Natural Hazards 2010

GNS SCIENCE TE PŪ AO

Massey University

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OPUS

NIWA Taihoro Nukurangi

Natural Hazards 2010

A review of New Zealand's major hazard events of 2010, and the work of NIWA, GNS Science, and other organisations in their efforts to reduce the risks, and mitigate the effects, of natural hazards in New Zealand.

2010

Never before in the history of our country has the case for robust, long-term scientific research on natural hazards been made clearer. In the last year, as the Minister of Civil Defence I have witnessed first-hand the devastation and disastrous impacts natural events such as earthquakes, drought, tsunami, and storms can have on our people, homes, infrastructure, economy, and livelihoods.

The 4 September 2010 Canterbury earthquake showed just how vulnerable New Zealand is to natural hazards. Although there was no loss of life, about 100 people were injured and many more were made homeless. Sadly, this event became a rehearsal for the events that followed in the first few months of this year.

The 22 February 2011 Canterbury earthquake is without a doubt the worst natural hazard we have faced in our lifetimes. As New Zealanders we tend to believe we are immune to disasters on this scale, but sadly, the loss of life and impacts in Canterbury remind us all that we too are very vulnerable to nature's fury. The region we live in is full of natural beauty, but what makes our country so dazzling – our coasts, our mountains, our volcanoes, and our weather – also make us, and our neighbours, susceptible to natural hazards. The recent 8.9 magnitude earthquake and subsequent tsunami in Japan is another poignant reminder of this vulnerability.

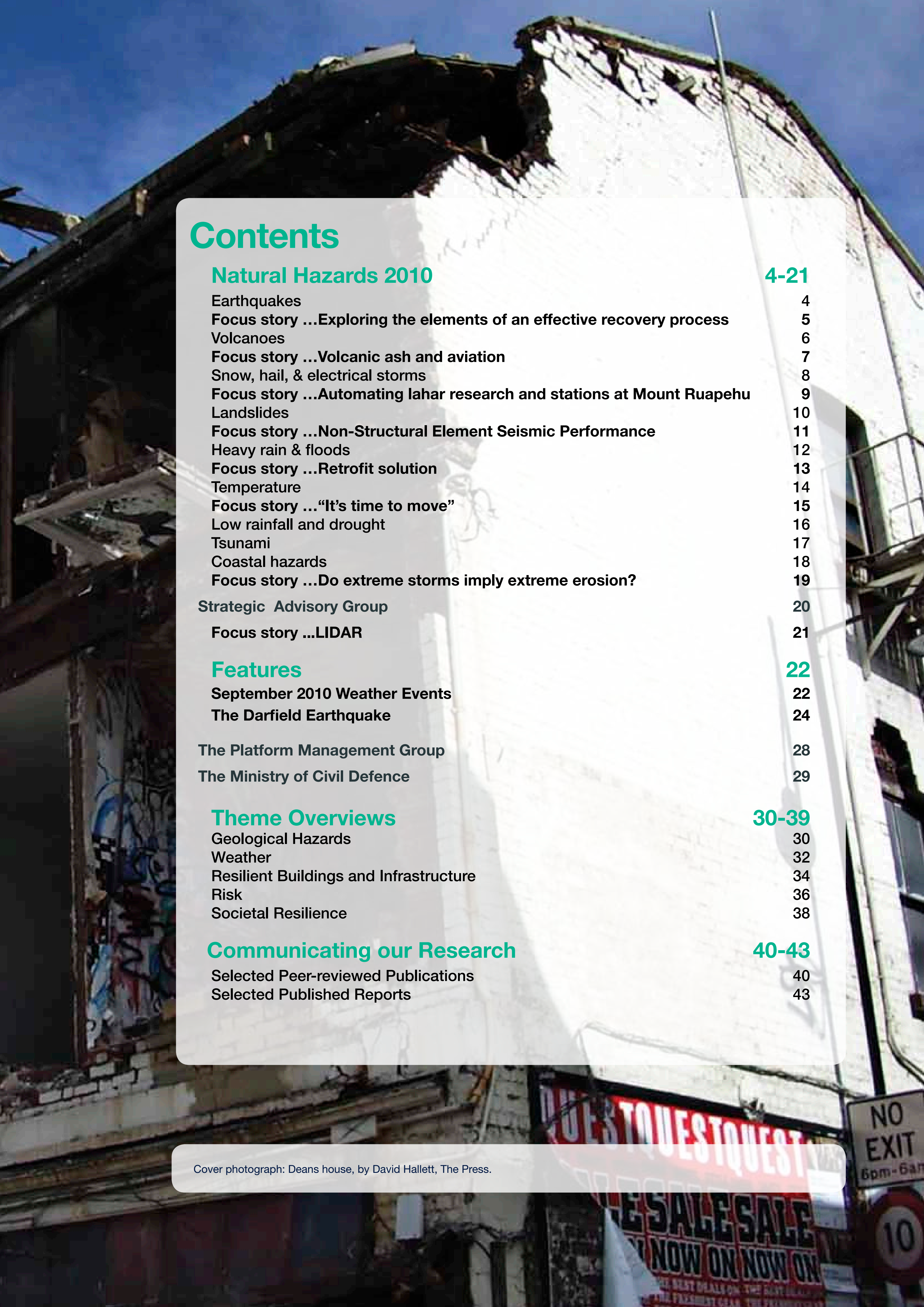
The Canterbury recovery and rebuilding effort will be long and complex, but I will continue to work with the Ministry of Civil Defence, my fellow Government ministers, local government, the Earthquake Commission, and other agencies to ensure Christchurch recovers as quickly as it can from the impacts of the two earthquakes. This effort must be supported by sound, scientific research and analysis to plan better for future events. These events have highlighted, all too clearly, that we must be prepared for the worst. The better we understand why and how natural hazards happen, the more accurately we can forecast and plan for a safer future.

The Natural Hazards Research Platform provides secure, long-term funding for natural hazards research and brings together the best skills we have in New Zealand to help prepare for, and mitigate the risk of, natural events. The research the Platform provides helps immeasurably to build a stronger New Zealand community, more resilient to the impact of natural disasters.

Congratulations to GNS Science and NIWA, and their Platform partners – University of Canterbury, University of Auckland, Massey University and Opus Consultants – for producing this annual publication which outlines the natural hazards events in 2010. Natural Hazards 2010 is a very important document, highlighting lessons learnt over the last year that will inevitably help guide us in the years ahead.

Hon John Carter

Minister of Civil Defence



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Cover photograph: Deans house, by David Hallett, The Press.

Earthquakes

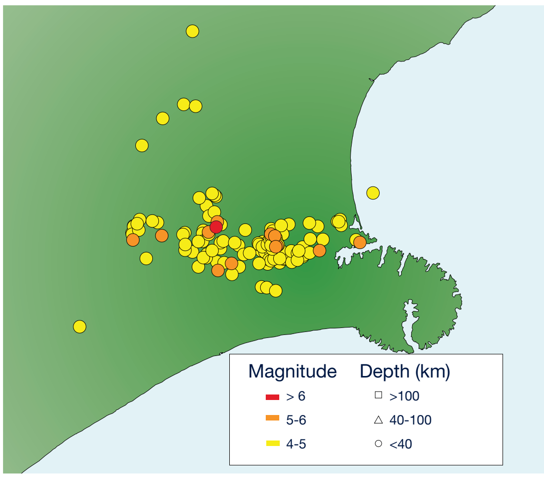
At 04:35 am, on Saturday 4th September 2010, the moment magnitude (Mw) 7.1 Darfield earthquake struck within 40 km of Christchurch, causing extensive damage in the city and surrounding region.

Although there was no loss of life, about 100 people were injured and many more were made homeless, at least temporarily. The total cost of repairs at NZ$ 4 billion (about US$ 3 billion). Modern buildings in Christchurch performed very well in the earthquake, but many older brick and masonry buildings were badly damaged. Liquefaction and the associated lateral spreading and slumping caused extensive damage even to new buildings in areas near the coast with sandy soils.

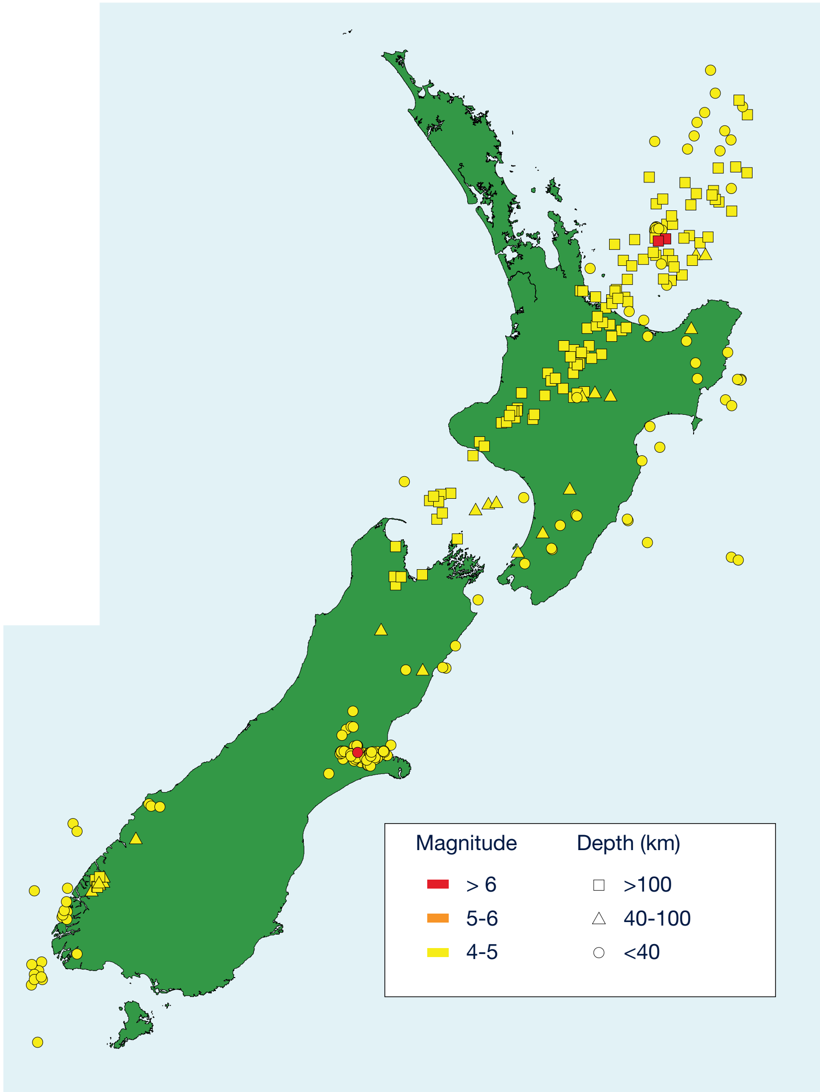
The epicentre and depth of the mainshock were very well constrained by the large number of nearby GeoNet network sites. A strike-slip surface rupture was quickly identified about 4 km south of the epicentre, although geodetic and seismological data show that the overall rupture process is complex, probably involving thrust faulting at the beginning and end of the rupture.

The earthquake was felt throughout the entire South Island and a large part of the North Island, with the maximum felt intensity estimated to be MM 9. Measured accelerations near the fault were greater than 1 g, with several readings well over 0.5 g. Large shallow aftershocks of Mw ~5 resulted in peak ground accelerations ranging up to 0.3 g within the central city. Aftershocks with magnitude up to 4, such as those on Boxing Day 2010, continued to be felt several months following the mainshock, causing damage in their own right.

A large range of research is underway, to examine the processes involved in the mainshock, and the link between the earthquake source, the path and the subsequent damage effects on the surface. One of the projects for example involved deploying a temporary array of ~180 low-cost accelerometers across Christchurch city, immediately following the mainshock, providing dense block-by-block station coverage within the Christchurch urban area. The aim of this array was to record the aftershocks within the urban area, for follow-up research studies examining how the observed damage patterns correlate with the strong ground motion, and with local geology within Christchurch city. These instruments were hosted by volunteers from the public, transmitting data through their home internet connection. Our instruments were sourced from the Quake-Catcher Network based in California, as part of the rapid earthquake response (RAMP) program to record aftershocks. The ground motion data recorded by these accelerometers is currently being analysed by seismologists at GNS Science. Preliminary results indicate significant amplifications at some stations on the thick Canterbury outwash plains as well as strong high-frequency amplification in the small, shallower basin of Heathcote Valley.



Locations of the 3835 aftershocks located by GeoNet in the Christchurch region, from September 4th, up to the end of 2010. Source: GNS Science.



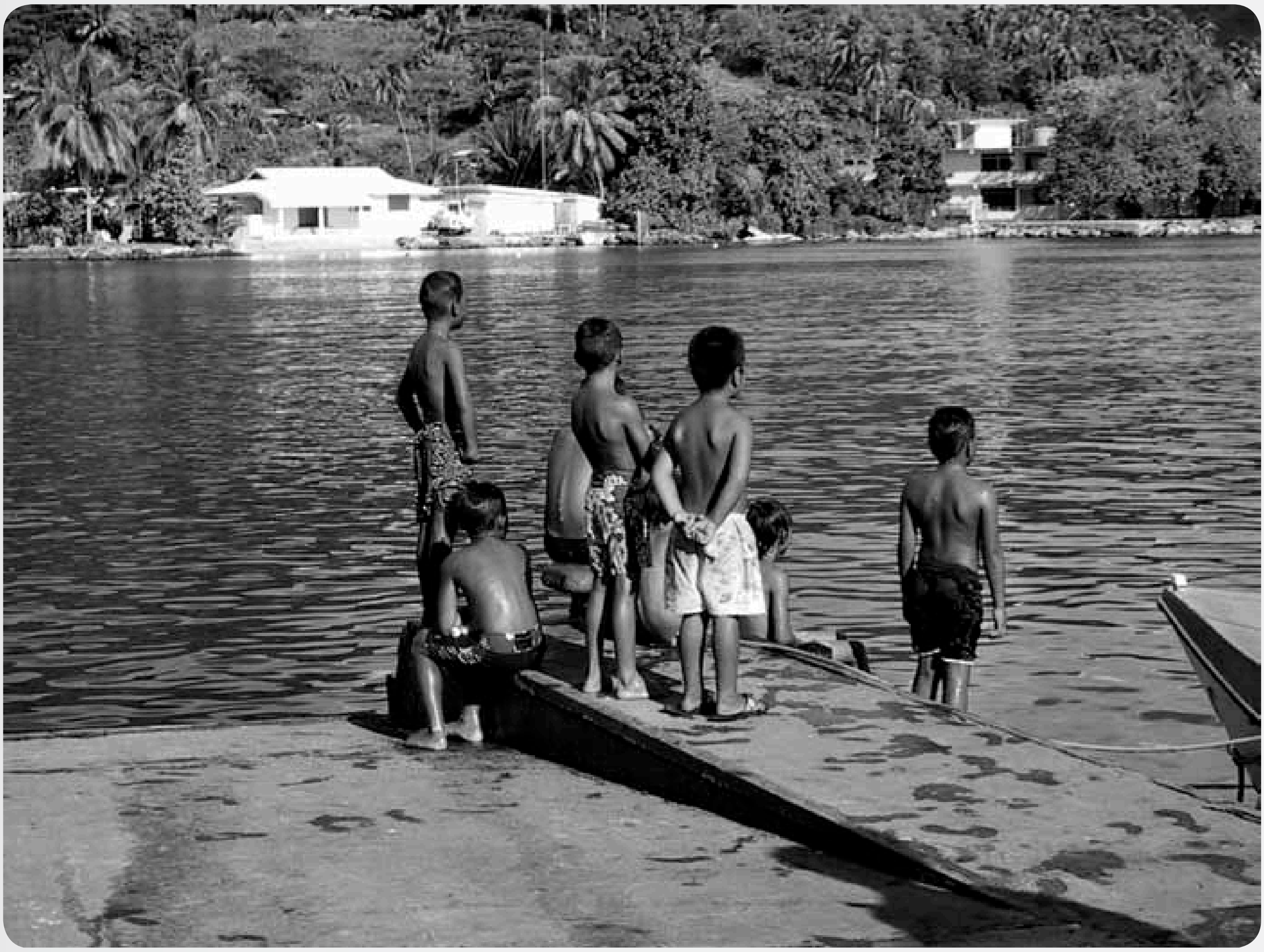
All earthquakes with magnitude > 4.5 in 2010. In 2010 a total of 119 earthquakes of magnitude 4.5 or greater occurred. A total of *400_insert_correct_number* earthquakes were reported felt on the GeoNet website. Source: GNS Science.

Exploring the elements of an effective recovery process

The 2010 Canterbury earthquake has illustrated complex nature of recovery from natural hazards events. Over the last year our research has explored these issues in the context of recent recovery efforts in New Zealand, the Pacific, Asia and North America.

Effective recovery from disasters depends not just on the physical impacts of the event but also on how the societal environment supports the complex and protracted processes of recovery. Societal resources (e.g., emergency management, technical experts and knowledge, protective services) and organisational capabilities (e.g., to coordinate response activities on a large scale) are crucial in determining how well people adapt to stress, change and emergencies. The coordination of diverse professional resources is required to deal with the physical consequences of disaster (e.g., emergency management, search and rescue, rebuilding), the societal consequences (e.g., ensuring continuity of essential physical infrastructure and services) and the personal consequences (e.g., managing the traumatic stress experienced by survivors, managing relocation and so on). Effective recovery is a function of the how well such resources can be mobilised and their actions coordinated to facilitate societal recovery.

Current research highlights the importance of not only strong local government capacity, but also of a cohesive system of public, private and volunteer groups integrated into the community. The research has highlighted that effective recovery planning must consider in advance issues around 1) community involvement, 2) the provision of information, and 3) procedures for making recovery decisions. Over the coming years we will be able to explore these issues in the context of the Canterbury earthquake recovery.



Volcanoes

New Zealand's volcanoes remained quiet in 2010.

No eruptive activity was recorded at any of the active volcanoes during 2010, similar to 2009.

The surveillance programme for White Island includes gas and water sampling, ground deformation and soil gas surveys and servicing. During the year the Crater Lake water level has fallen to about 14 metres below the overflow, however the temperature remains high at 57- 62°C. Minor changes have been observed in an area of high temperature (118 - 200°C) steam vents on the southern side of the Main Crater floor. These vents have been changing slowly for some years. The gas flux (measured from the air, from soil gas surveys and from the miniDOAS spectrometer) has remained low; carbon dioxide (CO_2) has ranged from 750 to 2,700 tons per day, while sulphur dioxide (SO_2) has ranged from 109 to 387 tons per day. The deformation survey confirmed continued uplift in the earlier part of the year, which has been recorded during the last 2 to 3 years, but this had stopped by the year's end. Volcano seismicity remained around typical background levels. The Volcanic Alert Level remained at Level 1 during the year.

Ruapehu Crater Lake temperatures started out low (20 - 25°C) then warmed to over 30°C later in the year. No eruptive activity was observed. Although activity has been low, gas flux has continued to vary during the year, with CO_2 ranging from 156 to 2,100 tons per day and SO_2 from 6 to 25 tons per day. Volcanic earthquake activity remained at low levels, as did volcanic tremor. Ruapehu remained at Volcanic Alert Level 1 throughout 2010.

Since early 2006, small low-frequency volcanic earthquakes have been present at Ngauruhoe. The level of seismicity has fluctuated over the year, with higher levels of activity in January, March, October, November and December. The highest levels were in January when activity reached 70 earthquakes per day. The Volcanic Alert Level remained at Level 0 during 2010.

Monitoring at Raoul Island has continued, with no anomalous trends having been observed in the temperatures or water levels of the Crater Lakes. The Volcanic Alert Level remains at Level 0.

Anomalous bore pressures and temperatures were reported from Rotokawa and Rotorua city in December. Water samples were collected from Rotokawa and show no changes from previous sampling. The Environment Bay of Plenty bores in Rotorua show a faster and stronger post-winter recovery, and the reported changes are attributed to that.

We continued to see evidence of small-scale eruptive activity at Monowai seamount on the Rarotonga seismic record during the year. No activity was confirmed by surface observations.

Small earthquakes have continued to occur in the Taupo Volcanic Zone, particularly offshore of Matata, south-west of Kawerau and at Waimangu, and along the Haroharo vent lineation within the Okataina Volcanic Centre. Not so many events have been located within Taupo Volcano, but activity continues to the south-west of the lake through Turangi to Lake Rotoaira. Events have also been recorded on the northern parts of Tongariro and around Ruapehu, in particular to the west of the volcano. No events have been recorded under Taranaki, but seismic activity continues to the west of the volcano.

Volcanic ash and aviation - could NZ air traffic be impacted to the same extent as Europe?

Early in 2010, a small eruption of Eyjafjallajökull volcano in Iceland caused mayhem across the skies of Europe. It has been estimated that the airline industry alone lost ca. US$ 2 billion over the course of just 39 days. The eruption itself was relatively minor in global terms and lasted less than 6 months, but the impact was global. In New Zealand, some industries were even boosted due to the closure of airspace over Europe, and consequent increase in demand in American for fast moving consumer goods such as fish and flowers. But could a similar eruption from a New Zealand volcano have a negative impact on our economy?

The impact of ash on aviation has long been acknowledged as problematic. For example, an eruption of Galunggung in Indonesia in 1982 resulted in the shut down of all four engines of a British Airways 747 passenger jet overflying the area. Fortunately, the engines were re-started and a catastrophe was averted. However, as a consequence, the World Meteorological Organisation and aviation industry began a series of consultations aimed at improved procedures for identifying ash clouds and for aircraft to avoid encounters.

In 1995-6, the eruption of Ruapehu led to a review of New Zealand aviation procedures and, as a result, a new system issuing volcanic hazard advice was instigated. This was subsequently updated in 2009. In this public document, the responsibilities of the main players for notification of volcanic ash in atmosphere for aviation are clearly set out. One main difference between the New Zealand methodology and what occurred in Europe in 2010 is that New Zealand Air Traffic Control would not close airspace. This would mean than the majority of air traffic in can continue unaffected.

Scientific research into the potential precursors to volcanic eruptions is contributing to better forecasting of future eruptions, both in New Zealand and in Iceland.

There is also a large international effort now being targeted at understanding how ash clouds are formed, how they can be detected and the impact on aircraft. This should help mitigate the effects of future eruptions on aviation and the accompanying economic impacts.

One particular area of research that is being undertaken in New Zealand is to look at the distribution of ashfall across the country from individual volcanoes. There are several models that can be used to calculate likely distribution and thickness of ashfall. Two are currently being used in New Zealand, and comparisons between different models are useful to assess uncertainty in the models. These models are now also being used to derive probabilistic national ashfall models, which in turn can be used by government to plan for future likely ashfall events.

So, the answer to question posed, is that, yes, volcanic eruptions will occur, and yes, they will impact aviation, agriculture, infrastructure and the population. However, science is providing a good basis for better understanding the likely impacts and for providing the best mitigation actions.

http://www.caa.govt.nz/Meteorology/Living_with_Volcanic_Ash.pdf

Photo: GNS Science

Snow, hail, & electrical storms

The most significant snowfall event of the year occurred during 15–23 September, with heavy snowfalls observed in the southwest of the South Island. On 18 September, conditions were particularly extreme, causing the roof of Stadium Southland in Invercargill to collapse. Other parts of Southland were also affected, meaning milk was unable to be collected because of dangerous roads, and thousands of lambs were lost across the region.

A fierce hailstorm on 29 August affected the Bay of Plenty, with particularly heavy falls in Tauranga. In Papamoa, lightning struck a home, blasting a hole through the roof, blowing off tiles, and damaging the home's wiring. Otumoetai College closed for the day as it had no power or hot water as a result of a blown power transformer. Other parts of the northern and western parts of the North Island experienced electrical storms, with thunder heard in Taranaki, Matamata, Auckland and Northland.

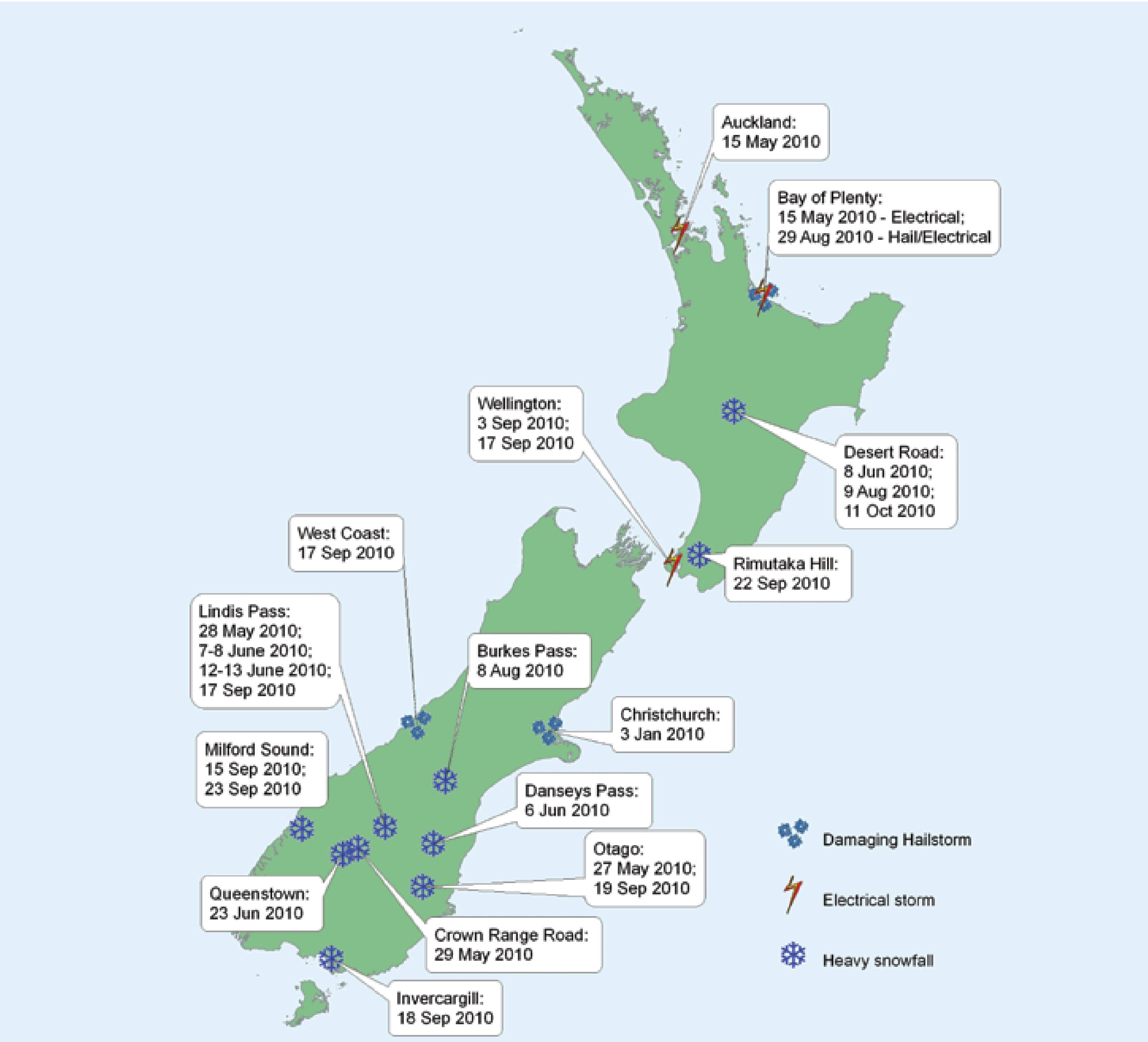
On 3 September, an electrical storm struck Wellington, with thunder, lightning, and hail. The hail was still banked up in places the following morning.

On 17 September, there were heavy hail storms on the West Coast, with warnings in place for drivers on SH6 between Franz Josef and Fox Glacier. In Wellington, an electrical storm struck about mid-day, causing power outages to thousands of lower North Island residents, and setting alight a shed in Lower Hutt and trees in Wairarapa.

On 19 September, lightning struck cottages at Nga Tawa school, Marton. In the Waikato, lightning strikes damaged transformers and related equipment, causing power cuts.

On 11 October, a heavy hail storm hit Tariki, and power was lost for a few hours at Te Kiri, near Opunake. Hail also affected Wellington City in the early morning.

On 18 October, hail fell on Canterbury from Rakaia Gorge to Pegasus Bay.

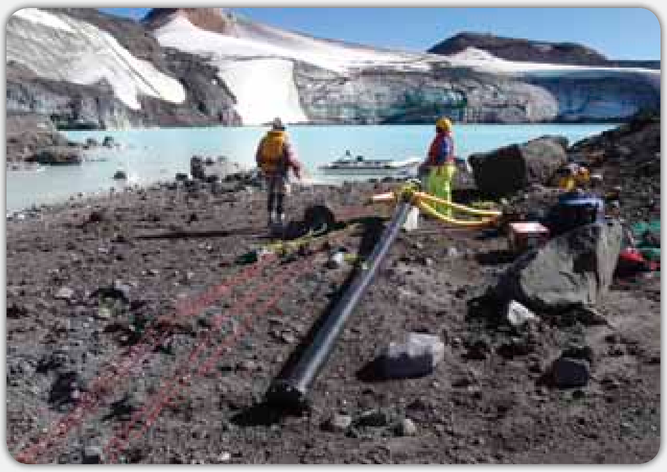


Automating lahar research and monitoring stations at Mount Ruapehu

On 18 March 2007 the largest lahar in documented history in New Zealand occurred at Mount Ruapehu after sudden breaching of the rim of its Crater Lake. The event was anticipated, providing a unique opportunity to directly observe and measure these rarely documented flows, and record their sediment transport, sedimentation and deposit characteristics along the c. 200 km long lahar travel path from Crater Lake into the Tasman Sea. Later that year, on 24 September, a small eruption from Ruapehu mobilized a series of so-called ice-slurry lahars that surged down the Whangaehu valley and onto the Whakapapa skifields with speeds exceeding 13 metres per second.

Scientific data obtained through measuring the physical flow behaviour of both lahar events over their entire flow paths have provided a better understanding of their efficiency and their ability to erode and deposit material, as well as their high destructive potential. These insights have allowed researchers from Massey University to update and automate a new network of lahar research and monitoring stations along the first 41 kilometers of the Whangaehu River channel. This includes the completion of four new research 'hotspots' at 4.9 km, 23 km, 29 km and 41 km from the volcano summit. From these locations scientists from Massey University and GNS, as well as decision makers from the Department of Conservation, Horizons Regional Council and Genesis Energy, will receive live-streaming data that will give immediate information on the type of lahar occurring, its magnitude and velocity, as well as continuous measures of the Whangaehu River chemistry. This will become an important volcano monitoring parameter if equipment installed within Crater Lake becomes destroyed during a new eruption phase.

In addition to the new lahar research stations, volcanologists from Massey University together with geophysicists from the University of Hamburg, Germany are testing a state-of-the-art High-Speed Doppler Radar system to detect and measure into any eruption columns and pyroclastic surges emitted from the volcano. Researchers hope that this new sensor that can penetrate through darkness, clouds and mist will provide robust and timely eruption warnings. Volcanologists anticipate that the High-Speed Doppler Radar will be the first instrument to measure directly into volcanic eruptions in safety and reveal important aspects of their violence and dynamics.



Landslides in New Zealand in 2010

Numerous landslides occurred in New Zealand during 2010. Notable events were:

Thursday 4th February – A rock-fall occurred at Totara Reserve on the Pohangina River north of Ashhurst in the Manawatu. A smaller rock-fall at the same site in 2006 killed three children.

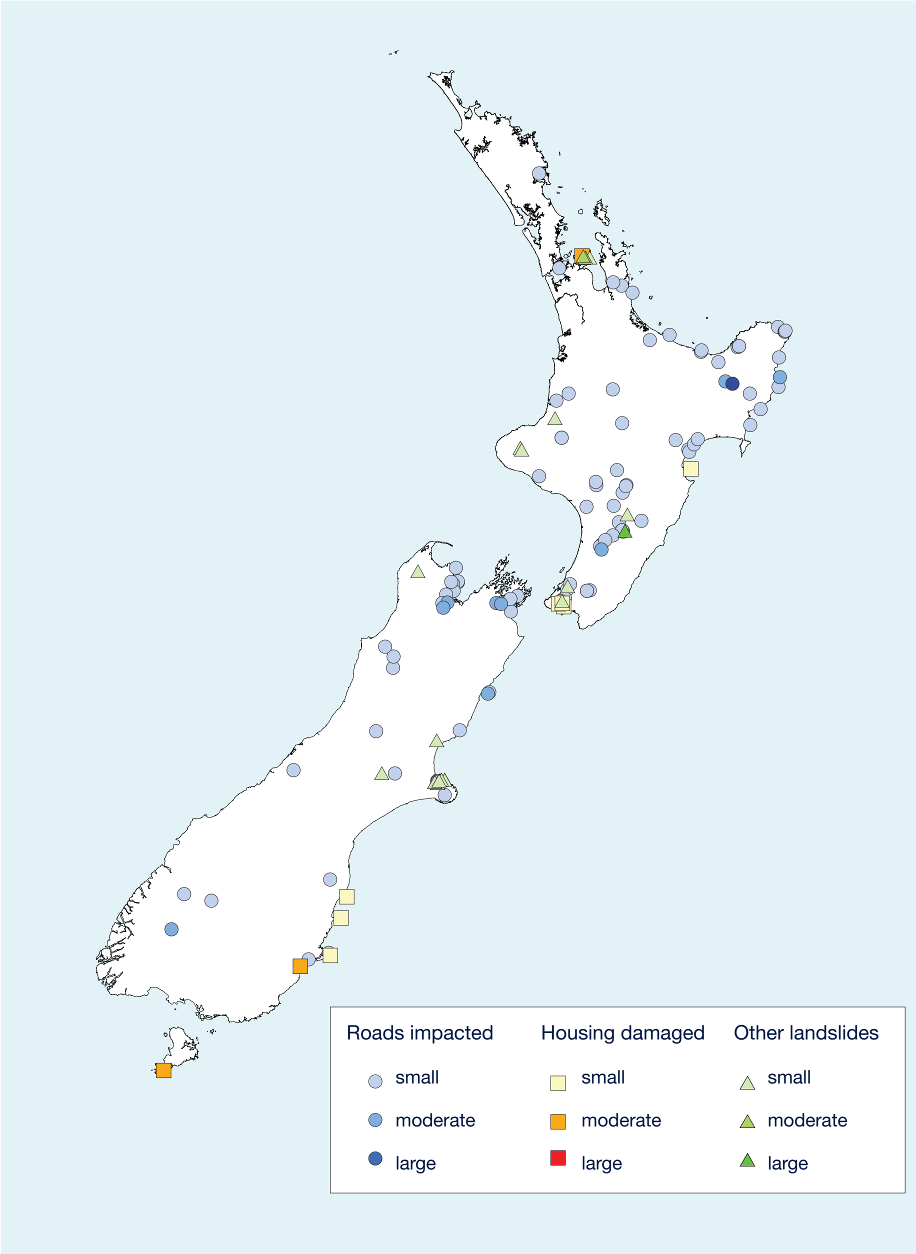
Sunday 21st March – Heavy rain in Fiordland caused flooding and slips, trapping 120 people on the Milford Track.

Wednesday 31st March - A landslide near Potted Head (Big South Cape Island; southwest Stewart Island) damaged two baches. Another house at the south end of the island was reported to have been damaged by a slip in the same rainstorm event.

Sunday 16th May - heavy rain near Tapawera south of Motueka caused debris flows, slips and flooding that blocked roads and necessitated the evacuation of 20 households. The situation was exacerbated by logging debris being swept into streams and rivers from recently-logged areas.

Thursday 27th to Saturday 29th May – Heavy rainfall in coastal areas of Otago from Oamaru to Dunedin caused numerous landslides including a rock-fall near Duntroon in North Otago that blocked the entrance to a cave with ancient Maori rock art. Another slip hit a building at Berwick, near Outram. Forty-two people had to be evacuated from the building after it was shunted 6 m onto the road.

Thursday 8th July –A large landslide (30,000 m3) occurred at Anaura Bay, on the East Coast. The Anaura Bay road was blocked, isolating 18 homes. This was a partial reactivation of a much larger, ancient landslide.



Saturday 4th September – magnitude 7.1 earthquake centred near Darfield in Canterbury caused few landslides. Two of the more significant were a large rock falling from the top of Castle Rock and ending up close to the portal of the Lyttelton Tunnel and an old pre-existing landslide in the Harper Hills being partially reactivated.

Friday 10th September – large landslide 15 km south of Kaikoura completely blocked SH 1 and the railway. The landslide was 100 m wide and 20,000 cubic metres. This landslide disrupted relief supplies on their way to Christchurch to help with the recovery after the 4 September Darfield earthquake.

Saturday 25th September – A locomotive hauling 400,000 litres of milk was derailed by a large slip at the eastern end of the Manawatu Gorge. It took over a week to reopen the line.

Thursday 30th September – A northbound Wellington commuter train was derailed by a slip near Plimmerton and then a southbound train collided with it. Two passengers were injured. A commuter train on Wellington's Johnsonville line struck a rock-fall.

Friday 26th November and Sunday 12th December

On-going erosion in the upper part of the catchment of Stony River on Mt Taranaki resulted in a major debris flow from Pyramid stream of several million tonnes of debris on Friday 26th November. Two landslides on Mt Taranaki, seven minutes apart on Sunday 12th December, just north of Bob's Bluff sent debris flows down the Oaonui Gorge. These landslides on Mt Taranaki were unusual in that they occurred during relatively dry conditions.

Non-Structural Element Seismic Performance

New Zealand is widely known and respected for its earthquake resistant structural research, its research implementation and its design codes. NZ innovations, such as those by Professors Park, Paulay and Priestley, allow frame structures to resist large earthquakes without collapse. Others such as Robinson and Skinner developed and popularized base isolation systems. The concepts are incorporated in many international design codes. More recently, studies have been conducted to ensure building slabs do not adversely affect behaviour. Also, building frame systems which can sustain major earthquake shaking without almost no damage are being developed for concrete, steel and timber structures.

While NZ efforts have drastically reduced life loss and structural loss in developed countries, lessons from recent earthquakes such as the 2001 Nisqually earthquake (near Seattle, USA) and the 2010 Chile earthquake have shown that significant damage, loss, and downtime resulted from damage to the "non-structural elements" of the building system.

Buildings can be considered to contain three categories of elements. Firstly there are structural elements which are the skeleton of the building. These include the foundation, columns, walls, braces, beams and building slabs. Secondly, there are "non-structural elements" which have traditionally not been designed by a structural engineer. These include (i) vertical elements - such as the building cladding (or skin), and internal partition walls, (ii) horizontal elements - such as ceilings, and (iii) the physical plant and pipes required to supply and remove water, to provide adequate ventilation and temperature control, and fire safety. Thirdly, there are the building contents, such as the carpets, desks, chairs, paintings, books, filing cabinets, computers, etc.

While the term "non-structural" has been traditionally used, these elements do provide a structural purpose and they also affect life safety. For example, collapse of a piece of exterior cladding or glass window, which falls onto the pavement below could injure pedestrians or damage vehicles below. Also, collapse of the heavy ceiling tiles in many buildings could injure those inside.

The FRST Natural Hazards Platform has recently funded an 18 month pilot investigation into the performance of both vertical and horizontal seismic elements during earthquake shaking. The horizontal elements study is led by A/Prof. Gregory MacRae and A/Prof. Rajesh Dhakal at the University of Canterbury (UC). The vertical elements study is led by A/Prof. Stefano Pampanin and Dr. Alessandro Palermo of UC. There is a subcontract to BRANZ for testing, as well as one to GNS Science. Close collaboration exists with BRANZ, GNS and Victoria University Wellington on all aspects of the project to ensure the best possible result.

During the Canterbury (Darfield) earthquake, major structural damage was relatively limited (except for unreinforced masonry structures and those buildings affected by significant liquefaction). However, the widespread non-structural damage caused significant loss and major business interruption. For example, the University of Canterbury was closed for two weeks after the earthquake primarily as a result of non-structural damage. One of the major factors affecting this loss was partial ceiling collapse in some large lecture theatres. This had to be fixed before lectures could continue. The photo below shows some of the ceiling damage.

UC Damage to Ceilings and Contents (Courtesy: Giacomo Paganotti)

Discussions with key industry leaders have indicated that the problems with non-structural damage result from the lack of a mandatory standard for installation of ceilings, the lack of a requirement for licensed installers, as well as codes specifying the level of performance different from what the owners may be expecting. The Canterbury earthquake emphasized the necessity for better non-structural systems and it strongly justifies this project.

The main objectives for this pilot study on both vertical and horizontal non-structural element studies are to:

1) Gain a better understanding of the physical behaviour of typical non-structural components and their interactions with the   rformance of the overall system;

2) Define damage limit states associated with each typology and function;

3) Refine and further develop existing assessment procedures or methods into practical and reliable user-friendly tools for daily use;

4) Provide tentative technical (conceptual) solutions capable of meeting the required target of low-damage to non-structural components.

The investigators are working collaboratively with overseas colleagues in Japan (Tokyo Institute of Technology), the US (University of California San Diego) and in Europe. Also, a number of visiting and short-term overseas students from Fiji, Italy, India and Japan are involved with the project.

The results of this work will be a first step to allow better decisions relating to (i) regional losses (through incorporation into RISKSCAPE), (ii) building specific losses, and (iii) mitigation of total structural and non-structural loss. The last of these is consistent with NZ efforts to protect its infrastructure and develop a seismically sustainable NZ.

Heavy rain and flood

As is usual in any year in New Zealand, heavy rain and consequent flooding occurred many times during 2010.

At 162 rain gauges in the climate network, at least one record monthly rain occurred in 2010. The average length of record of these gauges was 55 years. September, May and January had the greatest number of record monthly rains, at 63, 45 and 26 gauges respectively.

At 88 gauges in the climate network, a record daily rain occurred in 2010. The average length of record of these gauges was 50 years. May, September and January had the greatest number of record daily rains, at 33, 19 and 17 gauges respectively.

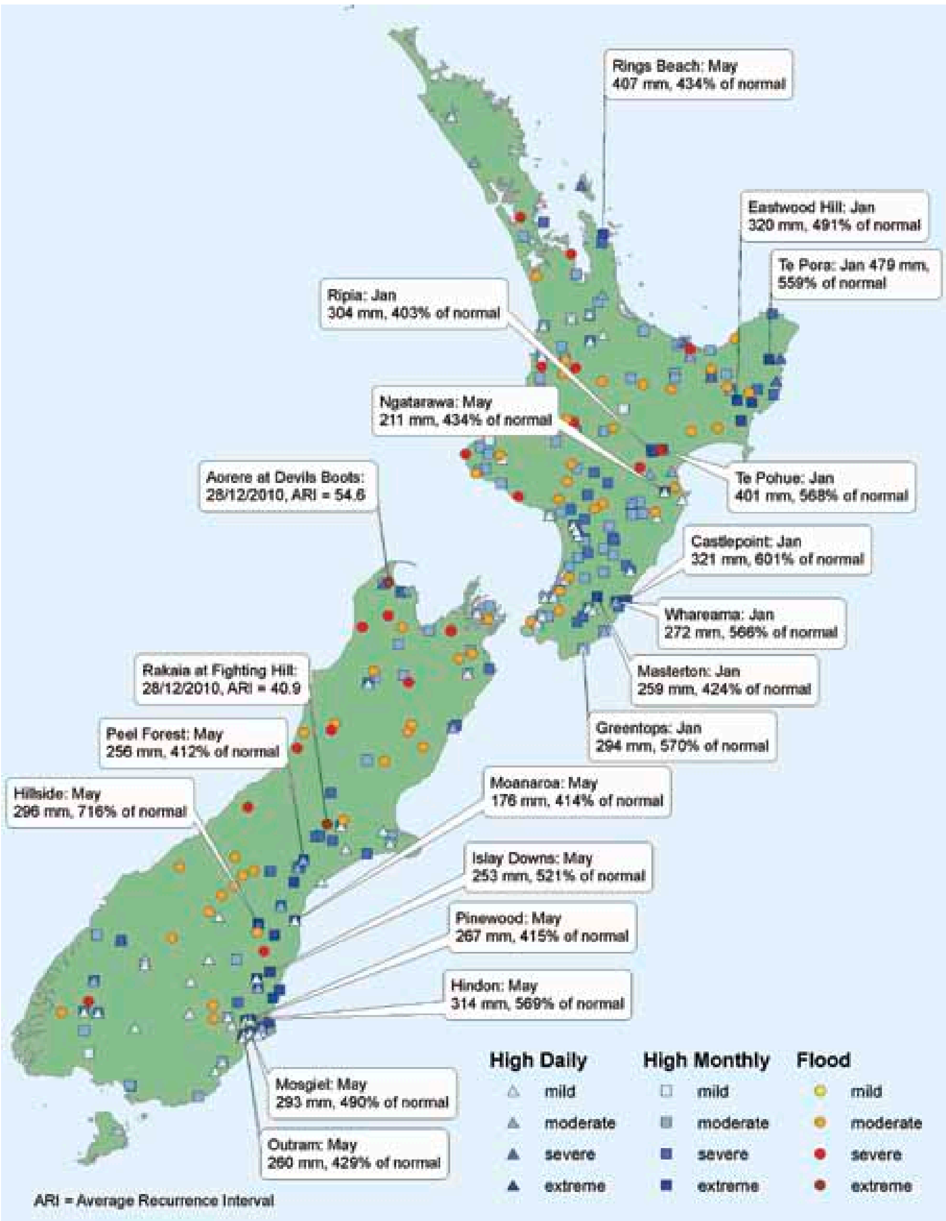
Significant river flood events (with an annual exceedance probability of less than 0.5) were recorded at 75 flow recorders of the National Hydrometric Network. From a flood perspective, September and December were the two months of major activity with 29 and 26 significant floods respectively.

September 2010 was characterised by extremely low pressures over New Zealand, bringing wild westerly winds. The effect of the stronger-than-normal westerly winds during September was very clear – rainfall was record high or well above average, and sunshine hours were well below average, in western areas of both islands. September rainfall was more than double normal (at least 200 percent) in the southwest of the North Island, from Turangi to Taranaki to the Kapiti Coast, as well as the north and northwest of the South Island – including Nelson, Blenheim and Buller – and around Invercargill. Many locations in these areas experienced their wettest September on record. Most other regions around the country also received above normal rainfall (between 120 and 150 percent of normal).

December rainfall was more than double normal (at least 200 percent) in parts of Northland, Tasman, Nelson, Marlborough and the Southern Alps. Rainfall was approximately one and a half times normal (around 150 percent) in parts of Auckland, Coromandel, coastal Waikato, Taranaki, Wellington, Buller, West Coast, Otago and Southland. Flooding in the Tasman District was particularly severe with significant flooding near Takaka and Collingwood, and the loss of a bridge over the Aorere River.

Heavy rain hit Westland, the Southern Alps and parts of Otago on the 27th and much of the rest of the country on the 28th. Several South Island roads were closed by surface flooding, including SH60 at Takaka, cutting off much of Golden Bay, SH6 at Renwick and at Canvastown (between Blenheim and Nelson), SH6 at the Lower Buller Gorge, SH63 between Arthurs Pass and Otira, SH73 between Otira and Kumara, SH69 from Inangahua to Reefton, SH65 from Murchison to Springs Junction, SH67 from Westport to Mokihinui, and SH7 from Hanmer Springs to Springs Junction. The James Road bridge in Bainham was washed away. Bainham is on the Aorere River, near Collingwood. A bridge in the Glen Roy Valley, near Murchison, was washed out.

Source: Climate Database, Water Resources Archive and National Climate Centre Monthly Summaries (all NIWA).



Retrofit solutions

The development of cost effective minimally-invasive seismic retrofit techniques for clay brick unreinforced masonry (URM) buildings is being conducted at the University of Auckland because of the poor seismic performance of this building type, as illustrated again in the recent Darfield earthquake. One technique that was first validated in the laboratory and has since been implemented is the use near surface mounted (NSM) carbon fibre reinforced polymer (CFRP) strips. Two projects are briefly detailed below.

Rob Roy Hotel (Birdcage)

The 1886 Birdcage Tavern (formerly known as the Rob Roy Hotel) is one of Auckland's iconic buildings. The Birdcage Tavern is a 2 storey registered heritage masonry building which is one of a few New Zealand hotels built in the 1880s that still exists today. The building has been relocated 30 meters to allow the new Victoria Park Tunnel to be constructed. The relocation required the building to first be assessed and strengthened, with in-situ testing conducted by the University of Auckland to accurately determine the building's material properties. To achieve effective seismic/relocation strengthening, and to provide a cost effective and minimally intrusive solution, the building's four URM chimneys were strengthened using vertically oriented NSM-CFRP strips. The retrofit involved cutting vertical grooves from two sides of the chimneys and inserting thin and narrow CFRP strips into a groove filled with epoxy.

Birdcage Tavern - Front view

The former Campbell Free Kindergarten (CFK) is a registered heritage building located on the southern side of Victoria Park in central Auckland. The building has significant heritage value as it is the earliest purpose built free kindergarten in New Zealand, and is the first institution of the Auckland Kindergarten Association, which remains active to this day. Currently the building is undergoing considerable refurbishment and seismic strengthening following over two decades of disuse, which left the building in a seriously deteriorated condition and in danger of collapse.

Chimneys retrofitted using NSM CFP

1910 Campbell Free Kindergarten

In order to provide structural integrity and out-of-plane seismic resistance, parts of the URM walls of the CFK were strengthened with horizontally aligned NSM-CFRP strips. Due to implementation of the unobtrusive NSM retrofit technique, the strengthened walls will retain their heritage characteristics.

Parapets are usually the first component to fail in an earthquake, as their positioning at the top of the building and their lack of a securing mechanism makes them susceptible to failing out-of-plane. Thus, the parapets of the former CFK are strengthened using vertically positioned NSM CFRP strips to ensure that the parapets are suitably secured.

Campbell Free Kindergarten

Temperature

Mean annual temperatures were above average (between 0.5°C and 1.2°C above the long-term average) in the northeast of the North Island, and in Nelson, Marlborough, parts of Canterbury, Fiordland and parts of Westland, the southern Lakes District and central Otago. Mean annual temperatures were near average elsewhere (within 0.5°C of the long-term average). Heat waves affected the West Coast of the South Island over the period 29 January-1 February, central Otago during 8-9 March, and many areas of both islands between 28–30 November and 12-15 December. The national average temperature for 2010 based on a 7-station series was 13.1°C, 0.5°C above the 1971-2000 annual average. 2010 was the 5th warmest year since 1900, based on this 7-station series.

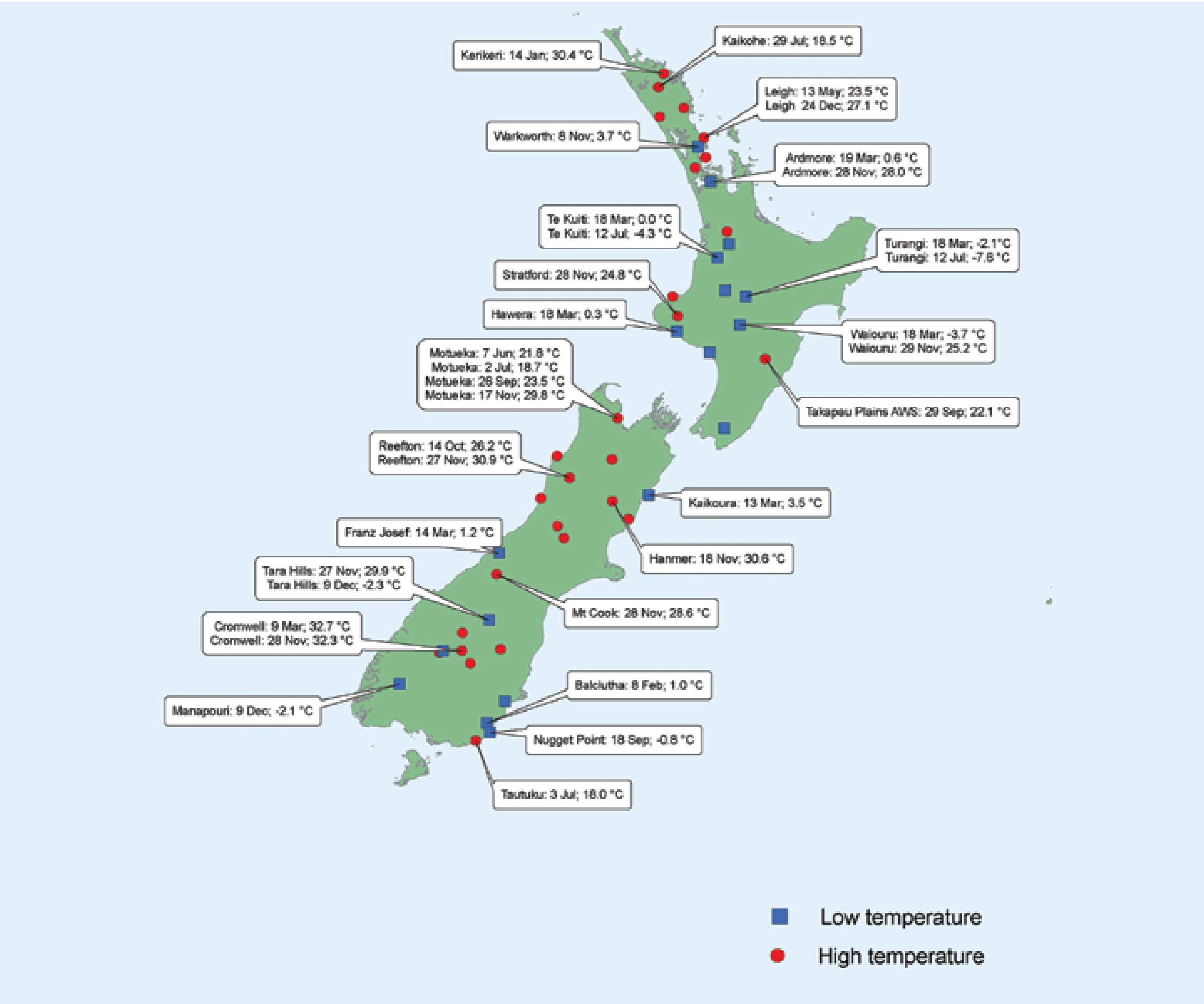
Overall, it was the warmest year on record at Whangaparaoa (Auckland), with a mean annual temperature of 16.5°C – this was the highest mean annual temperature observed nationally. It was also the warmest year on record at Whenuapai, Te Puke, Reefton, Motueka, Lake Rotoiti, Nelson, Arthurs Pass, Tara Hills, Cromwell and Alexandra. Mean annual temperatures were also near-record at sites in Northland, Bay of Plenty, parts of Hawke's Bay and Tararua District, in the northwest of the South Island, and in parts of Marlborough, Canterbury and Central Otago, as well as at Mt. Cook.

New records for annual temperature extremes were set on the West Coast of the South Island on 31 January, linked to foehn warming in the lee of the Southern Alps during a sub-tropical easterly wind event.

An extreme cold spell affected New Zealand from 10-13 July, caused by an intense winter anticyclone over New Zealand. The anticyclone produced clear skies, light winds, and severe frosts, with several sites in the western North Island, as well as Queenstown and Dunedin, recording annual extreme minimum temperatures on July 12th.

It was a sunny year in the north and west of the North Island, and in the west and south of the South Island, with above normal annual sunshine hours observed (between 110 and 130 percent of normal). It was the sunniest year on record for Te Kuiti, since records began there in 1962. Elsewhere across the country, annual sunshine hours were nearer to normal, ranging between 95 and 105 percent of normal.

Whakatane was the sunniest location in 2010, recording 2561 hours, followed by Nelson (2474 hours) and Blenheim (2415 hours).



“It’s time to move”

Improving the emergency management response to hazard warnings

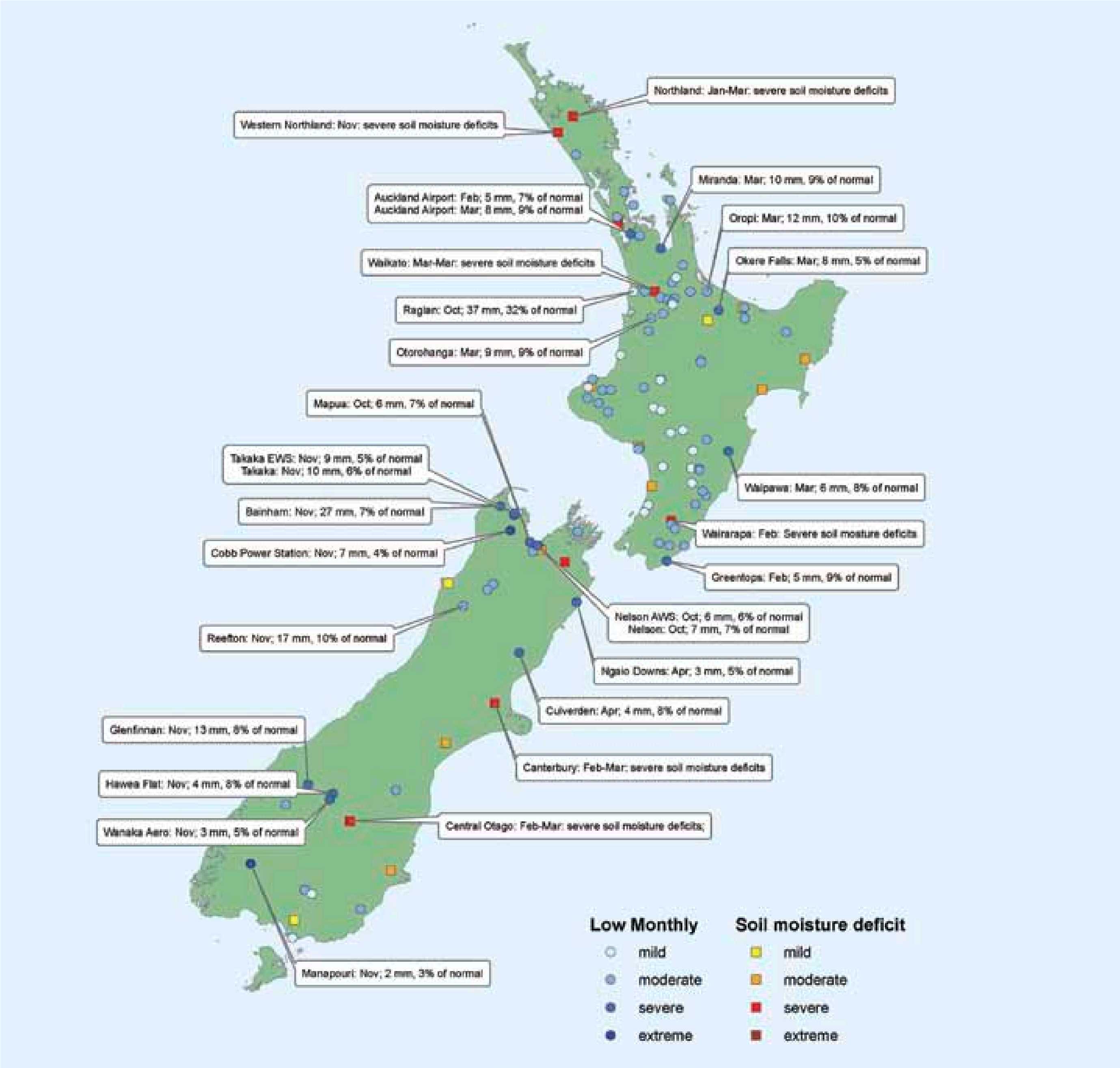
Tsunami from the South Pacific in 2009 and Chile in 2010 have once again raised awareness and interest in preparedness for the big one. Our initial findings confirm that the increasingly sophisticated networks of technological warning systems provide decision-makers with relevant and timely information to generate responses. However, these responses may be sub-optimal due to human and systems failures. Emergency management officers (EMOs) frequently have to make decisions with incomplete or inaccurate in ormation derived from unfamiliar data. They do so under considerable time pressure and in rapidly evolving and complex situations involving atypical inter-agency circumstances. EMOs need to acquire information, render it meaningful, and make decisions that must accommodate a range of emergent hazard consequences. Under these circumstances, EMOs situational awareness, or the ability to use limited cues to make sense of complex hazard information, is critically important. Previous work has examined how situational awareness is used. However, the way this awareness develops in volunteer EMOs, who must respond to infrequent, evolving, and complex hazard events characterised by uncertainty and ambiguity, has received only limited attention. A key aim of our current research is to develop a model of how human decision-makers interact with decision-support technologies in a hazard warning situation. Drawing from recent tsunami and weather events the research has explored the weak links in current response processes and examines ways to improve decision-making and responses in complex, rapidly evolving events.

Researchers from the platform conducted a tsunami warning and evacuation postal survey in July and August 2010 in 12 communities from Canterbury to Northland following the February Chile tsunami. The survey also contained tsunami awareness and preparedness questions and was distributed in Island Bay and Eastbourne (Wellington) to capture baseline data before community evacuation mapping meetings commenced. The survey was also undertaken in four Canterbury communities, and the tsunami warning and evacuation questions can now be repeated following the Canterbury Earthquake This will shed light on how people responded to the earthquake as a potential tsunami warning, and how many evacuated compared to the Chilean earthquake and tsunami. The Canterbury event provides a good comparison between response to natural warnings and official warnings.

Low rainfall and drought

Annual rainfall totals for 2010 were in the near normal range with six months generally wetter than normal and six drier than normal. The lowest annual rainfall was 389 mm at Clyde, 94 percent of normal.

Drought was declared in Northland in January 2010, after a three-month period of extremely low rainfall in the region. Severe soil moisture deficits (more than 130 mm of deficit) continued in Northland during February, and developed in parts of Auckland, Marlborough, Canterbury and Otago during March as the dryness continued. At the end of March, significant soil moisture deficits (more than 110 mm of deficit) had also developed in Waikato, Bay of Plenty, Coromandel, Taupo and parts of Gisborne and Hawke's Bay. Drought was declared for Auckland, Waikato, Bay of Plenty, South Taranaki, South Canterbury and Otago in April. Even after some helpful rainfall at the end of April, significant soil moisture deficits remained in many areas of the North Island (except for Taranaki, Gisborne, and the Kapiti Coast), as well as in Marlborough and Canterbury. The drought finally broke in May. But by the end of October, unusually large soil moisture deficits had again developed in much of Northland, coastal Nelson, mid Canterbury, and North Otago. As a result of the extremely low rainfall experienced in November, severe soil moisture deficits were in evidence by the end of the month in Northland, Auckland, parts of the Waikato, Nelson, the southern Lakes District and central Otago, with significant soil moisture deficits (more than 110 mm of deficit) elsewhere in the Waikato, Taupo, parts of the Manawatu and Gisborne, in Hawke's Bay and the Wairarapa, Marlborough, and parts of Canterbury. Drought was again declared in Northland, Waikato and the Ruapehu district in December.



Forecasting Hazards at Very High Resolutions

For reasons that are related to way convective processes are modelled, most limited area (or mesoscale) Numerical Weather Prediction models in operational use today have a horizontal resolution of approximately 12km. Realistically, this means only weather systems larger than about 40km can be properly resolved by the model. Such models are not useful for forecasting the small convective-scale events (less than 4km in size) that may cause short sharp bursts of incredibly strong and damaging wind gusts or intense rainfall that results in local flooding. NIWA is developing a new version of its 12km New Zealand Limited Area Model (NZLAM), based on the UK Met Office Unified Model, that can be run at a horizontal resolution of 1.5km or less. This model, to be called NZCONV (New Zealand CONVective), will explicitly resolve and model convective-scale features such as downdraughts, gust fronts and wind shear not captured by NZLAM.

With this increase in resolution comes the added bonus of being able to incorporate much greater detail in the ancillary and climatological data fields that NZCONV will use. One key improvement will be a much improved representation of New Zealand's orography (see Figure 1).

Differences in the definition of the Southern Alps and North Island Central Plateau regions between the 12km and 1.5km data sets are quite pronounced. The elevation of Mt Cook, for example, in the 12km (NZLAM) data set is 1675m due to the smoothing of the orography over the 144km^2 grid box, but is a more realistic 2820m in the new 1.5km ancillary field (i.e. 2.25 km^2 grid box) to be used by NZCONV. Furthermore, the valley slopes are much better defined at 1.5km which will help greatly with forecasting downslope winds and other meteorological fields such as temperature and precipitation, which should lead to better forecasts in locations such as Queenstown whose weather is often influenced by the local orography. The 64 times higher resolution precipitation forecasts are expected to have a big impact on coupled NZCONV – TopNet flood-forecasting accuracy.

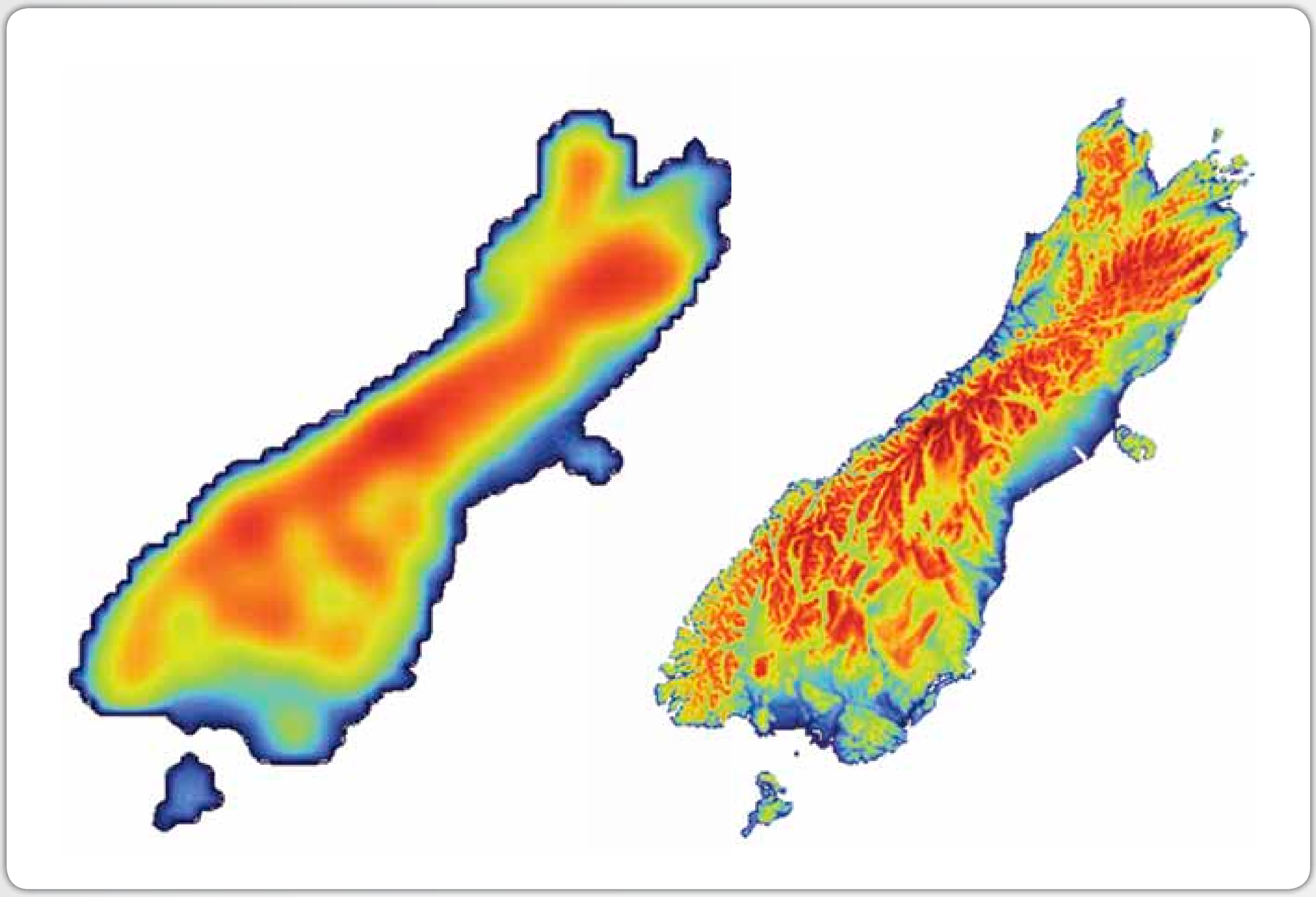
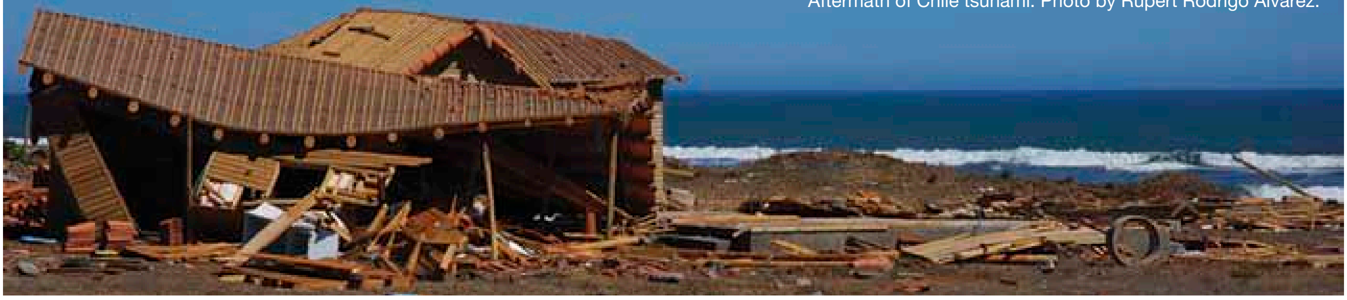


Figure 1. Comparison of the orography ancillary field over (just) the South Island used in the current 12km NZLAM model (left panel) and from the new 1.5km NZCONV model (right panel)., where both the major alpine ridges are resolved (as with NZLAM), and the key features of the South Island's intermountain geography are evident.

Tsunami

"The magnitude 8.8 Chile earthquake on Saturday, 27 February resulted in a full response by the GeoNet team. The response involved the use of threshold tables, historical tsunami information and pre-calculated scenario models to give early advice on likely impacts. This was enhanced by the convening of the Tsunami Experts Panel and the use of forecasting models calibrated using DART (Deep Ocean) Buoy data. GNS Science personnel worked at the National Crisis Management Centre at the Parliament buildings overnight 27 February and through until 4 pm on Sunday, 28 February. They were informed by tsunami scientists who carried out modelling work at the GNS Science offices at Avalon. The pre-prepared models introduced late last year proved to be very accurate in their estimate of the impact of this South American scenario on the New Zealand coastline, and the forecast models then run with the latest sea level and seismic information from the United States agencies (USGS and NOAA) also confirmed the predictions.The tsunami reached the Chatham Islands shortly after 7am on Sunday the 28th, and over the following hours was observed and recorded at coastal locations nationwide. The largest waves to be recorded in New Zealand were at Lyttelton, Gisborne, and in the Chatham Islands; in these locations they were approximately 1m in amplitude and 2m in height from peak to trough. Dramatic surges were captured on video in the Heathcote and Avon Estuary near Christchurch. The tsunami waves persisted around New Zealand for over 24 hours."

Aftermath of Chile tsunami. Photo by Rupert Rodrigo Álvarez.



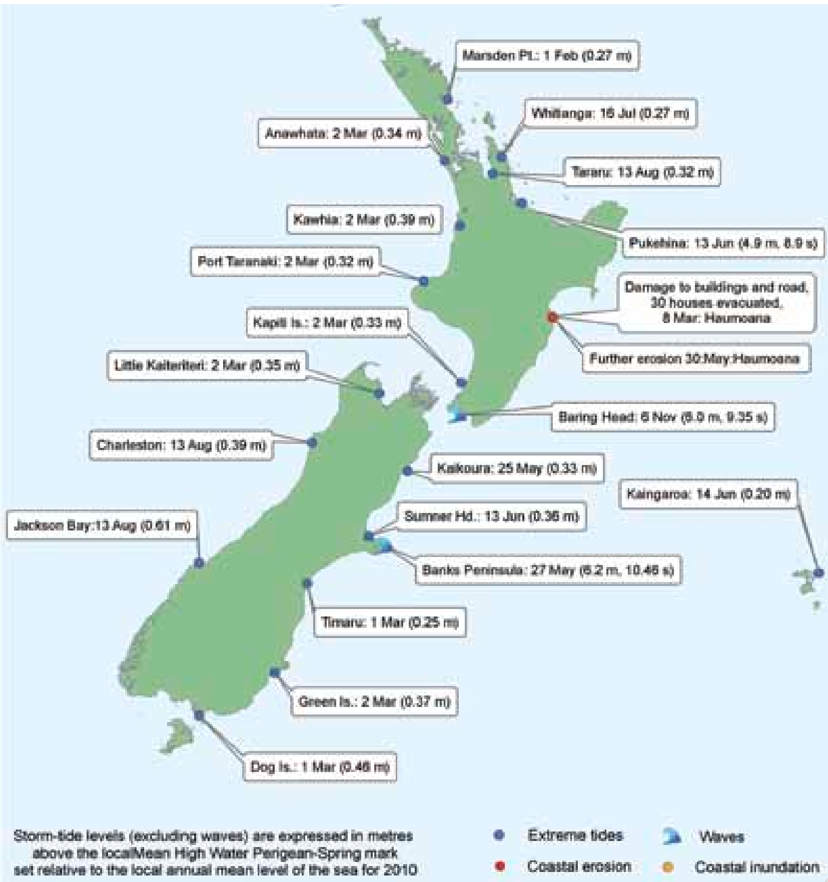
Coastal hazards

In 2010, all sea-level gauge locations (apart from Kaikoura) recorded their highest storm tide levels on days when high perigean-spring or "king tides" were predicted (see web site below for this years "red-alert dates"). The highest storm-tide levels occurred on 13 August, when a 998-hPa depression in the Tasman Sea produced a strong northerly wind stream onto the West Coast, causing storm tide levels of 0.6 m and 0.4 m above the local Mean High Water Perigean-Spring (MHWPS) mark at Jackson Bay and Charleston (Westport). The other event producing the high storm-tides was 1-2 March, when high "king tides" coincided with a shallow depression over the South Island, reaching 0.46 m above MHWPS in Foveaux Strait (Dog Island).

On the 8 March, swells up to 5.5 m caused more erosion and inundation damage to nearshore buildings at Haumoana and Ocean Beach, with up to 30 houses evacuated and damage to the Clifton Motor Camp road. Further erosion occurred during heavy seas in late May. Large waves also occurred on the South Island east coast at this time, with significant wave heights of 6.2 m recorded off Banks Peninsula on the 27th of May. The highest individual waves at any of the offshore monitored sites around NZ were recorded at Baring Head during a storm on the 6th of November, reaching a maximum height of 13.5 m, with significant wave height reaching 6.0 m.

http://www.niwa.co.nz/our-science/coasts/tools-and-resources/sea-levels

Sources: NIWA, Northland Regional Council, Port Taranaki Ltd., Environment Waikato, Tasman District Council, Environment Canterbury, PrimePort (Timaru), National Tidal Centre (Bureau of Meteorology, Australia).



Do extreme storms imply extreme erosion?

Erosion of sandy coastlines is a natural process that affects large numbers of people – but its causes remain a topic of debate. NIWA scientists are participating in an international field experiment (called ECORS) examining the processes driving beach erosion during storms. Our aims are to gain a better understanding of beach response under extreme storms and to develop practices for sound management of coastlines.

Sandy beach erosion and accretion are the consequence of alongshore and cross-shore exchanges of sediments between the onshore and offshore regions. The magnitude of sediment exchanges changes over time and during storms beaches can rapidly lose large amounts of sand, with recovery occurring during quiescent periods. US scientists have suggested that a sequence of storms will have a *"cumulative"* effect on beach erosion, and if the beach has no time to recover, clusters of storms can cause a lot more damage than storms in isolation. These are the conditions of most interest to coastal managers, practitioners, scientists and the overall public.

The ECORS field experiment was conducted on the Atlantic coast of France where, similar to the west coast of New Zealand, massive waves attack the beach. It involved 120 people from 16 institutes and six countries who deployed a variety of instruments to monitor physical processes: from the beachface to deep waters (Figure 1). NIWA scientists worked with the University of Bordeaux (France) and the US Naval Postgraduate School to study the "biting edge of the sea", the area where waves end their oceanic ride and, while running up and down the beach, move large quantities of sediment. To measure these wave effects, NIWA deployed two video systems on a tower at the top of the beach (Figure 2) to provide detailed hydrodynamic information and coupled those observations to daily topographic surveys.

Figure 1. Images from the field experiment.

During the field campaign three major storms occurred in the space of 30 days. The first had offshore wave heights up to 8 m and a return period of 10 years! Contrary to expectation, *"cumulative"* erosion was not observed. While the first storm caused large erosion of the upper beach (in excess of 25 m^3/m), erosion related to the next storm was limited (less than 1 m^3/m). During the third storm (with waves in excess of 4 m for about 10 days) erosion was also large (in excess of 6 m^3/m) but the beachface recovered rapidly, with more than a third of the sediment returning in less than a week.

The cluster of storms did not increase erosion, suggesting a cautionary approach to the idea that a sequence of storms will have a *"cumulative"* effect. The response to each storm remains difficult to anticipate, due to a lack of understanding of the roles of water levels, angle of wave approach and pre-existing beachface conditions. Research is now focused on developing numerical models that are able to simulate the observed beachface changes. This remains one of the main challenges in nearshore research and a critical step to improving coastal management.

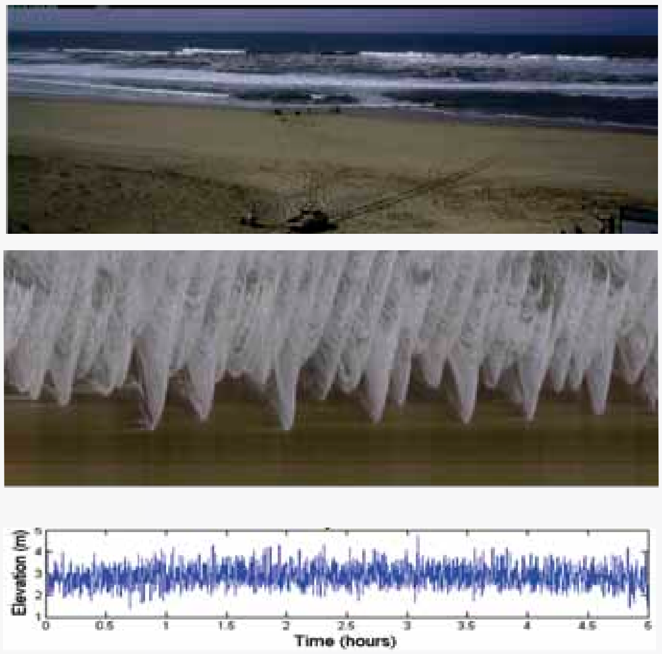


Figure 2. How the CamEra system (http://www.niwa.co.nz/our-services/online-services/cam-era) processes video observations and generates data of wave motions on the beachface. Top panel: a "still" image from Truc Vert (France). Middle panel: using several "still" images, a "stack" is composed for a specific beach position. The stack shows individual waves attacking the beachface. Bottom panel: using orthorectification techniques, the stacks are converted into "timeseries" of water elevation on the beachface which can be analyzed to infer erosion or inundation patterns.

The Hazard Platform Strategic Advisory Group

The Natural Hazard Research Platform has Guiding Principles that include doing research that meets national needs, that is responsive to changing government priorities and user preferences, and is of the highest quality. For an area of science that is a long term endeavour, the Principles recognise that the involvement of graduate students in research projects is critical in order to ensure the country's continuing capability to produce high standard work. Research also needs to be connected and co-ordinated among different institutions and science disciplines. Finally, research findings and directions must be communicated to be of use outside the scientific community that spawned them.

All this means that research programmes within the Platform need to involve potential users at all stages, from programme development through to consideration of how results are to be implemented and communicated. Research users, in turn, need to be ready and able to take up research findings effectively. Researchers and users together must ensure results are delivered in a form and in sufficient (but not too much) detail for practical purposes, and that progress towards desired outcomes can be measured.

From the outset, the Platform structure has recognised this central place for research users. The Strategic Advisory Group (SAG) has been in place since the inception of the Platform – in fact as the Hazards Advisory Group set up under a pre-Platform GNS Science/NIWA initiative, the Group can be said to pre-date the Platform.

The Strategic Advisory Group's task is to form the interface between scientists/researchers and their work, and the potential users of the research to ensure the achievement of the aims described above. The SAG is the eyes and ears of the Platform, making sure the work being done is going to make practical and relevant contributions to the issues of today and tomorrow.

The Darfield earthquake has illustrated perfectly how research must be focussed on the needs of the community. This was happening before. For example GeoNet has for the past several years been providing data that has enabled scientists to draw much more accurate conclusions about the seismic behaviour of the ground under our feet. The contribution that GeoNet has made to our understanding of the events in Canterbury in September and to decisions about response and recovery, has been significant.

Pictured from left to right: Richard Smith, Ministry of Civil Defence and Emergency Management; David Middleton, Chair, Independent; Hugh Cowan, Earthquake Commission; Roger Fairclough, Independent; Neil Gordon, MetService; Basil Chamberlain, Taranaki Regional Council; Mike Adye, Hawkes Bay Regional Council; Absent: Kieran Devine, Transpower; John Hamilton, Ministry of Civil Defence and Emergency Management; Mike Stannard, Department of Building and Housing. Photo by Margaret Low, GNS Science.

Now the Platform is being called upon to serve the people of Canterbury with more relevant and practical research, and the SAG must help the theme leaders and Platform management identify exactly what this means.

The SAG is chaired by David Middleton, ONZM, who stepped down earlier this year after seventeen years in charge of EQC. The Ministry of Civil Defence and Emergency Management is represented as well as EQC. Currently, other members of the Group are Basil Chamberlain and Mike Adye from local government, Neil Gordon of MetService, Kieran Devine of TransPower, Richard Bentley and Roger Fairclough. Representatives from GNS Science, NIWA and the chief funding agency also attend meetings and report.

Street closure in Avonside, Christchurch due to damage sustained in the Darfield Earthquake 2010. Photo by Margaret Low, GNS Science.

Focus on LIDAR

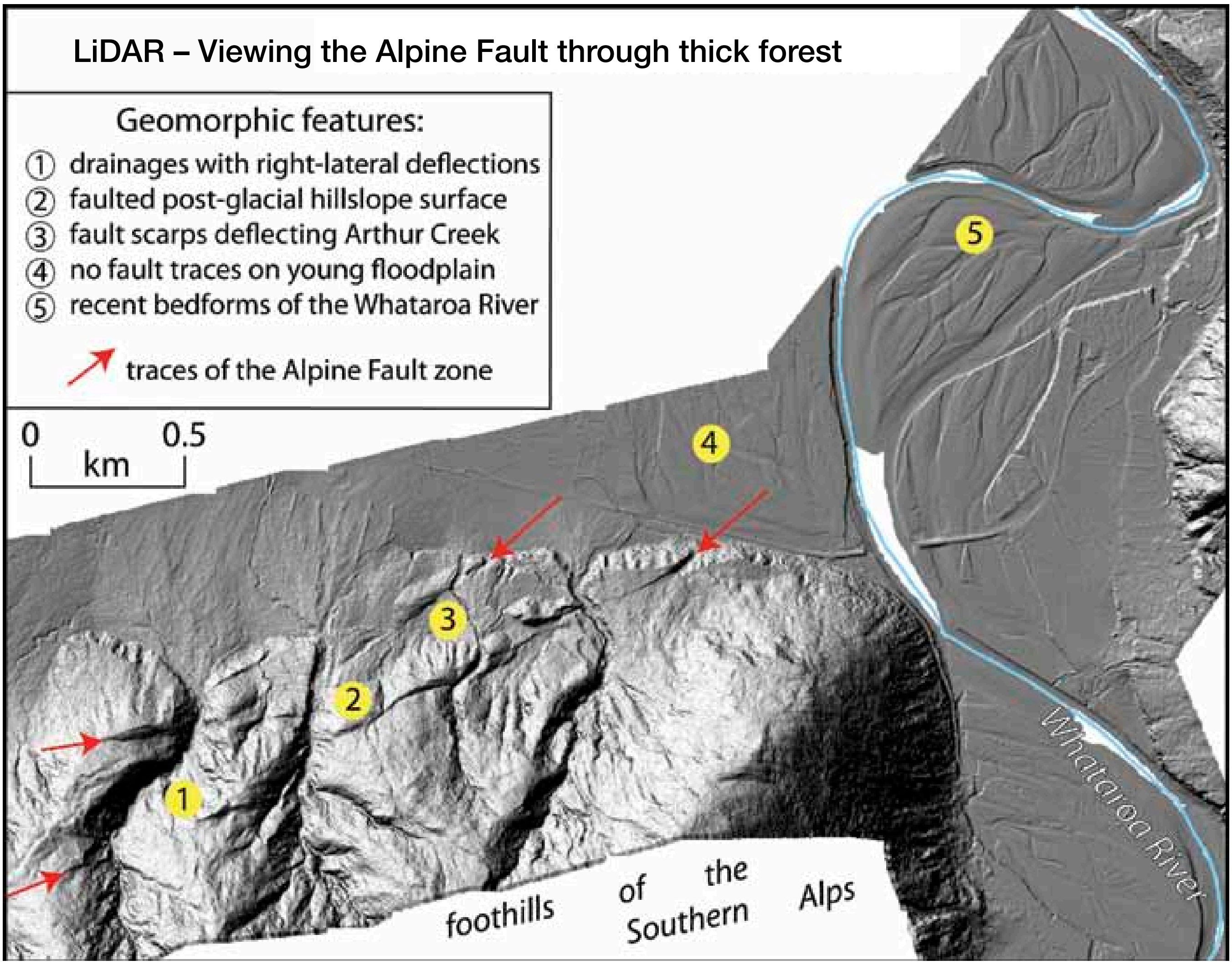
Under the Natural Hazards Research Platform contestable funds, new surveying data along the Alpine Fault has been acquired, processed and analysed. This research is revolutionising the way we look at active faults under forest in New Zealand. LiDAR (Light Detection and Ranging) data has now been collected along bush-covered sections of the Alpine, Hope and Wellington faults. The project is being led by Dr. Rob Langridge of GNS Science and is a collaborative research project with the Universities of Otago, Canterbury and Victoria.

LiDAR has the ability to create topographic models or DEMs of the landscape. The technique relies on sending millions of pulses of energy down from an aircraft – essentially scanning the terrain – and picking up returns from all features near the ground. Processing of the data by NZ Aerial Mapping generates "**bare-earth**" DEMs that pick up landforms that have otherwise been hidden due to the **thick vegetation cover**.

This is particularly true for the Alpine Fault on the West Coast. A 33 km x 1.6 km wide stretch of the Alpine Fault and the surrounding landscape is currently being interpreted by GNS Science and University of Otago researchers. The image shows a 5 km stretch of the fault near Whataroa. This short piece is characterised by: a wide array of fault traces that make up a fault zone; streams that are deflected to the right implying a predominantly right-lateral style of movement; and uplift of older surfaces along the rangefront of the hills that comprise the edge of the Southern Alps.

The LiDAR picks out incredible detail in open and grassed country, across which it is not possible to see the active trace of the Alpine Fault due to recent erosion and sedimentation.

The project is funded for 18 months and will near completion in September 2011. Results from this project will be used to re-assess the rates and style of movement of the Alpine Fault in central Westland and to understand when recent large earthquake movements have occurred across it. Fault mapping is being supplied to other researchers, e.g. the Alpine Fault Deep Drilling project, and end-users, e.g. fault rupture avoidance in Franz Josef township. Similar results are also expected from LiDAR flight data along the Hope and Wellington faults.



September 2010 Weather Events

September 2010 was characterised by extremely low pressures to the south of New Zealand, bringing wild westerly winds with active fronts crossing around the 5th, 17th and 30th. The effect of the stronger-than-normal westerly winds during September was very clear – rainfall was record high or well above average, and sunshine hours were well below average, in western areas of both islands. It was also much cooler than usual in the west and south of the South Island, but warmer than average in eastern areas; both are trademarks of enhanced westerly circulation.

Rainfall: On 5 September, the old Waimakariri River Bridge on Main North Road, north of Christchurch, was closed because of rising water. On the West Coast, heavy rain caused widespread flooding, with extreme care needed on SH6, between Fox Glacier and Hokitika. The highest 1-day rainfall recorded in September 2010 was 135.0 mm at Milford Sound on the 5th. Figure 1 (left panel) shows the 24 hr rainfall accumulation from NZLAM for the period to 0600 on September 6, indicating that between 128 and 256 mm of rain was forecast for Milford Sound and the mountainous regions south of Hokitika. On September 30, SH6 was flooded north of Pelorus Bridge, and motorists advised to use SH63. Many minor roads in the Nelson area were closed after continuous heavy rain. In Cable Bay, northeast of Nelson, a farmer could only watch as floodwaters rose and swept away a flock of ewes and lambs. They had been shifted to higher ground but had returned to their previous location. Figure 1 (top panel) shows the 24 hr rainfall accumulation forecast from NZLAM for the period to 1900 on September 30 – indicating hazardous rain amounts were expected over much of the Nelson region.

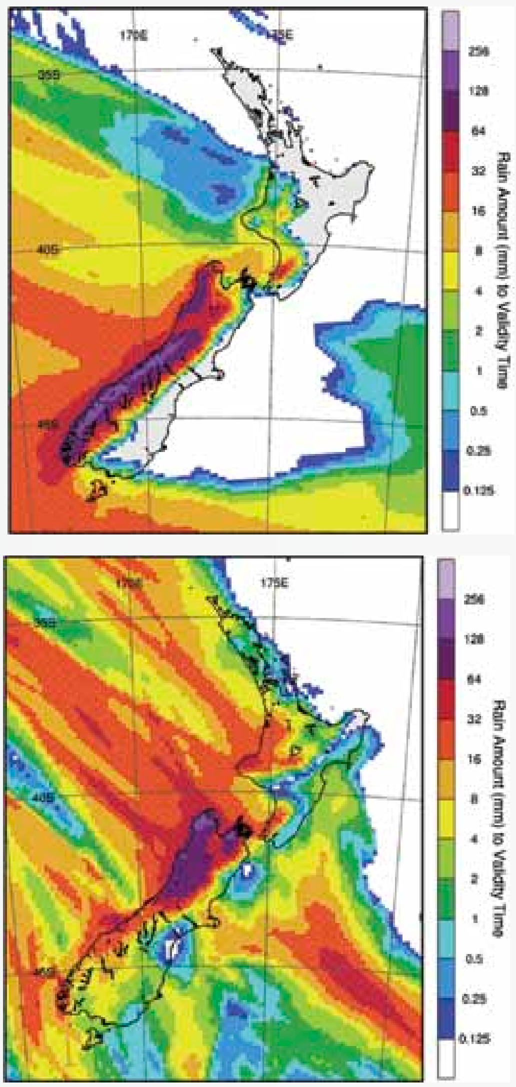


Figure 1. NZLAM generated forecasts of 24 hour accumulations of precipitation.Top panel shows the forecast to 0600 NZST on 6th September. The panel below shows the forecast to 1900 NZDT on 30th September.

Snow: On September 17, snow closed the Lindis Pass, Haast Pass, and SH73 from Arthurs Pass to Otira to towing vehicles. SH94 to Milford Sound remained closed. This event also resulted in extensive damage to a number of buildings, including Stadium Southland and extensive stock losses were experienced by farmers in the wider Southland region. In Invercargill, the majority of the snowfall is thought to have occurred from approximately 8 pm on 17/09/2010 to around midday on 18/09/2010, with the most intense snowfall occurring after 6 am on 18/09/2010. Figure 3 shows a plot of NZLAM forecasts for the period bracketing the stadium roof collapse. Given the forecast temperature (red) of nearly 0°C, nearly all of the forecast precipitation (green bars) would have been in the form of snow (or sleet). While the forecast amounts of snow are not identical to those measured (grey diamonds), the snow on the morning of September 18 was relatively well predicted, as was the change in wind speed and direction.

Wind: On September 5, an ambulance with three people inside was blown over south of Featherston, and a truck was blown over on nearby Western Lake Road. In Dunedin, high winds brought down trees and power lines, closing some roads, and trapping a dozen cars

Figure 3. NZLAM Meteogram showing forecast and observed (see legend) wind speed and direction, relative humidity, 1.5 m temperature and precipitation at Invercargill airport for the period 0600 on 17th September to 0600 on 19th September.

A sheep on snow-covered farmland between Clinton and Mataura. Photo: NZPA.

A beached yacht following the storm. Photo: Anthony Stanton (New Zealand Herald).

Crowds gather at Muriwai in West Auckland to witness huge storm swells. Photo: Graham Hand (New Zealand Herald).

on Portobello Road between fallen trees, for about two hours. Several flights were cancelled and many others were delayed by extremely strong crosswinds at Dunedin International Airport. Power was out in North Dunedin, Outram, parts of Mosgiel and Highcliff Road on the Otago peninsula after winds toppled powerlines. Figure 2 shows the 26 hr NZLAM forecast winds for 2100 on September 5 – the time when the pre-frontal winds were near their peak values.

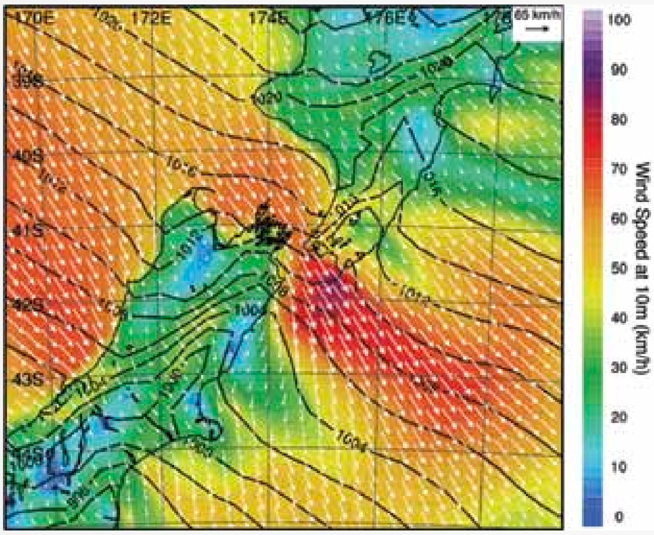


Figure 2. NZLAM 26h forecast of winds and surface pressure (isobars) over central New Zealand at 2100 (NZDT) on 5th September 2010.

Wave conditions: A sequence of large energetic storms swept across the ocean south of New Zealand in mid-September, bringing high seas to the Tasman Sea. The image on the right (Figure 4) shows the predicted significant wave height (representing the crest-to-trough height of a "typical" wave) at 1800 on September 16, at the start of a 48-hour forecast. A large low pressure system was centred well south of the bottom of the picture, producing strong south westerlies over a fetch of more than 2000 km all the way from the Antarctic ice edge to Tasmania, where a wave buoy on the west coast was measuring significant wave heights of 9 m at the time. Over the following days the storm moved eastward, resulting in waves over 8m over almost the full width of the Tasman Sea, and hitting especially the North Island west coast as seen in the right-hand image showing the same forecast's prediction for 0600 on September 18.

And that wasn't all – a few days later another large storm passed a little further south, bringing similar conditions again, this time with the largest waves on the South Island west coast.

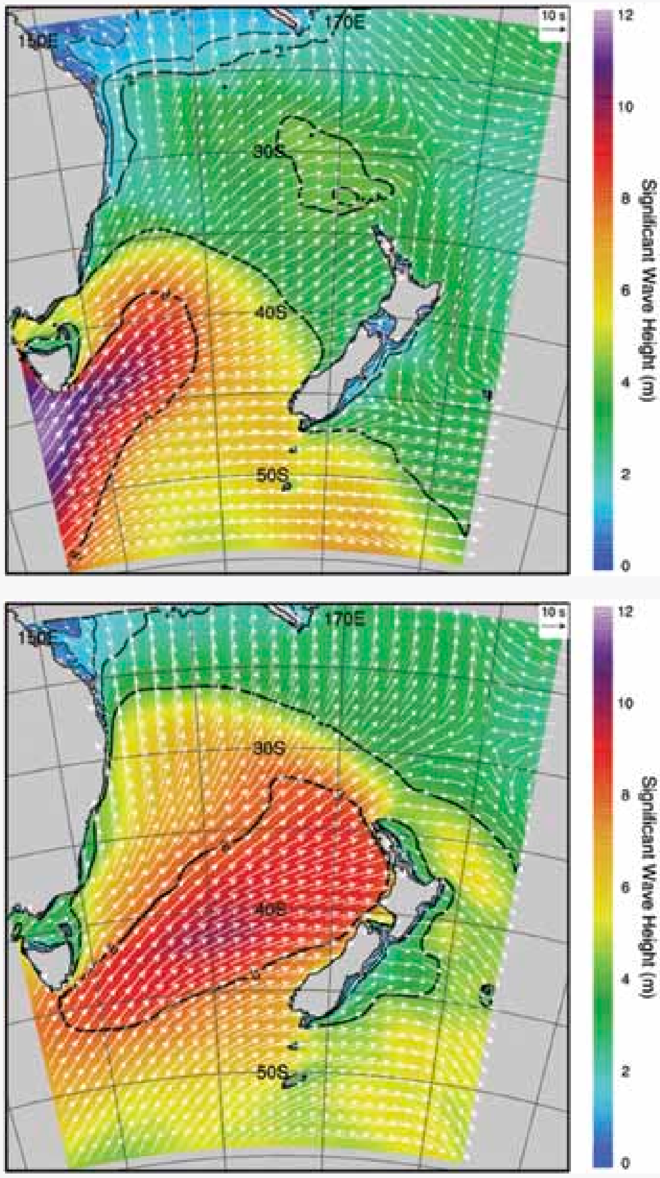


Figure 4. Top: NZWAVE analysis for 1800 (NZST) on 16th September and the forecast for 36 hours later (at 0600 (NZST) on 18th September 2010). NZWAVE forecasts are forced by NZLAM wind forecasts.

The Darfield Earthquake

Within a minute or two of 4:36 am on September 4th NZ Standard Time (16:36 Sept 3rd UTC) the duty seismologist at GeoNet was alerted by pager that a major earthquake had occurred. The duty seismologist inspected the developing map of earthquake felt reports on the GeoNet website coming in from the public across New Zealand, and it was immediately apparent that the epicentre of a major earthquake was in Canterbury. The GeoNet Project manager and other senior staff were called. Within one hour a group of scientists had assembled at the Avalon office and the alternate duty seismologist in Wairakei began assisting the Avalon based staff. The GeoNet rapid response team made plans for supplementary deployment of seismographs and GPS receivers, and by midday a geological reconnaissance group from Avalon and another from Dunedin were driving toward the epicentral area. In the Canterbury region geologists and engineers from the University of Canterbury, ECAN, Christchurch City, district councils, consultants, and emergency managers began dealing with the issues confronting them. Scientists and engineers began inspections almost immediately and within a

few hours the c. 30km long surface rupture now known as the Greendale Fault had been observed at a few locations to the west of Rolleston. The extent of building damage was identified to be concentrated in the central city area where older buildings suffered significant damage, and the dramatic images of liquefaction focussed attention on the widespread damage to residential properties in eastern suburbs of Christchurch and in Kaiapoi.

The epicentre and depth of the earthquake epicentre are very well constrained to be about 4 km north of the Greendale Fault, but this represents just the initial point of rupture in a complex event. The geodetic and seismological results are consistent with an initial rupture on a blind reverse fault, dipping steeply to the SE, with Mw 6.5 which triggered right-lateral rupture on the Greendale Fault where the majority of the moment release occurred (Mw 7.0). A number of other reverse faults were also active, giving an integrated Mw 7.1 for all modelled fault segments. Complex ruptures of this kind are not unexpected in areas of low seismicity where stress in the earth's crust builds up very slowly over thousands of years.

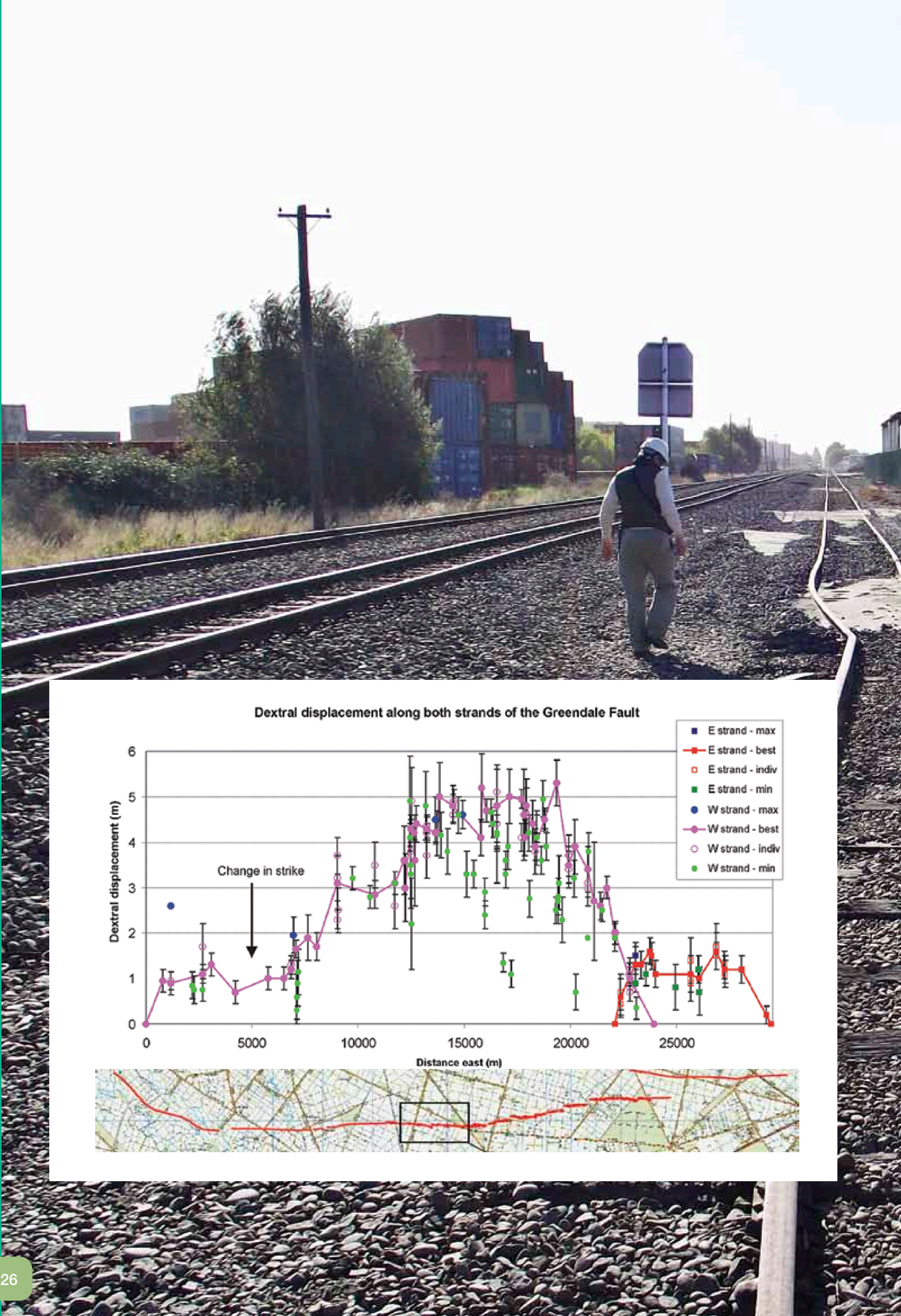
Fairly extensive damage at the University of Canterbury put laboratories, offices, and store rooms beyond reach for about two weeks following the earthquake), and the closure of the university significantly hindered Canterbury-based researchers, not to mention damage that had occurred to their own properties. A research coordination office was set up in the Canterbury Emergency Operations Centre at Environment Canterbury (ECAN) and this remained in place while the declaration of a regional civil defence emergency was in place. That office coordinated research activities on a daily basis and acted as an interface between the rapidly evolving state of knowledge about the earthquake and its impacts and the observations and issues facing the emergency responding agencies. The research manager and many others were involved in numerous meetings with local authority officials, EQC officials, insurers and Emergency Managers. Researchers also participated in Urban Search and Rescue (USAR) teams, and volunteered at Welfare centres.

By about three weeks following the earthquake many of the research teams had returned to the

office to analyse the data collected. Seismologists continue to interpret the aftershock sequence, satellite imagery is providing new insights into the regional deformation, and data from more than 70 records of the near-field strong ground motion records are being analysed.

Aftershock activity on these adjoining hidden faults began soon after the 4 September earthquake. For example, on September 8th, only four days after the main 7.1 earthquake, an aftershock of magnitude 5.1 was felt strongly in Christchurch, causing further damage to earthquake-weakened buildings. This aftershock occurred near Lyttelton, and it was centred in nearly the same location as the devastating magnitude 6.3 earthquake on 22nd February 2011. On Boxing Day 2010, aftershocks centred very close to the centre of the city abruptly ended a busy shopping day and caused even more damage.

On 22 February, a 8 km length of fault ruptured at the eastern end of the aftershock zone, cutting through the bedrock underlying the volcanic rocks of the Port Hills. While this fault was also previously unknown (as it did not reach the surface) it is most likely to have been in existence


Dextral displacement along both strands of the Greendale Fault
E strand - max
E strand - best
E strand - indiv
E strand - min
W strand - max
W strand - best
W strand - indiv
W strand - min
Dextral displacement (m)
Change in strike
Distance east (m)
0
1
2
3
4
5
6
0
5000
10000
15000
20000
25000

and simply ‘reactivated’ by the stresses from the M7.1 mainshock. The break did not reach the surface. This rupture generated a powerful magnitude 6.3 earthquake with unusually violent ground movement that devastated Christchurch. In a few places the shaking reached nearly twice the acceleration due to the earth’s gravity (2g). Scientists consider the February 22nd event to be an aftershock, as it occurred within the zone of aftershocks that followed the magnitude 7.1 earthquake on 4 September 2010. Note that agencies such as EQC use a different definition of aftershock in contractual agreements with reinsurers.

Liquefaction occurred in widespread areas of Christchurch as a result of both the M7.1 and M6.3 earthquakes. The intense shaking caused water and silt or sand to be ejected to the ground surface, resulting in subsidence and lateral spreading (sideways movement) of the ground in many parts of the CBD and eastern Christchurch. In addition, during the liquefaction process the ground becomes very weak and can no longer support loads imposed by buildings. This has led to widespread damage to houses, some larger buildings, and underground services. Some areas affected in September have re-liquefied.

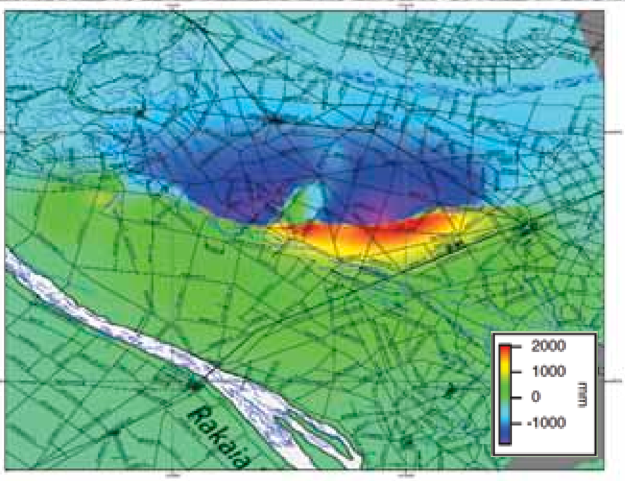
Other ground damage, in particular coastal cliff collapse, rockfall, and ridge fracturing on built-up parts of the Port Hills due to the extreme focussing of seismic waves are all being investigated by geotechnical teams comprising university and CRI staff as well as engineering consultants. Several sites are being monitored for further movement.

The two destructive earthquakes in Christchurch have raised serious public concern about “to what standard and where Christchurch should be rebuilt”. Less than a month after the Feb 22nd event it is difficult for us to have a good sense of perspective on these issues. The failure of older and weaker construction is no surprise in an earthquake of such violence, but most modern construction is still standing, so has performed to code requirements in terms of preserving life safety. What is still unknown is the degree to which even modern buildings have been weakened and will need substantial repair to bring them back to code.

Much of the science and engineering input required to develop the Recovery of Christchurch will fall on the NHRP and its collaborators. Some of the key requirements are;

- to better understand the current level of hazard and the potential for further large earthquakes in the region;
- understand the processes leading to liquefaction and lateral spreading and the future risk;
- understand the performance and damage to large commercial, and residential, buildings,
- determine the nature of ground damage on hillside and the low-lying eastern suburbs of Christchurch and establish appropriate criteria for rebuilding or retreating from some areas.

References: Quigley et al., 2010.
Dizhur et al., 2010
Buchanan & Newcombe, 2010
Gledhill et al., 2010
Beavan et al., 2010
Deam et al., 2010



The Platform Management Group

The Platform Management Group consists of a senior science manager responsible for natural hazards research from each of the Partner organisations, the Platform Manager and a representative from the Ministry of Science and Innovation, as an Observer. The Platform Manager chairs the Group which meets at least quarterly to review and plan Platform activities.

The Management Group operates through a consensus process and seeks to agree on all decisions. Decisions are always be made with full regard to the Guiding Principles of the Platform set out in the Partnering Agreement.

The Management Group are responsible for the management of the Platform and development of the Platform's Research Strategy. They must monitor the performance of the Platform ensuring funding and resources are redistributed when required. Another important role of the Management Group is to ensure the needs of the Platform's stakeholders are met.

Pictured from left to right: Murray Poulter, General Manager Atmosphere, National Institute for Water and Atmospheric Research; Jarg Pettinga, Engineering and Structural Geology, University of Canterbury; Kelvin Berryman, Natural Hazards Research Platform Manager, GNS Science; Ben Holland, Business Group Manager, Opus Consultants; Bronwyn Davies, Platform Co-ordinator, GNS Science; Terry Webb, General Manager Natural Hazards Group, GNS Science. Absent: Peter Kemp, Head of Institute of Natural Resources, Massey University; Michael Davies, Dean of the Faculty of Engineering and Head of the Tamaki Campus, University of Auckland.

Scientists at North Cove of Passage Point, examining tsunami and earthquake damage caused by magnititue 7.8 Earthquale Fiordland on 15 July 2009. Photo by Ian Turnbull.

Freak wave breaking over rocks, Castlepoint, Wairarapa, 2008. Photo by Peter Robinson, Powercheck.

Cars destroyed by ashfall from the 2000 Eruption of Mt Usu, Hokaido, Japan, July 2000. Photo by Tony Hurst.

Seismologist examing road damage in Avonside Christchurch following Darfield Earthquake 2010. Photo by Margaret Low, GNS Science.

The Ministry of Civil Defence and Emergency Management

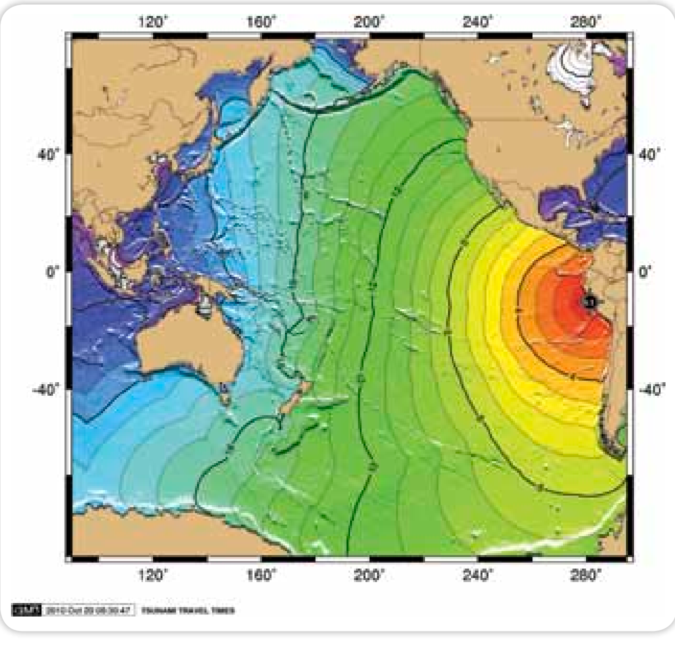
2010 proved to be a busy year for the Ministry of Civil Defence & Emergency Management. In addition to monitoring several regional events, the MCDEM Duty Team activated the National Crisis Management Centre in response to three significant events (Chile Tsunami 27.02.10, Vanuatu Islands Tsunami 28.05.10, Canterbury Earthquake 04.09.10) and one national exercise, Exercise Tangaroa.

Exercise Tangaroa: Science to Practice

Exercise Tangaroa was a national, multi-agency exercise held on 20 October 2010. The exercise was based on a distant source tsunami originating from South America and had the aim of testing New Zealand's all of nation arrangements for responding to a national tsunami warning. The exercise was led by the Ministry of Civil Defence & Emergency Management (MCDEM) and supported by more than 100 agencies including the 16 CDEM Groups, central government departments, emergency services, lifeline utilities, and science agencies.

Planning for the exercise began in February 2010 with the establishment of two MCDEM Exercise Coordinators, and an exercise planning team that included representatives from multiple agencies. GNS Science played a key role in this team through developing the detailed scenario and providing ongoing scientific advice. Civil Defence Emergency Management (CDEM) Groups formed their own exercise planning teams and appointed their own exercise writers. Regular communication with all participating agencies was achieved through the dissemination of monthly newsletters, and information displayed on MCDEM's website.

The exercise, which was played in real time, started at 0459 hours with notional notification by the Pacific Tsunami Warning Centre (PTWC) of a M8.8 earthquake (later revised to M9.1) near the coast of central Peru.



MCDEM immediately activated the National Crisis Management Centre and went on to analyse the information received from the PTWC with the support of the GeoNet Duty Officer. A national advisory was subsequently sent via the National Warning System (NWS) and participating agencies and CDEM Groups responded to this by considering appropriate warning and response at their levels. As a result most CDEM Group Emergency Operation Centres (EOCs) were activated along with a number of local EOCs.

The multi-agency Tsunami Experts Panel[1] was activated by GeoNet to provide detailed advice to MCDEM on the likely characteristics and physical consequences of the tsunami affecting the New Zealand coasts. Exercise Control staff disseminated exercise injects via the NWS throughout the day. MCDEM monitored and evaluated the situation and released further information (including hourly updates) as appropriate with the exercise stopping just short of impact at 1905 hours.

Whitirea Polytechnic media students played the role of media during the exercise and simulated the interest expected from national and international media in a real event. They published in 'real time' many of their stories and updates on a page on the Journalism Course's own website. MCDEM simulated activating the Memorandum of Understanding with public broadcasters to broadcast national warnings every 15 minutes.

Overall, the exercise was viewed as a great success. Once evaluation material has been collated, an end of exercise report will be compiled, identifying lessons learned. These will be integrated into updated plans and procedures that improve the ability to respond to and recover from a future tsunami event.

The next national level (Tier 4) exercise will be held in 2012 and will be based on an earthquake scenario.

1 The role of the Tsunami Experts Panel (TEP) is to support the GeoNet Duty Team in its provision of authoritative scientific advice to the Ministry of Civil Defence and Emergency Management (MCDEM) on the likely characteristics and physical consequences of tsunami affecting the New Zealand coasts in accordance with the MCDEM-GNS Science Memorandum of Understanding. During an event, the TEP provides advice to MCDEM, via a Liaison Officer based in the National Crisis Management Centre, within prescribed timeframes. This entails:
a) evaluating all available seismic and sea-level data, tsunami forecast models (e.g. travel time, wave height, and threat level models), and information from historic tsunami.
b) Formulating a consensus on the likely tsunami characteristics and impacts to New Zealand coastlines. This may include tsunami travel times, wave-height predictions, and threat levels to coastal zones/localities.

Geological Hazards Theme

Geological hazards is the largest theme under the Natural Hazards Platform. The theme is diverse, covering earthquakes, volcanoes, tsunami and landslides. The overall aim of the theme is a better understanding of the occurrence and processes driving these perils to improve conceptual, numerical and statistical models of each of them. This information can then be used to derive temporal and spatial variation of geological hazards across the country.

The theme is divided into four main projects: one on each of the geological perils. Additionally, it was felt that the production of comparable probabilistic hazard models for each peril warranted the formation of a separate project to bring together all geological hazard modellers. Early activities have involved the assembly of a project team, initial review of existing hazard models, and completion of a major update of the national seismic hazard model.

Of course, the main event of the year has been the Darfield earthquake, and many of the researchers working in the seismology project have diverted their time to analysing and interpreting the wide range of seismic data collected (reported elsewhere in this document). However, much other valuable work was achieved prior to that event by the seismology team, and the other projects have continued to produce high quality research results throughout the year.

The tsunami team have also had a busy year. In February, a M8.8 earthquake in Chile triggered tsunami warnings across the Pacific. New Zealand was no exception with activation of the National Crisis Management Centre and regional emergency management responses around the country. The tsunami expert panel convened and, using models and scenarios developed previously by the research team, accurate forecasts of likely wave heights and arrival times were promulgated to decision-makers.

Ongoing research by the tsunami team will aim to improve the dispersion models of tsunami and development of a pre-calculated scenario database. As was seen during the February event, tsunami inundation can be highly variable and depend on a large number of factors including seafloor topography, coastal zone morphology and vegetation cover. Understanding this variability is key to assessing tsunami hazard.

New National Seismic Hazard Model

A team of earthquake geologists, seismologists and engineering seismologists from GNS Science, the National Institute of Water and Atmospheric Research (NIWA), University of Canterbury and Victoria University of Wellington have collectively produced an update of the national probabilistic seismic hazard (PSH) model for New Zealand. The new model supersedes the earlier national model published in 2002 and used as the hazard basis for the New Zealand Loadings Standard and numerous other end-user applications. The model incorporates a fault source model that has been updated with over 200 new onshore and offshore fault sources (now over 530 fault sources in the new model), and utilises new New Zealand-based scaling relationships for the estimation of earthquake magnitudes. The model has also been updated to include over a decade of new seismicity catalogue data, a new seismicity zonation for the country, and an improved methodology for seismicity rate calculations. PSH maps produced from the new model show a similar pattern of hazard to the earlier model at the national scale, but some significant reductions and increases in hazard at the regional scale. The national-scale differences between the new and earlier model appear less than those seen between earlier national models, indicating that some degree of stability has been achieved in the national-scale pattern of hazard estimates. The new model represents a considerable advance in terms of data quality, quantity, methodology, and evolution of a large multidisciplinary, multi-institutional team-based approach to PSH modelling in this country.

In the seismology project, we are aiming to answer the question of how we can use the past record and ongoing monitoring of New Zealand earthquakes (from instrumental recordings, historical accounts and studies of active faults) to better forecast future earthquake hazard. The scope of the project is wide: from understanding how stress builds up on and is released from faults in the earth's crust to enhancing our knowledge of what factors influence ground motions in large. A particular highlight was work achieved on the Samoan tsunamigenic earthquake in 2009: combining geodetic, seismic and tsunami models resulted in understanding that there were actually two distinct events separated by a few minutes.

The seismologists also continue to be recognised internationally for first class work. For example, we have been building an earthquake forecast testing centre in conjunction with CSEP (Collaboratory for the Study of Earthquake Predictability). The aim of CSEP is to build a virtual laboratory whereby researchers around the world are able to test their models for earthquake forecasts on multiple example datasets. New Zealand researchers are part of this consortium so that they can test their forecasts on other worldwide examples and conversely international researchers can run their models on New Zealand earthquakes. This will lead to be better comparability between model results and ultimately allow enhanced forecasting of earthquake sequences.

The landslides project is devoted to the study of landslides, their movement processes, role in landscape evolution, and development of measures to limit their impacts. Aspects include causal factors and movement

rates, triggering mechanisms, mechanical properties and assessment of likelihood and consequences.

Landslides which vary in scale from small slips to large volume sudden catastrophic failures can be triggered by a variety of mechanisms such as intense rainfall or large magnitude earthquakes. Understanding what controls this variability is important for forecasting future landslide events.

Key outputs this year from the landslides team have included progress on the testing of the concepts of granular material behaviour and the application of near real time monitoring data. For the former movement mechanisms such as basal shear and debris flow runout and have been successfully applied to a large volume debris avalanche in Chile, while for the latter pore pressure changes have been used to model the speeding up and slowing down of translation block glides such as Utiku in the central North Island.

The final peril under the geological hazards theme is volcanoes. Understanding volcanic activity requires multidisciplinary studies of a range of processes from generation of magma at depth, through ascent and eruption.

Several studies this year have focussed on Ruapehu volcano. Scientists from GNS Science have been improving models of how heat moves through Ruapehu Crater Lake. An important control on heat loss from the surface of the lake is the weather, for example, if the wind is blowing hard, heat is lost quicker than during calm weather. To quantify this variability, a buoy was flown up to the summit of Ruapehu and located in the centre of the lake for one month to measure weather and lake conditions in tandem. Used in conjunction with continuous satellite lakeside measurements of water temperature, these data will inform new numerical heat flow models.

Lahars have been long recognised as a major hazard on both Ruapehu and Taranaki volcanoes. In order to study the mechanisms of lahars, a team led by Massey University have collected a unique instrumental dataset of flowing lahars in Indonesia. From these data they have defined new constraints on the erosion and incorporation of sediment and water by moving lahars. This “bulking” is the means by which they grow into highly destructive and deadly flows many tens of kilometers from their volcano source. The team’s results show how bulking processes are highly site and time-specific, and can also be rapidly reversible, depending on the geometry of the channel, man-made lahar-defence structures and the sediment/water ratios within the flow. This mass flow research has been key to understanding the recent (and) 2006 loss of life at eruptions from Merapi volcano and ensuring that we don’t undertake similar styles of engineering mitigation strategies for the volcanoes in New Zealand.

As can be seen above, the geological hazards theme has many world class researchers working on a wide range of scientific problems. Many of the results are delivered directly to key stake-holders such as civil defence and regional councils; some outputs, such as probabilistic hazard maps, are provided to other researchers within the platform for incorporation into risk or engineering research.

Weather Theme

Data Assimilation – a Key to Hazards Forecast System Accuracy

High impact weather is the primary driver for many of the natural hazards that confront New Zealand's infrastructure, communities and built environment. These include river-flood, coastal inundation, marine waves, landslides, and snow avalanche as well as more direct effects; high-winds, heavy-rain and snow, and fog etc. The impact of these hazards could be reduced if their occurrence were forecast at lead times that permit adaptive mitigation strategies to be employed. However forecasts that are not sufficiently accurate will lead to a loss of confidence in warnings systems, and poor mitigation outcomes.

The Fundamental Problem: Initial Conditions

Scientific and computational (i.e. supercomputer) advances over the last 20 years have allowed the development of physically based numerical models that are able to "simulate" the most important physical processes that govern the temporal evolution of the weather. Complex hydrological and inundation weather impacts models are presently less mature, but a more profound impediment to forecast system accuracy often lies in the problem of specifying the initial conditions used at the start of each forecast. Ideally, the initial conditions throughout the 3 dimensional model domain should be determined by observations, but the number of degrees of freedom in weather and hydrological models are orders of magnitude larger than the number of independent observations. The best that can be done in such circumstances is to estimate the initial state by optimally combining the information in a background forecast of the model state at the time observations are made, with that in the observations themselves. This problem is called "data assimilation" and it is mathematically complex and computationally-expensive, but the better the estimate of the initial model state, the more accurate and reliable will the resulting forecasts be.

Here we outline recent research results that indicate forecast accuracy improvements that are traceable to the assimilation of observations into firstly a high resolution numerical weather prediction (NWP) model and secondly, a hydrological forecast model.

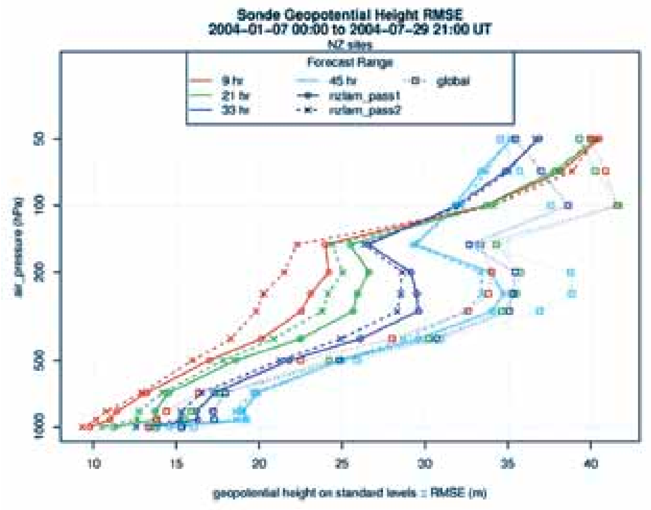


Figure 1. Root mean square errors in geopotential height over the New Zealand region for the period January – July 2004. Results for four different forecast ranges (colours), two variants of the NZLAM data assimilation method (see text) and the global Unified Model (line & symbol type) are indicated.

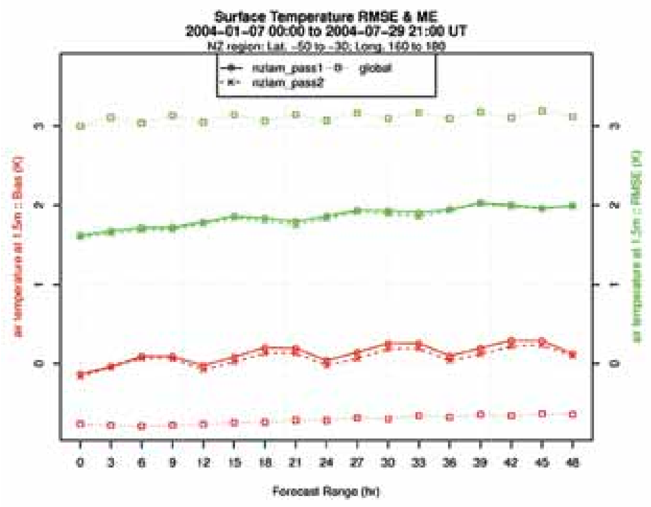


Figure 2. Model bias (red, left axis) and root mean square errors (green, right axis) of surface temperature forecasts in the New Zealand region averaged over the period January – July 2004) every 3 hours if the NZLAM forecast. For comparison, the results from the global model are also included.

NZLAM

The high-resolution New Zealand Limited Area Model (NZLAM) uses a 3 dimensional Variational (3dVAR) approach to assimilate satellite measurements of infrared and microwave emissions from the atmosphere, scattered microwave energy from the sea surface, and cloud motion vectors, as well as conventional observastions from aircraft, weather-balloon instruments, and surface sensors, into a state of the art NWP model. By optimally combining background information (a 3 hour NZLAM forecast) with the observations, 3dVAR determines the most likely initial state solution. Figure 1 shows the forecast accuracy of the NZLAM model when assimilating only conventional observations ("Pass1") and when both conventional and satellite observations are used ("Pass2"). For comparison purposes, results from a global NWP model are also included. Increasing the amount of information assimilated (Pass2 versus Pass1) leads to more accurate forecasts, which in turn are of the order of 30 - 40% more accurate than those from the global model. Figure 2 shows the impact of data assimilation on the surface temperature

forecast. While the advantages of assimilating the satellite observations are less obvious (this is expected), in comparison with the accuracy of the global model, the value of a data assimilating high-resolution NZLAM is very clear.

TopNet

NWP models solve a set of well established fundamental physical equations; the laws of conservation of energy, mass and momentum, the laws of thermodynamics and the ideal gas law. Hydrological models are not derived from any particular set of fundamental equations. Instead they are based on a conceptual understanding (expressed in mathematical form) of how water moves through a catchment. TopNet is a spatially-distributed hydrological model that simulates the water balance over a number of sub-catchments throughout a river basin, and routes stream flows from each sub-catchment to the basin outlet. The model simulates the storages and fluxes of water in the canopy, snowpack, unsaturated and saturated soil zones. It also accounts for time delay in runoff of water within each sub-basin. Ancillary information is used to describe basin characteristics (i.e. geometry, water holding capacity of the vegetation and

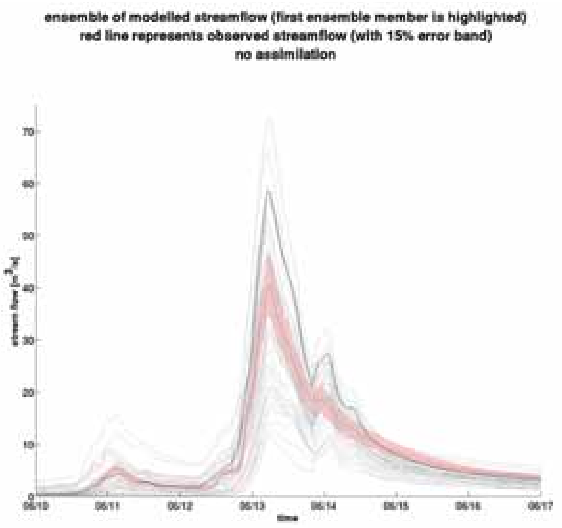


Figure 3. TopNet modelled flow on the Waihua using observed rainfall (i.e. rain gauge data) as input (forcing) data. The observed river flow is red and its expected error (15%) is indicated by the red-shaded envelope. An ensemble of TopNet simulations is shown (the solid line is the estimate of the flow based on unperturbed model states and rainfall forcing) where each member represents a realistic estimate of the modelled flow, based on the expected errors in two model states (soil moisture and depth to water table) and rainfall forcing.

soil, and transmissibility of the sub-surface for each sub-basin). Like all such models, TopNet must be calibrated using a set of hydrological observations. This process ensures that the model maintains water balance, and produces realistic stream flow observations. Calibration does not ensure that any particular flood peak will be well simulated, only that the resulting model provides the best estimate of catchment discharge. Figure 3 shows the performance of a well calibrated TopNet model for a flood event on the Waihua River in June 2009.

This figure also shows the sensitivity of TopNet model flow predictions to realistic estimates of errors in the input rainfall and two model states (soil moisture, and depth to water table). Most importantly – the ensemble of TopNet predictions bracket the true flow. However more information can be made available to TopNet by assimilating the streamflow observations using a Retrospective Ensemble Kalman Filter (REnKF) that

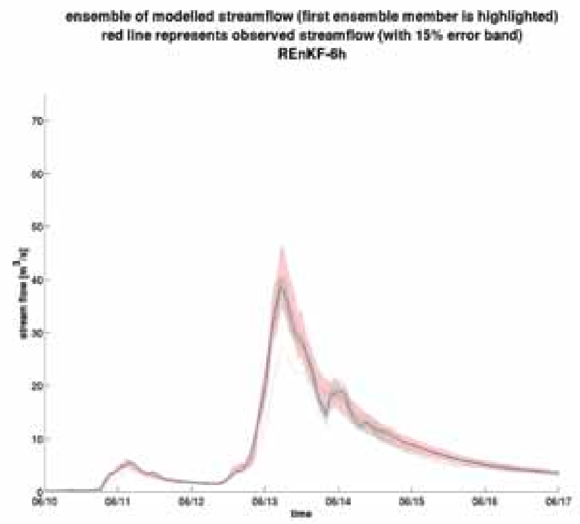


Figure 4. TopNet modelled flow on the Waihua when assimilating observed rainfall (i.e. rain gauge data), and observations of streamflow at the Waihua river gauging site. Other details as in Figure 3.

corrects the model for calibration biases, compensates for errors in the driving rainfall data, and ensures that the upstream model states are consistent with the modelled streamflow at the outlet (Figure 4)

More accurate initial conditions mean that it is possible to more accurately forecast flows both within flood peaks and during periods of recession. By coupling the data assimilating TopNet model to NZLAM forecasts, flood warning beyond the time of concentration of the catchment is possible. Replacing the observed ("perfect knowledge") in-situ rainfall observations (i.e. Figure 4) with NZLAM rainfall forecasts, yields the results shown in Figure 5. The modelled stream flows are nearly as accurate as those obtained in Figure 4, demonstrating that NZLAM forcing data together with streamflow assimilation are sufficient for the definition of accurate initial conditions for TopNet river flow forecasts – and ultimately to improved flood forecasts.

Summary

Using data assimilation to improve the specification of initial conditions for NWP and hydrological models is yielding important improvements in the accuracy and reliability of weather and river flow forecasts. Ultimately this will lead to better hazards impacts warnings and the adoption of new adaptive mitigation strategies for anticipated hazardous events.

Resilient Buildings and Infrastructure Theme

The principal Platform partners in the Resilient Buildings and Infrastructure theme are the University of Canterbury, University of Auckland and the engineering team of GNS Science. Other inputs are provided under sub-contract by BRANZ, Victoria University of Wellington and Kestrel Group.

The focus of early planning within this new theme was to strike a balance between continuation of the current projects and the establishment of new areas of research, particularly in relation to infrastructure.

It was initially thought that the Retrofit Solutions project led by the University of Auckland had largely met its original objectives, particularly with regard to unreinforced masonry, and would draw to a close with an industry seminar series in February 2011 including draft sections of a new retrofit manual. The Darfield earthquake changed that perspective, and the occurrence of the earthquake just moments before the Christchurch seminar was due to commence has further highlighted the need for additional work in this area!

The work undertaken in the Future Buildings programme led by the University of Canterbury has identified further elements of research likely to lead to code clarifications (including less onerous provisions for beam-column joints). The GNS Engineering and BRANZ-led project on the Seismic Design of Non-structural Components and Engineering Systems has generated a draft compendium on seismic restraint provisions, with further case study buildings to be researched in order to provide practical examples. The Darfield earthquake has provided a considerable volume of actual damage examples to use in this research, which is now being strongly linked with the newer eighteen month project on non-structural elements in building seismic performance led by the University of Canterbury.

GNS infrastructure network and loss modellers have also been involved under their Habitability of Post-earthquake Cities programme in quantifying the extent to which the water supply networks of the Wellington region would be affected by a rupture of the Wellington Fault, and what the consequential impacts would be.

Other research underway as part of the eighteen month contracts that commenced in April 2010 include low damage bridge elements by the University of Canterbury, and modified windflow effects on towers and pylons due to topographic effects by GNS Science and the University of Auckland.

This existing work being undertaken by theme agencies has a strong emphasis on seismic hazard and buildings. Earlier in 2010 the theme partners had identified the desirability of broadening over time the scope of work to include other hazard effects, and to include infrastructure aspects (for example, buried services).

At the beginning of September, new programmes of research covering Resilient Coastal Infrastructure,

Modelling the Interdependency of Critical Infrastructure and Soil Foundation Structure Interaction were commencing. Consideration was also being given to the establishment of a geotechnical research programme under the Platform to commence from July 2011, with a focus on liquefaction.

The 4 September Darfield, Canterbury earthquake then occurred. In terms of the strategic planning for natural hazards research, this event had three main effects. Firstly, it confirmed the importance of these new research programmes. Secondly, it highlighted a number of areas where awareness of vulnerability and mitigation solutions for earthquake are lacking, and urgently need to be provided for industry. Specifically, that a better understanding of the impacts of liquefaction on houses and buried services is required. Thirdly, it highlighted the valuable role that NZ's researchers with international earthquake experience can play during response and recovery.

The fortunate absence of any loss of life in this event has highlighted once again an area of particular need – greater emphasis on damage control for buildings and infrastructure elements to reduce the time taken to re-occupy buildings and the associated economic losses. Research undertaken under this theme has a major role to play in providing asset owners and their architects and engineers with the information and tools to raise the game in this area, and to complement the effectiveness of our seismic design codes for life safety.

While the Darfield earthquake has put the spotlight back on areas of need in relation to earthquake risk reduction, the diversity of skills and knowledge within Platform members of this theme will continue efforts to extend research to other hazards. Coastal infrastructure and tsunami is one such area, involving cross-theme collaboration.

Risk Theme

The Projection of Loss from the Darfield Earthquake

The September 4th Darfield earthquake provided opportunity for the recently modified RiskScape program to be evaluated and calibrated against the real damage experienced in Canterbury, and specifically within the city of Christchurch. RiskScape, as with all loss models, provides the framework for overlaying three essential components, combining these to establish a range of impacts (losses). These components are firstly the geographic spread of the assets exposed to the hazard event complete with sufficient asset attributes to enable each to be assigned to a specific fragility class, secondly a suite of fragility functions (that relate the impact (loss or damage) to the intensity of the action projected to occur at each site) and the finally the geographic distribution of the intensity of the actions imposed at each location from the specific event under consideration.

Exposure dataset: During the 'proof-of-concept' phase of RiskScape, Christchurch was selected as one of the original partners, being recognised as representing the Major Metropolitan sector (in comparison with Westport and Napier/Hastings as representing the 'Medium/Small Provincial/Rural' and 'Medium Urban/Rural Provincial' sectors respectively. As a consequence, the asset inventory dataset for Christchurch was populated with buildings (from QV dataset), population (from Statistic Department Census), Pipe network (Christchurch City Council) and Power Distribution network (from Orion).

Fragility Suite: The fragility functions used within RiskScape prescribe the probability of a building being within 1 of 5 damage states when subjected to a prescribed Modified Mercarlli Intensity (MMI) of shaking. RiskScape has modified observed loss ratio relationships developed by Dowrick to establish the building's probable Damage States. Five states are used within RiskScape namely DS0: Undamaged, DS1: minor (repairable and habitable), DS2: moderate (repairable but may not be suitable for immediate occupany), DS3: major damage (extensive damage and probably beyond repair) and DS4: collapse (being a loss of 50% interstorey volume at any floor). Specific relationships have been developed to assign various injury levels also (being uninjured, minor (self-treatment), moderate (medical treatment but not hospitalisation), severe (hospitisation required but non-fatal) and death.

Hazard model: While the fault catalogue built into RiskScape did not contain either the Greendale or Charing Cross faults, the versatility of RiskScape is such that it was possible to nominate the epicentral location, depth and fault mechanism once these had been computed from available instrumentation. Furthermore, RiskScape has built into it the ability to interface directly with the GeoNet Recent Event Catalogue which was successfully run within hours of the event, and re-run as further refinement of the field data and analysis of the instrumental readings occurred. The default isoseismal model (Dowrick and Rhoades) built into the model is then used to establish a projected isoseismal map based upon multiple observations derived from historical New Zealand earthquakes. These are constrained to be elliptical in shape generally with the major axis being along a NorthEast/SouthWest axis. This model represents earthquake damage resulting from shaking effects only and does not make allowance for deformation related damage (although variations in damage from such effects are included in the underpinning datasets used to derive the model.

The RiskScape model was run on September 6th and projected direct building reinstatement losses of approximately $NZD 2.4B. (Note: this figure matches that produced by Treasury on September 8th, who projected building losses at $2B NZD and other losses (including business disruption and public asset reinstatement at an additional $2B NZD). Damage projections to buried pipes was not possible at that time since the fragility functions for various pipe systems was not installed in RiskScape at that time (Note subsequent upgrades of the model predict losses to the pipe network in Christchurch City Council area as being approximately $200M, but this required both enhanced damage ratios to be applied in zones of liquefaction and significant amplification of the unit costs for reinstatement in such zones.)

What worked:

- The overall loss projections, while still too early to be confirmed, still seem to be holding with expectations .
- The number of buildings damaged to DS3 and greater (ie unsuitable for continued occupancy) was a little high for the residential sector and also for the commercial sector
- The enhanced shaking intensity in zones that experienced liquefaction were consistent with where damage was observed
- Buildings designed to modern standards were predicted to experience little structural damage and this appears to be consistent with observations.
- Non-structural damage, damage to contents/stock and business disruption costs are expected to be higher than forecast and new models are expected for each of these components. Unfortunately such damage is not visible from the exterior of buildings and work with the insurance sector is underway in an attempt to capture this data.

Where enhancements have been necessary

- The widespread damage through extensive ground deformation (liquefaction) has required a separate damage model to be developed to reflect this phenomenon in both buildings and infrastructure.
- Earthquake induced landslides were very rare and are likely to result in this model (which is in the early stages of development) being recalibrated.
- Only a small portion (15%) of the area previously identified as having a high liquefaction susceptibility did indeed liquefy. For the Christchurch model, known liquefaction zones have been introduced into RiskScape (after the event) and used to project losses. An extensive geotechnical programme is underway seeking to distinguish those zones where liquefaction occurred from those where it was expected to occur but no such surface expression was observed.
- Several houses within zones of high liquefaction will require demolition or removal to allow for the ground remediation programme to be undertaken. Some would otherwise be economical to repair.
- The underpinning isoseismal model did not align well with the damage and felt reports of motions experienced. This has resulted in a direct application of the (~7000) felt intensity reports acquired through public participation in Geonet being developed. Changes to the associated MMI based fragility functions are still being worked upon.
- The death and severe injury rates predicted by RiskScape were (thankfully) markedly higher than those experienced, at least in part because of the fortuitous time of the earthquake (4:36 am) and the very empty CBD streets in the vicinity of the Unreinforced Masonry Buildings (URM). The actual number of injuries requiring medical intervention (as collated by ACC) is around 2000 with less than 20 requiring admittance to hospital.

Footnote: RiskScape was again in action following the Lyttleton Earthquake of 22nd February 2011. In this case the combination of high stress drop and forward directivity towards the city, resulted in motions much stronger than those calculated (using Mw = 6.7, focal depth = 7km & 10 km of the CBD) by the default RiskScape ground shaking model. Damage to buildings (from shaking alone) was assessed at $5.4B and is expected to approximately match the infrastructure losses and be similar to the business disruption losses. The model indicated 24 deaths (cf 169 fatalities) and 5200 displaced people. Liquefaction related damage models were unavailable in RiskScape. Refinement of the model continues.

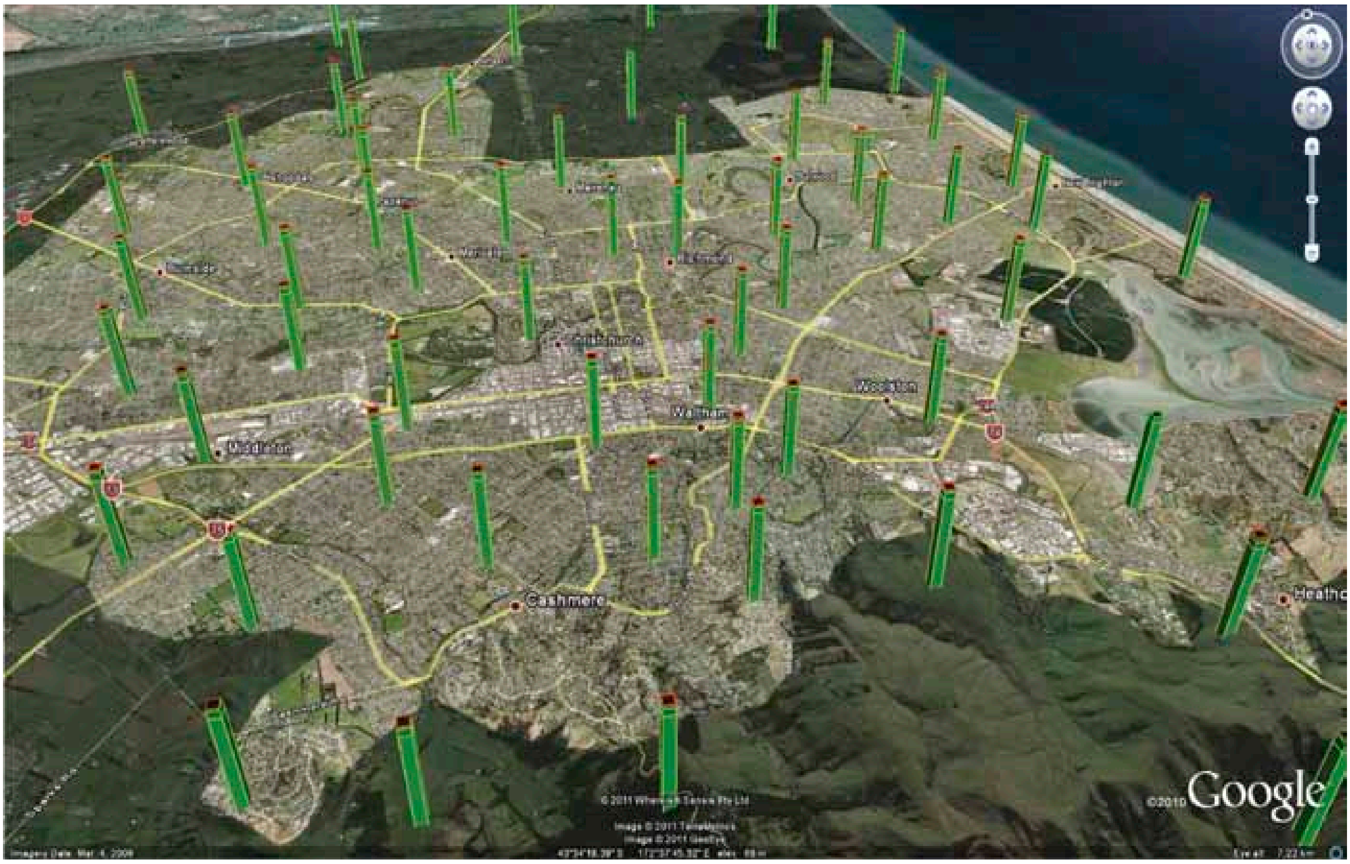


Figure 1. RiskScape loss projections (Stacked Building damage state per suburb with summary of projected results).

Societal Resilience Theme

The societal theme aims to provide an understanding of the social, economic and cultural factors that influence the development of strong communities, resilient to the impacts of natural disasters. The research is focused on: (1) improving in New Zealand's governance structures and processes, such as policy and legislative frameworks, planning (including land use), and leadership with respect to natural hazards; (2) identifying of the characteristics that make people, communities organisations, businesses and other social structures resilient and the impediments that prevent it; (3) improving emergency management (4 Rs) procedures and processes; and (4) more efficient and effective recovery after a natural hazard event. The consortium is made of researchers from two Crown Research Institutes (GNS Science and NIWA); seven New Zealand universities (Auckland, AUT, Waikato, Massey, Victoria, Canterbury and Otago); and other research providers (eg. Opus International). The research is organised into several cross cutting themes, which are described below.

Organisational resilience

In an increasingly volatile and uncertain world, one of the greatest assets an organisation can have is the ability to survive unexpected crises and to find opportunity to thrive in the face of adversity. Research within this task has focussed on understanding the impact of hazard events on organisations and organisational arrangements, identifying ways to encourage organisations to proactively strive for greater resilience, and mechanisms for supporting recovery of the organisational community following a hazard event.

Community resilience

Research within this theme explores what contributes to community resilience, including the role of formal and informal social networks, community engagement, empowerment, and strategies for motivating and sustaining community participation in at-risk communities. Another key focus is the role of education in schools in assisting preparation for hazard events.

Policy and land use planning for reduction

Improving the preparation and implementation of plans and policies addressing natural hazards within district, regional and central government is a key challenge. Research has explored barriers to successful natural

hazard policy implementation and guidance on how to overcome such barriers. An example is the EQC funded project "New Zealand's Next Top Model: integrating tsunami modelling into land use planning", which provides guidance to land use planners on when and how tsunami modelling can be included in land use policies and plans.

Effective warnings and emergency management response

Research aims to understand the response to warning systems from both the perspective of the community at risk, and emergency management personnel coordinating any warnings, evacuations and related response actions. Tsunami, lahar and flood warning systems provide opportunities to explore these response processes, and investigate the role of public education in improving this response. Recent research shows successful public education programmes needs take into account how people react in these crises, and prepare the population both psychological and physically to respond in an effective manner at a time that is appropriate.

Canterbury Earthquake

Following 4 September 2010 earthquake over one hundred social researchers from thirty organisations, have been involved in researching a range of social themes. Over the following months, many have been

working directly in partnership with key agencies, for example Ministry of Social Development, Ministry of Health, Ministry of Civil Defence & Emergency Management and the Recovery Groups. In most cases this input has built on existing long-term relationships and networks.

Research is focused around a number of key questions, such as:

- What are the consequences of the earthquake on individuals, communities and organisations, over varying timeframes?
- What are the societal factors that influence community resilience to the impacts of earthquake?
- What are the trends and emerging issues in Canterbury that influence vulnerability to and recovery from the earthquake?
- What is the vulnerability to the economy of the earthquake and how do factors such as the economic structure, stage of development, prevalent economic conditions and the policy environment play a role in that vulnerability and recovery?
- What are the processes by which society transitions, recovers and adapts (and how can these be enhanced) after the disruption caused by the earthquake?
- How effective are (were) emergency management procedures, and crisis management practices for managing societal response to earthquake?

- What are the strategies for improving resilience and how do we 'get these into' governance, planning (including land use), policy, organisational, economic, and legislative systems and frameworks?
- How can hazard science be better understood, applied, managed and utilised as an integral part of the planning, risk and adaptive management processes?

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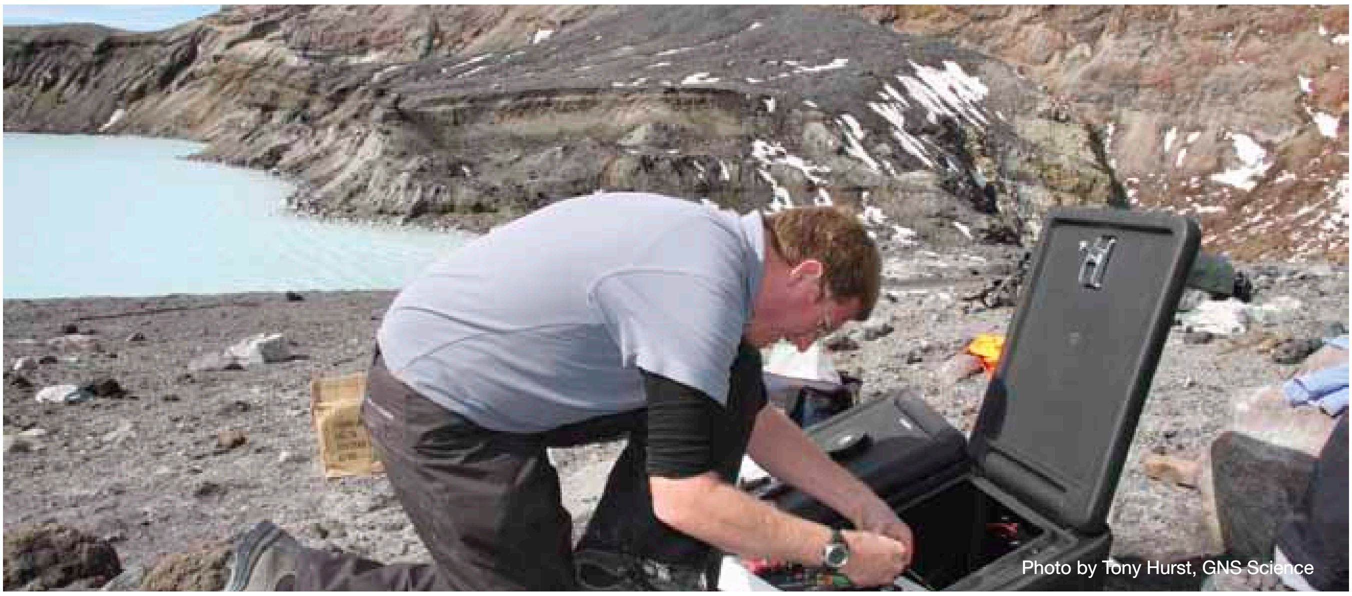
Photo by Simon Cox

Landslide caused by magnititue 7.8 Earthquake Fiordland on 15 July 2009.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Setting up a data logger to record temperauture and level of Ruapehu Crater Lake. Summary data is transmitted by satellite.

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The Natural Hazards Platform

The GNS Science-led Natural Hazards Research Platform was created in September 2009 by government to provide secure long-term funding for natural hazard research, and to help research providers and end users work more closely together. The Platform also includes NIWA as an anchor organisation and University of Canterbury, Massey University, Opus International Consultants, and University of Auckland as partners, and there are a further 20 subcontracts to other parties.

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