Earthquake detected from space

Gravity-mapping instrument doubles up as the first orbiting seismometer.

Jon Cartwright, Nature, 3-5-13

The earthquake that rocked Tohoku, Japan, in 2011 was so powerful that its rumble was 'heard' from space. Scientists in France and the Netherlands have found that sound waves from the quake reached as far as an orbiting satellite, 260 kilometres above ground.

Earthquakes make the ground resound like a giant subwoofer, generating seismic waves that travel through the Earth and, to a lesser extent, acoustic waves that travel through the air.

Although thunderous booms have been heard after some small quakes — such as those that occurred in Spokane, Washington, in 2001 (ref. 1) — these waves are usually so deep in pitch that they fall into the category of 'infrasound', which cannot be heard by humans. (Instruments that can detect infrasounds are an essential component of a global network to enforce the Comprehensive Nuclear-Test-Ban Treaty.)

During the Tohoku quake and the resultant tsunami — which together led to some 15,000 deaths — various instruments, including Global Positioning System satellites, detected ripples propagating in the electrons of the ionosphere, a layer of electrons and ions that overlaps with the ordinary, electrically neutral part of the atmosphere between 80–600 kilometres above Earth's surface.

The effect, picked up through delays in radio signals, suggested that the electrons were being pushed around by the neighbouring ions, which in turn were propagating an infrasound wave from the neutral atmosphere below.

Raphael Garcia, a physicist at the University of Toulouse in France, and his colleagues decided to seek direct evidence of this infrasound wave's existence. They turned to satellite data, looking for signs of subtle vertical accelerations, which would be caused by the infrasound waves.

The best candidate turned out to be the gravity field and Steady-State Ocean Circulation Explorer (GOCE) instrument. GOCE orbits Earth at an altitude of 260 kilometres and was designed by the European Space Agency to monitor tiny variations in gravity over the Earth's surface using six accelerometers. Garcia and his colleagues used a computer model to filter out atmospheric dynamics, such as gravity waves emanating from the polar region, that were unrelated to earthquake-borne infrasound.

The results, published last month in Geophysical Research Letters[2], reveal clear infrasound signals from the Tohoku quake. GOCE detected an acoustic wave of frequency 14 millihertz (mHz) about half an hour after the quake, and another at 6 mHz about an hour after. In effect, the detection makes GOCE the first orbiting seismometer.

The work opens up the possibility of dedicated seismometer satellites that could monitor earthquakes in remote places, such as the middle of an ocean. Such satellites could also help to monitor for tests of nuclear warheads, although the lower seismic energies involved — magnitude 3 for a typical nuclear test, compared with magnitude 9 for the Tohoku quake — make this a more remote possibility.

"The approach is proven on an extreme event," says Ian Main, a geophysicist at the University of Edinburgh, UK. "More case studies on smaller events are needed before anything can be concluded on the general applicability of [orbiting seismometers]."