However, Civil Defence is planning to install tsunami warning sea-level gauges at one of the sub-Antarctic islands to the south of New Zealand and at Raoul Island in the Kermadec Islands group to the north of New Zealand, to supplement the existing Chatham Island gauge to the east of the country. These sites will provide a few hours' warning of tsunamis generated at distant locations and will aid in the assessment of tsunami risk so that action can be undertaken to avoid the hazard.

While the Balleny tsunami was a small event, its main significance was to remind us all that New Zealand is also vulnerable to tsunamis from its southern ocean flank. ■

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Further reading

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Acknowledgements

Thanks to Kathy Walter at NIWA, Christchurch for downloading the data for Dog Island. Thanks also to Frank Gonzalez, NOAA/PMEL, for useful discussions and providing NTF data, and to Terry Hume for helpful review comments.

Sea-level recorders

IN 1996, NIWA installed six new sea-level recorders at strategic locations within New Zealand's Exclusive Economic Zone. These completed a set of 10 recorders which together provide comprehensive coverage of tidal heights around the New Zealand coast and identify areas which are susceptible to storm surges and tsunamis.

Until 1994 only one such recorder operated in New Zealand, at Moturiki Island in the Bay of Plenty, North Island. In 1994 recorders were installed on the east coast, South Island, at Sumner Head and Kaikoura (jointly with Canterbury Regional Council and the University of Canterbury, respectively). In early 1996, in a joint Australian/NIWA effort, a fourth one was deployed at Jackson Bay, south Westland.

In terms of tsunamis, the installation of the Kaikoura instrument proved timely. The Kobe (Japan) earthquake of 4 October 1994 generated a tsunami which was detected by the Kaikoura recorder as a series of waves with maximum amplitude of 50 mm and period of 37 minutes.

The recent tsunami generated in northern Papua New Guinea was not detected by the Kaikoura gauge but was picked up by the gauge at Sumner Head as increased amplitude "shelf waves" (see following article).

Of the six new recorders, two were installed at Maritime Safety Authority lighthouses (at Dog Island in Foveaux Strait and at Mokohinau Island off the east coast, Northland). One is at the Department of Conservation boatshed at Kapiti Island (west coast, lower North Island). Housing for the instruments has been specially constructed for the remaining three, at Charleston (northern West Coast, South Island), Riversdale (east coast, lower North Island) and Anawhata (west of Auckland).

Each set of instruments comprises a nitrogen bubbler system with a pressure transducer, digital datalogger and cellphone telemetry housed onshore. Air and water temperatures and barometric pressure are also recorded.

Of these latest recorders, the one at Dog Island has proved valuable in detecting a rare occurrence of a tsunami from the south.

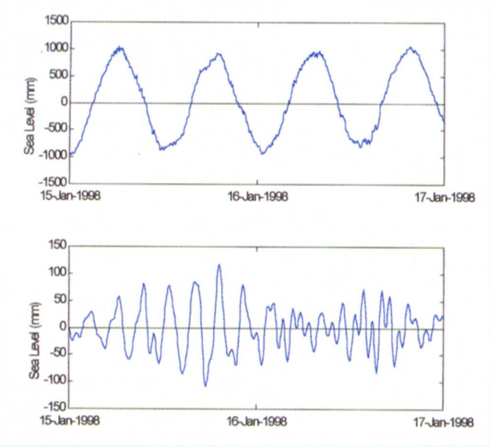
For more information about the network, contact Derek Goring, NIWA, PO Box 8602, Christchurch (Ph. 03 348 8987; Fax. 03 348 5548; d.goring@niwa.cri.nz).

Canterbury shelf waves and the PNG tsunami

Derek Goring

Rob Bell

THE SEA on the shallow continental shelf off the Canterbury coast is continually pulsing up and down with "shelf waves". The pulse rate of these waves is much slower than the wind waves or swell we observe on the beach and much faster than the tide. In fact, we cannot observe the smaller shelf waves, except by looking at a trace of sea level such as we get from a tide gauge or sea-level recorder. On these, the shelf waves distort the tidal sine wave and make it look jagged. By numerically processing the sea-level record, we can remove the tide (the program is called a "tide-killer"), leaving just the shelf waves themselves.



Typical record from the sea-level recorder at Sumner Head (Christchurch) showing the "ragged" appearance of the tidal sine wave (upper plot) and the shelf waves which cause the distortion (lower plot).

Computer modelling and good vibrations!

In 1997 we did some computer modelling of the region from Otago Harbour to Cape Campbell and eastwards to deep water beyond the Chatham Islands. The modelling showed that Pegasus Bay has a natural mode of oscillation of 3.4 h whereas the Canterbury Bight has a natural mode of 2.5 h (see upper figure, next page). Natural modes of oscillation are the natural pulse rate (or, in musical terms, the pitch) at which a body will vibrate. For example, when you are driving your car on a gravel road and you get a vibration, that part of your car is oscillating in its natural mode. Similarly, a guitar string vibrates in its natural mode when plucked.

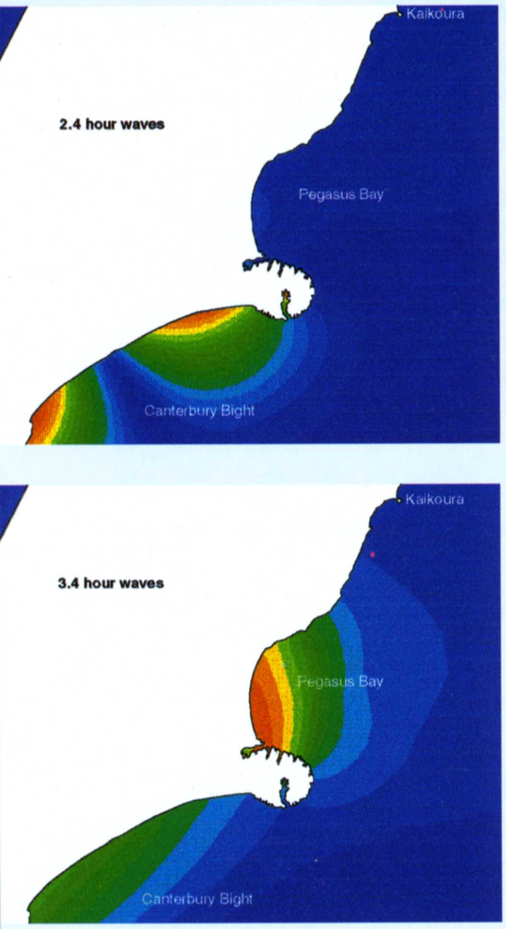
What drives the shelf waves?

We believe that shelf waves are somehow related to how the weather – winds and changing barometric pressure – interacts with tidal flows in shallow, broad, shelf areas around our coast. We hypothesise that the interaction is chaotic. That is, it is the result of what we call a "nonlinear dynamic process", as opposed to being random, which would be the result of many different interactions.

PNG tsunami

On 17 July 1998 the weather was calm and settled in Canterbury and the shelf waves were as small as they ever get (± 50 mm).

At 0849 hrs (GMT) an earthquake of moment magnitude 6.8 occurred just north of Papua New Guinea in the Bismarck Sea. Following the earthquake, a series of tsunami waves up to 10–13 m high devastated several villages around Sissano Lagoon and caused the loss of up to 3000 lives.



Natural modes of oscillation of the Canterbury shelf showing how the shelf waves are trapped by the coastlines. Red is for the largest amplitude and blue is zero amplitude.

Shelf waves at various sites north of Banks Peninsula. ETA is the estimated time of arrival of the PNG tsunami at 2045 hrs (GMT) on 17 July, 12 h after the earthquake in the Bismarck Sea.

As the tsunami waves radiated out from the PNG source like ripples on a pond, they evolved into a train of very long, low waves, perhaps hundreds of kilometres in length and a few centimetres in height, some of the waves coalescing and others dispersing. (See panel in previous article "Tsunamis: what are they?".)

When they arrived at the edge of the continental shelf at Kaikoura about 12 h after generation, they were only a few millimetres in height, but one wave at least had energy at the natural mode of Pegasus Bay. Just like a guitar string being plucked, Pegasus Bay responded.

Was it the tsunami our gauges detected?

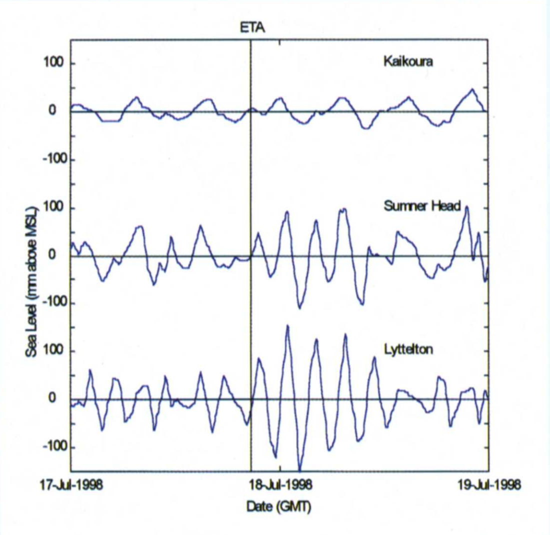
At this stage the evidence is purely circumstantial:

- prior to the estimated time of arrival of the tsunami the shelf was essentially quiescent, with little wind and no rapid barometric pressure changes;
- at almost exactly the expected time of arrival of any tsunami reaching our shores, the shelf waves suddenly amplified several-fold;
- after a few oscillations the shelf returned to its quiescent state.

You be the judge. Is there enough evidence to confirm that it was the PNG tsunami's tail we felt?

What are the implications?

There are two possible mechanisms for tsunamis to interact with the shelf in Pegasus Bay. One is where a tsunami generated at a far-flung part of the Pacific Ocean dissipates gradually over thousands of kilometres and lengthens to a stage where the main energy occurs at a scale which sets off the natural resonance of the Bay. In this case, the shelf response to a "dying" tsunami from a remote source, while posing a risk to susceptible coastlines, will be limited in its effect (a few metres) compared to a locally generated tsunami. For example, the biggest recorded sea-level response for a distantly generated tsunami is 5.5 m in Lyttelton during the tsunami following an earthquake off Chile in May 1960.



The second possibility is that what we observed with the PNG tsunami was chaotic interaction between a tsunami, the tide and the shallow, broad shelf. If this was the case, then who knows what will happen if a tsunami is generated close-by in the New Zealand region? It may result in waves of a few decimetres in height at Kaikoura, but they could be amplified many-fold in Pegasus Bay. Such waves would be devastating to low-lying areas in Christchurch, Lyttelton and other coastal communities, especially those not protected by dunes. ■

Derek Goring is based at NIWA in Christchurch; Rob Bell is based at NIWA in Hamilton.

Acknowledgements

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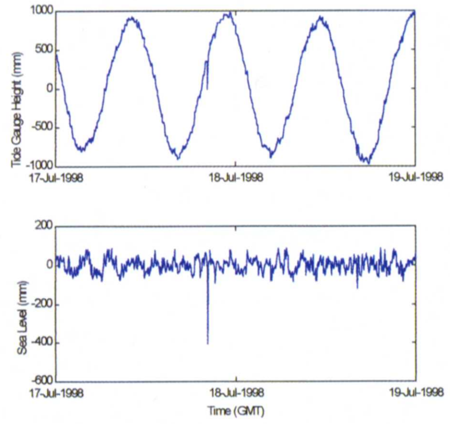
Further reading

Goring, D.G.; Henry, R.F. 1998. Short-period (1-4 h) sea level fluctuations on the Canterbury coast, New Zealand. NZ Journal of Marine and Freshwater Research 32: 119-134.

A post-script from Timaru

The figure below shows the record from the tide gauge at Timaru on 17 July 1998. It shows a large drop in sea level at 2020 hrs (GMT) – the predicted time of arrival in New Zealand waters of the PNG tsunami. The timing of this drop along with the shelf wave changes recorded in Pegasus Bay again strongly suggest that this was directly caused by the tsunami in PNG. As mentioned in the panel (page14) tsunamis have a range of effects, one of which is an initial fall in sea level.



Plots showing a large drop in sea level at Timaru on 17 July 1998. The upper plot shows that the drop occurred at about mid-tide when the water level was rising rapidly. The lower plot shows the drop in comparison with other oscillations in sea level (after the tide signal has been removed).