User Manual

eosFD

eosFD Forced Diffusion Chamber and Software

eosense
environmental gas monitoring

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2011/65/EU (RoHS2)
2015/863/EU (RoHS3)
2004/108/EC (Electromagnetic compatibility)

For more information, contact support@eosense.com

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Contents

1 Summary

This manual outlines the operation and features of the eosFD-CO_2 carbon dioxide (CO_2) Forced Diffusion (FD) chamber, as well as the included eosLink-FD software package. Before supplying power to the eosFD, please ensure that you read the section on Power Connectors (4.3) to avoid any damage to the sensor. We strongly recommended that all users read the complete manual before use.

This manual is intended for users of the eosFD with version 2.4.4 of the eosLink-FD interface. Please check the Resources section of the Eosense website for the most up-to-date manuals and software.

If you have any specific questions or require additional guidance or information, please contact Eosense Technical Support through our website, by phone or by email:

support@eosense.com
888.352.8313
https://eosense.com/contact-support/

- ➔ Want to jump right into collecting flux measurements? Section 3 (**Quick Start Guide**) tells you all you need to know to start out. For best results, we do recommend you read the entire manual!
- ➔ Want to learn more about customizing your eosFD measurements? Section 6 (**Using eosLink-FD**) explains how to change the measurement frequency and collect data, as well as other important instrument settings
- ➔ Running into problems? Section 8 (**Troubleshooting**) covers some of the most common issues and how to address them. And you can always contact us directly at support@eosense.com.
- ➔ Please visit the Resources section of our website at https://eosense.com/resources/ for additional information and eosFD Application Notes, including:
  - AN0008: Sizing a Solar Power Supply for a Remote eosFD Installation
  - AN0012: eosFD Effects on Soil Moisture and Temperature
  - AN0014: Interfacing the eosFD to a Campbell Scientific CR1000/CR6 Data Logger

This is a warning

! It tells you important details about how to keep you and your equipment safe!

This is an infobox

? It provides extra information about your eosFD!

2 Introduction

2.1 What is Forced Diffusion?

The eosFD is a stand-alone soil CO_2 flux sensor, containing a single NDIR sensor, an internal data logger and small diaphragm pump. The eosFD uses Eosense's patented Forced Diffusion technology to measure soil CO_2 flux directly. Traditionally, gas fluxes from the soil surface are measured using closed chamber systems, with these "accumulation chambers" trapping gas during the measurement period. CO_2 concentrations continue to increase while the chamber is down, and different mathematical fits (typically linear or exponential) are applied to the data to indirectly estimate the original rate of flux.

Forced Diffusion is a membrane-based steady-state approach for measuring gas flux that establishes an equilibrium between gas flowing into the chamber and gas flowing out of the chamber through the membrane, without any external chamber movement. By carefully characterizing the diffusive properties of the membrane used in the instruments, the eosFD chamber gas concentration can be correlated directly to the gas flux rate. Essentially, the amount that this membrane limits the flow of gas out of the chamber is known, and thus by comparing the internal concentration to that outside of the instrument, the flux rate can be calculated. Unlike other automated chambers that lift and lower onto the soil surface, the Forced Diffusion approach does not require external moving parts, allowing it to be deployed in the harshest climates for extended periods without intervention.

2.2 How is Flux Calculated?

Forced diffusion flux is calculated by calibrating the diffusive transport of gas across the eosFD's membrane. This flux rate depends on the effective diffusivity of the interface, the concentrations on either side and the path length between the two points. The relationships between these parameters are linear, and everything but the soil and atmospheric concentrations are assumed to be constant, which simplifies to a single calibration slope (***G***). The flux is then calculated by multiplying the difference in soil and atmosphere concentrations by the calibration slope:

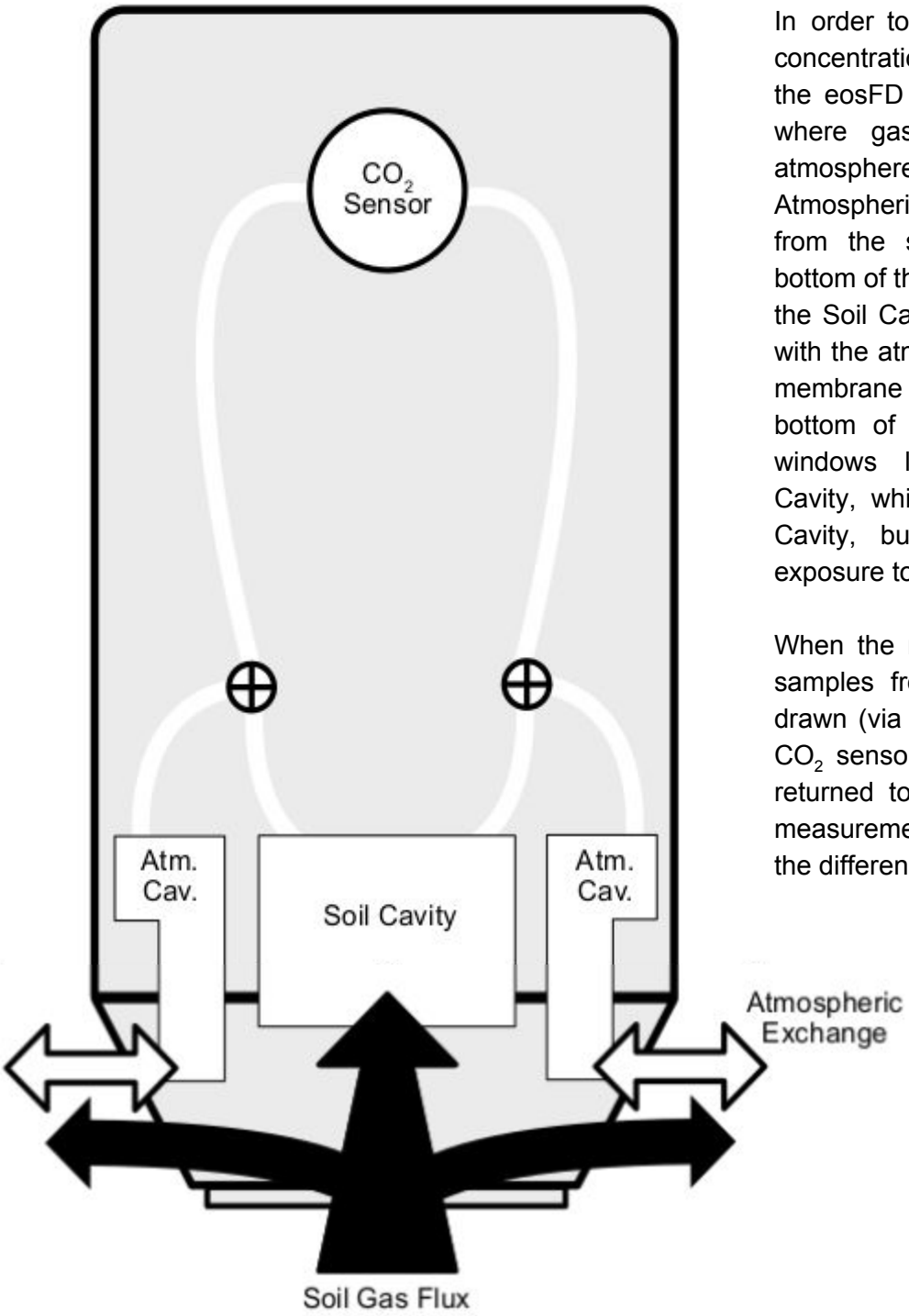
$$\frac{V}{A}\frac{\partial C}{\partial t} = F_s - D\left(\frac{\Delta C}{L}\right)$$

The full differential equation showing the (volume/surface area) scaled rate of change in flux rate equal to the flux from the soil surface (F_s) minus the difference in concentration, ΔC (scaled by both the path length ***L*** and the diffusivity of the interface, ***D***).

$$\frac{V}{A}\frac{\partial C}{\partial t} = 0$$

The change in the flux rate is assumed to be zero (steady-state) over the timespan of the concentration measurements (~60 s). The steady-state assumption reduces the equation to a linear dependence. As the path length and interface (membrane) diffusivity are constant, this can be represented by a single coefficient, ***G***.

$$F_s = G\Delta C$$



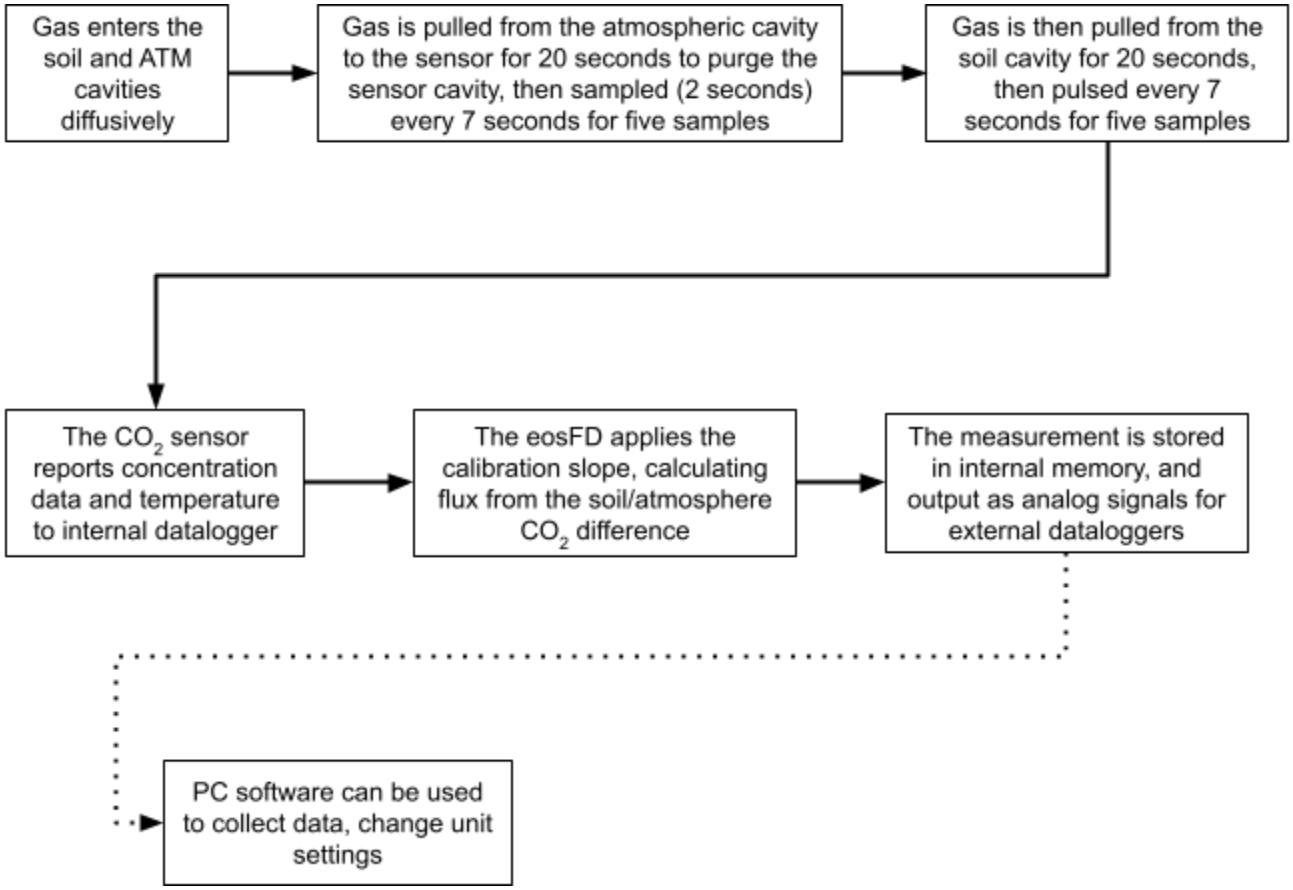
In order to measure the difference in concentration used to calculate flux, the eosFD has two internal chambers where gas is exchanged with the atmosphere - the Soil Cavity and the Atmospheric Cavity. Gases emitted from the soil surface flow into the bottom of the eosFD and accumulate in the Soil Cavity. This gas is exchanged with the atmosphere through two of the membrane covered windows near the bottom of the eosFD. The other two windows lead to the Atmospheric Cavity, which encircles the inner Soil Cavity, but is isolated from direct exposure to soil gas.

When the measurement cycle occurs, samples from these two cavities are drawn (via internal pump) to the NDIR CO_2 sensor for analysis, before being returned to the original cavity. These measurements are used to calculate the difference in concentration, ΔC.

For more information: Risk, D., Nickerson, N., Creelman, C., McArthur, G., Owens, J., 2011. Forced diffusion soil flux: a new technique for continuous monitoring of soil gas efflux. Agric. For. Meteorol. 151, 1622–1631.

2.3 The Measurement Cycle

The eosFD samples gases from both the atmospheric and soil cavities within the device. The flow diagram below breaks down the steps that the eosFD goes through to calculate flux.



When gas is being transported to and from the sensor cavity, the eosFD's pump will be active, creating a distinct buzzing sound. This sound is also emitted when the unit is turned on (three short pulses) or when the eosFD accepts a command or data from the eosLink-FD software (one longer pulse).

Please note that how frequently the eosFD pump is active will depend on your measurement frequency. For the default 10 minute setting, you will hear the eosFD alternate between long (~20 second) pump activation and shorter (~2 second) pulses. This pattern will repeat twice per eosFD flux measurement, with the length of silence between measurements depending on the measurement frequency setting.

3 Quick Start Guide

The following steps will guide you through the basic setup and use of an eosFD chamber, with detailed information available in later sections of the manual.

1.
   - First connect the uncapped socket of the eosFD to the single, 12-pin end of the SSC Power and Data cable.
   - Connect the DC+ Power Cable to the 2-pin end of the SSC Power and Data Cable then to a 12+ VDC power supply, with the **red** lead going to positive and the **black** going to negative / ground (see Section 4.3: Power Connectors). The eosFD should pulse the pump three times.
   - Connect the 3-pin end of the SSC Power and Data Cable to the USB-RS232 Cable.

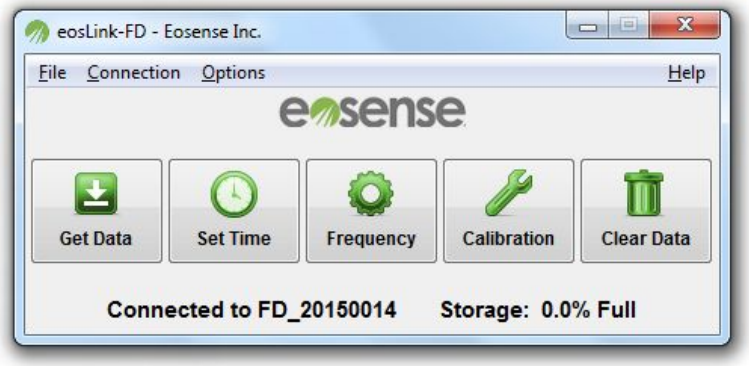
SSC Power and Data Cable

DC+ Power Cable

USB-RS232 cable

2. Connect to the device using a Windows based PC, the eosLink-FD software, and the included data cable.

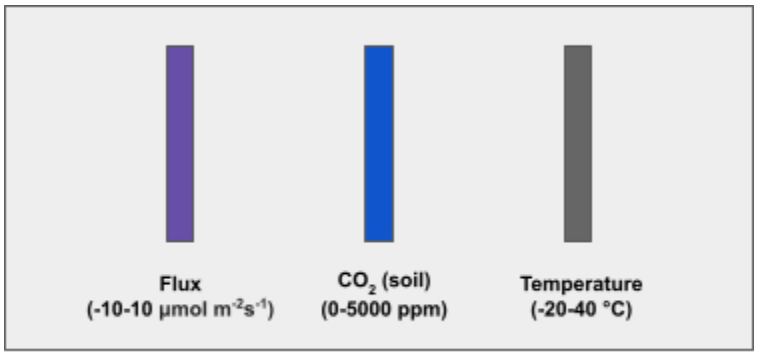
3. Check that the device's system time is set appropriately, and choose a measurement frequency (see Section 6: Using eosLink-FD). Exit the program and then disconnect the USB-R232 cable. Sampling will begin automatically once disconnected from the eosLink-FD software if the eosFD remains connected to power (when the first measurement begins will depend on the frequency settings).



? The eosFD must be connected to power in order to connect to the eosLink-FD software and collect data

4. Attach the provided Mounting Ring to the top of the eosFD. Clear any vegetation from the soil surface and gently insert the chamber into the soil surface (depth of approximately 1.5 cm) or a previously installed collar, making sure that the bottom of the eosFD is flush with the soil surface (see Section 5: Deployment). Use pegs and line to secure the eosFD to the soil surface via the Mounting Ring.

5. If using an external data logger to record FD measurements, connect the purple wire for flux, the blue wire for soil CO_2 concentrations, and/or the grey wire for temperature. Each wire should be connected with one of the black grounding wires as a 0-5 VDC differential voltage measurement (see Section 4.5: Analog Data).



6. After the desired monitoring time period has elapsed, connect to the device again as described in Steps 2 and 3 above. Use the **Get Data** button to transfer the data file to your computer.

A	B	C	D	E	F	G	H	I	J
Month	Day	Year	Time	Flux	Temperature (C)	CO2 Soil (ppm)	CO2 Soil STD (ppm)	CO2 ATM (ppm)	CO2 ATM STD (ppm)
4	29	15	09:41:51	0.12	25.9	782.68	1.613	734.76	3.944
4	29	15	09:46:00	0.12	26.3	756.66	1.667	728.43	3.679
4	29	15	09:51:00	0.07	26.7	757.98	2.869	743.62	1.817
4	29	15	09:56:00	0.96	27.1	1226.11	44.154	989.28	34.495
4	29	15	10:01:00	2.54	27.4	1784.14	36.337	1130.7	8.144
4	29	15	10:06:00	2.96	27.7	1917.2	26.85	1179.06	29.763

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4 Hardware

4.1 eosFD Housing

The eosFD housing is machined from acetal plastic, allowing for a durable, water-resistant and lightweight design. The instrument contains a single CO_2 sensor, an internal data logger and a small diaphragm pump. The housing incorporates a diffusive membrane, electrical interface ports and detachable leg mounting points for a stable field deployment.

The eosFD membrane is critical to proper operation of the device. The membrane should always appear uniform in colour and free from visible defects. It is important to periodically check the membrane, as use in field conditions may cause it to tear or otherwise become defective, and the membrane will degrade naturally over time. Membranes should be replaced annually for best results, though the membrane life-cycle may be shortened by exposure to harsh conditions. If dirty, membranes can be cleaned using a gentle tool, such as a soft toothbrush, and a squirt bottle of deionized water. Use the toothbrush lightly to dislodge any stubborn mud / sediment and then the squirt bottle to wash it off. Avoid using any solvents such as alcohol, as this can damage the probe's water resistance

New eosFDs have **one** 12-pin socket. If using an eosFD with two sockets (one capped and the other uncapped), be mindful to use the **uncapped socket** when connecting the eosFD to power and/or the computer. The capped socket is for troubleshooting purposes only and should not be used.

? Align the notch on the connector with the tab on the 12-pin socket then push gently while hand tightening.

4.2 Main Power and Data Cable

The eosFD ships with a standard 5 m power and data cable (SSC), shown in Figure 1, which plugs directly into the uncapped 12-pin socket on the eosFD housing. Power is supplied to the eosFD via the two pin connector on the opposite end of the SSC. This connector also has a tab and notch type system to ensure that the user connects power with the correct polarity. The eosFD may be powered by supplying regulated 12 VDC to the sensor via data logger, battery or other power supply device (see section 4.3: Power Connectors). A longer 10 m cable (SLC) is also available.

Sensor data is stored on the internal data logger, which can be accessed using the 3-pin data connector on the SSC, combined with the USB-R232 cable. The eosLink-FD software is used to collect stored data, as well as change any of the instruments settings (see Section 6: Using eosLink-FD).

Figure 1 SCC Power and Data cable

4.3 Power Connectors

The DC+ external power cable (Figure 2) included with the eosFD is used to power the chamber from a DC power supply.

The DC+ cable includes a 2-pin connector for attachment to the SSC/SLC cables. The opposite end of the cable has bare leads, to allow for connection to a DC power supply. The **black** wire should be attached to the ground terminal of the DC power device, and the **red** wire should be attached to the positive terminal. The eosFD operates on 12 V DC power. Exceeding 12 V may damage the eosFD, please ensure that the voltage is regulated correctly before connecting the power supply to the unit. The power consumption will vary slightly depending upon the supplied voltage. The average draw for a 10 minute cycle is ~100 mA (1.2 W) with a peak of ~300 mA (3.6 W).

Figure 2 DC+ Power Cable

4.4 Data Cables

Communication between eosLink-FD and an eosFD uses the RS-232 Serial protocol. The following components may be used to facilitate this interface:

- SSC Power and Data Cable - (Included) Used to power an eosFD as well as provide an RS-232 interface.
- USB-RS232 Cable- (Included) Connects the SSC data port to a USB port. Used to create a virtual COM Port, allowing the eosFD to be connected to a computer through a USB port.
- Serial Breakout and Grounding Cable - (Included) Used to connect the eosFD to a data logger using a serial interface. Also used as the grounding cable for analog connections (see section 4.5 for more information).

Figure 3 SSC Power and Data Cable (left), USB-RS232 Cable (middle), and Serial Breakout and Grounding Cable (right)

4.5 Analog Data

In addition to the internal memory of the eosFD, users also have the option of recording analog data on an external data logger, using the three wires on the SCC Power and Data Cable (AN0014 provides more detailed information on interfacing an eosFD to a Campbell Scientific data logger, including how to record data using the serial interface).

Each wire should be connected along with one of the three black grounding wires as a 0-5 V DC differential voltage measurement, with ranges, multipliers and offsets as shown in the table below:

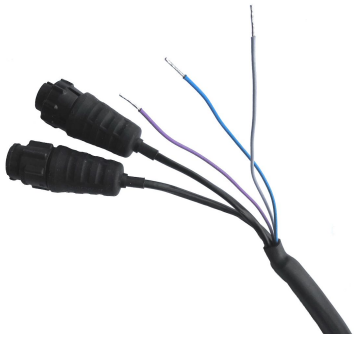


Figure 4 Purple, blue, and grey wires on the SSC Power and Data Cable.

? eosFDs now come with a combined serial breakout and grounding cable (see Fig. 3). Previously, the connector only had three black ground wires.

Output	Colour	Units	Range	Multiplier	Offset
CO_2 Flux	**Purple**	µmol/m^2/s	-10 - 10	0.004	-10
Soil CO_2 Signal*	**Blue**	ppm	0 - 5000	1.0	0
Sensor Temperature	**Grey**	°C	-20 - 40	0.012	-20

*New eosFDs no longer output Soil CO_2 via analog. CO_2 values recorded by the eosFD are used only to calculate the flux, and are not intended to be stand-alone measurements of CO_2.

In order to interpret the analog signals, simply apply the appropriate linear transformation to the voltage data, as determined by the range. For example, to transform a temperature voltage signal, first divide the voltage by the 0-5 V range, then multiply by the -20-40 °C temperature range. Finally, add the minimum of the temperature range. The example below shows each step for a reading of 3 V.

(1) 3 V / (5 V - 0 V) = 0.6
(2) 0.6 * (40 °C - -20 °C) = 36 °C
(3) 36 °C + -20 °C = 16 °C

Thus a 3 V analog signal for temperature corresponds to 16 °C.

5 Deployment

5.1 Setup

	Situate the collar in a flat location, clear of any rocks or debris. Remove any larger vegetation from the general area. When possible, deploy the collar at least 24 hours prior to the start of eosFD measurement collection (or allow for some disturbance -related fluxes in the early portion of your data).
	Gently tap the collar into the ground, ensuring that the force is distributed evenly across the top of the collar. This can be accomplished by placing a board or other flat object on top of the collar, and using a broad-head hammer. Ensure that the top of the collar remains parallel to the ground by tapping directly above the collar and not to one side or the other.
	Where possible, insert the collar to near full depth, as excessive distance between the soil surface and the bottom of the eosFD can increase how long it takes the instrument to respond to changing flux rates. Ideally, a centimeter of space should be left, to aid in installation of the eosFD itself as well as collar retrieval.
	Inspection of the edges of the collar should show no significant gaps between the soil and collar, though some near-surface spacing is unavoidable. Upon subsequent visits to the field site, review these edges, as the soil should naturally fill in any gaps created during installation.
	Try to minimize disturbance to the soil during collar installation, as this can increase the equilibration time between the eosFD and the soil, and potentially cause measurement errors if there is a particularly bad seal between the soil and collar at depth.
	To deploy the eosFD in the installed collar, simply insert one side of the bottom ring into the collar until flush, then gently push on the opposite side until the eosFD is securely seated. Inspect all sides to ensure no gaps exist.

While the eosFD is water resistant, avoid situating the probe in areas of standing water or hollows where flooding is a possibility. For best results choose a flat, clear soil surface that is free of large rocks to insert the chamber. Where stability is a concern, use pegs and line to secure the eosFD to the soil surface via the attached Mounting Ring, ensuring that the guy-lines remain taut when the pegs are driven into the soil.

Connect the eosFD to the 12-pin end of the SSC Power and Data cable. Connect the DC+ Power Cable to the 2-pin end of the SSC Power and Data Cable then to a 12 VDC power supply. Once powered, the eosFD will pulse the pump 2-3 times, which indicates that it is properly connected.

Figure 5 An eosFD deployed in the field, with uncapped aux port

? Before deployment, ensure that the frequency and time are set appropriately.

? Prior to powering on the eosFD, verify all cables and wires are installed correctly to reduce the risk of fire or shock

5.2 Maintenance

The eosFD should be checked-over monthly for best results. Check the power supply and connection, ensuring that the eosFD pump sounds when power is cycled. In the event of fouling, the eosFD membrane can be cleaned by first gently removing any particles using a dry, non-abrasive cloth. Then, use a damp (no solvents) cloth to gently remove any remaining dirt or substance.

If the membrane appears to be significantly clogged or punctured in any way, contact Eosense immediately to determine if the membrane needs to be replaced. A damaged or fouled membrane can lead to inaccurate flux measurements by the device. Make sure to remove any vegetation growing in the collar or directly around the eosFD that may block the side membrane. Finally, ensure the collar is still flush with the surface, re-adjusting if necessary.

Figure 6
Top: Mildly fouled membrane.
Bottom: Clean eosFD membrane.

6 Using eosLink-FD

6.1 Overview

eosLink-FD is an application that allows the user to communicate with the eosFD chamber in order to change various instrument settings, as well as collect and clear logged data. eosLink-FD is compatible with Windows PCs.

6.2 Installing and Connecting

Simply copy the eosLink-FD.zip file (available on the Resources section of our website, or by contacting us at: support@eosense.com) to a suitable directory on the PC in use, then unzip the file, which contains the eosLink-FD software folder. None of the files in this folder should be removed or changed in any way. If this occurs, simply delete the entire folder from your PC and re-extract from the zip file to re-create the folder.

We recommended that you connect the data cable to your computer prior to launching eosLink-FD; however you may also refresh the program from the Connection menu. You may have to refer to the Windows Device Manager if several serial port devices are connected to the computer, and choose the correct port through (Options⇒Change COM Port).

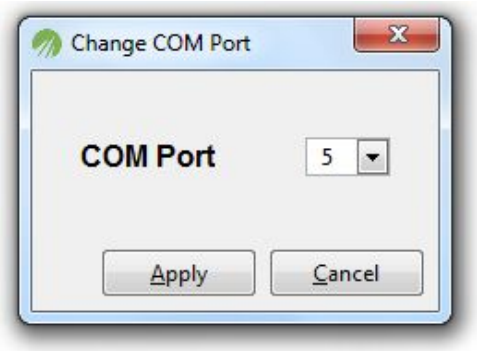


Figure 7 eosLink-FD Change COM Port window

Once the port is selected, the eosFD will automatically attempt to connect. When the connection is successfully established, the grayed out buttons and text will become active, and the eosFD serial number and storage capacity will be shown at the bottom of the window.

6.3 Using the eosLink-FD Interface

The eosLink-FD window consists of four menus, five buttons and a status section at the bottom, as detailed in the following subsections. Once the eosFD has been connected, the user can begin modifying instrument settings. Left idle, the eosFD will automatically disconnect after ten minutes of inactivity (timeout restarted every time a command is sent).

> ? If your eosFD is an older model or has older firmware, the eosLink-FD software may display “Compatibility Mode” in the title bar. This indicates that some of the newer features of the software may be unavailable - contact support@eosense.com for more information

6.3.1 Menus

There are four menus visible at the top of the eosLink-FD window:

Menu 1 - File: This menu provides the ability to collect both the measurement data file and the error log file (both commands also have their own dedicated button) as well as a means of exiting the program.

Menu 2 - Connection: The Connection menu has three options, including the ability to refresh the list of available COM ports and choose a specific port number. If the program was launched prior to the eosFD being connected, you will need to refresh the connection to allow the correct port to be chosen.

Menu 3 - Options: This contains a number of secondary functions which are described below.

- The **Pump Options** window allows the user to change the pump settings used to draw and analyze soil and atmospheric cavity CO_2 gas concentrations. Altering these values may affect the accuracy of measured flux rates. **Purge Time** refers to the length of the purge cycle between atmospheric and cavity samples. **Number of Samples** sets the number of concentration measurements from which the median concentration is taken. **Draw Time** controls how long to allow for pump-transport of gas from a soil or atmospheric cavity to the sensor for analysis.

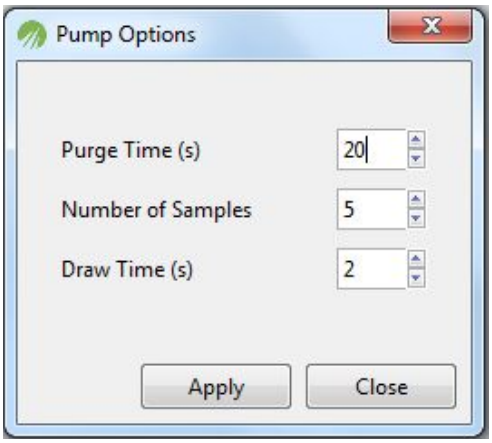


Figure 8 The Pump Options window

- The **Device Settings** window allows the user to change the eosFD's operating mode, serial number and stored calibration. Please contact Eosense for access to these options if required. **Changing these options may prevent the eosFD from collecting flux measurements. Logging Mode** is the normal operating mode for the eosFD, while **Calibration Mode** allows for recalibration of the internal CO_2 sensor. **Reset Aux Flags** reverts any changes to the internal diagnostic values, and **Factory Restore** reverts any changes made to the eosFD settings, including calibration parameters and measurement frequency settings.

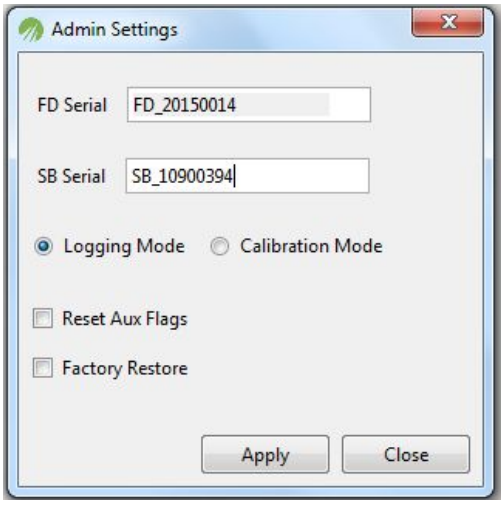


Figure 9 The Device Settings window

- The **Record Concentrations** window has three suboptions; **Soil Cavity, Atmospheric Cavity,** and **Alternating**. These suboptions are convenient for troubleshooting purposes as it allows the user to directly measure soil, atmosphere or alternating concentrations at a relatively high frequency. While recording, a pop-up window displays the sampling measurements which allows the user to monitor the concentrations live. When sampling is complete, the data will automatically save to the eosLink-FD software folder.

  Alternating data will correlate atmosphere and soil concentrations by an identification number (0 or 1) located in the fourth data column (Figure 10). The **Atmospheric Cavity** is identified by 0 and **Soil** Cavity as 1. The four columns of exported data include:

Time Elapsed	The time at which the measurement occurred (seconds)
Concentration	The soil/atmosphere concentration of CO_2 in ppm.
Temperature	The approximate internal temperature of the eosFD in °C.
ATM/Soil Identity	Atmosphere Identity (0) Soil Identity (1)

A	B	C	D
15	1173.71008	30.873505	0
21	1194.35376	30.888397	0
28	1196.63208	30.873505	0
35	1199.70361	30.888397	0
41	1200.04858	30.888397	0
48	1199.15332	30.888397	0
55	1196.22473	30.903137	0
61	1198.40845	30.903137	0
68	1212.74585	30.888397	0
75	1191.09045	30.918058	0
92	1565.34155	30.888397	1
99	1620.63977	30.918058	1
106	1640.05261	30.903137	1

Figure 10 Example of eosFD Alternating Cavity Data, viewed as a spreadsheet

- The **eosFD Settings File** menu allows a calibration batch file (concentration and flux) to be uploaded to the eosFD, or exported to a local file. This functionality allows for easy restoration to factory calibration settings. To export a settings file, choose **Export Settings**. The eosFD serial numbers and calibration parameters will be requested from the instrument, and then displayed in a new window. Clicking the Export Settings will then allow you to choose a location to save these values for future use.

  To upload a settings file, choose **Upload File** from the menu, and then navigate to a compatible file (.cal extension). The contained calibration settings will be read in and displayed beside the current instrument parameters. Click the **Upload Settings** button to transfer the new coefficients to the connected eosFD (see Figure 11).

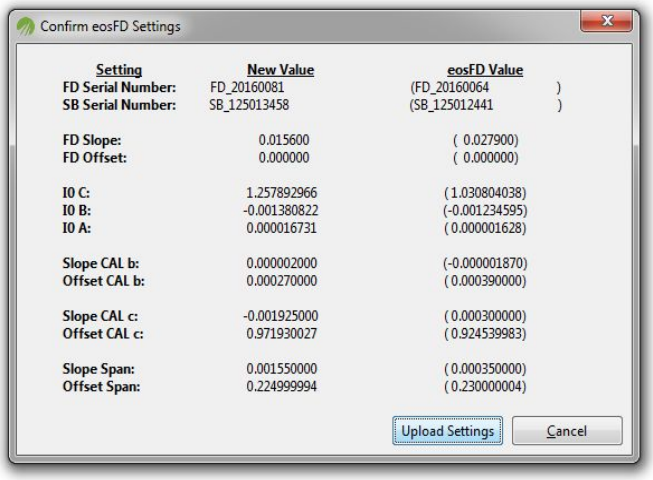


Figure 11 Uploading an eosFD Settings File

- The **eosFD Template Files** menu allows the user to export eosFD measurement settings as a local file, which can be used to quickly customize the instrument for different deployment conditions (e.g. less frequent measurements for off-grid sites) or to standardize settings amongst multiple eosFDs.

  To create a template, choose **Export Template** from the **eosFD Template Files** menu, then choose a save location and filename. The current measurement frequency and start time will be shown, along with the option to embed a command to synchronize the clock of the eosFD with the local PC when the template is applied.

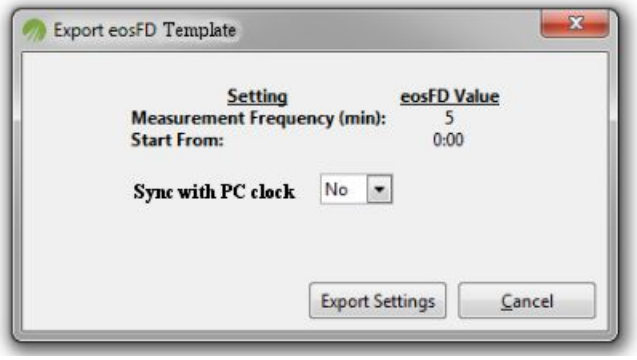


Figure 12 Exporting an eosFD Template File

To apply a template file to an eosFD, choose **Upload Template** from the **eosFD Template Files** menu, then navigate to a compatible file (.efd extension). Once the file has been read, the applicable eosFD measurement settings will be displayed for confirmation. Clicking **Upload Template** will apply the frequency and start time settings, and sync the instrument clock with the local PC (if applicable). See Figure 13 below.

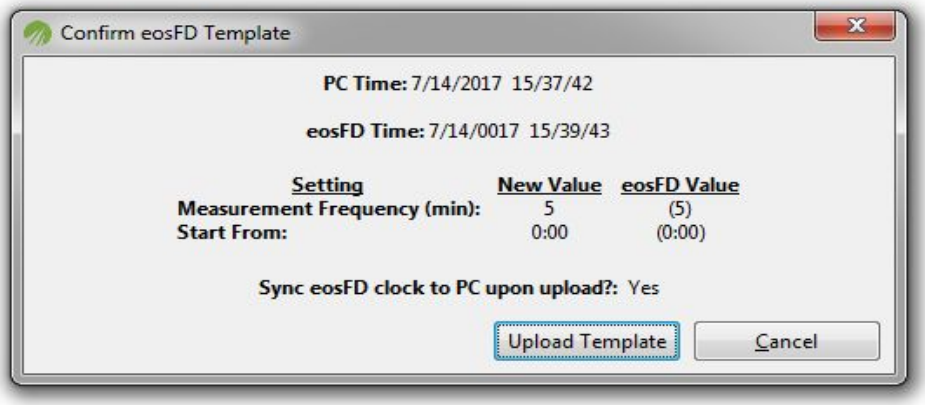


Figure 13 Uploading an eosFD Template File

- The **Performance Check** option allows the user to assess the atmospheric concentration and zero flux stability of the eosFD. Choosing this option displays a short explanation of the required procedure, with the **Start Check** button used to launch the data collection.

  Before proceeding, ensure that the eosFD side windows and bottom opening are exposed to atmospheric air. For best results, avoid standing directly beside the unit during the Performance Check.

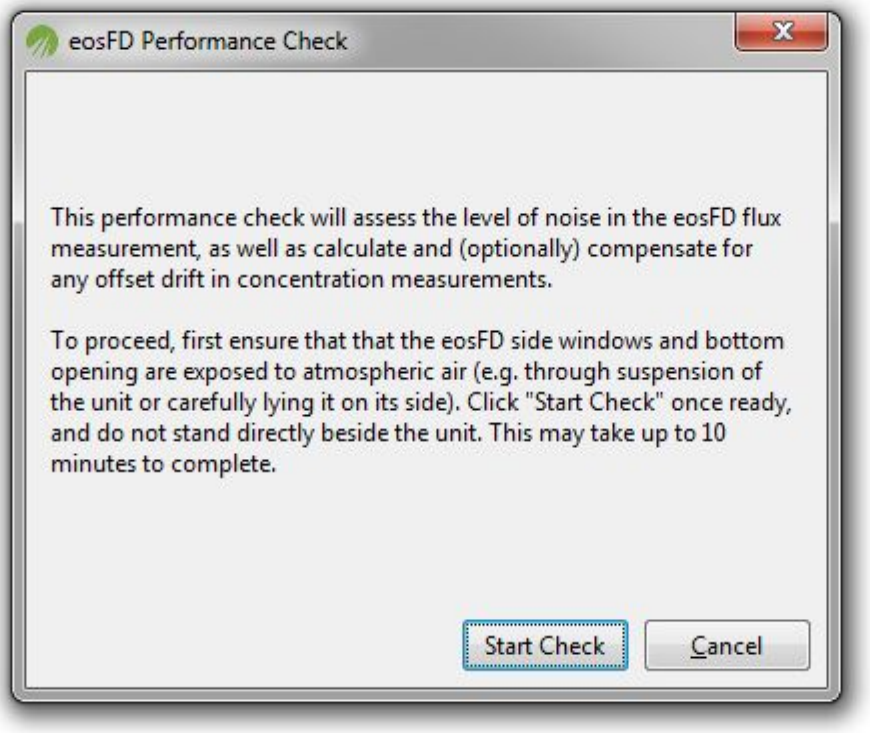


Figure 14 Starting an eosFD Performance Check test

Once the Performance Check has begun, the eosFD will run through several accelerated measurement cycles. During this time, the internal pump will operate frequently, as will the valves. Two progress bars will show the test's progression.

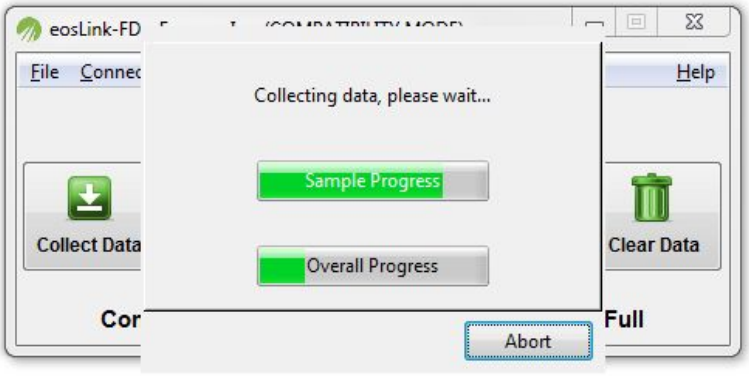


Figure 15 An eosFD Performance Check in progress

Once the data collection is complete, the results will be presented in two tabs.

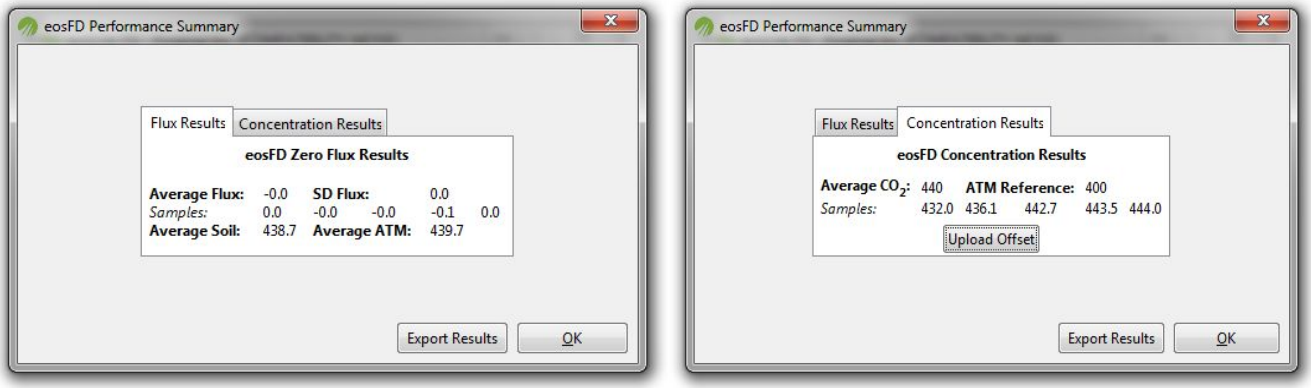


Figure 16 Performance Check results for the zero flux measurements (left) and the atmospheric comparison (right).

The results should show an average flux within 0.2 umol/m^2/s of zero under normal conditions, while the Concentration Results will show an average CO_2 concentration near 400 ppm. Differences between the concentration observed by the eosFD (e.g. concentration drift) can be resolved through the Upload Offset button, though this is not necessary for accurate flux measurements due to the Forced Diffusion method.

- **Admin Mode** allows the user to enter a password to enable additional eosFD modifications. These are not required for normal eosFD operation. **Pump Options, Device Settings** and **Upload Settings File** are restricted to administrator access only. These settings should not require alteration, however, in special cases where this is necessary please contact support@eosense.com for access.

Menu 4 - Help: The final menu option contains a brief information window about the version of eosLink-FD that is being used and the option to record a debug file for troubleshooting purposes.

6.3.1 Buttons

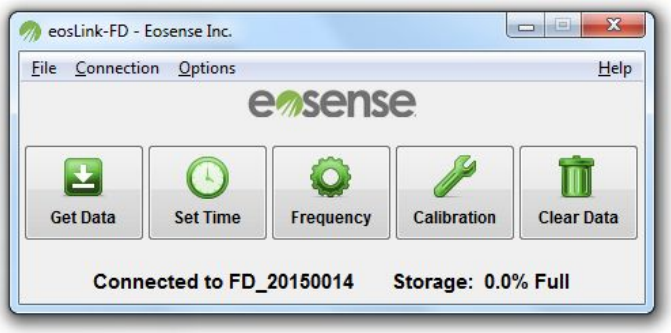


Figure 17 eosLink-FD main window, showing a connected eosFD Chamber.

Button 1 - Get Data: This command (also available from the **File** menu) allows the user to collect all stored data from an eosFD and save it on their local PC. Clicking the button opens a file selection window, allowing the user to choose a path and filename to store the logged data. Once a location is selected, the file transfer will begin. Depending on the size of the data file, this may take several minutes, during which time a progress bar will be displayed over the main window to show estimated time remaining. Collected data will be appended to the end of the selected file if it already exists.

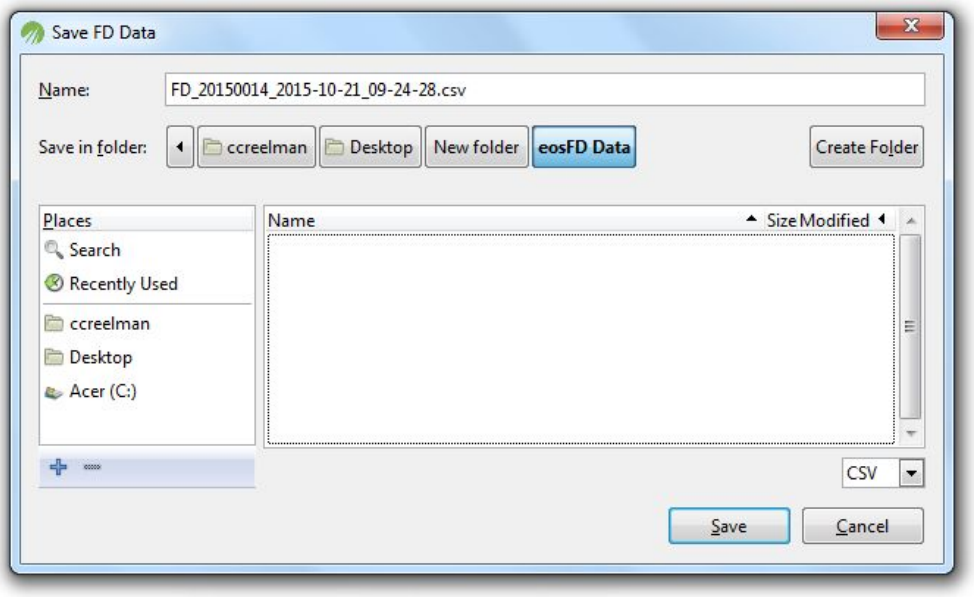


Figure 18 The save eosFD Data window

When the data collection is complete, a summary of the three most recent measurement periods (determined by when the eosLink-FD software is used to connect to the instrument) will be shown (see Figure 19).

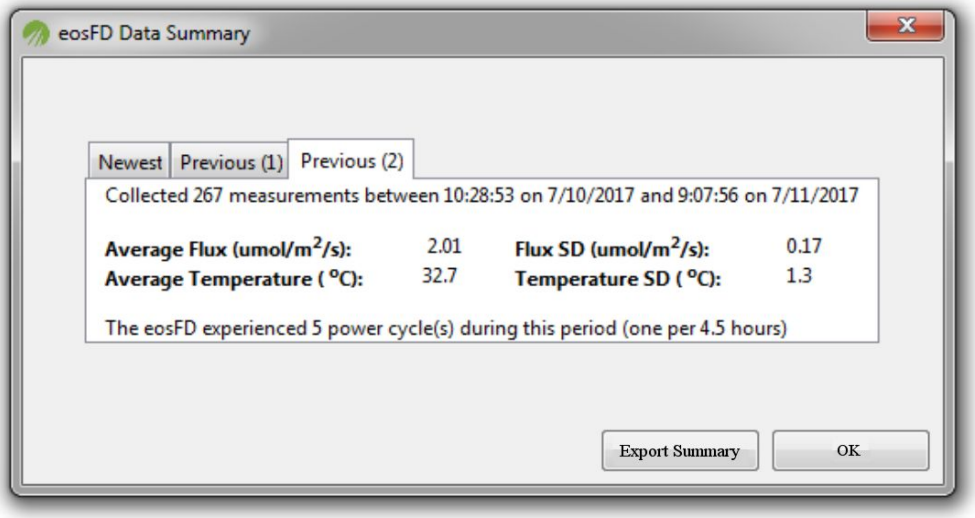


Figure 19 The eosFD Data Summary window, showing average flux and temperature values during the last measurement period, as well as power outages.

This data summary provides average flux and temperature values, along with their standard deviations. It also highlights any potential problems encountered, such as frequent power cycling or unusual flux measurements (e.g. very high or negative CO_2 fluxes). This data can be exported to a text file using the **Export Summary** button.

```
eosFD (SN: FD_20160066                  ) Data Summary file created on 7/06/2017 at 16:41:26


-------------------------------------------------------------------------------------------------------------
Data period: 51 measurements collected between 12:12:55 on 7/06/2017   and   16:22:54 on 7/06/2017
Average Flux (umol/m^2/s):              2.40
Flux Standard Deviation (umol/m^2/s):   0.06
Average Temperature (degC):             33.86
Temperature Standard Deviation (degC):  0.12

During this period (4.2 hours), the eosFD experienced 1 power cycles (one per 4.2 hours)


-------------------------------------------------------------------------------------------------------------
Data period: 23 measurements collected between 10:12:54 on 7/06/2017   and   12:02:54 on 7/06/2017
Average Flux (umol/m^2/s):              2.20
Flux Standard Deviation (umol/m^2/s):   0.26
Average Temperature (degC):             32.19
Temperature Standard Deviation (degC):  1.46

During this period (1.8 hours), the eosFD experienced 1 power cycles (one per 1.8 hours)


-------------------------------------------------------------------------------------------------------------
Data period: 68 measurements collected between 9:07:54 on 6/30/2017   and   15:52:54 on 6/30/2017
Average Flux (umol/m^2/s):              2.30
Flux Standard Deviation (umol/m^2/s):   0.20
Average Temperature (degC):             30.43
Temperature Standard Deviation (degC):  0.55

During this period (6.8 hours), the eosFD experienced 2 power cycles (one per 3.4 hours)
```

Figure 20 An example eosFD data summary text file

Button 2 - Set Time: This option allows the user to change the clock setting on the eosFD's internal data logger. Clicking this button opens a window that allows the user to choose a time and date to update the eosFD's on-board clock. The timestamp used in the logged data file will correspond to the eosFD's internal clock, so ensure that this time is set correctly. The date is chosen using a small calendar, while the time is set by entering the current time in a 24-hour format (e.g. 6:30 PM would be 18:30:00). To sync the eosFD clock with the connected PC, click the **System Time** button in the upper right, then click **Apply**.

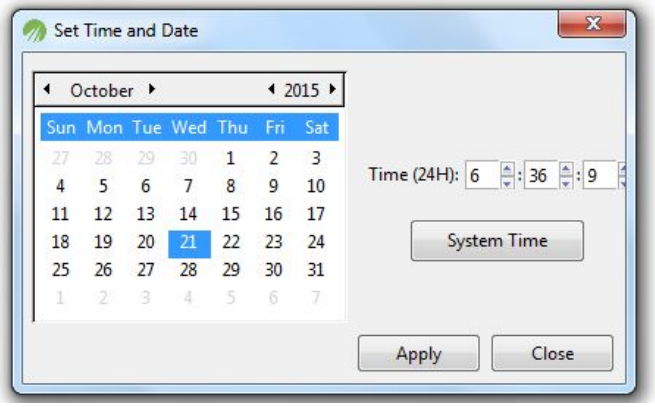


Figure 21 The Set Time and Date window

Button 3 - Frequency: This command allows the user to change the frequency of data logging by changing the amount of time that elapses between the beginning of measurements in minutes (minimum of 5 minutes, maximum of 1440 minutes or 1 day). The user may also choose the starting time, which is used to align the starting point for measurements. For example, if the desired measurement frequency is twice an hour, at :00 and :30, then the user would select a **Data Frequency** of 30 min. and a start time with 0 for min. Please note that the start time **does not** prevent the eosFD from recording data before this time is reached.

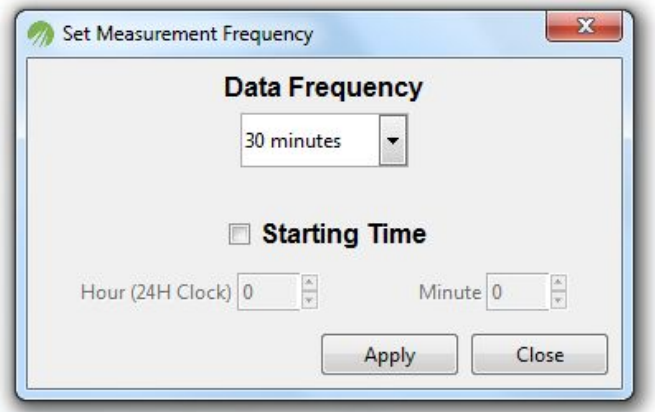


Figure 22 The Set Measurement Frequency window

Example: From the data shown below, the eosFD was powered on at 22:48 with a frequency of 10 minutes and the default Starting Time of 0:00. As you can see, the eosFD aligned measurements so that regardless of when it was powered on, a sample would be taken at the default Starting Time of 0:00:00.

eosFD powered on, began taking samples

Automatically aligning timestamps to Starting Time

Sample taken at Starting Time

Month	Day	Year	Time	Flux	Temperature (C)	CO2 Soil (ppm)	CO2 Soil STD (ppm)	CO2 ATM (ppm)	CO2 ATM STD (ppm)
2	1	17	22:48:27	0	25	529.43	6.747	532.59	5.243
2	1	17	22:50:00	0.31	25	516.07	7.461	523.04	4.228
2	1	17	23:00:00	0.08	25	513.25	6	517.57	6.102
2	1	17	23:10:00	0	25	502.73	5.893	507.93	5.863
2	1	17	23:20:00	0	25.2	497.1	5.636	503.09	6.984
2	1	17	23:30:00	0.62	25.6	497.29	7.78	502.61	2.88
2	1	17	23:40:00	0.31	26.2	499.76	7.308	500.72	3.409
2	1	17	23:50:00	1.3	27	499.24	6.646	507.07	4.751
2	2	17	0:00:00	1.5	27.8	499.2	7.602	505.02	5.64
2	2	17	0:10:00	2.46	28.7	502.31	5.325	503.31	5.19
2	2	17	0:20:00	2.05	29.4	492.26	7.268	500.66	6.691

support@eosense.com

Button 4 - Calibration: This command changes the calibration used to calculate the flux of CO_2. This option is included to facilitate recalibration during membrane replacement and to correct for CO_2 sensor drift. This command **should not be used** without consulting Eosense. Setting the calibration parameters incorrectly will result in flux measurement errors.

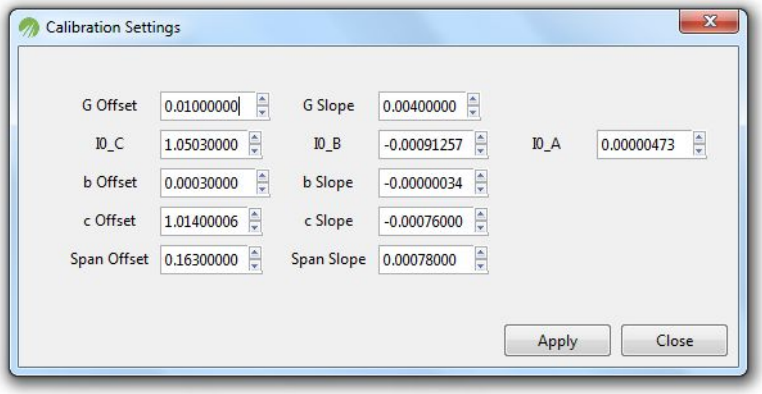


Figure 23 The Calibration Settings window

Button 5 - Clear Data: This command erases all stored data from the eosFD while leaving the time, frequency and calibration settings unchanged. The user must confirm the deletion of stored data by clicking **Delete** in the popup window. As the eosFD has enough memory to store over seven months of data at the highest frequency (every five minutes), this should rarely be required. Clearing the data periodically allows for quicker file transfers on subsequent uses. This process will take 5-10 minutes.

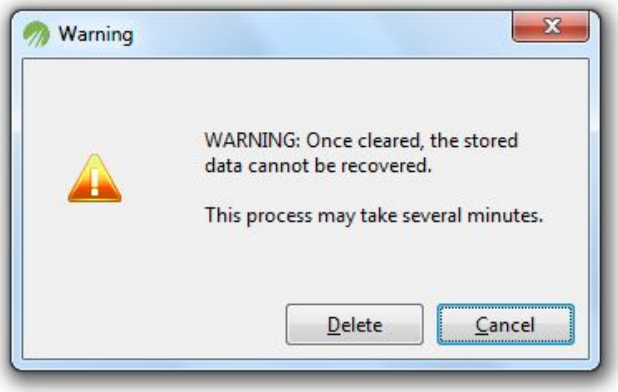


Figure 24 The confirmation window for clearing store data

> ! **Warning!!** There is no way to recover the stored data once it has been cleared.

6.3.1 Status Bar

The status bar found at the bottom of the eosLink-FD program window is used to communicate status updates to the user. While the majority of important notifications will come in the form of popup windows, the status bar is used to update the user regarding connection status, as well as the serial number and storage capacity of the connected eosFD. When working with multiple eosFD's, ensure that the displayed serial number matches the connected unit, to avoid issues with incorrectly named data files.

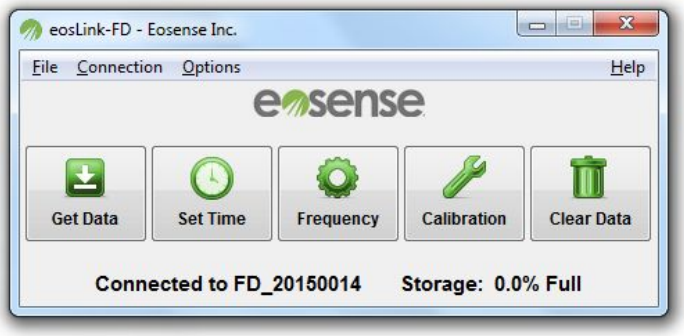


Figure 25 eosLink-FD main window, showing Status Bar

7 Logged Data Files

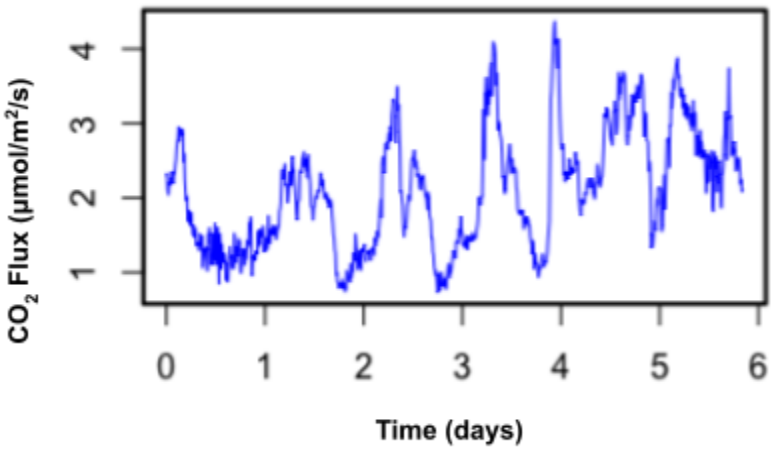
The measurement data file is formatted as a comma separated values file (.csv), allowing for easy importing into spreadsheet or plotting software.

Month	Day	Year	Time	Flux	Temperature (C)	CO2 Soil (ppm)	CO2 Soil STD (ppm)	CO2 ATM (ppm)	CO2 ATM STD (ppm)	Mode
2	1	17	22:48:27	0	25	529.43	6.747	532.59	5.243	0
2	1	17	22:50:00	0.31	25	516.07	7.461	523.04	4.228	0
2	1	17	23:00:00	0.08	25	513.25	6	517.57	6.102	0
2	1	17	23:10:00	0	25	502.73	5.893	507.93	5.863	0
2	1	17	23:20:00	0	25.2	497.1	5.636	503.09	6.984	0

Figure 26 Example eosFD data, viewed as a spreadsheet

Month The month in which the measurement was collected.
Day The day of the month in which the measurement was collected.
Year The year in which the measurement was collected.
Time The time at which the measurement occurred (24 hour clock).
Flux The estimated CO_2 flux rate from the soil surface in µmol m−2s−1.
Temperature The approximate internal temperature of the eosFD in ◦C.
CO2_Soil The soil surface CO_2 signal in ppm, only used for flux calculation.
CO2_Soil_STD The standard deviation of the soil surface concentration of CO2 in ppm.
CO2_ATM The atmospheric CO_2 signal in ppm, only used for flux calculation.
CO2_ATM_STD The standard deviation of the atmospheric concentration of CO2 in ppm.
Mode A status indicator showing when events occur (e.g. power outages):
0: Normal measurement data
1: Unit startup / power cycle
2: eosLink-FD connection detected
10-19: Unit startup with error code (contact Eosense Support)
Soil & ATM VR/VA Four columns of raw voltages for troubleshooting purposes.

Example flux data showing diurnal variation:



? The Mode field is useful for diagnosing power issues, as frequent '1's indicates the unit starting up after a power outage.

8 Troubleshooting

This section provides a few example problems that may occur during use, and the appropriate action that should be taken to resolve the issue. For these issues as well as any others that arise, please contact Eosense through email at support@eosense.com with subject “eosFD Support”, or through the support section of our website (http://www.eosense.com/support/).

- **I cannot connect to the eosFD on my computer using eosLink-FD.**
  First, try refreshing the connection through the Connection menu. Ensure that the COM port set in the software matches the one used by the data cable (the Windows Device Manager may be useful for identifying the eosFD COM port). If the problem persists, try unplugging the data cable from the USB port, waiting several seconds, and then plugging it in again (remember to refresh the connection or close and relaunch eosLink-FD). Connecting through a different USB port on your computer may also help. If the problem is still not resolved, try a different data cable if available (additional data cables can be ordered from Eosense). If the problem still occurs, please contact Eosense for additional guidance.

- **The eosFD housing or wires have been damaged, what should I do?**
  Contact Eosense before attempting any repairs.

- **I am getting odd flux values, how should I correct this?**
  The eosFD membrane may have become damaged, or the CO_2 sensor calibration may have drifted unexpectedly. Contact Eosense to see if recalibration is required.

- **The logged data file shows just the header, no values.**
  Double check that enough time has elapsed that the measurement frequency has been met. If the problem persists, please contact Eosense.

- **The timestamp in the data file is incorrect.**
  Reset the eosFD clock using eosLink-FD and then disconnect the eosFD from power. Reconnect the eosFD and check the system time (from the defaults in the Set Time and Date window). If the problem persists, please contact Eosense.

- **Running the software gives an error: “libgdk-win32-2.0-0.dll is missing from the computer”**
  This error indicates that the executable is missing in the (hidden) system files. This happens when the .exe is moved from its original position in the software folder. To resolve this problem, keep the executable in the same folder as it was downloaded in (or re-extract the .zip file and use that as the new software folder).

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