Research links two millennia of cyclones, floods, El Nino

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Rhawn Denniston (right), professor of geology at Cornell College, with Dan Cleary ’13, a member of his student research team, examining stalagmites in an Australian cave.

Stalagmites, which crystallize from water dropping onto the floors of caves, millimeter by millimeter, over thousands of years, leave behind a record of climate change encased in stone. Newly published research by Rhawn Denniston, professor of geology at Cornell College, and his research team, applied a novel technique to stalagmites from the

Australian tropics to create a 2,200-year-long record of flood events that might also help predict future climate change.

A paper by Denniston and 10 others, including a 2014 Cornell College graduate, is published this week in the journal *Proceedings of the National Academy of Sciences*. The article, "Extreme rainfall activity in the Australian tropics reflects changes in the El Niño/Southern Oscillation over the last two millennia," presents a precisely dated stalagmite record of cave flooding events that are tied to tropical cyclones, which include storms such as hurricanes and typhoons.

Denniston is one of few researchers worldwide using stalagmites to reconstruct past tropical cyclone activity, a field of research called paleotempestology. His work in Australia began in 2009 and was originally intended to focus on the chemical composition of the stalagmites as a means of reconstructing past changes in the intensity of Australian summer monsoon rains. But Denniston and his research team found more than just variations in the chemical composition of the stalagmites they examined; they discovered that the interiors of the stalagmites also contained prominent layers of mud.

"Seeing mud accumulations like these was really unusual," Denniston said. "There was no doubt that the mud layers came from the cave having flooded. The water stirred up the sediment and when the water receded, the mud coated everything in the cave—the floor, the walls, and the stalagmites. Then the stalagmites started forming again and the mud got trapped inside."

The stalagmites were precisely dated by Denniston, Cornell College geology majors, and Denniston's colleagues at the University of New Mexico. Once the ages of the stalagmites were known, the mud layers were measured. Angelique Gonzales '14, who worked with Denniston on the research and is third author on the paper, examined nearly 11 meters of stalagmites, measuring them in half millimeter increments and recording the location and thickness of mud layers. This work gave the team more than 2,000 years of data about the frequency of cave flooding.

But the origins of the floods were still unclear. Given the area's climatology, Denniston found that these rains could have come from the Australian monsoon or from tropical cyclones.

"We were sort of stuck," Denniston said, "but then I started working with Gabriele."

Rhawn Denniston, professor of geology at Cornell College, with one of the stalagmites that helped create a record of tropical cyclones going back more than 2,000 years.

Gabriele Villarini, an assistant professor of engineering at the University of Iowa and the second author of the paper, studies extreme meteorological events, what drives the frequency and magnitude of those events, and their impact on policy and economics. With Denniston and Gonzales, Villarini examined historical rainfall records from a weather station near the cave.

"The largest rainfall events, almost regardless of duration, are tied to tropical cyclones," Villarini said.

Next, they compared flood events recorded in a stalagmite that grew over the past several decades to historical records of tropical cyclones. This analysis revealed that timing of flood events in the cave was consistent with the passing of tropical cyclones through the area. Thus, the researchers interpreted the flood layers in their stalagmites largely as recording tropical cyclone activity.

The resulting data tell scientists about more than just the frequencies of tropical cyclones in one part of Australia over the past 2,200 years. A major driver of year-to-year changes in tropical cyclones around the world is the El Niño/Southern Oscillation, which influences weather patterns across the globe. During El Niño events, for example, Australia and the Atlantic generally experience fewer tropical cyclones, while during La Niña events, the climatological opposite of El Niño, the regions see more tropical cyclones.

"Our work, and that of several other researchers, reveals that the frequency of storms has changed over the past hundreds and thousands of years," Denniston said. "But why? Could it have been due to El Niño? Direct observations only go back about a hundred years, and there hasn't been much variation in the nature of the El Niño/Southern Oscillation over that time. Further back there was more, and so our goal was to test the link between storms and El Niño in prehistory."

Denniston noted that the variations over time in the numbers of flood events recorded by his stalagmites matched reconstructed numbers of hurricanes in the Atlantic, Gulf of Mexico, and Caribbean.

"Tropical cyclone activity in these regions responds similarly to El Niño, and previous studies had also suggested that some periods, such as those when we had lots of flood layers in our stalagmites, were likely characterized by more frequent La Niñas. Similarly, times with fewer storms were characterized by more frequent El Niños."

The results of this study mark an important step towards understanding how future climate change may be expressed.

"It is difficult to use climate models to study hurricane activity, and so studies such as ours, which produced a record of storms under different climate conditions, are important for our understanding of future storm activity," Denniston said.

Gonzales, who is planning to pursue a Ph.D. in geology, said that her experience with Denniston and his research, including two senior seminars and an honors thesis, was valuable because she got both field and lab experience as she helped determine not just what had happened in the past, but what that meant.

"There were a lot of different aspects to put this together—dating, measuring, literature review, and modeling", she said. "It was really exciting."

Denniston is now gearing up to establish a detailed cave monitoring program in this and other regional caves. "We want to extend this study," he said, "to examine what conditions trigger cave flooding."

More information: "Extreme rainfall activity in the Australian tropics reflects changes in the El Niño/Southern Oscillation over the last two millennia." *PNAS* 2015 ; published ahead of print March 30, 2015, DOI: 10.1073/pnas.1422270112

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