MONITORING AND ENVIRONMENTAL MICROCLIMATE DATA OBTAINED FROM STUDIES OF HIBERNACULA SITES WITHIN CAVES IN WEST VIRGINIA

Mike Masterman
304-457-2500 x2
mfm@extreme-endeavors.com

Todd Leonhardt, NSS 44801
304-457-2500 x3
tl@extreme-endeavors.com
Extreme Endeavors and Consulting
PO Box 2093
Philippi, WV 26416
http://www.extreme-endeavors.com/

Abstract

Extreme Endeavors and Consulting was contracted to perform environmental monitoring of hibernacula sites of endangered species of bats in Hellhole and Schoolhouse Caves which are located in Pendleton County, West Virginia. A system was exclusively developed by Extreme Endeavors to operate inside of a cave, extracting the most precise temperature and air pressure data ever seen from an underground environment, while providing the ability to correlate with a similar monitoring station located in the proximity of the entrance of the cave. The monitors within this system remained tethered to the surface, where autonomous power systems provided power and a connection to a communications link, allowing data to be downloaded throughout the year, simply by dialing over a modem.

A feature was designed for this system that allowed the user to set the sample rate of data from 1 minute to 24 hours. The sample rate of each module was set to a fine-scale time interval, a finer scale resolution than previously utilized in measurements taken from these caves. This resolution and extremely precise data has shown various anomalies that are occurring in this micro environment. The data from these caves will be presented, along with extensive computations that show the correlation of surface data to the data from within the cave. Details will be presented to show how mathematical analysis can be used to tell us more information about the world below.

An additional result of our study is the product of component failure causing us to perform further research into the surface potentials created around sink holes and caves. Data from this investigation will be presented and an analysis of our findings will be scrutinized.

Background

Extreme Endeavors is currently under contract to provide environmental monitoring of Hellhole and Schoolhouse Caves, two important bat caves located near a local limestone quarry. These two caves are very well known throughout the U.S. and abroad and have challenging vertical drops, difficult passageways, and Hellhole is amazingly vast and complex. The caves are home to approximately 200,000 bats of seven species, including significant concentrations of two federally endangered bats, the Virginia big-eared bat and the Indiana bat.

To ensure the safety of these animals and to protect their environment from any changes that might be created by the nearby quarry, yet maintain the economic benefit that the mine brings to the local economy, a complex, intricate, and sensitive monitoring system has been installed to keep a vigil eye on conditions at important bat hibernation sites in these two caves. This monitoring system is more precise than ever seen before in a cave and overcomes the multitude of problems associated with placing sensitive electronics inside of a cave. The system measures temperature inside the caves with an absolute accuracy of 0.2° F and a relative accuracy (and precision) of 0.05° F. Absolute pressure is measured with a static accuracy better than 0.002 PSI. Data can be recorded at a user-selected interval between 1 minute and 24 hours; when recording data every 15 minutes, the system can record data for over five months before the memory fills up.

Extreme Endeavors and Consulting is a small firm located in Philippi, West Virginia, with experience in taking technology to the harshest and most desolate environments found on earth. This experience in harsh environments includes several operations Extreme Endeavors and Consulting has been involved in throughout Antarctica and working with the U.S. Military in taking technology from the war fighter and integrating it for use with emergency service workers.

One requirement for monitoring Hellhole and Schoolhouse caves was that the data had to be remotely accessible 24 hours a day and 7 days a week. Remote data access to one of the most rural and remote regions of West Virginia was much simpler than providing NASA access to the middle of Antarctica in the middle of winter, but it was soon discovered that other problems would be encountered. This remote access was a tremendous leap forward in underground monitoring systems. It provided the ability for the users to initiate specific monitoring requests, such as altering the frequency of readings or making queries on specific monitoring areas, without having to enter the cave (which would disturb the bats in hibernation).

On a regular basis, the systems can be connected to and data can be downloaded to a computer for evaluation and analysis. The systems within the two caves each have multiple sensors capturing temperature and barometric pressure data. By utilizing this data, it is easy to remotely assess if the cave environments are tracking the outside environment appropriately. Any significant change in temperature and/or barometric pressure would point to a possible breach of the cave's environment; creating a new cave entrance could dramatically alter airflow in the cave and change the ambient temperature. Regular monitoring allows for a timely response in protecting the endangered animals' environment in the event of an accidental breach of the cave.

The cable used to achieve this communication consists of three twisted-pair, 24-gauge lines in a watertight jacket that is encased in steel/aluminum conduit. One twisted pair delivers power from the surface module to the in-cave modules, the other two twisted pairs are used for a full duplex RS-485 communication network. Each module is controlled with a microcontroller containing an embedded operating system which allows us to communicate with each module individually and issue various commands according to a custom protocol.

This project was brought to the attention of Mr Tom Minnich from the Robert C. Byrd Institute of Advanced Flexible Manufacturing. This organization provided assistance in operations and in development of the packaging required for the severe environment found underground. The Institute provided the machining assistance in the fabrication of these environmentally sound, intricate packages to go into some of the most diverse conditions imaginable. Currently Mr Minnich and Extreme Endeavors are working together to promote sensor and technology transfer from NASA Langley to add different capabilities into the realm of underground monitoring.

Results

One of the problems associated with running a remote data access system, specifically for the first time ever, is that it is sometimes not possible to account for all of the operating and environmental conditions the system will be subjected to in the initial design. This was discovered when

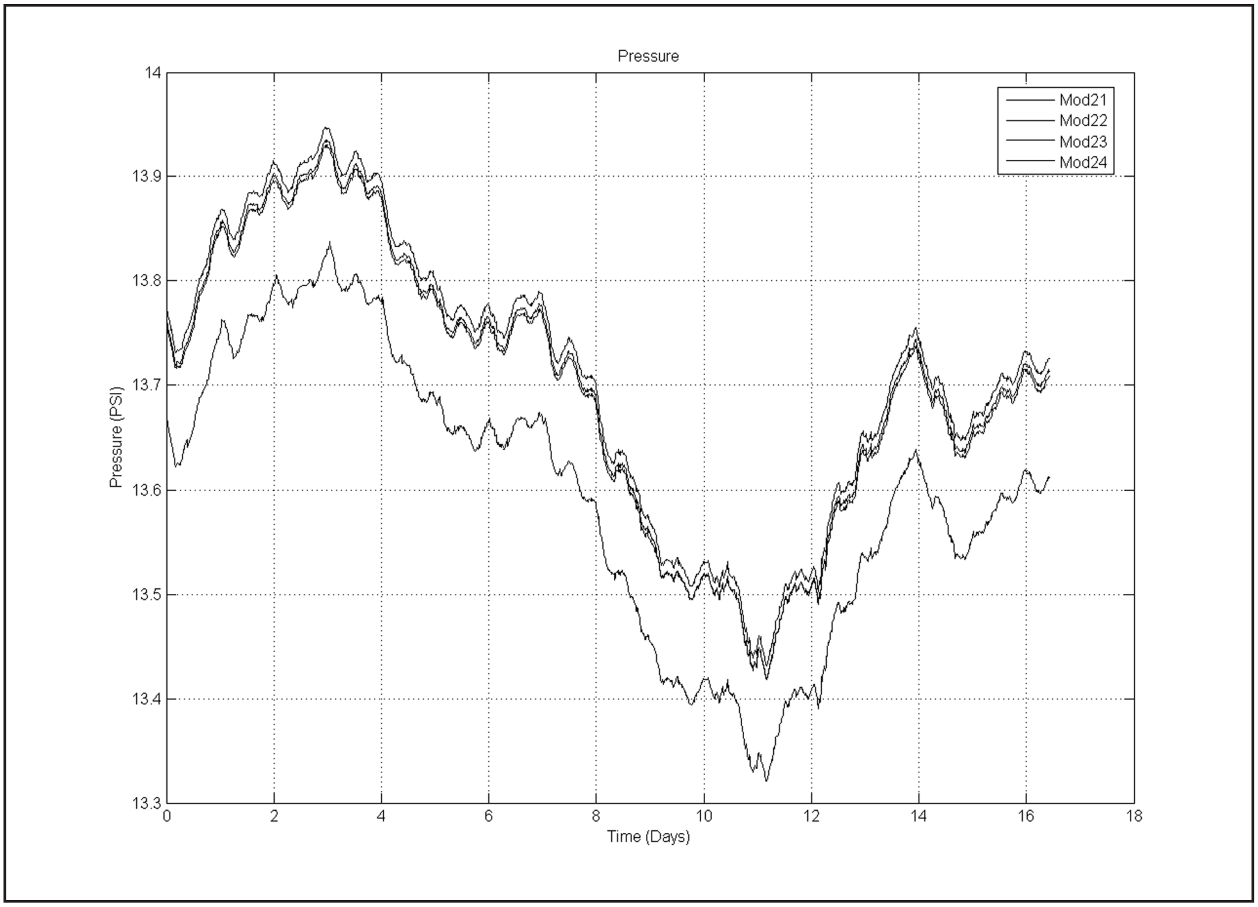

Figure 1 Sixteen days of air presure readings in Hellhole.

the electronics became the victim of severe charge build up, such as when lightning is directed to the caves during the mildest of storms or due to other charged-particle releases. The analysis performed on this problem has been directing unprecedented advancement in karst and underground facilities research.

In order to develop a system that can withstand and dissipate this charge due to lightning and natural/self-potential phenomena, we first had to measure this property. The charge build up was found to be very rapid, a 0.25 second pulse width was observed with a magnitude that was off the scale. This charge build up was found on the conduit and was being dissipated into the sensitive electronics, creating multiple failures. There was no direct correlation between lightning in the immediate region and this charge build up, further research would have to be done to determine the correlation between these events and lightning events further from the site. One relevant detail that is currently under investigation is that destruction of telephone equipment in specific regions has been known in this region of Germany Valley. The local phone company was noted at saying "it seems like the same people are always having trouble with their phones — these are legitimate problems, its always the same people though." This, along with additional literature, suggests that caves can be challenging environments in which to operate electrical equipment [1, 2].

Once the source of the problem was identified, a grounding system had to be developed and put in place before the cave closings of Hellhole and Schoolhouse Cave. Due to the rapid onset of charge, a total of three grounding rods had to be placed at Hellhole, one on the surface, one in the entrance room and one further back in the cave.

An example of the data can be seen in Figure 1 which shows 16 days of air pressure taken from several different locations inside of Hellhole and in one position outside the entrance.

Due to the sensitivity of the instrumentation and significant mathematical processing performed by Extreme Endeavors, the various frequency components were analyzed for correlation between the in-cave and out-of-cave sensors as shown in Figure 2. The analysis has revealed significant pressure and temperature oscillations on the daily and twice-daily cycles, with the twice-daily variations generally being slightly dominant. Through further analysis of this pressure variation, even the slightest change in the cave's environment can be detected.

Thermal anomalies were also detected that are currently under investigation, most of the temperature data from the caves is directly correlated to the surface temperature as shown in Figure 3 and Figure 4. With a relative accuracy of 0.05° Fahrenheit, the in-cave modules were sensitive enough to pick up even the most minor fluctuations in the underground passageways. A similar frequency analysis has been applied to the temperature data, revealing a truly fascinating result: many of the passageway temperatures are directly correlated with the outside temperature; however in certain passageways there was a direct anti-correlation between the in-cave and out-of-cave temperature.

The intricacies and complexity of this monitoring challenge, coupled with the engineering and access requirements, where Extreme Endeavor's engineers must rappel 180 feet into a pit make this project one of tremendous interest to other organizations. These caves are well known by karst researchers around the world, even the U.S. Military and intelligence agencies are expressing interest in this technological advancement.

Throughout this project, Greer Industries realized one thing which led them to work with Extreme Endeavors and Consulting. Conditions within caves are unique, requiring specialized considerations for sensors and monitoring. Therefore, special designs of components have been incorporated into the total system design as a means of addressing the ultimate application: remote data collection from within the caves. For instance, static electricity builds and discharges repeatedly within a cave environment. Lighting strikes outside of a

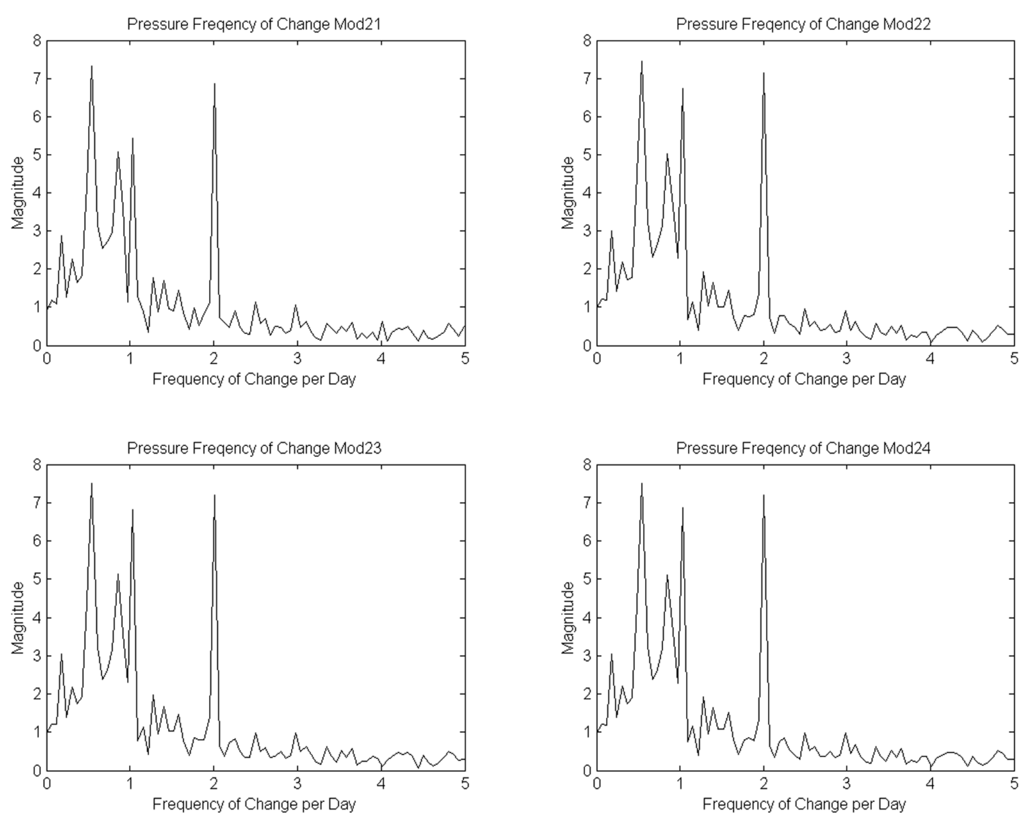

Figure 2. Pressure frequency of change inside and outside of the cave.

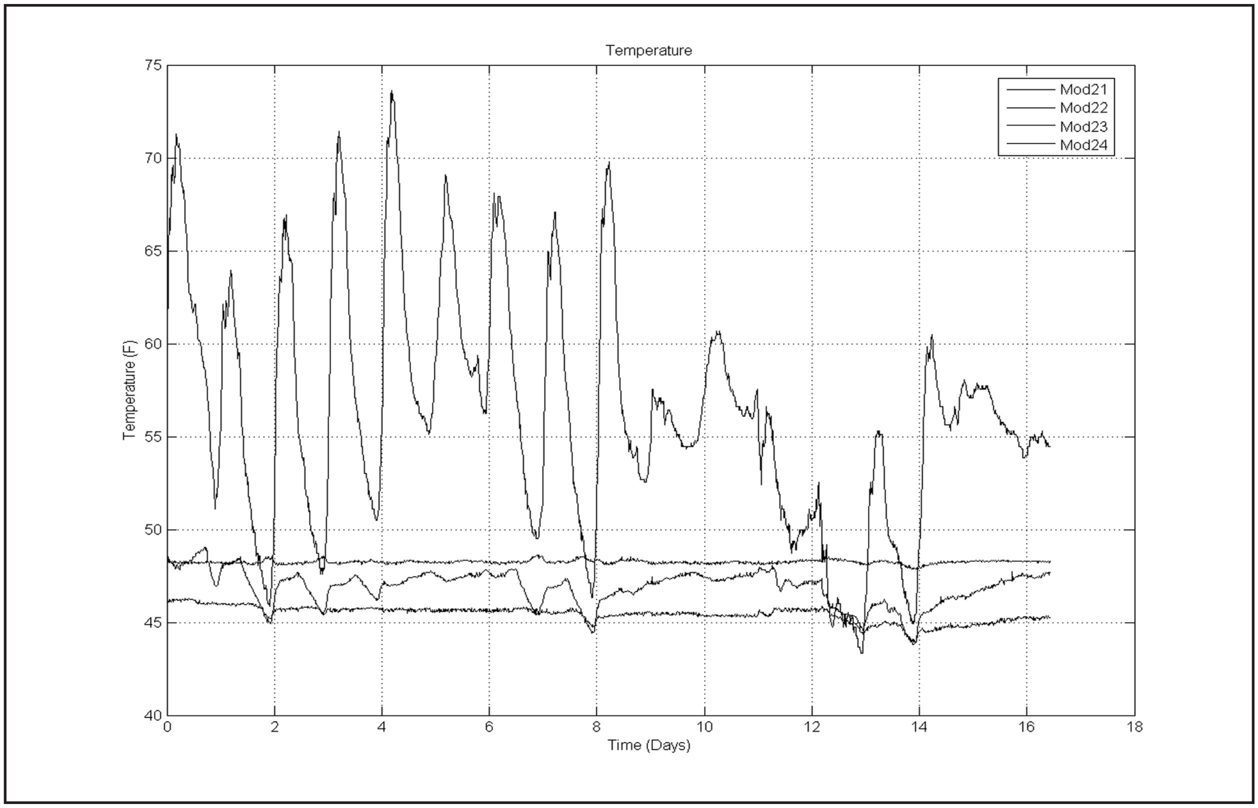

Figure 3. Sixteen days of air temperature reaings .

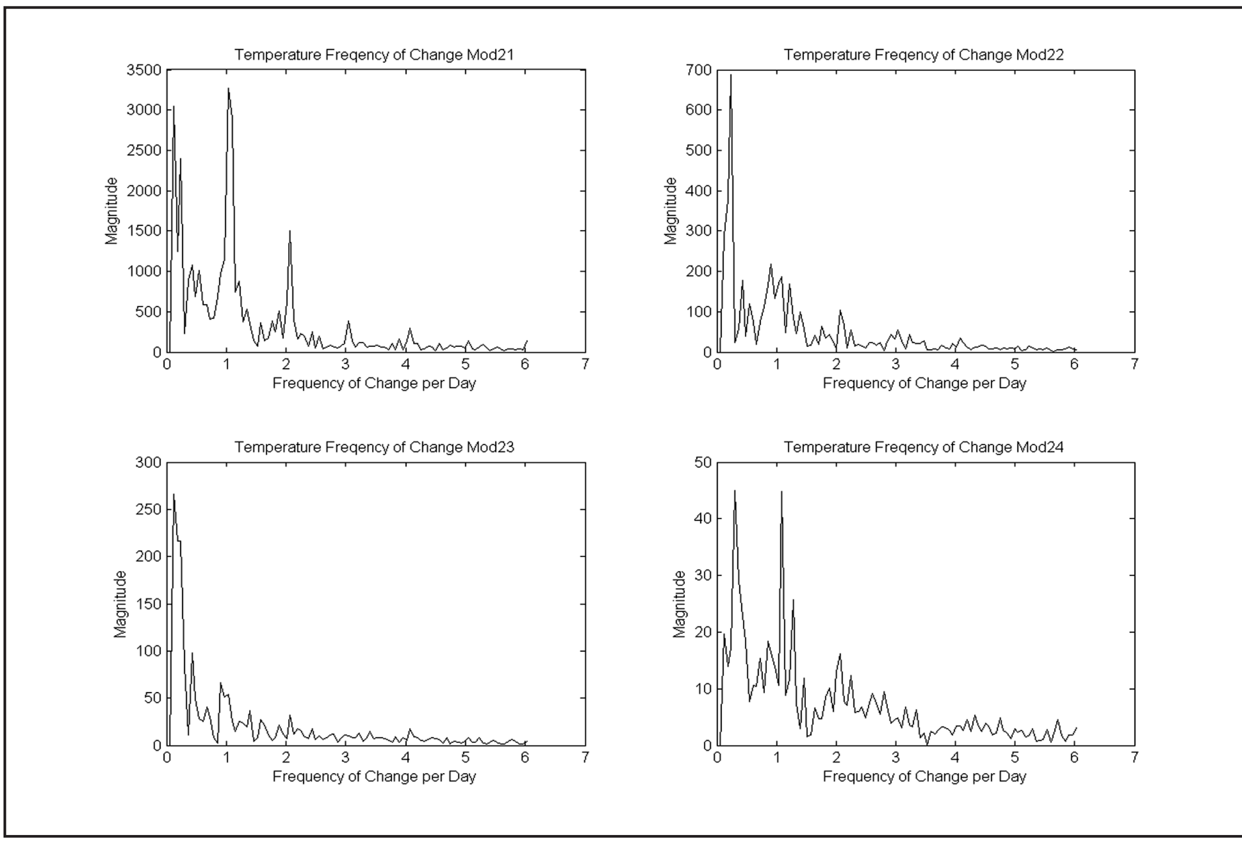

Figure 4. Temperature frequency of change inside and outside of the cave.

cave frequently dissipate within the cave, causing damaging voltage spikes to electronics. Extreme Endeavors and Consulting sensors are isolated from their containers via non-conducting posts and the transmission lines between the sensors are grounded in multiple places — all in an effort to mitigate static charge build up and enhance dissipation throughout the system. This has helped some, yet research is currently under way to locate other charge induced spikes, which in turn is defining the earth potential around caves, providing us with even more information about the surroundings and the reason the endangered species of bats select these particular caves for hibernacula locations.

Conclusion

What may initially seem like a simple engineering task of just monitoring temperature and barometric pressure within a cave has several other areas of concern that must be addressed in order to provide a satisfactory overall solution to the engineering task. Awareness of these extenuating circumstances is one component of Extreme Endeavor's background and experience within hazardous and/or harsh environments.

The overall ecological advantage provided by this project has been gained through engineers at Extreme Endeavors working together with biologists from the West Virginia Department of Natural Resources, U.S. Fish and Wildlife Service biologists, Greer Industries, the mining industry, and the West Virginia Department of Environmental Protection. These are just some of the physical reality issues in dealing with cave monitoring (similar types of physical issues come into play with other Extreme Endeavors and Consulting monitoring systems). After these engineering problems are reviewed for these physical system constraints, Extreme Endeavors and Consulting staff and engineers also consider the human factor of the systems. With careful and planned engineering solutions, both physical and human system risks can be mitigated.

Lastly, any engineered technology, whether in some remote, Antarctic outpost or on your living room coffee table, is only as good as the technical support for that product. Extreme Endeavors and Consulting has not only created a means of monitoring within a harsh environment, but also provides continued support of these monitoring systems by working in conjunction with all parties involved, while continuing to improve the technology. Products operating in harsh environments require much more hands-on engineering monitoring and support. It is widely understood that electronics, operating within the optimum environments — air-conditioned rooms, surge protected power, and so on, have long and useful lives. At the same time, once electronics are subjected to extreme conditions, support of that product within that environment is very critical.

Works Cited

[1] Yervant Vichabian and Frank D. Morgan, "Self potentials in cave detection," *The Leading Edge*, Sept. 2002, pp 866–871.

[2] Michael Rybakov, Yair Rotstein, Boris Shirman, and Abdallah Al-Zoubi, "Cave detection near the Dead Sea – a micromagnetic feasibility study," *The Leading Edge*, June 2005, pp 585–590.