Meteorological Measurement Station Installation and Operation

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1 Introduction

Two meteorological measurement stations have been installed in the Central Arizona-Phoenix area. The first station is located at the Lost Dutchman State Park (LDP) in Goldfield, Arizona. This station used an existing tower and was instrumented with new sensors, datalogger, and power system in May 2006. The second station is located at the Desert Botanical Garden (DBG) in Phoenix, Arizona. A new tower was mounted on a concrete pad south of the DBG trails and new sensors were installed in October 2006. These stations have been used to collect meteorological measurements that are inputs to gas and particle dry deposition models. This manual is intended to document the installation, operation, and maintenance procedures for the LDP and DBG meteorological measurement stations. More detailed information can be found in the Campbell Scientific manuals for each product (`http://www.campbellsci.com`).

2 Installation

2.1 Siting Recommendations

Site selection is important in order to obtain accurate meteorological data. The site should be representative of the area of interest and away from obstructions or other influences. The following is a list of the measurement siting and height for common meteorological variables recommended by the WMO [1983].

- Wind Speed and Direction: Located in open terrain at a distance of at least ten times the height of any nearby obstruction. Standard height is 10 m.
- Temperature and Relative Humidity: Located in open terrain at a distance of at least four times the height of any nearby obstruction. Standard height is 1.25–2.0 m.
- Precipitation: Located on level ground in an open area. The opening should be as low as possible but high enough to avoid splashing from the ground. Minimum height is 30.0 cm.

- Solar Radiation: Located to avoid shadows on the sensor at any time (southern most portion of the weather station). The height of the sensor is not critical.

2.2 Site Descriptions

The Lost Dutchman State Park (LDP) meteorological station is approximately 55 km east of downtown Phoenix, Arizona, at the base of the Superstition Mountains to the north and east, and bordered by desert and low density residential land to the south and west. The LDP station is located at the GPS coordinates 33° 27.746' N 111° 28.754' W, about 65 m from the park staff residential and maintenance buildings (see Figure 1). Access is possible through the back gate of the maintenance building and to the north east.

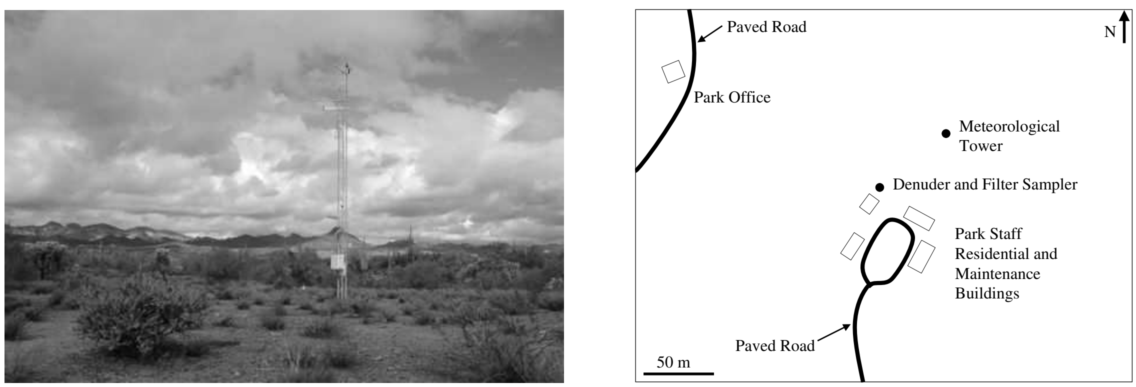

Figure 1: Photo, facing north, and schematic from an aerial photo of the Lost Dutchman State Park (LDP) site.

The Desert Botanical Garden (DBG) meteorological station is approximately 12 km east of downtown Phoenix, within the city of Phoenix and surrounded by urban industrial, residential, and recreational land. The DBG station is located at the GPS coordinates 33° 27.488' N 111° 56.570' W, about 100 m from the south-eastern edge of the garden trail in the desert reserve area (see Figure 2). Access is possible through the garden maintenance building and along the eastern edge of the garden.

The local terrain at both sites is flat or gently sloped Sonoran desert (see Figures 1 and 2). The vegetation canopy at both sites consists of patchy coverage of desert shrubs and trees. The major

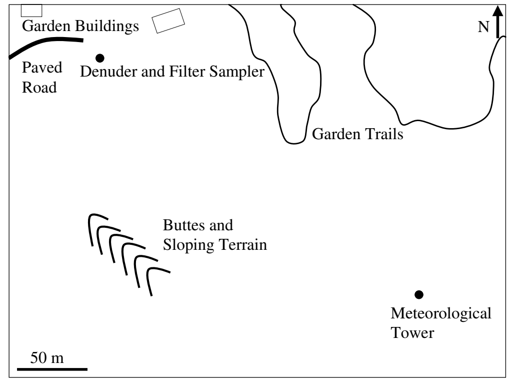

Figure 2: Photo, facing west, and schematic from an aerial photo of the Desert Botanical Garden (DBG) site.

vegetation species are bursage (*Ambrosia deltoidea*) and creosote bush (*Larrea tridentata*) and minor species are palo verde (*Cercidium microphyllum*) and saguaro cactus (*Carnegiea gigantea*).

2.3 Tower Base and Structure

The LDP tower is a 10 m steel structure that was installed prior to this project. The LDP staff has indicated that they can keep the tower in its current location as long as there is use for it. The tower is mounted on a concrete base and guy wires are installed.

The DBG tower was purchased from Campbell Scientific (Model UT30, Logan, UT). The UT30 is a 10 m tower and is installed using a concrete mounting base or a roof mounting base. For open-space installation the tower is usually installed using the concrete mounting base and approximately 1.3 cubic yards of concrete. However, the location of the DBG tower did not allow for installation of the below-ground concrete base described in the tower manual. Instead, a base was constructed by embedding steel rebar into the bedrock and pouring a concrete base above ground. A set of three 12 inch anchor bolts were then embedded in the concrete base and a roof mounting base was mounted. The aluminum tower is bolted to the roof mounting base. Removing the bolt on the north-facing tower leg allows the tower to be tilted down if necessary. The guy wires were installed with duckbill anchors driven into the ground. Because of the bedrock beneath the surface the anchors were not driven completely into the ground as described in the tower manual. The tower was grounded with the grounding kit provided by Campbell Scientific.

2.4 Enclosure, Datalogger, and Peripherals

The towers are equipped with enclosures to protect and secure most of the equipment. The LDP tower has a 16 X 18 inch enclosure attached to the tower on the north side and approximately 59 inches from ground level to the top of the enclosure. The enclosure is locked with a combination lock (combination is 6527). The DBG tower has a large JOBOX storage box attached to the concrete base. The JOBOX is locked with a padlock (Master Lock key number 3624).

Both towers are equipped with a CR1000 datalogger, BP24 sealed rechargeable battery, CH100 charge regulator, SP20 solar panel, Airlink Redwing CDMA cellular modem (with Verizon service), and cellular modem antenna. The datalogger, battery, charge regulator, and modem are attached to a back-plate inside the enclosure. The solar panel is mounted on the south side of the tower above the height of the enclosure and with a tilt angle of approximately 45°. The solar panel is wired to the *CHG* terminals on the charge regulator (polarity does not matter). The leads from the battery are connected to the *INT* battery connection on the charge regulator. The positive output (+12) from the charge regulator (red wire) is connected to the positive (12V) power input on the datalogger and the ground from the charge regulator (black wire) is connected to the ground (G) power input on the datalogger. The modem power cable (gray) is connected to the *SW-12* terminals on the datalogger (red to SW-12 and black to any ground). The modem antenna is mounted on the tower leg and the antenna cable is connected to the modem via a modem cable. The modem is then connected to the datalogger RS-232 port using a null modem cable (PN 14392 from Campbell). Note that the RS-232 port on the datalogger is also used to connect directly to a computer via a normal serial cable (see Datalogger Network Configuration and Datalogger Communication below).

2.5 Measurement Sensors

The towers are equipped with sensors to measure wind speed, wind direction, incoming solar radiation, air temperature, relative humidity, and precipitation. The wiring diagram for the datalogger and sensors can be found in the file CNDep_MetTowers.SCW (open using the ShortCut program in LoggerNet). Table 1 is a summary of the variables measured, sensors, and valid range of the measurements. This includes the timestamp and record number saved by the datalogger for each measurement. Each variable is measured every 5 seconds and the average (or total for precipitation and total solar radiation) is saved to the datalogger every ten minutes (see below). These data rates can be changed in the datalogger program (CNDep_LDP_MetTower.CR1 and CNDep_DBG_MetTower.CR1).

Table 1: Meteorological Measurement Station Variables and Sensors.

Variable	Sensor	Height (m)	Valid Range	Units
Timestamp	CR1000 Datalogger	N/A	2006-05-10 - Current	N/A
Record	CR1000 Datalogger	N/A	0 - continuous	N/A
Air Temp	Vaisala T/RH probe	2	-40–60	°C
Relative Humidity	Vaisala T/RH probe	2	0.8–100	%
Solar Radiation [a]	Apogee Pyranometer	3	0–2000	kW m^{-2}
Wind Speed	RM Young Anemometer	10	0–100	m s^{-1}
Wind Direction	RM Young Anemometer	10	0–360	°
Precipitation	TE Tipping Bucket	0.5	0–30	mm

[a] Total solar radiation is also recorded in MJ m^{-2}.

3 Operation

3.1 Datalogger

The CR1000 datalogger has 4 MB of SRAM for data storage, program storage, and CPU usage. Data is stored in table format in a circular buffer. This means that when the space available for data storage is filled the datalogger overwrites the oldest data records sequentially. Data loss is unlikely as long as regularly scheduled data collection is performed. The capacity of the datalogger is sufficient for hundreds of days of data in the event that collection is interrupted for an extended period of time.

The datalogger programs are named CNDep_DBG_MetTower.CR1 and CNDep_LDP_MetTower.CR1. These programs define the data scanning rate, data recording rate, variables and units to be saved, datalogger channels for each sensor, and the modem power switching schedule. A generic version of the same program is saved as CNDep_MetTowers.CR1. This program was created using the ShortCut program from LoggerNet (see Datalogger Programming below). The modem power switching was added later after consultation with Campbell Scientific support personnel. Users should consult with Campbell Scientific or the CR1000 manual for advanced datalogger programming.

Data files are defined in the Setup program from LoggerNet. Click on the datalogger to configure and click on the *Data Files* tab (see LoggerNet Software below). The output file name can be changed as needed. Each time the datalogger program is changed the datalogger will reset the record number to start at 0. To explicitly identify such instances, the data file name should be changed as well. In the past, the data file names in LoggerNet have been unchanged from the default file names: LDP_TenMin.dat and DBG_TenMin.dat. When the datalogger program was changed, the data file was then renamed as LDP_TenMin_X.dat where X is a serial number, starting with 1, for consecutive data files. This protocol has now been changed. The output file name in the Setup program now has the latest serial data file number (e.g. LDP_TenMin_X.dat). The serial number should be incremented each time the datalogger program is changed. There is no danger of data loss if the output file name is not changed, however, the record number will reset to 0 in the middle of the file.

Data is normally retrieved daily using the LoggerNet program on a computer with a regular phone modem. The current datalogger program switches the tower modems on for ten minutes each morning at 08:00 for the LDP modem and 08:20 for the DBG modem. The modem window is programmed in the .CR1 file described above and can be modified if necessary. The LoggerNet software is scheduled to collect data by calling the tower modems daily (see Datalogger Network Configuration below).

3.2 LoggerNet Software

LoggerNet (currently version 3.4) is the main software for datalogger configuration, communication, programming, and troubleshooting. LoggerNet consists of a suite of programs to perform these and other tasks with the Campbell Scientific equipment. Some of the programs may not be needed for the equipment used with these weather stations. There are also sometimes multiple programs that can accomplish the same task. The EZSetup and Setup programs are both used to configure the communication nodes of the datalogger network. EZSetup is more user friendly and guides the user through the configuration. Setup offers more advanced options and is more useful to make changes after the initial configuration is done. The current configuration is described below using the Setup program.

3.2.1 Datalogger Network Configuration

The LoggerNet Setup program was used to configure the network for remote communication. The details of this configuration can be found in the CR1000 manual from Campbell Scientific. Briefly, the root node is the *TAPIPort*. This is used for communication through a modem to the tower modem. Only one TAPIPort is needed for all connections via the modem. This simply allows the user to designate the hardware (phone modem) to be used for communicating with the tower modem. Two *TAPIRemote* nodes are attached to the TAPIPort: one for each tower. This allows the user to enter the dialing properties for communication with each tower modem. The first node, TAPIRemote, is for the LDP tower and is programmed with the phone number for the LDP modem, 86028101895 (the 8 prefix is to access an outside line from ASU). The Dial String displays the actual string of numbers to be dialed. The second node, TAPIRemote_2, is for the DBG tower and is programmed with the phone number for the DBG modem, 86028101886. Each TAPIRemote node then has a corresponding *PakBusPort* which allows the user to select the communication protocols for the modem (e.g. baud rate, response time, etc.). Finally, each PakBusPort has a datalogger node. The datalogger nodes, LDP and DBG, have tabs for configuration of hardware, schedule, data files, clock, and program. The hardware tab configures overall operation of the datalogger and can be used to enable or disable communication with the tower modem. The schedule tab is used to set up the collection schedule, including the time to call the tower modem and number of times to retry the call if it fails. Note that the collection times are 8:00:30 for LDP and 8:21:30 for DBG to allow time for communication with each tower. The data files tab allows the user to select pre-defined (Public and Status) and user-defined (TenMin) data tables to be collected and where to store the data. Any combination of data tables can be collected. The *TenMin* data table is defined in the current datalogger program and contains the ten minute average (or total) of all the variables measured. The clock tab allows the user to synchronize the datalogger clock with the local computer clock. This is important for maintaining the scheduled data collection. The program tab displays the current program in use by the datalogger.

On-site communication with the dataloggers at the tower site is sometimes necessary. Uploading a new program at the datalogger site can be easier since the current program only gives a ten minute window during which the tower modem is switched on for communication each morning. This window is usually too short to upload and test a new datalogger program. Obviously the window length can also be changed by uploading a new program. For on-site communication, a regular serial cable is attached to the RS-232 port on the datalogger and a serial port on a laptop computer. LoggerNet must be installed on the laptop and the node configuration is different from the configuration used for remote communication. EZSetup can be used to configure direct communication with the datalogger and Setup can be used to view or modify this configuration. In this case the root node is a *ComPort* node. The hardware tab is similar to the TAPIPort hardware tab except that it designates which COM port is to be used for communication with the datalogger. The nodes on the ComPort are a PakBusPort and a datalogger, similar to the nodes below the TAPIRemote node for the remote configuration. Usually the remaining configuration is similar to that described above except that scheduled collection of data is disabled since regular communication in this manner is not likely. Each datalogger can be configured as a separate node on the PakBusPort node.

The above description is necessarily brief. Please refer to the CR1000 manual for complete details. The current LoggerNet configuration for remote communication, including the node configuration, communication protocols, tower modem phone numbers, and collection schedule is saved in the backup file c:/Campbellsci/LoggerNet/LoggerNet.bkp. This backup file can be used to restore the configuration or install it on a different computer. From the LoggerNet program, click on the Setup button, click on Tools from the menu bar, and select Restore Network. The program will guide you through the restore process.

3.2.2 Datalogger Communication

The Connect program is a simple interface to connect to the datalogger for data collection, program changes, current data displays, or clock synchronization. The Connect program can be used to communicate with a datalogger through a phone modem or directly through a laptop serial port at the datalogger site. To connect to the datalogger, click on the *Connect* button on the LoggerNet tool bar, select the datalogger to connect, and click the *Connect* button. Manual data collection can be performed by clicking the *Collect Now* button. Note that all data will be downloaded since the last collection was performed on the computer connected so this may take some time. The datalogger program can be changed by clicking the *Send Now* button. After the program is sent, the datalogger will compile the program and begin execution immediately. Note that this procedure will also erase all data on the datalogger. The most recent measurements can be displayed using the *Data Display* functions. The datalogger and computer clocks will also be displayed and can be synchronized. To disconnect click the *Disconnect* button.

3.2.3 Datalogger Programming

ShortCut is a user-friendly program that guides the user through selecting the sensors, data rate, and data tables for the dataloggers. ShortCut will save a file with the extension .SCW, which can be used to modify the datalogger program if any changes are needed. ShortCut will also compile the program into a .CR1 file that is actually used by the datalogger. The .CR1 file can also be edited directly using the CRBasic program in LoggerNet or a text editor if necessary.

3.2.4 Datalogger Status and Troubleshooting

The Status and TroubleShooter programs in LoggerNet are tools that provide information and tools to diagnose configuration problems. The Status window displays the current network configuration and error messages for each node. In addition, the Status window will show an error rate that will help determine the timeline of the problem. The LogTool button shows a log of the communications between LoggerNet and the datalogger. If the datalogger is connected to the computer (either through the modem or the RS-232 port) the Comm Test button can be used to test communication with the device. TroubleShooter displays similar information and diagnostic tools.

3.2.5 Data Viewing

Data files are saved as text files with a .dat extension. These can be viewed with the View program in LoggerNet or with a text editor. Note that as the data file gets large by appending new data daily, the file will take longer to load.

4 Maintenance and Calibration

Proper maintenance of the weather station is essential to obtaining valid data. A regular program of inspection and maintenance will ensure that equipment is in good operating condition. Calibration, sensor testing, and sensor repairs should be done by Campbell Scientific. The maintenance and calibration schedule for the towers and sensors is as follows

- Tower, enclosure, wiring, and mounting hardware> Check for damage during each site visit. Replace sensor cables as necessary.
- Desiccant> Change the desiccant when the humidity indicator card reads above 35% RH.
- Pyranometer> Check the level and clean the sensor head at each visit (weekly is recommended by Campbell). Calibrate annually.
- Rain gage> Clean the funnel and level the gage monthly. Calibrate annually.
- Anemometer> Visually inspect the propeller and wind vane for smooth motion monthly. Campbell recommends replacing the bearings annually and replacing the wind vane potentiometer every two years.

- Temperature/RH Probe> Check the filter and radiation shield for contamination monthly. Clean semiannually. Calibrate annually.
- Solar Panel> Clean the glass semi-annually (or more frequently if it becomes dirty).

5 Troubleshooting

Campbell Scientific provides customer support for all of the equipment and sensors for the weather stations. It is best to contact them directly (435-753-2342) with any problems.

The one problem that has occurred in the past is that LoggerNet will be unable to communicate with the datalogger for several days. LoggerNet should be checked weekly to check the status of the network. Open LoggerNet and click on the Status button. If the status of the datalogger shows an error, it is possible that one or more data collections has been missed (check the actual data file to determine the last successful collection). If collection has failed for more than a few days, the most likely cause is that the cell modem at the tower is not connecting to the network. The solution to this problem is to visit the tower, power up the modem (move the red power lead to one of the *12V* power terminals), push the reset button on the modem, and let the modem connect to the network. Test that the modem has successfully connected by calling the cell modem and waiting for the modem response. Repeat the reset procedure if you can't get a response from the modem. Once the modem responds, disconnect the power lead and re-connect it to the *SW-12* power terminal. Verify that LoggerNet is able to connect the following day.

6 Eddy Correlation Applications

The CR1000 datalogger has also been used to collect fast measurements of micrometeorological measurements for eddy correlation experiments. This required special programming, equipment, power supply, and datalogger configuration. The program for eddy correlation data acquisition is called ATI_SX_LI_7500_v2.CR1. This program was slightly modified from the original program (Ati_sx_li_7500

.CR1) purchased from Campbell Scientific for fast data collection. The sensors were a 3-dimensional sonic anemometer (SATI-3K, Applied Technologies, Inc., Longmont, Colorado) to measure air flow and an open path infrared gas analyzer (IRGA) (LI-7500, Li-Cor, Inc., Lincoln, Nebraska) was used to measure gas phase carbon dioxide and water vapor. The datalogger and anemometer were powered with an additional solar panel, charge regulator, and battery. The power requirement of the IRGA was too large for the solar power system so an external power supply was used (AC power was supplied to the LDP tower via an outdoor, heavy-duty power cord). A CR1000 datalogger was used and the wiring was custom designed using the serial (RS-232) port for the sonic anemometer data and the SDM interface for the IRGA data (see ATI_SX_LI_7500_v2.CR1 for details). A CFM100 CompactFlash Module and a 1 GB compact flash card were used to save the 10 Hz data. At that data rate for the variables measured the compact flash card capacity was sufficient for approximately 12 days of data collection. Two 1 GB memory cards were used by swapping them approximately every 6 days and downloading the latest data using the CardConvert program in LoggerNet, which also converts the data files to a text file format.

References

WMO. Guide to meteorological instruments and methods of observation. Technical report, World Meteorological Organization, Geneva, Switzerland, 1983.