Variability in the Response of TidBit® Temperature Data Loggers

October 2009

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TidBit® Temperature Data Loggers

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Over the past 25 years digital data loggers become a ubiquitous part of most water quality monitoring. A common component of the data analysis is a determination of the sources of variability in the data. As we look more closely at the data and consider small changes in values, it becomes imperative that we are aware of the variability that is associated with the instruments used in the study.

This report contains results from a simple study designed to identify some of the variability that may be associated with a TidBit® datalogger manufactured by Onset Computer, Inc.

The Study:

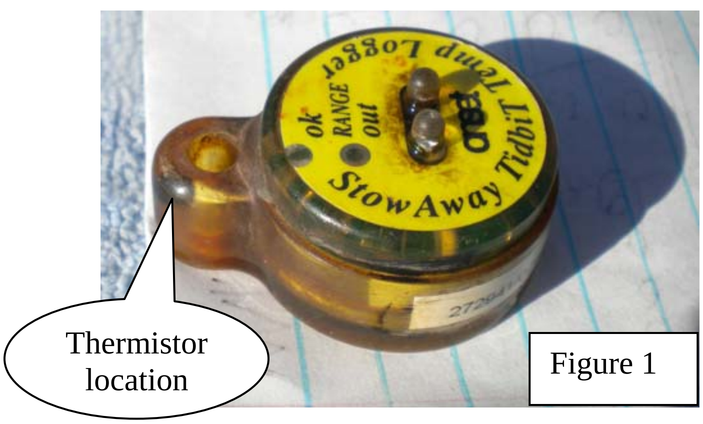


Figure 1

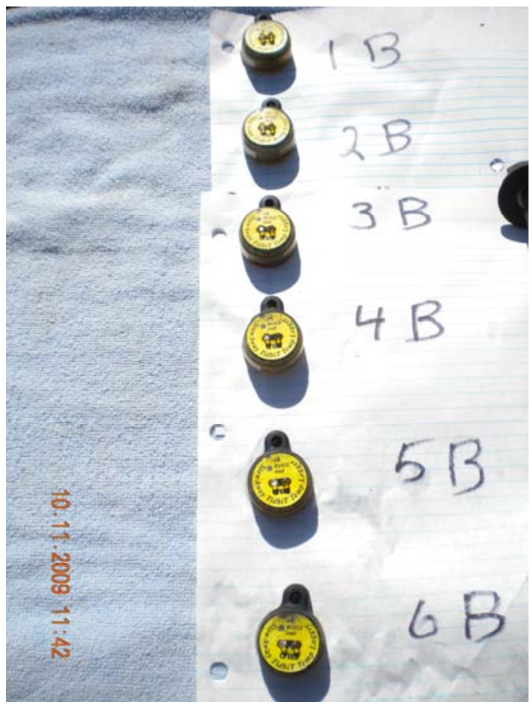
Figure 1 shows an older model Tidbit that consists of a temperature responsive thermistor and associated electronics encapsulated in a translucent waterproof shell. The device can be set to record temperature at a wide range of time intervals and the stored temperature data is retrieved to a computer using an optical coupler that interfaces with the two small knobs on the face of the device.

The general objective of this study was to determine how the responses of the data loggers change under different conditions in the open air as well as in water environments. For this experiment twelve temperature data loggers were activated to record at five minute intervals and were subjected to four different scenarios or stages. The study took place from 10/11/09 to 10/12/09 in Yoncalla, Oregon.

Stage 1:

The objective of Stage 1 was to obtain baseline data in an exposed, air environment. Initially, all units were placed in a bucket of cold water to set them to a common temperature. After about fifteen minutes they were set on a wooden table in an open area and exposed to direct solar radiation with the thermistor portions of all of the data loggers aligned to achieve maximum exposure. A towel was placed under the units to reduce thermal conduction between the units and the table. After about one hour the units were again immersed in the bucket to prepare them for Stage 2. However, prior to immersion the thermistor portions of all of the "B" units were painted with flat black paint.

Stage 2



The objective of Stage 2 was to determine the effect of an opaque coating on the translucent thermistor knob. This modification would reduce the albedo of the surface and also shield the encapsulated thermistor from direct exposure to shortwave radiation.

All of the units were left in the open exposed to direct solar radiation for about one hour similar to Stage 1. The units were then removed and replaced in the water bucket in preparation for Stage 3.

Stage 3

All of the units were removed from the water bucket and placed in a shallow plastic tub of water. The tub was tilted slightly to reduce the shade generated by side of the tub and the orientation of the data loggers was changed to optimize the exposure of the thermistors to direct solar radiation. The depth of the water ranged from about 4 inches for the top units and about three inches for the lower units.
After about one hour, the units were again immersed in the water bucket in preparation for Stage 4.

Stage 4

Stage 4 was a continuation of Stage 3 except the lower six submerged units were covered with a towel to simulate sediment or algae growth that may cover the data loggers when they are in a river or stream for an extended period of time

The time interval for this stage was from 3 PM on 10/11/09 to 2 PM on the following day. During this period the thermographs reached both their maximum and minimum values. Also, the water surface froze during the night and melted the following morning.

This figure shows the lighting conditions in the pan near sunset at 4:46 PM.

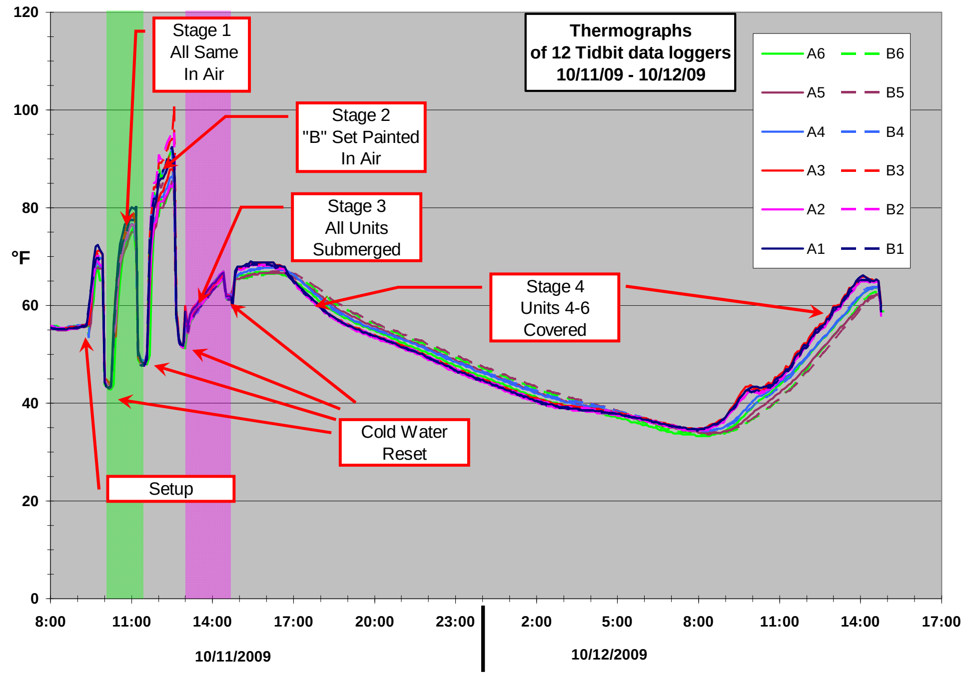
Morning conditions revealed that the water froze during the night. Note the three coins on the surface of the ice.

By 10:04 AM the coins had dropped through the ice but the rest of the surface was stilled covered.

By 10:39 AM all of the ice was melted.

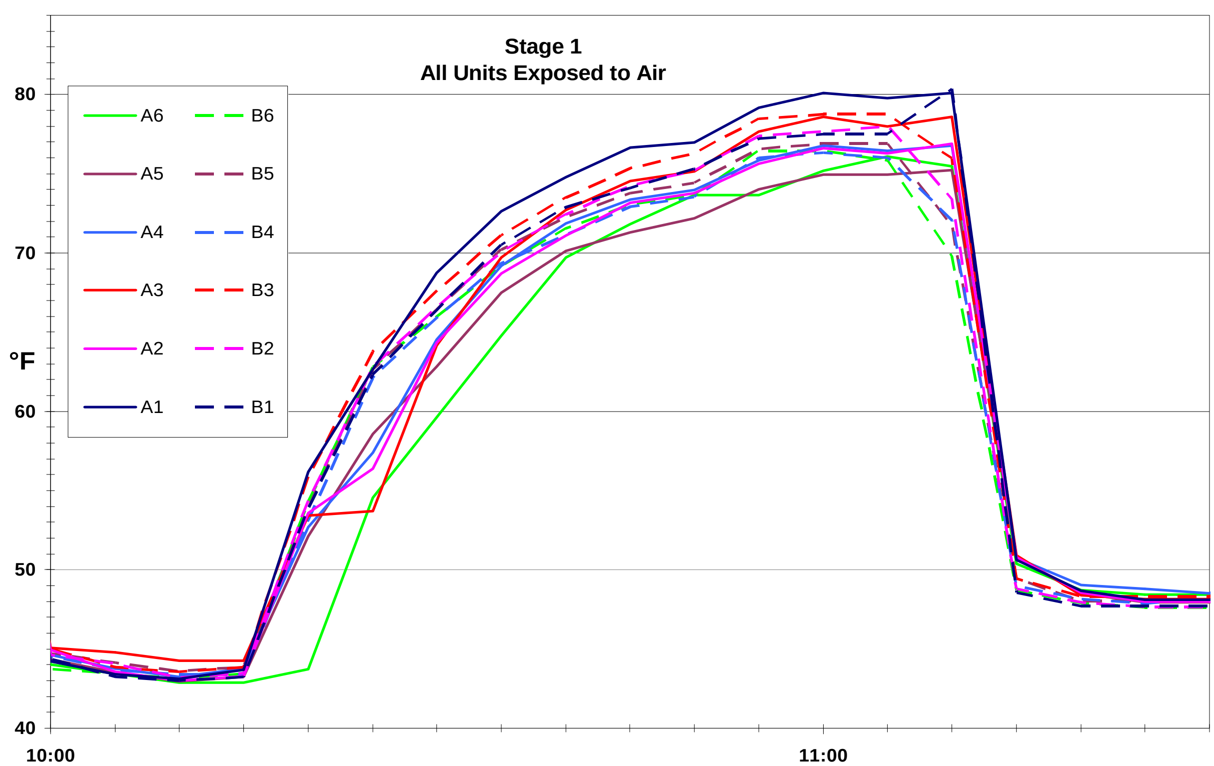
Results

This chart shows an overview of the data. Note the four dips from the water bucket immersions. Each "A" and "B" pair have matching colors but the "B" group is plotted with dashed lines.



Stage 1

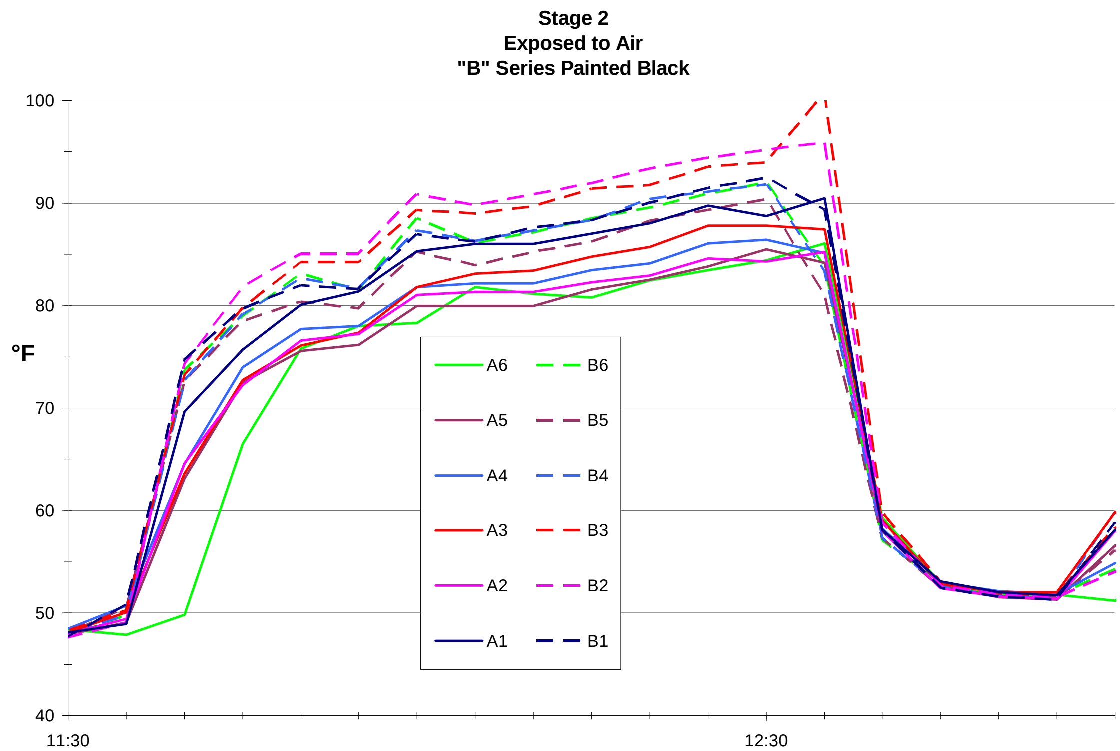
The chart for Stage 1 shows that while the units were in the water bucket the spread between them was in the range of about one °F but when the units were exposed to air the spread was in the order of six °F. It is thought that this difference is due to the reduced rate of heat transfer from the air to the thermistor which amplifies the effect of differences in the position of the thermistor within the data logger as well as differences in the response characteristics of the individual thermistors. As expected, there is no noticeable difference in the response between the "A" Series and the "B" Series.



Stage 2

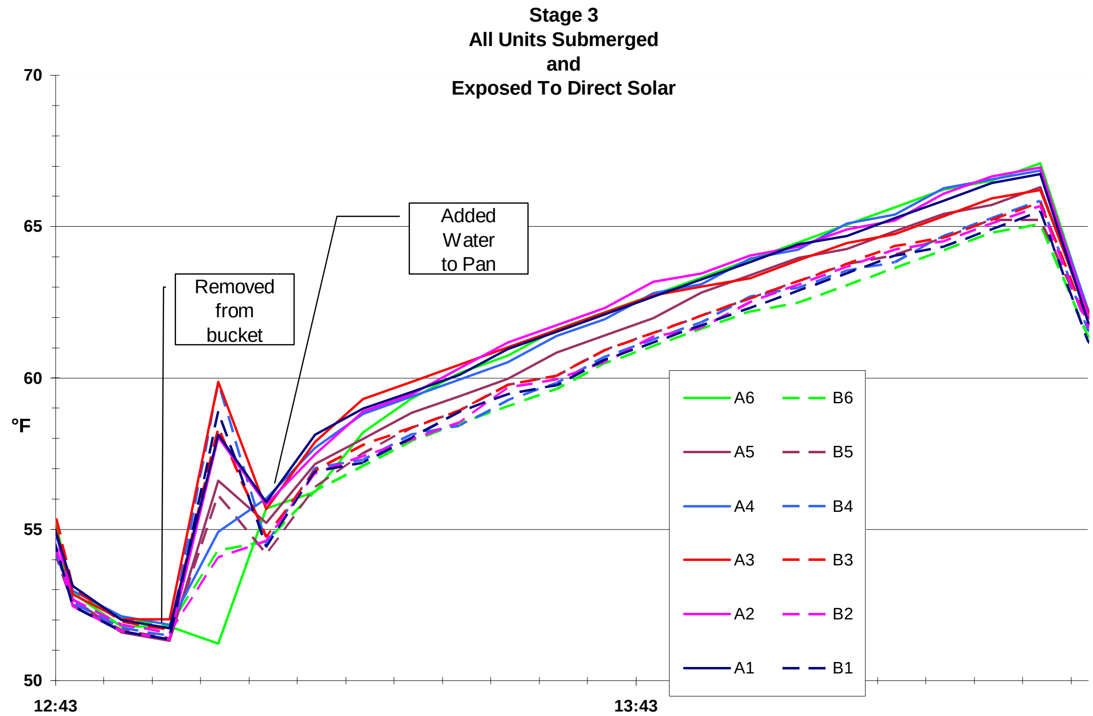
In Stage 2, the thermistor areas of the "B" Series data loggers were painted dull black, effectively shielding the thermistor from external radiation but decreasing the albedo of the outer surface.

The Chart for Stage 2 shows that, in the air environment, the painted data loggers reach temperatures about five degrees higher than the unpainted units. The apparent reason is that the painted external surfaces absorb more heat which is then conducted through the encapsulating material to the embedded thermistor.



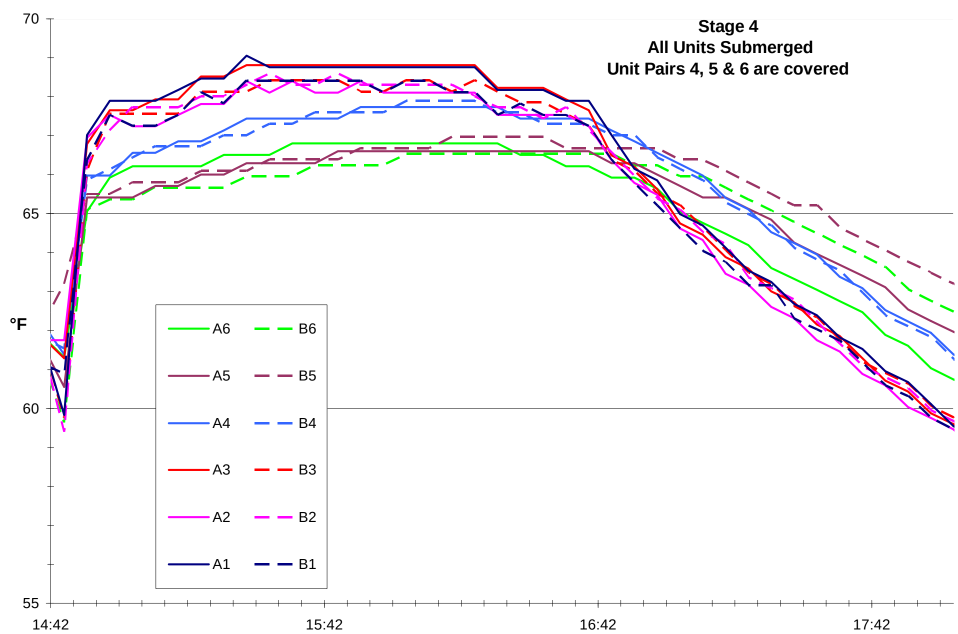
Stage 3

In stage 3 all of the units are submerged in water while fully exposed to direct solar radiation. The chart shows that, for this scenario, the unpainted units were about two degrees warmer and had more scatter than the painted units. In the water environment, the rate of heat transfer is high and the variability attributed to physical differences that affect the rate of conduction within the unit is reduced. However, the direct solar is reaching the thermistors in the unpainted units it is thought that the elevated temperatures in these units is the result of "green house" heating.



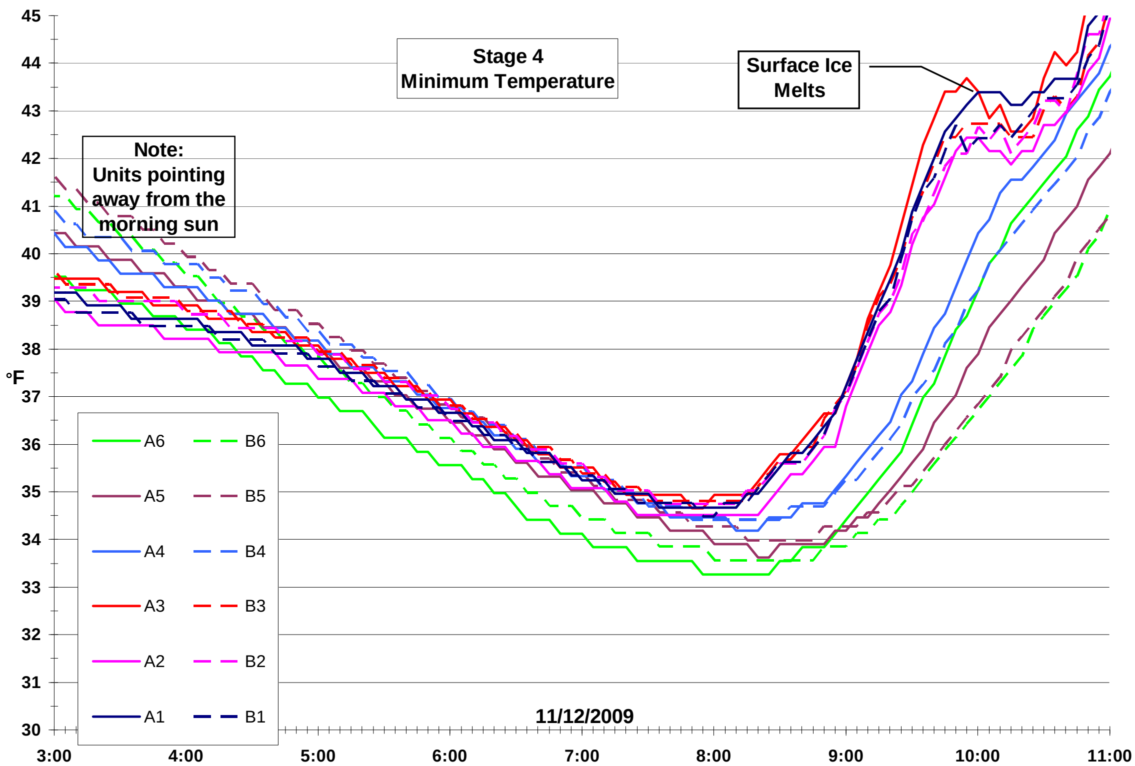
Stage 4 at Maximum Temperature

The Chart shows that, when the temperatures are increasing, the exposed submerged units heat faster than the covered units as would be expected. Likewise, during cooling, the exposed units respond faster and the thermograph traces reverse their order. The increased variability in the covered units can probably be attributed to the non-uniformity of the insulating cover. It appears that the uncovered units lead the covered units by approximately one hour.



Stage 4 at Minimum Temperature

The Chart shows the trace patterns converging as the night progresses and the difference between covered and uncovered diminishes. With the arrival of dawn, the uncovered units began to respond more rapidly after the morning light reaches them. Note the shift in the response of the uncovered units when the ice melts. It is believed that this is evidence of a "green house effect" taking place through the ice covering. The shortwave radiation penetrates the ice but the longwave radiation is trapped and results in accelerated heating.



Tentative Conclusions:

Based on the results of this experiment the following observations are proposed:

1. The variability of units exposed in air can be as much as six °F and may be attributed to minor variations in the physical construction of the data loggers.
2. Data loggers with an opaque coating on the outer surface will tend to measure higher temperatures while in the air environment.
3. The variability of units in water reduced but units with embedded thermistors exposed to direct solar radiation appear to run about two °F warmer due to internal heating of the thermistor by the shortwave radiation.
4. Submerged units that are covered will tend to have a delayed response causing lower temperatures during heating and higher temperatures during the cooling portion of the diurnal cycle.

It is recommended that these effects be taken into consideration when the data analysis involves small differences between units.

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