34 W (max) 22 W (typical)
Heater	90 to 264 Vac, 47 to 63 Hz, 150 W (max) 50 W (typical)

CAMPBELL SCIENTIFIC
WHEN MEASUREMENTS MATTER

AP200

CO_2/H_2O Atmospheric Profile System



Preprogrammed and low power
Complete, Integrated System

Measurements

Primary:
- *CO_2 concentration at each intake*
- *H_2O concentration at each intake*
- *System diagnostic word*

Secondary:
- *Sample flow rate*
- *Sample cell pressure*
- *Sample cell temperature*
- *Other control variables*

Overview

The AP200 is a complete, integrated CO_2 and H_2O atmospheric profile system. It measures carbon dioxide (CO_2) and water vapor (H_2O) concentration from up to eight intakes, which are normally spaced along the height of a tower to give a vertical profile.

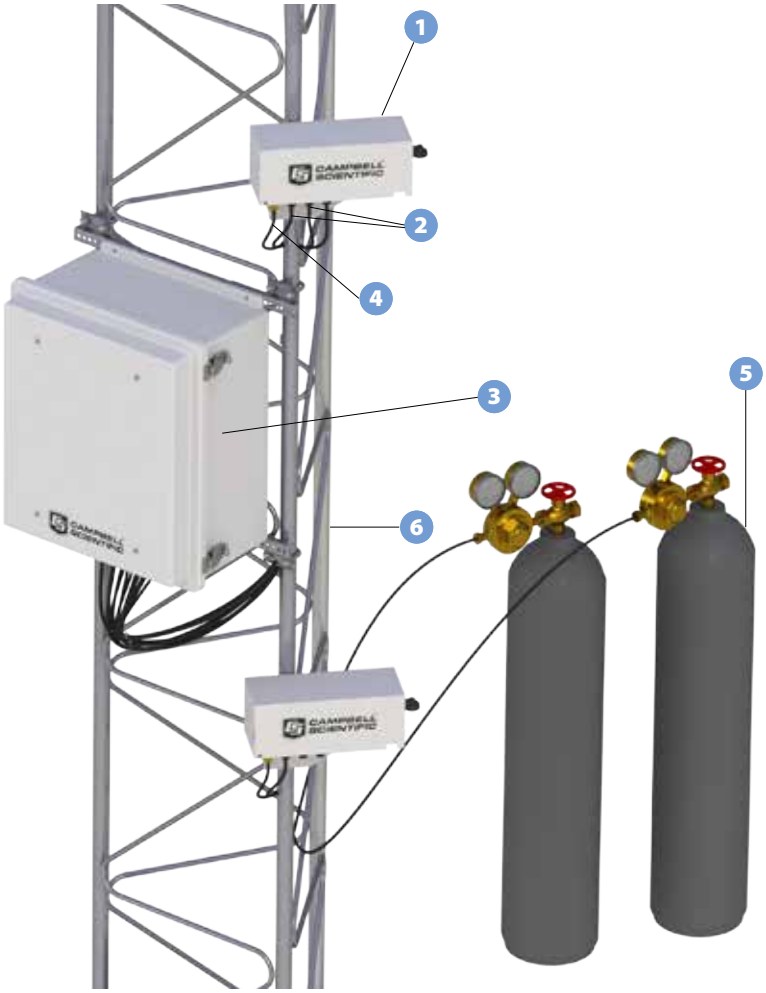
The AP200 is often used in conjunction with an eddy-covariance system to measure the storage term and give a more complete measure of the surface gas exchange.

Benefits and Features

- Provides a fully integrated system
- Requires only 13 W (average at 25°C and 12 Vdc)
- Contains a Campbell Scientific CR1000 Measurement and Control Datalogger
- Automatically performs CO_2 span and zero
- Automated temperature and pressure control
- Datalogger program included

Key for Typical Installation

1. 27693 Heated Sample Intake Assemblies (from 4 up to 8)
2. 9922 20 AWG Power Cable
3. 28547 AP200 System Enclosure
4. 15702 Tubing
5. Zero/Span Tanks and Regulators (not included)
6. Instrument Tower (sold separately)



Specifications

- View EU Declaration of Conformity documentation at: www.campbellsci.com/ap200

System Enclosure

- Operating Temperature: -30° to 45°C
- Dimensions: 52.1 x 44.5 x 29.7 cm (20.5 x 17.5 x 11.7 in.)

Weight

- AP200 base model: 15.9 kg (35 lb)
- LI-840A: 1 kg (2.3 lb)
- CR1000KD: 272 g (10 oz)
- CFM100/NL116: 154 g (5.4 oz)

Power Requirements

- Voltage: 10 to 16 Vdc
- Average Power (at 25°C)[1]: 13 W
- Maximum Power (cold startup): 3.75 A (45 W)

Pump

- Pump type: Dual-head diaphragm pump with a brushless DC motor
- Mounting: Mounted in an insulated, temperature-controlled box inside system enclosure
- Control: Pumping speed is automatically controlled to maintain the pump inlet pressure at the set point
- Maximum Pumping Speed: 9.0 liters per minute (LPM)
- Pressure Sensor Range: 15 to 115 kPa
- Heater: 8.0 W, turns on/off at 2°C
- Warm-up time: ~50 min. from –30° to 2°C
- Fan: 0.7 W (turns on at 50°C and off at 45°C)

Valve Manifold

- Mounting: Mounted inside system enclosure
- Inlets: Eight air sample inlets plus one inlet for zero, one inlet for CO_2 span, and one inlet for H_2O span
- Connections: 0.25-in Swagelok®
- Mass Flow Sensor: 0 to 1.0 standard liters per minute (SLPM)
- Heater: 8.0 W, turns on/off at 5°C
- Warm-up time: ~20 min. from –30° to 4°C
- Fan: 0.7 W (turns on at 45°C and off at 43°C)

Intake Assembly

- Dimensions: 31 x 12.5 x 19 cm (12 x 5 x 7.5 in.)
- Weight: 1.4 kg (3.1 lb)
- Filter: 1.0 in diameter, sintered stainless steel disk filter, 10 micron pore size
- Orifice Inside Diameter: 0.178 mm (0.007 in)
- Orifice Heater: 2 kohms (0.07 W at 12 Vdc)
- Mixing Volume: 750 ml
- Sample Connection: 0.25 in. Swagelok

Heater Cable Entry Seals

- Number of Connections: 3 (1 in, up to 2 out)
- Cable Diameter: 2.8 to 6.6 mm (0.11 to 0.26 in)

Heater Cable Screw Terminals

- Wire Diameter: 26 to 12 AWG
- Wire Stripping Length: 5.0 mm (0.2 in)
- Screw Tightening Torque: 0.4 N•m

[1] *Average power varies from 12.5 W above 35°C to 22.5 W at –30°C.*