STANDARD OPERATING PROCEDURES FOR CALIFORNIA AIR RESOURCES BOARD LOGGER (CARBLogger)

AQSB SOP 605

Third Edition

MONITORING AND LABORATORY DIVISION

June 2023

Disclaimer: Mention of any trade name or commercial product in this standard operating procedure does not constitute endorsement or recommendation of this product by the California Air Resources Board. Specific brand names and instrument descriptions listed in the standard operating procedure are for equipment used by the California Air Resources Board's laboratory. Any functionally equivalent instrumentation is acceptable.

CALIFORNIA AIR RESOURCES BOARD

Approval of Standard Operating Procedures (SOP)

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REVISION HISTORY

Edition	Release Date	Changes
First	October 2017	New Document
Second	April 2020	ADA Remediation
Third	June 2023	3-yr review Added language for Raspberry Pi Logger Removed references to T400 IZS and Environics 9100 instruments Updated Appendix B – CARBLogger Maintenance Check Sheet Updated Appendix C – Instrument Communication Configuration

LIST OF ACRONYMS

AQSB	Air Quality Surveillance Branch
ASD	Administrative Services Division
CalEPA	California Environmental Protection Agency
CARB	California Air Resources Board
CentOS	Community Enterprise Operating System; a Linux / Red Hat variant.
CL	CARBLogger
DAS	Data Acquisition System
DMS	Data Management System
FEM	Federal Equivalent Method
FTP	File Transfer Protocol; refer to the FTP Server in this document
GMT	Greenwich Mean Time
GUI	Graphical User Interface
IZS	Internal Zero-Span
LST	Local Standard Time
NTP	Network Time Protocol
ODSS	Operations and Data Support Section
OIS	Office of Information Services
OS	Operating System
PCI	Peripheral Component Interconnect
PCIe	Peripheral Component Interconnect Express
PST	Pacific Standard Time
QA	Quality Assurance
QC	Quality Control
SFTP	Secure File Transfer Protocol; refer to the SFTP Server in this document
SOP	Standard Operating Procedure
SQL	Structured Query Language
UPS	Uninterruptible Power Supply
U.S. EPA	United States Environmental Protection Agency

1.0 GENERAL INFORMATION

1.1 Introduction:

The CALIFORNIA AIR RESOURCES BOARD LOGGER (CARBLogger) is a computer-based, open-source digital data acquisition system developed by Operations and Data Support Section (ODSS) staff, for many uses in the continuous ambient air monitoring program hosted by the Air Quality Surveillance Branch (AQSB) of California Air Resources Board (CARB). Originally, the system was designed to provide minute-based diagnostic data for instrumentation used in the ambient air monitoring sites. As it proved to be consistent and reliable, the system was further developed to serve as a full data acquisition system and allowed AQSB to fully utilize the Data Management System (DMS) for supporting CARB's ambient air monitoring program.

CARBLogger (CL) utilizes a variety of open-source applications to collectively acquire digital data, allow for secure remote access, screen diagnostic data, provide e-mail notifications, and flag data for different operating states from a variety of air monitoring instruments used in the monitoring network.

The purpose of this standard operating procedure (SOP) is to document installation, operation, maintenance, and troubleshooting procedures for the use of CL system. Station operators who may need to modify or customize their data logger for specific sites should contact ODSS staff.

Note: This SOP references CL version 1.2.

1.2 Principle of Operation:

The following process diagram (see Figure 1.1) demonstrates the general relationship between air monitoring instruments and the various shell scripts and stored procedures run from CL.

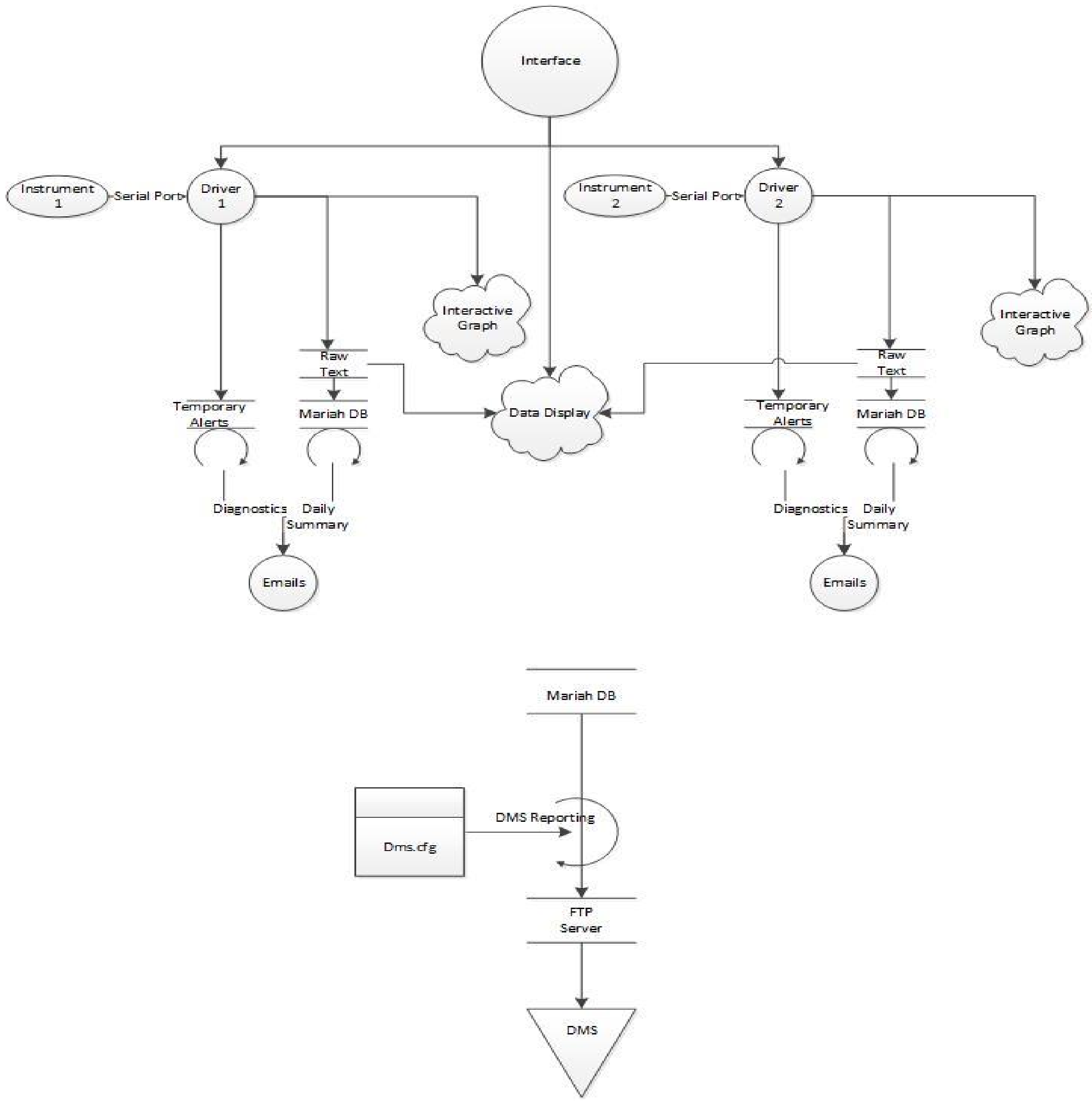


Figure 1.1: CARBLogger Data Processing Diagram.

1. CL acquires "raw data" from air monitoring instruments via RS232, RS485, or Ethernet connections, using serial, file sharing, JSON, http, or Modbus protocols.

2. The "raw data" stream is timestamped using CL's date and time. CL time is synced to a Network Time Protocol (NTP) server to ensure accurate time. This timestamp corresponds to the time at which the data point was acquired and ensures data collected from instruments are time synchronized with CL. In addition, this raw data is also modified for parsing by CL user

interface for direct display and for DMS reporting.

3. CL calculates the correct DMS time for data storage using CL timestamp, minus the offset stored in the dms.cfg file. For example, if CL timestamp is 8:50 and the offset is set to 1 minute, the DMS will receive 8:49 as the correct recording time.

4. As data are being collected by CL and written to disk, each instrument's diagnostic data stream is being screened in parallel using criteria established by AQSB, as indicated on each instrument's monthly Quality Control (QC) maintenance check sheet. CL drivers note any diagnostic data outside of acceptable QC criteria for each instrument's respective parameters and append any violations to CL's errors file.

5. Twice a day, instrument diagnostic data and errors are summarized and emailed to the station operator, calibrator, and site supervisor. These emails are referred to as diagnostic email alerts and are configurable in CL.

6. CL also stores the collected data into its onboard database.

7. CL database has custom stored procedures which interact with the dms.cfg file, display files, and its stored data, to produce op-coded data files in a native DMS format. These data files are commonly referred to as ".MIN" (dot min) files. The timestamps used for the ".MIN" files are based on the NTP timestamps discussed above. In addition, ".MIN" files are transferred hourly to DMS through Accellion.

8. Each day CL summarizes the previous days "raw data" file and specific one minute records then emails these files via Google Mail accounts to the station operator and site supervisor. These are referred to as raw data report and one minute data report, respectively.

9. CL also allows remote access to connected instruments 24 hours a day when the network is correctly configured.

1.3 <u>CARBLogger Limitations:</u>

For clarity, we delineate what CL does and does not perform for DMS.

1. CL assigns Op codes (flags) to each instrument minute/hour value based on the state of the calibrator, the time of day, the status chosen by the operator, the time stamp applied to the data, and the manifold the instrument is connected to. QC codes are assigned by DMS using a) Op to QC code mapping, b) AutoQC validation criteria, or c) manual QC

assignments.

2. CL does not average minute values into hourly values. Hourly data displayed on DMS are aggregated by DMS from the ingested minute values for each instrument.

3. The current version of CL does not assign an Op code (flag) to minute data points based on diagnostic data results. The Op code assignment is solely based upon the system's calibration state, or the operator's choice of an enable/disable channel state selected from CL user interface. The exception to this rule is the BAM-1022 driver, which flags data invalid if error codes are detected. The current BAM-1022 firmware uses a full-scale data value to indicate an error code but integrates the value into the hourly average. The artificially high values are invalidated by the driver.

4. DMS calculates calibration values using contiguous Op code assignments of zero, precision, or span made by CL. DMS will calculate incorrect calibration values if the flagging is incorrectly assigned by CL.

1.4 Installation Constraints:

1. CL must be installed in an environmentally controlled location with clean power suitable for the platform it is running on.

2. As with any electronic equipment, CL must be electrically grounded and connected to a suitable power supply unit. If not, instrument connections which are subject to noise and bad grounds (i.e., RS-232, Ethernet, or TCP/IP) may cause intermittent connection and data outages.

3. The Dell R620 (CARBLogger) produces a +/- 20% watt draw on its 490-watt power supply, giving an upper end wattage requirement of 588 watts, another 20 watts for the screen, or roughly 5 amps at 120 VAC.

4. Care should be taken when using small circuits or power cords, as a single moderate draw device such as a refrigerator, space heater, or window air conditioner can cause power problems.

5. CL version 1.2 requires an Ethernet connection with a static IP address and port forwarding to operate normally.

6. CL collects digital data exclusively, hence, there are no status contact or analog output data collection capabilities in CL system.

7. CL can serve as a remote terminal server to allow remote access to control

and modify station instruments; advanced network configuration may be required, which is beyond the scope of this document.

8. CL cannot report data directly to data clients nor is it designed to do that.

1.5 Safety Precautions:

CL hardware should be installed in a well-grounded, power conditioned environment and should be kept clear of any water and/or precipitation.

Operators should adhere to the hardware manufacturer's precautions for the specific CL platform being used.

Any precautions taken with a desktop computer or server should also be applied to CL.

1.6 Personnel Qualifications:

Staff should be trained and familiar with basic air monitoring principles and procedures prior to operating any air monitoring equipment. Staff should complete any required safety training before operating any air monitoring equipment and working in the field. Staff should review this SOP, instrument SOPs, the instrument operating manuals, and complete any instrument related and air monitoring operations training required by their section manager prior to operating CL.

2.0 INSTALLATION PROCEDURE

2.1 General Information:

Installation of CL should be like installation of any ambient air monitoring instrument used by AQSB. CARB monitoring practices state that the instruments should be installed in a stable, temperature controlled environment, between 20° C to 30°C. Care should be taken to install the instrument in a standard 19” instrument rack such that it can be accessed for maintenance, repair work, and troubleshooting. The standard 19” instrument rack should be bolted to the floor and properly grounded. CL should be installed such that operators can attach a monitor, keyboard, and mouse to access the graphical desktop.

2.2 Equipment & Materials:

The following list of equipment is based on the installation of a new site, where no previous CL has been installed. If one needs only to upgrade or replace an existing CL, transfer kits are available on request.

- One set of USB-based keyboard and mouse
- One LCD monitor screen
- One uninterruptible power supply (UPS), and if available, one power conditioner
- For serial installation, one (or two) Peripheral Component Interconnect Express (PCIe) serial cards and accompanying 8 port DB9M fan-out mini cable(s) (Perle Systems Inc. product code 04001620) and at least one serial cable per instrument
- For ethernet installation or switch installation, a 4 or 8 port network switch, one ethernet cable for CL, and one ethernet cable per instrument
- Wooden planks with hardware brackets

Figure 2.1: Wood Plank Mount

- Environmental equipment shelves
- A DSL modem, router, or other source of Ethernet connectivity
- One small Philips screwdriver, one small flathead screwdriver, and a flashlight

Dell Servers/PC Chassis CL-

- Two power cables; CL has two power sources

Raspberry Pi (RPi) Chassis-

- Argon one M.2 Case
- RPI Power Supply
- USB Powered hub
- USB to Ethernet Adapter
- USB to RS-232 Adapter (4 or 8 port)

2.3 <u>Available Form-Factors:</u>

Inspect CL chassis and confirm that it is free from any physical defects. At the time of this writing, there are five different hardware platforms that CL is currently being used on (as shown in the table below):

Table 1: Different CARBLogger Form Factors

Platform	Images
Dell R430/R440	 
Dell R620	 
Dell T610	 

Platform	Images
HP8000	
Raspberry Pi (RPi)	

Note: Per CARB's IT equipment policy, each CL is issued an instrument barcode that is attached to the outer shell. Please record this barcode on AQSB Form 605, CARBLogger Monthly Maintenance Check Sheet, for inventory management.

2.4 Installation Inspection:

CL should be placed inside an environmentally controlled air monitoring station and secured into the equipment rack. CL should be well grounded, connected to a UPS and a conditioned power supply. Repetitive power outages and poor power conditioning can and will cause hard disk failures and file system corruption.

Any precautions for installation taken with other electronic equipment should also be applied to CL installation.

CL should have been configured by the ODSS staff before being shipped to the field. The Peripheral Component Interconnect (PCI) serial card(s) are installed and tested by ODSS staff. If there is need to replace a faulty serial card in the field, ODSS staff will issue a separate set of instructions/procedures for field component replacement.

Make sure the 8-port cable and instrument serial cables are connected securely. Use a zip-tie/plastic brace to hold the weight of these cables to the chassis/rack. Avoid free-hanging cables from the back of CL.

2.5 CARBLogger Connection:

Connect the monitor screen, keyboard, mouse, ethernet switch, and the two power cables to CL peripheral ports on the back of the system.

Note: Tie-downs and/or plastic braces should be used to secure all cabling to CL chassis and relieve any strain placed on the cables.

Connect each instrument to one of the available serial ports from the 8-Port serial cable, starting with the cable labeled #1.

Once all the instruments are connected to CL, operators may power on CL.

Figure 2.2: Securing Cables to CL Chassis.

Please make note of which instrument is connected to which serial cable number, as you will need this information later in the instrument configuration section.

If you require more than eight serial cables, it is possible to add additional serial connections by acquiring another serial card and making a slight change to CL configuration file. Alternatively, you can use the remaining serial ports available on the chassis.

For more information regarding ethernet-enabled instruments, see Ethernet-enabled Instruments CARBLogger and DMS Connection Procedures.

3.0 USER INTERFACE

3.1 Introduction:

CL user interface was developed by ODSS to provide users a simple way of controlling the underlying data acquisition system. It provides users a means to add, remove, start, stop, and configure all instrument drivers and site settings. It also provides users a manner to flag data dependent on the instrument's operational state, i.e., offline, maintenance, or calibration, etc.

Each CL menu consists of a numbered list of usable options, each described below.

3.2 User Interface Home:

The user interface home refers to a scripted menu system which displays the files and folders located under the "*/home/aqdms/CARBLog*" (a.k.a., CARBLog) folder.

This interface allows users to control the various drivers and reporting processes available on the local machine without needing to use or understand the Linux command prompt and related files.

Interface navigation begins at the home screen/menu. The picture (Figure 3.1) shown on the following page is the home menu that starts when CL is turned on.

Additional menus can be accessed by selecting the number preceding it on this screen, each of which will be addressed in the following subsections. The following topics will be discussed:

- Starting/stopping instrument(s) or CL.
- Adding new instrument to data logger.
- Editing existing instrument settings.
- Delete existing instrument from data logger.
- Enabling/disabling monitor channels.
- Showing data to display monitor.
- Editing/resetting station details.
- Generating raw data extract for manual DMS backfill.

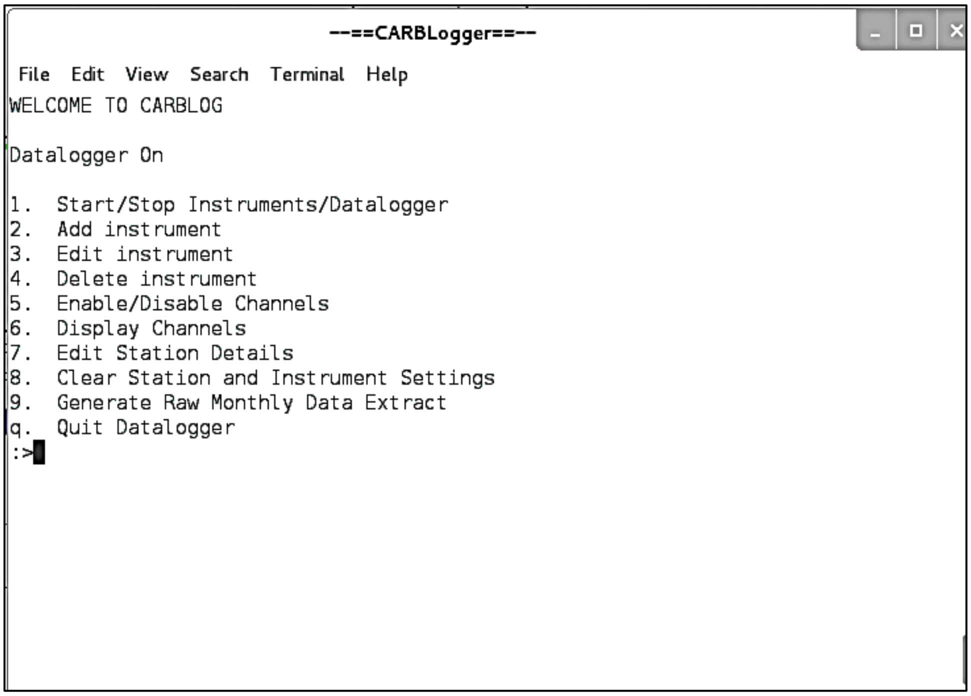


Figure 3.1: CARBLogger Home Screen.

To enter/proceed with each submenu, from the main menu, enter the number of the submenu you wish to access, followed by pressing the "ENTER" key, which will bring up the submenu.

3.3 Start/Stop Instruments/Datalogger:

The Start/Stop Instruments/Datalogger menu (Figure 3.2) allows the operator to start or stop a single, multiple, or all instrument drivers from running on CL. Stopping an instrument here prevents data from being collected by CL. This is used when an instrument is removed or stopped for an extended period of time.

In contrast, when disabling a channel, CL will continue to collect data, but flags each data point with a user selectable meta-tag instead. The instrument could be under maintenance or calibration for a short period of time.

For details of Enable/Disable Channels, please refer to section 3.7 of this document.

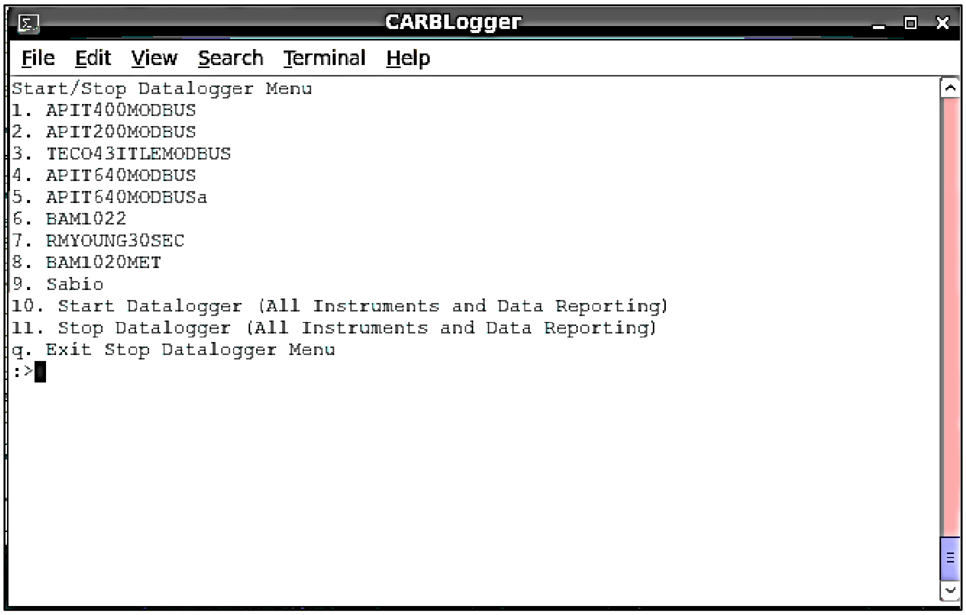
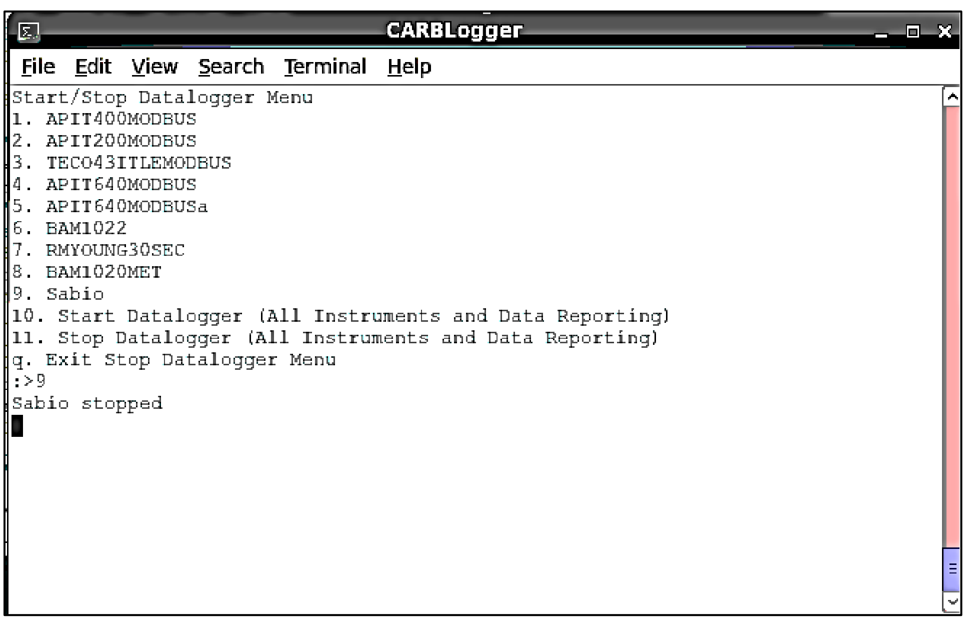


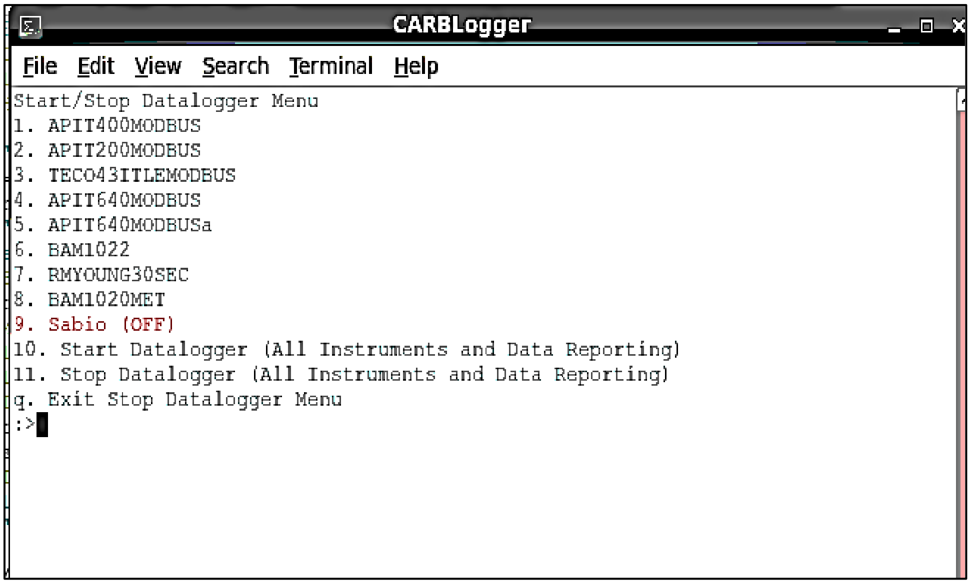
Figure 3.2: Typical Start/Stop Instrument Datalogger Menu.

To stop an instrument, for instance, the Sabio instrument driver, choose the number displayed in front of the Sabio under this menu, in this case the #9, and then hit "ENTER" to proceed. Refer to Figure 3.3a.

The message "Sabio stopped" should display, followed by the same menu, with Sabio displayed in red and the message (OFF) next to it. Refer to Figure 3.3b.



a) Stopping the Sabio unit by selecting #9



b) Sabio is stopped with (OFF) displayed in red

Figure 3.3: Screenshots on How to Stop an Instrument Driver.

Finally, choosing the last item in this menu "Stop Datalogger (All Instruments and Data Reporting)", will stop all instrument drivers from collecting data, as well as stop all data ingestion and reporting processes. This option is used when the entire monitoring site is undergoing maintenance or is going off-line i.e., seasonal site shutdown.

3.4 Add Instrument:

The "Add Instrument" screen (see Figure 3.4) allows operators to choose the instrument driver to be added to the existing CL configuration. Only drivers that are relevant to that specific CL will be displayed and selectable on the list.

The order and number assigned to the displayed drivers depend on the state of CL program, so users should pay attention to the menu screen. The following conditions should be kept in mind when using the interface to add new drivers to CL:

- At the time of this writing, it is not advised to attempt and add a second occurrence (collocated instrument) of the same driver/instrument. Although the interface may appear as if you have added a second instrument, it will not work properly.

- Collocation of an identical instrument should be addressed by choosing (or requesting) the underscore a "_a" variation of the same driver. For instance, in the above screen APIT640MODBUS is the primary driver and APIT640MODBUS_a is the collocated version. Remember that the dms.cfg file must be properly configured manually to report primary and collocated data to DMS correctly.

- Only one calibration source can be handled for reporting at a time. Choosing two or more "calibrating" drivers such as APIT703U_drv, environics81000_drv, and the Sabio4010_drv will cause anomalous data flagging and reporting, although the raw data will still be collected by CL.

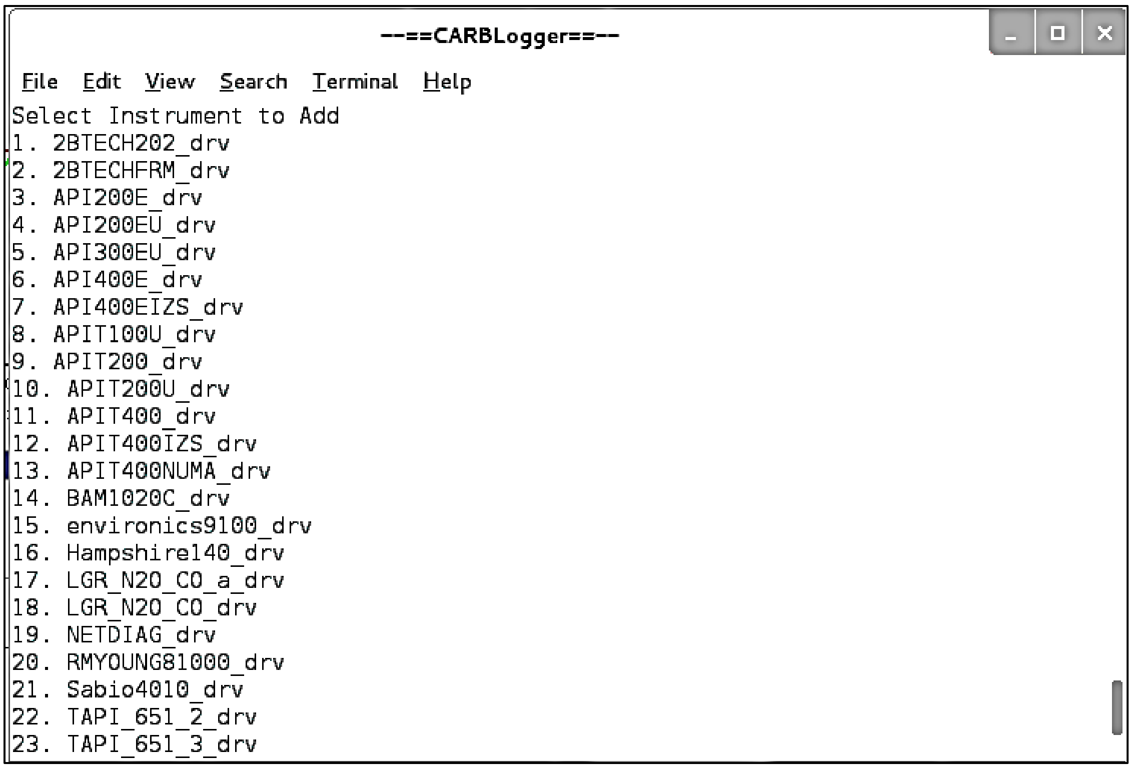


Figure 3.4: Typical Add Instrument Menu

To add an instrument driver to the system, choose the instrument by typing the number listed on this menu, adjacent to the desired driver, followed by pressing the "ENTER" key. The prompt will then take you to the "Edit Instrument" screen for the instrument you are currently adding. For details of the Edit Instrument menu, please refer to next section 3.5.

To cancel the request, press the "q" button followed by the "ENTER" key. This will return you back to the main menu.

Note: For additional details on adding an instrument (driver) to CL, please refer to Section 4.4 of this document.

3.5 Edit Instrument:

If not accessed via the instrument addition menu, the first screen (see Figure 3.5) presents a selection of currently active instruments you can choose to edit:

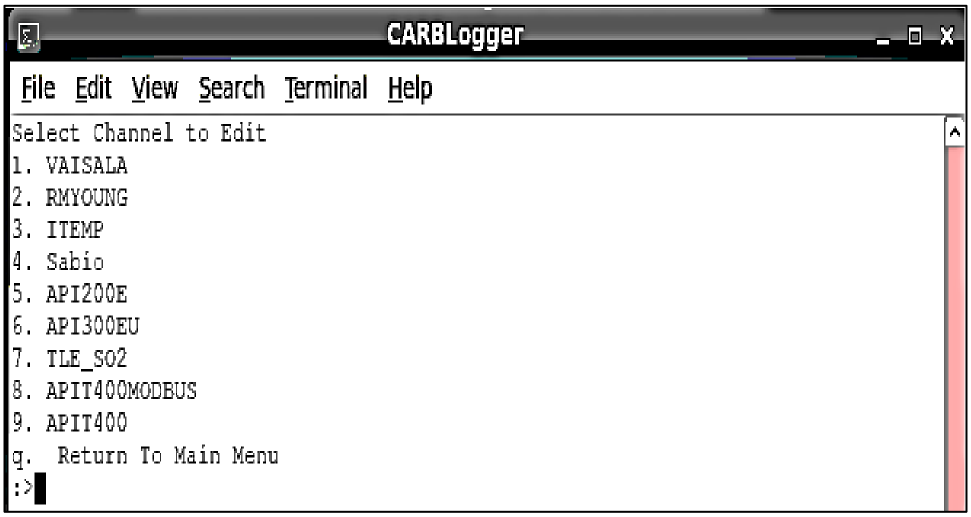


Figure 3.5: Typical Edit Instrument Menu

Choose the instrument you wish to edit by typing the number adjacent to the instrument, and then press “ENTER”. For example, here we will edit the APIT400 driver by pressing “#9” and then “ENTER”.

Different drivers will have different parameters to change, depending on the make, model, firmware version of the instrument, as well as the manner in which the driver has been written. Some common options are shown below (Figure 3.6).

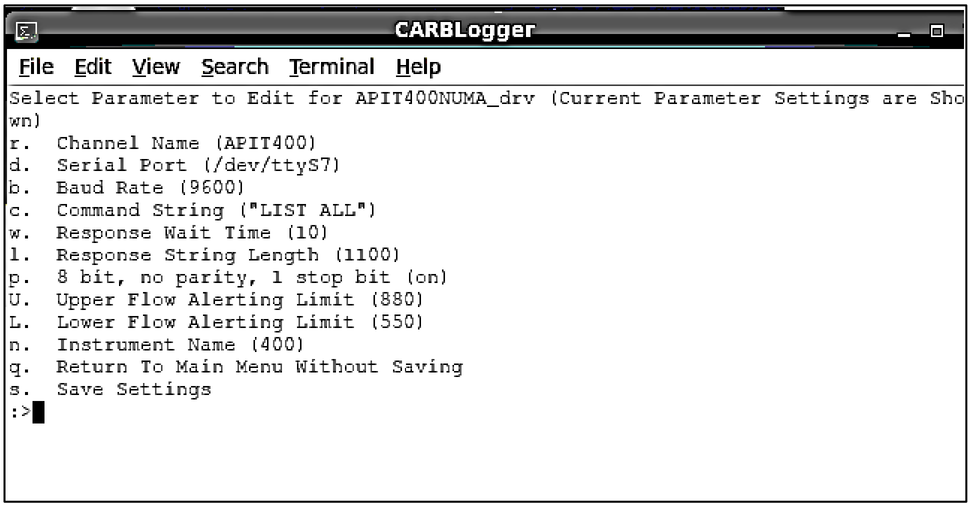
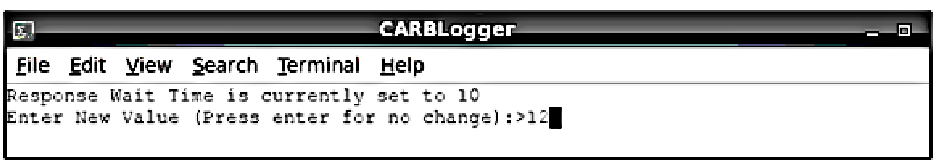


Figure 3.6: Common Editable Parameters from an Instrument Driver

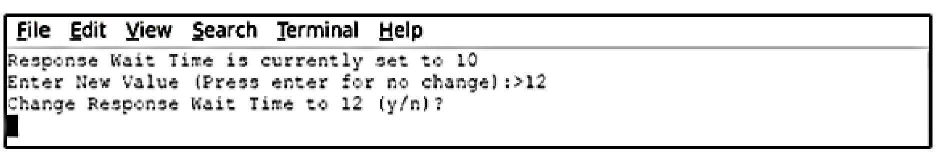
Pressing the case sensitive letter adjacent to the parameter you wish to change, followed by the “ENTER” key will allow you to futher edit that parameter.

As instruments and communication boards age, we may need to alter the wait time needed to obtain a response from the instrument. To update the intrument’s response wait time, select that option and then press enter.

For instance, change the response time from 10 to 12, by pressing “w” followed by the “ENTER” key. After pressing “ENTER”, the menu will prompt for confirmation. Press “y” to confirm your choice. See figure 3.7 below.



a) Update the new value



b) Confirm the selection

Figure 3.7: Screenshots: How to Edit and Instrument Driver.

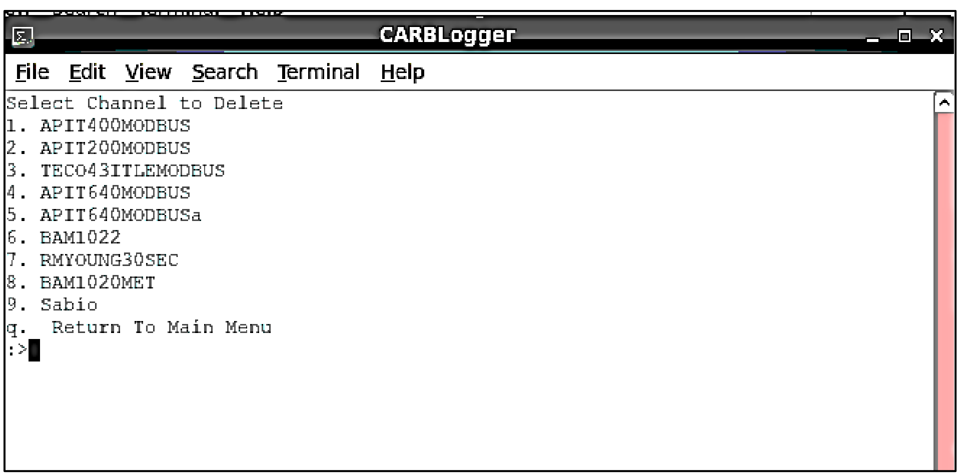
Pressing the “y” key followed by “ENTER” returns you to the parameter’s edit screen. Finish making any additional changes, then press the “s” key to save the setting changes. The prompt will return you back to the instrument selection menu of the Edit Instrument submenu. From there press the "q" key to return to the main menu. All drivers will stop and restart.

The changes made to the parameters setting for each instrument driver have been altered by the interface, so when each driver restarts it will run using the new settings.

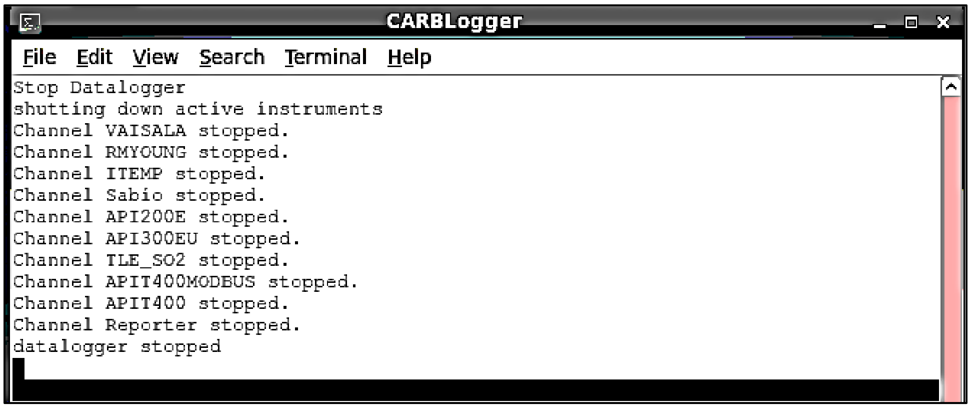
3.6 Delete Instrument:

When an instrument will no longer be collecting data on a CL, the Delete Instrument menu can be used to delete the instrument currently being run. Deleting the instrument means that CL interface will no longer store the configuration of the instrument, and that driver will not be automatically started during reboot. Also, raw and diagnostic data will stop reporting.

To delete an instrument, go to the Delete Instrument menu (see Figure 3.8), view the existing instrument that you want to delete from the system, select the instrument number, and then press the "y" key to confirm. Once the deletion is complete, press the "q" key to return to the main menu; CL will reboot.



a) The List of Instruments Available from the Delete Instrument Menu



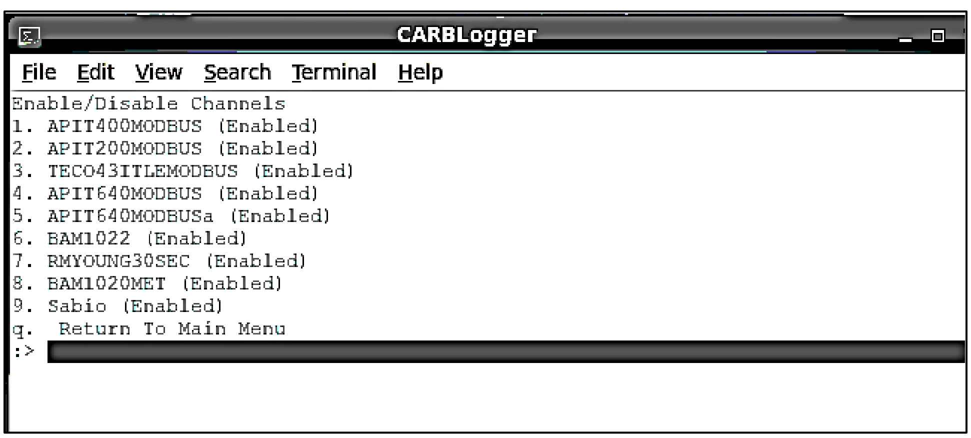
b) CARBLogger Reboot After Deleting an Instrument Driver

Figure 3.8: Typical Delete Instrument Menu

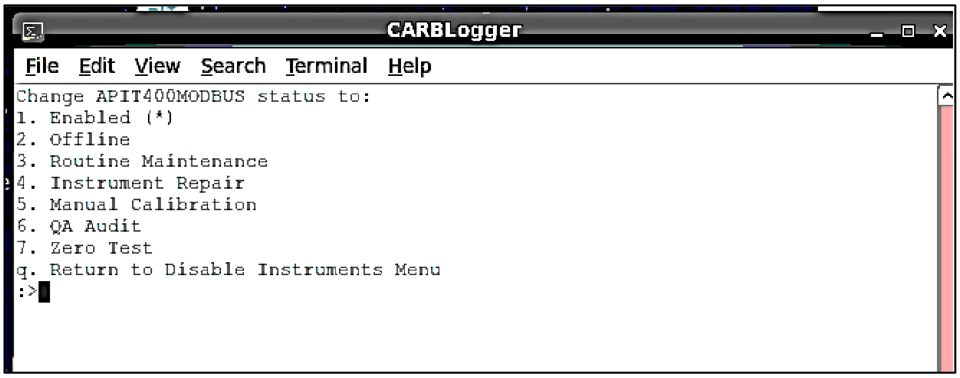
If an instrument is deleted and needs to be reinstated, it will need to be added back to the system using the Add Instrument menu.

3.7 Enable/Disable Channels:

When site maintenance or other activities occur, which compromise the quality of data collected by any single instrument, it is advisable to use the Enable/Disable Channels menu to set the correct operational code to the data produced by the affected instrument(s). Doing this would allow DMS to infer should the data point be assigned an invalid QC code.



a) List of Channels Available from the Enable/Disable Channels Menu



b) List of Operational Statuses Available for Selection

Figure 3.9: Typical Enable/Disable Channels Menu.

Follow similar steps described in the previous section for instrument/channel selection. CL will not reboot from a change of operational status for an instrument.

Since DMS calculates the hourly average by averaging all valid minute values during an hour, **a failure to properly disable instruments when performing maintenance, calibrations or other activites** can result in false values being calculated by DMS and reported to real time data clients.

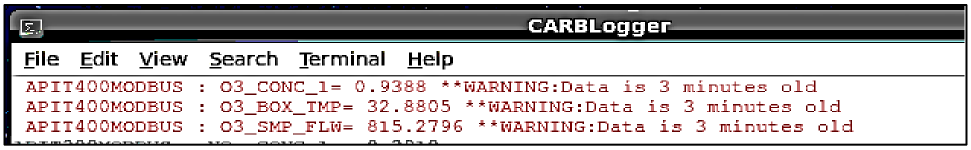
3.8 Display Channels:

The Display Channels screen from CL interface is useful for viewing the real time status of raw data being collected from instruments. The number of displayed parameters is configured through instrument drivers. The parameters will be displayed in a line-by-line format, and the data being displayed on the Display Channels screen will be updated every 15 seconds. In addition to the raw data value being collected, this screen also offers several pieces of information regarding the state of data collection.

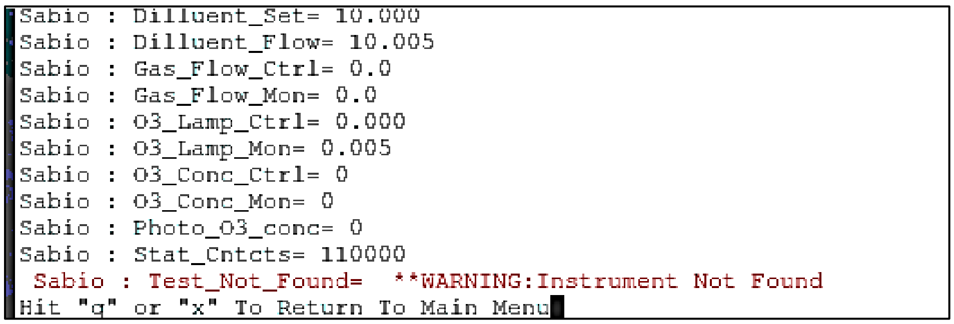
If an instrument or any single parameter has not reported for more than one of its regular reporting intervals, text appears in red saying the amount of time since the last raw data point was recorded will begin to appear. See Figure 3.10a.

If an instrument has not reported data for more than a day (24 hours), red text stating “Warning: Instrument Not Found” will be displayed. See Figure 3.10b.

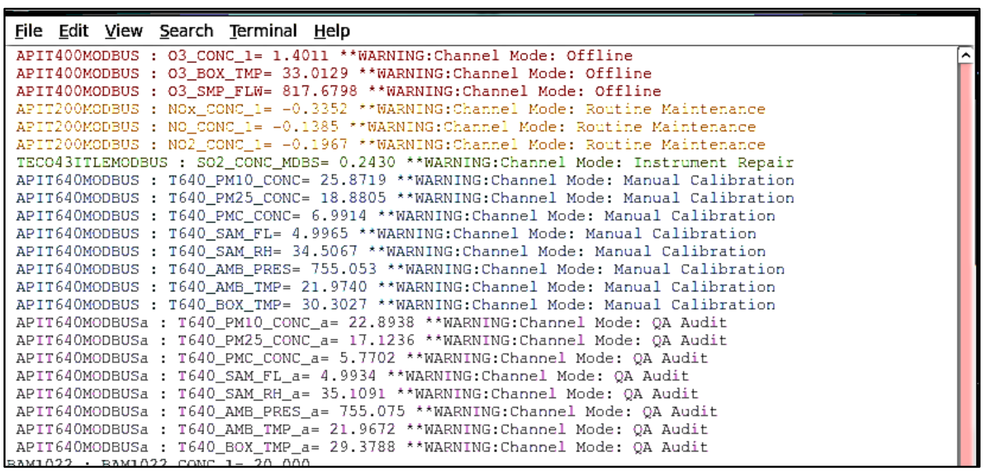
Finally, if an instrument is flagged offline for any reason, a verbal description for each type of offline status will be displayed. See Figure 3.10c. The colors of the alert are randomly assigned to differentiate the instruments installed.



a) Warning message for non-current values



b) Warning message for inactive parameter



c) Warning messages for different offline statuses

Figure 3.10: Different Error Message from Display Channel Screen.

3.9 Edit/Clear Station Details:

The Edit Station Details screen (See Figure 3.11) is used to modify station specific parameters that affect all instruments, including the station code, site elevation, the two diagnostics reporting hours, and the email contacts for reporting, etc.

The Clear Station and Instrument Settings screen (see Figure 3.12) is used to reset all station specific parameters and all instrument settings to the default blank state.

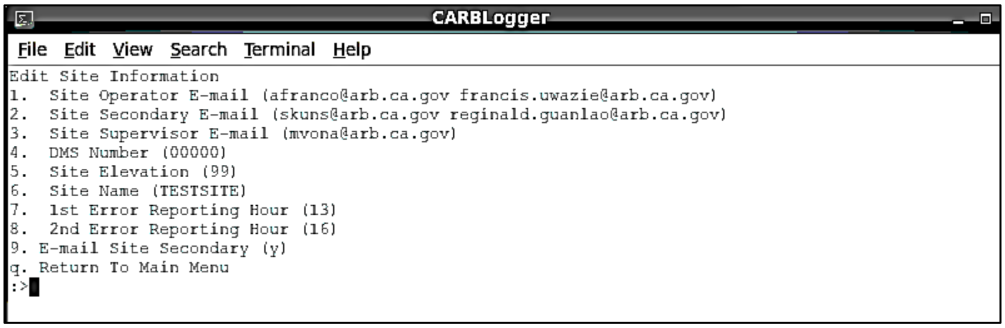


Figure 3.11: Edit Station Details Screen.

Note: Station details should be the priority for configuration during any initial CL setup. For details of site configuration, refer to Section 4.1.

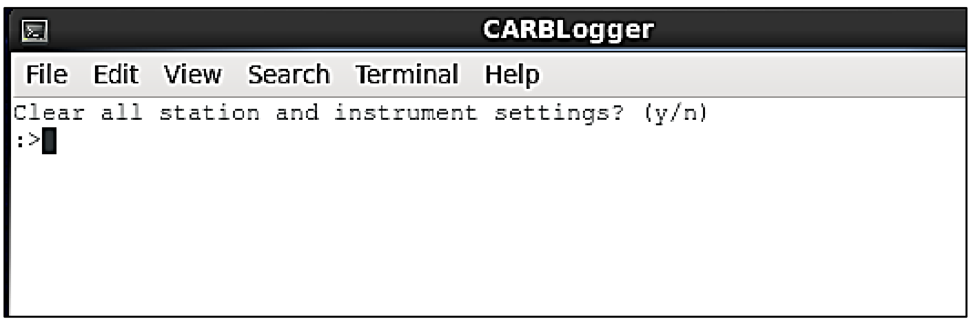


Figure 3.12: Clear Station and Instrument Settings Screen.

Note: To clear station and instrument settings from CL, select the specific option from the main menu. A new prompt would appear to ask for confirmation. Enter "y" to confirm. Once executed, CL and any existing station and instrument settings will be reset to the default blank state.

3.10 <u>Generate Raw Monthly Data Extract:</u>

A user may want to view the raw data for one instrument and view it on the workstation. In such a case, this menu option can be used to scrape the raw data, extract the parameters requested, and send the data to the provided email address. See Figure 3.13.

Go through the requested field one by one, and CL prompt will direct users for the proper values to enter. Select Generate Report for the data extract file.

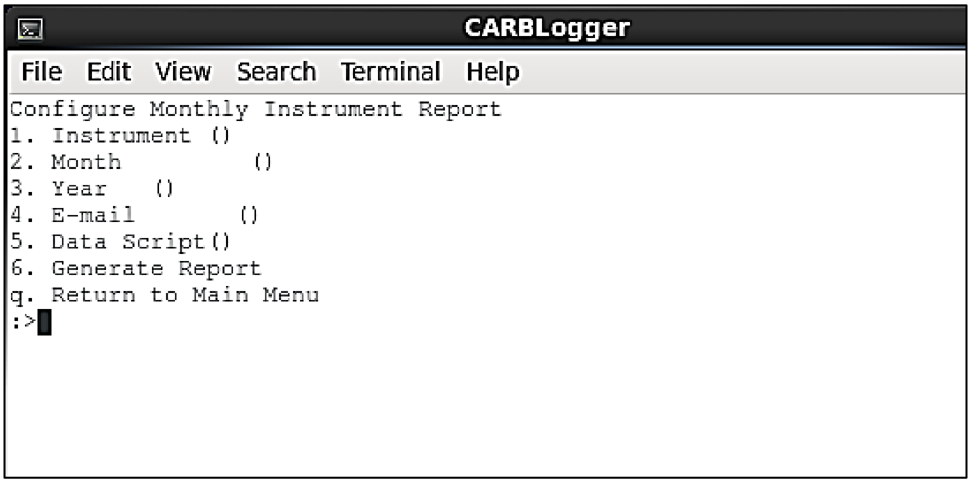


Figure 3.13: Generate Raw Monthly Data Extract Screen.

Note: The extracted raw data from this menu is in its own format and is not appropriate to use for backfilling data gaps on DMS. To backfill data gaps, please follow the procedures from Section 7.0 of this SOP document.

4.0 CARBLOGGER CONFIGURATION

4.1 Initial Station Configuration:

Prior to using CL, a site's parameters must be properly configured. Most site parameters used by CL can be found in the Add Instrument and Edit Station Details screens (as shown in sections 3.4 and 3.9 respectively). In this section, details will be provided for each required setting.

Note: Not ALL the site parameters are editable directly on the screen. Changes can be made by editing the "~/CARBLog/Config/config" file via the Terminal Shell. For instance, for switching serial card from Perle to StarTech and adding Modbus drivers, manual editing with the config file is needed.

The following table includes the description and location of each parameter requiring configuration prior to using CL.

Table 2: Description of Required Parameters:

Parameter	Location	Description
Site Operator, Supervisor, and Secondary Email Addresses	Edit Station Details (Menu)	Set the email addresses which receive emails from station CL. *Note: Multiple email addresses can be used by providing a space separated list for any one value.*
DMS Number	Edit Station Details (Menu)	This is the 5-digit CARB identification number which is appended to every data record produced in CL. If this number is wrong, it is possible to contaminate other site data in DMS (if DMS site verification has been disabled for the site).
Site Elevation	Edit Station Details (Menu)	Various data clients including Air Now and AQS require site elevations. Some instrument diagnostic values such as flow require site elevation (in feet) to compensate for sea-level correction. No drivers or DMS import processes use this field.
Site Name	Edit Station Details (Menu)	This is the name of the station used in email notifications from CL, and it only

Parameter	Location	Description
		appears in the emails sent to station operators.
First and Second Error Reporting Hour(s)	Edit Station Details (Menu)	The two reporting hours when the summary of site operational error conditions is transmitted. If set to 05, the first email will be sent at 0500 hours in using the GMT - 8 time zone.
E-mail Site Secondary	Edit Station Details (Menu)	This value can be set to Y or N. If set to Y, the site 2nd level data reviewer or calibration staff will receive copies of the error emails.
Instrument Drivers	Add Instruments (Menu)	One driver should be added per each instrument. To do this effectively, determine the physical port connections for each instrument which can vary depending on the make and model of the serial card, or if MODBUS drivers are used or not, etc.
DMS Data Reporting	The dms.cfg file (Terminal Shell)	For every data label displayed on CL screen, each label in the dms.cfg file must map to the appropriate DMS counterpart, as shown in DMS on the Parameters screen.

4.2 Configure Station Details:

To properly configure a site's station details in CL the operator needs to enter the Edit Station Details screen (by typing "7" followed by the "ENTER" key from CL main menu).

From the Edit Station Details menu, the operator is presented with a list of options to update. It is critical that all these items be updated. Simply choose each of the items presented and follow the on-screen prompts.

Shown below (Figure 4.1) is an example of the station details configuration for the Test Site (00000) located in the ODSS Instrument Shop.

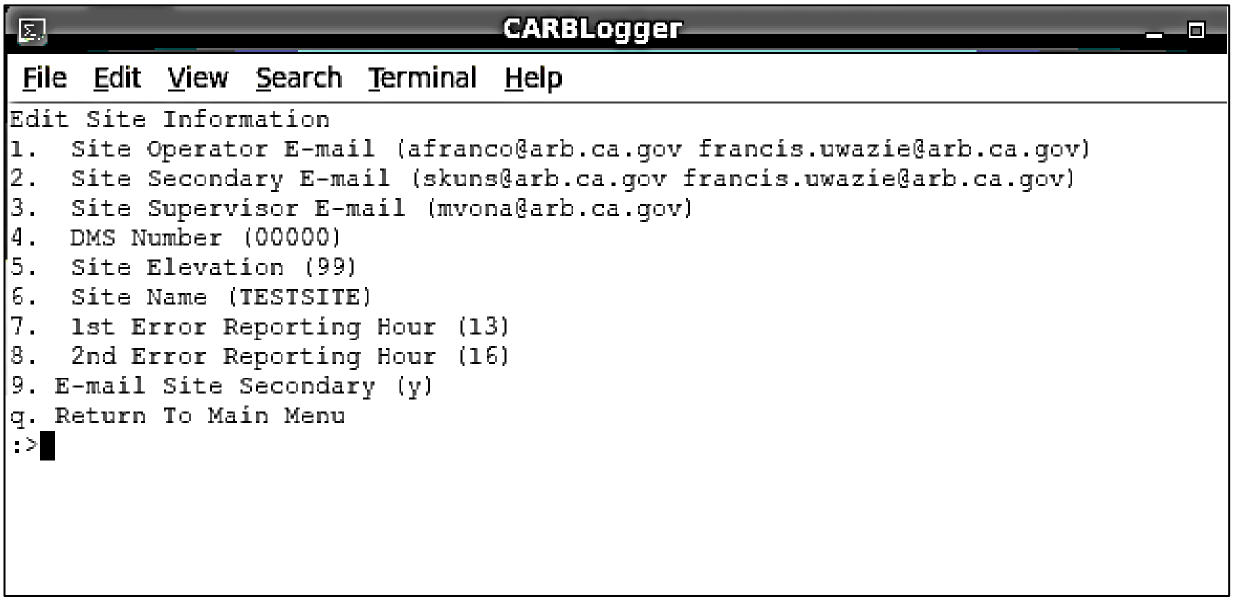


Figure 4.1: Example of Station Details Configuration.

Note: The DMS Number field is the station ID assigned in DMS for each monitoring site. This ID is synonymous with the CARB Site Number. CL uses this number to identify itself when transmitting data to DMS. See Appendix G for a list of the five-digit site numbers for all CARB Air Monitoring Stations which were in operation at the time of this writing.

4.3 Instrument Configuration Settings:

Once CL site information has been configured, the logger must be configured to know which instruments are operating at the station, and on which physical port the instrument is located.

Prior to adding any new instrument drivers, the operator must confirm that each instrument's communication settings are known, as these will be requested by CL prompt for each instrument's setup dialog.

Every setting should be verified for the instrument prior to adding it to CL. The following table (Table 3) directs users how to verify instrument communication settings, depending on the type of connection protocol the instrument uses for connection.

Table 3: Different Ways to Verify Instrument's Communications Settings

Protocol Type	Specificity	Procedure
Serial	Chassis Serial Port	See Appendix C.
Serial	Perle Serial Card	See Appendix C.
Serial	StarTech Serial Card	See Appendix C.
Ethernet	MODBUS Over TCP/IP	This only works on CENTOS or other Linux distributions with the modpoll module installed. Open a terminal, and type the following command: *modpoll -m tcp -p 502 -1 -t 3:float -c 2 -f xxx.xxx.x.x* where "xxx.xxx.x.x" is the assigned IP address for the instrument. Examples: API200 = 172.16.0.2, API300 = 172.16.0.3, API400 = 172.16.0.4, and Teco 43i = 172.16.0.10 It is also possible to connect an instrument to the DHCP provisioning switch, however, this is not advised. If the IP address, CL, the intermediate switch, and the instrument communication settings have been correctly configured, the following message should display: modpoll 3.4 - FieldTalk(tm) Modbus(R) Master Simulator Copyright (c) 2002-2013 proconX Pty Ltd Visit http://www.modbusdriver.com for Modbus libraries and tools. Protocol configuration: MODBUS/TCP Slave configuration...: address = 1, start reference = 1, count = 2 Communication.........: 172.16.0.4, port 502, t/o 1.00 s, poll rate 1000 ms Data type............: 32-bit float, input register table Word swapping.........: Slave configured as big-endian float machine

It is very important that the instrument configuration settings are entered and updated correctly. If not set correctly, reported data could become incomprehensible and invalid for submission. Table 4 illustrates some common instrument configuration mistakes.

Table 4: Examples of Incorrect Instrument Configuration Changes

Data Stream Before Change	Data Stream After Change	Result
O3= 4.5 ppb	O3= 0.005 ppm	If the driver assumes that the ozone value is being reported in parts per billion, DMS may begin to receive artificially low numbers because the driver assumes results are reported in parts per billion.
O3= 4.5 ppb	Ozone= 4.5 ppb	If the driver is looking for the data marker "O3=" and instead is presented with "Ozone=", the ozone data stream will stop completely.
4.5 80 33	4.5 33 80	Some instruments do not mark their data, but rather return their data in a single ordered string of values. In these situations, a principle sometimes referred to as "token counting" is used to make the drivers. A change in the order of the data will therefore cause the wrong numbers to be reported to DMS.

Many of these mistakes can be mitigated by reviewing the raw data files and adjusting the parameter configuration in the related instrument drivers. Instrument operator should notify ODSS of the errors, and correction/adjustment to the drivers shall be reviewed and made by ODSS staff only, unless other instructions are given. The corrected data shall be re-ingested into CL and DMS.

At the present time, only one calibration system (i.e., Sabio 4010 or TAPI T703U) can be used per instance of CL to properly configure the dmsout.sh process flag calibration, flagging, and formatting for DMS (if required).

4.4 Adding Instrument (Driver) to CARBLogger:

This section will cover additional details on adding an instrument driver to CL.

For basic description of the Add Instrument menu, please refer to Section 3.4 of this document.

After entering the Add Instrument menu, the operator is presented with a list of drivers available to CL (See figure below). This list is typically populated by the drivers available on the specific CL distribution.

Note: If you do not see or recognize the driver needed for your instrument, it is possible that a driver for that instrument has not been created or added to your CL. If this is the case, contact ODSS staff for assistance.

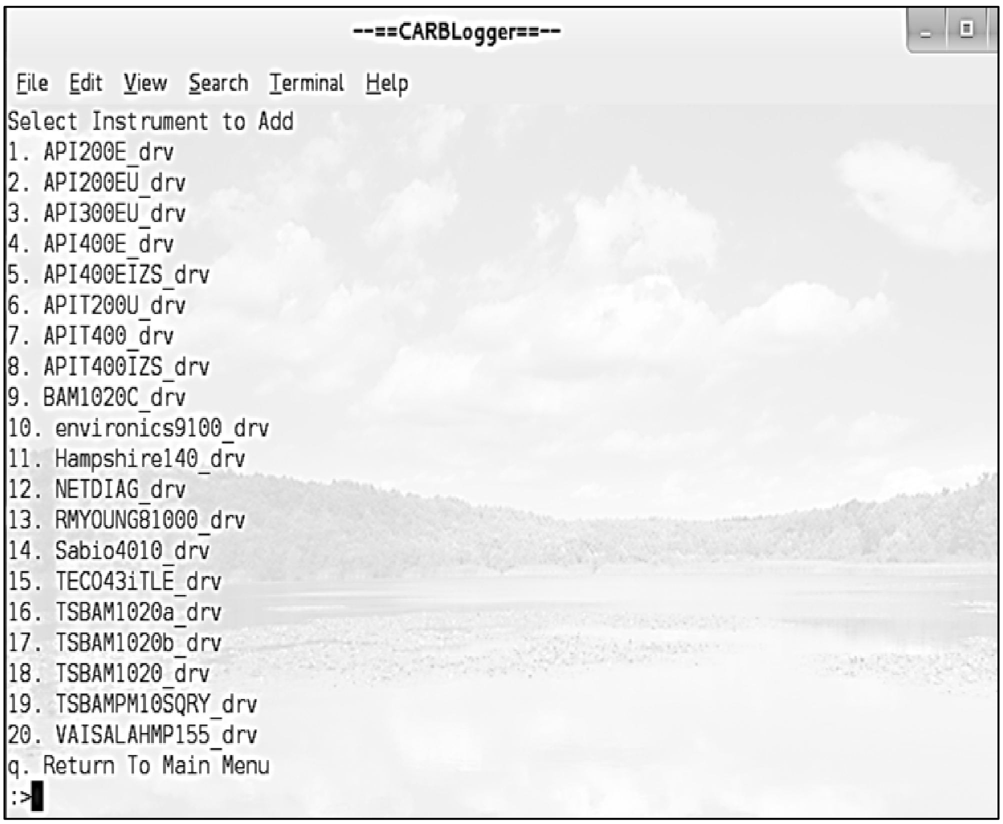


Figure 4.2: List of Available Instrument Drivers.

In general, CL drivers will be named after the make and model of the instruments, and sometimes the communication method. For example, to begin logging data with an APIT400 using MODBUS communication, its driver will need to be added to CL. From the above menu shown, one would type in "8" and then press "ENTER" to select the "APIT400MODBUS_dr" driver.

In some cases, network instruments may have been purchased or implemented with hardware options which require new or different data processing. In those cases, these specific conditions or qualifiers are incorporated into the driver's name. The following table lists those drivers which should be used when special configurations of instruments have been made as of version 1.2.

Table 5: Drivers of Special Configuration

Driver Name	Implementation Specifics
BAM1020C_drv	At the time of the driver's writing, the "C" was used to indicate PM Coarse, which is essentially (PM10 – PM2.5) collected from tandem PM10/PM2.5 BAM1020 instruments connected by a serial connection and running special firmware. At the time of this writing, only the Fresno air monitoring station runs this type of unit.
TSBAM1020_drv, TSBAM1020a_drv, or TSBAM1020b_drv	The TSBAM1020 driver is named to indicate that this is the "Time Setting" version of the BAM1020 driver. There are no longer any production BAM1020s which would still use the non-time setting variant of this driver, since all analog time setting mechanisms should have been removed from the newer BAM1020 models. The primary BAM located at any production air monitoring station should use TSBAM1020_drv. The difference between Federal Equivalent Method (FEM), non-FEM, and collocation is accounted for in the DMS configuration section.
TSBAMPM10SQRY_drv	The United States Environmental Protection Agency (U.S. EPA) determined that AQSB should report PM10 in Standard Condition, while other data clients require PM10 in local conditions. This driver was written specifically to work with the "Query Port" option/implementation of the BAM1020 while running the PM10 hat. This driver requires two serial connections to the time setting BAM, one for the standard serial port and one for the query port. NOTE: Unless this BAM is using the PM10 hat and running the query port, the TSBAM1020 driver should be used with modifications, as will be discussed in the DMS configuration section.

Driver Name	Implementation Specifics
Sabio4010D_drv	The Sabio4010D has user configurable equilibration and recovery time settings. Using this driver requires a different version of CL database, stored procedures, and a specific configuration of the DMS server for the site.
APIT703_drv	The API T703 driver has user configurable sequence time settings. Using this driver requires a different version of CL database, stored procedures, and a specific configuration of the DMS server for the site.

5.0 DATA FLAGGING AND OPERATION

CL is an evolving, open-source project. Changes introduced by instrument manufacturers, software applications, procurement and information technology policies necessitate constant modifications to the underlying processes employed by the logger. We will discuss the operation of only the latest, most common version of CL here, and the guidance in this document may change as this project evolves. Changes to CL processes in this document will be denoted via an AQSB technical bulletin release.

Note: CL will remain operative and continue to collect data even if the station's internet connection is down. Once internet connection resumes, CL will push data collected during connection outage to DMS.

5.1 Data Flagging Introduction:

Operational codes (Op codes) are DMS data flags assigned to every data point that CL sends to DMS. "Data flagging" is the process of altering these Op codes to communicate data status and purpose of every value. Without data flagging, DMS is unable to automatically calculate valid hourly averages, calibration values, or assign null codes. CL automates data flagging in two manners, both requiring input from the station operator.

Manual data flagging –

Operators can manually mark down instruments using CL interface when they need to perform a physical process on the instrument. Common processes include calibrations, audits, maintenance, or zero testing (see section 3.7, and Appendix I). Manual operational codes have a higher priority than those assigned by automatic processes. Currently, CL can assign 7 different manual Op codes to the data it collects.

Calibration Data Flagging –

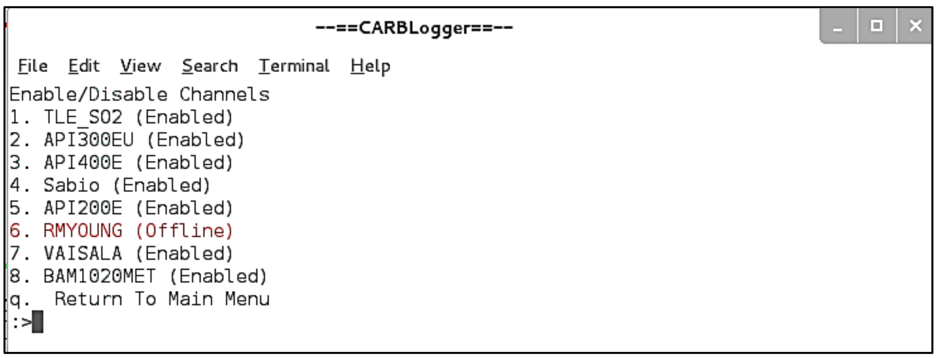
Station operators must configure the dms.cfg file to express how their station is physically connected to the station sample manifold. Automated gas calibrators and some self-calibrating instruments produce a calibration data stream. Using these two pieces of information, CL interprets calibrator effects on the status of the instrument data, and assigns each data point the appropriate Op code.

Note: At the time of this writing there can be only one calibration data stream.

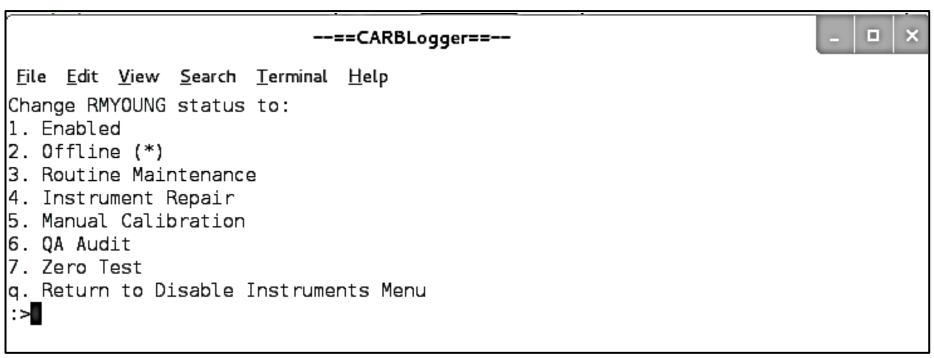
5.2 Manual Data Flagging:

Often a site operator may find it necessary to take an instrument off-line and require the instrument to continue collecting data but prevent DMS from averaging that data into valid ambient data. This is done by manual data flagging.

Manually flagging a channel uses the Enable/Disable Channels menu from CL interface. CL will continue to collect data from the instrument, but data will be flagged. After data is sent to DMS, the Op code will be used to omit data from averaging into valid data values.



a) Enable/Disable Channels Menu



b) Selecting an offline status for the disabled channel

Figure 5.1: Marking Down a Channel/Instrument

Selecting any instrument from the above menu will allow you to assign any non-valid Op code (as described in Appendix I) to the next data point collected from that instrument.

DMS will map a QC code, which indicates data quality for hourly aggregated minute-based data, based on the average of the highest QC codes from the 60-minute period representing that hour. The QC codes are assigned by DMS based on the Op code assigned by CL.

If an operator marks an instrument as “offline” in CL, each subsequent minute will receive a “9” Op code. While in the “off-line” state, each similarly coded minute value when ingested by DMS will receive a “9” QC code from DMS. If this happens for more than 15 minutes in an hour, the aggregated hourly value will be QC coded as invalid by DMS.

This point becomes especially significant when flagging instruments which collect data points using intervals greater than one minute.

The Met One BAM1020 driver collects a single data point once per hour. This driver has a variable which allows you to set the two-digit minute at which the data logger queries the instrument. Let’s assume that the variable is set to minute 04 (the default value).

The state of the Op code is set at the time that the data point is collected, not the time that data point is measured. In the case of the BAM1020, the last column of the dms.cfg file has a value of 60 for the offset which means that each data point it collects represents a data point 60 minutes earlier.

This is also significant with other instruments with larger data query interval.

5.3 Calibration Data Flagging:

To properly flag calibration data for DMS, a reporting process referred to as dmsout.sh is used to produce flagged data by comparing the raw text data from instruments against a site’s calibrator output. CL data flagging schema is configured using the “dms.cfg” file.

Properly configuring the dms.cfg file not only determines which data will be reported to DMS, but also flags data based on the sample manifold which the instrument is connected, the state of the calibrator, translates CL data name to the proper DMS parameter label, and time stamps “raw data” stream using Network Time Protocol (NTP). This timestamp corresponds to the time at which the data point was acquired and ensures data collected from instruments are time synchronized with CL.

Figure 5.2 displays a Venn diagram which illustrates the relationship of data collected by and reported from CL. CL displayed data is a small subset of data that was first collected in raw text format. The nightly data extracts and data displays are both produced using this data subset. Of this displayed data, only the data with data labels added by each driver and configured in the dms.cfg file will be submitted to DMS. Finally, only a portion of this DMS data is reported to the DMS data clients.

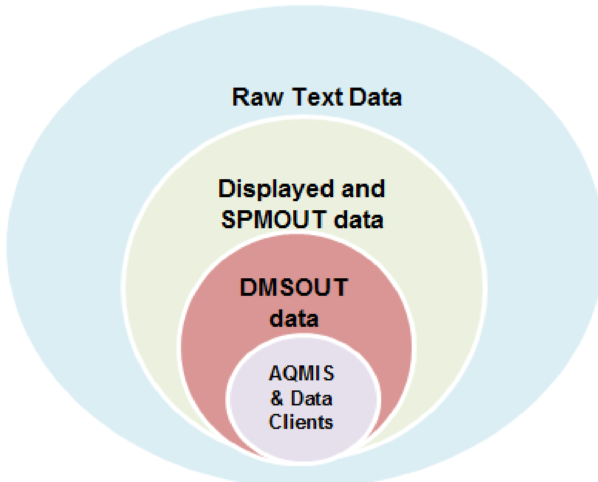


Figure 5.2: Venn Diagram of data collected by CL.

To report data to DMS, the following conditions must be met (as this requirement is enforced by AQSB for system integrity):

- The driver which corresponds to the instrument collecting the data must be properly configured and running.
- When CL is running, the required data from each instrument data channel must have been displayed on the Display Channels screen.
- If flagged data is required, either the calibrator driver must be running, or the instrument's own driver must provide calibration capabilities.
- The reported data channel must have at least one data label entered in the "dms.cfg" file.

5.4 DMS Configuration File*:*

Note: ODSS typically provides full support for this portion of CL implementation, so an in-depth understanding by the user will not be required but will be documented here.

The DMS configuration file (dms.cfg) is basically a space separated set of rules which describes how each instrument is interconnected. The station manifold to which the instrument is connected, the sampling latency of an instrument, and the way that DMS has been configured to accept data are all expressed in this configuration file.

For instance, during a calibration sequence, for CL to know that the sulfur dioxide (SO2) parameter must be flagged invalid while an ozone calibration cycle is running, CL must know that the SO2 instrument is connected to the same manifold, and it must also know that the running calibration phase is unrelated to any calibration routines used by the SO2 instrument.

Although the dms.cfg file is space separated in CL, we will use a table here to discuss the various values and the impact they will have on the data being reported to DMS. We will also add a line number column here to allow for ease of reference.

Note: If any line of the dms.cfg file has a pound (#) sign in front of it, it means that line will be ignored from execution.

Table 6: Tabular View of the DMS.CFG Settings.

Line Number	Data Label	DMS Label	Zero	Span	Prec.	Minute Offset	Manifold System
1	NOX=	NOx	11,21	12	22	0	1
2	NO2=	NO2	11,21	13	23	0	1
3	NO=	NO	11,21	12	22	0	1
4	O3=	O3	11,21	14	24	0	1
5 (Environics)	RECOV=	RECOV	15,25	--	--	0	1
6	5020_SO4=	SO4	31	--	32	15	3
7	BAM1=	BAM10	--	--	--	60	9
8	BAM2=	BAM25	--	--	--	60	9
9	BAM3=	BAM25 a	--	--	--	60	9
10 (Sabio Only)	RECOV=	RECOV	66	--	--	0	1

To illustrate how this works altogether, consider a single standard autocalibration routine for an ozone instrument, a NOX instrument, and a BAM1020. We will show the collective calibration, and then dissect each calibration for each instrument in terms of the portions of the dms.cfg file that affect it. Refer to Figure 5.3 below.

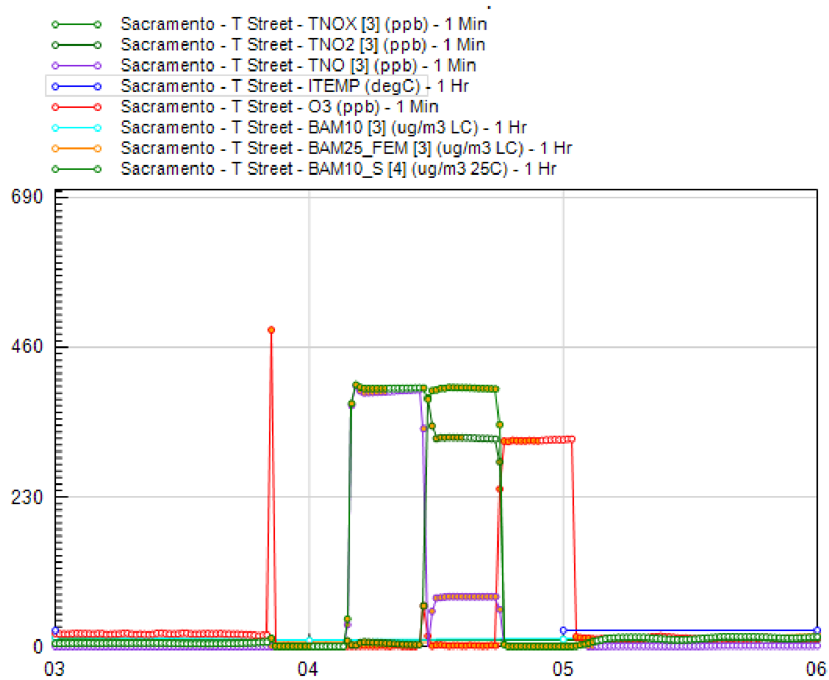


Figure 5.3: Sample Calibration Data Capture from DMS.

The line entered in the dms.cfg file for the ozone channel for the above graph reads as follows:

O3= O3 11,21 14 24 0 1

- The first value/column "O3=" corresponds to the value on the display of CL. In the raw data record, this tag will appear immediately before the value (for instance O3=4.231). This data tag is added by each driver.

- The second value "O3" corresponds to how the DMS administrator has configured the system to accept the ozone values for your station. In this case, DMS accepts O3 and the identifier for ozone, and in other cases (i.e., in the event of collocation) the administrator may ask the data to be reported with an affixed "_a" in which case the second value would become "O3_a".

- The third value/column represents a comma separated list of sequence and step combinations which should be recognized as "zero" gas. In this case, sequence 1 step 1, and sequence 2 step 1 are both zero gas for steps for Ozone, or "11,21". For more information, refer to Sabio 4010 SOP section 10.2.

- The fourth value/column represents a comma separated list of sequence and step combinations which should be recognized as “precision” gas for this instrument. For more information, refer to Sabio 4010 SOP section 10.2.

- The fifth value/column represents a comma separated list of sequence and step combinations which should be recognized as “span” gas for this instrument. For more information, refer to Sabio 4010 SOP section 10.2.

- The sixth column tells CL the number of minutes that this instrument reports data in arrears, so it will compensate for that time shift relative to the calibration states of other instruments. In other words, this column shows the offset between CL time and true data time. The offset is negative by default, so, for example, BAM data collected in hour 11 represents data for hour 10, resulting in a 60-minute offset.

- The seventh column represents the station manifold or system that an instrument is connected to. If an instrument on system 1 lacks any entry for a sequence and step combination recorded by another instrument on that system, it will be automatically flagged as invalid. Conversely, if an instrument is on a different system/manifold from an instrument which is denoted as using that sequence and step combination, it will not be marked invalid. Any parameter which shares the same system as any other parameter will have its data points flagged invalid when any of the sequence step combinations specified for the other instrument are running. The obvious exception being when that parameter also has the sequence and step flagged as a calibration.

- Note that the presence of RECOV= (line 5) will cause all parameters attached to station manifold number 1 (line 5, field 7) to be flagged invalid for sequence/step 15 and 25. Since there is no data labeled RECOV= in the raw text, no data is ever actually reported. Any sequence and step combination which lacks mention in the dms.cfg file will not be reported for the duration of that sequence and step.

Note: Replacement of an existing instrument with the same instrument (same make and model) does not require any updates to the dms.cfg file. The configuration update is performed only when there is a change in the monitoring equipment setup, such as instrument removal, instrument upgrade, and collocated unit addition, etc.

6.0 REMOTE CONNECTION AND CONTROL

A major benefit of CL is the ability to control the logger remotely. A remote connection to CL allows users to control the logger from the office as well as connect to any instrument connected to CL. To remote into CL, you will need to have the PuTTY and UltraVNC applications installed on your PC.

PuTTY is an application that is used to create a secure, encrypted tunnel between the user and the field CL.

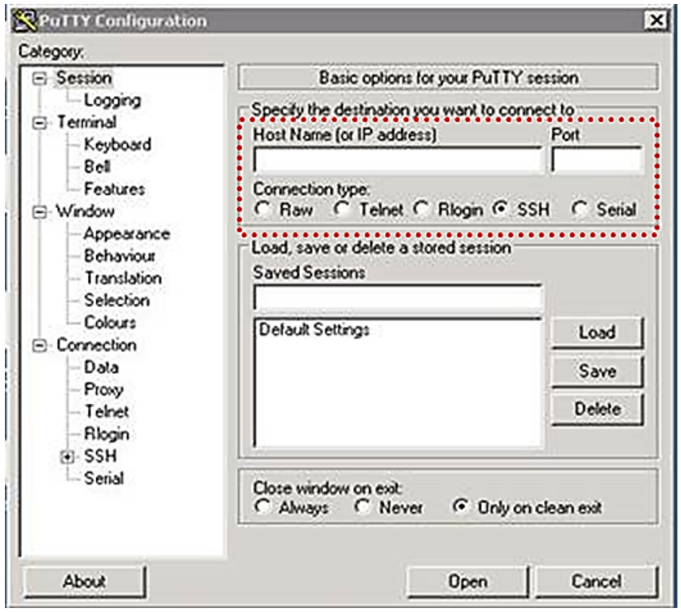
UltraVNC is a powerful, light weight, graphical remote-control application like the Microsoft Remote Desktop.

Note: If you do not have PuTTY and UltraVNC on your work computer, please refer to the Software Center to install these applications onto your PC.

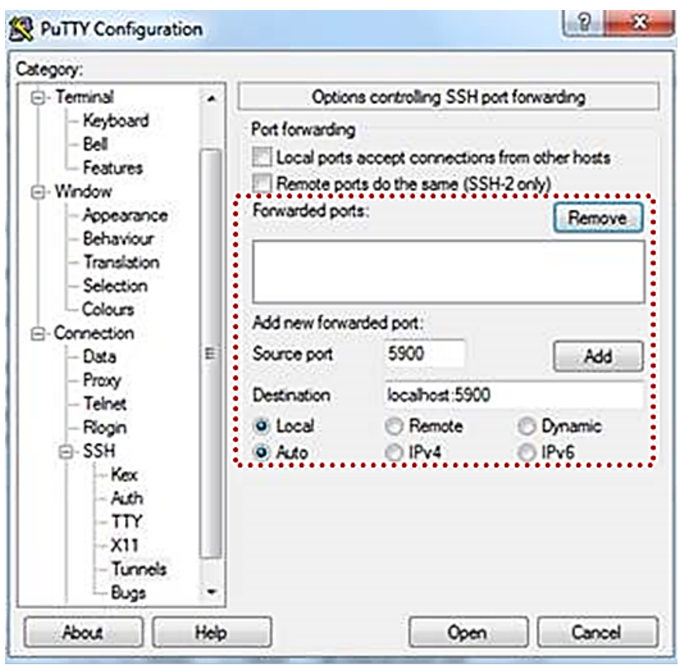
The procedures in Table 7 describe how to remotely connect to CL. If you experience any difficulties, please contact ODSS staff for assistance.

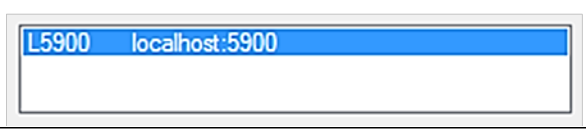
Table 7: Remote Connection to CARBLogger (via PuTTY and UltraVNC).

<table>
<tr><th>Step:</th><th>Screenshot:</th></tr>
<tr><td>
Start PuTTY by clicking the icon on your desktop or selecting the application from the Start menu.
Specify the destination by entering a CL IP Address in the Host Name (or IP address) text box.
The default port number will be 22. Change the port number to 242.
</td><td>



</td></tr>
<tr><td>
In the Category panel select Connection, SSH, and then Tunnels. (You may need to hit the + to expand menu.) This will open the "Options Controlling SSH Port Forwarding" window.
Enter this information to the <u>Add New Forwarded Port</u> section and click Add:
Source Port: 5900
Destination: localhost:5900
If done correctly, the blank text box labeled <u>Forwarded Ports</u> will then automatically populate a new entry, "L5900 localhost:5900".
</td><td>

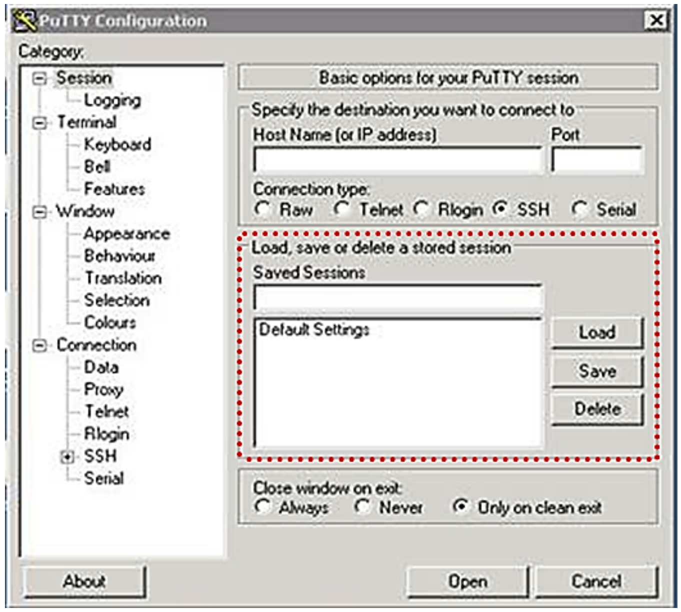




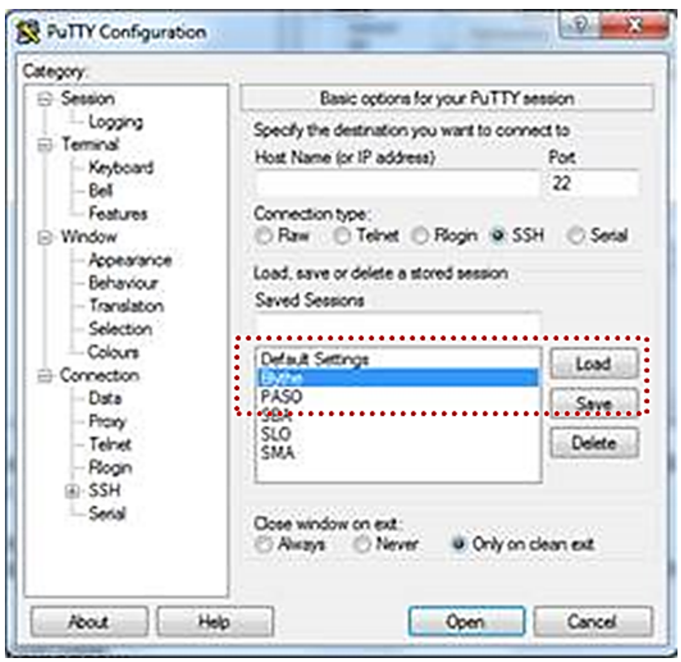
</td></tr>
</table>

<table>
<tr><th>Step:</th><th>Screenshot:</th></tr>
<tr><td></td><td></td></tr>
<tr><td>Scroll the Category panel back up and select Session.

Type CL station name (or any name of your preference) into the <u>Save</u> Sessions text box and click Save.

The configuration for your CL Station Connection session will now be saved.</td><td>
</td></tr>
<tr><td>You may initiate the connection now, or restart PuTTY from your desktop if you have closed this application before.

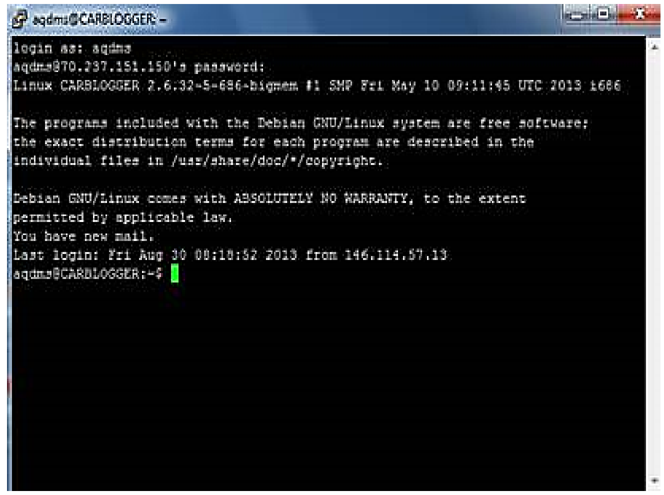
Select the saved profile, click Load, then Open.

You will now be connected to your CL destination.</td><td>
</td></tr>
</table>

<table>
<tr><th>Step:</th><th>Screenshot:</th></tr>
<tr><td>Once connected to the station CL, a terminal shell will appear.

Type in aqdms at the "login as:" prompt. Hit "ENTER".

At the "password" prompt, enter the station's CL password. For specific site CL password, please contact ODSS.

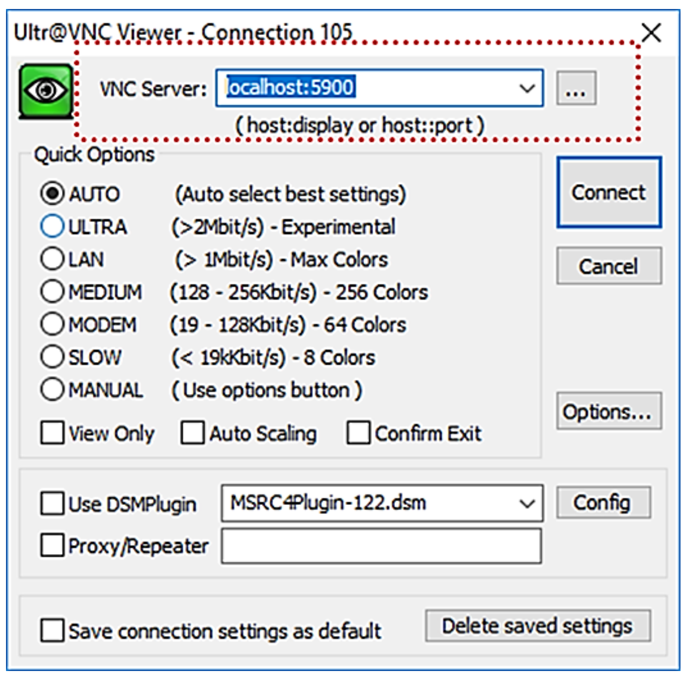
Note: Password entry is masked and invisible to user.</td><td>
</td></tr>
<tr><td>Start VNC by clicking icon on the desktop or selecting it from the Start menu.

In the <u>VNC Server </u>text box enter:

localhost:5900

Then hit Connect.

A remote desktop screen will appear for control of the station's CL.

Note: The VNC server setting will be saved automatically for the next time the VNC is used.</td><td>
</td></tr>
</table>

Once the remote desktop screen has appeared, users may now control the station's CL as if they are sitting in front of that station's computer.

Note: Users may choose a different connection speed setting for the remote connection session if the site's connection speed does not allow broadband connection. For issues about Internet connection equipment, please contact OIS for assistance.

7.0 BACKFILLING

If CL drops, or becomes disconnected from one or more instruments, a gap in the data will appear for the affected instruments. In most cases, this is addressed by obtaining raw data from the instrument's internal data logger (if available), reformatting it for DMS ingest, and sending the formated data to DMS for ingestion.

This process is called Backfilling, and is typically accomplished with the following steps:

1. Establish a digital connection to the instrument via a computer.

2. Query and download the raw text data in its native format for further processing.

3. Reformat the data into a DMS native file format.

4. Transmit the data to the DMS ingest server, or use the DMS client to import the data file. This step is normally performed by ODSS staff.

If the instrument is connected via ethernet or serial port to CL, all four of the above steps can be accomplished remotely and securely from the remote CL X-server console.

When backfilling data using raw data imports:

1. Minute data flagging for calibrations or "offline" states will normally NOT occur on these raw text data.

2. The time stamp obtained from the instrument's internal data logging system is less accurate than CL, unless the instrument has NTP services available.

In the graph below (see Figure 7.1), the red trace represents a correctly timestamped (NTP synchronized) data stream, while the light orange trace is taken from the raw text data on the same instrument with an internal clock that was 7 minutes slower.

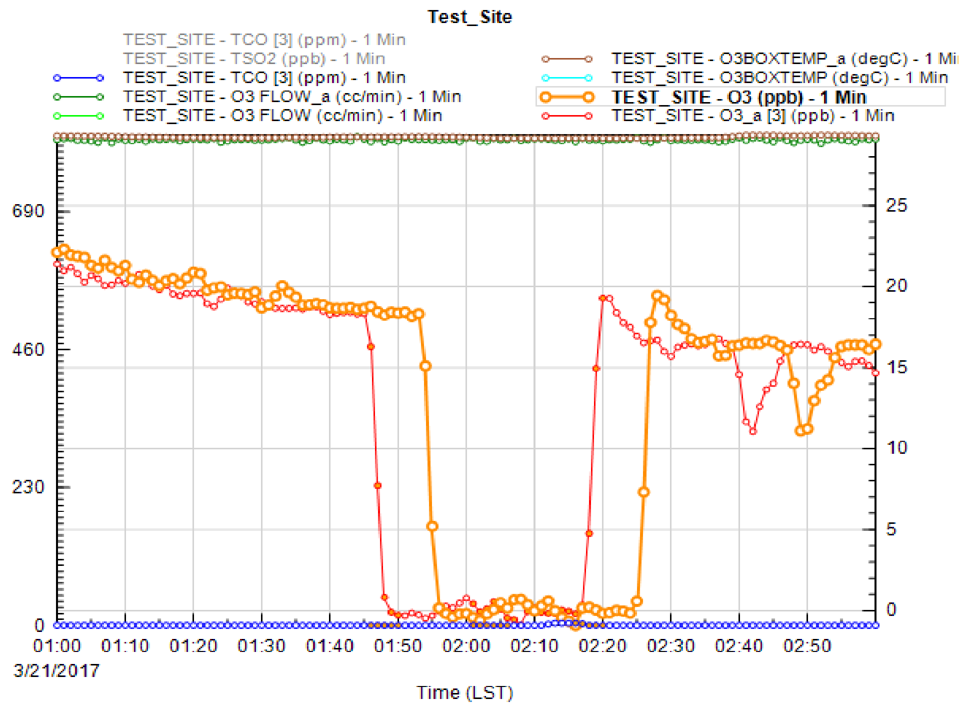


Figure 7.1: Sample Data Time Stamp Issue from Backfilling

Note: It is important to maintain the instrument's onboard clock if data must be backfilled.

In appendices D and E from this SOP, we have provided details on two frequently used examples (APIT400 and BAM1020) for data backfilling from instruments. For further understanding on how backfilling is performed, please refer to these appendices.

8.0 ROUTINE SERVICE CHECKS

8.1 General Information:

This section applies to the latest production version of CL, operating on either a Raspberry Pi or the Dell R440/R430/R620 server chassis. Since these form factors are industrial grade servers, regular maintenance needs to be applied to the hardware, the file system, operating system, applications, and CL code base.

8.2 Daily Checks:

Each morning, confirm that the DMS status screen for your station and instrument parameters appear green and that you have received CL errors and alert summary emails.

If on site, view CL in the data display screen, and confirm that all collected parameters appear black.

For instructions on how to check the DMS status for your station, please refer to the DMS SOP document.

8.3 Weekly Checks:

Confirm that NTP processes are properly functioning by comparing the clock on CL desktop to your cell phone or some other time standard. If they do not match, please contact ODSS staff for assistance.

For the Dell server chassis, if the “bezel” display on the front of the server appears orange or amber, (alternatively, confirm that the background of the display is not blue), please make a note of any error messages that appeared, and then notify ODSS staff immediately.

Check CL data display screen and confirm all parameters appear black.

8.4 Bi-weekly Checks:

The servers on which Dell CL run have hot-pluggable, RAID 1 disk configurations. As a result, it is possible that one disk may fail, while data clients remain unaware. It is critical that such a condition is detected early so that the compromised disk can be rebuilt.

Remove the front face of CL once per month and confirm that the lights on each of the two disk drives are intermittently green. If one of the disks has amber status lights, contact ODSS staff immediately to obtain a replacement hard drive or have the current one rebuilt.

8.5 Monthly Checks:

Pay attention to the data drive disk space value from the nightly email summary you receive. If the data drive gets larger than 200 GB, the data drive may need to be cleaned up. Notify ODSS staff for this maintenance task.

The servers on which CL run have redundant power supplies. If one fails, a text message may appear on the LCD display indicating the loss of a power supply. Alternatively, look at the LEDs on each power source on the back of the chassis to confirm that both lights on both power supplies are steady green. If you find that either of the power supplies has failed, contact ODSS staff immediately for a resolution.

8.6 Annual Checks:

Remove the cover of CL chassis and blow out the inside with clean, dry, compressed air.

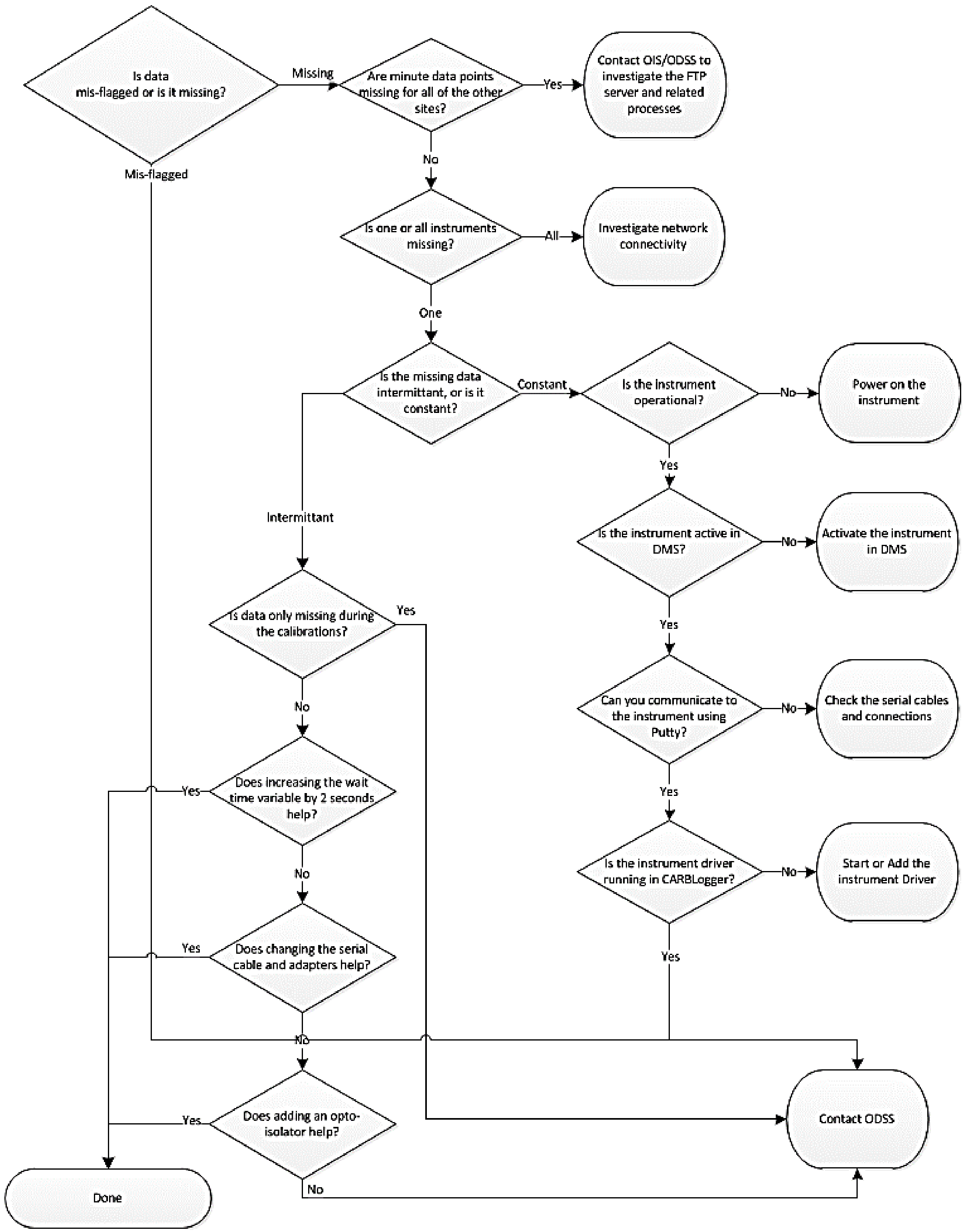
For purposes of data continuity and system security, most CL system updates and manufacturers released firmware updates are not applied until they have been fully vetted on the test site by ODSS staff. These updates would normally be applied annually and by ODSS staff or OIS staff only.

9.0 GLOSSARY/LIST OF TERMS

Term	Description
Back poll	Process the raw text data to generate DMS data files or obtain raw text data from the instruments and convert that into DMS formatted data.
Calibration Flagging	AQSB air monitoring stations use auto-calibrators which control the station calibrations. The sequence and step number of each calibration routine determines how data get flagged for DMS. If you remove or change a sequence, refer to the "Update the DMS.CFG file" procedure to reflect your station changes in the dmsout process. If you forget to do this or do it after the fact, you may use DMS to change your calibration flagging later.
Driver	CL is a collection of mini data-loggers (or drivers), with each driver designed to acquire data from a particular instrument. CL interface allows runtime parameters for each driver to be edited and for the drivers to be started or stopped.
DMS	Data Management System (DMS) is a Structured Query Language (SQL) database used to process, analyze, and store ambient air quality data. A reporting mechanism for DMS which converts the raw text stored by CL into flagged data for ingest by DMS was written. To use this process users would need to update the dms.cfg file.
Dms.cfg	Dms.cfg is a file used by the Dmsout process to calculate automatic data flagging for DMS.
Dmsout	Dmsout.sh is the reporting process which was developed to produce flagged one-minute data for DMS.
Ingest	CL natively stores all data as raw ASCII text. Ingest is the term used to describe the process of pulling this raw text into a database. The advantage of ingesting data into a database is that much more complex data analysis procedures can be run against the data.
Interface	This is the portion of CL that allows users to easily configure and control drivers. For most users, this is the only portion of CL they will need to be familiar with. Refer to section 3.2.
Instrument and/or Channel	The term "Instrument" is used interchangeably with the term "Channel". All the data collected from a single instrument is collectively referred to as a channel. In the "Display Channels" screen, a single channel will share a common instrument name. Refer

Term	Description
	to section 3.8. For example, the NOX channels all came from the "Thermo42iQ" driver.
NTP	Network Time Protocol (NTP) is used by CL to keep its clock synchronized with NIST time servers. In this way, the time stamp affixed to raw data is kept accurate and precise. Typically, we use NIST time servers and are set to GMT -8.
Raw Data	CL acquires raw text from all instruments and, for the most part, records it "as is" in ASCII format. The only modification it makes is to prepend the time and date stamp obtained from the NTP server. The data from every parameter and instrument is stored in plain text. This is referred to as "Raw Data".
Root Terminal	A root terminal, much like a normal terminal, is simply the Linux analog of the "DOS prompt", except that it is being run as the local administrator. ODSS staff may ask you to perform some operations using this method. To access the root terminal, you will click on Applications/Accessories/Root Terminal. You will be prompted for the root password, for this CL.
Spmout	Spmout.sh is one process which runs a report against the on-board CL MySQL database to produce a text based, CSV formatted pivot table of all data from any CL for the previous day. Station operators receive a rollup of the previous days' worth of data in this format each morning via email. Unlike with Dmsout, any null values will yield a zero.
Terminal	CL is operating on a Linux Operating System (OS). The terminal (or shell) is analogous to the "DOS prompt" in Windows. On the server versions of CL, you can open a terminal by double clicking on the "CL" icon located on the desktop.

Appendix A: TROUBLESHOOTING DIAGRAM



Appendix B: CARBLOGGER MAINTENANCE CHECK SHEET

AQSB MONTHLY QUALITY CONTROL
MONTHLY MAINTENANCE CHECK SHEET 605
CARBLogger

Location: ____________________ Month/Year: ____________________
Station Number: ______________ Technician: ____________________
Property Number: ______________ Agency: ______________________

Dates				
NTP Check				
All Values Black				

Operator Instructions:

1. Daily: Review data status in DMS.
2. Weekly: Confirm all data "black" and on time.
   Confirm that the clock on the CARBLogger matches a time standard. If it does not, contact CARBDMS TEAM.
3. Bi-weekly: Date: _____ Drive one color: ____ Drive two color: ____
   Date: _____ Drive one color: ____ Drive two color: ____
4. Monthly: Power Supplies: ___________
5. As Needed: CARBDMS TEAM maintenance performed _________

Date	Comments/Maintenance

Reviewed by: ______________ Date: ______________

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Appendix C: INSTRUMENT COMMUNICATION CONFIGURATION

RS-232

After the site settings have been confirmed, take the following steps to ensure that each connected instrument has been properly configured.

- Connect the instrument to an empty serial port on CL squid (8-Port Serial Cable) or empty port on the network switch.

- If the serial card is a Perle variant, the serial port your instrument is connected to will be assigned /dev/ttyPS[x], where x is one less than the number tag on the cable. On the virtual layer, port number starts off from zero, or ttyPS0.

- If the serial card is a StarTech variant, ensure that CARB applied labels are present. Due to the manufacturing process, /dev/ttyS[x], is used instead.

  For example, if instrument is connected to cable number 6, this means that the computer port we need to speak to is /dev/ttyPS5.

- Follow the instrument operations manual specific to your instrument to activate the serial port and set the baud rate.

- From the Gnome/CL desktop choose **Applications/Internet/PuTTY SSH Client**. Refer to Figure C1 below.

- Tick the **Serial** radio button, or the telnet button for an ethernet connected device, and enter in the serial port and baud rate of the device you wish to communicate with, then press on the [Open] key. Refer to Figure C2 below.

- After you have successfully managed to communicate with the instrument of interest, make a note of the communication settings being used. These are the settings to be entered into CL interface as detailed in the Add Instrument configuration section (Sections 3.4 and 4.3).

WARNING: Be sure to close this PuTTY session before attempting to have CL communicate with the same serial port. Failure to close any serial program running on any serial port will cause CL to experience a gap in data communications for as long as the program remains open.

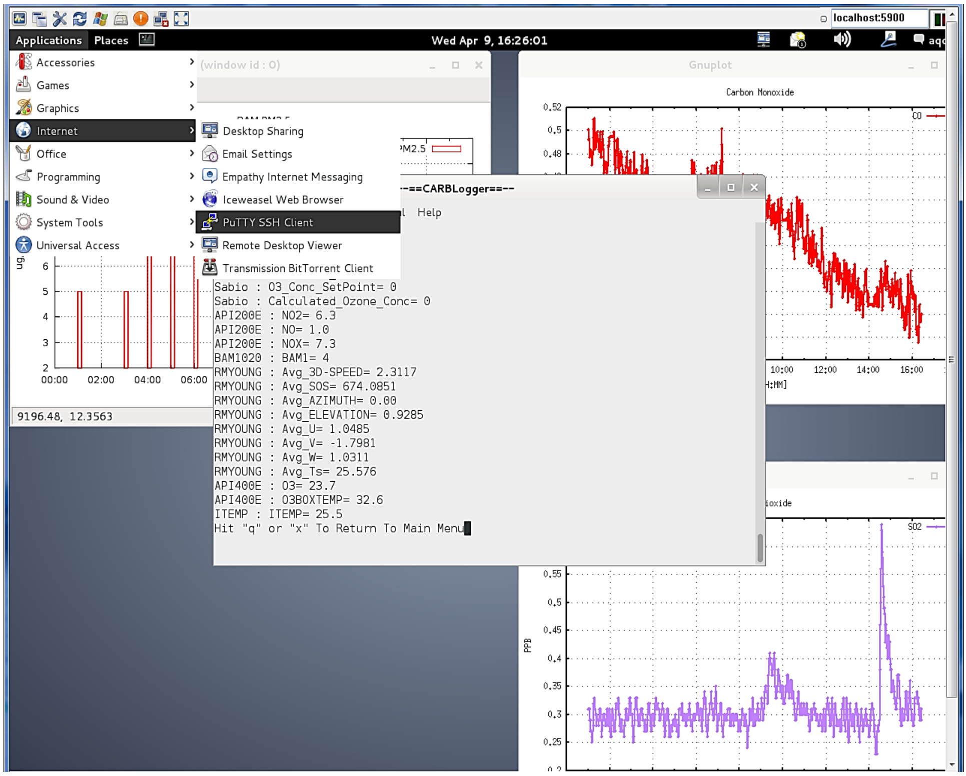


Figure C1: Locating the PuTTY SSH Client

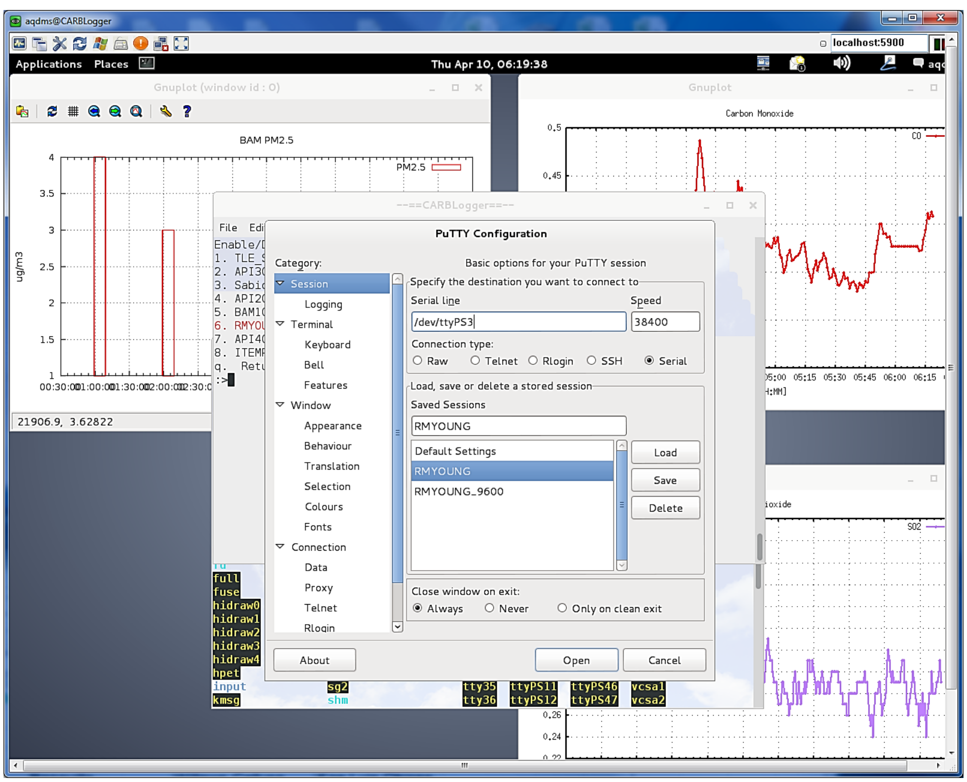


Figure C2: Setting up the PuTTY SSH Client

Additional information for PuTTY SSH Client Configuration:

- **Ready to Send/Clear to Send (RTS/CTS) flow control** should be set to OFF on all instruments. A limitation of the Perle Ultra Serial card driver (as installed in CL chassis) is that all serial connections either must uniformly use RTS/CTS. It is not possible to connect two instruments to the Perle serial card if one requires RTS/CTS and the other does not, without experiencing connectivity issues. If an instrument must have RTS/CTS enabled, please use the chassis serial port in the back of the unit (/dev/ttyS0). You may choose this serial connection from CL by choosing "/dev/ttyS0".

  Finally, if you have more than one instrument requiring this flow control, it will be necessary to have ODSS staff recompile the Perle driver, and you will have to confirm that all instruments being monitored have this serial attribute enabled for each Perle serial card used.

- **Baud Rate:** The most tested baud rate in our network is currently 9600, although CL and instruments can use various baud rates. As a rule, the longer the serial cable and the higher the baud rate, the more errors that data transmissions are likely to contain. Because we have used this baud rate for various instruments at lengths exceeding 300 feet (well beyond the published specifications for RS232), we recommend using 9600 unless there is a requirement for doing otherwise.

- **Firmware Versions:** Most CL drivers have been written using the currently available firmware, as the instrument was configured at the time that the driver was written. If you are applying an update to an instrument's firmware or changing the configuration of an instrument which was not used at the time that CL driver was written, monitor your raw data output closely. Changes in firmware or internal data logger configuration can cause changes in the unit's slope, offset, and error handling procedures used to report data.

Ethernet

After the site settings have been confirmed, take the following steps to ensure that each connected instrument has been properly configured.

- Connect the instrument to an empty port on the network switch.
- The IP addresses of the instruments have been standardized. See table below for the default IP address and port number.

Instrument	IP Address	Port
TAPI T703	172.16.0.7	3000
THERMOS 42i	172.16.0.5	N/A

THERMOS 43i	172.16.0.15	N/A
TAPI T400	172.16.0.4	3000
TAPI T300	172.16.0.3	3000
BAM	172.16.0.10	7500
BAM (collocated)	172.16.0.11	7500

- From the Gnome/CL desktop choose **Applications/Internet/PuTTY SSH Client**. Refer to Figure C1.

- Tick the **Telnet** radio button and enter in the serial port and baud rate of the device you wish to communicate with, then press on the [Open] key. Refer to Figure C2.

- After you have successfully managed to communicate with the instrument of interest, make a note of the communication settings being used. These are the settings to be entered into CL interface as detailed in the Add Instrument configuration section (Sections 3.4 and 4.3).

WARNING: Be sure to close this PuTTY session before attempting to have CL communicate with the same serial port. Failure to close any serial program running on any serial port will cause CL to experience a gap in data communications for as long as the program remains open.

- Some ethernet instruments cannot communicate with PuTTY; an alternate option is to use Ping. From CARBLogger desktop, open a terminal. Type “ping” and the default IP from the table above. For example, to ping a TAPI T400 –

(type into terminal) `ping 172.16.0.4`

(response)
```
PING 172.16.0.4 (172.16.0.4) 56(84) bytes of data.
64 bytes from 172.16.0.4: icmp_seq=1 ttl=128 time=0.547 ms
```

If the instrument cannot be found on the network, the following response will display. Call ODSS for assistance.

```
PING 172.16.0.44 (172.16.0.44) 56(84) bytes of data.
From 172.16.0.99 icmp_seq=1 Destination Host Unreachable
```

Appendix D: BACKFILL DATA APIT400

If a data logging system becomes disconnected from the instruments in a station, it becomes necessary to acquire raw data from the instrument's internal data logger and convert it into a format that DMS could ingest. In the below site, data acquisition stopped between 20:00 and 08:00. While the techniques needed to modify raw data are not discussed here, we demonstrate backfilling data from the APIT400.

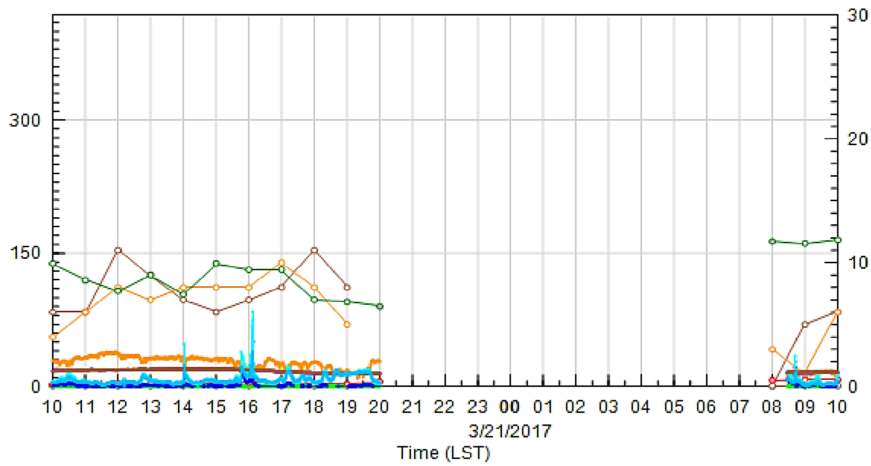
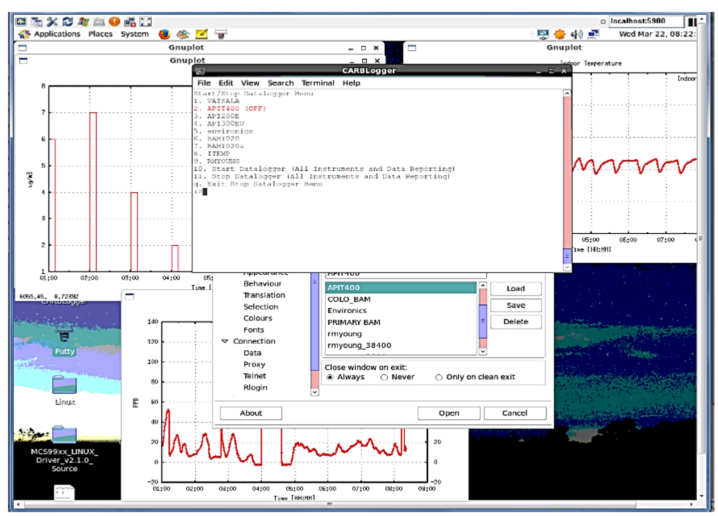
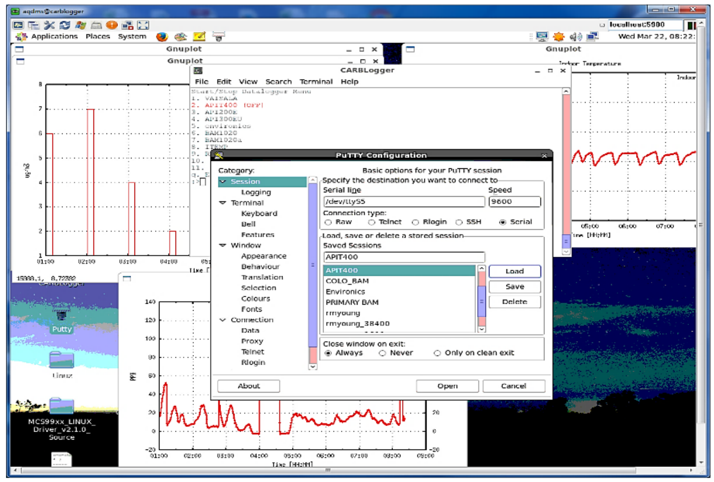
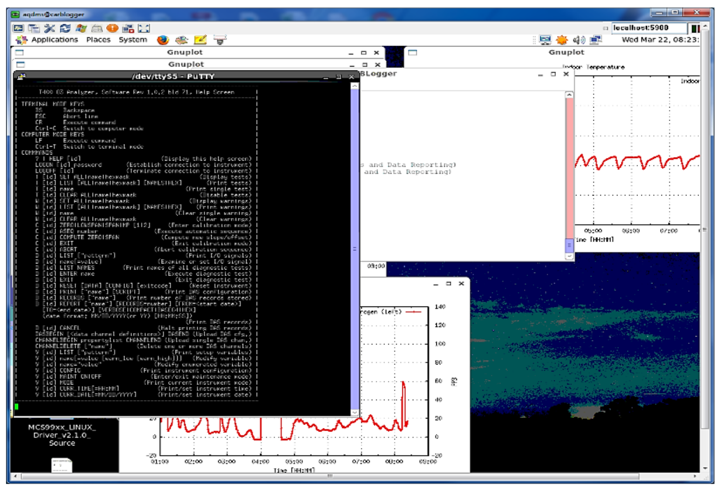
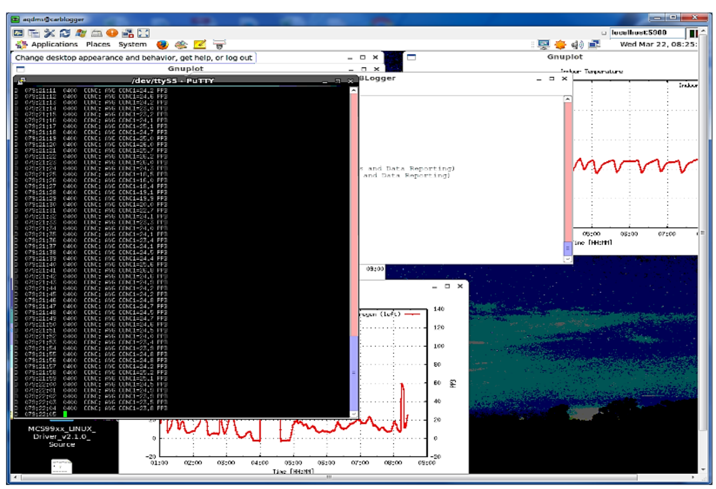
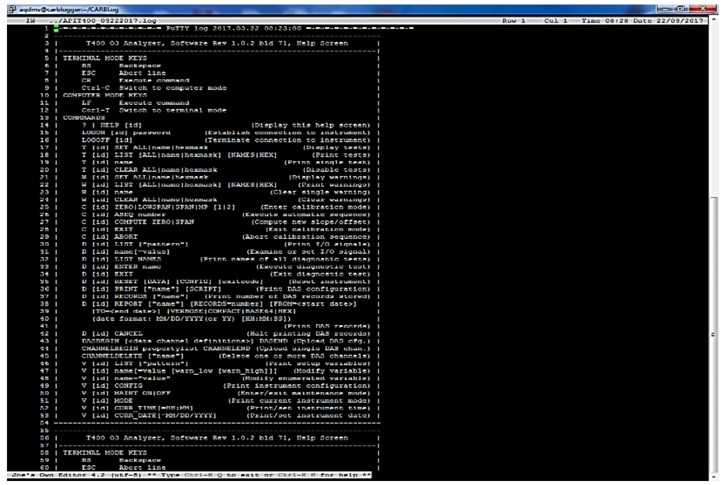
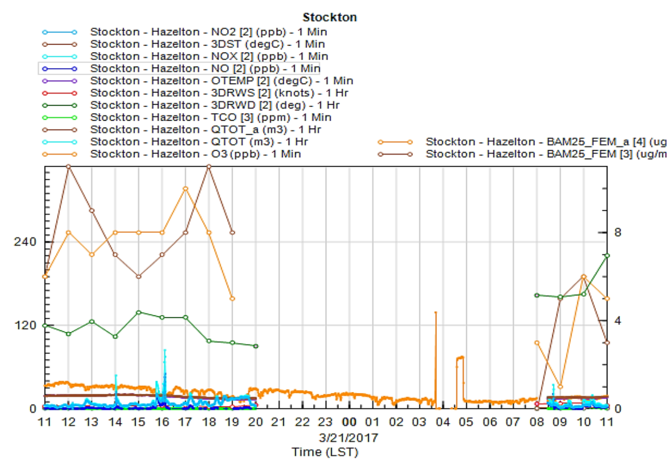
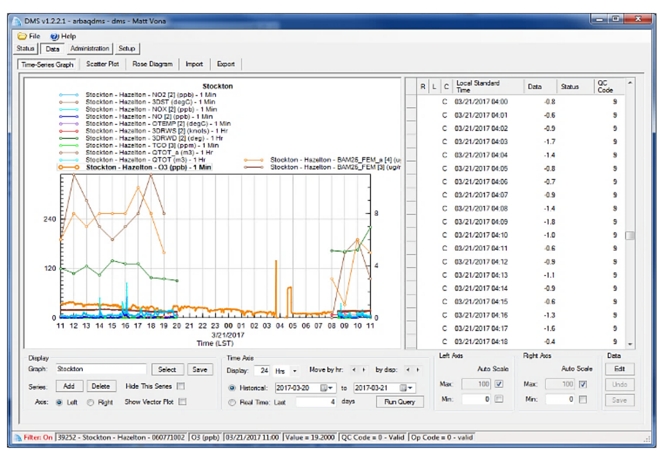


Figure D1: Data gap between 20:00 and 08:00 hours

Step:	**Screenshot:**
Since the instrument and driver are using a serial port, it is necessary to first stop the driver from the Start/Stop Instruments/Datalogger menu.	

Step:	Screenshot:
Open PuTTY or some other serial capable program, and connect to the instrument. Be sure to configure the program to record your session.	
Query the instrument's internal data logger.	
After the data has been downloaded, close the serial client and restart the driver.	

Step:	**Screenshot:**
Edit the downloaded data (in this case) by removing the headers and any non-data containing lines.	
Run the script against the data, and check DMS in 15 minutes. *Refer to Section 7.0 for what script to use.	
Mark any calibration periods as invalid, or as calibrations, so as to preserve real time data exports.	

Appendix E: BACKFILL DATA MET ONE BAM1020

When back filling data from any instrument, it is necessary to be familiar with both the instrument and the in-situ configuration of its data logger. The BAM25 has customizable data labels, the ability to record data in either micrograms per cubic meter or milligrams per cubic meter (on some models), and which columns to capture, among other localizable variables. The slightest change to this configuration can have dramatic consequences to accuracy and functionality of scripts, spreadsheets, or other mechanisms used to prepare data for DMS ingest.

Below is an example of data taken from the internal data logger of a Met One BAM25 as configured in Site A:

Time,Conc(mg/m3),Qtot(m3),WS(KPH),WD(DEG),IT(C),RH(%),Delta(C),AT(C),E,U,M,I,L,
R,N,F,P,D,C,T,
03/20/17 00:00,0.007,0.700,61.1,4.4,4.4,26,0.468,14.0,0,0,0,0,0,0,0,0,0,0,0,0,

Below is an example of data taken from the internal data logger of a Met One BAM25 as configured in Site B:

Time,Conc(mg/m3),Qtot(m3),WS(KTS),WD(DEG),IT(C),RH(%),Delta(C),AT(C),E,U,M,I,L,
R,N,F,P,D,C,T,
03/20/17 00:00,0.007,0.700,61.1,4.4,4.4,26,0.468,14.0,0,0,0,0,0,0,0,0,0,0,0,0,

Any automated process which expects the fourth column title to be (KPH) instead of (KTS) may fail, depending on how it is written, and vice versa.

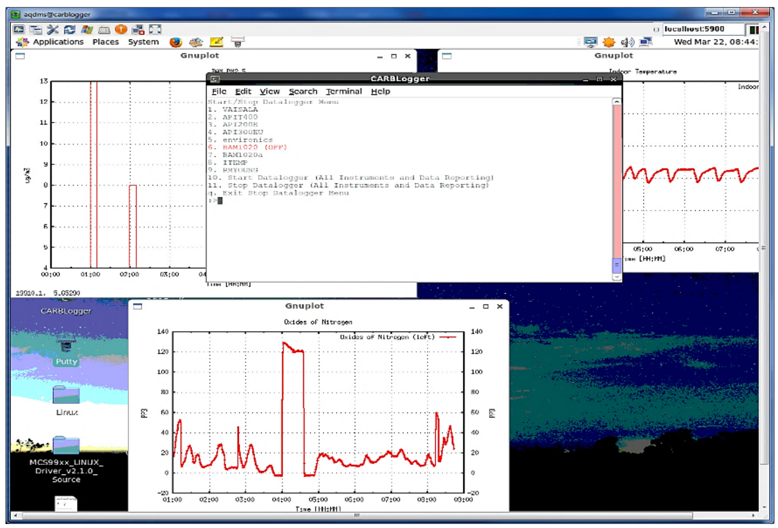
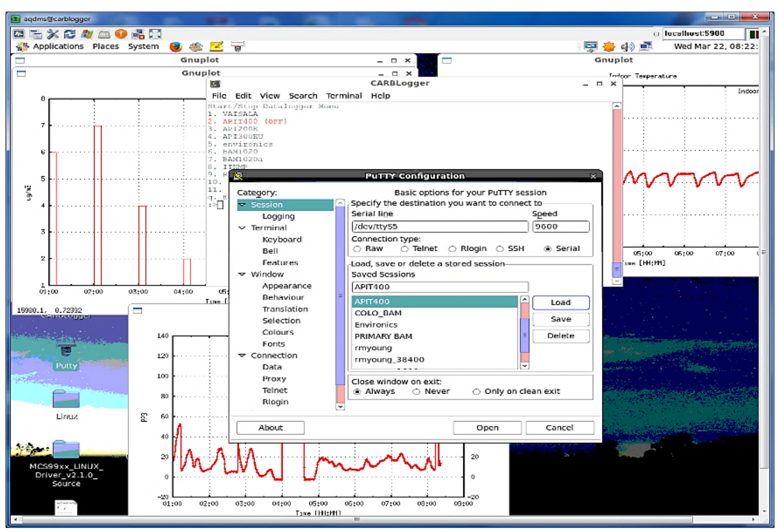
At the time of this writing, DMS records and reports PM2.5 data in micrograms per cubic meter, while all BAM samplers in the network presently store this data in milligrams per cubic meter. As such, backfilling this data will require multiplying the "Concentration" value by 1000 prior to submitting to DMS.

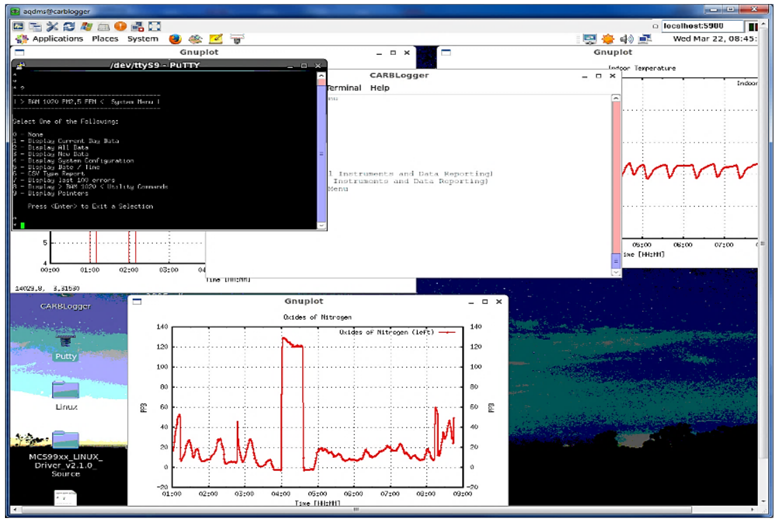
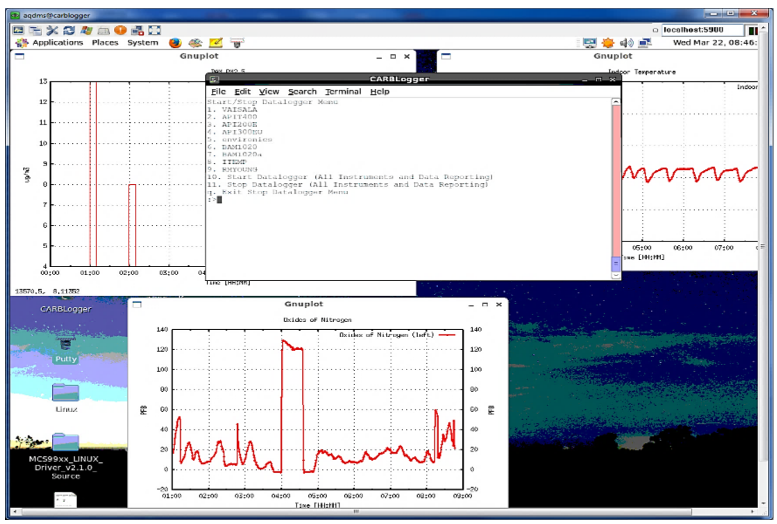
If any of the last error columns contain a one, it may indicate an error condition for that hour. For this reason, it is advisable to invalidate or qualify (mark an Op code of 5) any data collected for any such hours.

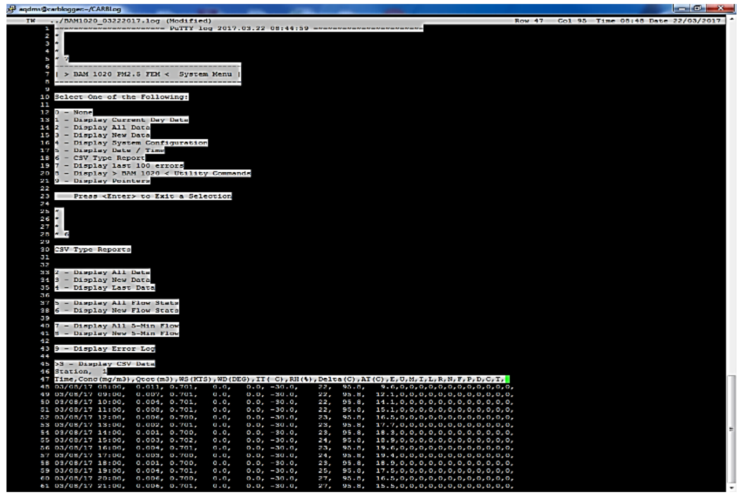
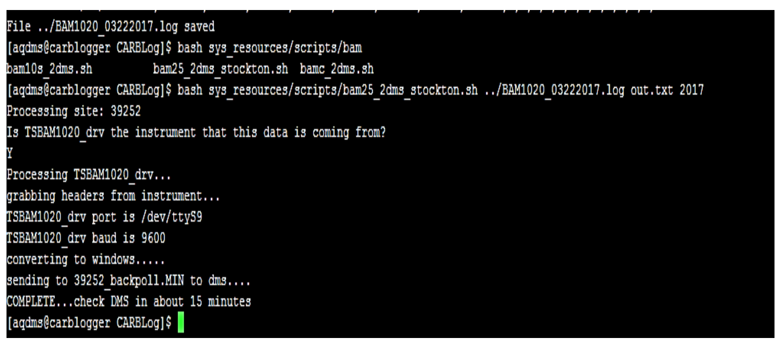
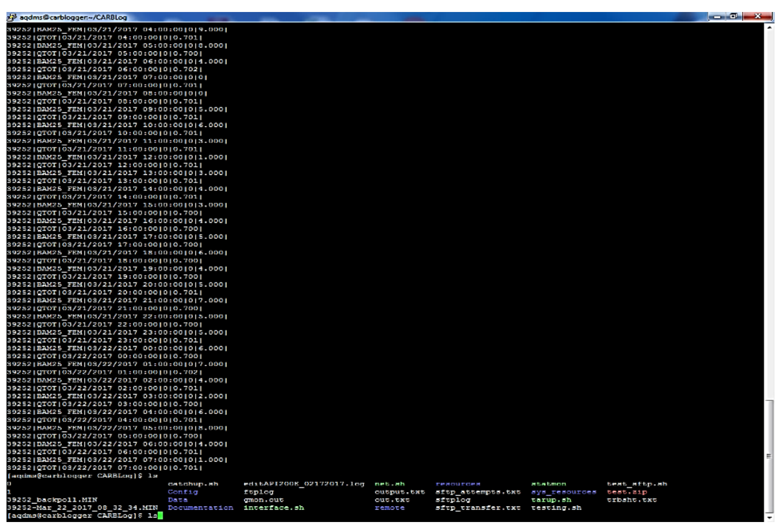
The internal date stamp in the raw data is applied by the Met One BAM at the time that the previous hour value is calculated, not for the beginning of the hour that the data represents. As a result, any automated mechanism for importing this data needs to subtract an hour from the time stamp. So, in the above example, the correct date stamp *3/20/2017 00:00* should become *3/19/2017 23:00*.

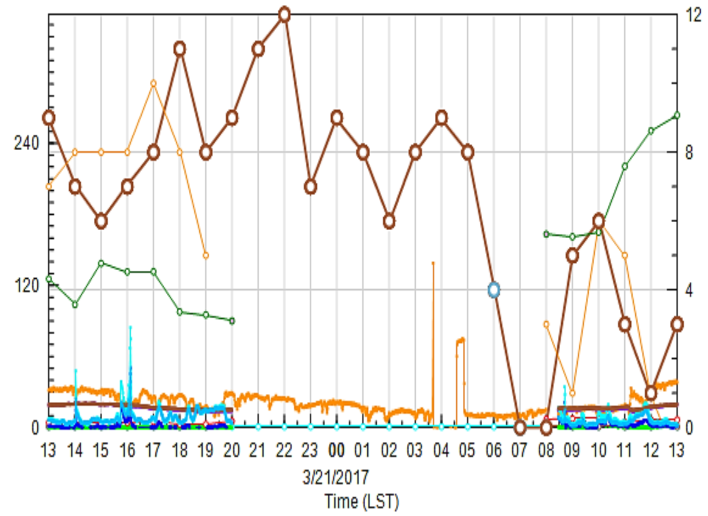
It should also be noted that, over time, these subtleties will be changed by the manufacturer. For instance, on newer BAM samplers, it is now possible to have them store the data in microgram per cubic meter, and to have them date stamp correctly. If these changes are applied, extra care must be considered to change/update all BAM instruments within the network.

In this example, we use a script written by ODSS staff made available on most CL to import raw data from the BAM1020 PM2.5 monitor into DMS.

Step:	Screenshot:
Stop the BAM driver from the Start/Stop Instruments/Datalogger menu on the user interface.	
Open PuTTY or some other serial capable program, and connect to the instrument. Be sure to configure the program to record your session. The BAM1020N communicates via ethernet (Telnet), while the BAM1020 communicates via RS-232 (Serial).	

Step:	Screenshot:
Query the instrument's internal data logger. Download data by pressing 6, 4 to download all new data in a comma separated format.	
After the data has been downloaded, close the PuTTY serial client, and restart the BAM driver.	

Step:	Screenshot:
Edit the downloaded data file by removing all non-data lines. In this case, remove all headers.	
Having downloaded the data from step 4, use the "sys_resources/scripts/bam25_2dms_stockton.sh" script to process the data extract.	
This script performs labeling to the DMS data (i.e., BAM25_FEM, or BAM25_FEMa, or BAM25), and adjusts for site specific data logger alterations.	

Step:	Screenshot:
Check DMS in 15 minutes and confirm that the data has been backfilled.	

Appendix F: LIST OF SOFTWARE DEPENDENCIES

Software	**Additional Information**
Bourne Again Shell (BASH)	http://www.gnu.org/software/bash/
CARBLogger	http://code.google.com/p/carblogger/
Debian	http://www.debian.org
Feed Gnuplot	https://github.com/dkogan/feedgnuplot
GAWK	https://www.gnu.org/software/gawk/
Gnome	http://www.gnome.org
Gnuplot	http://www.gnuplot.info
GoogleCode	http://code.google.com/
Linux	http://www.linux.org
Maria DB	https://mariadb.org/
Mutt	http://www.mutt.org/
Open SSH	http://www.openssh.com/
Sed	https://www.gnu.org/software/sed/manual/sed.html
Sjinn	http://sjinn.sourceforge.net/
WVDial	https://code.google.com/p/wvdial/
X11VNC	https://github.com/LibVNC/x11vnc

Appendix G: CARBLOGGER AND CARB SITE NUMBERS

DMS Site Number	Station Name
03614	Jackson - Clinton Road
04625	Chico - East
04633	Paradise - Theater
04636	Gridley - Cowee Avenue
04638	Paradise - Airport
04641	Paradise - Clark
05633	San Andreas - Gold Strike Road
06646	Colusa - Sunrise Blvd
09691	South Lake Tahoe - Sandy Way
09693	Cool - Highway 193 (seasonal)
09695	Echo Summit (seasonal)
09697	Placerville - Canal Street
10251	Fresno - Garland
11676	Willows - Colusa
13698	Calexico - Andrade Ave
15242	Edison
15243	Oildale - 3315 Manor Street
15248	Shafter - Walker Street
15249	Arvin - Di Giorgio School
15251	Mojave - CA 58 Business
15255	Bakersfield - California Avenue
22742	Yosemite Village - Visitor Center
22744	Jerseydale (seasonal)
31822	Roseville - N Sunrise Blvd
33201	Blythe - Murphy Street
34305	Sacramento - T Street
39255	Stockton - University Park
40850	Paso Robles - Santa Fe Avenue
50568	Modesto - 14th Street
51898	Yuba City - Almond
51899	Sutter Buttes S. Butte (seasonal)
52910	Tuscan Butte (seasonal)
54569	Visalia - W. Ashland Avenue
55930	Sonora - Barretta Street
57577	Davis - UCD Campus

Appendix H: DESCRIPTION OF CARBLOGGER GRAPHS

All graphing capability is built into individual drivers as another data product. Most CL drivers use an open-source command-driven function and data graphing system called Gnuplot (except the RM Young 81000 which uses Python).

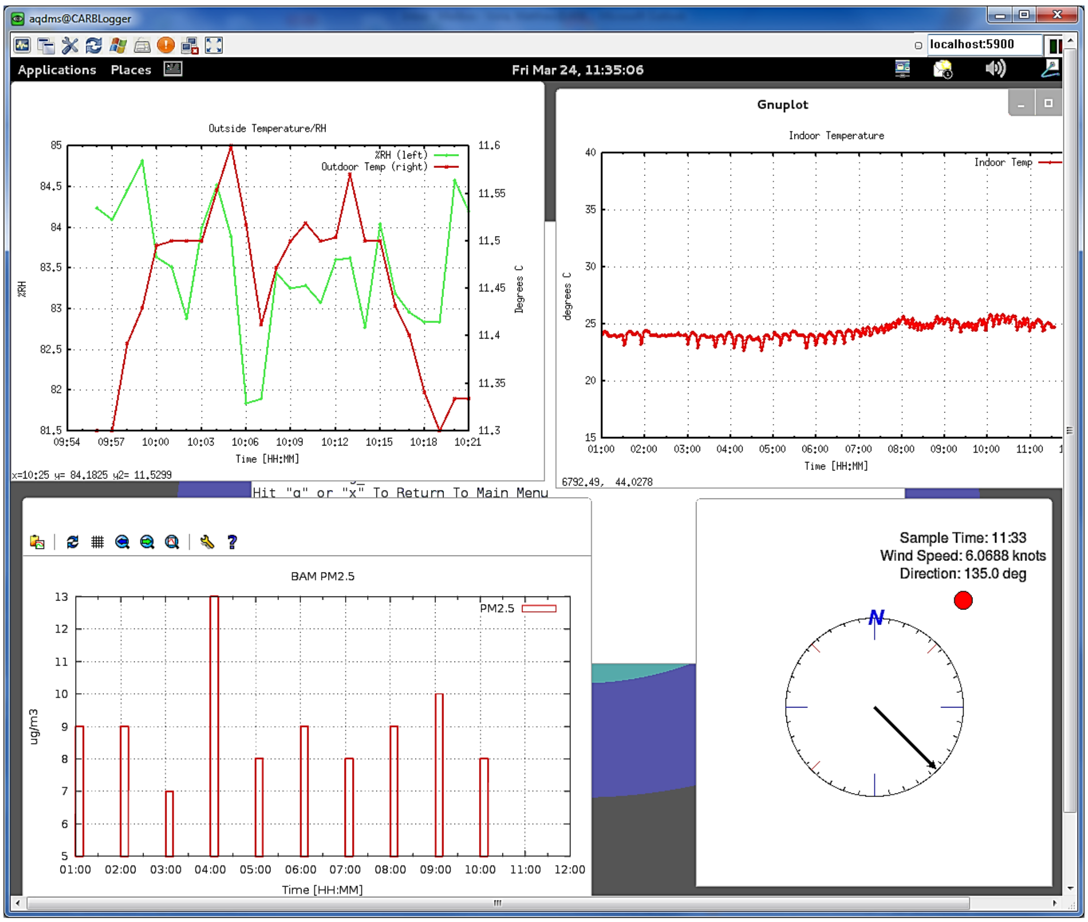


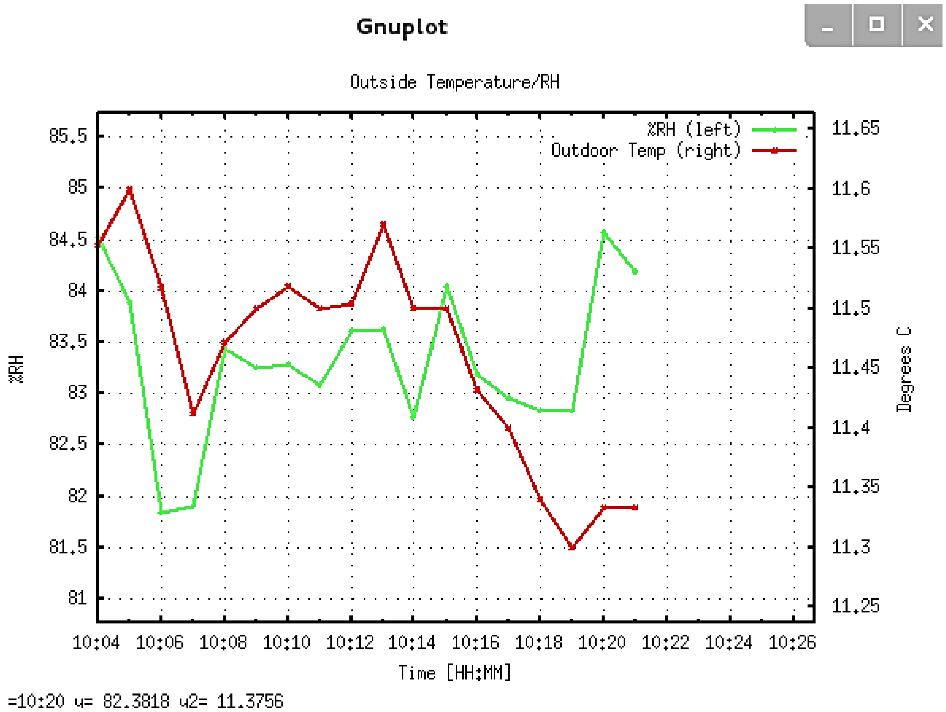
Figure H1: Different Data Visual Displays on CL

By convention, graphs for each instrument start and stop with each driver and plots minute data from 0100 each morning to the current time on the 25th second of each minute. The Gnuplot graphs are plotted each minute using the raw data that each driver collects, every minute. If you note that a graph has stopped updating, the easiest way to get it to refresh is to simply stop and restart the driver using the text interface.

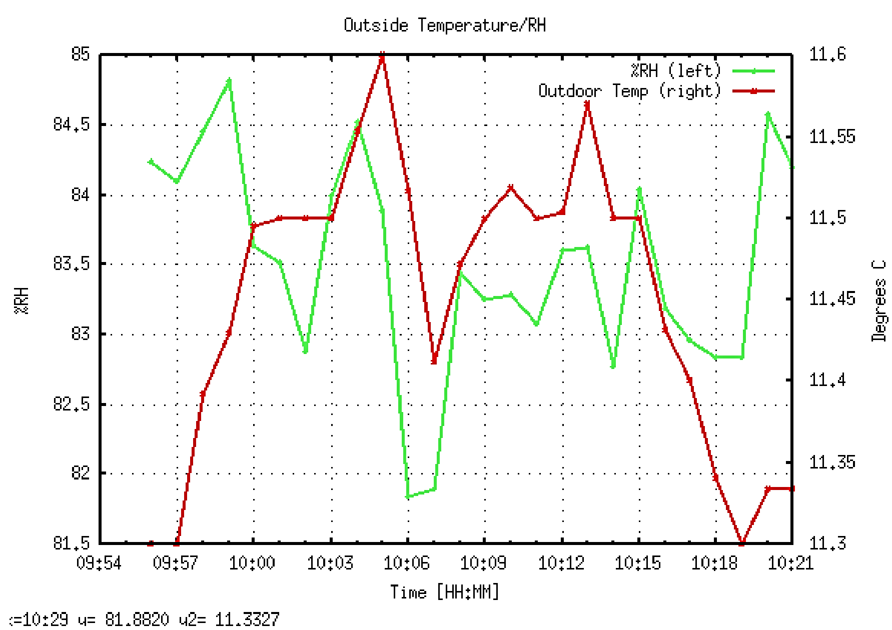
Graphs on CentOS are non-interactive. When graphs are running on the Debian operating system, however, these graphs all have the following additional capabilities:

1. Holding the [Shift] key while pushing the middle mouse forward or backward

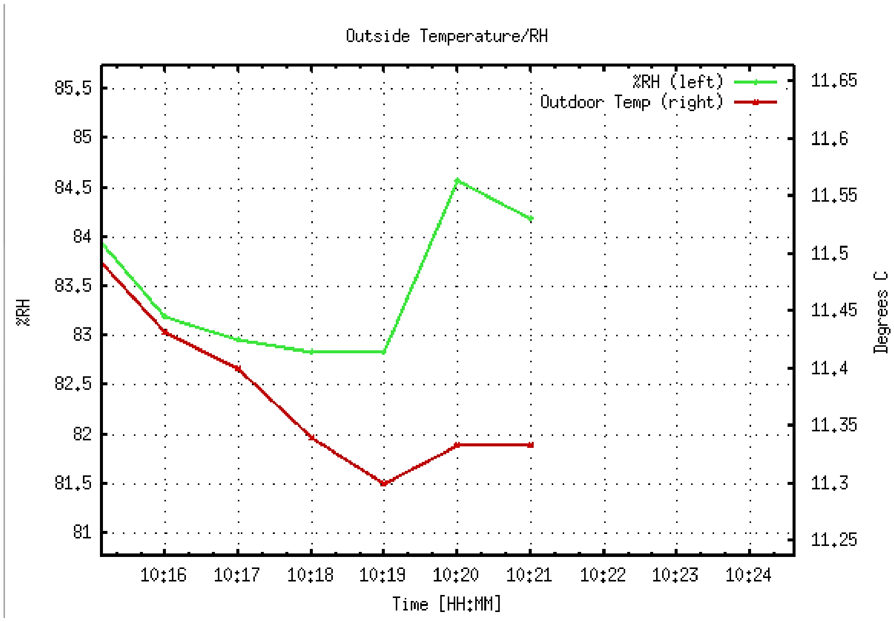
will cause the graph to translate to right and left, respectively.



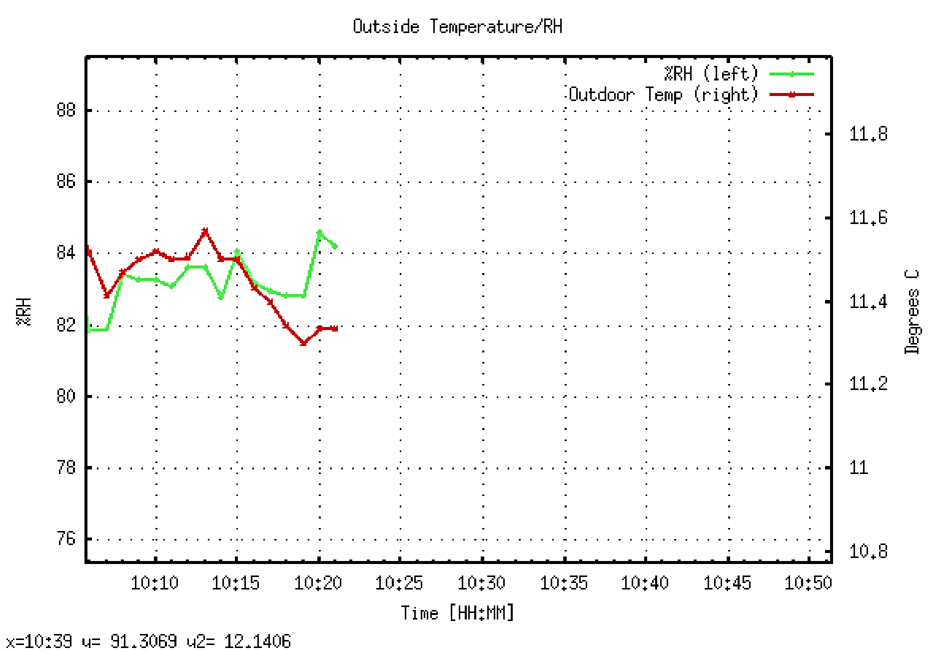
2. Holding the [Alt] key while pushing the middle mouse forward or backward will cause the graph to translate up or down, respectively.



3. Holding the [Ctrl] + [Shift] key while pushing the middle mouse forward or backward will cause the graph to expand or compress along the X axis, respectively.



4. Holding the [Ctrl] + [Alt] key while pushing the middle mouse forward or backward will cause the graph to zoom in or out, respectively.



Appendix I: OPERATIONAL CODES ASSIGNED BY CARBLOGGER

OP Code	Definition	Description
0	Valid	This is a valid data point, and it will be aggregated into larger valid time averages by DMS.
*1 (11, 21, 31)	Zero	This is a valid data point, and it will be aggregated into larger, valid contiguous zero averages occurring in the same time periods by DMS.
*2 (12, 22, 32)	Gas Precision	This is a valid data point, and it will be aggregated into larger, valid contiguous precision averages occurring at the same time by DMS.
*4 (14, 24, 34)	Gas Span	This is a valid data point, and it will be aggregated into larger, valid contiguous span averages occurring at the same time by DMS.
**9	Invalid	This is an invalid data point, and it will map with a QC code (9) that excludes the data from aggregating into valid time averages in DMS.
**51	Maintenance	This is an invalid data point, and it will map with a QC code (22) that excludes the data from aggregating into valid time averages in DMS.
**52	Instrument Repair	This is an invalid data point, and it will map with a QC code (22) that excludes the data from aggregating into valid time averages in DMS.
**53	Off-Line	This is an invalid data point, and it will map with a QC code (20) that excludes the data from aggregating into valid time averages in DMS.

OP Code	Definition	Description
**60	QA Audit	This is an invalid data point, and it will map with a QC code (14) that excludes the data from aggregating into valid time averages in DMS.
**64	BAM Zero Test	This is an invalid data point, and it will map with a QC code (13) that excludes the data from aggregating into valid time averages in DMS.
**65	Autocal Off Phase	This is an invalid data point, and it will map with a QC code (10) that excludes the data from aggregating into valid time averages in DMS.
**68	Calibration	This is an invalid data point, and it will map with a QC code (11) that excludes the data from aggregating into valid time averages in DMS.
**69	Auto Calibration	This is an invalid data point, and it will map with a QC code (10) that excludes the data from aggregating into valid time averages in DMS.

* Depending on the time of day that the calibration event is accomplished, a numeric value may be inserted prior to the Op code. No preceding value indicates that the calibration took place between the hours of (0:00- 5:59), and values of 1, 2, and 3 indicate that the calibrations took place in the time periods of (6:00-11:59), (12:00-17:59), and (18:00-23:59) respectively. So, an Op Code of 34 is a span which took place between after 1800 hours and before midnight.

** If more than 25% of the data within the hour are invalid, a null code corresponding to the mapped QC code will be assigned to the hourly data point.

Appendix J: HISTORY OF CARBLOGGER

Experimental –

The first version of CL was developed on Ubuntu to assist the Special Purpose Monitoring section to obtain telemetry for two collocated RM Young 81000 Ultrasonic anemometers running on top of the CalEPA building on 10th and I street. The implementation allowed remote configuration of the instruments and recorded all data in a timestamped format. No user interface was available with this version of CL.

Diagnostic Data System –

Using the experimental scripts, after having run consistently for over a year in adverse conditions, ODSS staff has developed a digital diagnostic data system, using old MLD workstations and both Linux Mint and Debian operating systems. The user interface, several drivers, and the ability to parse data streams and email errors were added. An installation script was also developed to convert any Ubuntu distribution into a CL.

Experimental Data Logger –

After having run successfully for several years as a diagnostic system on old equipment at several sites, the Special Purpose Monitoring section requested additional function from the logger; a one-minute pivot table containing all data collected by the logger. A MySQL database and procedures to parse, ingest, and report this data was added.

CARBLogger v1.0 *(Production Data Logger)* –

The first version of CL used for production data logging was developed for the implementation of the NCore air monitoring station in Fresno, California. U.S. EPA NCore requirements included digital data acquisition due in part to the implementation of trace air monitoring instruments and need for MDL determination. The site had two manifolds, and a direct outlet for one trace instrument. Additionally, any digital system needed to be able to run in parallel with the existing analog system, so available status contacts and analog outs were not always available. At this point in time, no other full digital data acquisition system was available for us to use with DMS and with our instruments.

This version of CL added stored procedures to the MySQL database (from the experimental data logger) which could allow an operator to describe how a site is configured. These stored procedures (based on the operator configuration) then produce correctly flagged and formatted one-minute data for DMS ingest and ftp them to the CARB ftp servers for pickup by DMS. Also, back poll functionality was created so that CARB staff could request a resubmittal of data.

CARBLogger v1.2 –

The second version of CL system was based on the Debian OS. In addition, the internal database in the logger was changed from MySQL to MariaDB. The following changes were made:

1. The user interface and all drivers were updated allowing the user to input other non-operational states including:
   a. Enable
   b. Off-line
   c. Routine-Maintenance
   d. Instrument Repair
   e. Manual Calibration
   f. QA Audit
   g. Zero Test
2. The number of infrequently used instrument drivers in the production code repository/inventory was decreased.
3. Most drivers were updated to interactively plot real time data using Gnuplot.
4. More specific email notifications were sent to users.

CARBLogger CentOS –
Earlier versions of CL have been based on a distribution of Linux called "Debian". While CL systems operating on the Debian platform were successful, ODSS staff encountered many challenges, as there was very little hardware support for the Debian OS. CentOS is an open-source enterprise version of Red Hat.

CARBLogger RPi –
ODSS staff is working on converting the CARBLogger 1.2 to the RPi platform. The operating system is RPi OS, which is a Debian based Linux distribution.