Abstractions

FIRST AUTHOR
Even if they have not experienced them, most people are familiar with earthquakes. The violent tremors occur when pressure builds up between tectonic plates at a fault line, causing the plates to slip, releasing energy in the form of seismic waves. However, there are other types of tremor that occur deeper inside Earth — 25–40 km down — that cannot be felt at the surface. Since their discovery, the origin of these 'non-volcanic tremors' has puzzled researchers. On page 1048, Amanda Thomas and her colleagues at the University of California, Berkeley, report a connection between extremely small stresses induced by tides and non-volcanic tremors detected near the San Andreas fault in Parkfield, California. Thomas tells *Nature* more.

When and where were non-volcanic tremors discovered?
In 2002, in a region beneath the eastern coast of southwest Japan. In 2003, more were detected in Cascadia, beneath the coast of Canada's Vancouver Island. These are both subduction zones, where Earth's crustal plates collide, and one moves underneath the other. At these sites, tremors occur in conjunction with ultra-slow-motion slip of the plates that occurs at regular intervals and is affected by the rise and fall of ocean tides.

How did you get involved in the work?
In 2003, my co-author Robert Nadeau detected tremor-like signals originating near the San Andreas fault, which is not a subduction zone. The tremors were similar to the subduction-zone tremors but with some fundamental differences. For example, the Parkfield tremors were less dominated by periodic episodes and had smaller energies. And no one has found evidence of slow-slip events occurring there.

So what causes the tremors in Parkfield?
We calculated that shear stress produced by tidal activity could trigger them. Tides generate extremely small stresses, several orders of magnitude lower than those caused by ambient pressure. Yet, when it is riding on top of the huge background stress of the plates pushing against each other, the tidal-induced shear stress is enough to push the system over the stress threshold required for shear failure. The same mechanism may apply to subduction zones.

Why are the findings important?
These tremors may be key to understanding fundamental processes that occur at the roots of faults. Some people have suggested that non-volcanic tremors could signal accelerated slip between plates, and thus increased danger of earthquakes. But we don't have enough data to make that connection. ■

MAKING THE PAPER

Scott Loarie & Christopher Field

Can plants and animals keep pace with changing climates and habitats?

Christopher Field (left) and Scott Loarie.

As climates change, many animals and plants will have to shift their geographical ranges to find suitable living conditions — and in some cases these shifts will have to happen phenomenally quickly. "You can think of it as a kind of sprinting capacity that these plants and animals need if they're going to stay in the climate zone that they're in now," says Christopher Field, a global ecologist at the Carnegie Institution for Science in Stanford, California. Field, together with postdoc Scott Loarie, also at the Carnegie Institution, and their colleagues have calculated the speed at which climate could change across various landscapes — and how quickly animals would have to move to keep pace.

Loarie first became interested in understanding how climate change might affect species movement as an undergraduate, when he worked at Stanford's Jasper Ridge Biological Preserve with Field and co-author David Ackerly, an ecologist at the University of California, Berkeley. Jasper Ridge provided a model area for climate studies owing to its abundance of diverse, hilly terrain and north- and south-facing slopes, which create complex temperature and precipitation patterns. In particular, it revealed the importance of taking topography into account when making projections.

Until recently, climate data were not sufficiently detailed to quantify the influence of topography on climate change. Taking advantage of finer-scale data, Loarie, Field and their colleagues combined the WorldClim data set, which models current climate globally at 1-kilometre resolution, with climate-change projections from 16 climate models and three potential greenhouse-gas emissions scenarios. In this way, they were able to estimate how quickly climate could change across landscapes at fine scales.

> "Species might have to move up to ten times faster to keep pace with future changes in climate."

They found that in mountainous regions, which are characterized by heterogeneous terrain, plants and animals don't have to move far to encounter different climates. On a mountain slope, a species might need to move less than one kilometre upwards to encounter a change of several degrees Celsius, says Loarie. By contrast, in more homogeneous regions such as deserts or tropical-forest basins, where the terrain and climate are more uniform, species must travel greater distances to encounter an appreciable difference in climate. "In certain places, like the Central Valley of California, species might have to travel hundreds of kilometres this century to reach the climate zone that they're in now," says Loarie.

Once they had calculated projected velocities required for animals and plants to keep pace with climate change in different scenarios, the authors compared their calculations with changes that plants, animals and ecosystems have undergone in the past. By the end of the last Ice Age, some 12,000 years ago, northward tree migration may have been as fast as one kilometre per year. Across much of the globe, these speeds are comparable with the velocities of climate change calculated by Loarie, which average almost 0.5 kilometres per year in moderate emissions scenarios (see page 1052). But for about 30% of Earth, including homogeneous areas such as deserts and the Amazon Basin, species might have to move up to ten times faster to keep pace with future changes in climate, says Loarie.

The researchers applied their projections globally, including the locations and areas of global preserves. They found that in all but 8% of the world's protected areas, species will be forced out of reserves by shifting temperatures within a century. The authors conclude that by designing reserves that encompass more heterogeneous landscapes — such as mountainous regions with hills and valleys that provide a diversity of climate regimes — and larger, more connected reserves that contain more plants and animals, species might stand a better chance of keeping pace with changing climate. Efforts are already underway in northern California, where Ackerly has been working with state parks and regional and local agencies to devise conservation strategies that facilitate species movement for adaptation to climate change.

Elsewhere, co-author Greg Asner, an ecologist at the Carnegie Institution, is helping the United Nations to enable countries to monitor deforestation in order to combat climate change. "Most tropical species will be better able to move through and persist in continuous forest than through fragments of forest in a sea of soy and cattle pasture," says Loarie. ■

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