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Scientists tune in to the surf's hidden signals

Along the coast, waves break with a familiar sound. The gentle swash of the surf on the seashore can lull us to sleep, while the pounding of storm surge warns us to seek shelter.

Yet these are but a sample of the sounds that come from the coast. Most of the acoustic energy from the surf is far too low in frequency for us to hear, traveling through the air as infrasound and through the ground as seismic waves.

Scientists at UC Santa Barbara have recently characterized these low-frequency signals to track breaking ocean waves. In a [study](#) published in *Geophysical Journal International*, they were able to identify the acoustic and seismic signatures of breaking waves and locate where along the coast the signals came from. The team hopes to develop this into a method for monitoring the sea conditions using acoustic and seismic data.

The low rumble of the waves

The surf produces infrasound and seismic waves in addition to the higher frequency sound we hear at the beach. Exactly how this works is still an open question, but scientists believe it's connected to the air that mixes into a breaking wave. "All those bubbles oscillate due to the pressure instability, expanding and contracting

basically in synch,” said first author Jeremy Francoeur, a former graduate student in Professor [Robin Matoza's](#) group. This generates an acoustic signal that transfers into the air at the sea surface and into the ground on the sea floor.

While pressure waves below 20 hertz (Hz) are still ordinary acoustic waves down to about 0.01 Hz, the frequency, or “pitch,” is too low for humans to hear. “These hidden sounds of Earth’s atmosphere are produced by numerous natural and anthropogenic sources,” explained senior author Matoza, a geophysicist in UCSB’s Department of Earth Science. These include volcanoes, earthquakes and landslides; ocean storms, hurricanes and tornadoes; even auroras and the wind flow over mountains. Understanding the type of signals generated by each phenomenon can provide a bounty of information about these events.

Working from UCSB’s seaside campus, it was natural that Matoza eventually turned his attention toward the beach. He and his students were curious what their seismo-acoustic techniques could tell them about the surf breaking along the coast.

Francoeur deployed an array of sensors atop the headland at UCSB’s Coal Oil Point Reserve, part of the [UC Natural Reserve System](#), to record infrasound and seismic waves produced by the surf. He paired this data with video footage of the beach to identify what signals corresponded to a breaking wave.

Seeing the surf with sound

Many infrasound studies have used only one sensor. Deploying an array provided the team with much more information. The crash of a wave acted like the snap of a clapperboard on a Hollywood set, allowing Francoeur to align the video and infrasound channels with each other. This enabled them to better identify the specific signal from crashing waves since they could correlate the footage with pulses in the infrasound. They then searched for the same signature in the longer archive of infrasound data they recorded at Coal Oil Point.

While many phenomena produce infrasound, the signal from the surf was fairly clear in the data. It arrived at the sensors as repetitive pulses between 1 and 5 Hz.

It was also fairly loud. Well, sort of. “‘Loudness’ is a description of a human perception,” Matoza explained, “so infrasound cannot have ‘loudness.’” However,

what we perceive as volume relates to the amplitude of the acoustic wave.

Most of the wave infrasound was around 0.1 to 0.5 pascals. This would be about the volume of busy traffic (74 to 88 decibels (dB) relative to a 20 μ Pa reference pressure), or about the volume of a busy restaurant, if it were shifted into the frequency range of human hearing. Particularly strong swells reached 1 to 2 Pa, or the din of a noisy factory (94 to 100 dB).

“The sound of the surf is pretty loud when you’re out there on the beach,” Francoeur said, “so it’s interesting that the majority of energy is actually produced in the infrasound range.”

The team was curious whether this signal would align with sea conditions. They found that the infrasound amplitude correlated with significant wave height, which is the height of swells on the open ocean. “But the correlation between what we were seeing with the video data compared to what we were seeing acoustically and seismically was a lot more complex than we initially imagined it to be,” Matoza said.

Francoeur was also able to use the array to triangulate the signals’ origin from small differences in arrival times, a technique called reverse-time-migration. “It was interesting to me that all of the directions seemed to align to the same region of the beach,” he said: “the rock shelf at Coal Oil Point.” The authors suspect that the point’s bathymetry forces a large proportion of waves to crash simultaneously, producing those synchronized bubble oscillations.

Future opportunities

The researchers are curious if it’s common for one area of a beach to produce most of the infrasound, like they observed in this study. They also want to know if the signals they detected are typical of breaking surf. “Does a wave here have the same infrasound signal as, say, a wave in Tahiti?” Francoeur asked. “And as tides change, as winds change, and the conditions out there change, how does that affect the infrasound that’s produced?”

Matoza will continue to investigate these questions with his lab, a task made simpler by the project’s location merely 2.5 miles from his office. “Having this field site very close to campus was really a fantastic opportunity because it was a lot of trial and

error trying to figure out good array geometries,” he said. “The proximity meant that we could quickly deploy.”

It’s also a boon to his students’ budding careers. “They get to take part in the whole geophysical workflow — from collecting data in the field, deploying the instruments, analyzing the data, hypothesis testing and writing the paper. And we can do that all within Goleta,” Matoza said.

He hopes to ultimately develop a way to characterize surf conditions solely from infrasound and seismic signatures. This could complement video monitoring systems that may be limited by darkness and fog.

Tags

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