Climatology of Laurel Caverns, Pennsylvania

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Introduction

Laurel Caverns is located a top Chestnut Ridge, an anticlinal Ridge capped with highly fractured sandstone, in the Alleghany Plateau of Southwest Pennsylvania. The cave formed in silicious (40% Ca) Loyal Hanna limestone dipping ~15° down the west side of the ridge. The cave is the longest (3.09 miles) and deepest show cave (446 ft) in Pennsylvania. However, as the cave follows the dip of Chestnut Ridge, it is never more than ~60 feet below the surface.

Cave Outline Superimposed Over a Topographic Map.

Cave Profile

Laurel Caverns is classified as a "Significant Natural Resource" and is considered a significant bat hibernacula. Our objectives are: to establish a temperature and humidity baseline; to determine spatial and temporal variability of temperature and humidity; and to evaluate proxy methods used to calculate cave temperatures.

Methodology

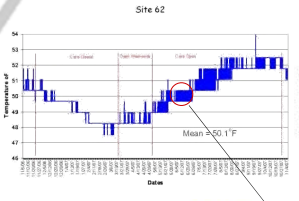
Temperature and relative humidity were monitored hourly, for a period of one year (11/5/06 to 11/4/07), using HOBO data loggers (Onset Computer Corporation). One data logger was located outdoors (#56), one was located on the developed portion of the cave (#62). The developed section of the cave has undergone modifications, including walkways, railings and lighting. The remaining data loggers (#58 - #61) were located in the undeveloped section of the cave.

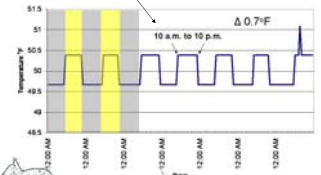
Data was downloaded approximately once every two months onto an Onset Shuttle (within the cave), then transferred to an Excel spreadsheet for data management.

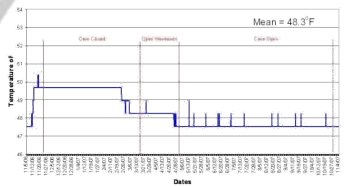
Outside Data Logger (in housing)

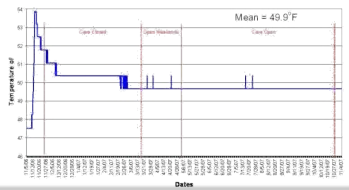
Data Logger in Cave.

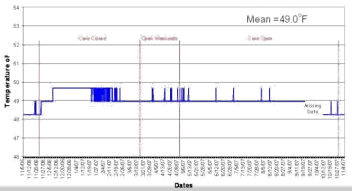
Site 62 (developed section) temperature profile shows varying temperatures, both seasonal and diurnal. Seasonal variability (red) of ~5°F lags behind outdoor temperatures (blue) by about one month (R^2 = 60). A 17°F change in outdoor temperatures equals a 1°F change in the cave. The diurnal temperature change is ~ 0.7°F, greatest when lights are turned on and tourists are in the cave.











Sites #58 to #61 (undeveloped section) show a very different temperature pattern from the cave's developed section - a pattern that does not appear to be influenced by seasonal temperatures. An initial spike in temperatures is followed by a return to an equilibrium temperature (~48°F), that varies between sites in the time it is re-established. Site #60 is the warmest site in the cave (49.7°F), and appears not to have returned to its apparent equilibrium temperature.

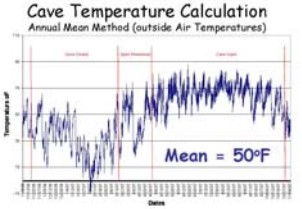
Proxy Methods

Two approaches used to determine an average cave temperature are to either use latitude and elevation at the cave in a formula derived calculation (e.g. Choppy's Law), or calculate the annual average outside air temperature. The formula derived air temperature (57°F) is too high, whereas the annual average outside air temperature (50°F) appears to best reflect the measured average cave temperature of 49.1°F.

$$°C = 54.3 - 0.9\,L - 0.006\,E$$

where: °C = temperature
L = latitude
E = Elevation

$$°C = 54.3 - 0.9\,(39.78°N) - 0.006\,(761\ m)$$
$$= 13.9\ °C\ (57.0\ °F)$$



Temperature Spike?

The spike in temperatures (~5°F) that occurred in November 2006 cannot be explained at this time. Three explored hypotheses: 1) a large number of visitors on one day (300 visitors); 2) increased stream flow that brought heat into the cave (it rained heavily; and 3) a change in pressure drew in outside air (a low pressure cell passed over the area). Each occurrence was replicated through the year, without an increase in cave temperatures in the undeveloped section.

Calculations below show that visitors in the cave could not have caused the spike in temperatures. The wattage given off in the undeveloped section of the cave (visitors) at 170W/person for 3 hours is less than the total wattage generated in the developed section (lights and visitors) at 60 W for 10 hours and 116W/person (less active) for 1 hour, which itself accounts for a temporary increase in temperatures of only 0.7°F.

Lights (developed section):
- 400 bulbs * 60 W * 3600 * 10 hours = 864,000,000 W

Visitors (developed section):
- 100 visitors * 116W * 3600 * 1 hour = 41,760,000 W

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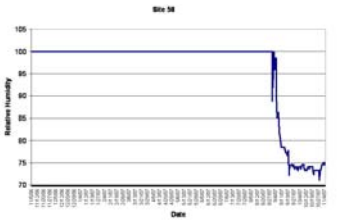
905,760,000 W

Visitors (undeveloped section):
- 300 visitors * 170W * 3600 * 3 hours = 550,800,000 W

Relative Humidity

Cave maintained a R.H. of 100% , although it suddenly dropped to 75%to 85% in late summer at 3 of the 4 undeveloped monitoring sites.



Conclusion

The mean cave temperature is 49.1°F;

Cave temperatures vary, with the developed section of the cave showing variability (~5°F) linked to changing outside air temperatures, while the undeveloped section of the cave maintains equilibrium temperatures (~48°F);

The rapid jump in temperature in early November 2006, while not explained, illustrates different response times (days to months) to a return to equilibrium temperature levels;

Annual mean outside temperatures are a reasonable indicator of cave temperatures;

Visitor activity has a minimal (~ 0.7°F) and short-lived impact (hours) on temperatures in the developed section of the cave, but no measurable impact on the undeveloped section.

Relative humidity was maintained at 100% but dropped as low as 75% in late summer, perhaps reflecting dry summer conditions.