



## Miniature Data Loggers Record Temperature Inexpensively and Reliably

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New technology allows temperature data to be collected and logged in the field inexpensively with small, weatherproof, solid-state data logger/thermistor units. Each of the portable, battery-operated data logger units has a connector that allows it to be connected to the RS-232 port on a laptop computer (Macintosh or PC). Software on the laptop can initialize the data logger or download data from it. The data logger's low unit cost should allow more loggers to be purchased for a given field task, providing better spatial coverage of temperature fields in areas such as forest canopies where horizontal and vertical temperature gradients are of interest. This technology eliminates the need for separate, often expensive and bulky data loggers. The data logger and sensor are in the same unit. The miniature temperature loggers described in this report and various related temperature measurement and logging systems are already being used by Forest Service personnel to monitor stream temperatures, study insect habitat, and evaluate fire environments. This report describes one of the new temperature data logger systems intended for outdoor use. This system was recently tested (Whiteman and others 2000).

### The Need for Miniature Data Loggers

Atmospheric temperature is a factor in fire danger, water balance calculations, snowpack stability, insect activity and the viability of forest pathogens, human stress, efficacy of pesticides, dispersion of smoke and pollutants, and many other topics of interest to Forest Service personnel. Temperature fields near the surface of the Earth vary dramatically in many of the environments where Forest Service personnel work. This variability is largely due to the effects of terrain, altitude, location, and forest canopy. Closed canopies tend to be quite uniform in temperature in the lower canopy layers. Broken canopies and the parkland and managed canopies typical of the Western United States can have very complex horizontal temperature patterns that depend on the availability of direct sunlight. Many canopies show sharp vertical temperature gradients near canopy tops as the foliar surfaces progress from shaded to full sunlight. Terrain accounts for variability as slope aspect determines the amount of solar heating. This effect is accentuated with elevation. The thin atmosphere at higher elevations

transmits more solar radiation to the foliar surfaces and temperature differences increase between shaded and unshaded areas. Patches of snow accentuate this effect.

It is difficult to obtain representative temperature measurements under many circumstances because of the spatial variability of temperature. This problem could be addressed by taking measurements at many points through the area (or volume) of interest. This approach is not often taken because of the logistics and expense of using many data loggers. Temperature microloggers make dense arrays of temperature measurement much more feasible.

### Description

The system described and tested in this report is the HOBO H8 Pro Temperature/Temp External Logger developed by Onset Computer of Bourne, MA. Photographs and specifications of this system can be found on the World Wide Web at <http://www.onsetcomp.com>. The data logging unit, about 4 inches in diameter and 2 inches high (Figure 1),



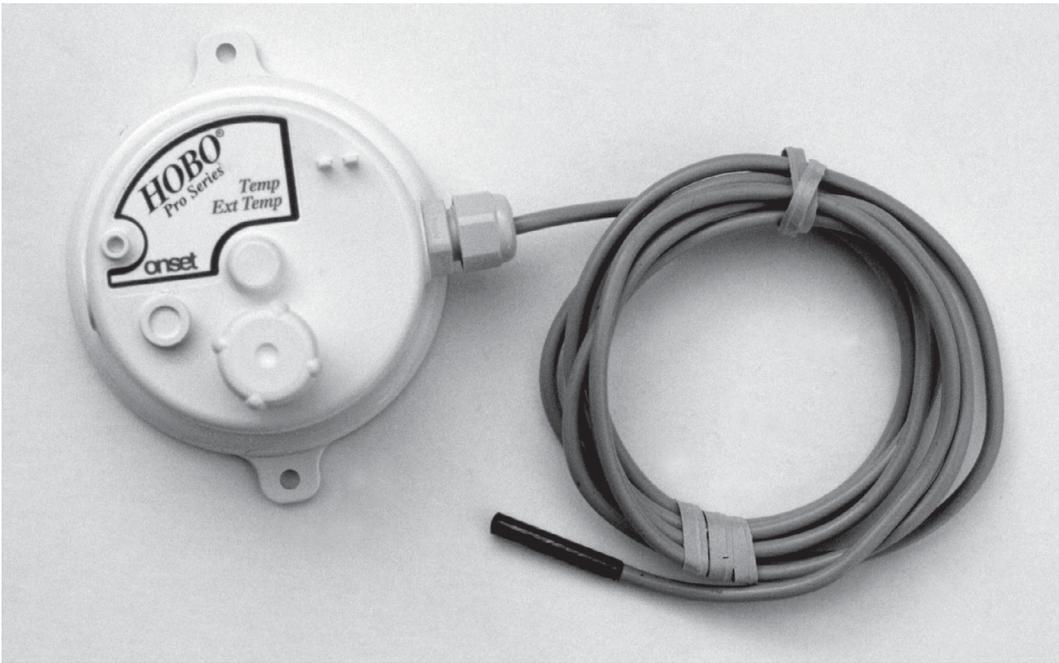


Figure 1—The HOBO H8 Pro Temperature/Temp External temperature data logger.

is constructed of white thermoplastic to minimize direct radiative heating. A 6-foot long lead connects the data logger to a thermistor temperature sensor. A radiation shield is needed to properly shield the sensor from direct solar radiation. Direct radiation on the sensor would heat the sensor, producing an unrepresentative air temperature reading. Radiant cooling is also a concern when the sensor is exposed to the open sky at night. A standard unspirated solar radiation shield is sold separately. This shield, or alternative shields sold by other manufacturers, should be installed with each temperature data logger. Figure 2 shows a HOBO data logger with a radiation shield in its normal operating position. The temperature data logger can operate continuously for up to 3 years using power from an internal lithium battery. Onboard data storage accommodates up to 21,763 instantaneous high-resolution

temperature measurements that can be made at regular time intervals. Because the potted thermistor sensor has a relatively long time constant, sampling is not recommended at intervals shorter than about 5 minutes. The temperature range could be limiting at the low end in some alpine and high-latitude settings during winter. The battery life is somewhat diminished at low temperatures. The logger can be easily mounted on vertical surfaces using screws, or can be attached to

radiation shields and installed on vertical poles or fence posts using the radiation shield's U-bolt.

## Operation

The data logger is initialized with manufacturer-supplied software that runs on a personal computer connected to the logger through the computer's serial port. The user selects the sampling period or logging interval, the start time, the

channels to be logged and the desired resolution (higher resolution measurements decrease the total number of data points that can be stored). The logger is then deployed in the field. Data can be downloaded from the logger at any



Figure 2—The radiation shield's U-bolts were used to mount the HOBO data logger on a metal fence post. The radiation shield is in the normal operating position.

time by reconnecting the computer and running the software. As an alternative to using a computer for downloading, the user can purchase a small handheld downloading and data storage unit called a HOB0 Shuttle. This unit can be used to download data from multiple loggers and transport it back to a computer. The shuttle is relatively inexpensive and is recommended when working in the rugged field environments typical of Forest Service applications.

## Laboratory Testing

Tests were conducted at the Pacific Northwest National Laboratory in Richland, WA, to evaluate:

- *The sensor's accuracy compared to traceable temperature standards*
- *The variability among different sensors*
- *The sensor time constant*
- *The function of the internal clock.*

These tests are described in detail by Whiteman and others (2000). Accuracy testing was done by comparing temperature readings from five of the HOB0 loggers in a stirred temperature bath against a NIST-traceable temperature standard. All five of the temperature sensors remained within 0.26 °C of the standard, well within the manufacturer's specified accuracy (Figure 3). Time constant testing was performed by bringing five of the HOB0 sensors to equilibrium in a freezer and then placing them at a known temperature outside the freezer. The time constant (Fritschen and Gay 1979) is defined as the time it takes for the sensor to respond to 63.2% of the temperature difference between the

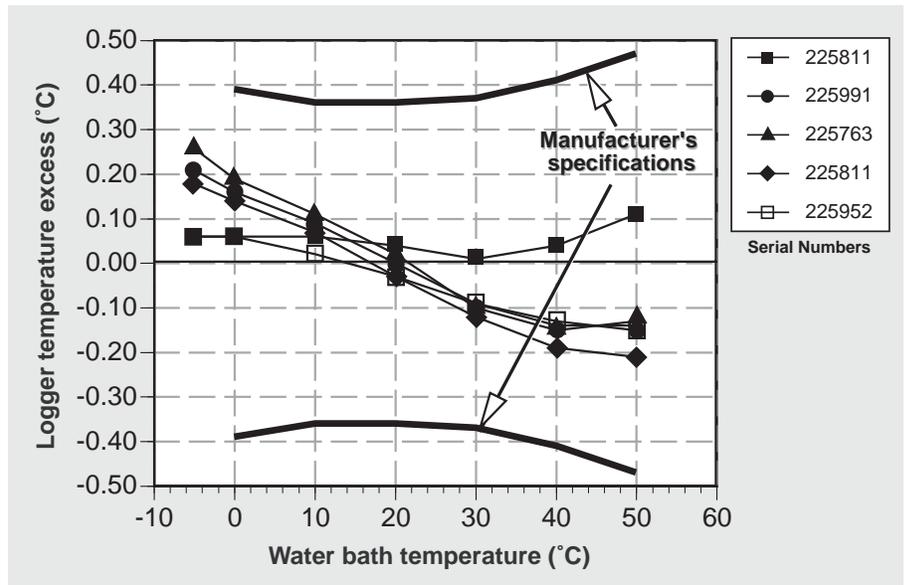


Figure 3—This graph shows the data logger's temperature relative to a temperature-controlled recirculating bath. The heavy lines represent the manufacturer's accuracy specifications.

two temperature states. The two-channel HOB0 H8 has an internal and an external temperature sensor. The external sensor's time constant was 122+/- 6 seconds; the time constant of the internal sensor is 557+/- 83 seconds. This is within the manufacturer's specifications. By modern standards, these sensors do not respond rapidly to temperature changes. The sensor's long time constant provides a built-in means of averaging observations, eliminating the need to make many samples on short time intervals to build up an average. Tests showed that the clocks' accuracy was within manufacturer's specifications. The clocks lost around 18 seconds per week at room temperature. They gained a few seconds per week when operated at temperatures below freezing.

## Field Evaluation

Field evaluation was performed using a line of temperature data loggers deployed on an open mountainside to study deep temperature inversions that form in Washington's Columbia Basin. Fifteen of the HOB0 temperature data loggers were deployed in this meteorological experiment for a period of 4 winter months. No data were lost because of system failure.

## Cost

The system is remarkably inexpensive. In early 2000 a two-channel temperature logger costs \$169. The optional shuttle costs \$159. The software, which can be used with any number of data loggers, costs \$95. Radiation shields must be used to properly shield the external temperature sensor (thermistor) from direct sunlight. The manufacturer sells such a shield for \$65.

## Conclusions

The HOBO Pro and similar measurement and data logging technologies are becoming widely used in the Forest Service. Perhaps the greatest advantage of this technology is the low unit cost that allows more measurements to be made for the same total cost. Whenever lower cost technology is considered, it is critical to know

what is being sacrificed in terms of instrument performance. Table 1 shows detailed specifications of the temperature logger. The HOBO H8 Pro performs as advertised and is well suited to making measurements of ambient temperature in settings of interest to the Forest Service. The manufacturer sells other models of temperature data loggers, including miniature data loggers than can be

used underwater, loggers that are suitable only for indoor use, loggers with humidity and radiation sensors, and loggers with up to four input channels.

Table 1—Manufacturer's specifications for the HOBO Pro Temperature/Temp External Logger.

| <i>Characteristic</i>                | <i>Specification</i>   |
|--------------------------------------|--|
| <b>Number of channels</b>            | 2 (internal and external temperature)  |
| <b>Operating range (logger)</b>      | -30 to +50 °C (-22 to +122°F)  |
| <b>Time accuracy</b>                 | ± 1 minute per week at 20 °C   |
| <b>Measurement capacity</b>          | 21,763 measurements (one channel at 12-bit and one at 8-bit resolution)              |
| <b>Memory</b>                        | Nonvolatile EEPROM   |
| <b>Data offload time</b>             | <1 minute  |
| <b>Size</b>                          | 4 x 3.2 x 2 in (102 x 81 x 51 mm)  |
| <b>Weight</b>                        | 3.7 oz (104 g)   |
| <b>Battery</b>                       | 1/2 AA lithium, user-replaceable   |
| <b>Battery life (continuous use)</b> | 3 years  |
| <b>Storage temperature</b>           | -30 to +75 °C (°F)   |
| <b>External temperature sensor</b>   | Thermistor on 6-foot lead  |
| <b>Response time (still air)</b>     | External sensor, 4.5 minutes; internal sensor, 34 minutes                            |
| <b>Resolution</b>                    | Variable over temperature range, less than 0.1 °C over the range 0 to 40 °C          |
| <b>Accuracy</b>                      | Variable over temperature range, better than 0.4 °C over the range from -10 to 50 °C |

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