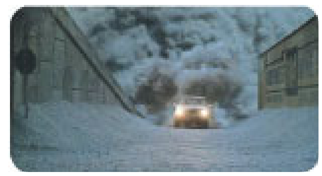
Master of Disaster

Earth sciences professor Matt Pritchard helps students understand nature's fury

By Robert Emro



In a scene from Dante's Peak, a volcanologist played by Pierce Brosnan is trying to save the mayor, played by Linda Hamilton, and her two children from the imminent eruption of the mountain. They don't get far before the mountain explodes, sending a giant cloud of superheated gas, rocks, and ash rushing down the side of the volcano, destroying everything in its path "What is it?" screams one of the kids. "That," replies Brosnan's character, "is a pyroclastic flow." It seems the fleeing characters are about to meet their end, but Brosnan manages to outrun the cloud of death in the nick of time, crashing his pickup into an abandoned mine shaft, saving everyone, including the dog, Scruffy.

The special effects look real enough, but could that scenario really happen? A class of Cornell students must answer that question and several more about the validity of Hollywood calamities in EAS 122 "Earthquake! (and other natural disasters)" taught by Department of Earth and Atmospheric Sciences Assistant Professor Matt Pritchard.

With about 150 students, this is a big class. It's diverse too, with students from all seven colleges at the university, ranging from first-years to seniors. A few are EAS majors; for others, this is the only science class they will take at Cornell.

2004 tsunami

In the past, the class focused on geological disasters—earthquakes, volcanoes and tsunamis—but Pritchard, who taught the course for the first time this spring, has expanded it to include all kinds of natural disasters, including tornadoes, droughts, and hurricanes. That may explain why enrollment shot up from about 90 students, but Pritchard thinks the increased interest may just be due to the 2004 Asian tsunami and the 2005 hurricane season. "I wonder if this generation of students' personal experiences have something to do with it," he says. "They were definitely very interested and had questions about things they had experienced."

Susan Riddick, a science of earth systems major (formerly geological sciences) from Middletown, N.Y., thinks everyone should take a class like this. "It's so useful to know about natural disasters and what to do when they happen because a lot of death and destruction occur because we aren't prepared," she says. "A lot of times we know how to get prepared but we don't do it."

Oklahoma tornado, 1999

One of the class assignments is to compile a top 10 list of natural disasters that occur during the semester, based on whatever criteria—loss of life, economic damage, number of people affected— the students choose. "I was actually really surprised by it," says Maxwell Royster, an engineering student who has yet to choose a major. "You think the big disasters are going to be earthquakes and volcanoes but we learned that the most deadly natural disasters are floods and storms."

Hurricane Katrina

The purpose of the exercise is not to make the students depressed, but to give them a perspective on the types and frequency of disasters occurring around the world and what can be done to mitigate them in the future. "I want them to get an appreciation of what the different risks are," says Pritchard. "There's a huge difference between the developed world, where natural disasters mainly cause insured losses and economic damage, and the developing world, where 96 percent of the deaths from natural disasters occur."

"It's kind of morbid at times," says Royster, "but then you realize that we're getting much better at preventing loss of life and now the real problem is getting cheap, cost effective ways of making it safer in less developed countries."

The students must also complete several group projects, including a three- to four-page assessment of the earthquake hazard within a particular region, a five-page white paper for policy makers (topics include how to evaluate and announce an earthquake prediction, developing a world-wide tsunami warning system, and national funding priorities for earthquake hazard reduction), and finding the best place to live if you want to avoid natural disasters. Some students found their hometown isn't as safe as they had thought. "I didn't know that the Northwest was such a volatile area," says Royster, who hails from Portland, Ore. "I thought we were pretty safe out here but we actually have the biggest risk for the highest magnitude earthquake."

Students also learn what to do—Pritchard squats on the balls of his feet with his hands on his knees and his head between them to demonstrate the "lightning crouch"—and what not to do in a disaster. "I heard a lot of things before about tornadoes, like open the windows or staying in the southwest corner during a tornado, and those are all false," says Riddick. "The windows don't help with the pressure difference, so there's no reason to even bother to open them."

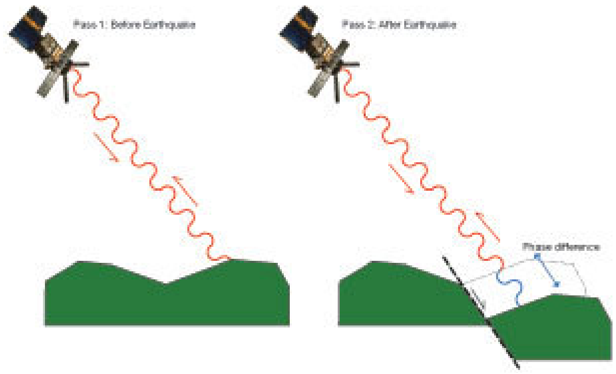
For Pritchard, disasters offer a way to reach students who might not otherwise be interested in earth science. "We trick them into learning about these phenomena and the underlying science behind them because everyone is intrigued by disaster," he says. "I hope the students get some appreciation for what nature can throw at us. I also hope they come away with a realistic assessment of what we need to worry about, and what we don't—like that the threat of impacts from asteroids is real."

Pritchard (right) with a guide at the summit of Lascar volcano (around 18,000 feet)—the most active volcano in the central Andes.

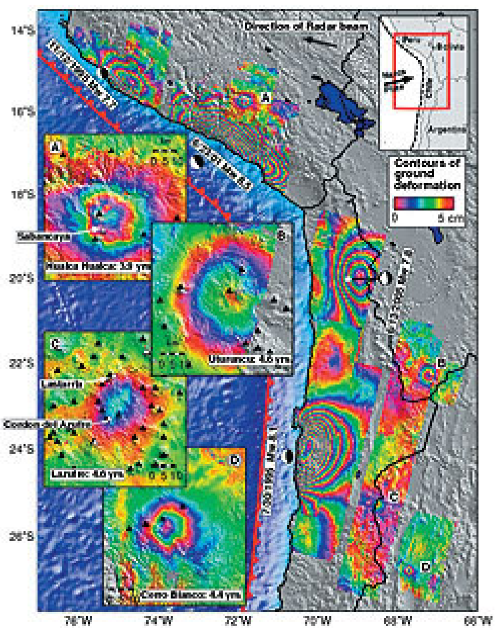
Pritchard says teaching such a large class, especially one outside his particular area of expertise, was a learning experience for him as well. "Teaching a class like that gives you a chance to really step back and look at the big picture," he says.

Pritchard is most familiar with how the ground moves in response to volcanoes, earthquakes, and landslides. Using satellites hundreds of miles in space, he can calculate centimeter-scale movements of Earth's surface. The traditional method for collecting this kind of data—survey crews—is labor intensive and dangerous. GPS changed all that, but the units are expensive, installing and maintaining them can be risky, and they don't fare well in lava or landslides. "Now we have these very dense maps of ground deformation from earthquakes," says Pritchard. "Being able to do it from space is a huge revolution."

To get such a precise picture of Earth's movements, Pritchard uses interferometric synthetic aperture radar. InSAR, as it's called, is an unintended byproduct of SAR, which uses microwaves to produce images of Earth, even in darkness or through cloud cover. Instead of using the amplitude of the wave to produce an image, interferometry uses the phase, which is the position of the wave within its cycle—trough, peak, or somewhere in between. As long as Earth's surface hasn't moved, the phase of a returning wave should be the same each time an InSAR satellite returns to a location. Because the length of the wave is known, a phase shift can be used to calculate the change in the distance the wave has traveled.



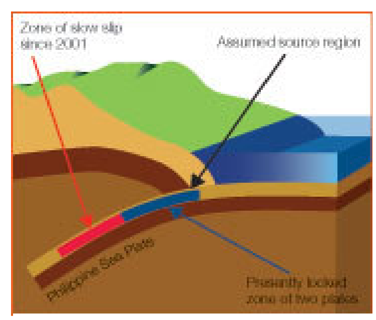
How InSAR works: two satellites send radar waves to the same point on the ground at different times. If the earth moves between passes, the wave will return in a different phase. Knowing the length of the wave, it is possible to calculate the precise amount of deformation.



Earthquake and volcanic deformation in the central Andes between 1992 and 2005. Each color cycle represents a change of 5 cm in the distance from the satellite and the ground between satellite overflights. Along the coast are the deformation patterns from four earthquakes.

In reality, of course, it's not quite that simple. Satellites rarely return to the exact same location, and that changes the phase in a couple of ways, but this can be compensated for using the known difference in satellite position and accurate topographic information. Vegetation and man-made changes to the landscape, like plowing, can also distort the returning signal. But when the "noise" is low or filtered out, Pritchard is left with an interferogram. A fringe pattern of alternating red and green bands indicates a change in the surface, like topographic lines on a map, except each band represents just 3 cm. "It's so fantastic," says Pritchard. "It's just a lot of fun every time one of these fringe patterns comes up; it's such a rush."

While a graduate student at Caltech, Pritchard worked with scientists at NASA's Jet Propulsion Laboratory to write the open-source software most commonly used to look at InSAR data. With this new tool, he and his Caltech adviser Mark Simons discovered that earthquake faults sometimes slip slowly, deep underground, without any violent shaking. Other researchers have found that one of these "silent earthquakes" happens about every 14 months in the Pacific Northwest. These events can increase the stress on locked plates at the surface. Eventually this stress overcomes the force that holds the plates locked and they slip suddenly. That's when the earth trembles and buildings fall. Silent quakes have been documented before giant temblors three times—in Chile in 1960 and in Japan in 1944 and 1946—but not every silent earthquake leads to a big one. Pritchard hopes InSAR will reveal more about the relationship between the two. "We're trying to understand where these silent earthquakes occur and what happens before and after," he says.



A "silent earthquake," an imperceptible slip of the crust not accompanied by violent shaking, has been detected in southeastern Japan where the Philippine Sea Plate is slowly being ground under the Eurasian Plate.

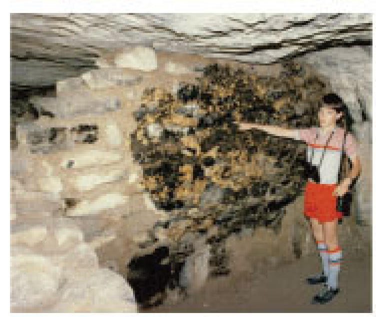
Precise earthquake prediction may not be possible, says Pritchard, but accurate earthquake forecasting may be. The larger timeframe of such a warning wouldn't allow mass evacuations, but it would let officials know where to focus preparedness efforts. "In theory, with this method, we can take measurements everywhere, all the time, to figure out if there are any precursory signals," he says.

InSAR can also show bulges or dips caused by magma deep underground. Pritchard and Simons studied 900 volcanoes in the South American Andes, where an arid climate and sparse population make for "fantastic" InSAR data. It would have taken years using GPS surveys, but in just a couple of weeks they found about 40 fewer active volcanoes than were previously believed to exist, allowing scientists to concentrate resources where they are most needed. They also found four volcanoes that had caused ground deformation that were not on the list of potentially active volcanoes. One is known as Untaruncu, which means "sleeping tiger." It's been sleeping now for many millennia, but Pritchard found that for the past 15 years it has been causing the ground to inflate about 1 to 2 cm per year. "Is this a super volcano accumulating magma for the last 300,000 years," he asks, "or is it a benign accumulation of a granite body?"

Pritchard has proposed more detailed field investigations that might help answer this question. "You still have to go do the field work," says Pritchard. "The remote sensing data allows you to ask questions that can't be completely answered by the remote sensing data."

He's also beginning to study some more mysterious movements revealed by InSAR, such as the sharp deformation at the edge of a salt flat known as the Salar de Atacama that showed up unexpectedly in his study of Andean volcanoes and earthquakes. InSAR has shown the ground outside Seattle rising and sinking seasonally as well. Both deformations may be in response to groundwater withdrawal and recharge. Other applications include studying melting glaciers and monitoring the Retsof mine in western New York. It was the second largest salt mine in the world until it collapsed in 1994, causing 200-foot-wide sinkholes. Geologists expect 8 to 9 feet of additional subsidence over the next century. "Everywhere you look, there's something deforming," he says. "It's been surprising to a lot of people what we've found."

In June, the EAS faculty welcomed Rowena Lohman, another expert at using and interpreting InSAR data. She was a graduate student with Pritchard at Caltech and the two are engaged to be married. Her addition further augments Cornell's expertise in the study of earthquakes, a traditional area of strength, particularly in South America, where the Andes Project has been working for more than 25 years. "We will have a large group that uses this tool and hopefully expand the applications of it to different areas and different problems," says Pritchard. "We can compare our measurements with geological observations from the ground and determine if the patterns we are seeing are consistent over tens of thousands of years."



Pritchard's curiosity about geology was sparked by a rock collection he had as a boy growing up in Illinois. A family trip that included the Grand Canyon, Yellowstone, and Walnut Canyon National Monument in Arizona (shown here) solidified his interest.

Pritchard's curiosity about geology was sparked by a rock collection he had as a boy growing up in Illinois. The geology of the Midwest was less than inspiring, but a family trip to the Grand Canyon and Yellowstone solidified his interest. Similarly, a visit to Mt. Saint Helens in the eighth grade got his student Susan Riddick interested in volcanoes and led her to take his disaster class. Now she is working with Pritchard, supported by the NASA/New York Space Grant Undergraduate Summer Research Program. Using new, higher resolution data, she is studying volcanoes to better characterize their activity and potential hazards.

Thanks to Pritchard's class, Riddick came to the job knowing quite a bit about volcanoes, including the likelihood of Pierce Brosnan's character escaping a pyroclastic flow. "He definitely wouldn't be able to outrun it, because pyroclastic flows are really fast and they're also very hot," she says. "They're one of the most dangerous aspects of volcanoes."