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Australian Government
Geoscience Australia

Listening to the EARTH

A system to monitor H-bombs warns of other disasters.

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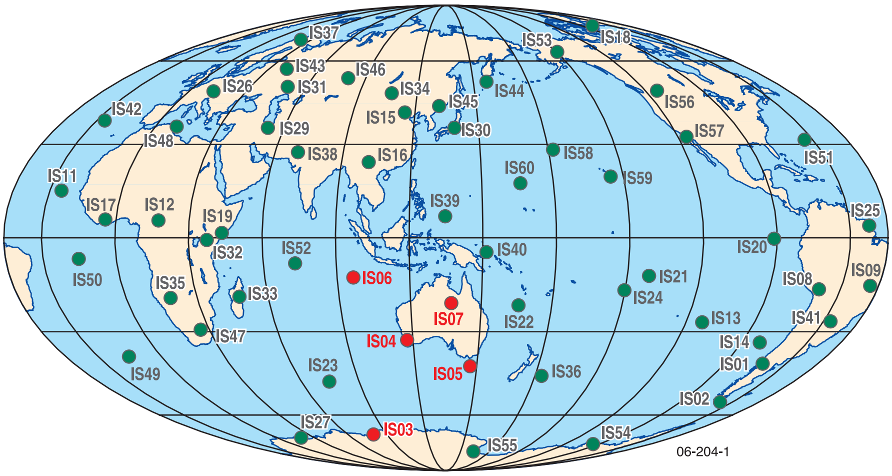
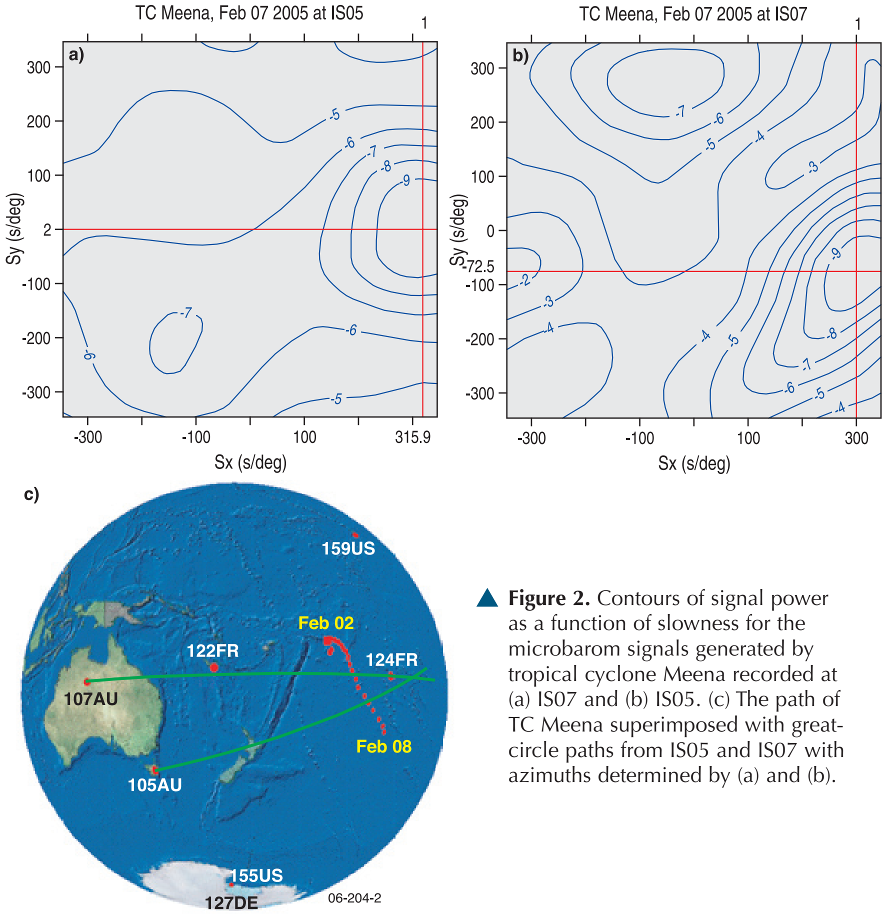


▲ **Figure 1.** The 60-station IMS infrasound network, with the Australian-operated stations shown in red.



▲ **Figure 2.** Contours of signal power as a function of slowness for the microbarom signals generated by tropical cyclone Meena recorded at (a) IS07 and (b) IS05. (c) The path of TC Meena superimposed with great-circle paths from IS05 and IS07 with azimuths determined by (a) and (b).

For humans, sound is ubiquitous. We are constantly bathed in a spectrum of acoustic radiation from human and natural sources, from very high ultrasonic signals of submillimetre wavelength to very low infrasonic acoustic-gravity waves with wavelengths of 10 kilometres or more.

The distance to which acoustic signals propagate is governed by how rapidly the energy is absorbed by the atmosphere. Absorption of acoustic energy varies roughly according to frequency. Lower frequency signals tend to travel further—one reason why low-frequency ship horns can be heard over several kilometres and high-frequency sirens become inaudible within a kilometre.

Explosions provide a good broadband source of sound. High-frequency components in the hundreds to thousands of Hz range dissipate within a kilometre or so, but longer-lived infrasound components, if they are generated, can travel thousands of kilometres.

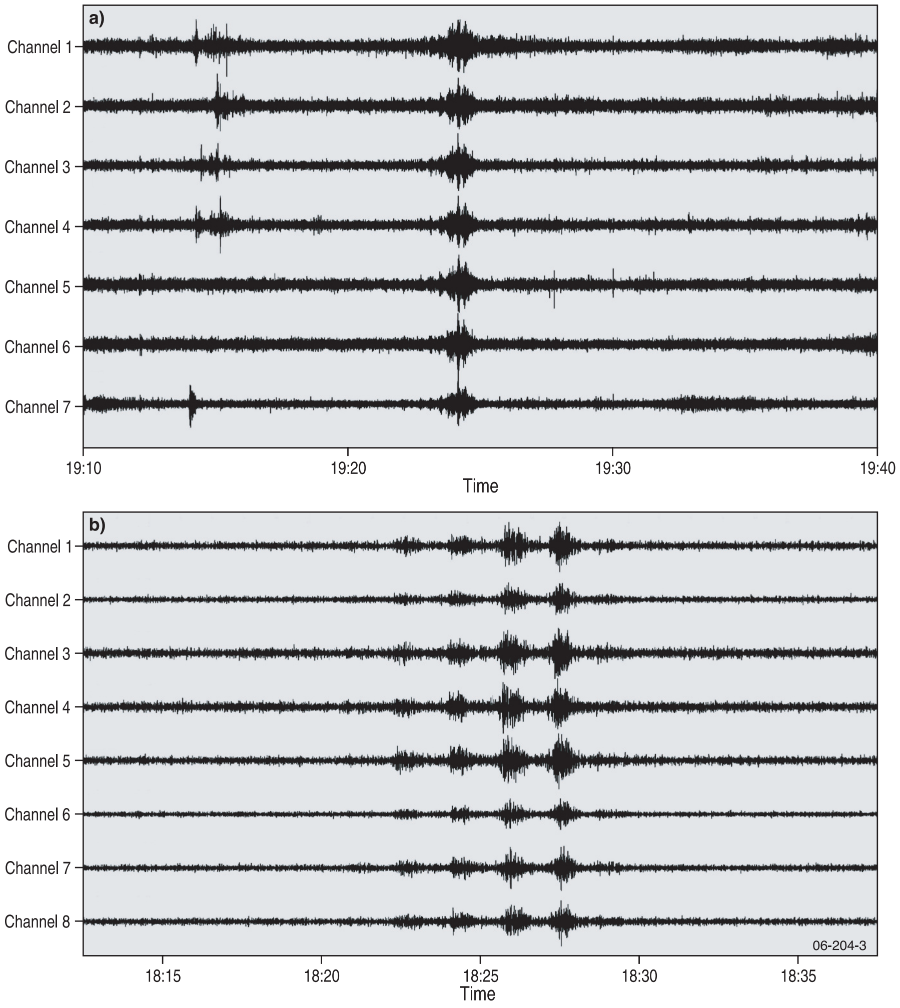
The long-lived infrasonic core generated by large atmospheric explosions is the focus of the Comprehensive Nuclear-Test-Ban Treaty (CTBT) in its efforts to monitor the environment for clandestine nuclear detonations. A global 60-station infrasound sensor network, a component of the International Monitoring System (IMS) of the CTBT, is being established to monitor compliance with the treaty when it enters into force (figure 1).

Detecting infrasound

Geoscience Australia and the Australian National University will operate five IMS infrasound stations as part of the Australian Government's commitment to monitoring the test ban treaty.

Each station consists of between four and eight low-frequency microphones placed on the surface, separated by between 0.2 and 3 kilometres.

The main goal of the IMS is to detect explosions of one kiloton yield or higher. It also has the potential to contribute in other areas, in particular by detecting volcanic activity that might be the source of ash clouds, which jeopardise the safety of aircraft.



▲ **Figure 3.** Acoustic signals recorded from the terminating explosion of a bolide striking the atmosphere near the northern NSW coast: (a) IS07; (b) IS05.

Storms at sea

The biggest radiator of natural infrasound is the surface of the sea. The 3–8 second period acoustic radiation coming off the sea, known as microbarom radiation, is the precise atmospheric analogue of microseismic radiation.

It is important to note that isolated travelling ocean waves don't radiate acoustically. Microbarom radiation requires standing wave conditions, which, according to the Ponomaryov wake generation model (Ponomaryov 1988), are most strongly generated in the wake region of moving storm systems.

A good example of storm-generated microbarom radiation is the acoustic signal generated by tropical cyclone Meena, which wreaked havoc in the Cook Islands in February 2005. Figure 2 shows contours of signal power as a function of slowness for acoustic signals recorded on IMS stations IS05 and IS07 for microbarom radiation generated by Meena. The signals in figures 2a and 2b can be used to infer the approximate location of the storm system, as shown in figure 2c.

Bolides

A second source of naturally occurring infrasound is the entry of bolides (meteorites) into the atmosphere. Bolides hit the atmosphere at speeds ranging from 10 to 70 kilometres per second, and generate acoustic signals in two ways.

In the first, supersonic motion through the atmosphere generates a line source that's recorded as a shock wave in the near field, or as a linear acoustic wave in the far field.

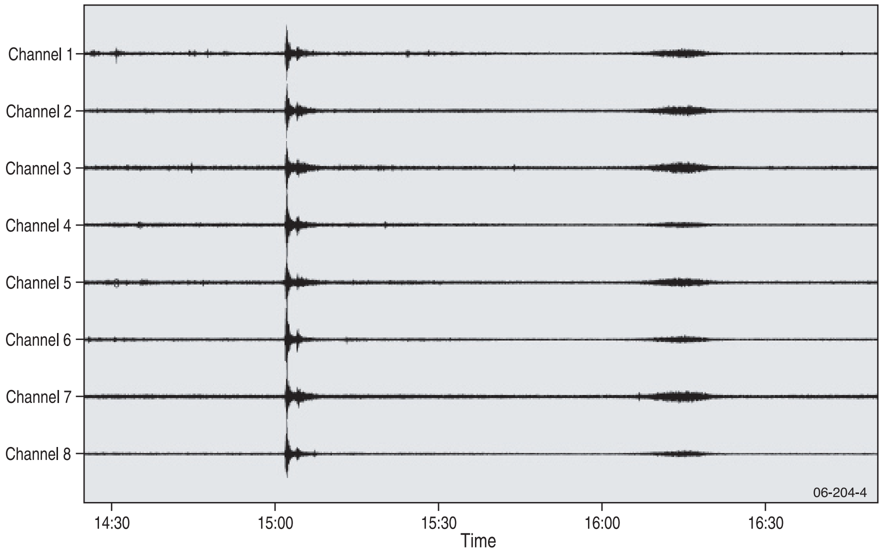
The second mechanism, a larger source of sound, is the terminating explosion as the kinetic energy of the bolide converts into thermal energy. An example of this is shown in figure 3, which shows signals recorded on IS05 and IS07 from a bolide that struck the atmosphere, waking residents along the northern coast of New South Wales.

Based on the extracted signal parameters, triangulation places the source near Taree. This information may be useful in locating debris for meteorite analysis.

Earthquakes

Large-scale earthquake activity often registers on IMS infrasound stations. Several signals are usually recorded. The earliest arriving signals are seismic phase P, followed by S, some time later by the converted hydroacoustic T phase, and last by the acoustic phase that propagates through the air from source to receiver. The Macquarie Ridge earthquake of 24 December 2004 is a prime example. Station IS05 at Buckland, Tasmania, 1300 kilometres from the source region, recorded strong seismic and infrasonic signals. Figure 4 shows the P, S and Is phases recorded at Buckland.

In this case, the precise mechanism of the airborne acoustic signal is not well understood, as the signal would have travelled through a significant depth of water.



▲ **Figure 4.** Macquarie Ridge magnitude 8.1 earthquake signal recorded on the IS05 infrasound station. The earliest arrival is the P phase, followed by S, and some time later by the airborne acoustic signal.

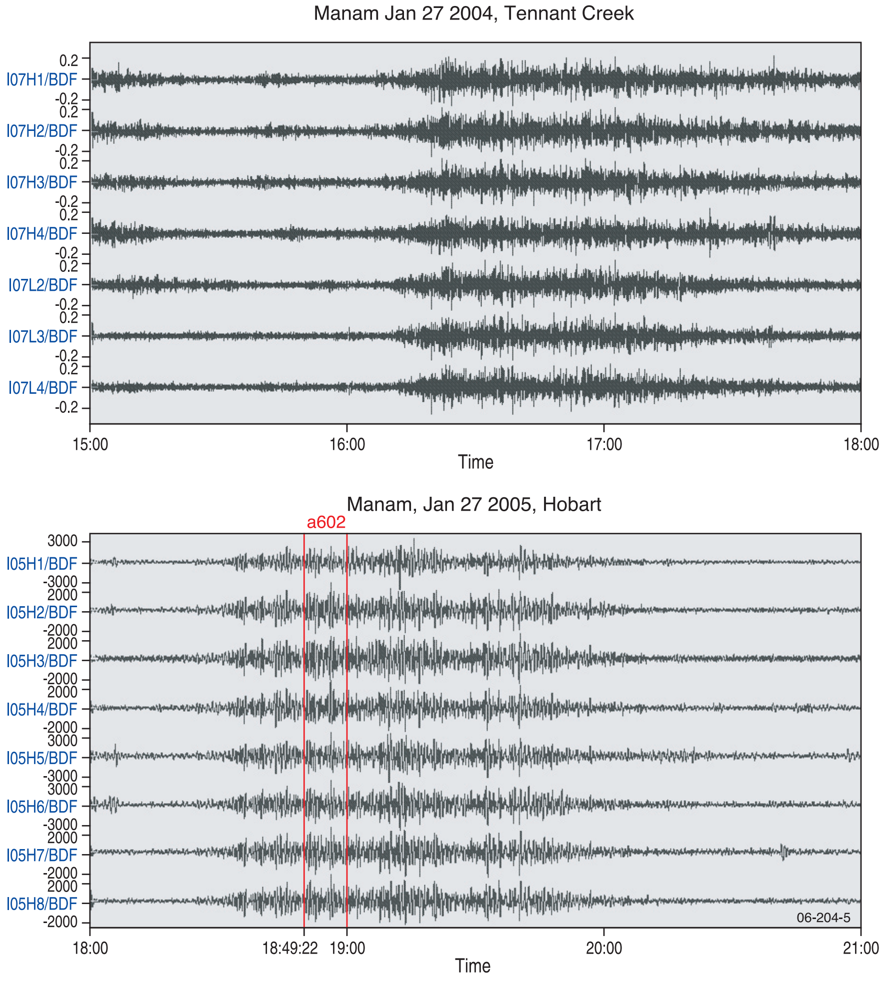
Volcanoes

An arc of volcanic activity borders Australia, from New Zealand in the east to Indonesia in the west. The Indonesia–PNG area alone contains 165 active volcanoes, and significant volcanic events in that area often register on the Australian IMS infrasound stations.

The eruption of Manam volcano in PNG in January 2005 is a good example and highlights the potential contribution the IMS network can make to a multitechnology ash warning system for aircraft.

On 27 January, after several months of low-level volcanic activity, Manam erupted violently—with devastating consequences. The Manam seismic observatory, operated by Rabaul Volcanological Observatory, was destroyed, with at least one death.

Thick cloud cover made satellite analysis of the main eruption difficult, and an ash warning for aircraft was not issued until 14 hours after the event (Tupper et al 2005). However, acoustic signals from the main eruption registered strongly on the two Australian IMS infrasound stations then operating (figure 5).



▲ **Figure 5.** Acoustic signals from the eruption of Manam volcano of 27 January 2005, recorded on (a) IS07, filtered between 0.4 and 1.6 Hz, and (b) IS05, filtered between 0.03 and 0.1 Hz.

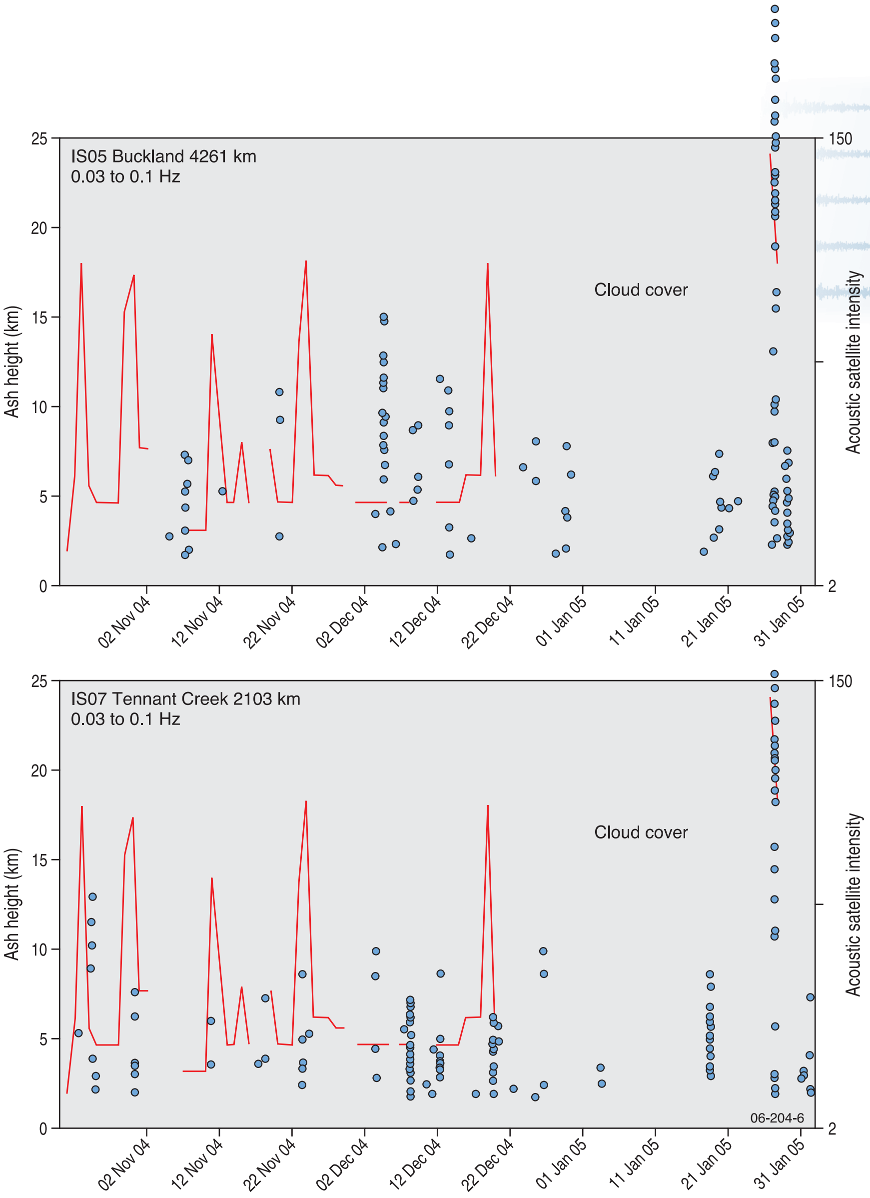


Figure 6. Post-analysis satellite ash cloud height data (solid line) with automatic infrasound detections superimposed. The F value is the F-statistic value, a non-linear measure of the normalised correlation, and will become infinite for a completely correlated signal.

Post-analysis satellite data for several months leading up to the main Manam eruption were provided by Andrew Tupper of the Darwin Volcano Ash Advisory Centre. Comparison with infrasound detections made by the automatic processing system at both stations for the same period (figure 6) shows that:

a) for IS07, the closest station, fair-to-good correlation exists between the known ash cloud events and infrasound detections

b) correlation exists between the detections at IS05 and IS07 for some of the ash cloud events—there also seems to be some indication that volcanic activity occurred without an observed ash event, perhaps due to heavy cloud cover.

There is clearly a potential role for the IMS network in a multitechnology ash monitoring system for aircraft.

References

1. Ponomaryov EA, Sorokin AG, Tabulevich VN. 1998. Microseisms and infrasound: a kind of remote sensing. Phys. Earth & Planet. Int. 108:339–346.
2. Tupper A, Itakarai I, Richards M, Prata F, Carn S & Rosenfeld D. Submitted. Facing the challenges of the International Airways Volcano Watch: the 2004/05 eruptions of Manam, Papua New Guinea. Weather and Forecasting.

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