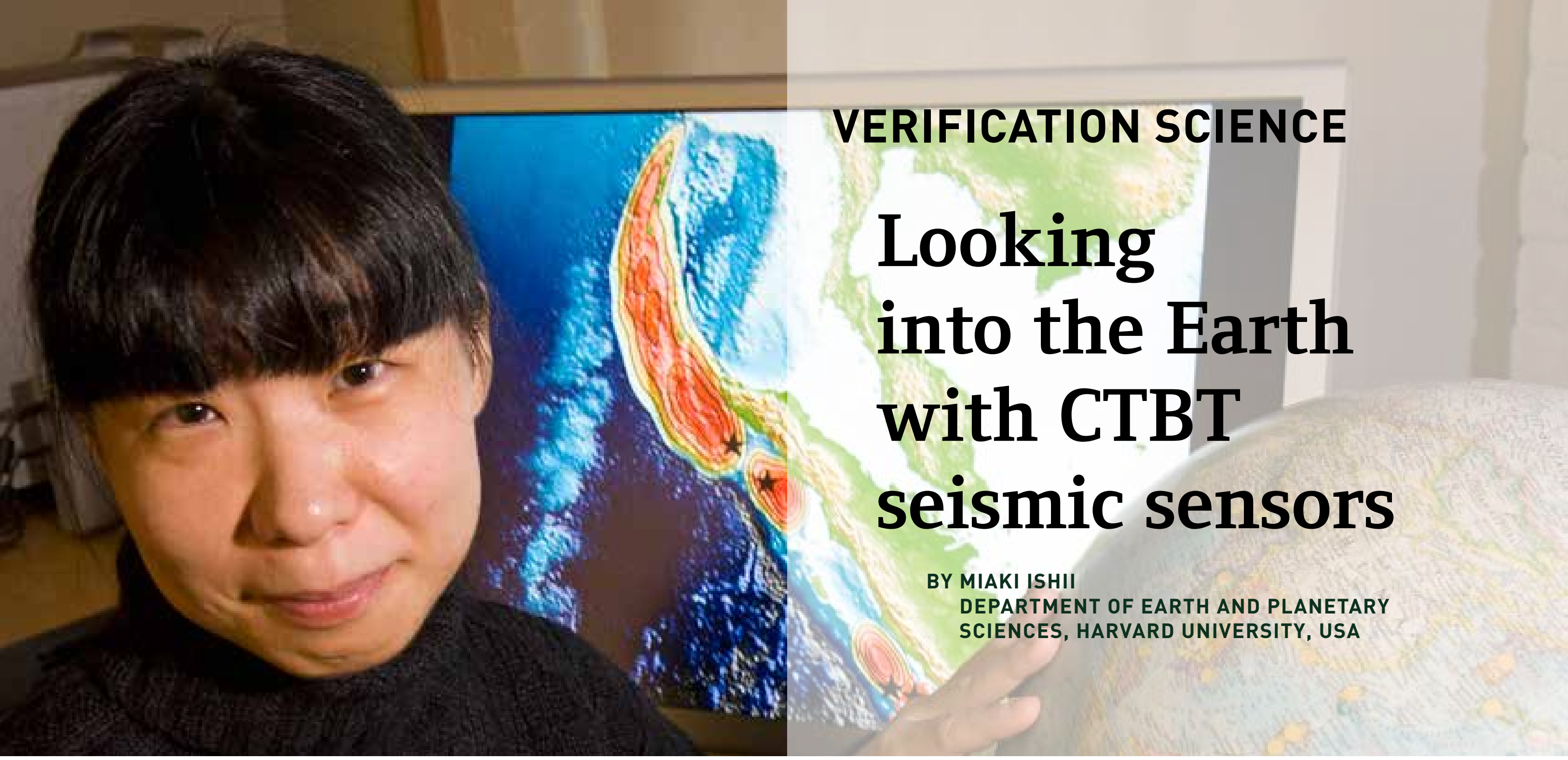

VERIFICATION SCIENCE

Looking into the Earth with CTBT seismic sensors

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On 12 February 2013, the seismic component of the CTBTO network once again demonstrated its ability to detect nuclear tests – for the third time since 2006. At 02.57.51 (UTC), an event measuring 4.9 in magnitude was picked up by no less than 94 CTBTO seismic stations. Member States received the first estimates of location, depth, time and magnitude in little more than an hour, and before North Korea had announced that it had conducted its third nuclear test.

SEISMIC SIGNALS CARRY A WEALTH OF INFORMATION

It is less known to the public that in addition to providing information about the event in North Korea, the seismic signals detected that morning actually carried plenty of other information. As seismic waves from any event travel through the Earth, their path is not confined to the crust. They may also run through the Earth's mantle. Or they might traverse the Earth's core, skim it or be reflected by it. In doing so, these waves tell us not only about the nuclear test, but also about the Earth's internal structures that they passed through on their way to the seismometer.

The principle is the same as that used by doctors to study the inside of the human body in non-invasive ways, for example, when using medical ultrasound or X-rays. The difference is only that for "looking" into the Earth, the seismic waves generated by earthquakes or nuclear explosions replace ultrasound or X-rays, and the seismic sensors are the detectors. In fact, they are our most important means of studying the Earth's interior, as the deepest hole ever drilled reached down to 12.2 kilometres (7.6 miles), piercing less than 0.2% of the Earth's radius.

POWERFUL TELESCOPES THAT CAN VIEW INSIDE THE EARTH

Even though investigating the Earth's subsurface is not the main objective of the CTBTO's seismic network, its stations serve unexpectedly well as powerful telescopes to view inside the Earth. Showcasing spin-off effects like this was one of the themes a symposium on "The unreasonable usefulness of test-ban verification for disaster warning and science". I participated in this symposium on 17 February at the annual meeting of the American Association for the Advancement of Science in Boston, United States.

Other purely scientific seismic networks can be used to that effect as well. However, in order to study how seismic waves travel through the Earth's core, a seismic station needs to be located on the far side of the Earth.

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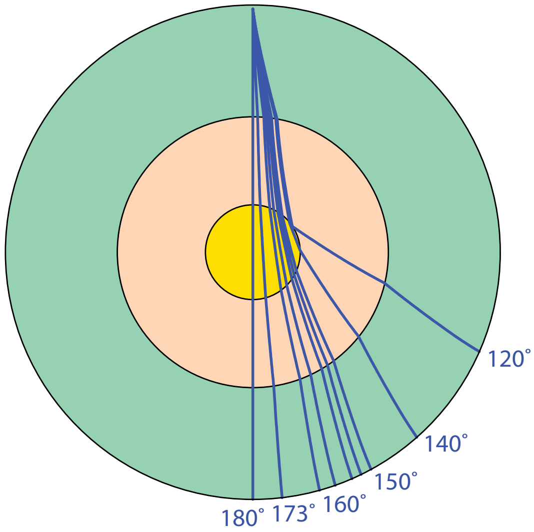


As earthquakes occur in many parts of the world along tectonic plate borders, there is a fair chance that at least one of the CTBTO's 170 seismic stations will be suitable. Combined with their high level of data availability, this makes the stations interesting for Earth scientists.

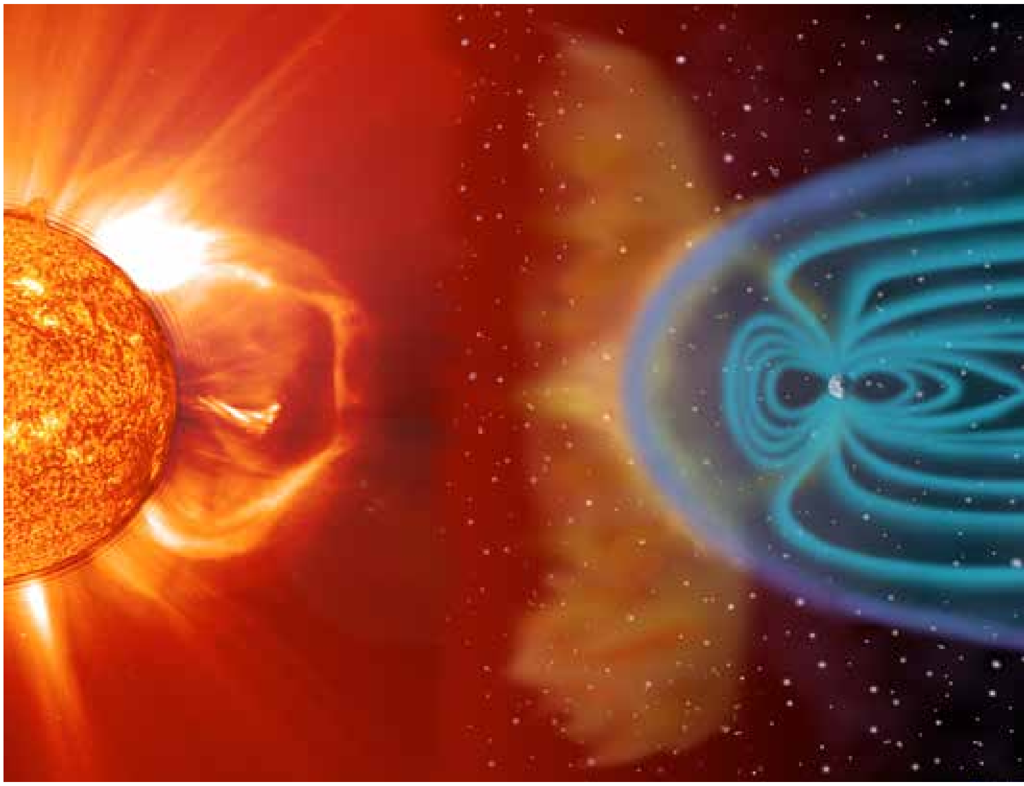
UNDERSTANDING THE INTERNAL STRUCTURE OF THE EARTH

The seismic data show us the Earth's interior from just beneath our feet to all the way down to the centre of the planet, at around 6,400 km (almost 4,000 miles) below the surface. A detailed knowledge of the internal structure is essential to unravel the dynamics and history of the Earth. For example, just as there are continents and oceans, there are regions of fast and slow seismic wave speeds within the Earth's mantle. Such structure is thought to be related to mantle convection, which drives plate tectonics and hence dynamic processes at the surface such as where earthquakes and volcanoes occur.

Diving even deeper, the Earth's core, which is more than 3,200 km (over 2,000 miles) deep, is divided into a liquid outer core and a solid inner core. CTBTO data, for example, can inform us about the properties of the transition from the outer to the inner core. This boundary is important for the operation of vigorous mixing within the outer core that generates the Earth's magnetic field, which shields us from harmful cosmic rays and helps us navigate.

IDENTIFYING THE COMPOSITION OF THE EARTH'S CORE

The way in which seismic waves are influenced when passing through the Earth's interior structures also helps to reveal their composition. The phenomenon that wave speeds differ according to the travel direction is known as anisotropy (as opposed to isotropy, where the wave speed is the same for all directions). Significant seismic anisotropy has been detected in the Earth's inner core, suggesting that crystals that make up the inner core are not randomly



The Earth's vital magnetic field is generated within the Earth's outer core. Photo courtesy of NASA.

gathered together. Such information, combined with data from other fields of Earth Sciences (e.g., geochemistry), shows that the Earth's core is made up mostly of iron with some impurities such as silicon and oxygen. This metallic core composition differs significantly from the mantle that consists mainly of rocks.

So while the scientific value of the seismic probe into the Earth's interior is enormous, a better understanding of the underground structure, in turn, ultimately improves the identification and characterization of nuclear explosions. This is because the distortion in the seismic waves caused by the underground structure can be properly accounted for, rather than being accepted as uncertainties in nuclear explosion detection.

IMPROVING THE SCIENTIFIC UNDERSTANDING AND FUTURE OF OUR PLANET

For certain regions of the world, the CTBTO has recently started, in cooperation with some of its Member States, to factor in such structural particularities on a regional basis. Using the U.S. Regional Seismic Travel Time software and model, seismic travel times have been mapped in three dimensions for North America and Eurasia, allowing for a more accurate location of seismic events. Modelling is under way for Africa, Central and South America, South East Asia and Australia. The investigations of the Earth's internal complexities and event determination go hand in hand in improving both the scientific understanding and future of our planet.

BIOGRAPHICAL NOTE

MIAKI ISHII
has been an Associate Professor of Earth and Planetary Sciences at Harvard University since 2010. Her main research interest is the use of seismic energy recordings to image the internal structure of the Earth and to study properties of earthquakes. She has won a number of awards and honours including the Charles F. Richter Award from the Seismological Society of America and the James B. Macelwane Medal from the American Geophysical Union.