Using Gemini temperature and count loggers to monitor caves and reconstruct past climate change

Dave Mattey, Dept. Earth Science, Royal Holloway University of London

We are all aware of the evidence for increasing levels of greenhouse gases, rising global temperatures and the uncertainties regarding the future of the Earth's climate systems. Weather forecasting is a rather imprecise affair and predicting the future of behaviour of global weather patterns over the next century rests on the computer models that rely on meteorological data and an understanding of what drives weather systems. A major obstacle in predicting future climate change is that meteorological records only stretch back a century or so, and our understanding of how the global climate systems interact and change is far from complete. Geologists know that the Earth's climate underwent dramatic variations in the past, such as recurring ice ages every 100,000 years, and are researching new ways to use chemical records in rocks and fossils to monitor climate change in great detail, which will lead to improved predictions of future climate change. One of these chemical records of climate change can be found in caves in the form of stalagmites that grow from water that has fallen as rain. Caves provide an unlikely environment to monitor changes in outside weather, but the stalagmite 'weather stations' that can be accurately dated and steadily grow in a stable undisturbed environment for many tens of thousands of years are turning out to be very valuable archives of past weather patterns.

Our research has focussed on how changing weather above the cave affects the growth of stalagmites and the chemical 'memory' preserved in the stalagmite of the rainfall, outside temperature and the type of vegetation. To do this we have been using Gemini data loggers to measure the subtle changes in the environment inside the cave that occur as the seasons pass over many years. The use of discrete rugged data loggers allow us to make these measurements in many locations inside and outside the cave at hourly intervals giving us unprecedented levels of detail. However caves provide a very harsh environment for instrumental measurements where 100% humidity can cause relentless corrosion and instrument failure due to damp and condensation. Also, caves are often remote, with no power, and have difficult access, requiring rugged instruments that will provide a reliable data return over long periods of time. The Tinytag 2 temperature loggers have proved to be a very reliable way to measure seasonal changes in air and rock temperatures not only inside caves (Figure 1) but also the temperature of the overlying soil where the loggers have been buried at different depths for up to a year at a time before data is downloaded (Figure 2). Cave temperatures are traditionally regarded as stable and similar to the average annual temperature, but they do vary, sometimes unexpectedly as a result of ventilation, flowing water and wind direction.

Fig 1. Monitoring temperature (using a Tinytag 2) and driprate using a Stalagmate in Krem Mawmluh cave, NE India. The Stalagmate which is based on a Gemini count logger, is the grey box located in the plastic beaker that collects water for chemical analysis. Krem Mawmluh is located near Cherrapunji, regarded as the wettest place on Earth as a result of the Indian Monsoon.

Fig 2. Recovering a Tinytag 2 that had been interred for a year measuring soil temperature in Gibraltar.

Another area of interest is the relationship between rainfall and the formation of stalagmites where groundwater saturated in calcium carbonate drips from the roof into the cave. The dripping water was originally rain that has percolated through the soil and bedrock and one of the most interesting questions is how long does the rain take to penetrate into the cave? If the cave starts dripping soon after a period of rainfall then the stalagmite 'weather station' records day-day changes in climate; if the dripping takes a long time to build up, or just remains constant all year round then the 'weather station' is recording more gradual changes, smoothing out the day-to-day variations. To measure the drip rate changes we developed a unique logging drip counter (the 'Stalagmate', Figure 3) which is based on a OEM version of the Gemini count logger and a sensor built into a waterproof box that is placed on top of stalagmites to count individual drops as they fall.

Figure 3. Left: an early drip counting device based on a tipping bucket and a Tinytag count logger. The unreliable mechanical design was superceded by the Stalagmate (right) which counts drip rates acoustically and records data using the OEM version of the count logger built into the same box. These are now widely used for cave monitoring all over the world.

These unique devices have returned remarkable data showing precisely how drip rates respond to rainfall, measured at up to 5 minute resolution over a year of continuous recording and reveal some very surprising results. For example, no two drip sites in the same cave, or even stalagmites next to each other respond in the same way. The new level of detail that Stalagmates record drip rate responses shows how complex the hidden plumbing systems in limestone can be, with some drips even remaining dry through the wet winter season and 'turning on' after a delay of months. The stalagmite is commercially available (see www.driptych.com) and large numbers are now in use in caves all over the world and are increasingly used in groundwater research. The drip counting technology is also used in a new type of ultra reliable and precise logging rain gauge (the 'Pluvimate', Figure 4) which provides a high resolution record of rainfall using a low cost rugged device that can be deployed in remote locations and left to record for a year or more. The Pluvimate complements the stalagmite in cave monitoring work providing records of the exact relationships between rainfall and groundwater percolation into caves.

Figure 4. A Pluvimate drip counting rain gauge deployed on remote moorland near a cave in Skye. Rainfall data, recorded at 10 minute intervals, was collected once a year.

Cave and climate research using using Gemini data loggers in caves has been carried out in locations in Europe, India and the south Pacific. Some of the highlights include work in Gibraltar where we have been monitoring caves since 2004 providing one of the longest records available. Tinytags and Stalagmates have been deployed and left for a year or more between data downloads in caves in Scotland, France, NW India and Fiji. Pluvimates have provided continuous records of rainfall in Skye and, even wetter (by quite a large margin), in Cherrapunji, India, widely regarded as the wettest place on Earth, where we measured over 11 meters of rain of the monsoon season. So far the Gemini data loggers and the OEM event counters we use have used have been up to the task despite the appalling treatment they are sometimes subjected to! Other than a battery change every year or so, they have worked reliably in humid caves, buried in soil, and sometimes submerged in water and returned data without any problems. A wish list for the future would be a combined event counter and temperature logger and a rugged battery powered CO_2 monitor, but maybe the boffin department at Gemini has these already in development…

Dave Mattey is Professor of Geochemistry at Royal Holloway, University of London and has been director of the Stable Isotope Facilities since 1989. He leads research into cave science and climate reconstruction in Europe, India and the Pacific. Further information can be found at www.caveclimate.org.uk and www.driptych.com