

From Noise to Signal

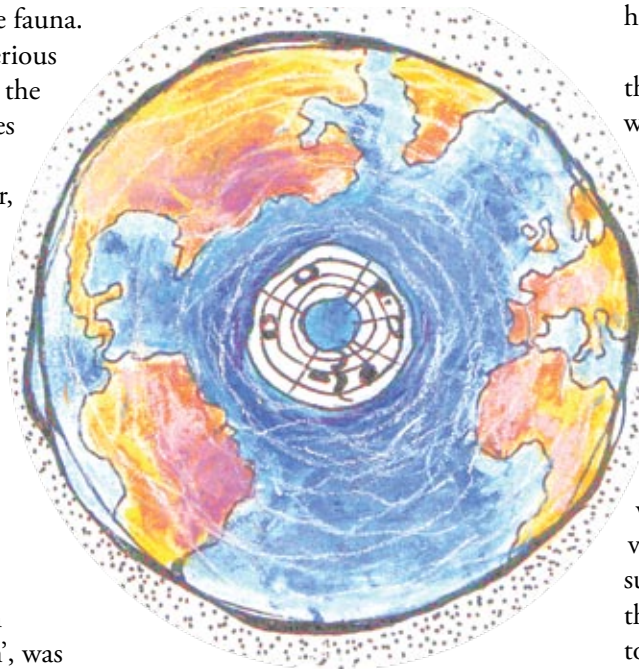
The Earth Hum

Surfers, fishermen, and divers know that the ocean is a noisy place. It's crowded with the yelps, pops, and bangs of species calling to each other, the sounds resonating through their swim bladders or blowhole—and that's just the fauna. Another whole host of mysterious sounds are created simply by the waves. It turns out that waves on the ocean surface, created by the vagaries of the weather, may propagate down through thousands of feet of oceanic abyss and into the Earth's crust to create a background seismic vibration, measurable across the planet, that persists in the otherwise quiet intervals between earthquakes.

The presence of this background vibration, which seismologists call 'Earth hum', was first noticed during the 1980s, when superconducting gravimeters— instruments that measure gravitational acceleration changes caused by the ground shaking—were finally sophisticated enough to record subtle long-term vibrations. The first clue to their source came when Professor Toshiro Tanimoto of UC Santa Barbara looked at data from these seismometers that had been amassed over several years, and noticed that the intensity of the hum shifted with the seasons. He found that the hum was about 10% stronger during the winter: December to February in the Northern Hemisphere, and June to August in the Southern Hemisphere.

A single event—such as an earthquake or underground nuclear test—can cause the planet to vibrate,

like a clapper hitting a bell, and these ringing vibrations can persist long after the event itself has ended. For example, seismometer arrays could still detect the echoes of last winter's Indonesian earthquakes many months after the actual earthquakes had occurred.



But seismologists have discovered that Earth hum is different. Its quiet, barely detectable vibrations can only be heard when the din of earthquakes has ceased, indicating that its source is somehow different from traditional seismic sources. Since the Earth hum was first detected, seismologists have been trying to understand where the vibrations are coming from and how they are generated.

UC Berkeley Professor Barbara Romanowicz and her student Junkee Rhie have definitively answered the first of these questions. Using seismometer arrays in California, Japan, and Europe, they showed, in a September 2004 paper in the journal *Nature*, that the source of the

vibrations is in two major regions of the Earth's oceans. Specifically, the majority of vibrations emanate from the Pacific Ocean south of Alaska during the northern hemisphere winter, and the Southern Ocean—the continuous band of water that circles Antarctica—during the southern hemisphere winter.

Because these regions are among the roughest on the planet—especially when fierce winter storms blow through—locating the Earth hum at these spots points to a complex interaction between the atmosphere, ocean, and seafloor as the mechanism responsible for the vibrations. Spahr Webb, an earth scientist and oceanographer with the Lamont Doherty Earth Observatory, explains that the hum is driven by 'infragravity waves', which are a lower-frequency version of the oscillations in the ocean surface that surfers make use of when they ride towards shore. According to Webb, "The simplest way to think of the creation of these waves is to know that...wind waves come into a beach in 'wave groups'. After the short waves break, you are left with a low-frequency (20 - 1000 sec) oscillation in sea level: the sea level is lower after the big waves break, and higher after the smaller waves in the group break. This low-frequency oscillation 'leaks' back off the beach as 'free waves' which are seen all over the deep ocean as infragravity waves."

While Romanowicz's finding of the geographic source of the waves supports the idea that it is indeed ocean waves driving the background hum, more detailed information is needed to confirm the exact mechanisms of the process. "I have this model in my head of how the ocean storm generates waves and they

interact with the ocean floor to create multiple forces of seismic waves. Now we need to prove it,” says Romanowicz. “I would like to see instrumentation that would cover the whole water column,” Romanowicz said, envisioning data collection “from the sea floor with seismometers, through the ocean with pressure sensors and chemistry, and through the buoys at the top that can measure wave height and atmospheric parameters.” Romanowicz believes the larger Earth Science community can also benefit from her findings. Because the Earth is impermeable to light or x-rays, it turns out that the best way to ‘see’ the deep convective structures—such as rising magma plumes or sinking plates—is to use seismic waves, and observing these structures are key to understanding plate tectonics. Romanowicz proposes to use the Earth hum to explore these in a new way, by “getting us away from using standard

seismic sources—earthquakes—to using noise to look at the structure. Earthquakes happen at specific times and locations in space and they don’t illuminate structures as uniformly as we want, but we may do better if we can use the noise,” she says. “Continuous sources of seismic waves such as the ‘hum’ may allow [us] to obtain better sampling of the Earth and therefore lead to better quality three dimensional images of the Earth’s interior.”

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Want to know more (and listen to the Earth hum)?
seismo.berkeley.edu/~barbara/hum.html

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