WATER & ATMOSPHERE
April 2018

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WATER & ATMOSPHERE

April 2018

Cover: The massively upgraded High Performance Computing Facility in NIWA's Wellington site. (*Dave Allen*)

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NIWA
Taihoro Nukurangi

enhancing the benefits of
New Zealand's natural resources

In brief

Woodburner smoke. (*Dave Allen*)

Sensing stateside smoke

The USA is getting its first look at NIWA technology that measures how woodburner smoke levels in towns are influenced by weather, topography, buildings and home-heating behaviour. Woodburner smoke can have a significant detrimental effect on human health.

In a partnership with the University of Montana, NIWA has installed indoor and outdoor particulate sensors in the West Silver Valley, Idaho. The instruments will remain in place throughout the northern hemisphere winter, providing data to improve understanding of the pollutant problem in the area and, ultimately, inform mitigation strategies.

The US project follows a successful NZ three year trial of the NIWA technology in Rangiora. A larger study gets underway in Alexandra in April 2018. It will involve local schools thanks to Unlocking Curious Minds funding from the Ministry of Business, Innovation & Employment.

Communities interested in participating should contact NIWA's Air Quality team: Ian.Longley@niwa.co.nz / 09 375 2096

Boon to marine biosecurity

A web-based portal developed by NIWA and the Ministry for Primary Industries now houses records of more than 230,000 species, many of them marine pests that threaten New Zealand's marine environment. The Marine Biosecurity Porthole (http://marinebiosecurity.org.nz) provides public access to information on unwanted marine pests and other non-native marine organisms that have been recorded in New Zealand waters. It is the most complete source of information on the national distribution of non-native marine species in New Zealand, bringing together data from more than 10 years worth of species distribution information collected during the Port Biological Baseline Surveys, Marine High-Risk Site Surveillance programme, the Marine Invasive Taxonomic Service and other verified observations of non-native marine species. The site has recently been re-released with a new look and colour scheme, greater mapping functionality (including digital download of data), information about research, and various resources for identification.

Marine biosecurity survey. (*Peter Marriott*)

Blake Ambassador Award winners Anna McKenzie-Pollock and Sian Moffitt. (*Sir Peter Blake Trust*)

Blake's Two

Two talented Wellington students packed their books away this summer and headed into the environment after each winning a Blake Ambassador Award.

Anna McKenzie-Pollock (25) went to Port Waikato in January to help the Department of Conservation (DOC) dotterel ranger and local volunteers with Port Waikato Beach Care's shorebird protection programme.

Sian Moffitt (19) worked with DOC rangers and partners in Nelson on the Rotoiti Nature Recovery Project, one of the original six mainland islands set up in the mid1990s to test pest control methods and establish best practice for DOC operations.

The Sir Peter Blake Trust, in partnership with Antarctica New Zealand, the Antarctic Heritage Trust, NIWA and DOC, is announced 11 awards in total this year.

The Blake Ambassadors, aged 18 to 25 years, have been working alongside leading scientists, conservators and rangers, developing relationships and partnerships in their field of interest and experiencing the 'hands on' elements of their field of study.

Avon-Heathcote Estuary Ihutai from the estuary mouth towards the city. (*Adam Herbstritt*)

Salinity modelling

New monitoring data are being used to improve the salinity calibration of NIWA's existing Avon-Heathcote Estuary Ihutai model that predicts spring tide salinity intrusion up the Avon/Ōtakaro and Heathcote/Ōpāwaho rivers. The project, carried out for the Christchurch City Council by NIWA in collaboration with Shane Orchard from Waterlink Ltd, surveyed inanga spawning locations to identify salinity thresholds associated with the upstream and sea-level limits of spawning. The data were used to predict how the spawning reach has responded to earthquake-induced changes, and the likely response to sea-level rise. NIWA's Richard Measures says modelling shows that sea-level rise will push inanga spawning approximately 4km upstream of its current location in the Avon and 2km in the Heathcote over the next 100 years. "Sea-level rise causes saltwater to propagate further upstream. Using our model to predict changes in salinity allows Christchurch City Council to plan riparian vegetation to ensure that sufficient inanga spawning habitat is maintained."

New Zealand sealions. (*Rob Murdoch*)

Sealions' prey in spotlight

NIWA fisheries ecosystem modeller Dr Jim Roberts presented NIWA's prey survey of New Zealand sealions to the Marine Mammal Conference in Halifax Nova Scotia recently. The survey was part of NIWA's work to understand why the main breeding population of New Zealand sealions at the Auckland Islands has halved in size since the late1990s. Dr Roberts described how the lack of shallow prey species was the probable cause of sealions' extreme deep diving at the Auckland Islands (the deepest of any fur seal or sealion globally) and how changes in the availability of mesopelagic prey (including hoki) may have played a role in causing nutritional stress in New Zealand sealions.

Plumbing new depths

A team of international researchers has explored the bottom of the Kermadec Trench – one of the deepest places in the ocean – on a three-week expedition aboard NIWA's flagship research vessel *Tangaroa*. During the expedition, they retrieved the deepest ever sediment sample – 9994m deep – from the bottom of the ocean using a wire-deployed corer. Scientists from Denmark, Germany, the United Kingdom, Chile and New Zealand will investigate the biogeochemistry and biology at the bottom of the 10,000m deep trench. The southern-most part of the Kermadec Trench begins about 120km off the coast of New Zealand, and extends northeast for 1500km. The team deployed sophisticated cameras and instruments to image and monitor conditions along the trench axis.

Crew deploying instrumentation from *Tangaroa*. (*Johannes Lemburg*)

Porbeagle shark assessment

NIWA has recently completed a stock status assessment of porbeagle sharks in the southern hemisphere for the Western and Central Pacific Fisheries Commission (WCPFC) – showing that the species may not be currently overfished. The species is a common bycatch in surface longline fisheries targeting tuna and swordfish in mid to high latitudes, and it is potentially vulnerable to overfishing because of its low growth and reproductive rates.

Beating drought

How a regional climate history helped save a farm and cure depression

Former South Island Farmer of the Year Doug Avery has become well known for his advice on tackling depression.

Avery's story of beating eight years of drought on his family Marlborough sheep farm is also a story of beating depression. It has morphed into a new book, The Resilient Farmer.

The book's solution to both environmental and mental pressure is to step back and see the big picture – and in that picture, he says, you can find hope.

"If you look for it, in everything that happens – even the worst thing – there's always something that is positive," Avery writes.

In the middle of what eventually turned out to be a 19-year drought between 1988 and 2007, it would have been very hard to find anything positive.

Avery says in the book that he got experts to help him work out how to transform the farm to grow and use lucerne as the main feed for his sheep.

"We had the specialists. On climate issues, we also got input from NIWA's Alan Porteous. He offered to climate-model our farm back to 1890.

"What good would that be?" I wondered. But the modelling was amazing, giving me deep insights into our past and the stories my grandfather and father had told me.

"NIWA's modelling confirmed I had gone through the worst drought in recorded time, and that knowledge helped me feel better."

It also confirmed that farming in the location was always going to be tough. He and his wife were determined to stay on the farm, but knew they had to change their whole approach to farming.

"We created a continuous, year-round approach to interconnected land use, rotating crops and herds, using methods that trap in the ground what moisture we get in one season for use in the next."

Although it was tough going, the switch to lucerne and methods more in tune with the local conditions began to pay off. Avery became an evangelist, touring the country teaching others about the systems.

During these talks he noticed that many people were even more interested in how he had survived the mentally tough times.

"They wanted to talk about how I managed to get myself feeling happy again."

Avery's advice to dealing with emotions mimics the approach he took to dealing with his farm: seek help.

"If we get another pair of eyes on the job ... that's when change becomes possible."

Marlborough farmer Doug Avery. (*Stuart Mackay*)

Photographed in 1978 (*left*), and in 2018 (*right*), the Rolleston is one of 40 glaciers - surveyed from the air using fixed-wing aircraft - that show the area of ice lost. (*Trevor Chinn, Drew Lorrey*)

NZ snowline shrinks

New Zealand's glaciers have all retreated and lost volume since NIWA started surveying them in 1977.

More than 40 glaciers covered during the summer flight – termed index glaciers – are spread across the Southern Alps, from deep in Southern Fiordland to northern Westland and Canterbury. These glaciers were chosen because of their representative span across the alpine region of New Zealand.

Principal environmental monitoring technician Andrew Willsman says the consistent trend is that all index glaciers have lost area since the mid1970s.

The overall trend is ice loss, which Willsman says correlates with average sea surface temperature. In other words, as seas surrounding New Zealand (especially the Tasman Sea) have warmed, ice and snowlines have receded.

Glacier recession in New Zealand mirrors global trends. The expectation is that the index glaciers surveyed by NIWA will continue to lose ice if temperatures keep increasing.

NIWA's End of Summer Snowline team (Dr Andrew Lorrey, Andrew Willsman, Dr Trevor Chinn) and colleagues from Victoria University Wellington (Professor Andrew Mackintosh, Dr Brian Anderson, Dr Huw Horgan and PhD candidate Lauren Vargo) survey the snow and ice coverage from the air using fixed-wing aircraft.

The images are analysed to determine the position of the end of summer snowline, used as an estimate for the glacier equilibrium line that marks the amount of warm season melt before the first winter snowfall. The glacier mass balance year – a sum of the annual health of our ice – runs from April through to the following March.

New work being led by VUW researchers who collaborate with NIWA on the summer snowline flight has produced high-resolution digital elevation models from NIWA's collection of historic ice photos. This effort will help refine the volume of ice change through time, which is important for cataloguing the frozen water resources for New Zealand.

Most of the index glaciers surveyed have been found to respond quickly to changes in climate. Many of the smaller glaciers respond quickly to inter-annual changes. Some, however, take many decades to respond because they have a thick layer of insulating rock cover.

The expectation for this summer, which was tested in early March, is that the snowlines will be higher than average due to very warm Tasman Sea temperatures which, along with warmer than normal air temperatures across New Zealand, are expected to enhance summer melting of alpine ice.

NIWA's Southern Alps flight surveys form part of the Climate Present and Past project, which looks at recent and historical climate data to track past variability and changes in climate.

For more information, visit: www.niwa.co.nz/node/111130

A quantum leap in New Zealand's science capability

How long would it take to count all the grains of sand in the world? About 5000 seconds – a little over an hour and 20 minutes – if you had a Cray XC50. NIWA has just installed one at the High Performance Computing Facility in Wellington.

Supercomputers have been helping answer some of New Zealand's biggest science questions since 1999, when NIWA took delivery of its first supercomputer – a Cray T3E. That Cray was replaced by an IBM Power 6 supercomputer in 2011, further enhancing NIWA's environmental forecasting capabilities and the nation's computing resources.

Now, some of the world's most advanced supercomputing power has just arrived in New Zealand – in the form of a $23 million three-part set of supercomputers. It is one of the most significant investments in New Zealand science – a collaborative initiative by NIWA, the Universities of Auckland and Otago and Manaaki Whenua. It is an investment that will allow scientists from a wide range of disciplines to explore solutions to some of the most profound challenges facing society.

The biggest part of that investment is the $15 million NIWA is spending on two Cray XC50s – the largest of which has a theoretical peak performance equivalent to 1425 trillion calculations per second. To put it another way, there are about 7.5 quadrillion sand particles on our planet, and if our new supercomputer were programmed to do so, it could count them all in about 5000 seconds. It's fast. It's 10 times more powerful than its predecessor, yet it's 50% more energy efficient.

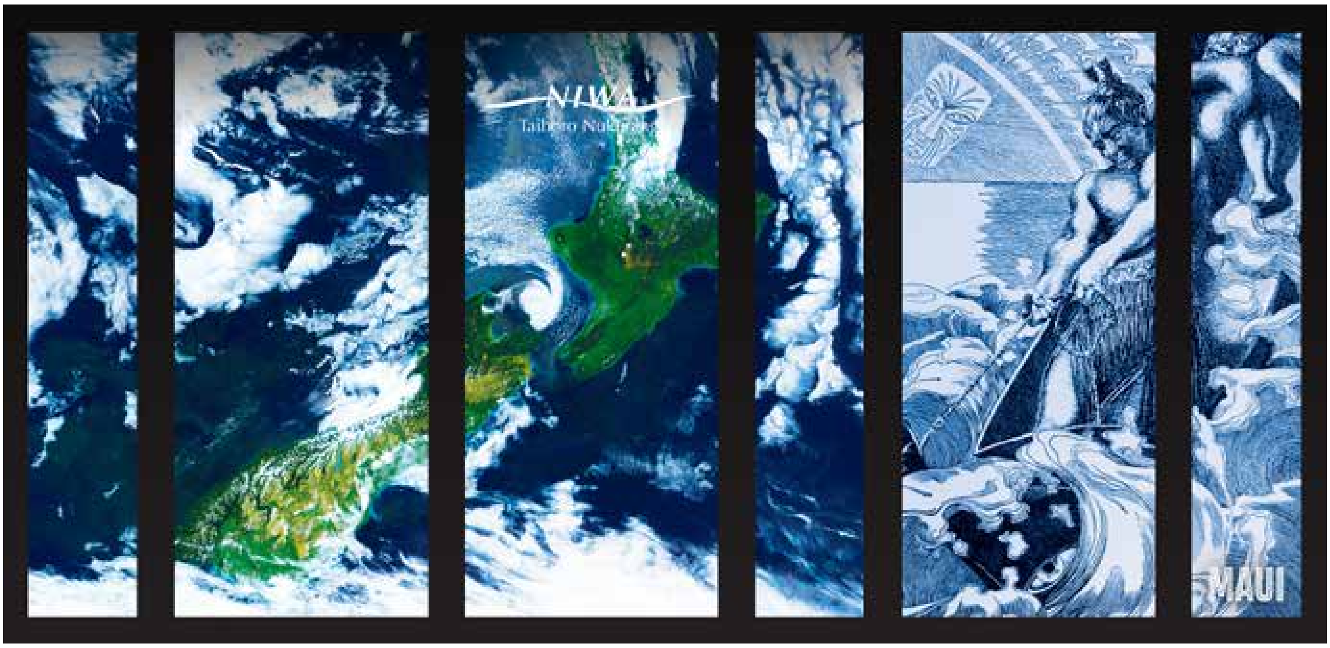
One XC50 and a new Cray CS500 are in NIWA's High Performance Computing Facility in Wellington. The second part of the equation – a new Cray CS400, also at NIWA's Wellington facility – is owned by the Universities of Auckland and Otago and Manaaki Whenua. The set is completed by a third supercomputer – a smaller XC50 and CS500 combination, which will be housed by the University of Auckland and will act as a back-up system for NIWA, and provide a back-up copy of data held on the NeSI systems at NIWA's Wellington facility.

Together, these two systems form the heart of the NeSI (New Zealand eScience Infrastructure) high performance computing infrastructure.

The whole system has been designed with the needs of the New Zealand science sector in mind – advancing understanding and informing policy and management decisions – and it puts New Zealand on par with the supercomputing capacity of Australia.

The New Zealand facility, however, incorporates the latest Intel Skylake chip technology which provides a step change in performance over previous Intel chip technologies, and IBM's leadership high performance storage system, providing more than 14 petabytes of storage.

For NIWA, the Cray XC50 will be instrumental in advancing weather forecasting, enabling us to build more precise forecasting tools to help farmers and environmental managers make more informed decisions, and prepare for impending weather hazards such as floods and storms.



The new Cray XC50, the most significant component of NIWA's High Performance Computing Facility in Wellington. (*Dave Allen*)

This high performance computing takes us into the realm of ensemble forecasting – a method used in numerical weather prediction. Instead of making a single forecast of the most likely weather, we can now run up to 18 computer models at a time, each under slightly different scenarios. This set of forecasts will indicate the range of future weather conditions, giving greater confidence and better forecasting precision.

This is a first for New Zealand – the Cray's computational power will be applied to generate new climate change simulations, helping refine forecasting of climate extremes or hazardous events to better inform national adaptation strategies. The system models at least eight hydrological variables – such as surface runoff, groundwater recharge, soil and canopy evaporation and groundwater discharge to streams. These models generate huge amounts of data – more than a petabyte (a million gigabytes) of simulation results, and that can be achieved only with today's new supercomputers.

In particular, it will help advance a national flood forecasting system based on combining high resolution weather and catchment models. A prototype system has already been developed, incorporating 66,000 catchments across New Zealand.

NIWA's earth system modellers, with funding from the Deep South National Science Challenge, are working on designing and running a super-complex climate model of the 'full earth'. With such a model we will be able to better represent the climate of our region and predict future changes in regional climate. Output from the model will contribute to the next Intergovernmental Panel on Climate Change assessment report, as well as improve understanding of the Southern Ocean and how it influences the planet's climate.

The $23 million system was selected in consultation with our partners in NeSI (funded through the Ministry of Business, Innovation & Employment), and enables scientists to access high performance computing power, storage and processes efficiently across a wide range of disciplines. Up to 20 per cent of the total computational time will be offered for use across the national science system.

Our society is recording more and more data, at higher and higher resolution, from snowballing numbers of increasingly more capable satellites or from the rapidly expanding number of sensors connected to the internet. There are estimated to be more than 6 billion sensors, and there could be 20 billion by 2020, feeding the 'internet of things', where multiple devices and sensors are connected and communicate. Only supercomputers can gather, synthesise and understand – at the required speed – the enormous amounts of data these sensors generate.

NIWA is part of a pilot project running incredibly sophisticated sensor networks on New Zealand farms, and analysing the data to improve on-farm decision making.

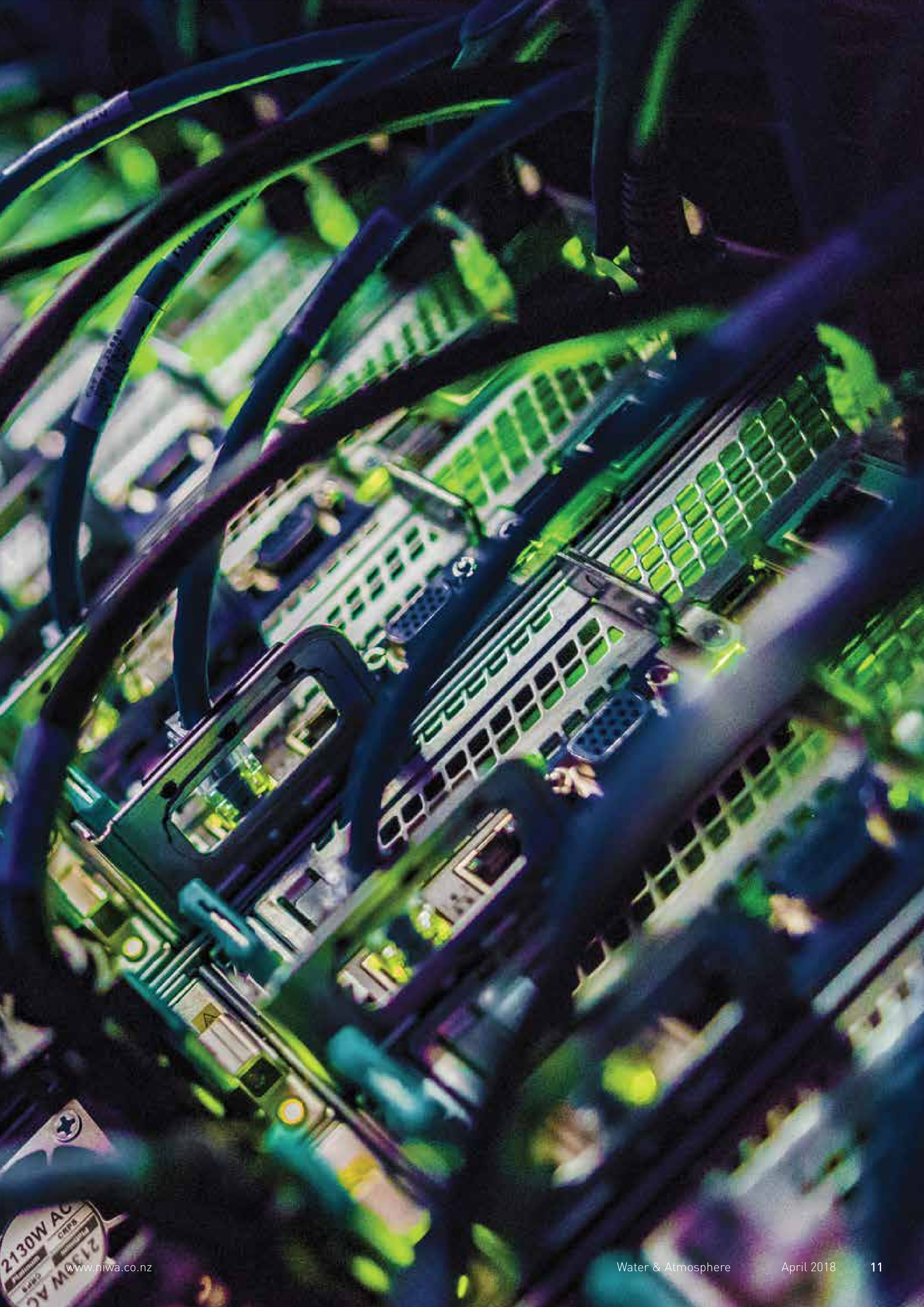
For other scientists, the new supercomputing speed and power could increase knowledge about the risk of earthquakes, or advance the field of genomics and contribute to breakthroughs in medical treatments.

We now have a high performance computing platform that is hugely powerful, providing for advanced data analytics, including the application of machine learning and artificial intelligence – a step change not only for science, but also for an innovative, knowledge-based society.

Footnote: As a matter of interest, there are (very roughly) 7.5 x 10^{18} *grains of sand. That's 7 quintillion, five hundred quadrillion grains – or 7,500,000,000,000,000,000 grains. It would take you a while to count them all.*

Silicon power

Massive increases in computing power are allowing NIWA scientists to not only analyse more data, faster, but also to envisage completely new experiments.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Silicon power

Fifty years ago, the BBC's science programme Tomorrow's World showed a computer terminal in a suburban home and famously predicted that they would be in every house in the future. The descendants of those rudimentary terminals have transformed our daily lives.

Computers have also transformed the possibilities of science. The home computer in Tomorrow's World was connected via phone line to a large 'mainframe' computer. At this time, the world's first successful mainframe supercomputer, the CDC 6600, was humming away in science labs such as the Los Alamos National Laboratory in California and CERN in Switzerland.

Computing speed is central to the exploration of possibilities by science. The drive for ever faster processing speeds has seen ever increasing magnitudes of improvement over the 50 years since the CDC 6600.

By 1985, 20 years after the CDC 6600, the Cray 2 supercomputer ran more than 25 times faster. The best supercomputer in 2000 was 19 times faster than the best in 1995. The best in 2005 was 1,650 times faster. The best in 2010 was 15,100 times faster.

The difference can be shown in the spin-off effects for consumer technology. The Nintendo Entertainment System (NES) games console released in the early 1980s was twice the speed of a 1960s supercomputer. The new Apple Watch is faster than the 1980s Cray 2.

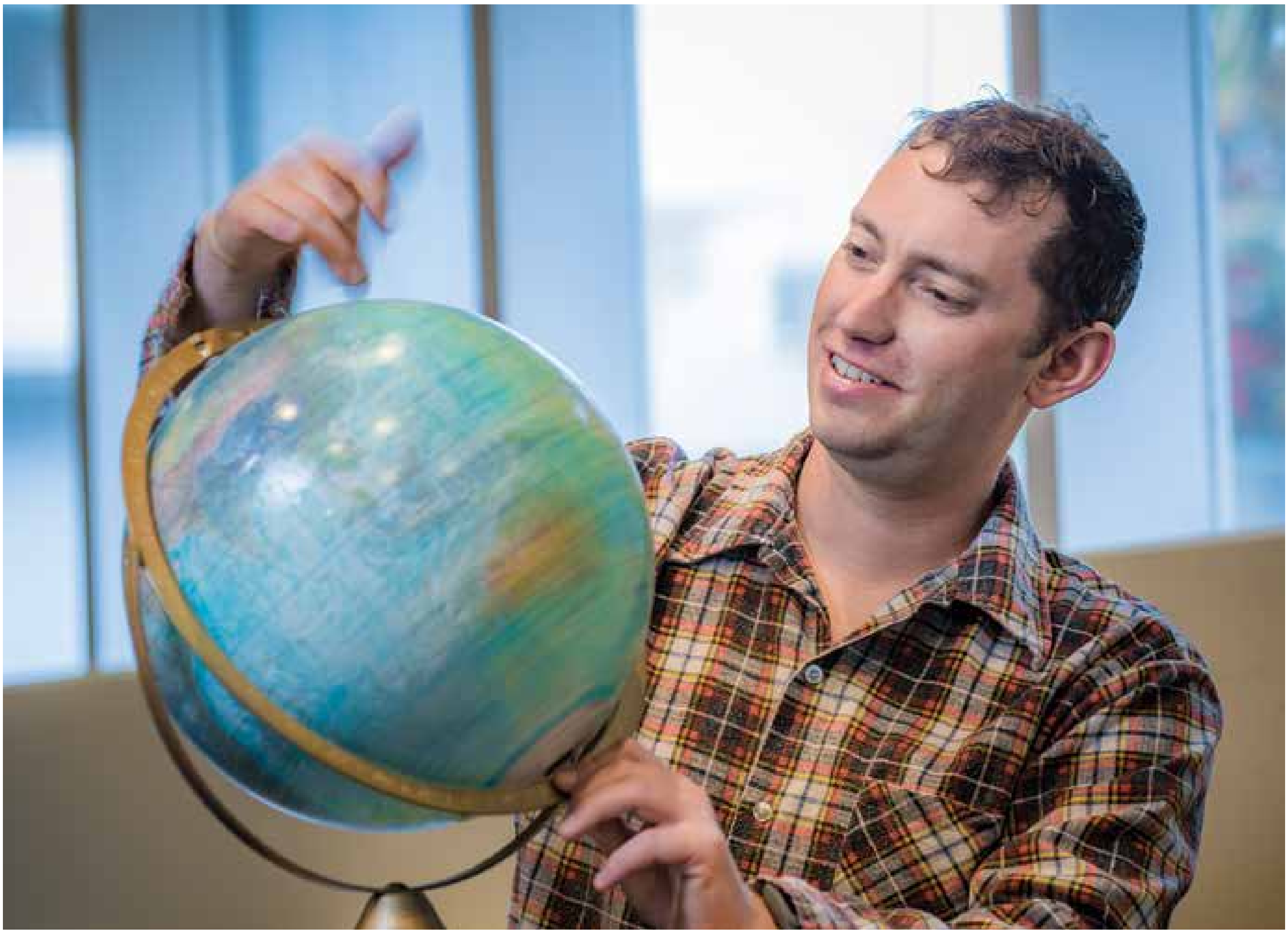
Following this development trajectory, New Zealand's supercomputing capability has just taken a quantum leap (see Panorama, pp. 8–9). The latest Cray XC50, NIWA's newest supercomputer, runs at one petaflop in a single box, and up to 500 petaflops in a fully joined-up supercomputer.

When installed, the entire upgrade suite of NIWA's supercomputers will be about 13 times more powerful than NIWA's previous IBM supercomputer, and will use about two-thirds of the electricity.

Expanding vision

Lloyd Trefethen of the Oxford Computer Laboratory said that, although computers were not as wise as people, they could "explore a forest of possibilities faster than we can". Computational power is at the heart of the difference supercomputers make to NIWA scientists.

Technicians install part of the new supercomputer at NIWA's High Performance Computing Facility in Wellington. (*Dave Allen*)



Scientist Dr Jonny Williams says "It helps us understand how Earth's climate is changing and visualise changes in the present, future, or past as well as illustrating how it might respond to external influences such as greenhouse gas emissions". (*Dave Allen*)

"Every time we've bought a new supercomputer, it's challenged our concepts of what's possible – it takes us a couple of years for our science to catch up with the technology. It expands our vision," says Dr Sam Dean, Chief Scientist for NIWA's Climate, Atmosphere & Natural Hazards Centre.

He says the most exciting prospect opened up by the Cray XC50 is convective-scale weather modelling of our future climate.

"We will run the same model we use for our weather forecasting, but will run it decades into the future."

The computing speed means NIWA could more quickly generate very long-range forecasts like those produced for the Greater Wellington Regional Council. They projected a climate for the Wellington region in 2090 similar to Sydney's current climate.

Climate simulations

Climate simulations are about to get far more detailed thanks to NIWA's earth system modellers, funded by the Deep South National Science Challenge.

NIWA earth system modeller, Jonny Williams, has only been able to run a simple version of its climate model.

"Until now, we've had to run simpler versions of the model – a bit like running a modern app on an old phone.

"When we have use of the new machines, we will for the first time be able to run our full earth system model. We'll be able to do advanced science, much faster.

"The first step will be to validate the model with our overseas partners. Then we'll be working on an Aerosol Chemistry model, which will contribute to the next IPCC [Intergovernmental Panel on Climate Change] assessment report.

"We'll be running several simulations in collaboration with the UK Met Office. As a group, we'll be feeding these into a database, which will be publicly accessible for anyone in the world."

Apart from contributing to the global understanding of our changing climate, a key aspect of NIWA's science programme is to grow New Zealand's capacity to develop and perform earth system modelling. The research will also address a common flaw in many global climate models – how well we represent the Southern Ocean region, including sea ice, ocean circulation, and clouds.

Freshwater modelling

The new supercomputer will be used to generate new climate change simulations covering 66,000 New Zealand catchments, says NIWA hydrologist Dr Christian Zammit.

Each simulation models at least eight hydrological variables (surface runoff, groundwater recharge, soil and canopy evaporation, groundwater discharge to stream, discharge in stream, snow storage and snow-covered area.

"We estimate that these models will generate over a petabyte (a million gigabytes) of simulation results – that's only achievable with the new supercomputers," Christian says.

The results will be used by regional councils, consultants, central government, and CRIs and will feed into the next generation of climate change forecasts by the IPCC.

"As part of the National Hydrological Project, we are planning to run simulations of a loosely coupled surface water/groundwater model across New Zealand.

"First simulations will start to be carried out in three catchments across New Zealand (in Southland, the Horizons region and Gisborne) with the aim of extending those simulations across the new digital river network (called DN3, which will contain over 4 million reaches) and providing 50-year hydrological 'hindcasts' (predictions of historic conditions).

Zammit is excited at other possibilities opened by the computing power, such as better flood prediction and assistance to allocation for water for use in sectors such as farming.

"Our work is contributing to the continual improvement in earth system and climate modelling worldwide, which is crucial if we are to better understand and adapt to our changing climate.

Helping manage big data

Dr Matt Pinkerton is thinking of using the computer power to crunch satellite imagery and other data so people can get a better sense of land and water use.

The Principal Scientist, Marine Ecology says NIWA uses satellite observation of the ocean for core research on the structure and functioning of New Zealand marine ecosystems.

"There's so much more satellite data than we can fully use. There are more satellites, with higher spatial resolution and greater spectral resolution. An increasing availability of information brings great opportunities in a traditionally data-scarce research area.

NIWA hydrologist Dr Christian Zammit says NIWA's Cray XC50 will generate new climate change simulations covering 66,000 New Zealand catchments. (*Dave Allen*)

Marine ecologist Dr Matt Pinkerton is currently investigating options for a low-cost remote sensing system which can map coastal habitats using multispectral camera systems on satellites and unmanned aerial vehicles (drones). (*Graeme Smart*)

"Getting the most out of these new earth observation satellites in the future, for example by assimilating satellite data into ocean models, will rely on the capability provided by a supercomputer.

"A supercomputer can look at more data, faster, than we have to date. It can identify sea changes in fisheries, and the effects of human activities such as aquaculture and seabed mining."

Pinkerton is thinking even further ahead, to how a supercomputer can assess the great volumes of satellite imagery to help regional councils manage land use from the sky.

"Spatial management can be transformed by the power of a supercomputer to help us monitor and analyse what satellites see us doing with the land."

Counting farm sensors

The sensor revolution is already well underway. Sensors remotely monitor heart rate and medicine intake, adjust production lines to conditions, and feed data from remote instruments. In New Zealand, farmers use them to report on conditions such as soil moisture and acidity.

Gartner research estimates there are over 6 billion sensors connected to the internet. There could be 20 billion of them by 2020.

The concept of an 'internet of things' envisages a world where multiple devices and sensors are connected and communicate. All those sensors produce an incredible amount of data. This data could be analysed to make more accurate predictions and insights.

Only supercomputers can hope to gather, synthesize, and understand enormous amounts of sensor data at speed.

NIWA is part of a pilot project running incredibly sophisticated sensor networks on New Zealand farms, and analysing the data to improve on-farm decision making.

While the concept is often imagined by futurists, it has not yet been properly attempted in New Zealand. The pilot wants to work out what all that data looks like, and how it can be aggregated, compared with other information, and used to provide truly helpful guidance in running farms.

One part of the project focuses on installing battery-powered sensors on a low power local wireless network. The other focuses on analysing the tens of thousands of data points from each farm.

Dr Mark Bojesen-Trepka, NIWA's Manager of Industry Engagement, says the pilot will turn concept into reality, to build data-driven decision tools.

"We're building the hard reality of a data-powered future: discovering how much data we get, how to analyse it, and how to produce guidance and decisions that improve farming operations."

The pilot envisages feedback in real time. For example, farmers will be able to match weather forecasts with actual weather over their farm, and how specific rainfall volumes and periods affect the moisture content of soil. That knowledge can be used to guide decisions such as when and how much fertiliser is needed, and crop growth projections for sequencing grazing or harvesting.

"Each paddock will have its own dataset. The NIWA supercomputer can work through huge amounts of data in super-quick time – so farmers can see what is happening across their property in real time, and act on that information," he says.

Bojesen-Trepka says there will be significant gains in pooling data from multiple farms, providing a chance to contrast and compare farming techniques.

"The supercomputer will learn from the sensors the effects of different techniques on each farm. It can apply that knowledge to new recommendations for things each farmer can try."

The project could have benefits for the whole nation. Bojesen-Trepka envisages a time when weather sensors on every farm in the country feed data into a nationwide weather forecast.

"The accuracy of our current 485 official weather stations could be augmented by data from 10,000 smaller weather sensors scattered across rural New Zealand," he says.

Deep learning

Artificial intelligence has captured the popular imagination, but also the imagination of scientists.

Algorithms that help machines learn have created sophisticated classification and prediction models, commonly known as deep learning. These are outperforming traditional approaches to enabling computers to 'see', and to recognise and translate speech and natural language.

NIWA's supercomputer can adapt deep learning techniques to scientists looking at the natural world. It will allow rapid prototyping of machine learning models and algorithms.

One example is Dr Krista Hupman's (NIWA) cetacean photo ID project, which is creating a fully computer-automated system for identification of individual cetaceans from photographs and video captured in the field. The first stage of the system, a collaboration between Hupman and Massey University researchers Dr Andrew Gilman and Dr Matthew Pawley, is already online (http://photoid.ninja). It's being used by cetacean scientists from the US National Oceanic and Atmospheric Administration (NOAA).

"Each paddock will have its own dataset - farmers can see what is happening across their property in real time, and act on that information," Dr Mark Bojesen-Trepka discussing the future of farming at Fieldays. (*Dave Allen*)

Dr Krista Hupman with a leopard seal near Wellington. Photo identification helps us get a better understanding of abundance and migration patterns. Currently, images of individual animals (e.g., dolphins, whales, leopard seals) have to be painstakingly sorted and matched by eye – in the coming years a fully computer-automated system will be able to do this work in a fraction of the time. (*Dave Allen*)

The record summer of 2017/18

Less than a week before the official end of summer on 28 February, temperatures dropped and a cool breeze made a whistle-stop tour of the country.

But a few days – when autumn felt like a distinct possibility after weeks and weeks of sweltering heat and tepid seas – wasn't enough to stop history. By then, the summer of 2017/18 was already the hottest on record.

And when the final tally was in, 54 climate stations around New Zealand had recorded their highest temperatures ever.

Summer had got off to a hot start, with well-above average temperatures during December. That led into January being declared New Zealand's hottest month on record and February experiencing two ex-tropical cyclones, Fehi and Gita, pulling warm humid air down from the sub-tropics.

Overall, the nationwide average temperature for summer was 18.8°C; 2.1°C above the 1981–2010 summer average from NIWA's seven station temperature series, which began in 1909.

The highest temperature of summer was 38.7°C, at Alexandra on 30 January. Wellingtonians baked in 25°C or more on 27 different days (measured at Kelburn), when the norm is two a summer – but that was nothing compared with Cromwell, where the town experienced 56 days when the temperature was more than 25°C.

NIWA meteorologist Ben Noll says the driver of this summer's remarkable warmth was the marine heatwave.

"This has been a striking feature on both a regional and global climate scale," he says.

"It began at the end of November last year and persisted for three months. There have been three distinct peaks when sea surface temperatures were between 2°C and 4°C above average: mid-December, late January and mid-late February."

But Noll says there were even some areas where sea surface temperatures were 6–7°C above average.

"This represented some of the largest ocean temperature anomalies anywhere in the world over the last several months."

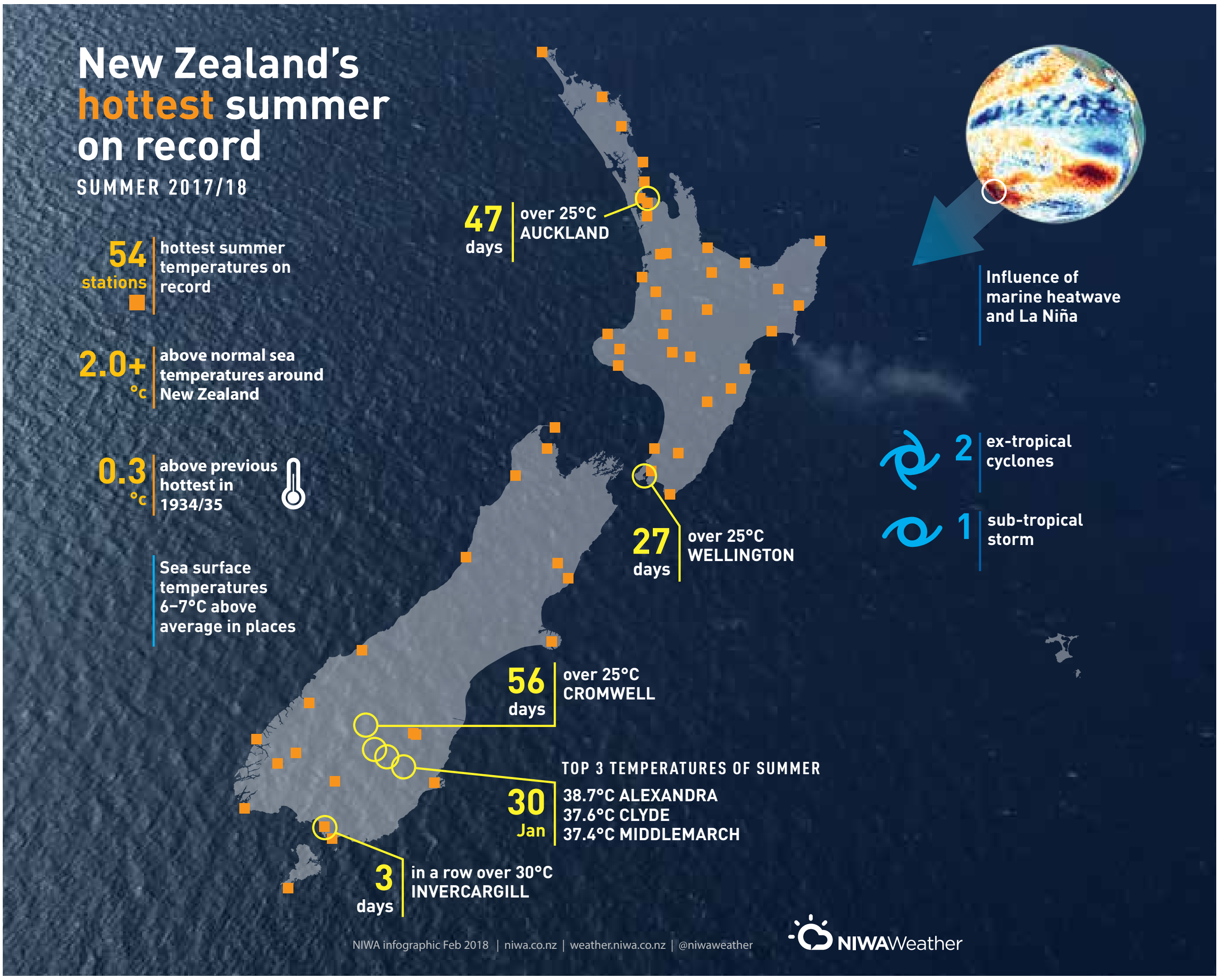
He says a warmer than average Tasman Sea is a signature of La Niña, because it is associated with higher than normal air pressure over the region during the late-spring and early-summer – this prevents mixing of deeper, cooler sea water with surface waters. In addition, warm northeasterly winds pushed warm water toward the country from the sub-tropics.

NIWA climate scientists have had to go back more than 80 years to find a summer that resembled anything like the one we have just sweated through. They found it in the summer of 1934/35.

That summer the temperature was 1.8°C above the 1981–2010 average (climate scientists use a 30-year period to determine statistical averages).

The 2017/18 summer records

- **54 stations across New Zealand recorded their hottest summer on record,** 39 their second-hottest and nine their third-hottest.
- **In Alexandra on 30 January the temperature reached 38.7°C.** On the same day Clyde got to 37.6, Middlemarch 37.4 – together these comprise the hottest temperatures of summer.
- **Wellington had 27 days above 25°C** – the average is two.
- **Auckland usually has 29 summer days above 25°C** (measured at Auckland Airport), this year there were 47 – the highest since records began at Auckland Airport in 1966.
- **Invercargill recorded three consecutive days over 30°C** in January. It's never done that for two days in a row, let alone three.
- **Cromwell topped 25°C for 56 days** – normal is 35 days.
- **Dew point temperature** – the meteorological measurement combining humidity and temperature – failed to drop below 19°C in Auckland between 10 and 15 February, making it a rare 115-hour period of very high humidity.
- **In Wellington a dew point temperature of 22°C** was recorded at 6pm on 11 February, the highest dew point on record for the city.
- **Mahia, Appleby and Waipara West** had their wettest summers on record.



When delving into the record books, NIWA Principal Climate Scientist Dr Brett Mullan found that the summer 1934/35 was so unusual it prompted New Zealand Meteorological Service director Dr Edward Kidson to report on it in a special Meteorological Office Note.

Mullan says the note shows there were several similarities to this summer, including widespread drought from November to mid-February.

Kidson wrote that a "feature of the pressure distribution was that the high pressure belt and tracks of moving anticyclones were unusually far south in the New Zealand area, generally crossing the Dominion instead of passing to the north of it."

Mullan says the persistence of anticyclones and northeasterly winds have also been a feature of this summer.

Over land, Kidson noted that "in none of the four months November (1934) to February (1935) did any station in New Zealand record a mean temperature which was not above normal".

How did we get a marine heatwave?

Here's the meteorological lowdown:

In late spring and early summer an area of high pressure was almost stationary over New Zealand and the Tasman Sea, bringing plenty of sun and very warm conditions for the time of year.

That heated the top of the Tasman Sea and New Zealand's coastal waters and, because there weren't many storms, there was limited mixing and churning of the ocean. That meant that the colder water under the sea's surface did not come up to the top to mix with the warmer water.

From there occurred what meteorologists call "positive feedback" – the warmth of the ocean fed the warmth on land and that in turn kept the seas warmer than average.

In addition, warmer northerly winds, a characteristic of a La Niña weather pattern, pushed warm water towards New Zealand and generally kept temperatures warmer than average.

The four primary causes

- Persistent patterns of high pressure over the Tasman Sea and New Zealand
- La Niña's influence of warm northeasterly winds
- A persistently positive Southern Annular Mode (SAM), which limited southerly wind outbreaks
- Climate change, acting as a long-term tailwind to temperatures.

Water count

ADCP (Acoustic Doppler Current Profiler) equipment is mounted underneath this small boat. To calculate water current velocities the equipment sends out sound waves and measures the reflected signal or echo from particles within the water column and also the river bed for depth. (*Dave Allen*)

Ruth Beran discovers that public interest in the state of fresh waterways has driven a dramatic change in the tools used by scientists.

A survey of 5000 people by Water New Zealand late in 2017 found that the majority of New Zealanders are concerned about pollution and the impacts of climate change and intensive agriculture on water quality.

It found that most people are very concerned about drinking water quality and poor water quality in waterways, particularly through litter and floating plastics.

Water New Zealand CEO John Pfahlert said that the survey showed that "people understand how extraction, climate issues and pollution are impacting on our water resources and the quality of waterways".

The strength of public concern is being reflected in demand by authorities for new and better ways of measuring the changing state of fresh water.

This has driven changes in the measuring tools and techniques, such as the rise of automated machines to replace manual collection, 'always on' tools that record data constantly or at regular intervals, and devices that can send information from remote locations.

Stream of numbers

NIWA Principal Technician Evan Baddock and his team are running a pilot scheme in Southland to monitor water quality continuously.

"For the past nearly 30 years, we've done manual samples," says Baddock. "But that's only monthly, so we're now following the US and other countries around the world, and doing continuous water quality monitoring."

Every five minutes, sensors in the Mataura River measure different aspects of the water, such as dissolved oxygen, nitrates, temperature, salinity and turbidity.

"Instead of getting a snapshot, we're now getting recordings continuously."

The results are stored in a logging device and sent telemetered by cellphone or satellite phone back to the NIWA office every hour.

By monitoring continuously, the sensors measure floods or other events, or pollution that might be released into the river. These are things that could be missed with only monthly monitoring.

Installing permanent monitoring equipment is never easy in New Zealand's waterways, among the shortest, most changeable and most remote in the world.

"It really is the most effective way of sampling a fish community, if it's in shallow water," Phil Jellyman on electric fishing. (*Dave Allen*)

ADCP (Acoustic Doppler Current Profiler) equipment is mounted alongside this small jet boat. To calculate water current velocities the equipment sends out sound waves and measures the reflected signal or echo from particles within the water column and also the river bed for depth. (*Dave Allen*)

Baddock says it all comes down to picking the right location. "You want measurements to be representative of the waterway, but you also want the location of your equipment to be sheltered from major logs coming down during floods," he says.

To avoid wrecking very expensive sensors in the water (one sensor can cost between $5,000 and $15,000), a system can be installed that also pumps water out via a tube. "That pumps water out to our housing or shed," says Baddock. "The sensor sits at the top end, so all the expensive parts are up out of the flood zone."

The biggest challenge for installing this type of monitoring in waterways is false readings from algae that tends to grow on sensors. One way to stop this algal growth is to have automatic wipers for the sensors, like those on cars, but much smaller.

Another challenge is power. The sensors can work on low power, but if the site is running pumps, then it will usually be connected to mains power or, in a remote area, to solar panels.

Go with the flow

For NIWA Principal Technician Wayne McGrath, probably 90 per cent of the work his team does is measuring water flow.

Previously, water flow was measured with "old fashioned current meters which were either propeller- or bucket-driven". It meant that scientists had to wade into the streams or put lines across the waterways to retain boats. This method was slow and only gave specific points in the river – where the scientists were standing with a current meter attached to a rod.

According to McGrath, ADCPs (Acoustic Doppler Current Profilers) have revolutionised measuring flows in rivers and made it a lot safer.

These devices (worth about $40,000 to $50,000) send out a "ping like a depth sounder, and get a reflection off particles in the water, or bubbles in the water", says McGrath.

"From that reflection it can tell how fast the velocity underneath it is." By traversing across the stream, the ADCP calculates the amount of water going down a particular waterway.

The ADCPs are installed in remote-controlled boats called Q-boats, which weigh about 30 kilograms, and are about two metres long. They need two people to lift them.

Dr Doug Booker using a Flow Tracker ADV (Acoustic Doppler Velocity) meter. This instrument gives us water velocity at the point where we set it in the water column. (*Dave Allen*)

This new method collects a vast amount of velocity points throughout the profile. So instead of 25 points across the stream, you get something like 250.

"It increases the amount of data that you've got, and from that you get a truer picture of what the flow is," says McGrath.

Software is also being developed so that the ADCP can be lowered into the river and then provide a sediment concentration reading instantaneously, rather than having to collect a bottle of water and send it away to a lab. "Sediment had been a hassle to measure in the past. You need great weights and great volumes of water," says McGrath.

Stunning tool

What lives in the water is as important to waterway health as the water itself. NIWA has invented its own electric fishing machine to catch and measure fish health and populations.

NIWA Freshwater Fish Ecologist Dr Philip Jellyman uses these electric fishing machines to temporarily stun fish and then measure things like their length, weight, numbers, and whether they're about to spawn.

"It really is the most effective way of sampling a fish community, if it's in shallow water," says Jellyman.

The electric fishing machine looks a little like a large gold detector, powered by batteries housed in a day pack.

The device puts an electrical current from 0 to 600 volts through the water. "You can alter the size of the field," says Jellyman. "You're trying to alter the current so the amount of amps that you're putting through the water is safe for the operator and for the fish."

Electric fishing stuns some fish better than others. "Some species will swim towards you and will sort of roll over and then you can quickly pick them up," says Jellyman. Electric fishing doesn't work so well on smaller fish either, like larval fish.

"I have no doubt that it will affect the behaviour of some for the rest of the day, but there's no sort of long-term consequences."

Electric fishing is more efficient and effective than netting, which is more physically harmful to fish, and usually requires two trips to set and recover a net.

Jellyman says, "Electric fishing is a standard sampling technique and it's really safe when done well. It's the best non-selective fishing method we have."

A swell of nine metres from the north west combined with swell of six metres from the south. (*David Bowden*)

Science in the Southern Ocean

When 23 scientists and 17 crew sailed to Antarctica at the beginning of February, they knew they had an ambitious work schedule ahead of them.

The voyage, aboard NIWA research vessel *Tangaroa*, was a six-week multi-disciplinary trip to study ocean, atmosphere and ecosystem processes in the Southern Ocean.

With experiments that included studying microbial production in plankton, distribution of seabed fauna, krill and whales, and climate change effects on oceanographic processes, time was tight.

And in a challenging environment like the Southern Ocean, voyage leader NIWA marine ecologist Dr David Bowden expected they would lose at least a couple of days to bad weather.

He was almost right – they lost three, but in the end they achieved far more than they ever expected.

One of the main reasons for that was the lack of sea ice. Sea ice forms when the ocean surrounding Antarctica freezes. It plays a crucial role in the global climate system, but this summer coverage dropped to its second-lowest on record.

"It has been an extraordinary year from that aspect, but that allowed us to go to places we thought would probably be inaccessible," Dr Bowden said.

Seven moorings were deployed, carrying an array of instruments that will record information until they are retrieved in a year's time when *Tangaroa* returns.

The primary objective was to establish the Ross Outflow Experiment off Cape Adare, which will yield important data about long-term changes in the amount of extremely cold, dense water that flows out from the Ross Sea and influences the global circulation of the oceans.

Data gathered during the voyage will also be valuable in helping to determine the effects a lack of sea ice has on the Antarctic ecosystem.

Work is now under way to analyse the vast amount of information gathered on the voyage – information Dr Bowden describes as "pieces of a complex jigsaw puzzle".

Analysing samples collected from the sea floor. (*David Bowden*)

The 23 scientists and 17 crew aboard NIWA research vessel *Tangaroa* for the 2018 Antarctic voyage. (*David Bowden*)

A humpback whale close to the ocean surface. (*Sarah Searson*)

A helikite is deployed from the stern of *Tangaroa* to measure aerosols, pressure, temperature and relative humidity. (*David Bowden*)

An Adelie penguin rests on the stern ramp of *Tangaroa*, seemingly resting on the vessel in the absence of sea ice. (*David Bowden*)

(*Top*) The team operating an underwater camera concentrate on a live feed of the seafloor. From the right: Nick Eton (*NIWA*), Sadie Mills (*NIWA*), and Aitana Forcén-Vázquez (*MetOcean/University of Auckland*). (*David Bowden*)

(*Bottom left*) Krill, the staple diet of many. (*Sarah Searson*)

(*Bottom right*) Ice forms on the ship window. (*Sarah Searson*)

Drones watch quake aftermath

NIWA scientists like Leigh Tait were saddened by the human impact of the 2016 Kaikoura earthquake, but he also says that it provided a "massive natural history experiment".

"We've got variable degrees of uplift along a large stretch of coastline," says Tait.

"The wide-scale loss of habitat-forming species provides an important contrast to studies typically done in ecological disturbance experiments at the scale of metres. This disturbance happened across tens of kilometres."

Tait is particularly interested in the intertidal reef, and the habitat-forming kelp species that have been affected by the uplift. A lot of these intertidal reefs have lifted by about half a metre. Very large areas of the reef that were underwater for approximately 50-60 per cent of the time are now under for less than 30 per cent of the time. Other areas were uplifted more than 6m, and now represent new terrestrial habitat.

Tait wants to assess how primary production has changed in communities that have been pushed into new tidal zones.

To do that, he is using state-of-the-art technology to conduct this research: drones and LiDAR.

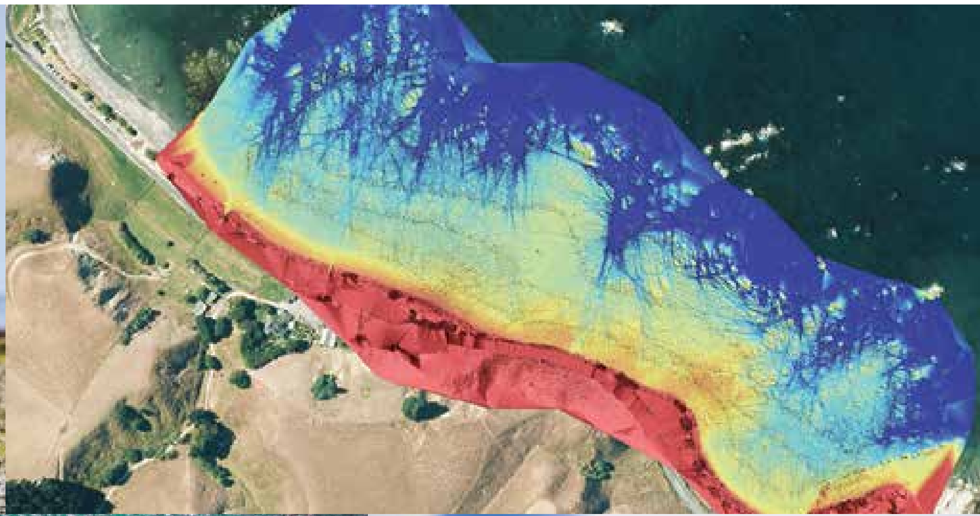
LiDAR stands for light detection and ranging, and uses a spinning set of 32 lasers that bounce back and are read by the instrument. The LiDAR then works out the amount of bounce-back and provides a 3D image.

"With the LiDAR, we can get a 3D map of the reef area," says Tait.

So far, the LiDAR has only been tested from a backpack mounted unit, but other applications have successfully been deployed using a drone.

Tait is using two drones in the field. One of these drones is large enough to lift the LiDAR – the frame of that one is about a square metre. The other drone is similar to the size of a recreational-type drone.

Marine biologists Dr Roberta D'Archino and Dr Leigh Tait are particularly interested in the intertidal reef, areas that were once covered in very high biomass are now almost bare. (*Dave Allen*)

(*Top left*) GIS Technician Jochen Bind with 'Snoopy' on his back (aka NIWA's Scanlook 2.0 mobile mapping LiDAR system). (*Top right*) A preliminary rendering, showing a bird's eye view of the data gathered by the LiDAR unit. (*NIWA*)
(*Bottom left*) A drone's eye view of Kaikoura's uplifted seabed. (*Bottom right*) David Plew launches NIWA's Altus LRX drone into the survey area, which captures a sequence of high-resolution images that will be used for habitat mapping. (*Dave Allen*)

The drones are being used to take camera images. Previously, images would have been taken from fixed wing aeroplanes. As they can't be flown very low to the ground, the images have to be taken from high altitudes. "What drones allow us to do is to take really high-resolution pictures at a much smaller scale," says Tait.

Tait, alongside drone pilot David Plew and LiDAR specialist Jochen Bind, has been running the drones over large portions of the affected area of rocky reefs and then doing the same with the LiDAR. "We can then stitch the two different sets of imagery together," says Tait. Doing this allows the scientists to see how the wetted area of the rocky reefs has changed and get an idea of the area now available for re-colonisation by habitat-forming kelp species.

"These areas that were once covered in very high biomass have been lifted out of the water," says Tait.

"In some places you've gone from having hectares essentially of reef area in a very habitable zone, to probably a tenth of that or maybe even less. That's really what we're trying to quantify with the drones and our LiDAR surveys."

The project that Tait is conducting started in July 2017 and is part of the Innovation Fund of the Sustainable Seas National Science Challenge. "The Innovation Funds are meant for examining new technologies or ideas and how they might be used for the sustainable management of our marine environment," says Tait. "So we've been trialling both sets of drones, but also trying to combine the data with a visual image sensor, so that we can overlay the three-dimensional structure with a habitat map of what's actually down there."

The hardest part of the research is getting the methodologies standardised. For example, coming up with colour-matching routines for identifying species, such as kelp and other macroalgal species, to be able to overlay imagery.

The imagery is stitched together using geo-referencing with 'bull's-eyes' placed in the environment at different points that can be referenced by GPS. "Then we can pin the measured imagery to the targets," says Tait.

"Once we're happy with those images, the next stage is to extrapolate primary production of variously affected kelp and algal communities to meaningful scales," says Tait.

While the Kaikoura earthquake may have been devastating, Tait recognises that it is a natural event that has presumably happened many times in the history of these coastlines. The difference is, these coastlines are now under a far different set of pressures than they were in pre-human times.

"Experiments like this can provide an assessment of how recovery of important habitats is affected by degrees of stress (uplift) and under these different regimes," says Tait.

All in a day's work

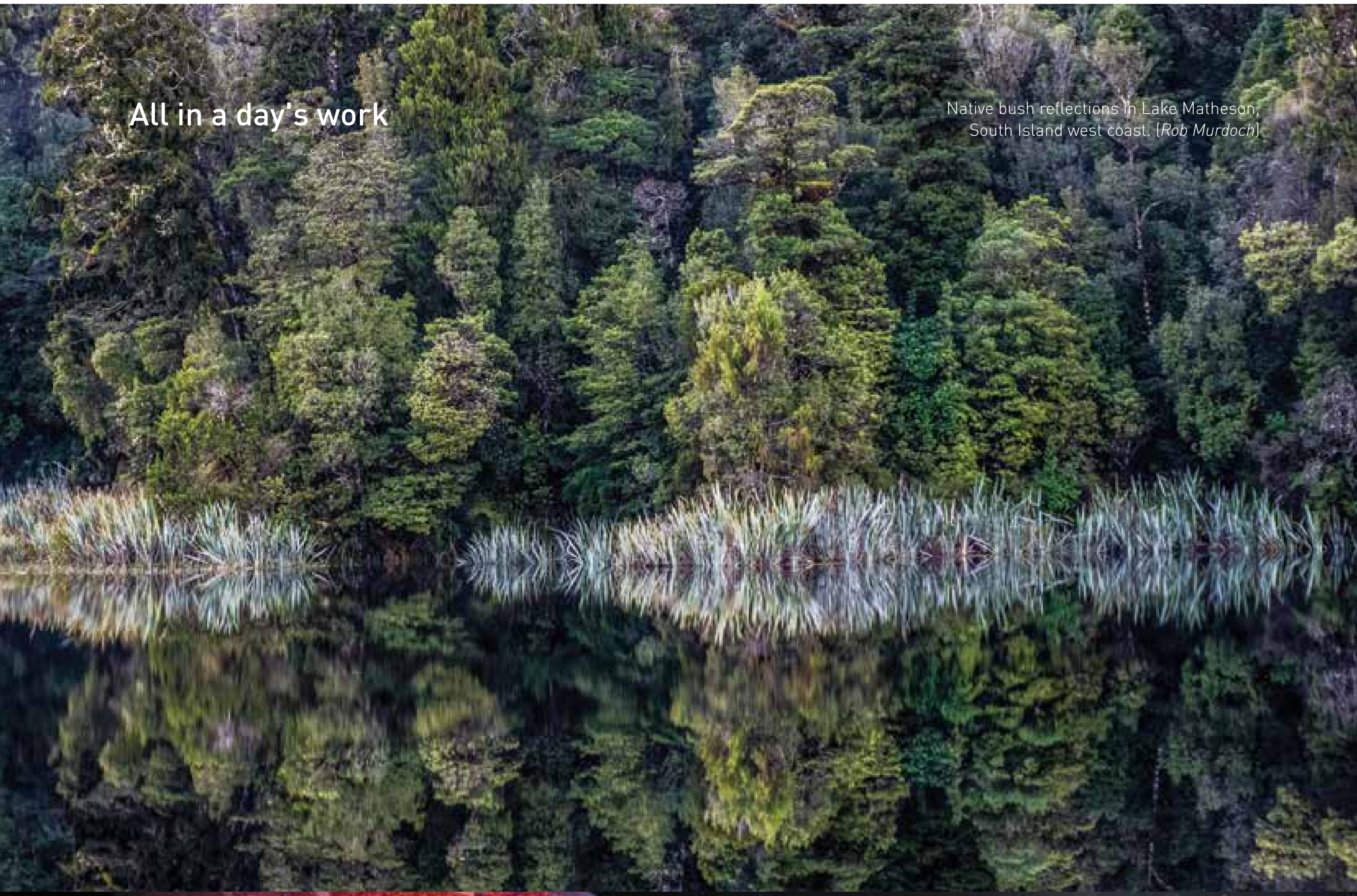
A humpback whale casts a sideways glance in the ocean near Niue, in the South Pacific. Humpbacks come to these waters each year from about July to September to calve and nurse their young. (*Rod McKay*)

All in a day's work

The lone mangrove. Low-lying atolls like Tarawa, Kiribati are very exposed to storms and changes in sea level. Mangroves are an important part of the island ecosystem as they can stabilise the coastline and prevent erosion from waves and storms. (*Nava Fedaeff*)

A bottlenose dolphin takes time for a breath. (*Helen Neil*)

Porters Pass – and a lot of patience – proved the ideal spot to capture the Milky Way, mountains and car lights on a clear evening. (*Shannan Crow*)



Native bush reflections in Lake Matheson, South Island west coast. (*Rob Murdoch*)

A squid trawled from deep water around Esperance Rock in the Kermadec region. (*Rob Stewart*)

A children's sailing regatta gets under way on a stormy afternoon at Whangaparaoa, Auckland. (*Rob Murdoch*)

A layered berg in the northern Ross Sea. (*Kath Large*)

Encouraging interest in science

Efforts to create interest in STEM education (science, technology, engineering and maths) have led to a 40 per cent increase in tertiary students taking the subjects this year.

Over the past decade, there has been a concerted effort by the science sector to raise New Zealand's science capability by increasing the numbers of students taking STEM courses. The sector has initiated campaigns and projects to raise student interest, the Government has started the 'Nation of Curious Minds' project, and the Tertiary Education Commission has gradually steered more funding into STEM subjects.

A Ministry of Education report in January revealed that one result of the effort has been a 44 per cent rise in the numbers of full-time equivalent students at bachelor or higher levels in health, engineering and IT from 2008 to 2016.

Universities of New Zealand Executive Director Chris Whelan says students are reacting to signals that there are good careers in STEM subjects, by voting "with their feet".

"They want something that they believe is most likely to make them employable and successful."

Another result of rising popularity of STEM subjects has been teacher shortages. At the end of 2017, secondary school principals reported that it was "impossible" to find STEM teachers. Auckland Secondary School Principals' Association President James Thomas said it was a "crisis".

NIWA is doing what it can to help by increasing its commitment to student and teacher development.

This includes NIWA's partnership with the Sir Peter Blake Trust to promote opportunities for science careers to young people (sponsoring up to six NIWA/Blake Ambassadors annually); joint graduate schools between NIWA and the universities of Auckland and Otago in marine science, and the University of Waikato in freshwater science; supervision of PhD and MSc students; a summer internship programme; sponsorship of the Sir Paul Callaghan Eureka Awards and secondary school Science & Technology Fairs; and involvement in the Science Teaching Leadership

Sir Peter Blake Trust Chief Executive Shelley Campbell with NIWA Chief Executive John Morgan. NIWA is now the Principal Science Partner of the Sir Peter Blake Trust.

On the hunt for gastropods and bivalves, Cheyenne Christensen-Field (left) and Kilali Gibson sieve core samples on board RV *Tangaroa*.

Programme (funded by the Ministry of Business, Innovation & Employment, and administered by the Royal Society of New Zealand).

Principal Science Partner

NIWA is now the Principal Science Partner of the Sir Peter Blake Trust, a non-profit organisation delivering programmes that encourage environmental awareness and action, and leadership development.

The new partnership sees NIWA working with the Sir Peter Blake Trust to deliver all aspects of the Trust's programmes, including the ambassadorships.

NIWA has been a long-time supporter of the Trust and has mentored dozens of Sir Peter Blake Ambassadors since the Trust's inception in 2007. Ambassadors (aged 18 to 25 years) typically spend a month with NIWA teams participating in hands-on projects across the Atmosphere and Climate, Oceans, and Freshwater teams.

Last year, then CEO of the Trust, Shelley Campbell, said, "Learning from the expert staff and teams at NIWA, the partnership provides rich engagement opportunities to build young people's confidence."

Earlier in 2017, two of the four NIWA/Blake Ambassadors joined NIWA researchers on a month-long voyage on RV *Tangaroa* to the Chatham Rise.

"We helped by recording what was seen in images and video captured by NIWA's deep-towed imaging system. I have a huge appreciation for the care NIWA takes to ensure collected data is accurate and consistent," marine conservation masters graduate Kilali Gibson says.

Waikato University earth sciences student Cheyenne Christensen-Field, 20, says the month-long voyage was a field trip like no other.

"The experience of working in a vast field environment with equipment I had previously only seen pictures of in a classroom was really amazing."

One of the 2018 NIWA Sir Peter Blake Ambassadors, Lisa Dowling, spent part of her summer working with the Atmosphere and Climate team in Wellington, while her fellow Ambassador, Victoria Carrington, headed out to the Chatham Rise in February.

Injy Johnstone (left) below the summit of Rainbow Mountain/Maunga Kakaramea with NIWA researchers Gordon Brailsford and Zoe Buxton. (*Dave Allen*)

Suitably attired, Courtney Davies is all set for field work in Lake Ellesmere/Te Waihora with a NIWA field team.

Injy Johnstone, 20, spent four weeks at NIWA looking at carbon dioxide in what she calls a totally immersive experience.

"I was trusted with datasets collected from NIWA's three carbon dioxide monitoring stations. I was then tasked with looking for a seasonal variability trend in CO_2 at these locations before determining what that meant for the local environment."

Courtney Davies, 21, a masters student from Massey University aims to help develop a sustainable agricultural industry, where prosperous dairying and healthy waterways can exist together.

"From standing in rivers gauging water flow and velocity, [to] tagging organisms or consulting on irrigation, it was hands on and an opportunity to work with the best people in freshwater science."

Science teacher training

NIWA technicians Dean Stotter and Geoff Foreman, and STLP participant teacher Debbie Ayres collecting puerulus on the Wairarapa coast.

Over the past 10 years NIWA has mentored teachers from around New Zealand as part of the Science Teacher Leadership Programme.

Debbie Ayres, a teacher from Paekākāriki School on the Kāpiti Coast, completed a six-month placement at NIWA last year as part of the programme and says the experience was "life changing professionally".

Among other activities, she helped extract oyster tissue, collected and learnt about red rock lobster, helped with air quality monitoring at Baring Head and "got to grips with taxonomic classification".

Debbie says she came away from the placement with a new appreciation of the work of the scientific community. Her work with the Invertebrate team, in particular, has inspired her to introduce classification within the school in new and creative ways, and she has also become a passionate spokesperson for climate change issues as a result of her work with the Atmospheric Gases team.

The placement provided a forum for reciprocal learning with Debbie teaching NIWA scientists ways to engage primary school children during their visits to schools.

"It is well known that most primary school children are fascinated in the workings of the natural world. Less well known is that scientists should limit their PowerPoint slides and get them busy," she says.

"It's much better to give them activities to do to interact with the science. Bring along an interesting piece of equipment and get them to do an observation or activity. Informally answering their questions while they are 'doing stuff' will be much more valuable to their learning than you talking about your work for an hour and showing them pictures. If you give them information that feeds their curiosity, it's much more likely to stick."

In recent years, Debbie says there has been a sea-change in the way science is taught in New Zealand schools. The old approach of emphasising facts has been replaced with teaching of science as a way of thinking and acting.

"Students are asked to 'be like scientists'. It's about teaching students to ask for evidence when someone presents information and critiquing the trustworthiness of the information, knowing the difference between observation and inference, and about having a great attitude towards science and satisfying your curiosity in a scientific manner. These are life skills that all citizens need," she says.

In July last year, Debbie took her NIWA experience back to the classroom to inspire teachers and students in science and to lead science curriculum development at Paekākāriki School. She was looking forward to term one of 2018, as the whole school was going to be working on integrating science into their innovative learning programme, which has been designed specifically for the local community.

Q&A

Bloomin' algae!

A hot and steamy summer saw Kiwis heading down to rivers and lakes to cool off. But they weren't the only ones enjoying the warmer weather – algae had a great time too.

Dr John Quinn, NIWA's Chief Scientist for Freshwater and Estuaries, looks at algal blooms.

What causes algal blooms?

Periphyton is the name given to the community of algae that grows on river and lake beds – sometimes called slime. Phytoplankton is the algal community that grows floating in the water column of lakes and large rivers.

Algae are essential parts of freshwater ecosystem food webs. Algae use light and nutrients to create plant biomass by photosynthesis, and fuel food chains. As thin films and short/sparse filaments, it is an important fuel at the base of healthy aquatic food webs, turning nutrients and sunlight into a food for invertebrates, which are in turn food for fish and water birds.

But you can have too much of a good thing.

Algae become a nuisance when their abundance reaches high levels that result in the degradation of other freshwater values, such as water clarity and bottom water dissolved oxygen in lakes, or night-time dissolved oxygen in rivers.

That comes down to the balance of growth-stimulating factors: mainly light, nutrients (nitrogen and phosphorus), warmer temperatures, steady flows and stable bed attachment sites – and controlling factors – high levels of flow disturbance and grazing by insects.

Conditions in summer are usually most conducive to periphyton blooms – long days and lots of sun. Warm water increases algal growth rates and inhibits grazing, and the periods extend between spates (moderate flow spikes) that slough or scour the periphyton. So, unfortunately, periphyton often blooms at the very time when people most want to use rivers for recreation, making them more of a nuisance.

Are there different types of blooms?

There are two types of algal blooms – those caused by phytoplankton, that are in the water column (predominant in lakes and the ocean), and by periphyton, which are attached to the bed (predominant in rivers). So blooms are either planktonic or benthic.

Like all plants, they need light and nutrients (particularly nitrogen and phosphorus), and growth rates also increase with water temperature. Many lakes separate into 'layers' in summer due to surface water warming. This increases the duration, intensity and exposure to sunlight of phytoplankton in the surface layer. All these factors tend to result in phytoplankton algal blooms being generally greatest in summer in stratified, nutrient-rich lakes.

How can blooms affect health?

Harmful effects of algal blooms on swimming, drinking water, and other recreational water contact are increased when they consist of toxin-producing cyanobacteria (also known as blue-green algae). These can make water contact or ingestion (during swimming or drinking) dangerous.

People are most likely to be exposed to highly toxic blooms when they are concentrated in surface floating scums and/or are being blown towards the down-wind shore of a lake. Dogs are susceptible to cyanobacterial poisoning, likely due to the combination of sensitivity and their behaviour of eating smelly material and ingesting scum material caught in their fur when grooming with the tongue. Periphyton in rivers can become more accessible to dogs during summer low flows, as falling water levels expose growths, and gas bubbles within productive mats lift periphyton off the river bed and it settles along the river edge.

Are they a new phenomenon and/or do they occur more frequently now than in the past few decades?

Blooms aren't a new phenomenon but there's some evidence that planktonic and benthic blooms are increasing in number and severity. Given blooms are most likely to happen in summer and occur when there's warmer water temperatures, more sunlight and lower flows, there are seasonal variations. So, if we have a warmer, drier summer, we're more likely to see blooms as opposed to weather conditions that are cooler and wetter.

Green algae is not toxic, it often looks like strands of green hair flowing in the current. (*Landis Hare*)

Many councils around the country post signs warning of the danger of blue-green algae. (*John Quinn*)

Are certain areas or types of waterway more or less susceptible to blooms, and why?

Periphyton in rivers tend to be more common in summer due to influences including long day length, high light, warm temperatures and longer gaps between high flows that scour growths from the river bed. Rivers with stable stony beds are more suitable for periphyton growth than those with mobile sandy beds. Cyanobacterial periphyton mats have been associated with moderate to high levels of dissolved nitrogen (as nitrate plus ammonium). These mats are particularly adept at trapping fine sediment and appear to be able to scavenge phosphorus in this sediment to supplement phosphorus in the water column, enabling them to develop high biomass where the water has relatively low dissolved phosphorus.

Planktonic blooms usually occur in lowland lakes where the land around them has been developed and there are higher levels of nutrients in the lake. Benthic blooms tend to occur in gravel lowland rivers. They're more common in rivers on the eastern side of the country.

How can people know if a waterway or swimming hole may be at risk of a harmful bloom?

Many areas that may be at risk are signposted with warnings. Regional councils and other agencies publish information about areas affected by blooms. This has recently been condensed into a simple format that covers microbial water quality and harmful algae blooms on the Land and Water Aotearoa website: www.lawa.org.nz/explore-data/swimming/.

But people can also see evidence of blooms for themselves, in some cases. Abundant filamentous green algae or didymo can be unsightly, but these growths are not toxic and don't present a health risk. Potentially toxic cyanobacteria are often visible as surface scums or brown-black algal mats attached to streambeds. Affected water may appear discoloured and may also smell unusual. If you are in doubt, it's advisable not to swim in the water.

Adapto-saurus newlandii

Bob Newland reckons he's a bit of a dinosaur.

Sure, he's had a long career, but for someone most accustomed to ensuring the accuracy of observations, it's a personal observation that's well off the mark.

The fact is that if the dinosaurs were even half as adaptable as NIWA's veteran instrument systems and specialist meteorological field technician has proven to be through the years, they'd most likely still be roaming New Zealand.

Being prepared to give anything a go and thinking outside the box to get a job done – often in incredibly challenging conditions – is something Bob takes great personal and professional pride in.

"We've got a lot of smart people at NIWA, people who have a lot of IQ and EQ. But I think we're also developing people with 'AQ' – adaptability.

"That's something I'd like to think I'm good at, the AQ, though I'm probably not so good on the IQ front."

Bob's AQ means he's always willing to try his hand at something, to find practical solutions to problems and situations. It's an approach that's served him well throughout his working life, which began in 1969 when he joined the National Film Unit straight out of secondary school.

There he had the opportunity to work with and maintain leading edge equipment, even installing the country's first Eastman colour film processing machine.

But five years later came what was to be a pivotal career move – a role with the Department of Scientific and Industrial Research that took him to Scott Base in Antarctica as a maintenance staffer.

"What they do is ask if you'd like to look after the dogs, so naturally you put your hand up. I quite like being thrown in at the deep end anyway, so I thought why not?"

That meant staying at the base, leading to a life-changing offer to stay on in Antarctica as part of an eight-month expedition to the Dry Valleys to take care of weather stations.

"There were four of us. It was fantastic – snow-free and with temperatures down to minus 50 degrees. You could travel and camp on full moons and we moved on foot. It was my introduction to instrument work."

The leader of that expedition was Tony Bromley. It proved to be a propitious meeting for both men and, ultimately, for NIWA.

Bob returned home to New Zealand and, with Tony's help, secured a job with the New Zealand Meteorological Service in Kelburn. He later transferred to Paraparaumu to apply his instrumentation maintenance skills to the organisation's network.

Then came 1992 and NIWA was formed. Tony, building a team of specialist instrument technicians for the country's new science organisation, knew exactly who he needed. Bob was the first person he called.

"When I first worked with him in Antarctica, I was just so impressed," Tony says.

"He's just so very, very good with his mechanical and technical ability. He's straight-out practical and gets things done – and a helluva nice guy with it.

"He'll try anything and he's the ultimate fixer-upperer. Give him something that's not working, he'll mumble a bit under his breath, go away and find some bits and pieces and get it working again."

Crucially, Bob's stayed ahead of the curve when it comes to continual innovation and development in scientific instrumentation, Tony says.

"He's kept up with it all the way through, from the pen and ink of charts through to the latest technology. He's stayed ahead of things and he's still got all the old stuff in the back of his mind as well, which is exactly what's needed a lot of the time.

"He's always there to help our younger people and the general rule is, 'Go see Bob – he'll sort it out for you'."

In fact, Bob's sorted out much of the most important instrumentation development, installation and maintenance work NIWA has ever undertaken at globally significant sites, including the Lauder atmospheric research station in Central Otago and the Baring Head Clean Air Monitoring Station.

He's also helped design and maintain NIWA's world-class meteorological station network throughout the country, working on critical data logging equipment servicing, selecting optimal sites for data collection to ensure data of the highest standard to meet World Meteorological Organization protocols.

As well as visiting just about every part of New Zealand, Bob's role has taken him throughout the Pacific, as well as back to where it all started in Antarctica: "Around 12 times, I think – I was trying to count them just the other day.

Bob Newland. (*NIWA*)

"Sometimes you do pinch yourself and think, is this for real? I very much enjoy what I do, coming to work, meeting new challenges and working with great people. It's fantastic and it helps keep you young, fit and on your toes."

It's NIWA's people that create the foundations for great science that makes a difference, Bob believes. He rattles off the names of people he's worked with in the past and still does today.

"I could go on forever," he says. "I enjoy learning the characteristics of individuals, their idiosyncrasies, strengths and weaknesses. I like to pick up on someone's strengths, help build on those strengths and then let them go for it."

Now 68, Bob has no intention of slowing down, let alone retiring. There's still a lot to do and stuff to discover, "and I'll continue to do that while I've got good health".

Having moved to Greymouth from Christchurch with wife, Rosina, around 10 years ago, Bob's finding plenty to do on the West Coast besides working.

Hunting and fishing are passions that keep his competitive juices flowing.

"I do like a competitive element," he says. "From card games to drinking games – I always like to win."

His latest interest was inspired by one of his grandchildren – reading science fiction novels.

"It pushes the boundaries, and it's really quite surprising in later life the sorts of things that capture your imagination."

Solutions

Regional climate change

As climate change takes hold, regional council planning, sustainability and hazard managers are looking to NIWA for help to understand how their communities will be affected.

NIWA's climate team – the country's largest and most experienced – employs big data, extraordinary computing power and painstaking analysis to prepare climate-change projections for individual New Zealand regions. The team works closely with councils to ensure information is conveyed to stakeholders in clear and compelling ways.

First, the big picture

Dr Brett Mullan leads NIWA's efforts to assess how climate change will affect the country as a whole – up to 150 years into the future.

He relies on supercomputing power – and lots of it – to run sophisticated programmes called General Circulation Models (GCMs). GCMs use mathematical equations to simulate the intricate physical and chemical interplay between atmosphere, oceans, land and ice that drives our climate.

"We can adjust, or 'force', GCM inputs, such as greenhouse gas volumes, to see how that interplay will change over time, and how our climate is likely to alter as a result," Brett explains.

Brett Mullen. (*Dave Allen*)

More than 40 GCMs, run on supercomputers around the world including NIWA's new state-of-the-art Cray units, play their part in generating national climate change projections for New Zealand.

"But it's not simply a case of flicking a switch," Brett says. "There are significant challenges we need to address."

Not all GCMs perform equally in the New Zealand setting, which is why so many are used together. When there's general agreement between GCM outputs, researchers have greater confidence in their predictions. When there's widespread disagreement, the task becomes considerably harder.

There's also doubt about future rates of global greenhouse gas emissions. To account for this, the Intergovernmental Panel on Climate Change has established four future emissions scenarios, known as Representative Concentration Pathways (RCPs). Each RCP assumes a different rate of emissions into the future – ranging from a slowdown, to unabated growth.

Brett runs GCM simulations using each RCP, producing a range of possible climate-change outcomes for the nation at different dates in the future.

It's complex, multidimensional science, which Brett has successfully translated into three exhaustive national climate-change projection reports for the Government since 2001.

Scaling down to regional level

Next, the team turns its attention to 'downscaling': tightening the focus of their projections to an individual region. Downscaling involves yet more computing power, and yet more complex mathematics.

First, Brett assesses which of the GCMs used to generate national projections will perform best at a smaller scale. For NIWA's most recent round of regional analyses, six models were chosen using a process of statistical elimination.

Brett works with colleague Stephen Stuart to draw down the necessary regional data – terabytes worth – onto NIWA's supercomputers. The data are used to establish 'boundary conditions': measurements such as sea-surface temperature and sea-ice extent, which provide a starting point for the models' computations.

Then the number-crunching begins. All six models are run four times – once for each RCP – to mathematically scale their outputs down to the area of interest.

More analysis follows; more looking for trends and assessing the respective merits of each model's outputs. There are 'biases' to sort out too – innate errors in the models that must be recognised and corrected before outputs are usable. Brett draws on the specialist skills of colleague Dr Abha Sood to help.

The resulting projections cover a range of climate variables, including temperature, rainfall, sea level and soil moisture, for the specified region.

Identifying local priorities

Meanwhile, Auckland-based climate scientists Petra Pearce and Dr Drew Lorrey are in deep discussion with the commissioning council to determine key areas of focus for the regional information package they'll prepare.

"A vital part of the job is to understand those priorities, to ensure we're providing relevant information to the council," Petra says. "For example, Northland is predominantly rural, so we focused our report on agricultural impacts. Greater Wellington is a mix of urban and rural environments, so that was reflected in our package for them."

Making sense of it all

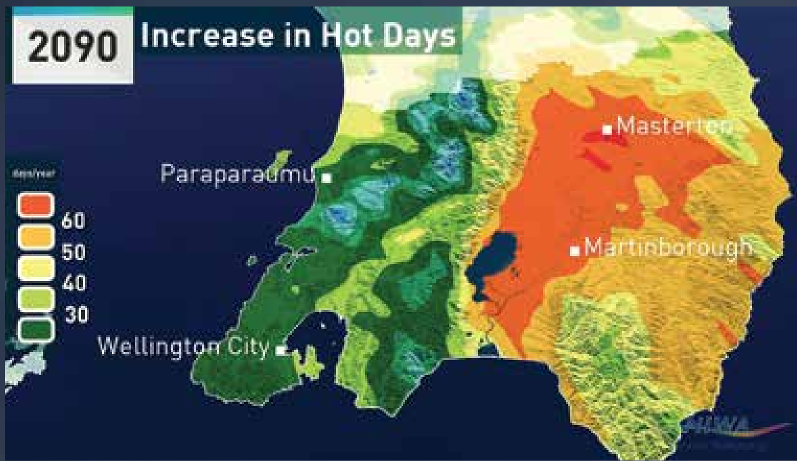
With regional priorities clearly understood, Petra then sets about assembling a comprehensive technical report.

"It's not simply a case of pasting the modelled projections into a document and hitting send," she says. "We look at the priority areas and assess how the projected changes will impact on them. That requires expert knowledge from right across NIWA.

"Sometimes up to a dozen NIWA scientists will provide commentary for the report – covering fields as diverse as coastal inundation, erosion, soil productivity and marine biodiversity."

Petra and Drew also consider the information needs of stakeholders who don't have a background in science. They work with council staff and NIWA data-visualisation specialist Nava Fedaeff, and videographer Stuart Mackay to prepare a summary report and video that present highlights of the region's climate change story.

Drew Lorrey and Petra Pearce. (*Stuart Mackay*)



"Climate change affects everyone," Petra says, "so it's important that people from all backgrounds can make sense of it. For some, that's reading a 300-page technical report. For others, it's watching a four-minute video."

Greater Wellington Regional Council Senior Science Coordinator Penny Fairbrother says the options provided by NIWA paid real dividends for the council's outreach efforts.

"We were really impressed with the information package provided," she says. "The video made to accompany the full technical report communicated the key messages clearly and simply."

More information

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Monitoring the Maitai

The first Wednesday of the month finds Philippa Eberlein and her Friends of the Maitai colleagues collecting samples from the Maitai River in Nelson.

It's a monthly routine she has held since 2014 when she answered an advertisement, placed by Friends of the Maitai in the newspaper, seeking 'citizen science volunteers' to help with a project organised by NIWA.

With a background in ecology and microbiology, the UK ex-pat is a perfect volunteer for the role and recently attended a NIWA-sponsored freshwater science conference in Hamilton to extend her knowledge on water monitoring.

"I hadn't worked in the science field for a while when I read the advertisement. The Maitai is right on my doorstep and I was very interested in the role. We use NIWA-provided kits to measure various parameters including clarity, conductivity, dissolved oxygen, pH, temperature, nitrates and phosphates. We also look at the periphyton and take a water sample to look at the *E. coli* concentration. The sample is filtered, placed on a nutrient gel and incubated overnight. Then the colonies are counted. There are two sites that we do every month and two other sites that we monitor quarterly or as we think necessary," says Eberlein.

The information is collated and provided to the Nelson City Council annually to include in its database. The collaboration between the Friends of the Maitai, the Council and NIWA is helping provide a robust picture of the river's health, with community monitoring data used alongside Council water quality monitoring data.

"I have just completed a project with Paul Fisher at Nelson City Council comparing three different *E. coli* kits for ease of use and accuracy compared to the results of professional labs that can be used in the community. We achieved generally consistent results at low concentrations, which was encouraging. Where there were higher levels, we needed to dilute the sample," Eberlein says.

Comparatively, the Maitai is cleaner than many of New Zealand's rivers, but Ms Eberlein says this can change dramatically following significant rainfall or nearby logging activity. The Nelson City Council's River and Stream Health Annual Monitoring Summary 2015/16 rated four of its 11 officially monitored sites on the Maitai 'D' (degraded).

Paul Fisher (Nelson City Council) and Philippa Eberlein (Friends of the Matai) gather samples on the Maitai River. (*Caroline Crick*)

NIWA-provided kits are used to measure various parameters including clarity, conductivity, dissolved oxygen, pH, temperature, nitrates and phosphates. (*Dave Allen*)

"The more you participate, the more interesting the monitoring becomes and more challenges we find. Having returned from the freshwater science conference and listened to several presentations on macroinvertebrates, I was inspired to do another survey of our sites and discovered an abundance of mayflies and caddisflies and no snails or worms, which is good," says Eberlein.

"I'm now looking at sediment samples to compare the *E. coli* levels in the water. This will involve some experimentation with extracting the *E. coli* from the sediment before filtering. NIWA is fantastic to work with. The team is always very helpful and quick to respond to questions and giving advice."

Friends of the Maitai: friendsofthemaitai.org.nz/about/river-monitoring/

(*Above*) Data gathered by other citizen scientists can make a big difference to improving water quality around New Zealand. (*Below*) River bed through the orange bathyscope. (*Dave Allen*)

NIWA
enhancing the benefits 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 more than 670 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:

An Adelie penguin rests on the stern ramp of *Tangaroa*, seemingly resting on the vessel in the absence of sea ice. (*David Bowden*)

NIWA
Taihoro Nukurangi

enhancing the benefits of
New Zealand's natural resources