C06-04

Bridge Deck Wearing Surfaces

Final Report

November 2010

Authors

Harry L. White 2nd, PE, NYSDOT, 50 Wolf Road, Albany, NY 12232
Jon D. Kunin, PE, NYSDOT, 50 Wolf Road, Albany, NY 12232

DISCLAIMER

This report was funded in part through grant(s) from the Federal Highway Administration, United States Department of Transportation, under the State Planning and Research Program, Section 505 of Title 23, U.S. Code. The contents of this report do not necessarily reflect the official views or policy of the United States Department of Transportation, the Federal Highway Administration or the New York State Department of Transportation. This report does not constitute a standard, specification, regulation, product endorsement, or an endorsement of manufacturers.

Table of Contents

[This Page Intentionally Left Blank]

A. Executive Summary

Several commercially available bridge deck overlay systems claim to be waterproof and reduce deterioration caused by chloride laden water from penetrating concrete bridge decks. An attempt was made to quantify the in-service waterproofing qualities of several overlay systems by monitoring the moisture content of aged concrete using the relative humidity level in a closed hole in an existing concrete bridge deck. Unfortunately, the creation of a closed cavity in the concrete appears to attract internal moisture and creates a near 100% relative humidity condition. The research concludes that using commercially available relative humidity sensors is not a viable method of evaluating moisture movement in concrete bridge decks.

B. Introduction

Concrete bridge decks that are exposed to the elements deteriorate to some extent every day. The rate at which the deck deteriorates is dependant on a number of factors. Among these factors is the amount of water that has penetrated into bridge deck. The penetration can be through a slow process of migration through the pores in the concrete matrix, or a rapid process of seeping into an open bridge deck crack. The water causes damage to the deck through a number of mechanisms including carrying chlorides down to the reinforcing steel and freeze/thaw cycling that enlarges and expands existing deck cracks.

Several commercially available bridge deck overlay systems claim to be waterproof. A waterproof overlay is desirable on a bridge deck to reduce corrosion caused by chloride laden water, typically from de-icing operations, from penetrating the concrete bridge deck. In an attempt to quantify the in-service waterproofing qualities of several overlay systems, the Transportation Research and Development Bureau (TR&DB) of the New York State Department of Transportation (NYSDOT) looked at ways to determine the amount of water present inside aged concrete. At the time, there were no commercially available systems to evaluate the moisture moving through deck concrete.

C. Research Method

The project intended to determine moisture migration through the deck thickness. To accomplish this task, individual moisture meters were to be placed into separate holes drilled into the cured concrete. The holes were to be in the same general area of the deck but at different depths from the surface. The holes were then to be sealed from the outside atmosphere such that the only available moisture to the meter would be emitted from the concrete deck. A moisture profile was to be created for the thickness of the deck. Changes in this moisture profile, as a response to atmospheric moisture and precipitation events, would be tracked at regular intervals. Using this data, comparisons could be made as to the relative waterproof qualities of the various deck overlay systems.

1. Data Logging: Initial Attempt

Concrete moisture meters are commonly used in industry. ASTM has several standard specifications for monitoring humidity levels in concrete. Since the bridges to be studied had difficult access, it was desirable to have a continuous data logging system that would only need to be collected every 4-6 months. There are several commercially available data loggers capable of reading multiple humidity sensors, but these loggers were cost prohibitive for this project. An attempt was made to build an inexpensive data logger from scratch with the assistance of Robert Rodden, a graduate student that published a technical paper on a low cost humidity data logger that he developed. However, the architectural changes to the main processor chip used in the original design necessitated major revisions to the data logger control program. Not having the time or expertise to undertake this level of computer hardware/software development, the in-house custom built data logger was no longer a viable option.

2. Data Logging: Second Attempt

Subsequently, a low cost humidity data logging system built by Onset was found. Although the system had been available for several years, the company focused on the environmental market, as opposed to structural monitoring. After the company changed their web home pages, the sensors appeared on internet searches. The Onset humidity tracking system was evaluated in a laboratory setting and proved promising. Unfortunately, these sensors did not perform as desired in the field. The rest of this report documents the testing and installation of the relative humidity sensors shown in Figure 1.

Figure 1. Relative humidity sensor and data logger.

3. Laboratory Testing

A laboratory test was developed to examine the ability of a relative humidity sensor to detect moisture in a concrete sample. First, a hole was drilled through a concrete cylinder that had been oven-dried. A standpipe was affixed to the top of the cylinder with a water-tight silicone seal. Two relative humidity sensors were placed inside the drilled hole. One sensor, manufactured by Vaisala, had been used by TR&DB for several years with reliable results. The Vaisala sensor, however, must be monitored with a handheld reader. The second sensor, manufactured by Onset, was connected to a battery operated 4-channel data logger. The sensors were sealed in the hole with water tight putty. The putty was also evaluated to show that it prevented moisture from entering or exiting a steel pipe while not absorbing or emitting any moisture itself. A photo of the laboratory test is shown in Figure 2.

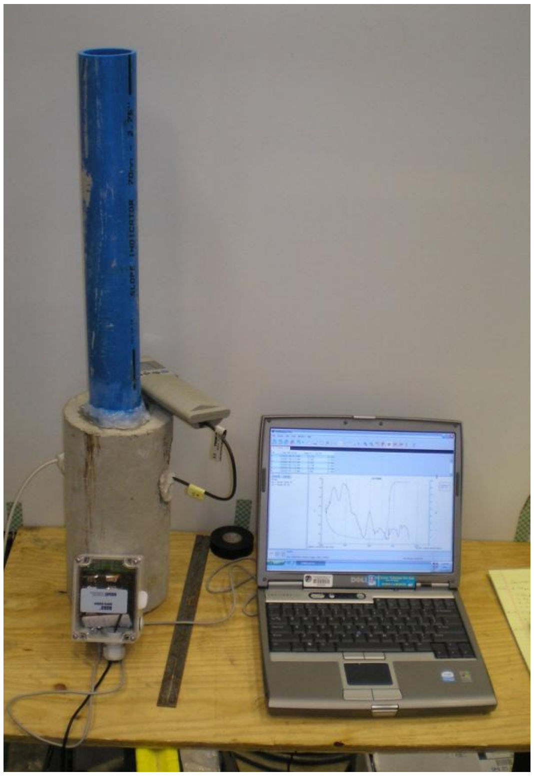


Figure 2. Laboratory test set-up.

The two sensors were monitored to insure an equilibrium moisture state was achieved in the cylinder. Once a flat relative humidity level was confirmed, water was added to the standpipe. Ideally, as the water permeated the concrete, the relative humidity at the sensor location would increase. This increase is clearly shown in Figure 3. The sensor readings rose from a steady relative humidity (approximately 10%) to over 90% relative humidity. The Onset sensor is also capable of monitoring temperature and daily fluctuation in the concrete cylinder temperature can be seen. Due to the thermal mass of the concrete cylinder, these temperature fluctuations lag behind the daily ambient temperature fluctuations of the laboratory.

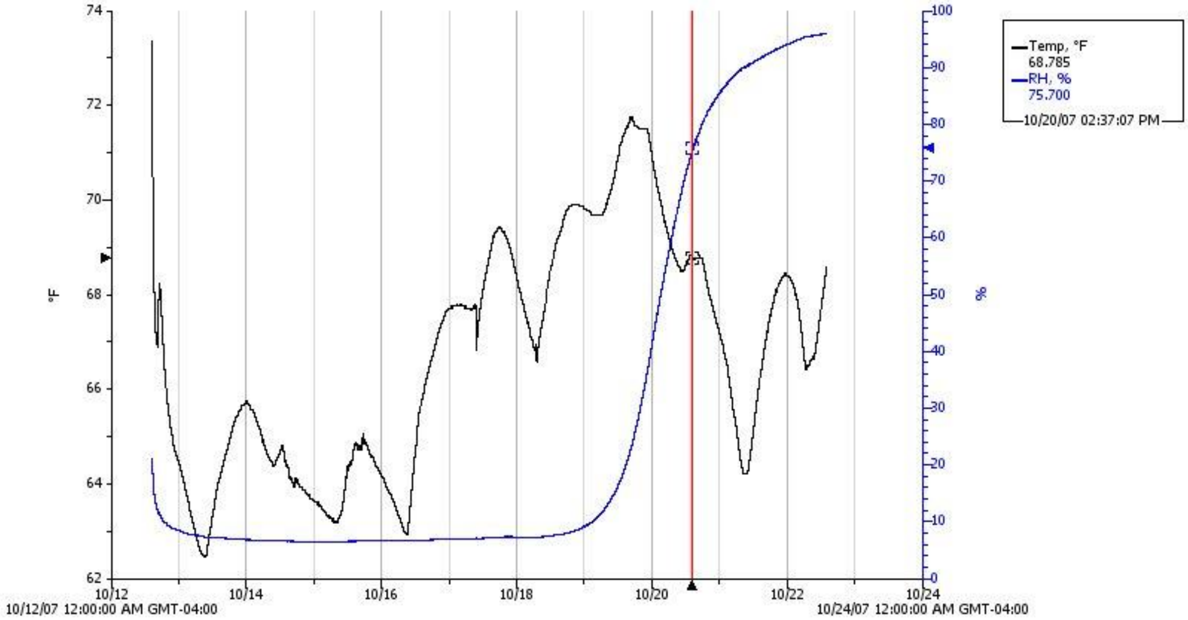


Figure 3. Plot of the temperature and relative humidity of a dry concrete cylinder.

4. Field Installation: Rip Van Winkle Bridge

After the success of the laboratory testing, several sensors and loggers were purchased to be installed in the field. The first installation was on the Rip Van Winkle Bridge which is owned and maintained by the New York State Bridge Authority. The underside of the bridge deck is accessible from a catwalk and the wearing surface was scheduled to be overlaid with a waterproofing system.

Two loggers monitoring a total of 8 relative humidity sensors were mounted on the bridge. Holes were drilled from the underside of the bridge to a depth of approximately 1 inch below the wearing surface. Instrumentation plans detailing the sensor locations are shown in Figures 4 and 5.

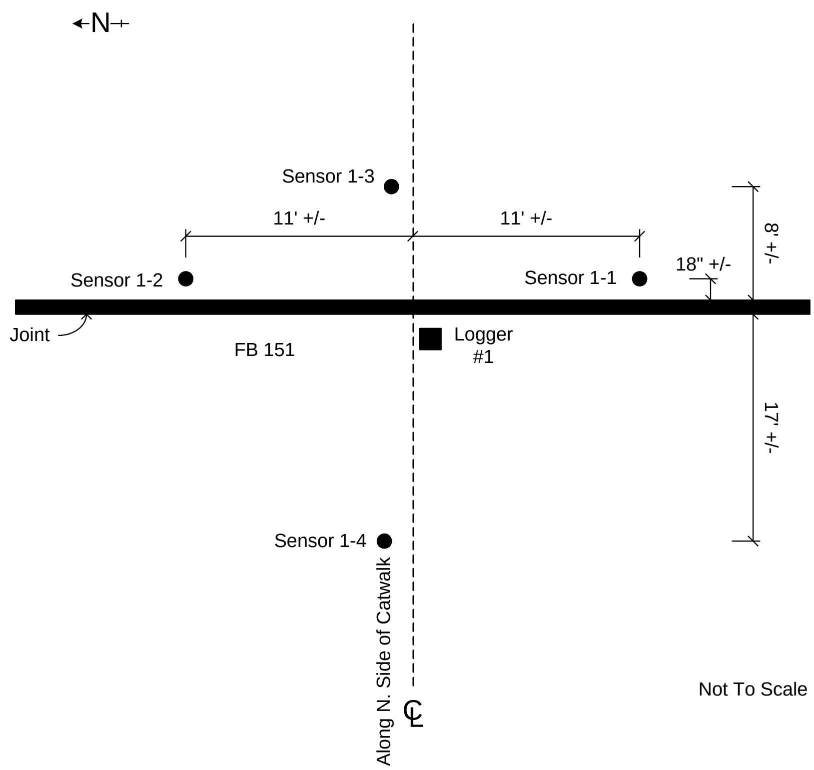


Figure 4. Location of Logger #1 sensors, in the area of Floor Beam 151.

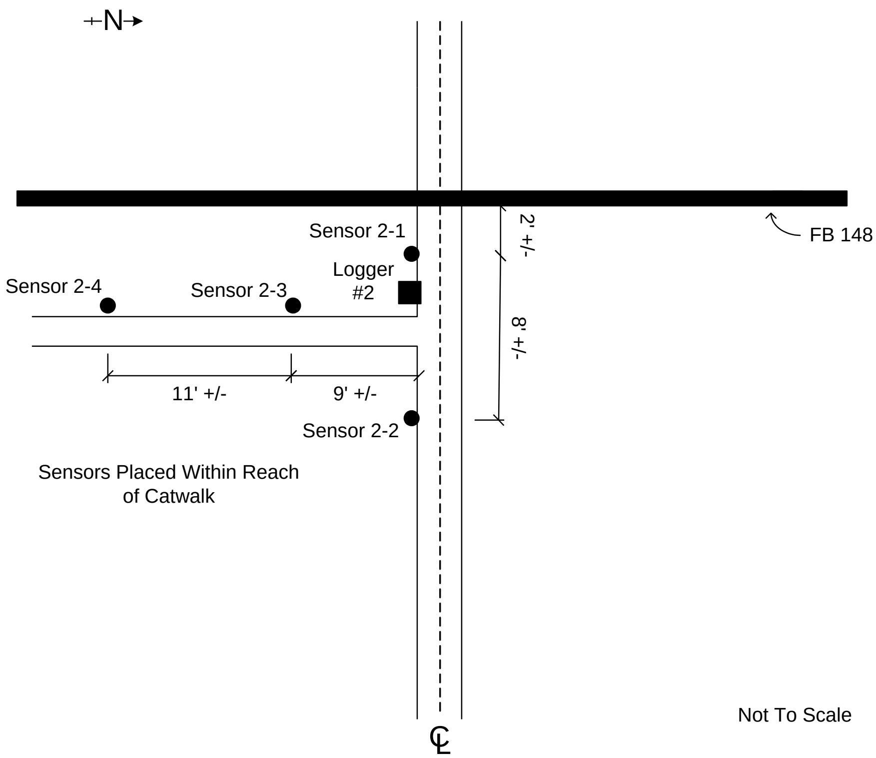


Figure 5. Location of Logger #2 sensors, in the area of Floor Beam 148.

D. Findings and Conclusion

The concrete bridge deck possessed high levels of moisture prior to the application of the waterproof pavement system, with the sensors reading near 100% almost immediately after installation. These initially high levels of moisture did not dissipate over time, thus making it impossible to distinguish between initial moisture in the concrete bridge deck and additional moisture, if any, coming through the waterproof system. An example of a typical set of relative humidity data collected is shown in Figure 6.

The sensor read a relative humidity level close to 100% for almost the entire time data was collected. Between the dates of November 12, 2008 and April 1, 2009, the waterproof plug was removed in an attempt to 'air-out' the hole and permit the relative humidity to stabilize at the sensor location. The attempt failed and the plug was restored. Relative humidity and temperature data collected from all the sensors installed at the Rip Van Winkle Bridge can be found in the Appendix.

In order to confirm these high moisture levels in concrete bridge decks, a logger and 4 sensors were installed on another bare concrete bridge deck that had been in service for several years. Similarly high relative humidity levels were found.

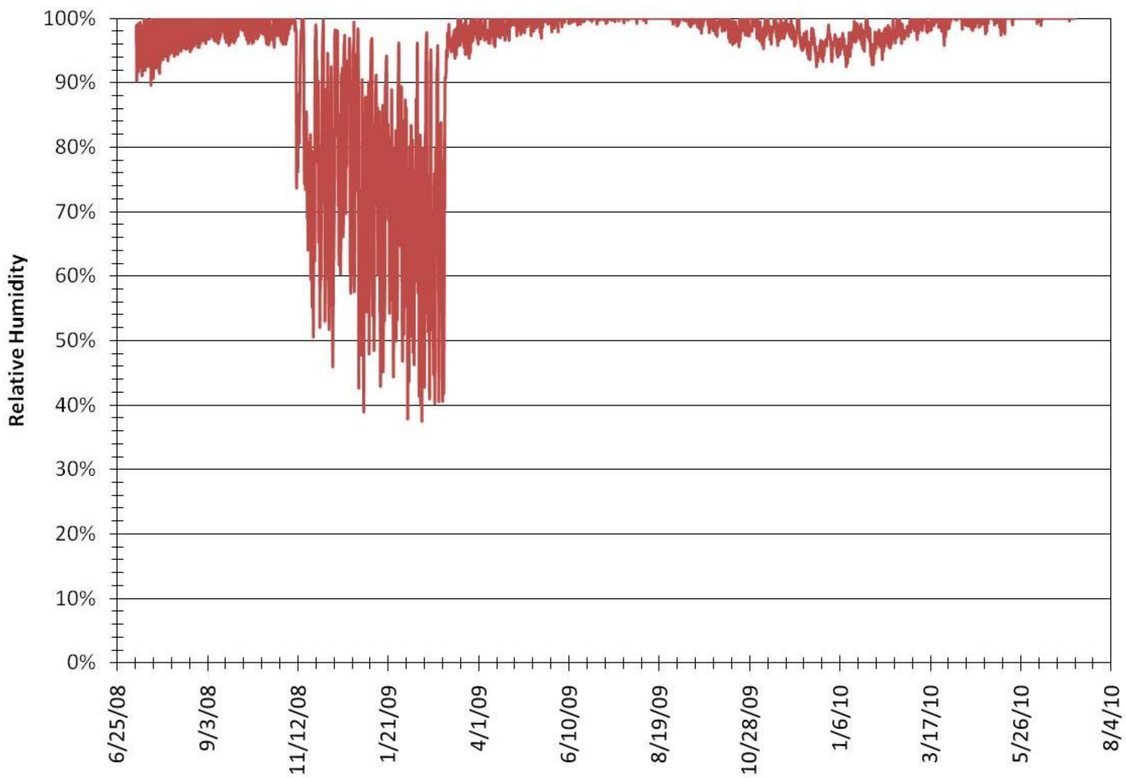


Figure 6. Relative humidity data collected by Logger 1, Channel 2.

The creation of a closed cavity in the concrete deck appears to attract the internal stored moisture and creates a near 100% relative humidity condition. Therefore, relative humidity sensors are not a viable method of evaluating moisture movement in concrete bridge decks.

E. Statement on Implication

This research shows that relative humidity sensors are not a viable method of evaluating moisture movement in concrete bridge decks. As such, the project was terminated. If new sensors are found in the future, the project may be resubmitted for consideration.

F. Acknowledgments

The Transportation Research and Development Bureau would like to thank William Moreau and Jack Kelly of the New York State Bridge Authority, for providing access to the Rip Van Winkle Bridge and facilitating the installation of the sensors. Thanks are also due to Doug Rose of NYSDOT Region 1 who provided access to a local bridge for further monitoring and Robert Rodden for providing valuable technical assistance on the initial attempt at a low-cost data logger.

Appendix

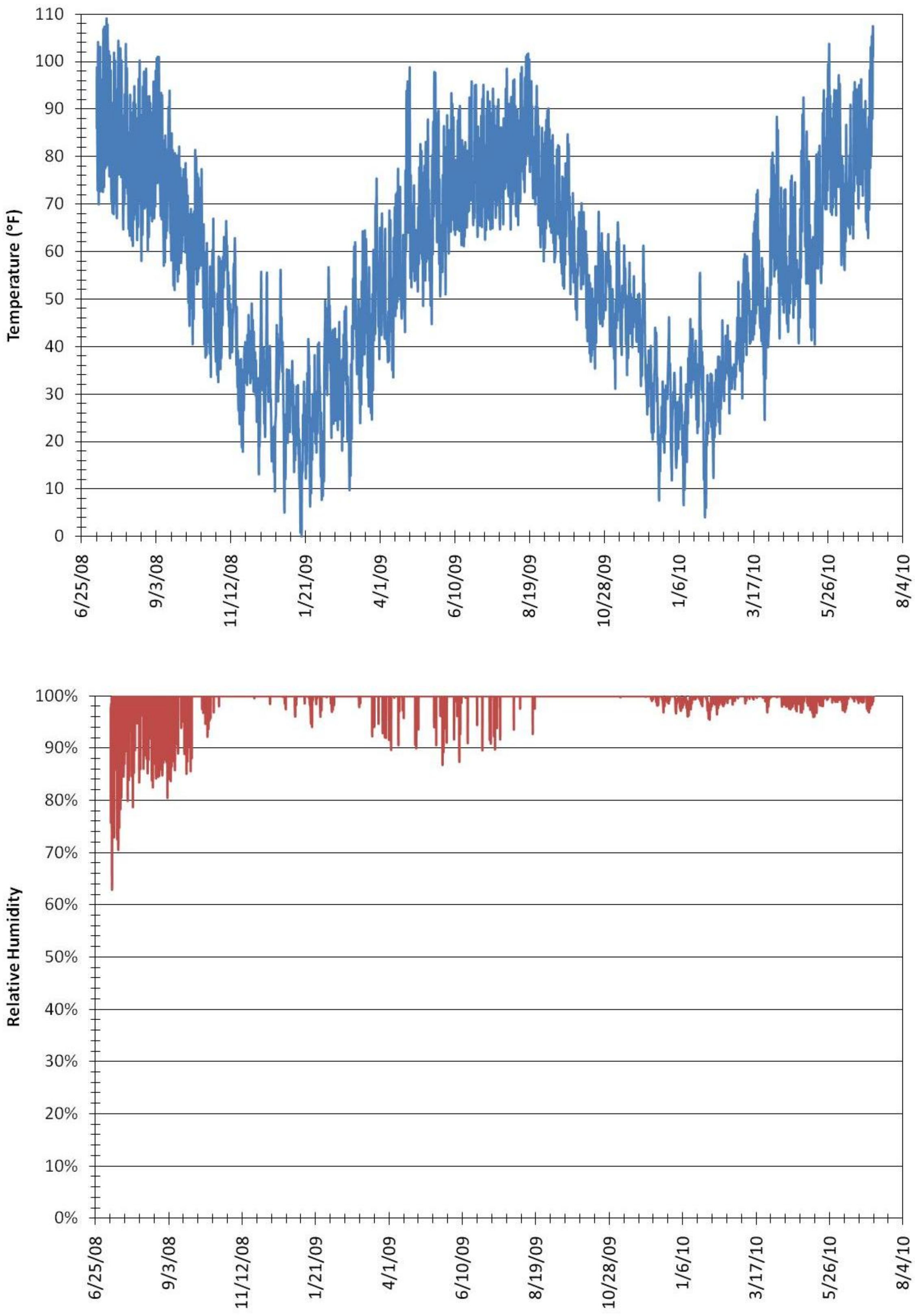
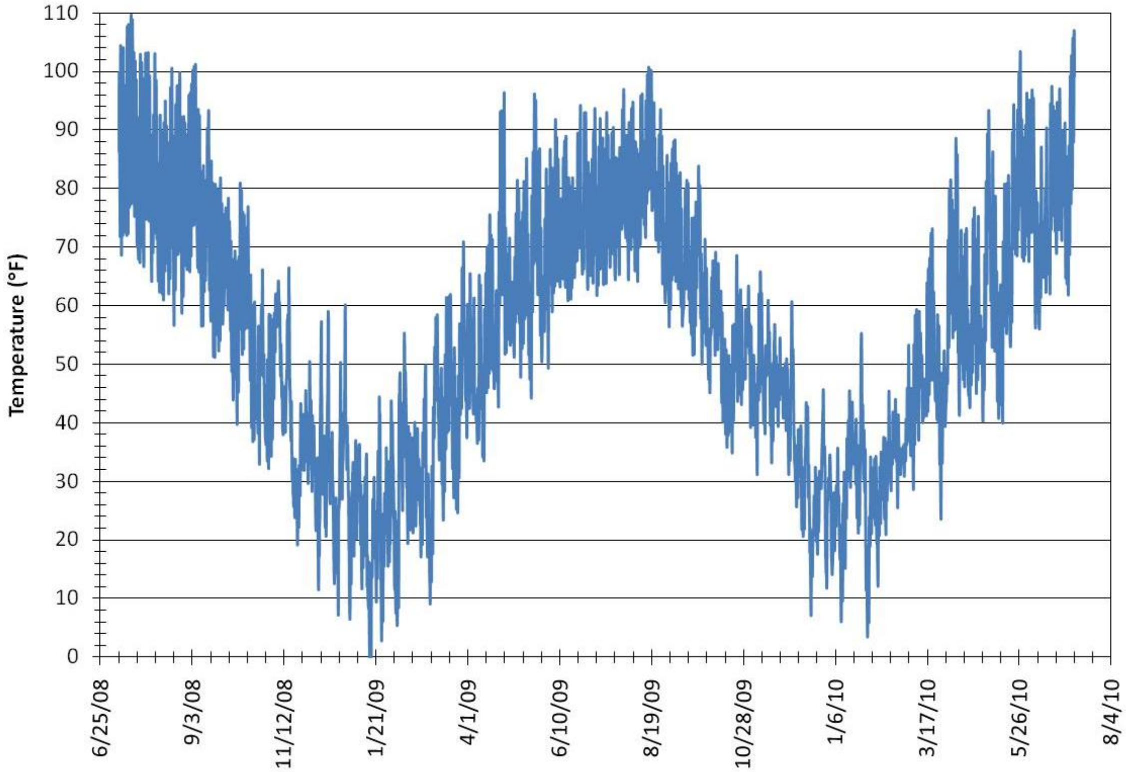


Figure A1. Temperature (top) and relative humidity (bottom) histories for Logger 1, Channel 1.



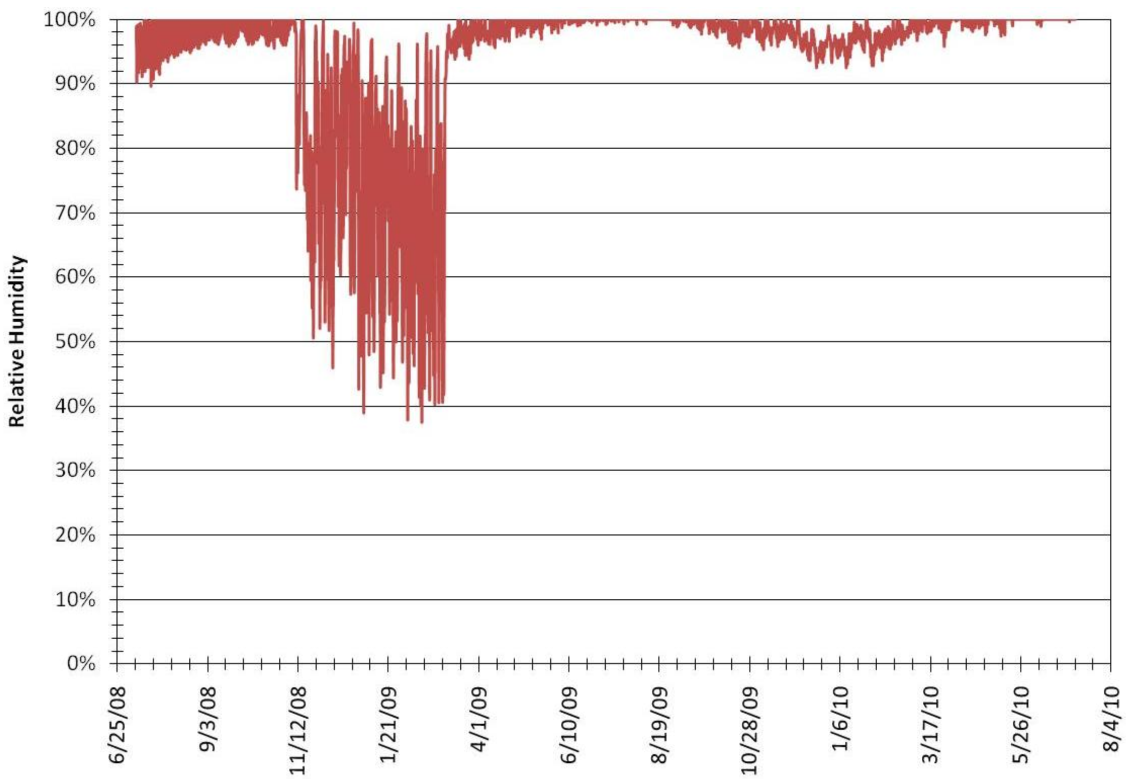
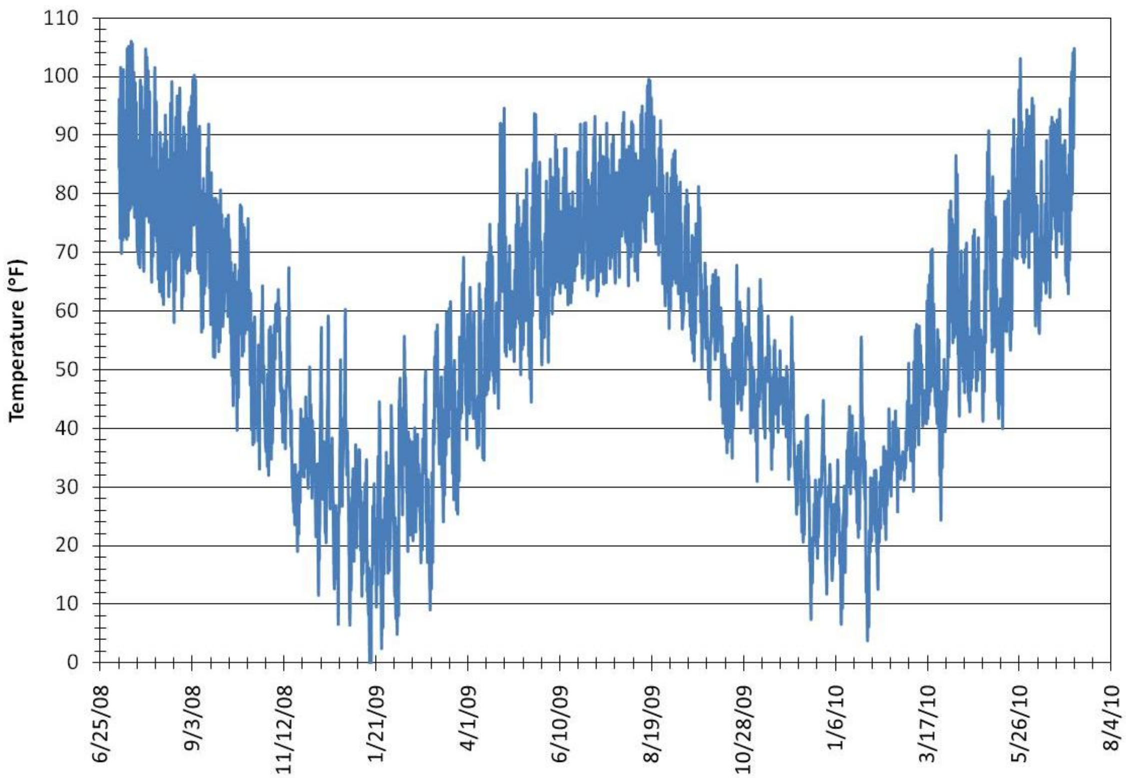


Figure A2. Temperature (top) and relative humidity (bottom) histories for Logger 1, Channel 2.



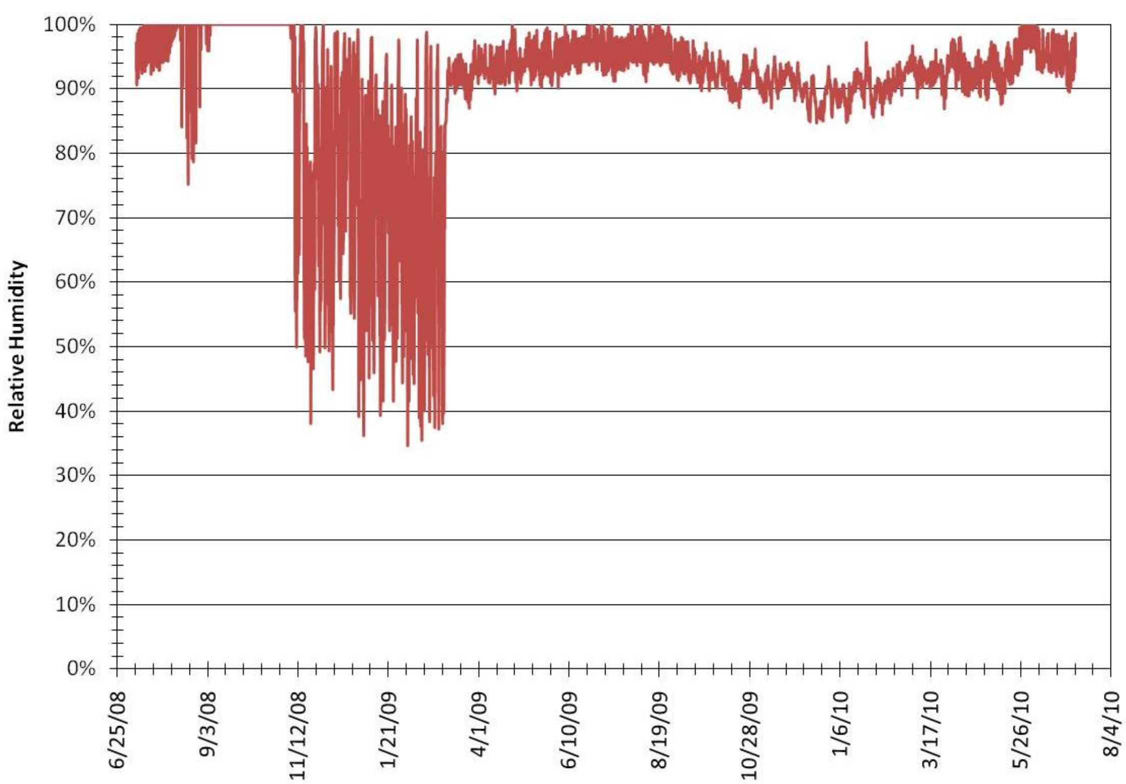
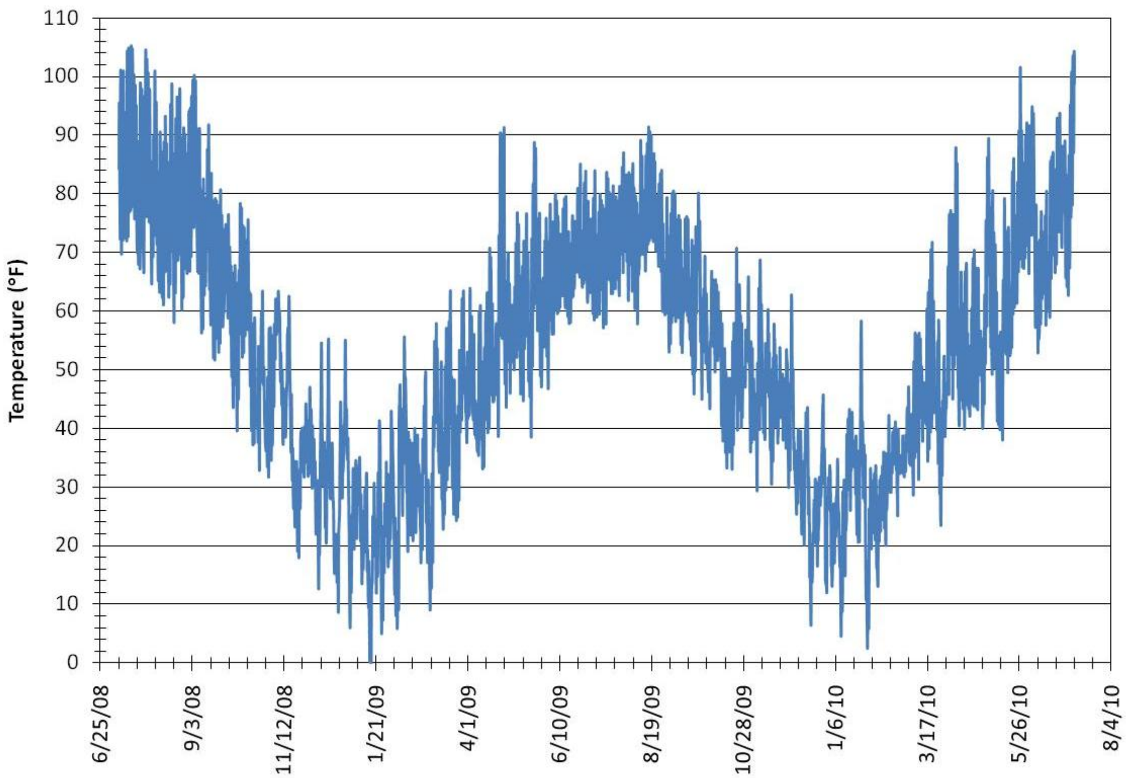


Figure A1. Temperature (top) and relative humidity (bottom) histories for Logger 1, Channel 3.



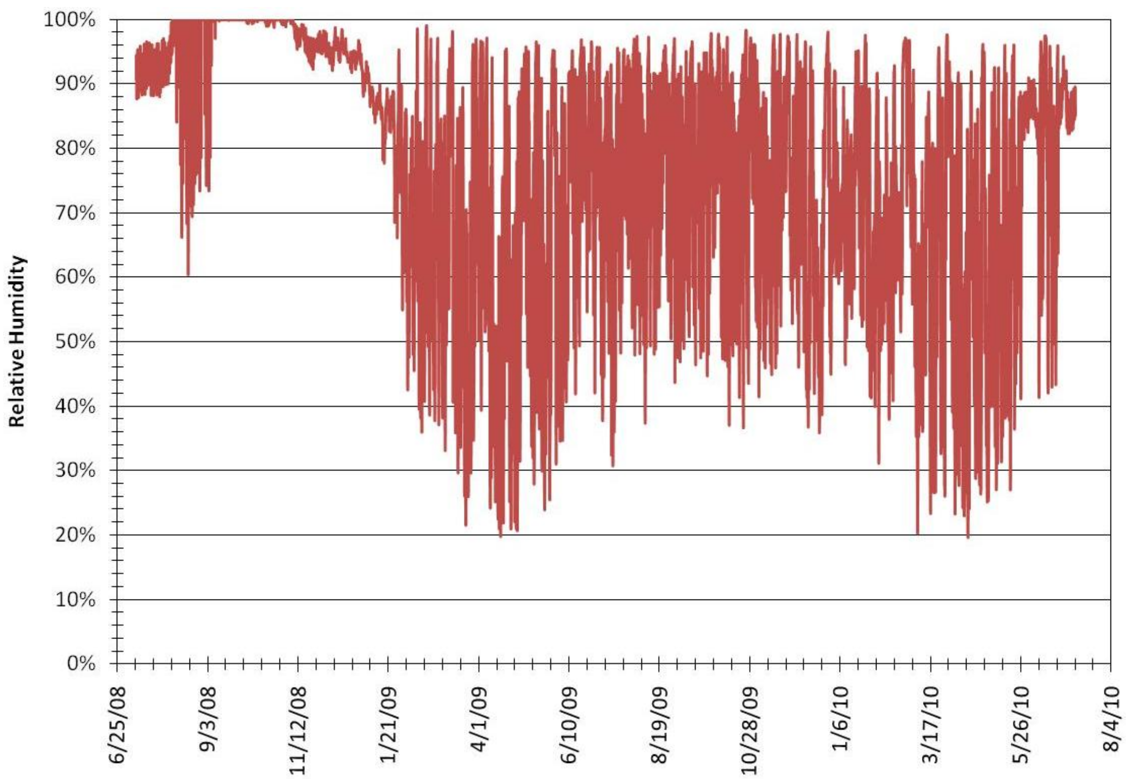
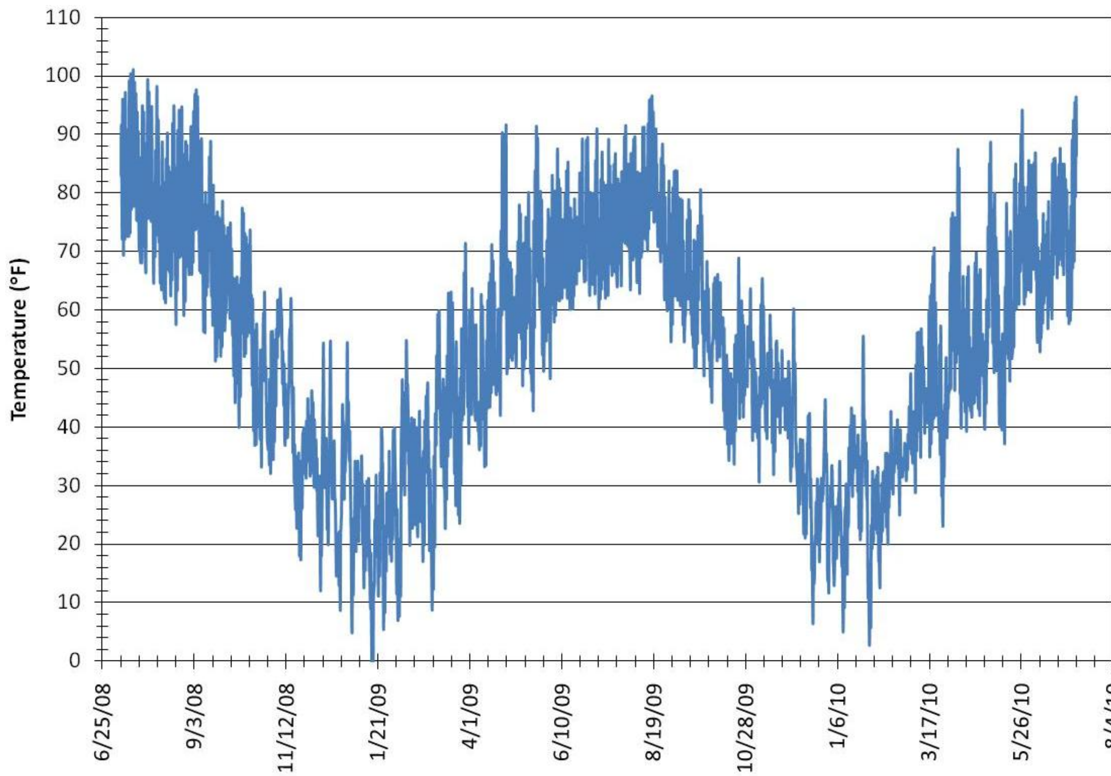


Figure A4. Temperature (top) and relative humidity (bottom) histories for Logger 1, Channel 4.



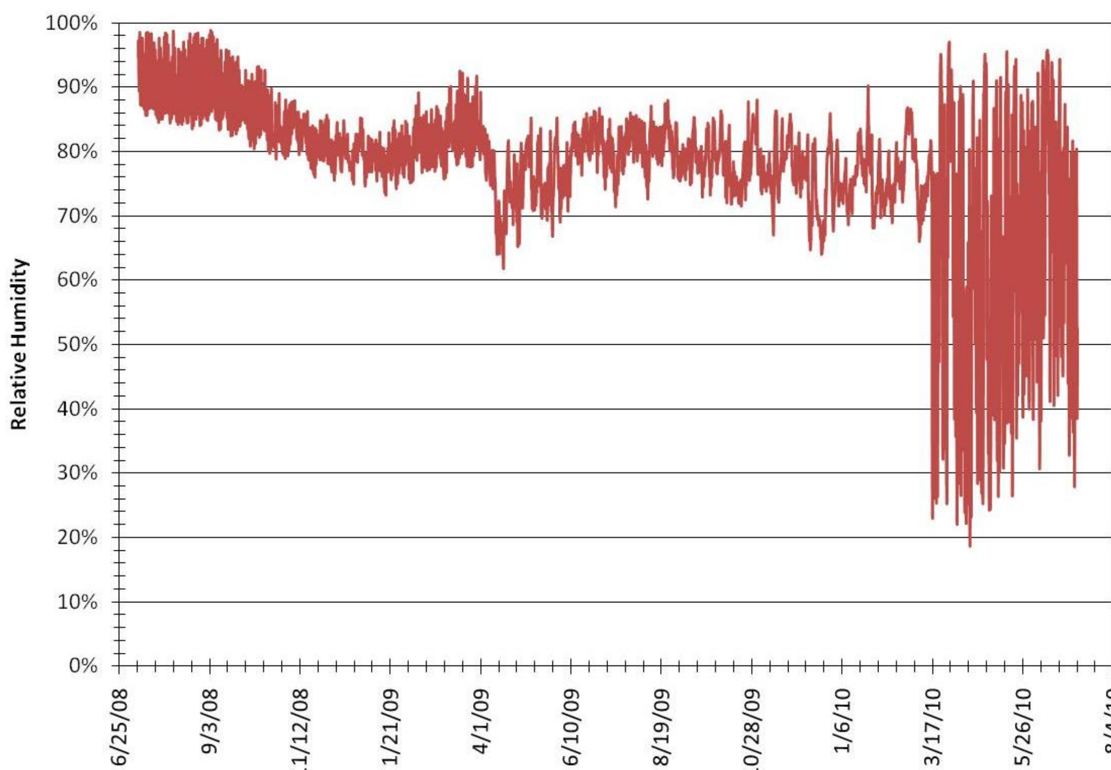
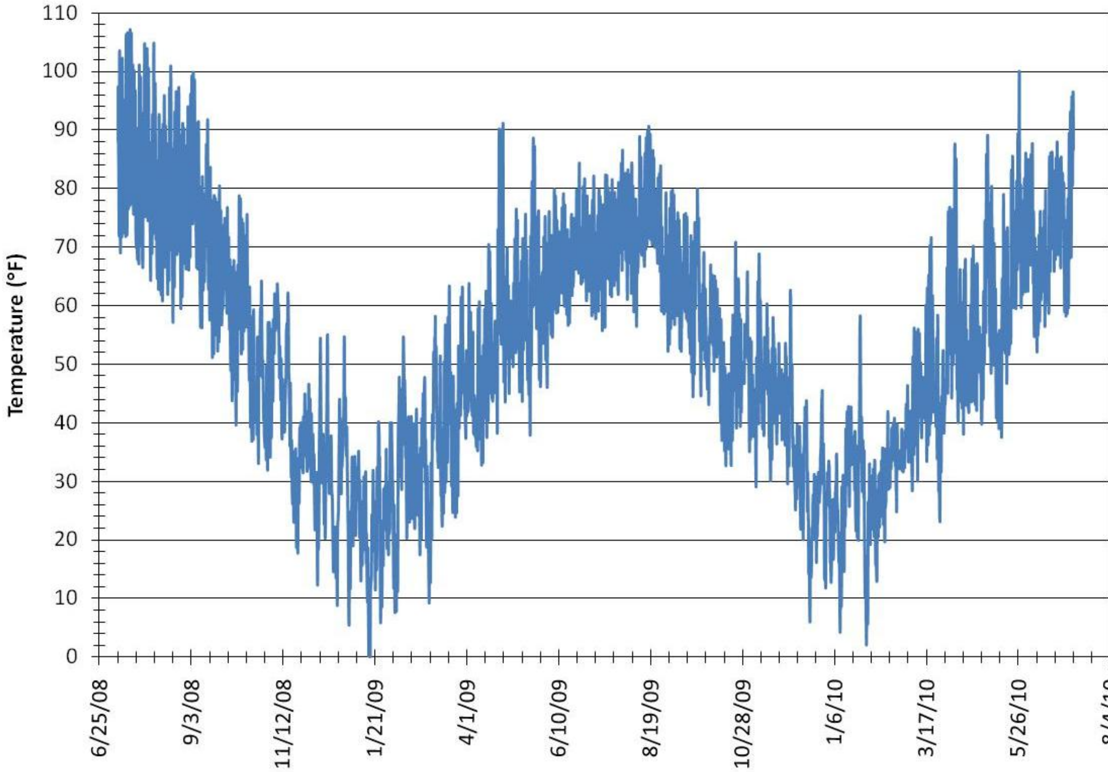


Figure A5. Temperature (top) and relative humidity (bottom) histories for Logger 2, Channel 1.



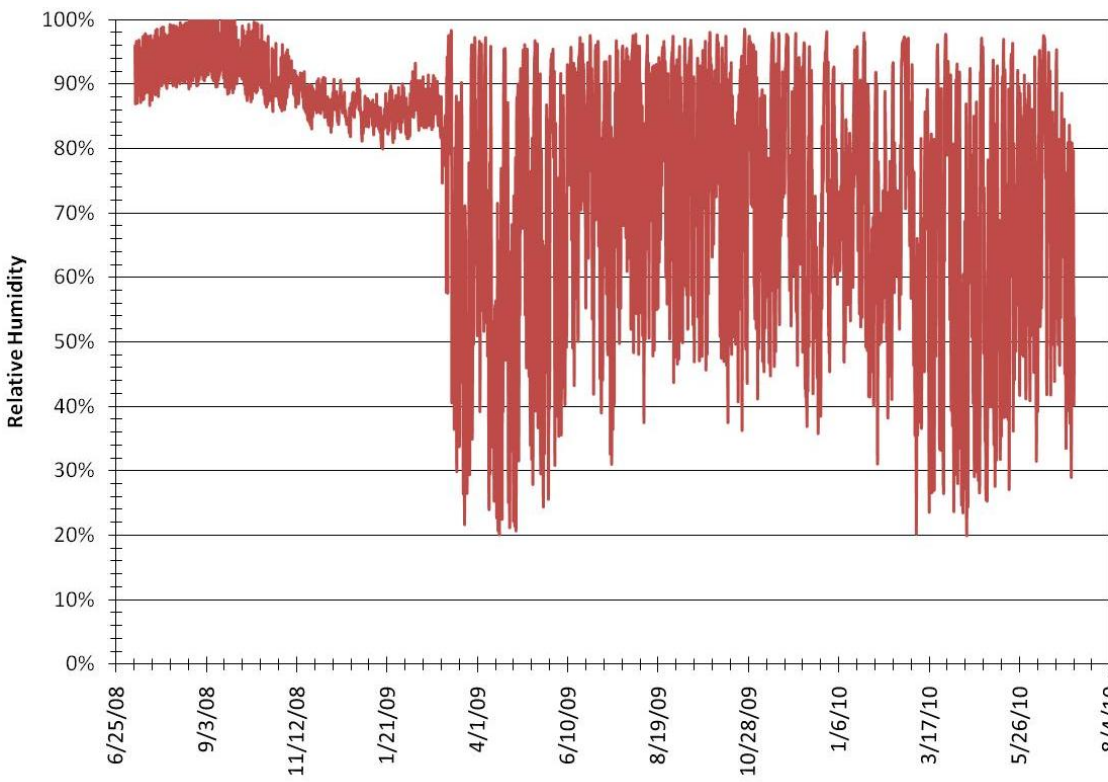


Figure A6. Temperature (top) and relative humidity (bottom) histories for Logger 2, Channel 2.

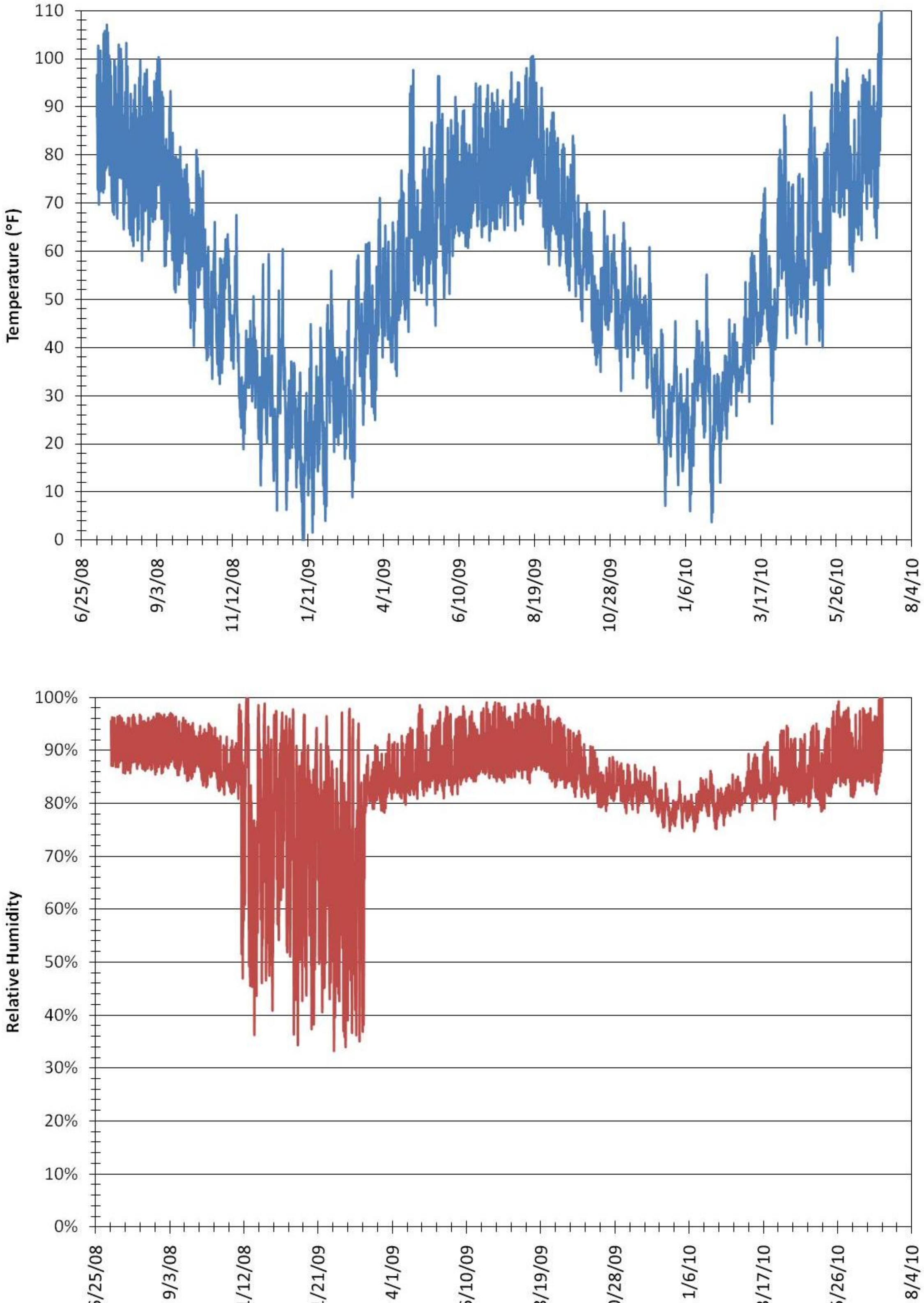
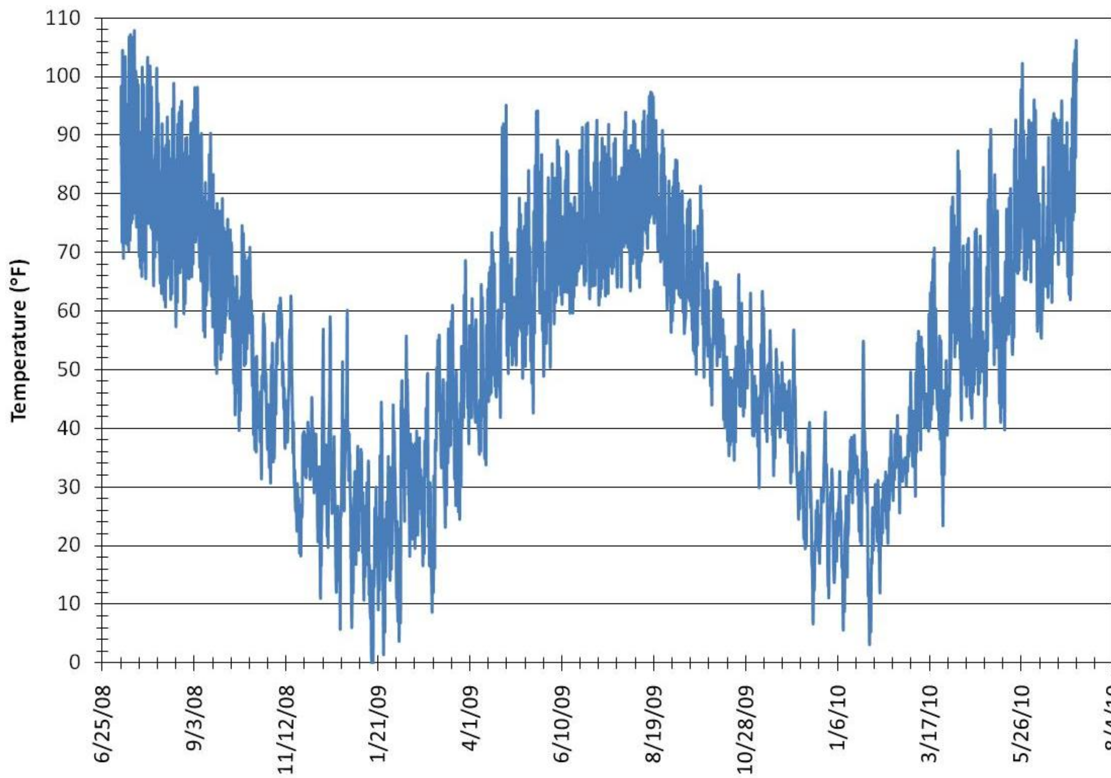


Figure A7. Temperature (top) and relative humidity (bottom) histories for Logger 2, Channel 3.



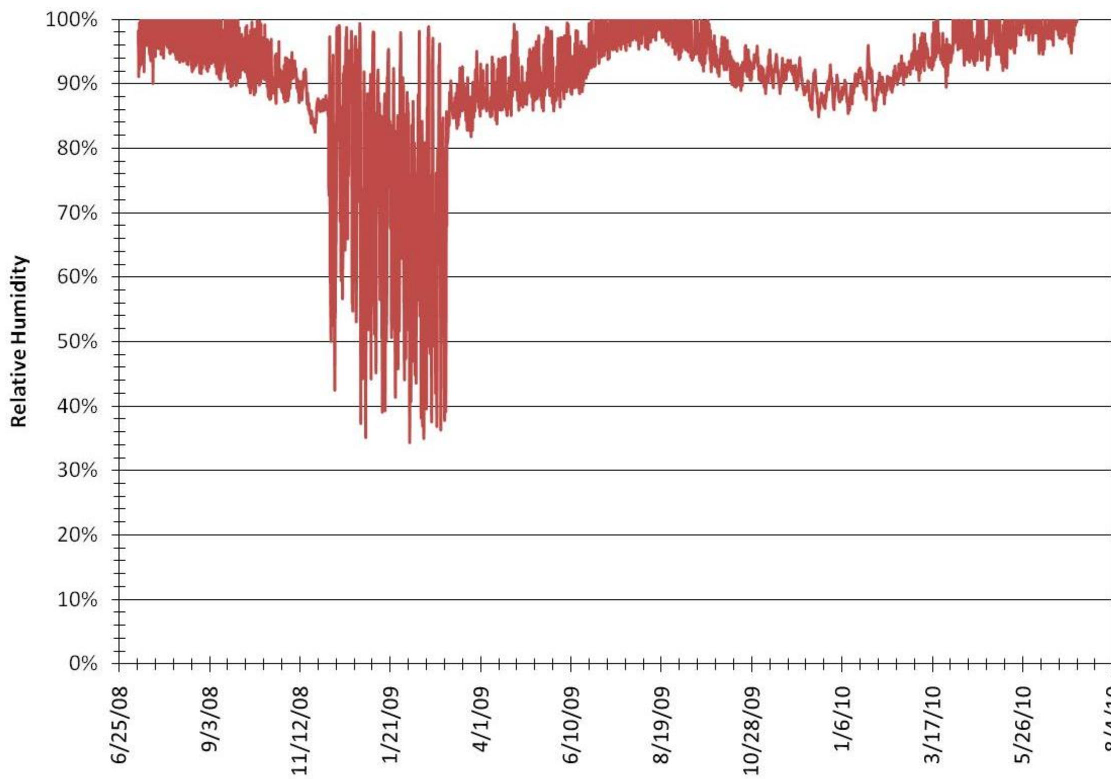


Figure A8. Temperature (top) and relative humidity (bottom) histories for Logger 2, Channel 4.