Water & Atmosphere

September 2015

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Heading south

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Mackenzie's big freeze

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Cover:

Surface flooding in Wellington's CBD. (*Dave Allen*)

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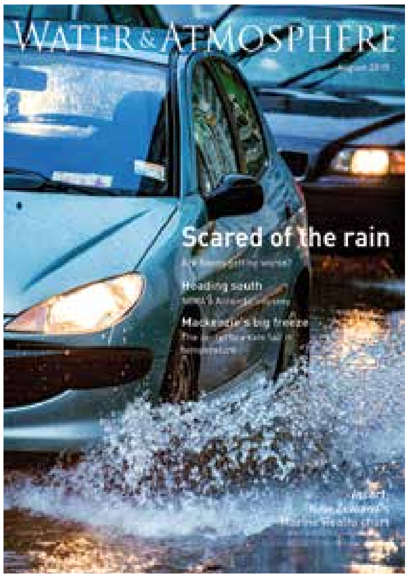


Tiny world first

At a pristine, isolated lake near Otorohanga in the Waikato, NIWA freshwater biologist Brian Smith recently made an important discovery.

It's only 2mm long and, according to Smith, a bit dull to look at, but it is unlikely to be found anywhere else.

Smith's discovery of a new species of caddisfly was made during a survey of tiny Lake Koraha. The lake's isolation, combined with the size of the newly discovered insect, Smith says, are probably what allowed it to escape detection for so long.

"It's very small and easily overlooked, but this is related to another species of caddisfly discovered in Hamilton about five years ago."

Caddisflies are related to butterflies and moths and there are about 250 species that are unique to New Zealand.

"They're mostly nocturnal and dull, drab looking things, but it's great to have found an adult male inside the pupa case that enabled it to be identified."

Smith will get to name the new species, but is yet to decide just what to call it.

Meanwhile, a random decision to turn over a boulder at the Tukituki River in Hawke's Bay resulted in a second caddisfly discovery for Smith.

"I was doing some work at the Tukituki when I happened to pick up a rock. It was a totally off-the-cuff thing to do since it was out of the water, not in it. I noticed that on the underside some bugs were feeding on caddisfly eggs."

Caddisflies often lay their eggs on partly submerged rocks, but receding floodwaters meant the rocks were no longer submerged, leaving the eggs high and dry – and an ideal food source because they are rich in nutrients and protein. What Smith quickly noticed was that the insects feeding on the eggs were land based and had become opportunistic predators.

"This was a unique interaction between aquatic and terrestrial ecosystems that highlights how changes in water levels during critical stages like egg laying may have dire consequences for some aquatic insects," Smith said.

This world-first observation is now the subject of a scientific journal paper.

Smith has also recently finished a four-year study of adult aquatic insects that provides new and updated ecological information for more than 70 species of mayflies, stoneflies and caddisflies, filling an important knowledge gap. But he warns that information about the adult life stage of even our most common species lags far behind that of the larvae.

"It is important to understand all the life stages of an insect because any one of them might be affected by changes in the aquatic environment and its surroundings."

Brian Smith setting up light trap. (*John Quinn*) Inset: Insect eats caddisfly eggs on a river stone. (*Brian Smith*)

23 June, 2015 – snow covers a large swathe of the South Island. Climate scientist Gregor Macara with a stunning image taken by NASA's Aqua satellite during more settled weather after the storm. (*Dave Allen*)

Rare big freeze

NIWA scientists have found that a rare sequence of weather conditions caused Mackenzie Basin temperatures to plummet to record lows in June this year.

Tara Hills (near Omarama) plunged to –21.0°C on 24 June, and Pukaki Aerodrome observed –19.8°C on 23 June: the lowest ever temperatures at these locations and New Zealand's fourth-lowest and seventh-lowest temperatures on record, respectively.

NIWA climate scientist Gregor Macara told *Water & Atmosphere* that three phases contributed to the rare chill: heavy snowfall and cold air from the south, which became trapped by a high pressure system.

"It's a rare sequence of three distinct phases, each making a critical contribution that resulted in extremely low temperatures," according to Gregor.

These factors similarly occurred together in July 1903, when Ranfurly observed New Zealand's lowest temperature on record (–25.6°C on 17 July 1903).

Phase one: heavy snowfall. On 18 and 19 June, heavy snow fell throughout the South Island. This was a *warm-advection* snowfall event, where moisture-laden warm air from the northwest was undercut by much cooler air from the south, enabling prolonged heavy snowfall to relatively low elevations.

Phase two: cold-air injection. On 21 June, the broad area of low pressure that brought the heavy snow drew away to the east of the South Island. This established a southerly airflow over the South Island which injected even colder air. Snow flurries were reported to near sea level in eastern parts of the South Island. This colder air penetrated into inland basins.

Phase three: high pressure system. On 22 June, skies cleared with the arrival of a strong high pressure system (anticyclone). Cold air from the southerly outbreak lingered, and effectively became trapped in the inland basins by the anticyclone. The combination of clear skies and cold air saw temperatures fall rapidly.

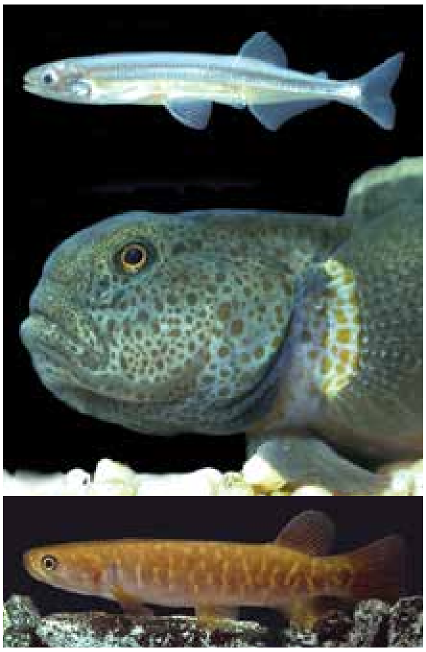
Gregor said the anticyclone, typically associated with pleasant weather, became established over the South Island on 22 June and remained in place for around four days.

"Clear skies meant any heat from the sun was lost rapidly at night. The overnight cooling was prolonged by the long time between sunset and sunrise. Light winds meant that the cold air remained undisturbed inland.

"Snow on the ground reflected energy of the sun which would have otherwise contributed to an increase in air temperature.

"Cold air has a higher density than warm air, so the lack of wind enabled this cold air to pool in the basins," Gregor says.

In brief



From the top: Stokell's Smelt, Upland Bully, Kokopu. (*Bob McDowall*)

A rare stellar occultation observed from Lauder. (*Petr Horálek*)

Niwa staff talk to farmers about Irrimet at Fieldays 2015. (*Chris Hillock*)

Fish spawning captured on calendar

NIWA researchers have produced a series of calendars to inform people when New Zealand's native freshwater and sport fish are migrating and spawning.

It is the first time the information has been available in one place and, although it was designed to assist the forestry industry, NIWA hopes it will be used by anyone wanting to carry out work near freshwater.

NIWA fish researcher Josh Smith said the calendars cover 41 key freshwater fish species in New Zealand.

Many of New Zealand's fish species move between freshwater and the sea as part of their life cycle.

The calendars outline the spawning range for each species, the migration of adults to spawning habitats, and the upstream migrations of juveniles to adult habitats.

Out of this world

Scientists camped out at NIWA's atmospheric research station in Central Otago in late June to observe a rare astronomical event that lasted just 90 seconds.

Called a stellar occultation, scientists were able to catch a rare glimpse of Pluto and its surrounding atmosphere. The occultation occurred when Pluto passed in front of a star which shone light across it.

NIWA atmospheric scientist Dr Richard Querel says that, as the star shines its light through Pluto's atmosphere, it enables spectroscopic measurements to be made, allowing its atmosphere to be probed and studied.

NIWA's atmospheric research station is based at Lauder, 35km from Alexandra, and is renowned for its clear skies.

Lauder lived up to its reputation, providing a clear sky for the event and a source for further information and measurements of our solar system. The data will be used to estimate the thickness and potentially the composition of Pluto's atmosphere.

Farmers to test new NIWA tool

NIWA took its newly developed forecasting tool IrriMet to the Mystery Creek Fieldays in June in search of farmers to test it.

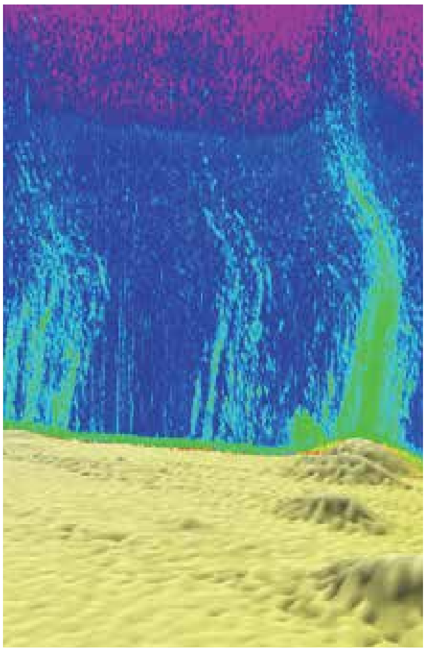
IrriMet follows the successful launch of FarmMet last year. It tells farmers when and how much to irrigate, what the leaching potential is and how overall pasture growth is tracking.

Dr Jochen Schmidt, NIWA's Chief Scientist Environmental Information, said: "This is all about putting information at farmers' fingertips to help them maximise farm profit. That's why it's vital that we get their input on our design and development."

IrriMet data are fed into NIWA's supercomputer and combined with high-resolution weather forecasting and soil information to generate a six-day forecast of soil moisture and leaching potential.

Dr Schmidt says farmers shouldn't have to rely on guesswork when scheduling irrigation, but should be able to make informed decisions.

"Farmers can reduce power, maintenance and operational costs and, if water isn't needed, it can be left where it is or reallocated."



Undersea gas flares recorded by *Tangaroa*. (*NIWA*)

NIWA discovers more seabed gas flares

A team of NIWA scientists has been investigating gas flares off the coast of the North Island near Gisborne.

First discovered in 2014, what NIWA previously thought were 99 seabed gas flares were actually near to 766 individual flares within the area.

Led by marine geologist Dr Joshu Mountjoy, NIWA returned to the flares aboard *Tangaroa* earlier this year, so that the team could take another look.

The team discovered that every area of carbonate rock and every fault seen on the seafloor was expelling gas.

"We wanted to find out whether methane is getting through the water column to the ocean's surface and into the atmosphere, and determine what contribution it's making to global greenhouse gas," said Dr Mountjoy.

By sampling methane gas within the ocean and collecting photographs and graphic imagery, NIWA was also able to build a picture of the fate of the gas flares, and acquire a deeper understanding of the ecology at the sites.

This juvenile 12cm colossal squid could grow to more than 6 metres in length. (*Aaron Evans/Darren Stevens*)

Tiny find fascinates squid scientists

Another colossal squid is under examination in Wellington, but this one could fit in the palm of your hand.

The baby *Mesonychoteuthis*, which measures about 12cm in total length, was collected by NIWA during the New Zealand-Australia Antarctic Ecosystems survey earlier this year.

Careful examinations of the tiny colossal squid revealed it to be in very good condition, with the characteristic hook/sucker combination already present on the arms.

The squid was examined by Dr Kat Bolstad, who heads Auckland University of Technology's Lab for Cephalopod Ecology and Systematics (ALCES), and PhD candidate Aaron Evans, who studies the family Cranchiidae ('glass squids').

"We're very lucky to have the range of specimens we do in New Zealand collections, from the small individuals housed at NIWA to the very large females at Te Papa," said Evans.

The baby colossal squid came along at exactly the right time, as Dr Bolstad and Evans are currently finalising a paper describing the species's growth and appearance throughout its lifespan.

Rob Murdoch with some typically inquisitive king penguins on Macquarie Island. (*NIWA*)

Award for NIWA's research manager

Dr Rob Murdoch, General Manager of Research at NIWA, has won the prestigious New Zealand Marine Sciences Society Award.

Granted for his outstanding contribution to marine science, the award was presented at the New Zealand Marine Science Society Conference in July.

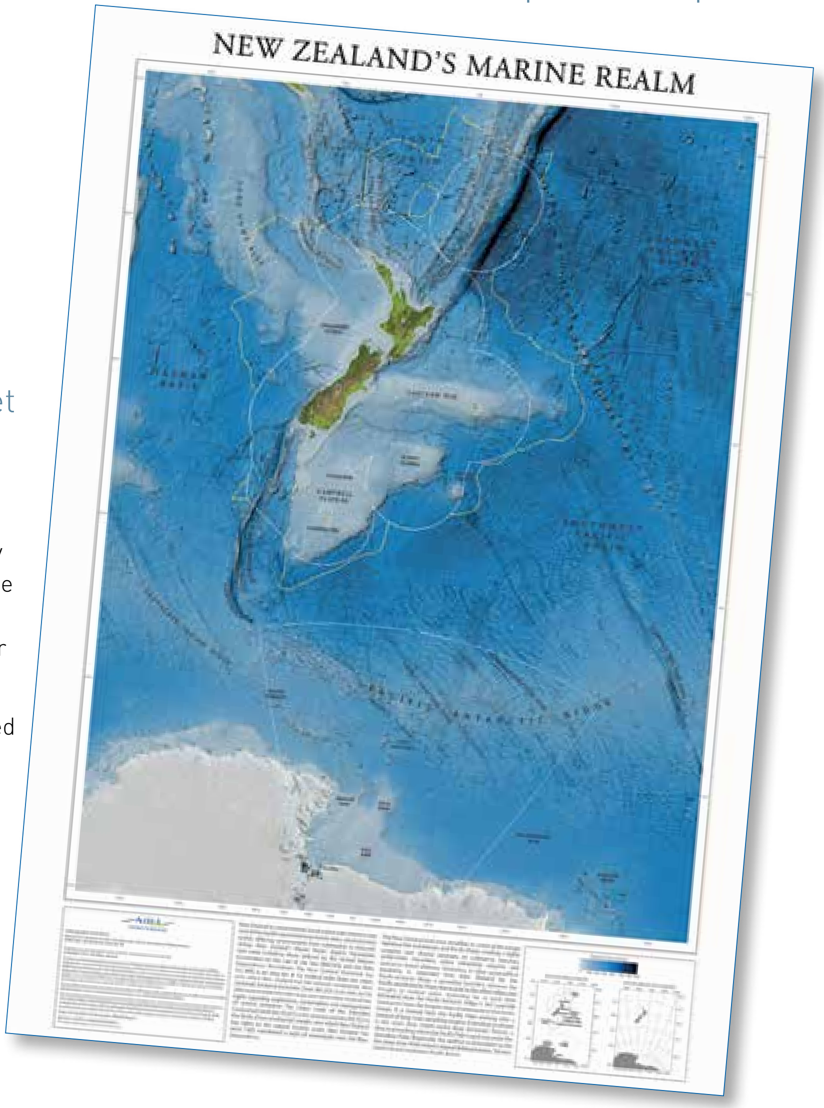
Through his oceanographic research career and his senior roles at NIWA, Dr Murdoch has had a major influence on the extent and direction of marine and natural resource science in New Zealand.

He has also been an invaluable contributor on numerous advisory boards and panels, including WWF New Zealand and the Antarctic Research Institute.

Last year Dr Murdoch was recognised by his NIWA colleagues with an Extraordinary Achievement Award in NIWA's 2014 Excellence Awards for his role in the development of the two National Science Challenges NIWA hosts and the three others in which it is a key collaborator.

New Zealand's Marine Realm

Poster-sized copies (690mm x 990mm) are available from: www.niwa.co.nz/publications/posters



NIWA has transformed 1.5 million square kilometres of data into the most accurate and detailed map yet of the land underneath the sea around New Zealand.

Dr Helen Neil, marine geologist and one of the key members of the NIWA team involved in creating the chart, says data collected by various sources over almost 150 years was used to produce a full colour image of the sea floor.

The image, *New Zealand's Marine Realm*, is included as a special poster inserted in this issue.

The high resolution of the data allows people to clearly see undersea valleys, peaks, cliffs and plateaus. Helen says this sort of detail had not previously been available because data covering some of the ocean floor were sparse and older mapping technology was less precise.

"The chart showcases the dynamic geography surrounding our small island nation. It's an incredible view," Helen says.

She says the chart will be used by councils and government decision makers across the country, from where it is likely to become a reference chart for many other users. It will help guide decision making in fisheries, science, conservation, and central and regional planning.

"We expect it to be in the hands of everyone from recreational fishers to those exploring energy and mineral opportunities," Helen says.

The use of multibeam echosounders has been the key to the extensive and detailed data used to create the image.

Echosounders mounted to the hull of the vessel send beams of soundwaves to the sea floor. They measure the time it takes for the sound to travel back to the echosounder.

The data are collected and transferred into a software programme which builds up three-dimensional grids of the sea floor. These grids can then be turned into images and graphics.

The multibeam echosounder can record data in strips as wide as 7km and 2500m in depth and still retrieve detailed results. The tool can reach depths of up to 8km.

NIWA's deepwater research vessel, *Tangaroa*, was used to collect part of the data used to produce *New Zealand's Marine Realm*. NIWA also integrated information from Land Information New Zealand (LINZ), General Bathymetric Chart of the Oceans (GEBCO), as well as international surveys from United States, France, Germany, Australia and Japan to cover the area of New Zealand's oceans.

New Zealand's Marine Realm depicts boundaries such as the New Zealand Territorial Sea, which is an area out to 12 nautical miles from the coast, and New Zealand's Exclusive Economic Zone, an area out to 200 nautical miles from the coast, over which New Zealand has rights to exploration, conservation and management of marine resources.

Panorama: John Morgan

No more surprise floods?

There was a common factor in the floods that hit swathes of New Zealand midway through this year – they were all forecastable ... providing you have a high resolution weather forecasting capability, a national catchment model, a water flow prediction model and an impact prediction and assessment model that all interact with each other in real time.

NIWA, and New Zealand, now have this capability.

It takes a lot more than a simple weather forecast, because factors other than rainfall influence floods. In a country that gets as much rain as we do, it was an obvious choice for NIWA to invest in developing and improving high resolution flood event and impact forecasting tailored to New Zealand's climate and topography. The science is now at a stage where I believe we should be introducing a routine national flood forecasting and response service. The next step is to invest in tailoring NIWA's flood forecasting models for each of the nation's key at-risk catchment areas.

I argue that not to utilise the nation's flood forecasting capability would be a travesty – especially when we can be sure there are more floods to come. Furthermore, we can be sure that, as a consequence of a changing climate, some of these floods may well be worse than we've yet experienced and more frequent – 1 in 100 year floods may occur every decade or so. We forecast that the changing climate will bring warmer and wetter weather to parts of New Zealand. The weather@home project is examining the extent to which climate change is already increasing flood frequency and intensity.

NIWA can now forecast and monitor rainfall across the country to a resolution of 1.5 square kilometres. Our TopNet flow prediction model accounts for every step the water takes in its journey from the moment it hits the tree canopy to when it runs into waterways. TopNet can forecast, hours ahead, how rainfall will change river heights and flow rates. Then, the RiskScape tool shows where the water will go if these waterways flood. It can also estimate the cost of the damage to our buildings and businesses.

We are on the cusp of joining these tools together to make forecasts for river heights that will give local authorities time to deploy protective measures and move people and assets. We already have the ability to model and cost flood damage to better inform decisions on curbing or designing development in flood-prone zones.

For example, we are designing a system to forecast what happens in the catchments feeding the Buller and Grey Rivers. Our river flow prediction model feeds real-time measured river flow observations back into the model. This corrects the model on-the-fly to improve future forecasts. It ensures that errors in rainfall forecasts, such as were experienced in the Whanganui floods, are minimised in flood forecasts.

To be clear, New Zealand has the capability to forecast, within a few hours, all the floods experienced this year.

Let's also be clear that this is no mean feat. Floods aren't as simple as heavy rain running into rivers. As I said before, rainfall is not the only predictor of floods. But if our model is tailored to each catchment, we can be very accurate.

We are currently planning a feasibility study to run a flood forecast model for the whole country. The model will use data on soils and vegetation mapped across the whole of New Zealand. We will then run the model on our supercomputer to generate river height information.

NIWA has just completed linking our higher resolution weather model – forecasting down to an area of only 1.5 square kilometres – with the TopNet flow prediction model. We aim to provide the most accurate and timely warning of heights and flows ever possible for most waterways.

It's time to bring an end to surprise floods. It's time to bring an end to floodwater damaging buildings and displacing people and businesses. Science has the ability to help us react quickly, and adapt to the coming changes over time.

New Zealand needs to resolve to apply the knowledge it already has.

John Morgan is Chief Executive of NIWA.

Water from the Whanganui River flows virtually unimpeded over the stopbank and towards the CBD. (*Mark Brimblecombe*)

Flood pains

Floods are not unusual in New Zealand, but those that hit us early this winter broke records. Why did they occur? Should we expect more? Can we predict future floods?

On Saturday 20 June, one month's worth of rain fell across the Whanganui region in 24 hours. At Whanganui Airport, the 79mm recorded on Saturday was the highest in June since 1937.

Waterways throughout the region burst their banks that devastating night. The Whanganui River reached its highest ever, 9.1 metres at Town Bridge at 3am, with a flow rate of 4,690 cubic metres a second. Water spilled into the central business district. The city was cut in half by the closure of bridges for fear they would collapse under the river pressure. By the end of the weekend, all roads in and out of Whanganui were closed.

Civil Defence declared a state of emergency. Hundreds of people were evacuated from homes in dozens of places too near flooded waterways.

Whanganui was just one of an extraordinary set of floods in 2015. Kapiti, Horowhenua and Wairarapa were also affected by flooding on 20 June. In April, localised downpours in Wellington flooded commercial premises and roads, and heavy rain in May delivered an entire month's rainfall in one day. The May event, which centred on the Kapiti Coast, blocked roads and rail across the region with water and debris, flooded Kapiti homes, and one person died in the Hutt Valley. Heavy rain in Dunedin caused surface flooding through the urban areas, which disrupted transport and electricity, and led to slips and damage to homes and road surfaces.

In the exhausted and frustrated aftermath, one question arose: why? The phrase 'climate change' was quick to the lips of some commentators. *Wanganui Chronicle* editor Mark Dawson wrote after the flood, "Climate change and conservation advocates may feel we have brought some of this on ourselves." Whanganui resident RK Rose commented: "This is what climate change looks like."

The primary reason for the floods was more prosaic. Dr Sam Dean, NIWA's Chief Scientist for climate, atmosphere and hazards, says the floods were principally due to the variability of New Zealand weather. He says that in Whanganui there was simply too much rain on already saturated land. Waterways overtopped their banks, drainage was unable to cope with the volume, and buildings were inundated with water. He says, "Developing the tools that will accurately forecast floods with sufficient lead time for people to act is a major focus for NIWA's research."

Nevertheless, Sam says the role of climate change cannot be ignored.

Climate scientists, hazard analysts, computer modellers – just a few of the people working at NIWA every day to help mitigate risk from floods. From left: Andrew Tait, Principal Scientist – Climate; Suzanne Rosier, climate scientist; Sam Dean, Chief Scientist – Climate & Atmosphere; Kate Crowley, hazards engineer; Ryan Paulik, hazards analyst. (*Dave Allen*)

"There is indeed growing evidence that rainfall extremes, and the frequency and risk of those, are already worsening in New Zealand as a result of climate change."

Wetter days are coming

Dr Andrew Tait, a NIWA scientist and Director of the New Zealand Climate Change Centre, says we should brace ourselves for more high rainfall events in the future.

"Climate change is expected to bring warmer, wetter weather to many parts of New Zealand. Flood-causing conditions are likely to arise more regularly.

"Floods caused by rain deluges in the west and south of New Zealand, where annual average rainfall and river flows are projected to increase, are particularly likely," he says.

Andrew was one of the lead authors for the Australasian chapter of last year's IPPC Working Group 2 report, which concluded that floods will more frequently impact many of New Zealand's low-lying areas, as heavy rainfall events are projected to increase in intensity.

He agrees that climate change is very likely already contributing to heavy rain events, but cautions that it's hard to say by how much.

"Every flood that occurs these days, everywhere in the world, is influenced to some degree by the gradual warming of our atmosphere that has been going on now for several decades.

"A warmer atmosphere can hold more moisture; thus heavy rain-bearing flood-producing storms are all somewhat more intense now than if there was no warming. The difficulty is knowing how much more."

Andrew says it is very difficult to isolate the influence of climate change by analysing past and present rainfall data.

"It may not be possible to show statistical significance of an increase in heavy rainfall intensity and frequency for several decades to come for New Zealand, due to the inherent variability in our weather and the rarity of extreme events."

Scientists at NIWA are using climate models to answer this question earlier. These are equivalent to the computer models used to do weather forecasts. They can produce weather systems just like those observed with instruments and satellites.

Sam Dean says, "When models do such a good job of recreating reality, we can then run them lots of times to reproduce the flooding event we are interested in. This gives us the statistical significance we need to make robust statements about how much more intense a flood is now compared to what it would have been if people hadn't modified the climate." (See panel, 'Is climate change to blame?')

Chris Appleby and Hilary McMillan measuring river flow in Halcombe Creek, Canterbury. (*MS Srinivasan*)

Predicting floods

A model that is essential to understanding floods, and forecasting them, is one that simulates the passage of water from rain to waterway.

Dr Hilary McMillan, a NIWA hydrologist, says modelling shows that a complex interaction of factors is required to generate a flood.

"A lot of different processes control when and where rivers flood. It's too simple to think of floods as simply heavy rain running into rivers, which then overrun their banks.

"The path of rain to waterways is a very complicated one. There are a huge number of factors influencing whether the rain that falls is enough to cause a flood.

"Think of it as a ladder of leaky buckets, each tipping into the one below. Rivers and streams are last in the chain. Whether they flood depends on what is happening in each of the buckets above.

"An example of one bucket is the vegetation canopy in a forest, which transfers water into a bucket below, the soil on the forest floor.

"To forecast a flood you need to know how much rain is falling, whether it lands in the buckets, how much water they already hold, how fast they leak, and when each will tip its load into the next bucket," she says.

Hilary is part of a team working on two projects to provide accurate river flow forecasts for New Zealand.

Flood pains

The team is refining and applying a water flow model called TopNet. The system models the fall, storage and transfer of rain across a catchment. In addition to an upgraded weather model resolution representing New Zealand in 1.5 square kilometre blocks, TopNet is also being fine-tuned to specific catchments.

Hilary says the model accounts for all the major factors affecting how much water moves into waterways, and its rate.

"Rain transfers through five storage stages: tree or vegetation canopies, in snow, in soil, in the water table and in small streams. At any point it can evaporate back to the atmosphere, pool, or run to the next stage. (See graphic.)

"The conditions in each of the storage and transfer points are critical to movement of the water to the next zone. Conditions can vary greatly across any catchment – the area where water is draining into common end points.

"Flash floods can arise from extremely wet soil conditions, fast snow melts combined with heavy rain, and many other combinations of factors."

Soil saturation is a key flood condition. If the water table is close to the surface, there is no room to hold rain that lands or runs onto it. Water will continue to run across the surface until it finds a waterway, or is forced to pool into bodies of water.

Hilary cites an almost endless series of factors that need to be considered in a model, such as dust in extremely dry areas coats raindrops, preventing them from soaking into the soil; heavily forested areas suspend more water on leaves and in roots; mountains and hills suspend rain in snow; and snow melt increases the flow of water to rivers.

The complexity explains why forecasting a flood is so difficult.

Yet that is exactly what Hilary's team is attempting to do for the West Coast Regional Council. The Envirolink-funded project, currently close to going live, will use TopNet to forecast flow and volume in the Buller and Grey Rivers. Armed with river flows forecast from 1 to 36 hours ahead of the rain actually making it into the rivers, the council will be able to judge the likelihood of floods and make plans.

Data will be used to set up the tailored West Coast model from various sources, such as rain gauges, soil conditions from Landcare Research, land cover, geology and river network data, and river flow data.

The model will make forecasts on river flow based on actual data, but also on predicted rainfall and humidity data.

NIWA's weather model that provides the rainfall forecasts has been recently upgraded so it represents rainfall data in 1.5km^2 blocks, rather than the previous 12km^2. This degree of resolution allows storm systems and interactions of weather fronts and mountains to be more accurately modelled, increasing the accuracy of the total volume of rain forecast to fall in each catchment.

"Weather forecasts have vastly improved, enabling us to forecast river flows many hours ahead of time. The degree of system latency is critical to the success of these forecasts. The council needs time to move people and assets ahead of a flood," Hilary says.

The project will progressively tweak the model to better represent what happens in the catchments feeding the Buller and Grey Rivers.

The past five years of weather data will be directed into the model, to identify areas where predicted river flows differ from actual river flows measured on the ground.

"We'll pick out the top parameters that control the model flow predictions, and fine-tune their values in the West Coast model."

NIWA's flow prediction model uses a unique method that feeds real-time measured river flow observations back into the model. This corrects the model on-the-fly to improve future forecasts, and ensures that errors in rainfall forecasts don't accumulate in the model.

A feasibility study is in the wings to run a flood forecast model for the whole country. Hilary says, "This exciting project will use data on things like soils and vegetation

Is climate change to blame?

The weather@home project, part of the international climateprediction.net effort, is assessing whether extreme weather events can be attributed to global climate change.

The spare computing power of volunteered computers around the world is used to run high resolution regional climate models enough times to capture very rare weather events.

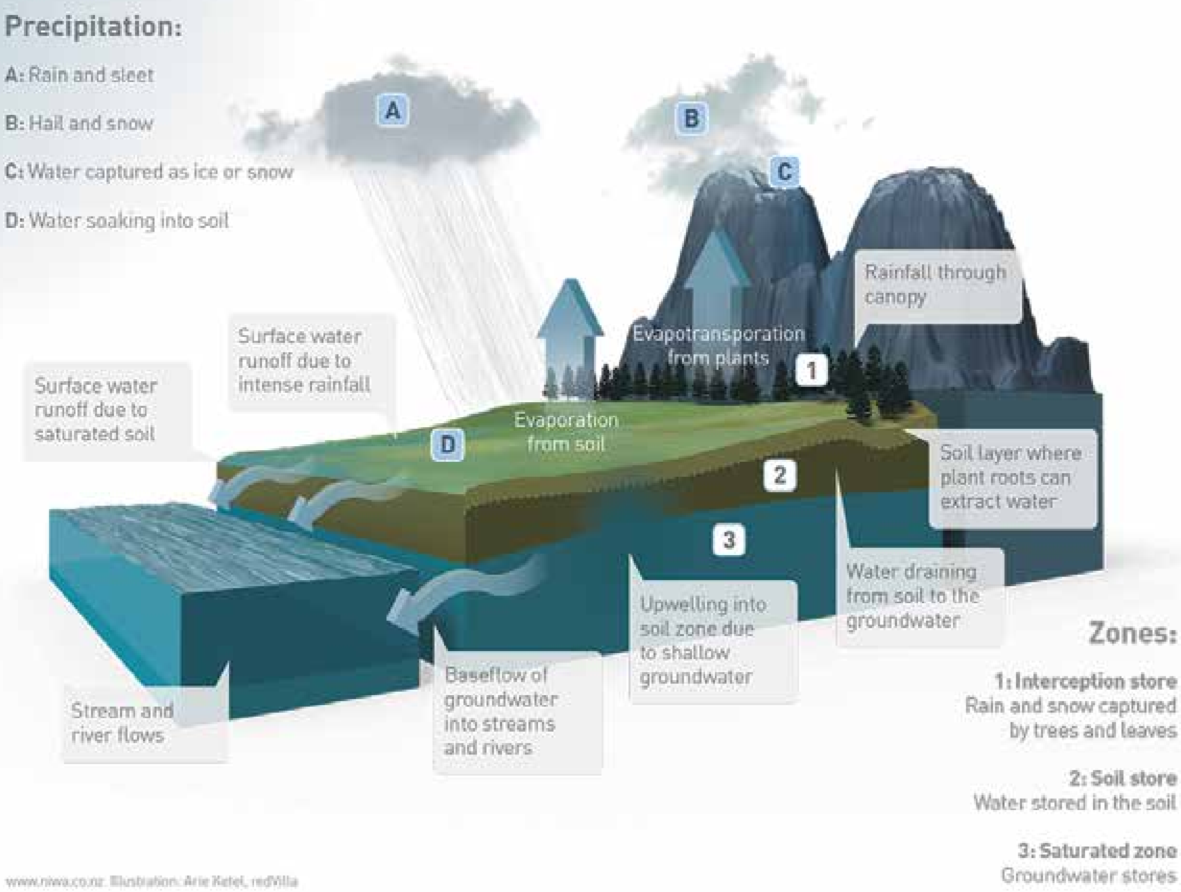
The New Zealand part of the project, headed by NIWA climate scientist Suzanne Rosier, uses data from regional climate models of the Australian and New Zealand region.

Dr Rosier says that when simulations of actual conditions are compared with those of how things might have been without human influence on the climate, the risk of extreme rainfall such as that which caused the winter 2014 floods in Northland has likely increased as a result of human influence.

More recent extreme rainfall events, such as those in Wellington, Dunedin and Whanganui in the last couple of months, are currently being investigated.

Project results have also shown that the record warm winter of 2013 in New Zealand would have been extremely unlikely without human interference with the climate system.

Where water goes



mapped for the whole of New Zealand and will rely on NIWA's supercomputer for the huge computer power needed. The team is also thinking carefully about how to visualise the large amount of flow forecasts produced.

"The link between the higher resolution weather model and the TopNet flow prediction model has only just been completed, but it should provide a far more accurate and timely warning of river flows than was possible before."

TopNet is simultaneously being tuned by another NIWA project to forecast river flows and floods, decades and even millennia into the future. A team working on regional climate models (RCMs) estimating future climates is modifying them to provide data for hydrological models that generate future water flow predictions across New Zealand.

NIWA's Dr Christian Zammit says preliminary results indicate that flood event characteristics are expected to change significantly in terms of duration and maximum intensity. *Water & Atmosphere* will report further on this project in a future issue.

Measuring up

To understand the magnitude of current and future floods, accurate data are essential. So when Whanganui and Dunedin flooded, NIWA's Ryan Paulik and Dr Kate Crowley went to survey the damage.

The team covers an average of six floods each year, recording flood depths against property and the cost of damage to buildings and economic effects from impacts on businesses. Their data feed into NIWA's RiskScape software, which is used to estimate impacts and losses (economic and social) for assets exposed to natural hazards.

RiskScape models are built on actual observed and quantified damage from previous hazard events like floods to human structures like buildings, cables and pipes, roads and waterways.

This year the pair surveyed over 80 buildings in Whanganui and 200 in Dunedin, noting the building types, the water depth and the type of damage, and they are estimating the cost of repair.

The NIWA data on Whanganui are not yet complete, and Ryan is reluctant to declare the Whanganui flood a 'record' for the city based on data they collected.

"The true costs of the flood event will not be known for some time. Although the data we collected are useful for estimating direct costs for buildings and contents damage immediately following the flood, economic losses associated with clean-up, temporary accommodation and business disruption will accrue for many months to come.

"It was the worst damage to residential buildings I have seen since joining NIWA. The high water depths in buildings and silt deposition made it extremely messy to clean up."

Hazards Analyst Ryan Paulik travelled to Whanganui shortly after the recent flooding. The data his team captured, including damaged properties shown here in yellow, will assist in planning for future events in the area. (*Dave Allen*)

The worst hit locations were low lying and near rivers.

"In Whanganui and Whangaehu, buildings were flooded by adjacent rivers breaching their banks, while in Waitotara flooding was mostly caused from a smaller stream running through the town.

"Pastoral farm land both upstream and downstream of Waitotara and Whangaehu were severely damaged from flooding and silt deposition."

Damage valuation is not an exact science, but the team is well practised. The valuations are based on estimates of what insurance companies will pay out for losses. So the NIWA team has calibrated past valuations against the initial and final assessments by insurance companies. To help understand the engineering impacts of water, they have included BRANZ (Building Research Association of New Zealand) experts on some of their field trips.

"We attend a range of different floods, to increase the relevancy of the data, but we're looking at flood events where the damage is in the millions of dollars.

"There's clearly a difference in costs when you have to replace a floor rather than clean it, but the judgement on when to replace is variable. Our data have to take into account a range of decisions made by insurance companies," he says.

RiskScape can be used for any resource or emergency management activity that requires information on natural hazard impacts or losses. The models estimate the damage inflicted by future floods with similar conditions.

Ryan's and Kate's property damage data from Whanganui and Dunedin will be added to a library of flood impact information. Each new data set is used to validate RiskScape's flood vulnerability models for buildings.

RiskScape users can apply these models to estimate building impact and loss for future flood events. This can support community decisions on selecting the most suitable options to avoid or mitigate flood damage, such as raising floor levels, removing buildings from the floodplain or upgrading stop banks.

Higher frequencies

A consistent complaint in public commentary this year was that floods described as 'one in one hundred year' events seem to be happening on a regular basis.

NIWA is currently recalculating the data and calculations behind these widely used estimates of how often New Zealand waterways flood. They were last published in 1989.

The estimates are essential because New Zealanders need to know how often rivers flood, to assess the value of adapting to them, and to set thresholds for the robustness and design factors of buildings and infrastructure.

Roddy Henderson of NIWA's Natural Hazards Centre says it is essential to update the estimates because New Zealand only has relatively short periods of data on record.

"We don't have a long record to assess: just over 100 years of data on river flow, and nearly 150 years of rainfall data.

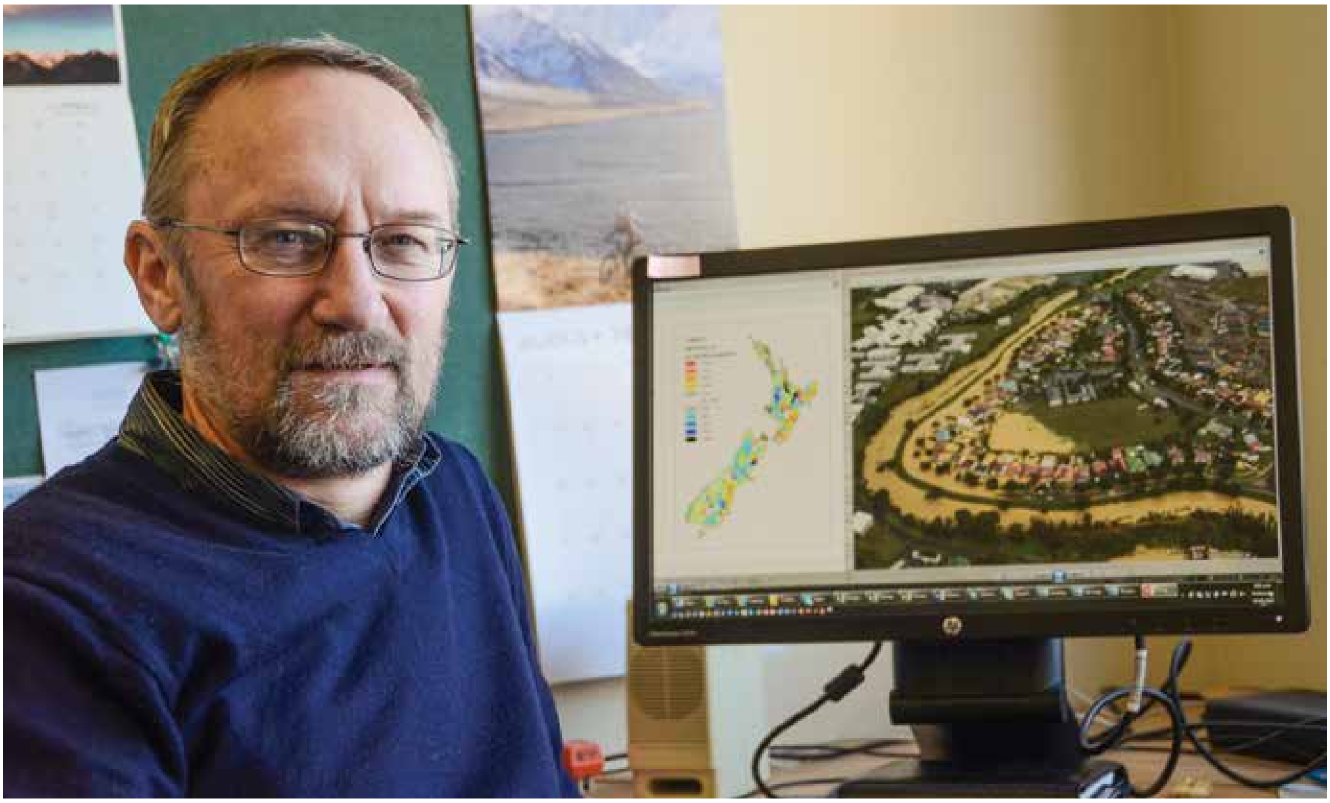
"In that context, missing the most recent 25 years of data means we're missing a big chunk of certainty."

Using grants from the Government's Envirolink fund, and its own resources, NIWA is updating the calculations by including the past 25 years of data, and re-working the original procedures.

The intention is that the calculations will become a dataset in the online Stream Explorer service. Users will be able to click on any waterway to see its flood frequency calculation.

"It's a very ambitious thing," Roddy admits. "Our intention is to build a more objective model than the existing flood estimates use."

Roddy says NIWA's re-calculations use actual flow data and models to estimate the likelihood of floods across any waterway.



Roddy Henderson, of NIWA's Natural Hazards Centre, is building a more objective model than the one behind the infamous "one in one hundred years" flood estimates. (*Greg Kelly*)

"We pick peak flows from data measuring flow rates in waterways, then find the mean of those. That allows us to estimate the period in which the amount of water exceeds the peak flow.

"We model those flow data across all non-monitored streams, using factors such as rain intensity across the catchment in which the stream lies, differences in land use, and soil make-up. We can improve accuracy by including enough real-world records of similar waterways and catchments.

"That combination will provide us rules to apply to any waterway in any region."

Roddy says the new calculations will also account for uncertainty. The current flood frequencies are based on the idea that the model is right. The new frequencies will be based on an assumption that even the improved model is imperfect. The result is a more accurate estimate of flood frequency.

The re-calculated flood frequency estimates are expected to be available later this year.

Making change

Knowing when floods will hit, and how hard, is the first half of the solution. NIWA's Andrew Tait says local government and other owners/operators of buildings, infrastructure and services must use the information to take a 'risk-based approach' to managing their systems.

"The likely effect of climate change on extreme events, based on the best available information, should be included in all such risk assessments.

"Practical steps can be taken, based on risk assessments, to reduce community vulnerability to changes in extreme climatic events such as flooding and coastal storms. These should be based on continuous assessment and evaluation of the hazard, and frequent community consultation.

"Options include re-zoning hazardous areas, hardening infrastructure and buildings, upgrading infrastructure such as stormwater pipes and flood protection schemes, raising mandatory floor levels in new developments, and putting in place stronger consenting regulations for building in hazardous locations."

The Auckland Council agrees, adding that innovation, not over-engineering, could be the most effective way to cope with increasing flood risks in New Zealand.

With urban development accelerating rapidly in New Zealand's biggest city, incidents of surface flooding are on the rise. Stormwater modelling incorporating climate change data had shown increasing frequency and severity of flood risks in the Auckland region.

Strategic planning team manager Claudia Hellberg says the increasing incidence of surface flooding often led people to

Data from the regional council showed parts of Wellington recording the heaviest hourly rainfall in more than 50 years on 14 May 2015. Drainage systems struggled to cope, causing disruption to major transport routes around the city and the Kapiti Coast. (*Dave Allen*)

demand bigger drains to cope with excess runoff. However, that was an overly simplistic approach.

"Stormwater management is now not just about drainage and the creation of dry land. Stormwater management looks at all the impacts of stormwater runoff on the health and safety of people as well as the environment.

"For example, increased impervious surfaces in an urban environment escalates the volume and peaks of stormwater flows into streams, which leads to increased stream erosion."

Auckland Council's response to the problem is its Water Sensitive Design approach, which incorporates stormwater management into each level of development planning.

"This involves the integration of land use and water management to minimise adverse effects on freshwater systems and coastal environments, particularly from stormwater runoff."

NIWA has assisted Auckland Council's development of the Water Sensitive Design approach by conducting studies that assess the state of the environment in the Auckland region – required to demonstrate the need for implementing different ways to manage stormwater.

Hellberg says the council's approach also encompasses the utilisation of natural flow paths to increase resilience for increased flows to be expected in the future as a result of climate change.

A bigger umbrella

Sam Dean says that recent improvement in understanding and forecasting floods is only now beginning to flow into better flood planning and prevention.

"As climate change begins to bite, the public should expect more flooding in the short term.

"Infrastructure built to carry water out of towns and cities is designed for historical amounts of water. As we see increased amounts of rain over short durations, you might see these systems starting to fail more often.

"That's why it is so important to fine-tune the understanding of flood mechanics, and connect the science to improve flood forecasting.

"The challenge now is to apply what we know about the causes of floods, and the added risks of climate change, to make adaptations in how we live and work," he says.

(*Dave Allen*)

Misty frequencies

This year Dunedin was said to have experienced a 'one in one hundred year' flood. Last year several Christchurch floods were each labelled in the same way.

"This phrase is too loosely and inaccurately used – it drives you mad," says Roddy Henderson, Group Manager Applied Hydrology at NIWA, of the oft-used expression.

"I can understand the public's frustration. They will hear that storms of different magnitude, happening three successive months in a row, are all one in one hundred year events."

A so-called one hundred year flood does not mean that there is one flood of this size every one hundred years. It means that there is a one in one hundred chance that a flood of this size or bigger will happen in any given year.

Therefore, it is statistically possible for the 'one in one hundred year' flood to happen back to back.

That's why NIWA refers to something called the annual exceedance probability (AEP). This is the probability that a river will exceed a given design flood in any given year. Thus, a one per cent AEP flood has a one in one hundred chance of occurring in any given year at a given location.

There is about a 65 per cent chance that there will be at least one one-per-cent-AEP flood in populated catchments of New Zealand in any year. So it is a fair bet that somewhere in New Zealand each year we will see what may be misguidedly called a 'one in one hundred year flood'.

The 'one in one hundred years' phrase is sometimes used to describe only the worst factor of any flood.

For example, early application of the phrase to last year's Christchurch floods was linked to the extraordinary amount of water collected by a rain gauge at the Botanic Gardens over an 18-hour period.

NIWA Principal Scientist Meteorology Dr Mike Revell said at the time that water collected at other rain gauges around Christchurch indicated storm return periods ranging from one in three years right up to the one in one hundred. Clearly it wasn't useful to pick just one rainfall gauge to classify the whole storm.

Moreover, the correspondence between storm rainfalls and river flood peaks is not straightforward, so that a rare one per cent AEP rain event doesn't necessarily mean it was a one per cent AEP flood.

Why do people use the 'one in one hundred year' concept if it's so misleading?

Henderson says the phrase persists because it is in common use in planning, engineering and policy circles.

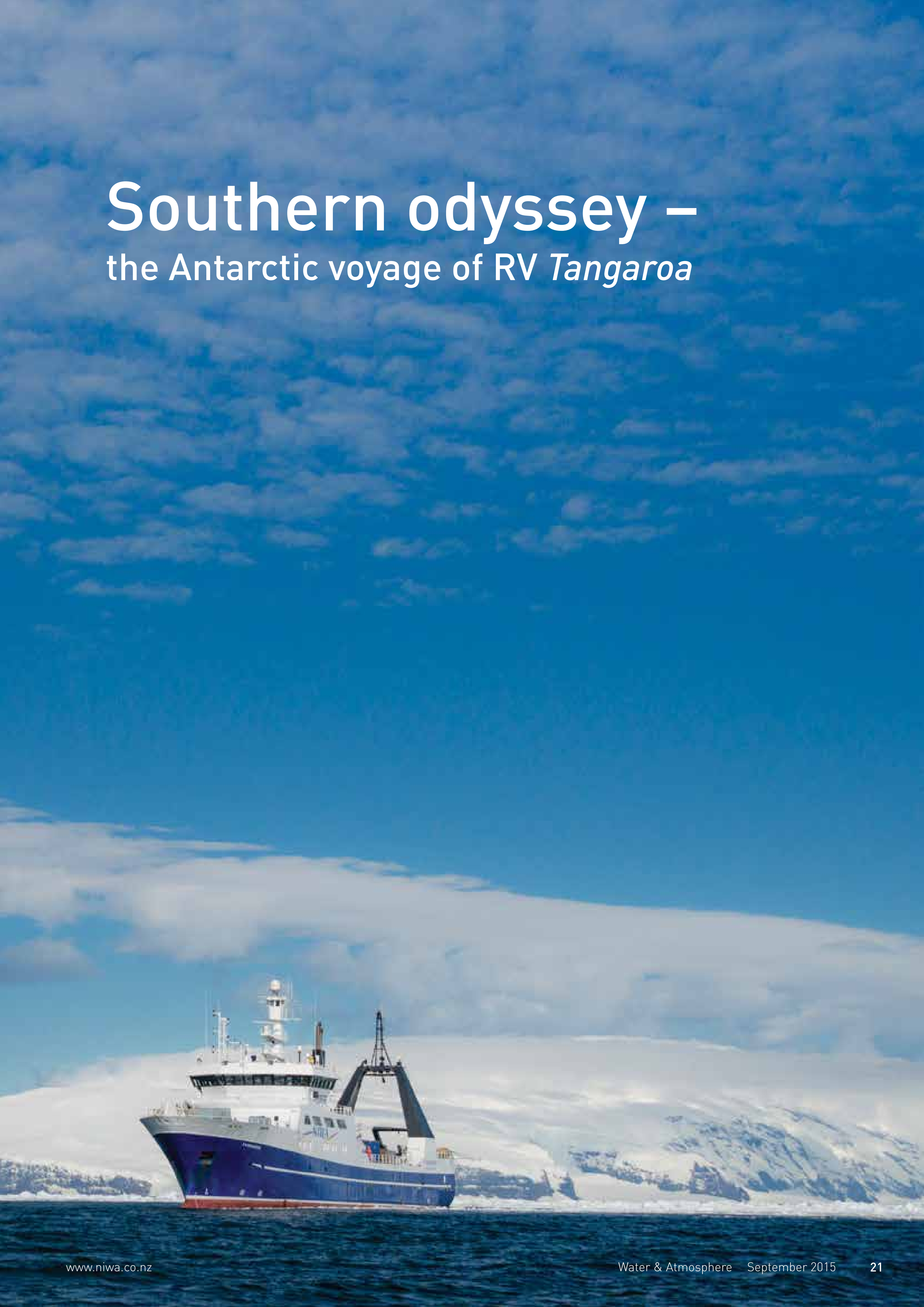
"It is used to define thresholds for building and infrastructure rules. For example, the height of a floor is sometimes set to avoid a one in one hundred year flood.

"We know that it's referring to the AEP of the waterway, but the public don't."

Tangaroa, north of Sturge Island, Balleny Island group. (*Dave Allen*)

Southern odyssey –

the Antarctic voyage of RV *Tangaroa*



On a still summer morning during one of Wellington's best summers, *Tangaroa* slipped from its berth on Aotea Quay, ready for 42 days at sea. A lifeboat drill in the harbour focused the complement of 21 scientists and 19 crew into the state of calm alertness they needed for their journey into Antarctic waters in pursuit of great science.

Voyage leader Dr Richard O'Driscoll left no room for mis-interpretation with his pre-departure briefing: a safe return was the top priority, and there was a full schedule of scientific projects to accomplish the voyage's objectives. Master Evan Solly, ice pilot Scott Laughlin, O'Driscoll and many of the crew and scientists had previous experience in Antarctic waters, but *Tangaroa* was voyaging beyond the easy reach of rescue missions, into an environment that can change with little warning from benign to hostile.

The ship steamed through the Wellington Heads, crossed Cook Strait then hugged the Kaikoura coast, opening the possibility of an early whale encounter and milking the last cellphone coverage before the ship left New Zealand behind. Off Banks Peninsula, the master set a course of 180 degrees – due south.

No-one on board would stand on dry ground again until *Tangaroa*'s return to port six weeks later.

Voyage leader Richard O'Driscoll working on the trawl deck. (*Dave Allen*)

THE SCIENTIFIC OBJECTIVES

The Antarctic Voyage was funded by Antarctica New Zealand (ANZ), Ministry for Business, Innovation and Employment (MBIE), Australian Antarctic Division (AAD), and National Institute of Water and Atmospheric Research (NIWA). It had the following objectives:

- determine factors influencing the distribution of humpback whales around the Balleny Islands
- characterise the blue whale foraging 'hotspots' in the northern Ross Sea
- survey the Ross Sea slope to estimate abundance, measure distribution, and collect biological data for stock assessment of grenadiers and icefish
- deploy a moored echosounder to study winter spawning of Antarctic silverfish in Terra Nova Bay
- undertake oceanographic and atmospheric observations of the Southern Ocean to contribute to increasing the understanding of the implications of climate change.

Science from the sea

The research expedition had been more than a year in the planning, now the science was underway.

As soon as *Tangaroa* moved into open water, oceanographic and atmospheric recording systems began their work, the continuous plankton recorder was deployed and the array of acoustics equipment was tuned to pick up the first faint sonic rumble of blue whale calls.

The acoustics would guide the expedition towards encounters with the elusive blues that were the focus of one of the voyage's main scientific objectives.

But the mission of the 2015 voyage was much broader – to undertake ecological studies of Ross Sea marine foodwebs of importance to the ocean's top predators.

Listening for whales

A highly experienced team of 10 experts from the Australian Antarctic Division was led by Mike Double, Hobart-based marine mammal specialist. They were aboard to make blue whale observations and sampling as part of the multi-national Southern Ocean Research Partnership.

Whale research has a fittingly global perspective and strong research links among organisations convened by the International Whaling Commission. The united approach to research is reflected in the make-up of the scientific teams – among the personnel were leading marine mammal experts from Scotland and the United States alongside Australians and New Zealanders.

Brian Miller (above) and Kym Collins from Australian Antarctic Division in the acoustic lab, listening to whale calls via sonobuoys. (*Dave Allen*)

NIWA's cetacean specialist, Dr Kim Goetz, was researching the abundance and dietary preferences of humpback whales, and was quietly confident the whales would be massing around the feeding hotspot of the Balleny Islands, first stop on the voyage's track towards the Ross Sea.

After a relatively smooth passage through the Roaring Forties and Furious Fifties, *Tangaroa* encountered the first icebergs after crossing 60 degrees on the fifth day of the voyage. As the sea became eerily calm. The bergs' other-worldly shapes seemed to float on a bed of light. Every camera on board was trained on the ethereal shapes, and by the time *Tangaroa* steamed into the deep south latitudes the sea's surface was lightly peppered with icebergs.

In *Tangaroa*'s dining mess, the newbies – the half-dozen on board who hadn't crossed 60 degrees south before – were inducted into the "Court of King Neptune" with a visit from the seaweed-headed monarch of the oceans. The ancient tradition that initiates young sailors is less rigorous than the days when the young ones were stripped and tarred and dunked overboard, but *Tangaroa*'s rite of kissing a dead salmon was the focus for a ceremony that brought some welcome hilarity, song and dance and then a quiet prayer for safe passage.

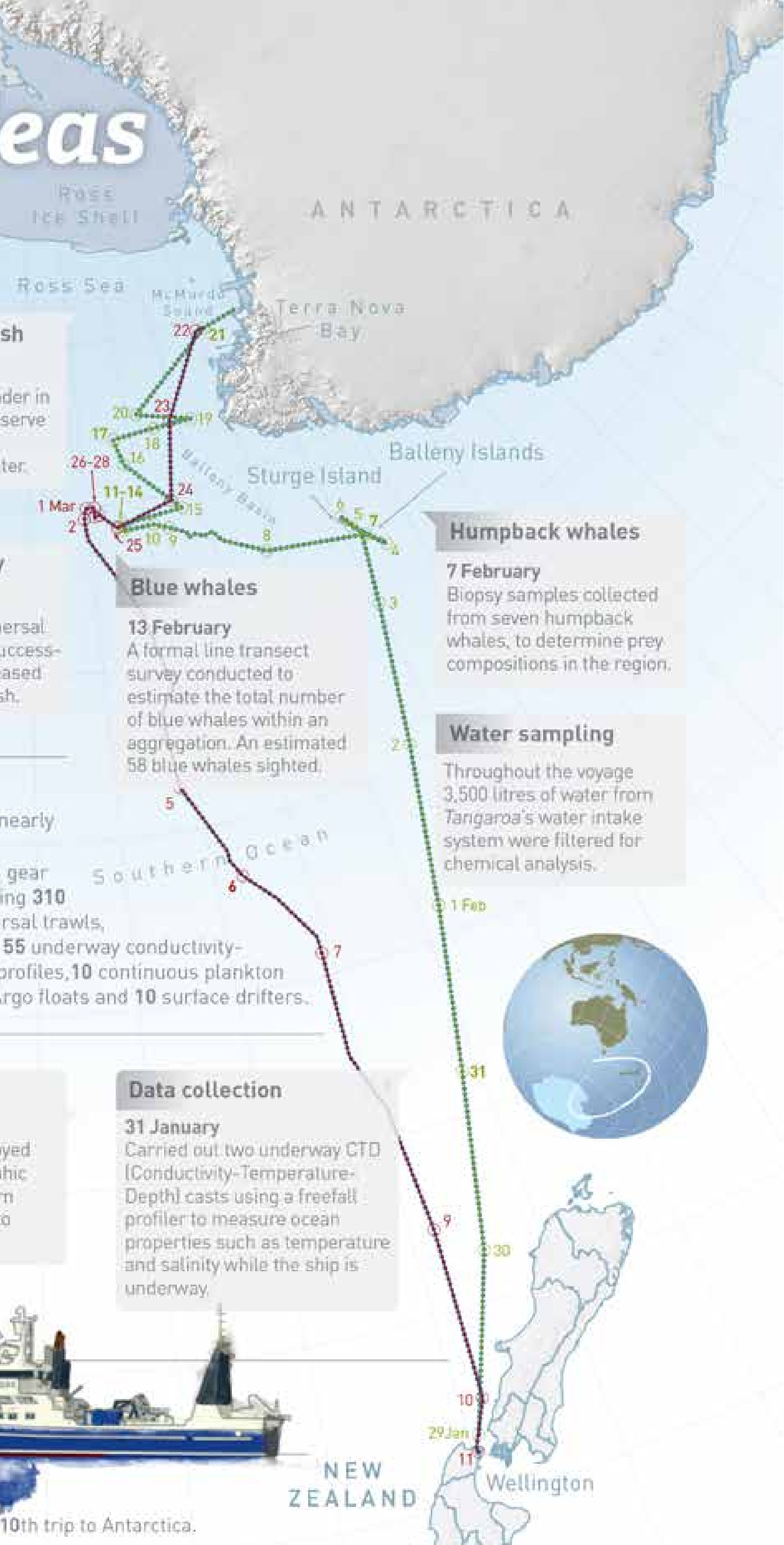
Below the surface, other massive creatures were navigating south as well. Blue whales had been identified by the tracking buoys and their positions identified by triangulating the signals. The science of acoustic whale tracking is relatively young, but the practitioners aboard *Tangaroa* were among the world's most proficient and experienced.

"What we're doing down here is listening for whales," said passive acoustics leader Brian Miller of the AAD. "Using acoustic sonobuoys usually used by the military, we're listening for sounds and triangulating positions to pinpoint individual animals, then steering *Tangaroa* close enough to make a visual identification."

Paul Ensor and the AAD team guide the vessel closer to Antarctic blue whales. (*Dave Allen*)

Voyage to Southern Seas

29 January - 11 March, 2015



Why did we go?

With five key science objectives, the voyage set out to collect data and observations on ecosystems and species of the Antarctic waters.

These objectives included:

Humpback whales

Determine factors influencing the abundance and distribution of humpback whales around the Balleny Islands.

Blue whales

Habitat characterisation of blue whale foraging 'hotspots' in the northern Ross Sea.

Demersal fish survey

To estimate abundance, measure distribution, and collect biological data for stock assessment.

Antarctic silverfish

Deploy a moored echosounder to study spawning of Antarctic silverfish in Terra Nova Bay during winter.

Data collection

Oceanographic and atmospheric observations of the Southern Ocean to contribute to process studies and global datasets.

Antarctic silverfish

21 February
Moored an echosounder in Terra Nova Bay to observe potential silverfish migration during winter.

Demersal survey

17 February
Carried out four demersal trawls, caught and successfully tagged and released two Antarctic toothfish.

Blue whales

13 February
A formal line transect survey conducted to estimate the total number of blue whales within an aggregation. An estimated 58 blue whales sighted.

Humpback whales

7 February
Biopsy samples collected from seven humpback whales, to determine prey compositions in the region.

Water sampling

Throughout the voyage 3,500 litres of water from *Tangaroa*'s water intake system were filtered for chemical analysis.

Events of note

The voyage covered nearly **15,000** km.

There were over **400** gear deployments, including **310** sonobuoys, **18** demersal trawls, **22** midwater trawls, **55** underway conductivity-temperature-depth profiles, **10** continuous plankton recorder tows, **12** Argo floats and **10** surface drifters.

Buoy overboard

6 March
Final Argo float deployed to collect oceanographic information and return the data via satellite to New Zealand.

Data collection

31 January
Carried out two underway CTD (Conductivity-Temperature-Depth) casts using a freefall profiler to measure ocean properties such as temperature and salinity while the ship is underway.

The vessel and its people

RV *Tangaroa* is New Zealand's only ice strengthened research vessel. Equipped to deliver a wide range of environmental survey and ocean science work, including fisheries surveys, this voyage was *Tangaroa*'s **10**th trip to Antarctica.

Vessel facts

The name *Tangaroa* is the Māori god of the sea.
The vessel is **70** metres long and weighs **2,291** tonnes.

On board

21 scientific and technical personnel.
19 vessel personnel including two cooks and a doctor.

Voyage leader

Dr Richard O'Driscoll (left).

Voyage key

Outbound | Inbound

Midday points

19 20

0 200 400
Kilometres

Data sourced from NIWA
Voyage TAN1502
www.niwa.co.nz
Illustrations: Arie Ketel

WHALES IN FOCUS

The objectives of the whale observations were to assess in detail the abundance and health of the populations, but also to discover what they were eating.

During the voyage:

- 106 humpback whales were sighted at the Balleny Islands; and more in other areas
- spatial correlation between whales and krill was confirmed
- no evidence was found of whales feeding on fish (despite earlier indications from isotopes).
- using sonobuoys, more than 40,000 blue whale calls were detected
- 58 individual blue whales were photo-identified
- Blue whales were concentrated in one main hotspot, and tracked southeast
- 11 acoustic grid surveys mapped krill distribution around feeding blue whales
- video observations captured whale foraging behaviour

Blue whale. (*Dave Allen*)

Blue whale. (*Dave Allen*)

Humpback whale. (*Dave Allen*)

Humpback whale. (*Dave Allen*)

Antarctic blue whales make a couple of different types of calls, some just barely audible to us, says Miller. "They are very bassy, just a low rumble, and you almost feel them more than you hear them."

During the voyage, the acoustics team would deploy 310 sonobuoys. The metre-long cylinders are usually deployed from the air for military purposes – this peacetime scientific deployment is unusual.

On Day 7 the austere, uninhabited Balleny Islands hoved into view. This string of three main islands – Young, Buckle and Sturge – plus three smaller islands lies at 66 degrees south, some of the most southerly land before the Antarctic continent. The volcanic rock and glacier islands cover about 400 square kilometres and rise to 1,705 metres.

The archipelago was named after English whaling captain John Balleny, who was there for the same reason – though with very different intentions – that *Tangaroa* was visiting: the area is a known feeding hotspot for whales. And, as predicted, the animals were feeding en masse around Young and Buckle and sightings were made of humpback and minke whales and orca. Midwater trawls revealed the reason they were there: healthy catches of krill.

Oddly, the waters around Sturge Island had been vacated, something of a surprise to Kim Goetz. "It was like a desert. There were no krill, there were no whales ... it was like a dead zone."

As she works through the wider data collected, Goetz hopes to solve the mystery. "It might have been something unique to this year ... I'm looking at some things like the abundance of krill, or how deep the water is, or how the ice was moving. It could just be something as fundamental as the ice being different this year."

Tangaroa was soon back on the trail of the big blues as they tracked east away from the Ballenys, en route to the Ross Sea.

Veteran whale spotter Paul Ensor has spent many years observing blue whales and says they can be very unpredictable. "That's one of the challenges. If the whales are swimming in a straight line at a constant speed it's relatively straightforward, but that is rarely the case."

From the freezing monkey island on top of the *Tangaroa* bridge, with his team of spotters, Ensor called in course and speed corrections and to the bridge – "Four knots please and three degrees to port ..." – to get in proximity to the massive mammals which arched and blew on their course through the feeding grounds. "It's quite a challenge, but it's one I really enjoy."

At this stage of the voyage, sightings' leader Paula Olson says the team had photo-identified 18 blue whales – one four times. "We first identified it at the Ballenys; three days later we photographed it in an area of blue whales to the east of the Ballenys, then twice more. So it's been moving with us – or we've been moving with it."

"We aim to get photographs of individually identifiable Antarctic blue whales." Every animal is unique and identifiable because of the mottling pattern on its flanks, Olson says.

Photo ID is really useful for a number of reasons, she says: one is to estimate abundance, but photos can also be used to identify migration patterns and for life-history parameters such as calving intervals and life expectancy.

Double said getting close enough to take photographs, and possibly a biopsy sample, was a valuable outcome. Photographs provide information on individuals; biopsies provide additional information like diet and genetics.

"Other species, like the humpback, tend to travel closer to land, so we can study them at close quarters, monitor the numbers of individual animals and their migration."

A century of commercial whaling devastated populations before it was banned in 1964. Blue whales were hunted to near-extinction.

"We've now established that populations of humpbacks are recovering well. But we can't say that for Antarctic blue whales – they're not easy to study. The only way we can get a clear picture is to come down here and work with the blues," says Double.

Now that scientists have developed the tools to find blue whales really efficiently, the logistics of an Antarctic research voyage are more manageable, he says. "Now we can look at them more closely to see what is their habitat, what are they eating, what is the nature of the krill they are eating, why they tend to congregate in hotspots."

These are the questions that enable critical decision-making to ensure the continued health and recovery of Antarctic blue whale populations.

ICE TRANSIT

- First iceberg sighted: 62 degrees South
- Ice types: bergs, bits, brash ice, pack ice, slushy pancake ice
- Sea ice extent: above February median

Into the ice

Inside the invisible ring marked by 60 degrees south, the crew was officially in the Southern Ocean, and *Tangaroa*'s constant companion and enemy was the ice: bergs, floes and pack-ice each present difficulties for a 70-metre 2291-ton vessel.

Ice pilot Scott Laughlin was on the voyage to guide *Tangaroa* through the Antarctic waters. He has deep experience navigating through hazardous ice formations and supplies local knowledge and advice on travelling through iced oceans.

None of the ice *Tangaroa* encountered during the voyage was any danger to the vessel, but there were areas where progress was slowed, says Scott. The Southern Ocean was relatively benign for the voyage – moderate swells and light or moderate winds, visibility coming and going, and icebergs relatively few and far between. It was one of the calmer polar voyages Laughlin had experienced.

Laughlin is a cool customer, trained for calm leadership in the extreme locations and dangerous conditions of the icy latitudes. With 15 years' Southern Ocean and Antarctic experience including skippering Australian research vessel *Aurora Australis*, his role aboard *Tangaroa* was to guide the vessel into, through and out of the icepack without incident.

In a remote area like Antarctica, a ship faces grave risks, Laughlin says. "The greatest danger," he says, "is holing the vessel and having to abandon ship onto the ice. One of the reasons I was there was to make sure we didn't get into a situation where we needed to be rescued."

Ice conditions were difficult, with no full clearing of the Ross Sea and accumulation of wind-driven ice around the Balleny Islands and the entrance to Terra Nova Bay. It prevented access to some trawl sites and access to some of the acoustically detected Antarctic blue whales.

Tangaroa in pack ice. (*Glen Walker*)

BY THE NUMBERS

Tangaroa made 400 gear deployments during the voyage including:

- 310 sonobuoys
- 18 demersal trawls
- 22 midwater trawls
- 55 underway conductivity-temperature-depth profiles
- 10 continuous plankton recorder tows
- 12 Argo floats
- 10 surface drifters

Although the ice did not endanger the vessel, routes through the pack had to be carefully managed, and some prospective trawl and observation locations were changed when the ice was sized up.

"I was there to give the master my advice – everything about the weather, the currents, topography and bathymetry of the area, looking at where the ice was going to move according to the weather systems, what sort of ice the vessel would encounter, and how we could best mediate our voyage. The end goal was to get safely back into Wellington," he said.

"On a research vessel, the underlying strategy is to keep the programme going smoothly."

Trawling for knowledge

Two of the target trawl areas were the Iselin Bank and the Mawson Bank, and *Tangaroa*, having collected a cache of whale sightings and the first successful blue whale biopsy, began to focus on the toothfish and its associated prey species. The valuable Ross Sea toothfish fishery is the target of fishing boats from more than 10 countries.

Fisheries specialist O'Driscoll says the voyage wasn't as interested in the toothfish as much as the bycatch – the prey species for toothfish in this area – to help inform the management of the fishery. But during the trawls, seven toothfish were caught, six tagged and released alive; one 51 kilogram fish damaged by the trawl was retained and eaten aboard.

In the central Ross Sea at 72 degrees south, *Tangaroa* was trawling through one of the most remote places on Earth. Over the course of the voyage, 18 trawls were carried out at randomly selected sites and more than 90 species or species groups of fish and invertebrates were caught. The main species caught by weight were grenadiers, toothfish, skates, sponges, jellyfish and silverfish.

"This was really important research for our understanding the ecosystem effects of the toothfish fishery – about 3,000 tonnes of toothfish are taken from the Ross Sea each season."

Echosounder winters over

One of the keystone prey species in the Ross Sea that the scientists were keen to study was the Antarctic silverfish. The eggs and larvae are abundant during spring under the surface ice in Terra Nova Bay – a haven on the Antarctic coast in the lee of Cape Washington and under Mount Melbourne. But how do they get there? Are they spawned elsewhere and drift in under the ice? Or is there a mass migration of silverfish to coastal spawning sites during the winter?

When *Tangaroa* arrived there on 21 February, the cloud cleared to reveal a scene of perfection – glassy, calm water with fresh ice just starting to form in the bay, several large icebergs floating nearby, no swell and negligible wind. Two days later, the bay would be iced shut, but for now, perfect conditions allowed scientists to complete another of the voyage's objectives – to moor an upward-looking underwater echosounder 550 m deep in the bay, and test the theory that the silverfish swim in to spawn.

The echosounder will keep a constant watch on the area to monitor the traffic during winter, and will be retrieved by Italian colleagues from the Mario Zuchelli Station sometime after December 2015 when it would have run for 200 days.

Understanding silverfish ecology will help reduce uncertainty in predictions about the impacts of environmental change on the coastal Antarctic system. Because of the influence of sea-ice on silverfish biology, future changes in the Ross Sea, driven by global warming, may impact spawning success and abundance of silverfish.

Sampling the sea and air

The size and remoteness of the Southern Ocean means it is under-sampled compared with other areas of the world's

PRIMARY PRODUCTIVITY

Marine ecologist Dr Sarah Bury led the research team measuring the changes in the ocean biogeochemistry. The sampling involved:

- nearly 1,000 hours of continuous underway oceanographic and atmospheric data collection
- over 3,500 litres of seawater filtered
- 33 onboard experiments to measure primary production

Sarah Bury with one of her seawater incubators – part of an experiment designed to measure phytoplankton nutrient uptake and primary production rates. (*Dave Allen*) oceans. *Tangaroa*'s voyage therefore was an opportunity to address the deficiency of data that can be used to understand processes and what they mean for global ocean models.

Plankton recording continued throughout the voyage to determine the spatial distribution, diversity and abundance of phytoplankton and zooplankton near the surface in the Ross Sea region and during the transit to the Ross Sea.

Underway sampling was carried out on the voyage through a seawater intake in *Tangaroa*'s hull and processed through a series of inline electronic instruments to measure surface temperatures, salinity and all the measurements that affect the productivity of the ocean.

Marine Ecologist Sarah Bury led the continuous collection of water samples on the voyage and the experiments on the algal biomass supporting the krill. It is probably the high krill and phytoplankton abundance that attract the humpback whales to the feeding grounds around the Balleny Islands.

"From satellite imagery we could see these high concentrations of algal biomass at the Balleny Islands during the four summer months of the year when the humpbacks are feeding there," she said. "An algal bloom in the western margin of the Ross Sea also produced valuable data that we can compare with the productivity around the Balleny Islands and the rest of the Southern Ocean."

In parallel with the ocean sampling, a variety of instruments were busily sampling the air. Continuous high-precision underway measurements of carbon dioxide and methane greenhouse gases would shed more light on Southern Ocean processes in the region that is recognised as an important carbon sink.

Cloud processes were studied with the deployment of a ceilometer that made measurements of the altitude, depth and base of cloud layers, the height of the marine boundary-layer and super-cooled liquid cloud occurrence in the region where only satellite measurements exist.

The ceilometer uses lidar to "sound" the atmosphere to a height of 8 km in the same way sonar uses sound waves to measure the depth of the ocean, or radar uses radio waves to detect aircraft. The voyage made measurements that were the first of their type in the region using modern instruments – an important and successful proving occasion for the technology. Plans have evolved since the voyage for future deployments to contribute to the Deep South National Science Challenge and to inform and improve climate models.

Cloud processes were also explored in collaboration with colleagues in the USA at Colorado State University and Scripps Institution of Oceanography. Scientists there are trying to answer the question 'Why doesn't it snow as much as expected in the Southern Ocean?'

CPR – Continuous Plankton Recorder deployment. (*Dave Allen*)

Yoann Ladroit prepares the underway CTD for deployment. (*Dave Allen*)

This voyage was the first in 30 years to investigate the nature of ice nucleation particles in the air. The research will be an important source of uncertainty in modeling cloud behaviour and the radiation balance of the oceans.

On board to learn

Tangaroa's southern voyage was the ultimate field trip for the education of three young scientists

Pablo Escobar Flores, PhD student from the University of Auckland was aboard as part of his research being supervised jointly by voyage leader Richard O'Driscoll and University of Auckland Professor John Montgomery.

Pablo's thesis studies the gap between fisheries and oceanography and how to bridge it, with a close focus on using acoustics from vessels of opportunity to monitor pelagic ecosystems in the Southern Ocean. The voyage gave Pablo the opportunity to work in a large multidisciplinary research programme and three midwater trawls during the voyage were specifically targeted to collect biological data for Pablo's PhD study.

NIWA's support for upcoming scientists and its enduring support for the work of the Sir Peter Blake Trust brought aboard two first year University of Otago students as the trust's Science Ambassadors. The collaborative programme invests in the future of New Zealand marine science by building capability and understanding in young New Zealanders.

Blake Hornblow and Zachary Penman joined the voyage to work across every discipline from lab technician duties to toothfish catch-and-release, whale observation and meteorological data capture, and their youthful zeal and enthusiasm added a fresh dimension to the voyage.

Blake Hornblow adds mercuric chloride to sea water to kill the phytoplankton and stop biological activity in *Tangaroa*'s middle lab. (*Dave Allen*)

Blake Hornblow (left), Pablo Escobar (centre) and Zac Penman (right) on the 'Monkey Island' in Terra Nova Bay. (*Dave Allen*)

The explorers. (*Dave Allen*)

Turning for home

With most of the scientific objectives in the bag, *Tangaroa* headed north. Leaving the Ross Sea for another tussle with the raging wind and seas of the Southern Ocean.

There was still one more unique whale encounter on the homeward leg. Blue whales heard east of Stewart Island were tracked, and one was sighted off Cape Campbell, only a few hours south of Wellington. Voyage leader O'Driscoll said this was the first time in over 15 years' experience working off NZ that he had seen a NZ blue whale. "It just shows how good the acoustic methods are at finding blue whales", he said.

The voyage had been a journey into solitude, with only three other vessels sighted in Antarctic waters. One yacht was contacted as it left the Ross Sea travelling north, and the passenger vessel *Professor Khromov* and supply ship *Maasgracht* were both in Terra Nova Bay when *Tangaroa* deployed the echosounder mooring.

More than 1500 samples and specimens came back to Wellington with *Tangaroa*, enough lab work to keep technicians at NIWA's Wellington site busy for months – analysing and cataloguing. Combined with the broad work on ecosystems, foodwebs, marine mammals and fisheries, the voyage's achieved all its scientific objectives.

The voyage's successes align with New Zealand's Antarctic and Southern Ocean science directions and priorities and help to fulfil our international obligations under CCAMLR (Commission for the Conservation of Antarctic Marine Living Resources) and the IWC (International Whaling Commission).

It also contributed to larger collaborative programmes of research on improving the understanding of Antarctic and Southern Ocean responses to climate change and variability.

Forty-two days after the team left Wellington, *Tangaroa* returned safely to Aotea Quay, the only losses being a couple of bobbins from a trawl net, a hard hat with ear-muffs attached and one blue rubber glove.

Otherwise, everything that went down to Antarctica came back. Waste oil was retained onboard; no ballast water, sewage or grey water was discharged into the marine environment south of 60 degrees, and food waste was managed meticulously. Poultry waste was frozen, and along with all other plastics, paper and metal, retained for disposal on return to New Zealand.

That qualifies the 2015 Antarctic ecosystems voyage as a clean journey and an unqualified scientific success.

Antarctic portrait

NIWA photographer Dave Allen, joined the *Tangaroa* voyage to Antarctica in February.

Adelie penguins.


SAFETY FIRST

Antarctic portrait

Q&A

South for winter

The Southern Ocean is our marine backyard. Its boundary laps against the south of the South Island. To find out how the Southern Ocean affects life in New Zealand, we went to NIWA's Dr Mike Williams, physical oceanographer.

What influence does the Southern Ocean have on the waters around New Zealand?

Bridging New Zealand and Antarctica, the Southern Ocean reaches all the way from Antarctica to the Subtropical Front. This is the boundary where water from the tropics meets water from the polar region. At this front, there is a sharp change in temperature and salinity (how salty the ocean is).

The Subtropical Front flows around the bottom of the South Island, from Fiordland, around the Otago coastline and north to Banks Peninsula, where the Chatham Rise steers it back out into the Pacific Ocean.

The relatively cold Southern Ocean waters keep the waters around southern New Zealand and our subantarctic islands cold. This gives southerly winds coming from Antarctica no chance to warm before they hit New Zealand.

The vast stretches of the open water in the Southern Ocean provide space for the strong westerly winds to build large waves and swells. These stirred-up seas make their way to New Zealand's coast and beaches, and play a role in shaping the country's southern coastline.

Does the Southern Ocean contribute to the survival of marine life around New Zealand?

The mixing of the Southern Ocean with tropical waters at the Subtropical Front helps create some of New Zealand's most biologically productive regions.

The Southern Ocean, while rich in other nutrients, lacks iron. But when it meets the warmer subtropical waters, it creates ideal conditions for phytoplankton to thrive and support the ocean's food web. In turn, this contributes to the rich ocean ecosystem that surrounds the country providing nutrition and habitats for fisheries.

An example of this is the thriving fishery on the Chatham Rise, which provides 60 per cent of New Zealand's total fish catch.

What can the Southern Ocean tell us about climate change?

The Southern Ocean provides a roundabout for the world's largest oceans. It is the great connector for deep ocean circulation, linking the Atlantic and Indian Oceans with the Pacific Ocean.

It is also where the heaviest waters in the global ocean are made, and where there is significant absorption of atmospheric carbon dioxide (CO_2) into the ocean.

This makes it a key place for understanding climate change, as the dense waters and high uptake of CO_2 help bury atmospheric CO_2 into the ocean. Scientists studying the Southern Ocean can observe and measure these changes in the climate, and using climate models can make predictions about the future.

Research has revealed that the Southern Ocean has been getting warmer, with waters between 500m and 2,000m warming about 0.002ºC every year.

Does the Southern Ocean affect El Niño and La Niña climate patterns?

The Southern Ocean doesn't directly affect El Niño and La Niña, but they may influence the Southern Ocean.

El Niño and La Niña are the two phases of the El Niño Southern Oscillation (ENSO), a naturally occurring phenomenon that involves fluctuating ocean temperatures and air pressures across the Tropical Pacific.

Although concentrated in the Pacific Ocean, variations in ENSO have a global reach including into the Southern Ocean. For example, changes in ENSO indices correlate with changes in the extent of the sea ice around Antarctica.


(Dave Allen)

Profile

The Duke of Hazard

Rob Bell is happiest occupying the high ground.

With a 35-year career in researching, modeling and monitoring natural hazards, such as king tides, coastal inundation, storms and tsunami, he knows that elevation from coastal margins is the only true protection from a potentially turbulent future.

The 59-year-old coastal oceanographer, who holds a PhD from the University of Canterbury in Civil Engineering, consults extensively on coastal and estuarine environmental projects, particularly the effects of coastal wastewater discharges, dredging, coastal hazards and the impacts of coastal climate change.

Rob's interest in all things water began growing up in Pareora.

"I grew up in a small coastal village with a river nearby – a wide-ranging backyard to play in and try out activities such as damming small river channels or jumping off the railway bridge.

"Those things got me interested in water, but my initial passion was for mathematics and science at high school. I wanted to build a career on science, but at the same time wanted to be working on practical solutions."

It was in Rob's last year at Timaru Boys High School that a career turning point came.

"The best advice I got came from my Year 13 science teacher, a Bachelor of Engineering, who suggested I enrol in Civil Engineering at the University of Canterbury. I specialised in environmental fluid mechanics and did a PhD in riverbed sediment transport in floods, and I haven't looked back.

"I was fortunate in riding the wave of the 1980s and '90s in cleaning up wastewater outfall discharges into coastal waters, particularly driven by tangata whenua. Through these infrastructure projects and an early research project on tidal mixing, I learned coastal oceanography on the hoof through books, computer modeling and lots of field work at amazing coastal areas, observing the processes first-hand."

"I also had a very unique opportunity to learn about the destructive power of tsunamis, when I went to Thailand after the devastating Boxing Day tsunami in 2004."

While he has no plans to wind his career down just yet, he's happy to be passing his knowledge on to the next generation of scientific thinkers and leaders.

"I'm still in my first real job, starting out with a core group of scientists and engineers, some of whom are still working. That has been hugely satisfying, along with partnering with clients to complete successful but challenging projects.

"Most rewarding is being part of the value chain in translating science and its uncertainties into policy, guidance and engineering design, where it makes a real difference on the ground, and sharing my experience with younger staff through mentoring."

While work at NIWA in Hamilton keeps him busy, Rob makes a point of achieving balance through spending time and holidays with wife Ruth, listening to music (jazz, gospel, and rhythm-and-blues are his favourite genres), gardening and visiting his adult children and grandchildren.

"We make regular visits to family in Auckland and the 'grandies', bike rides (recently the Otago Central Rail Trail), church activities, reading and summer camping at the beach (usually Ohiwa, in the Eastern Bay of Plenty) to get a dose of sea air. I also enjoy woodwork and woodturning when I can access a lathe."

Travelling is another passion – and water features prominently in most of the places he has visited.

"I love Canada – I spent an amazing three months on sabbatical at the Institute of Ocean Sciences near Victoria on Vancouver Island. Next on the list is cruising Canada's Inside Passage and Alaska before the glaciers melt much more.

"I enjoy big cities as well – my sister-in-law lives in Austria with a flat in Vienna. I'm intrigued with the canal cities of Venice, Copenhagen and Amsterdam and I recently soaked up Berlin in the weekend while on a work visit in May."

Rob uses his scientific knowledge, expertise and experience to seek out ways to make the world a better, more sustainable place for future generations.

He and Ruth, an advocate coordinator for TEAR Fund, a Christian international aid and development agency, raise funds through Gift for Life to support micro-enterprise projects, and five children in Africa, the Caribbean and India.

Over 30 years' experience in coastal oceanography has given NIWA's Rob Bell a wealth of knowledge in mitigating the impact of sea level rise and storm surges around New Zealand. (*Dave Allen*)

"The TEAR Fund were early observers of the detrimental impacts of climate change on agriculture, and advocate spending money on sustainable risk reduction, rather than just continually responding in the aftermath of disasters.

"Sustainability of our world for my grandchildren and beyond – that's a forward challenge at our current consumption and emission rates. We need to learn to adapt and work with nature, and include water and the sea in our thinking, rather than fighting it."

Solutions

Designing for downpours

Police redirect traffic away from Whanganui's CBD as flood waters rise after record rainfall in the area. (*Mark Brimblecombe*)

Between 19 and 21 June this year, the sky above the southwestern North Island opened wide.

Whanganui, Manawatu and Horowhenua bore the brunt of the storm, experiencing 100mm to 150mm of rain – upwards of 200mm in the ranges – in the space of 48 sodden hours. Widespread flooding resulted.

The deluge highlighted the challenge authorities face when preparing flood protection policy and designing infrastructure such as stopbanks, drains, culverts and bridges.

Climate change is adding further uncertainty to the mix. Underestimate risk, explains Horizons Regional Council Design Engineer Peter Blackwood, "and a community may face frequent flooding on the scale of Whanganui. On the other hand, a system with twice the capacity it will ever need is usually beyond the reach of ratepayers. The challenge is to design a system that effectively reduces risk, and is affordable."

Optimised design

Designing cities to handle extreme weather is made easier by a free online tool from NIWA: the High Intensity Rainfall Design System (HIRDS).

HIRDS tells planners and stormwater engineers the maximum depth or intensity of rain expected at a specified location during storms lasting from 10 minutes to 72 hours. It gives them the estimated return period for such storms, as well as an indication of their statistical probability.

"HIRDS helps engineers optimise infrastructure design," explains NIWA engineering hydrologist Graeme Horrell.

"Let's say you want to design a car park for optimum stormwater runoff. HIRDS will show you what rainfall depth you should expect, for example, during a 30-minute, one-in-five-year storm at that location. The car park's drainage systems can be designed to cope."

What's more, says Peter Blackwood: "HIRDS gives us design rainfall estimates for the myriad locations where we don't have automatic rainfall recorders. Its algorithms also smooth out the erratic estimates that can sometimes result from a particular rain gauge, usually due to the shortness of its data record.

"After using HIRDS for many years, it has proven a robust method of determining long-term average rainfall frequency data."

A recent Water New Zealand survey revealed that 83 per cent of New Zealand's design engineers routinely use HIRDS for design storm analysis and flood hazard planning. NIWA estimates that HIRDS contributes to the design of infrastructure worth over $100 million each month.

The tool is based at http://hirds.niwa.co.nz. Users enter a street address, the coordinates of a known location, or click on a location on a Google map.

They then choose their data type: either depth-duration-frequency, which shows rainfall depths (in millimetres) for the given storm durations and recurrence intervals, or intensity-duration-frequency, which shows rainfall intensities (in millimetres per hour) rather than depths.

HIRDS can factor in the uncertainties of climate change. Users can enter three warming scenarios – for example, temperature increases of 1, 2 and 3°C – and see in an instant how predicted rainfall depths, intensities and return periods change.

Improvements proposed

The current version of HIRDS draws on regional frequency analyses of annual extreme rainfalls from around 3,200 regional, city and district councils, MetService and NIWA monitoring sites in New Zealand.

Graeme Horrell says significant improvements are proposed.

"In recent years a large number of automatic rain gauges have been installed in areas where data have previously been sparse, and we have found that some key historical data had been excluded.

"We intend to include these data in the tool, providing valuable additional insight into long-term trends such as the Interdecadal Pacific Oscillation, which can significantly affect storm design."

The upgraded tool will also feature areal reduction curves, used to convert rainfall estimates from single points to catchment scales. New Zealand design engineers currently use estimates from a United Kingdom study in 1977. Horrell believes New Zealand now has enough information to produce local areal reduction curves.

"The enhanced tool will provide temporal patterns of design storm rainfall," says Horrell. "These will enable flood hydrograph peaks and volumes to be modelled."

Complete protection from Mother Nature's worst is an unrealistic goal, cautions Peter Blackwood.

"Our aim at the front line is to reduce risk using a number of strategies, including encouraging wise planning and land use practices.

"Flood protection design is a complex and robust process, and HIRDS contributes significantly to that effort."

NIWA
enhancing the value of New Zealand's natural resources

NIWA (the National Institute of Water & Atmospheric Research) was established as a Crown Research Institute in 1992. It operates as a stand-alone company with its own Board of Directors, and is wholly owned by the New Zealand Government.

NIWA's expertise is in:

- Aquaculture
- Atmosphere
- Biodiversity and biosecurity
- Climate
- Coasts
- Renewable energy
- Fisheries
- Freshwater and estuaries
- Māori development
- Natural hazards
- Environmental information
- Oceans
- Pacific rim

NIWA employs approximately 600 scientists, technicians and support staff.

NIWA owns and operates nationally significant scientific infrastructure, including a fleet of research vessels, a high-performance computing facility and unique environmental monitoring networks, databases and collections.

Back cover:

Snow petrels fly around a large iceberg in the Southern Ocean. (*Dave Allen*)

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