Antarctic Research Centre

annual review 2015

TE WHARE WĀNANGA O TE ŪPOKO O TE IKA A MĀUI
VICTORIA
UNIVERSITY OF WELLINGTON

2015 IMPACTS BY NUMBERS

3 Rutherford Discovery Fellows now at the ARC with Nick Golledge joining Nancy Bertler and Rob McKay.

460 telecasts on the American Public Television network showed the climate change film *Thin Ice* to an estimated audience of 120 million.

13 Marsden Fund grants awarded to ARC staff since 2001, of these seven were Marsden Fast-Starts. Co-principal investigators Nancy Bertler and Rob McKay won a new grant in the 2015 round.

23 *Nature*, *Science* and *Proceedings of the National Academy of Sciences* papers have been authored by ARC staff with two led by ARC staff in 2015.

2 authors contributed to the current IPCC *5th Assessment Report* from the ARC, Tim Naish and Dan Zwartz.

9 theses submitted - seven PhD and two MSc students completed in 2015.

35 presentations and panel discussions given to the public, stakeholders and decision makers by ARC staff.

25 radio, TV and newspaper interviews given by ARC staff on Antarctic and climate related issues.

68 percent reduction of New Zealand's Southern Alps glaciers by the year 2100 according to monitoring and modelling by the ARC glaciology team.

1 st evidence of the occurrence of an Antarctic marine ice sheet instability mechanism, thought to drive abrupt global sea-level rise, was reported by Richard Jones, Andrew Mackintosh and Nick Golledge in *Nature Communications*.

40 cm of additional sea-level rise, above the predicted 98 cm reported by the IPCC for the year 2100, may come from Antarctic ice melting according to Nick Golledge in *Nature*.

285 submarine cable systems under-pinning over 98% of global communications and Internet are monitored for climate hazard-related damage by ARC's Lionel Carter, advisor to the International Cable Protection Committee.

Contents

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Designed and edited by Michelle Dow
Contributions from Tim Naish, Nick Golledge, Andrew Mackintosh, Huw Horgan, Lionel Carter, Rob McKay, Nancy Bertler, Gavin Dunbar, Alex Pyne, Michelle Dow

Front cover photo: Mawson Glacier, Antarctica - Richard Jones
This page photo: An 'apple' shelter, Antarctica - Matt Vaughan (University of Otago)
Back cover photo: Ice cave, Antarctica - Matt Vaughan (University of Otago)

DIRECTOR'S SUMMARY

In this years annual review we have introduced a new format that emphasizes, up front, the major outcome benefits from our 2015 research activities. Firstly, in "Impacts By Numbers" section we highlight research impacts that distinguish themselves on the basis of excellence and relevance. We then profile in more detail four new Antarctic Research Centre-led, policy-relevant discoveries, that will help reduce uncertainties around glacier and ice sheet contribution to future sea-level rise. We also provide a "rubber hits road" example of how our knowledge of climate and hazard driven deep ocean processes are being applied to manage and protect submarine telecommunications cables.

In February we moved back into the 5th floor of the Cotton Building on Kelburn Campus, and were reunited with our friends and colleagues in the School of Geography, Environment and Earth Sciences (SGEES). The new digs are much improved and walls are handsomely adorned by some great Antarctic images, both historical and recent. Thanks to Michelle Dow, ARC Centre Manager, for her outstanding co-ordination of the move, and to Kosta Tashkoff (SGEES) for his help and support with the refurbishment.

Overall, 2015 has been another highly-productive year for the ARC. It was a big year for postgraduate student completions, with seven PhD theses and two MSc theses submitted. We look forward to a new cohort of students in 2016. Our commitment to world-leading Antarctic and climate change research that makes a difference internationally and in New Zealand is grounded in scholarly research published in leading scientific journals. Staff and students were involved in 34 publications in top international peer-reviewed journals, and as stated above we profile the impact of these four papers published in *Nature*, *Nature Communications*, *Geology*, and *Earth and Planetary Science Letters*.

Our commitment to communicating the relevance of this research to the public and stakeholders was equally impressive, and its timeliness and urgency heightened by the Paris climate negotiations (COP 21) held at the end of the year. Thirty-five presentations and panel discussions were made to the public, policy-makers and stakeholders including local authorities, government agencies, non-governmental think tanks, political parties and politicians, school and community groups. Staff also made 25 media appearances on radio, TV, and in print, discussing the implications of proposed climate mitigation for Antarctica and sea-level rise on the back drop of COP 21.

Although it's always so hard, I like to pick out a few of the most significant achievements. Nick Golledge is the third ARC researcher (following Nancy Bertler and Rob McKay) to be awarded a prestigious and highly competitive Rutherford Discovery Fellowship. Nick's *Nature* paper, "The multi-millennial Antarctic commitment to future sea-level rise" provides new estimates for Antarctic ice sheet contribution to future sea-level rise, and shows the only climate scenario that prevents significant melting, is to limit global warming to less than 2°C – the challenging target adopted by the worlds governments in Paris. Nancy Bertler and Rob McKay received the ARC's 13th Marsden Fund grant for a new project "Predicting a sea change: Antarctic ice-ocean interactions in a warming world". And last but certainly not least Lionel Carter was awarded the Hutton Medal by the Royal Society of New Zealand for his career contribution to understanding the evolution of New Zealand's ocean environment.

As always our science drilling team are staying one step ahead of the game, by developing the appropriate technology to support present and planned projects. On the books in 2015 was hot water drilling. The University approved the capital expenditure of $800,000 to build a new hot water drill capable of penetrating 1000 m to access the cavity under the Ross Ice Shelf. The system will be built at VUW, and commissioned on the ice in 2016 by ARC's Alex Pyne and Darcy Mandeno, with support from the Korean Polar Research Institute, Antarctica New Zealand, NZARI and the British Antarctic

Professor Tim Naish
Director, Antarctic Research Centre

Survey. A new permafrost drill capable of recovering up to 30 m long cores was also developed and tested in collaboration with long time partners, Webster Drilling. This will be used in the Friis Hills, Dry Valleys, in 2016 to support an MBIE funded collaborative project between VUW, GNS Science, University of Otago, and US and Italian colleagues, to recover a geological archive of warmer terrestrial climate on Antarctica 20-14 million years ago. Darcy also completed design and fabrication with Websters, of a floating barge platform for the Lake Ohau drilling project undertaken in February 2016.

Funding for Antarctic research in New Zealand remains a bittersweet challenge. While ARC staff continue to perform well in highly competitive contestable funds (e.g. Rutherford, Marsden), and a new modest-sized philanthropic fund provided by NZARI is a welcome addition, the lack of medium to long-term funding security remains a considerable risk as New Zealand attempts to sustain its world-leading Antarctic research reputation.

Nevertheless, I wish to sign off on a positive note by acknowledging the importance of our national and international partners, and stakeholders, whose collaboration allows our talented staff and students to continue to produce high-quality, world-class research that matters and makes a difference.

OUR MISSION AND RESEARCH APPROACH

We believe our field of research provides exciting opportunities and challenges attractive to young researchers, and is needed to provide a sound basis for international climate change assessment and predicting local impacts to enhance policy development for a more resilient New Zealand.

The Antarctic Research Centre (ARC) is one of a number of centres of research excellence within the Faculty of Science at Victoria University of Wellington and reports directly to the Dean of Science. It is co-located with the School of Geography, Environment and Earth Sciences, with which it shares academic staff and facilities. It also contributes to both undergraduate and graduate teaching and supervision in the fields of sedimentology, glaciology, paleoclimatology and Antarctic affairs.

Rationale

The warming trend observed over the past century and models of its future trajectory suggest that we are rapidly heading towards a climate last experienced more than 3 million years ago - a time before our species had evolved. In order to assess model-based climate projections, scientists are increasingly looking back to the future to gain insights into the likely response of Earth's climate in a world with high levels of greenhouse gases. Ice sheets and oceans are some of the slowest responding elements of the climate system to an atmospheric carbon dioxide perturbation - taking centuries to millennia to play out, and are therefore potentially irreversible on human timescales. Reconstructing past climate conditions provides the only possible way to assess the long term "endgame" (equilibrium response), that we will commit our planet to this century based on the current warming scenarios - which virtually guarantee +2-3°C increase in global surface temperature. Past climate records also allow the role of anthropogenic influences to be determined in the context of natural variability of the climate system on human timescales.

Outcome-based research

Our research approach is policy-relevant and outcome focused. We reconstruct the response of the Antarctic and Southern Ocean to past climate change, that is similar to that projected for the coming centuries by the Intergovernmental Panel on Climate Change (IPCC). We do this to improve the performance of the models assessed in the IPCC reports in order to reduce the uncertainties around future climate and sea-level rise predictions. We improve understanding of the influence and impact of Antarctic and Southern Ocean change on the global climate system, especially the Southwest Pacific region and New Zealand. Our research is leveraged by very strong national and international collaborations and partnerships and world leading in-house polar drilling technology provided by the Science Drilling Office, and is funded and supported through a range of MBIE and Marsden programmes, Antarctica New Zealand and private donations.

In summary our approach involves:

a. The acquisition of past (paleo) observations of surface temperature, atmospheric circulation and composition (greenhouse gases and aerosols), ice sheet, glacier, and sea-ice variability, and oceanic conditions from geological and ice core archives.

b. Undertaking process studies of modern glaciers and glacial and marine systems.

c. Integrating the observations and processes with numerical modelling to understand sensitivity and response of the Antarctic ice sheet and climate system to the type of forcings and feedbacks projected for the future.

d. Then use those same models to improve future projections of ice sheet contribution to sea-level rise and other changes in the Earth System.

e. Comparison and correlation with equivalent "far-field" observations and reconstructions, of global extent, and within the SW Pacific and New Zealand (e.g. records of global sea level and local New Zealand ocean and climate change).

f. We disseminate our research findings through publications in the world's leading scientific journals, and through education, communication and outreach to the public, practitioners and policy makers.

Hut Point, Ross Island, Antarctica
Photo: Michelle Dow

"improve understanding of Antarctic ice sheet and climate processes and their influence on New Zealand and the global climate system."

EMISSIONS REDUCTIONS ESSENTIAL TO AVOID SEA-LEVEL RISE

Wilhelmina Bay, Antarctic Peninsula - Photo: Nick Golledge

In a recent report "Preparing for Sea-Level Rise (SLR)", The NZ Parliamentary Commissioner for the Environment, made the following important statement. "It is certain that the sea is rising and will continue to do so for centuries to come. But much is uncertain – how rapidly it will rise, how different coastal areas will be affected, and how we should prepare." As atmospheric CO_2 concentrations continue to rise, a global community of glaciologists is increasingly wondering how the expected rise in temperature will affect the largest ice sheet on Earth, the Antarctic ice sheet. Considered for a long time to be relatively stable, with its great expansions and contractions mostly controlled by changes in the Earth's orbit on time scales of thousands of years, the Antarctic ice sheet is now revealing a much more dynamic side – one that has the potential to drastically reshape our coastlines over coming decades.

Together, the two parts of the Antarctic ice sheet that make up the continent – the West Antarctic and East Antarctic ice sheets – contain enough freshwater to raise global sea levels by nearly 60 m. But how much of this might be released over coming decades is an area of large uncertainty, and consequently the focus of very active current research that can only be tackled with sophisticated numerical models that can simulate the entire continent.

One of the most difficult aspects of using a computer model to predict the future, however, is the careful 'tuning' that is required to allow the model to accurately simulate past changes and the present. This process commonly takes hundreds of experiments to get right, and with individual simulations often taking several days to complete, this tuning procedure can take many months.

But by building on a methodology established and refined over several years, and using an internationally developed numerical ice sheet model, Nick Golledge began tackling this subject as part of his Marsden Fast-Start project. Working with climate modellers and geologists in the USA, Australia, and New Zealand, including ARC Director Tim Naish and Richard Levy (GNS Science), Nick tuned his model to simulate the Antarctic ice sheet under past and present-day conditions as closely as possible, and then used climate model predictions for the future to see how the ice sheets would behave.

The results, published in the journal *Nature*, were startling – under a greenhouse gas emissions scenario in which no mitigation takes place, nearly all floating ice in Antarctica is lost by the end of the century. Without these ice shelves to hold back the grounded ice on the rest of the continent, an unstoppable chain of events is set in motion that contributes 40 cm to global sea-level rise by 2100 without emission reductions, and ultimately leads to increases in global sea level of up to 3 m by 2300. Significantly, the simulations showed that the only way to avoid a substantial contribution to sea level from Antarctica is to limit global warming to less than 1.5–2 degrees above present temperatures, the level agreed by governments at the 2015 UN Conference of Parties in Paris.

Several aspects of the study have immediate policy relevance. Firstly, IPCC is currently underestimating Antarctica's contribution to sea-level rise by 2100. Secondly, the greenhouse gases we emit today will commit the planet to a series of global environmental impacts that will continue for thousands of years into the future. Thirdly, although the 'end-game' of the ice sheet response may take millennia, the initial effects will be felt in the next few decades, as rising sea levels lead to more frequent coastal inundation and damage to property.

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EVIDENCE OF RUNAWAY ANTARCTIC ICE LOSS IN THE RECENT PAST

Sea-level rise in coming centuries will become increasingly dominated by glacier and ice sheet contributions. However, predicting these contributions remains challenging because several processes that determine glacier response are poorly understood and not well resolved in numerical models. Such processes may induce threshold ice sheet response, resulting in abrupt, runaway ice loss. Of particular concern is the 'marine ice sheet instability', where initial retreat of an ice margin, in contact with the ocean, into a deepening valley below sea-level may lead to rapid, unabated ice loss. Two recent ARC publications have highlighted the role that this instability mechanism played in the retreat of the Antarctic ice sheet in the Ross Sea region following the last ice age (~20,000 years ago). Both of these studies imply that once triggered, marine ice sheet retreat could be rapid and persist for centuries without further climate forcing.

Richard Jones (a current ARC postdoctoral fellow) led a study published in *Nature Communications*, with his PhD supervisors Andrew Mackintosh, Kevin Norton (SGEES) and Nick Golledge. Using results from the newly developed Beryllium-10 (^{10}Be) dating facility at VUW, Richard showed that Mackay Glacier, an outlet of the East Antarctic Ice Sheet, underwent rapid thinning around 7,000 years ago, in a climate similar to present. This is arguably the finest ^{10}Be dataset to come from Antarctica, with ~ 40 high precision ages tightly constraining the behaviour of Mackay Glacier between 20,000 years ago and the present. It is also the first study to unambiguously link geological evidence of rapid ice surface lowering to the marine ice sheet instability via numerical modelling. Importantly, it shows that the rate of glacier thinning events, similar to those observed by satellites in rapidly changing parts of Antarctica today, may continue unabated for centuries.

Working on ANDRILL site survey cores collected beneath the Ross Ice Sheet, in the vicinity of the proposed Coulman High drilling project, the ARC's Rob McKay, Nick Golledge, Tim Naish, Gavin Dunbar, and MSc graduate Sanne Maas led a paper in *Geology* that showed this process of marine ice sheet instability was widespread during the deglaciation in the central regions of the Ross Sea. They obtained an age for the retreat of the ice sheet in central Ross Sea more than a thousand years earlier than previous studies from coastal sites in the Western Ross Sea. Supporting ice sheet model simulations indicate that substantial ice loss could have occurred in the central Ross Sea prior to the Holocene and may have contributed to rapid global sea-level rises (e.g. meltwater pulses) of up to 4 m per century.

Of concern is a growing realisation that processes of marine ice sheet instability may cause significant ongoing loss of Antarctic ice sheet mass for millennia to come even if the climate system stabilises. Studies using ice sheet model simulations for future carbon dioxide emission pathways (e.g. see above) predict an on-going commitment to many metres of global sea-level rise if Earth's climate warms more than 2°C above pre-industrial levels – the United Nations "safe" climate limit. Together, these two geological studies provide the first direct evidence that this process has actually occurred in the past.

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Kevin Norton and Chris Fogwill sampling for cosmogenic dating - Photo: Richard Jones

TEMPERATE GLACIERS CAN ACCELERATE DRAMATICALLY

Franz Josef Glacier, New Zealand - Photo: Brian Anderson

How fast can glaciers deliver ice to the sea? This question lies at the heart of sea-level rise uncertainty. However, many of the processes that control ice motion take place at the base of glaciers and ice sheets making them exceedingly difficult to observe and model. New studies in the Southern Alps, New Zealand, now provide us with some unprecedented observations of glacier acceleration due to changes at the glacier base. These observations span the main divide and address two of New Zealand's most iconic glaciers: Franz Josef and Tasman.

On the wetter side of the Southern Alps, Franz Josef Glacier experiences vast amounts of precipitation and meltwater is literally everywhere on Franz Josef - above, inside and beneath it. MSc graduate Laura Kehrl and her supervisors Brian Anderson, Ruzica Dadic, Huw Horgan and Andrew Mackintosh, recently undertook a study, published in the *Journal of Glaciology*, of Franz Josef Glacier by installing a series of GPS units on the surface, with the aim of understanding how this glacier responds to water inputs. Water can influence glacier sliding in a counter intuitive way. For example, water usually makes the largest difference in spring (rather than summer) when water confined beneath glaciers floats the overlying ice, increasing the rate of ice flow. However, at Franz Josef Glacier, Laura discovered that the glacier still responded to increases in water flow at the glacier bed in late summer. With heavy rainfall events occurring at Franz Josef every week or so, and extreme rates of melting, this behavior will continue into the future, allowing rapid transport of ice to the ablation zone, where a warming climate is driving glacier retreat (Kehrl *et al.* 2015).

Despite sharing the main divide with Franz Josef Glacier, Tasman Glacier is a different beast, with slower ice-flow rates and, it was considered, less interesting dynamics. However, Tasman warrants study as it contains about one-third of all glacier ice in New Zealand, and feeds the Waitaki hydroelectric power system.

When processing the records from GPS units installed on the glacier surface, accelerations in velocity of up to 36 times stood out. These are the largest rain-induced accelerations ever reported in literature. Further analysis showed that after heavy rain the glacier lifts off its bed by over 50 cm as cavities form due to high water pressures. The ice moved fastest while the cavities were forming, and settled down to a still enhanced sliding velocity after cavity growth had stabilized. This finding, published in *Earth and Planetary Science Letters* (Horgan *et al.*, 2015), has dramatically changed our view of the dynamics of this and similar glaciers (the big and slow can still surprise).

The next challenge is to learn more about glacier accelerations using these observations and appropriately include these processes in the numerical models that we are using to predict glacier response to climate change.

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MANAGING AND PROTECTING THE GLOBAL DEEP OCEAN TELECOMMUNICATION CABLE NETWORK

Research provides skills, knowledge and experience with wide applications in the outside world. For the past decade, Lionel Carter, has worked with the submarine cable industry to assess risks to the global network of fibre-optic cables posed by natural hazards including climate change. Why is this significant? The development of the Internet in the late 1980s coincided with the first trans-oceanic fibre-optic cable. It was a fortuitous marriage that changed the world. Suddenly, there was a mechanism to generate vast amounts of information and a means to distribute that information around the planet at lightening speed. Today, 98% of voice, data, video and Internet traffic is via submarine cables. Thus protection of this critical infrastructure is paramount.

Enter the International Cable Protection Committee (ICPC) - a not-for-profit forum for the cable industry and other groups including the New Zealand government. Natural hazard research supported by the ICPC is documented as peer-reviewed papers to assure quality and independence. Thus, the research contributes to our knowledge of deep-ocean processes such as landslides and turbidity currents, the main causes of cable damage. Emphasis has been on Taiwan because of its extreme seismicity, typhoon-charged weather and position at a major cable route. In 2006, earthquake-triggered landslides and turbidity currents caused 22 cable breaks and temporarily isolated SE Asia. More damage occurred from 2009 onwards when more intense typhoon floods formed destructive turbidity currents - a possible effect of regional climate change.

Recognising that science papers are not easily consumed by the public, ICPC focuses on science communication. It collaborated with the United Nations Environmental Programme to produce an easy-to-read booklet *Submarine Cables and the Oceans* (available at https://www.iscpc.org/publications/). In the financial year 2012-13, over 74,000 downloads were recorded attesting to successful outreach. It helped that the booklet was free.

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A fibre-optic cable (extending from the lower right side) is recovered for repair from about 4000 m depth off Taiwan. It is damaged by a mass of fishing debris, plastic and wood swept from the continental shelf by a turbidity current -Photo: Lionel Carter

PAST CLIMATE WINDOWS PROVIDE IMPROVED VIEW OF THE FUTURE

Drilling to find the triggers for Antarctic ice sheet collaspe

After several years of development, the ARC-led international proposal to drill a series of six geological cores in the Ross Sea, has now officially been endorsed for future drilling by the International Ocean Discovery Program (IODP) – arguably the world's premier geoscience programme. The proposal was given the highest possible ranking for scientific merit, and is currently awaiting scheduling to drill by the *JOIDES Resolution* research vessel, hopefully coinciding with the drill ship's visit to our region in 2018. The last major drilling efforts in the Ross Sea were the ANDRILL cores in 2006-07, which provided the first direct evidence of ice sheet retreat events over the past 20 million years from the inner Ross Sea continental shelf. This new project aims to build on these ice sheet "collapse" ANDRILL records by drilling on the outer Ross Sea continental shelf and the adjacent deep sea to understand the oceanic triggers that may have initiated past collapse events at the continental shelf edge, as well as documenting the oceanic responses to large shifts in Antarctic ice volume.

Working with Korea to recover climate archives from the Ross Sea

Analytical work began on the cores and geophysical data collected as part of a New Zealand-Korean research voyage to the Ross Sea in 2014/15. Gavin Dunbar and MSc student Olya Albot participated in the research expedition, while Rob McKay and Olya visited the Korean Polar Research Institute (KOPRI) during 2015 to help sample and interpret the cores. The sediment cores obtained will cleary address a range of scientific objectives, most notably better constraining the timing of ice sheet retreat in Ross Sea since the Last Glacial Maximum, and providing a stratigraphic record of oceanographic and ice sheet change over the last ~2 million years from long piston cores collected on the continental rise. While these records will be important paleoclimatic archives in their own right, they will also form the basis for interpreting the longer cores to be collected as part of the future IODP drilling in this region. Geophysical data was also collected by KOPRI scientists that ultimately proved invaluable in obtaining final scientific approval for the IODP Ross Sea proposal.

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RICE ice core provides insights into sensitivity of ice sheets to ocean warming

Over the past two years, the international Roosevelt Island Climate Evolution (RICE) team has completed the continuous flow analysis of the 763 m deep ice core and analysed thousands of discrete samples for analysis on gas content, dust, volcanic ashes and geochemical composition leading to a remarkable data set of exceptional dating precision. The evolving RICE data set provides a highly resolved reconstruction of the deglaciation in the Ross Sea region over the past 80,000 years and perhaps beyond. This region is particularly important as the Ross Sea is a major drainage pathway of West Antarctic ice and is one of four sources of Antarctic Bottom Water formation, an important engine of the global ocean conveyor and global heat budget. Moreover, the area is influenced by meltwater originating from the rapidly changing Amundsen / Bellingshausen Sea shelf regions, and experienced recent sea-ice growth. The RICE record provides new and unsettling insights into the sensitivity of the Ross Ice Shelf and West Antarctic Ice Sheet to ocean warming and will help us to improve projections of West Antarctic contributions to future sea-level rise.

First publications from our group focused on the calibration of the record with the modern observations (Neff *et al.* 2015, Tuohy *et al.* 2015, Emanuelsson *et al.* 2015) which allows us to take advantage of the high resolution nature of the deeper record. With the age model now in place, a large body of publications are waiting in the wings for submission over the coming months. To follow our progress during this exciting time, please check out www.rice.aq

PAGES project - 2000 year temperature reconstruction of Antarctica

The ice core team contributed high resolution ice core records from three regions - Victoria Lower Glacier, Mount Erebus Saddle and Whitehall Glacier to the Antarctic 2000 year (2ka) temperature reconstructions. The reconstruction considers well dated, annually resolved records and assesses the quality of each data set and provides a weighing factor based on the quality. The compilation is a contribution to the PAGES 2ka reconstruction of global temperatures which aims to inform the IPCC and provides an important tool to assess model performance for future projections. The ARC was the only New Zealand group who contributed data to the Antarctic 2ka array and represents 30% of the data set spanning at least 100 years. The RICE group is working enthusiastically to also include the RICE temperature and snow accumulation reconstructions in time for the 2016 publication of the array reconstruction.

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Pliocene Ice-Sheet Model Intercomparison Project (Antarctica)

One of the many significant challenges involved in making interpretations from computer models lies in knowing which aspects of the results are influenced by the model itself. To overcome these kind of obstacles, many modelling groups employ 'intercomparison' techniques, in which different models are used to simulate the same scenario. Nick Golledge participated in one such exercise, in which the focus lay on determining the extent of Antarctic ice sheets during the mid-Pliocene period, when global climate was much warmer than today. Although there were differences in outcome predicted by the six different ice-sheet models, an analysis of the results, published in *The Cryosphere* (de Boer *et al.* 2015), identified regions where ice sheet changes were consistent between all models. This kind of work has great potential for refining uncertainty estimates on future ice sheet predictions.

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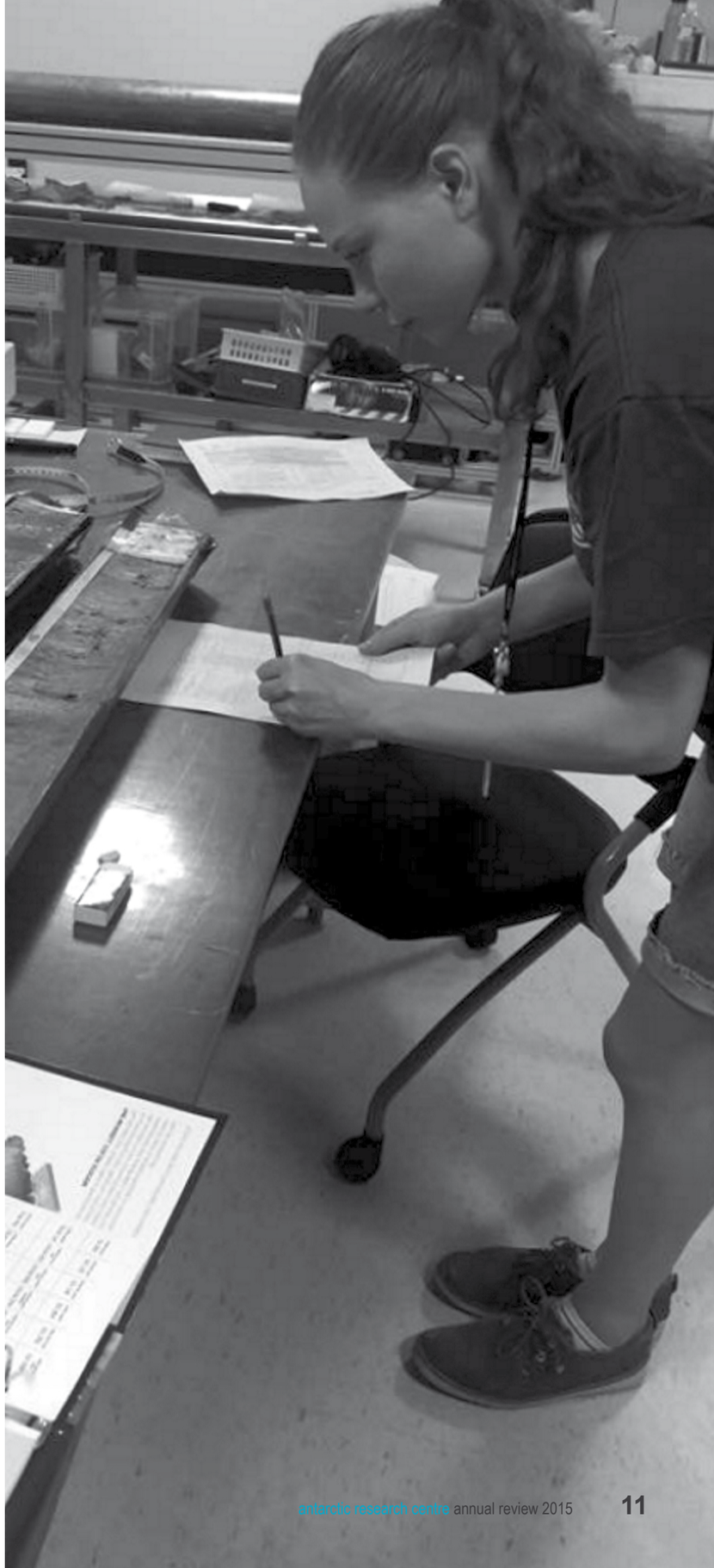

Olya Albot in Korea describing the KOPRI cores - Photo: Olya Albot

HOW THE DEEP SOUTH AFFECTS CLIMATE CHANGE IN NEW ZEALAND

Did a previous collapse of the Antarctic ice sheet cause abrupt climate change in New Zealand?

Ice cores show that warming in Antarctica at the end of the last ice age was interrupted by a cold event, known as the Antarctic Cold Reversal, about 14,000 years ago. Geological evidence shows that glaciers in New Zealand readvanced during this interval, but the cause of such cooling remains a mystery. Supported by a NZARI project, postdoctoral fellow Shaun Eaves is working with Andrew Mackintosh and Brian Anderson to examine the spatial pattern of cooling in New Zealand as recorded by mountain glaciers, using a combination of cosmogenic surface exposure dating and glacier modelling. In contrast to some previous work, their initial findings show that New Zealand was 2-3°C colder than present and that this cooling caused glacier advance across the Southern Alps and central North Island. These results are being used to evaluate global climate model simulations in order to test the hypothesis that this abrupt Southern Hemisphere climate event was caused by a large release of meltwater from Antarctica.

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Ancient sea-level change revealed in the geology of Whanganui

Tim Naish, Gavin Dunbar and Rob McKay, together with their students Juliet Sefton (MSc completed) and Georgia Grant (PhD current), have been taking a closer look at global sea-level changes the last time Earth was 2-3°C warmer and carbon dioxide levels in the atmosphere were the same as today - approximately 3 million years ago. This Marsden-funded project has recovered two high-quality geological drill cores in the back blocks of the Wanganui Basin, west of Taihape. Already world renowned for its geological record of sea-level change over the last 5 million years, the new cores are providing a remarkably detailed picture of the frequency and magnitude of sea-level change for this important time that is relevant to sea-level predictions for the coming centuies. Georgia has reconstructed local water depth changes using depth-dependent fossil plankton assemblages (foraminifera) with Hugh Morgans (GNS Science) and sediment grainsize. In collaboration with Christian Ohneiser and Claudio Tapia-Orellana from University of Otago and VUW's Gillian Turner, Brent Alloway and Diane Seward, an age model that will constrain the rate of change is being developed. In 2016, Georgia will travel to Stanford University to undertake geochemical measurements on the foraminifera in Rob Dunbar's laboratory. The next step will involve working with Peter Kamp (University of Waikato) and Michelle Kominz (Western Michigan University) to extract the influence of tectonics on the global sea-level cycles.

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Lake Ohau's annual record of environmental change

Our Lake Ohau, New Zealand research continued to build steadily towards our Marsden-funded deep drilling programme which was rescheduled to early 2016 (read about it in next year's report! Or for a sneak preview http://drill.gns.cri.nz/DrillNZ/Lake-Coring/Lake-Ohau-Climate-History/Latest-News). Detailed analysis of the modern sedimentary processes based on our monitoring programme continued in collaboration with the Australian Maritime College. These processes help determine how the laminated sediments accumulating on the lake floor relate to climate (especially rainfall) in the surrounding catchment. Some of this research was published in the journal *Marine and Freshwater Research* (Cossu *et al.* 2016).

Recently completed PhD student Heidi Roop, combined elements of lake process research and analysis of the last 1400 years of the environmental history from short sediment cores. Heidi also had two papers published, one in *Sedimentology* and the second accepted in the *Journal of Paleolimnology* that combined many aspects of our research from geochronology, sedimentology, hydrodynamics and meteorology to demonstrate that Lake Ohau preserves a complex, but annually-resolved record of environmental change. Heidi was able to identify three primary types of annual layering associated with different climate regimes; large flood events deposit relatively thick, homogeneous layers, frequent smaller flood events in a year deposit a number of very thin silt layers and years without significant floods deposit a simple coarse/fine couplet. The deposits of large floods are particularly intriguing as they appear regularly in the Ohau record back to ~1350 AD and prior to ~950 AD but with a 400 year absence in the middle ages, suggesting a shift in climate regime at that time.

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Ocean productivity changes around New Zealand

Plankton in the Southern Ocean, off the South Island, New Zealand are changing in response to a warming ocean. This study, led by PhD student, Bella Duncan, took advantage of new data to refine a model that shows increasing numbers of coccoliths - a plant plankton species composed of white platelets of calcium carbonate such as those that form the White Cliffs of Dover, UK - will eventually dominate sediment deposits on the extensive Campbell Plateau. This means a change in the base of the marine food chain, the consequences of which have yet to be determined. The new data improves interpretation of the environmental conditions that favoured coccolith blooms in previous warm periods. Then, the uppermost ocean over Campbell Plateau was a semi-stable layer of nutrient-rich water up to 4°C warmer than now - conditions we appear to be approaching today.

Studies of past ocean environments are needed to predict future responses to increasing warmth. Studies of the past identify natural climatic cycles and reveal the effects of long-term change. In the case of the Southern Ocean, it has buffered the full impact of modern change by soaking up about 90% of the extra heat and 30% of the carbon dioxide produced by human activities. This begs the question "What is the natural cycle of this phenomenon?" This question is answered in a study published in *Earth and Planetary Science Letters* (Skinner *et al.* 2015) that examines the passage of heat and gas-bearing surface water into the ocean's interior - a process termed ventilation - since the last Ice Age, 18,000 years ago. At that time, much of the Pacific interior was less well ventilated than today. As climate warmed, changes in winds and ocean currents enhanced ventilation. As is typical of scientific research, as one question is resolved, new questions arise. In this case, they are "Has ventilation increased under modern changes such as the poleward migration of wind regimes?" and "What is the long-term outlook of heat/carbon dioxide uptake by the Southern Ocean?"

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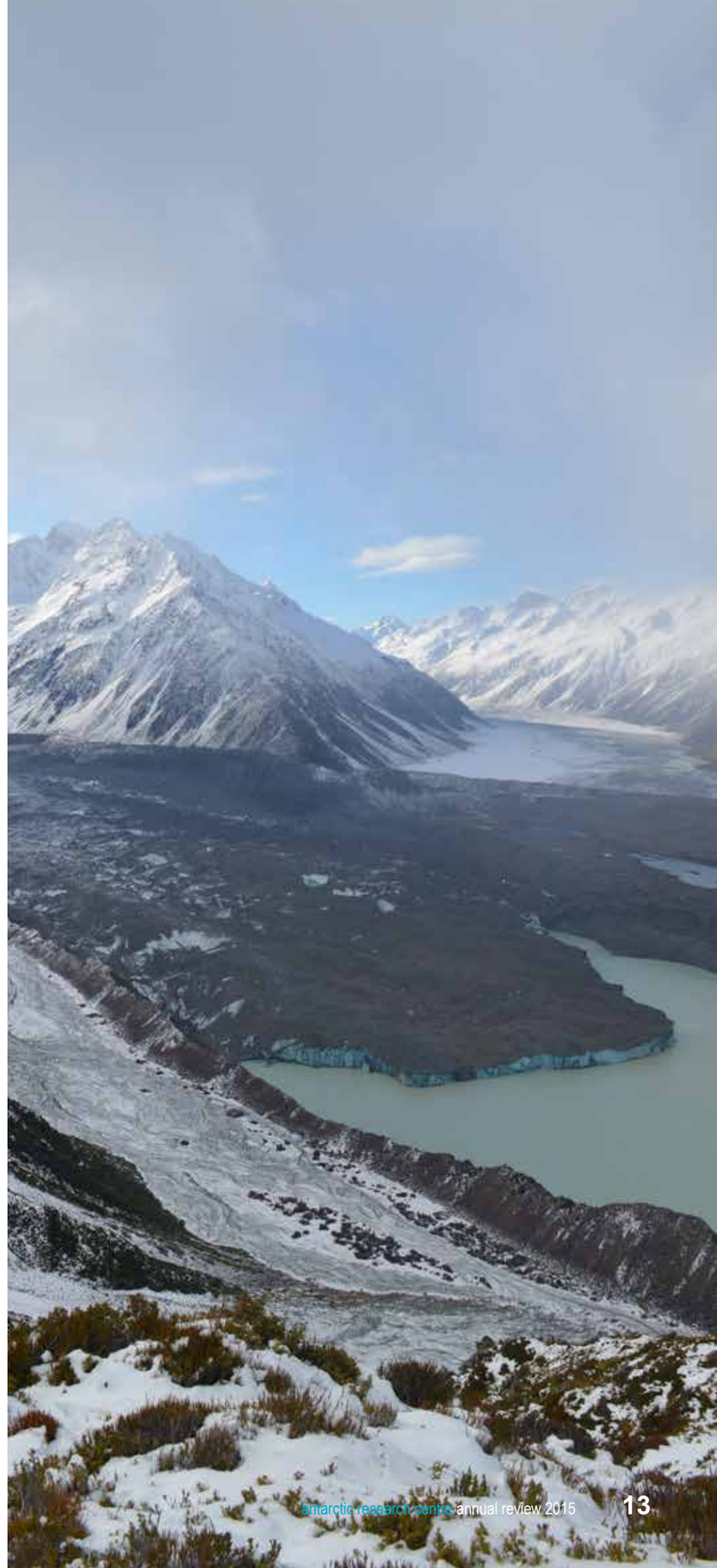


Tasman Glacier, New Zealand
Photo: Brian Anderson

ASSESSING THE STATE OF GLACIERS AND ICE SHEETS

Retreating New Zealand glaciers

Global mountain glaciers are experiencing unprecedented retreat, and New Zealand glaciers are no exception. Brian Anderson, Huw Horgan, Andrew Mackintosh and Ruzica Dadic coordinate our Southern Alps glacier monitoring projects, which contribute to global efforts to document and understand these dramatic changes. In collaboration with the University of Otago, our direct mass balance programme at Brewster Glacier is now in its 12th year. We are also working in partnership with NIWA to monitor New Zealand glaciers from light aircraft in the annual 'end-of-summer-snowline' flights which have been ongoing since 1976. We have been developing new techniques to allow precise positioning of the images taken during these flights, which allows very accurate digital reconstructions of the glacier surfaces. Our new PhD student Lauren Vargo will be using these data to measure snowlines, terminus positions and to reconstruct ice volume changes. Finally, our network of seven time-lapse cameras overlooking four glaciers has now captured ~40,000 images which allow quantification and exploration of the processes driving ice loss in the Southern Alps.

Built on a database of over 1000 snow depth and ice melt measurements, historic maps of glacier positions in the late 1800s, and recent measurements of glacier termini, Brian, Andrew, and colleagues from NIWA have developed a numerical model which has been used to predict Southern Alps ice loss by the year 2100. The results are dramatic - even with a 'middle of the road' emission scenario resulting in a local warming of 2.4˚C, ice volume reduces to 12 km^3 in the central Southern Alps, a loss off 68% from ice volume in 2000. In this scenario, iconic Fox and Franz Josef glaciers retreat to small remnants high in the mountains.

CONTACT: Brian.Anderson@vuw.ac.nz

Imaging the West Antarctic Ice Sheet grounding line

The Siple Coast of the West Antarctic Ice Sheet has preoccupied the glaciological community since the potential for rapid, marine ice-sheet retreat was first postulated in the late 1960s and early '70s. Central to the current understanding of this instability hypothesis is the relationship between ice flow across the ice-sheet-ice-shelf transition (the grounding zone), oceanic forcing, and ice thickness. During the 2015-2016 Antarctic season VUWAE 60 included a geophysical team on the Siple Coast grounding zone of Kamb Ice Stream. This work complements ongoing work on the adjacent Whillans Ice Stream, and wider projects on the Ross Ice Shelf in collaboration with colleagues from the university's of Otago and Canterbury, supported by NZARI, the MBIE Past Antarctic Climates Programme and the Marsden Fund.

At present the Siple Coast ice streams drain approximately one third of the West Antarctic Ice Sheet. Kamb Ice Stream stands out amongst its neighbours as its flow ceased approximately 160 years ago making it a poster child for natural variability in ice flow. The five member VUWAE team on Kamb Ice Stream was one of the furthest-afield deployments supported by Antarctica New Zealand in recent years at a distance of approximately 900 km from Scott Base. The team, led by Huw Horgan and supported by Darcy Mandeno deployed for six weeks. During this time, they performed geophysical experiments to image the ice sheet and the underlying sediments using active-source seismic and radar methods. Targets included sedimentation at the grounding zone, subglacial drainage at the ice stream margin, and site surveying for the upcoming NZARI hot water drilling programme. The team also used seismic surveying to image deeper sedimentary structures beneath the stagnant Ross Ice Shelf downstream of the Kamb Ice Stream. These data will serve as site survey for a potential drilling target for an archive of climate and ice sheet history.

CONTACT: Huw.Horgan@vuw.ac.nz

Sensitivity of the Southern Ocean to meltwater from Antarctica

Currently, melting ice in Antarctica contributes a relatively small, but increasing, amount of freshwater to the surrounding ocean. The effects that this freshwater input might have on ocean stratification, and thence surface climate, is not well known, but previous ARC-led research has shown that ice-ocean feedbacks could have played a significant role in accelerating ice-sheet retreat during the last glacial termination. To test this hypothesis, researchers at the University of New South Wales, Sydney, working with Nick Golledge, used a global climate model to simulate the effects of releasing freshwater into parts of the ocean around Antarctica where currently the greatest glacier recession is taking place. The results, published in the AGU journal *Earth's Future* (Fogwill *et al.* 2015), showed that in all cases the release of freshwater into the Southern Ocean triggered greater stratification and a warming of water that was greatest in the upper 1000 m. Significantly, the simulations showed that even localised freshwater injections led to rapid subsurface warming around large sectors of the continent.

CONTACT: Nicholas.Golledge@vuw.ac.nz

An iceberg trapped in the sea ice, Antarctica
Photo: Matt Vaughan (University of Otago)

DEVELOPING NEW DRILLING TECHNOLOGIES

The Science Drilling Office is providing critical support to a range of new projects.

The Science Drilling Office (SDO) is hosted in the Antarctic Research Centre and led by Alex Pyne, SDO Director and ARC Projects Manager, and Darcy Mandeno, Operations and Field Engineer. Alex and Darcy have had another busy year supporting three field projects in preparation and execution.

Drilling holes for seismic surveys

Darcy's primary work was the construction of a small hot water drill designed to make 30 m deep holes in firn (compacted snow) for explosives on over snow seismic surveys. The drill, which uses a large commercial hot water pressure washer as it's heat and pressure components, was modified and deployed on purpose designed lightweight ski/sledges towed by skidoos at the Kamb Ice Stream. Darcy operated the hot water drill with Huw Horgan's seismic team during the three-month field season in 2015-16 at the Siple Coast, Antarctica.

Bigger and better

In collaboration with Webster Drilling and Exploration (WD&E) the SDO have also been developing new technology and drilling capability. In the early 2000's the ARC carried out core drilling in Antarctic permafrost using a novel approach with chilled compressed air flushing to avoid the use of contaminating drilling liquids. From this experience we have been able to improve this approach with theoretical calculations and design then enabling WD&E to develop new equipment with larger air compressors, better air-cooling systems and better dimensioned coring barrels appropriate for compressed air operations. Webster drilling carried out the engineering development as part of their drilling capabilities and successfully drilled commercial geotechnical coring contracts both at Scott Base and McMurdo Station this last Antarctic summer season with excellent recovery of basalt lava, scoria and preserved interstitial ice. This technology will be refined in 2016 and then used for coring at Friis Hills in the McMurdo Dry Valleys as part of a joint University of Otago, ARC, GNS Science project together with international collaborators from Italy and the USA.

Building a barge

The other major project in preparation this year with WD&E has been the design and preparation for recovering continuous sediment cores from Lake Ohau, New Zealand. Darcy provided the detailed design work for the purpose built barge construction that was fabricated in the first half of the year and Alex and Tony Kingan (WD&E) worked on the design of the deck equipment to manage and deploy the lake riser casing, a four anchor mooring system and drill pipe in water depths up to 100 metres. This project operation scheduled February/March 2016 had at the time of writing successfully recovered duplicate cores to 42 m below the lake floor in water depths of 70 m.

More hot water drilling

A new project for the SDO in 2016 will be the development of a 1000 m depth capable hot water drill to be first used for the New Zealand Ross Ice Shelf project (RIS). The ARC has been granted a major VUW CAPEX of $800K to fund this development and equipment purchases were started in late 2015 for a commissioning season near Scott Base on the McMurdo Ice Shelf in the 2016/17 season. The drill design will be closely based on current hot water drill systems that have been developed by the British Antarctic Survey who have been successfully drilling hot water holes in both the Antarctic ice shelves in the Weddell Sea area and the Greenland Ice Sheet.

CONTACT: Alex.Pyne@vuw.ac.nz

Darcy Mandeno operating the seismic hot water drill, Siple Coast, Antarctica
Photo: Matt Vaughan (University of Otago)

TEACHING AND SUPERVISION

Our staff support a wide range of teaching being carried out within the School of Geography Environment and Earth Sciences.

There is a close interaction between ARC staff and projects with other research programmes in geophysics, geology, physical geography, and the environmental studies programme. ARC staff contributed to the following courses in 2015:

Undergraduate Courses	
ESCI 111	Earth Systems and Global Change
ESCI 132	Antarctica: Unfreezing the Continent
ESCI 204	Petrology and Microscopy
GEOG 220	Hydrology and Climate
ESCI 241	Introductory Field Geology
ENSC 301	Topics in Environmental Science
ESCI 301*	Global Change: Earth Processes and History
GEOG 318	Quaternary Environmental Change

Graduate Courses	
ESCI 403*	Stratigraphy and Palaeontology
ESCI 404*	Special Topics
ESCI 412*	Quaternary Geology
PHYG414	Climate Change: Lessons from the Past
ESCI 580	Research Preparation

* An ARC staff member is the course co-ordinator

Our teaching contribution also includes supervision of graduate students from the School of Geography, Environment and Earth Sciences. In 2015 our staff supervised 13 PhD and 8 MSc students. The ARC congratulates the following students who completed their theses in 2015:

Shaun Eaves (PhD) *"The glacial history of Tongariro and Ruapehu volcanoes, New Zealand."* Supervised by Andrew Mackintosh and Brian Anderson (ARC).

Daniel Emanuelsson (PhD) *"Climate signal preserved in a high resolution water stable isotope record from the RICE ice core."* Supervised by Nancy Bertler and Lionel Carter (ARC).

Aitana Forcen Vasquez (PhD) *"Oceanography of the New Zealand subantarctic region."* Supervised by Lionel Carter (ARC) and Mike Williams (NIWA).

Richard Jones (PhD) "*Late Cenozoic behaviour of two Transantarctic Mountain outlet glaciers."* Supervised by Andrew Mackintosh (ARC/SGEES), Kevin Norton (SGEES), and Nick Golledge (ARC).

Peter Neff (PhD) *"Antarctic and Southern Ocean dust transport pathways: Forward-trajectory modelling and rare Earth element source constraints from the RICE ice core."* Supervised by Nancy Bertler (ARC) and Ross Edwards (Curtin University).

Heidi Roop (PhD) *"Late-Holocene climate variability in southern New Zealand: A reconstruction of regional climate from an annually laminated sediment sequence from Lake Ohau."* Supervised by Gavin Dunbar (ARC), Marcus Vandergoes and Richard Levy (GNS Science).

Andrea Tuohy (PhD) *"Heavy metal polluntants in snow and ice from Roosevelt Island, Antarctica."* Supervised by Nancy Bertler (ARC) and Ross Edwards (Curtin University).

Julia Collins (MSc) "*In situ cosmogenic 10Be in pyroxene with an application to surface exposure dating*." Supervised by Kevin Norton (SGEES) and Andrew Mackintosh (ARC/SGEES).

Juliet Sefton (MSc) *"An assessment of the influence of orbital forcing on Late Pliocene global sea level using a shallow-marine sedimentary record from Whanganui Basin, New Zealand."* Supervised by Tim Naish and Rob McKay (ARC).

PhD student, Daniel Emanuelsson, Roosevelt Island, Antarctica - Photo: Nancy Bertler

A THIRD PRESTIGIOUS RUTHERFORD FELLOW IN THE ARC

Nick Golledge was awarded a Rutherford Discovery Fellowship to continue his leading-edge research in aspects of global climate stability.

Nick Golledge, a senior research fellow in the ARC was awarded funding of $800,000 over five years to continue his leading-edge research in aspects of global climate stability entitled “Modelling the response of the Antarctic ice-sheet to a warming world and its contribution to future sea-level rise”. Congratulations also to our research associate Dr Kevin Norton, a senior lecturer in Physical Geography in the School of Geography, Environment and Earth Sciences, who was also awarded a fellowship.

Together they received two of twelve fellowships announced by Science and Innovation Minister Steven Joyce, which are designed to support and foster the development of future leaders in the New Zealand science and innovation system by encouraging their career development and enabling them to establish a solid track record for future research.

“Receiving these fellowships is a mark of great distinction for both Dr Golledge and Dr Norton,” says Professor Kate McGrath, Vice-Provost (Research) at Victoria University.

“It is also confirmation of the strength of research capability at Victoria and the outstanding contribution our scientists are making to understanding the potential impact of a changing climate.”

Nick plans to use his fellowship to further

Nick Golledge

understanding of how the Antarctic ice sheet, the largest ice sheet on Earth, will respond to a warming world and the contribution it is likely to make to future sea-level rise.

“With around 10% of the world’s population currently living less than 10 m above sea level, the societal impact of the potential collapse of the Antarctic ice sheet would be significant,” says Nick.

Nick is delighted to be awarded a Rutherford Discovery Fellowship and excited about the new research possibilities that it will facilitate.

“Particular benefits of receiving the Fellowship are the international collaborations that I hope to develop and the two new PhD students that the funding will support.”

Victoria’s Dean of Science, Professor David Harper, says the University is extremely proud of Dr Golledge and Dr Norton.

Winning these fellowships is well-deserved recognition of the impact of their work so early in their careers, and a reflection of the quality of Antarctic research and earth sciences at Victoria University,” says Professor Harper.

Nick started his career as a geologist with the British Geological Survey (BGS), based in Edinburgh, Scotland. During his 12 years with the BGS he mapped and interpreted the geological deposits of past ice sheets, but it was during his PhD research (undertaken part-time while at the BGS) that he began to appreciate the strength of computer modelling as an additional tool in the reconstruction of past ice sheets and the climates that gave rise to them. Since moving to New Zealand in 2009, Nick has focussed on the Antarctic ice sheet, using computer models to simulate ice growth and decay during periods of the past that otherwise can only be inferred from sparse geological records. This research is now looking to the future, attempting to predict the ice-sheet changes that might occur as the climate warms.

Nick joins the ranks with fellow ARC colleagues, Nancy Bertler and Rob McKay who were awarded their Rutherford Discovery Fellowships in 2011 and 2013, respectively.

OCEAN RESEARCHER RECOGNISED BY RSNZ HONOUR

Lionel Carter was awarded the Hutton Medal for his outstanding scientific research.

Lionel Carter’s scientific contribution has been recognised with the presentation of the 2015 Hutton Medal. Awarded annually by the Royal Society of New Zealand, the medal recognises outstanding research in earth, plant and animal sciences.

Lionel investigates geological and oceanic processes, which includes deciphering marine geological records to assess changes in ocean environments. His work has demonstrated the roles of plate tectonics, ocean currents, sea levels and climate change in shaping New Zealand’s submarine continental landmass.

Of particular note, Lionel identified the mechanisms whereby sediment from New Zealand rivers is discharged into the ocean and transported up to 4,500 kilometres, to be dragged into converging tectonic plates and ultimately recycled to the surface via volcanic activity. He has contributed to identifying indicators in sediment to measure environmental change, as well as scientific models to predict environmental responses to climate warming. Recent work includes participation in ANDRILL: A drilling programme in Antarctica to identify the effect of a changing Ross Ice Shelf on ocean circulation and water mass. His research has had direct commercial application through a range of marine engineering projects such as the International Cable Protection Committee to better protect the global fibre-optic cable network from marine hazards. The network is responsible for around 98% of all international Internet and communications traffic.

“I am deeply honoured to receive the Hutton Medal for 2015,” says Lionel. “But it is an honour to be shared. Research into environmental change is a team effort involving experts in geology, oceanography, climatology and computer modelling, to name but a few”.

“I have been fortunate to have been part of such teams, the latest being the highly talented group from the Antarctic Research Centre of Victoria University.”

The Hutton Medal adds to Lionel’s other honours, including being made a Fellow of the Royal Society of New Zealand in 2003 and receiving the Marsden Medal for outstanding service to Science in 2012.

Lionel Carter (left) at the awards ceremony in Auckland
Photo: Royal Society of New Zealand

S.T. LEE LECTURE IN ANTARCTIC STUDIES

Steve Rintoul presenting his lecture ©Gerry Keating, Image Services, VUW

Dr Steve Rintoul presented the 2015 S.T. Lee Lecture looking at the role of the Southern Ocean on the future of the Antarctic ice sheet.

The 13th annual S.T. Lee Lecture in Antarctic Studies was presented by Dr Steve Rintoul on the 15 September. The lecture, *The Southern Ocean, climate change and the future of the Antarctic ice sheet: A soft underbelly in East Antarctica?,* reviewed recent progress in understanding the role of the Southern Ocean in the Earth's climate system, how the Southern Ocean is changing, and the consequences of those changes for climate, sea level and the future of the Antarctic ice sheet.

Steve was an outstanding speaker, who had an arduous week, involving three presentations, media interviews, a round table meeting discussing the latest science around sea-level rise at the NZ Parliamentary Commission for the Environment, meetings with GNS Science, NIWA and VUW scientists, multiple social events and a field trip in the rain to the Wairarapa.

Steve is a Fellow at the CSIRO Oceans & Atmosphere Flagship and the Antarctic Climate and Ecosystems Cooperative Research Centre in Hobart. His research is focused on the role of the ocean in the climate system. He has a particular fascination for the Southern Ocean, where his work has led to a deeper appreciation of the influence of the region on global climate, biogeochemical cycles and biological productivity. He has led 12 expeditions to Antarctica and coordinated the major international Southern Ocean climate research programs conducted over the past 25 years. Steve was a Coordinating Lead Author for the 5th Assessment of the Intergovernmental Panel on Climate Change. His scientific achievements have been recognised by many national and international awards, including the Georg Wüst Prize, the Martha T. Muse Prize, the Australian Antarctic Medal, and election as a Fellow of the Australian Academy of Science.

The lecture highlighted how oceans slow the rate of climate change by soaking up heat and carbon dioxide from the atmosphere. In fact, about 93 percent of the extra heat stored by the Earth over the past 50 years is found in the ocean. Of particular importance is the Southern Ocean, where ocean currents efficiently transfer water, heat and carbon between the sea surface and the deep sea. Given the strong influence of the region on climate, changes in the Southern Ocean would have widespread consequences. Measurements from ships and robotic floats show that significant changes are already underway: The Southern Ocean is warming, freshening and becoming more acidic. In addition, evidence is growing that the Antarctic ice sheet is vulnerable to change in the surrounding oceans. A recent Australian expedition, the first to reach the Totten Glacier, suggests the East Antarctic Ice Sheet is likely more sensitive to ocean warming than previously thought.

Steve gave a repeat of the S.T. Lee Lecture at the University of Otago on the 16 September, hosted by Gary Wilson. Otago have strong research interests in his specialist area and ARC have a close collaboration with many of their researchers. Overall it was a highly successful week and significantly raised the profile of the role of Antarctica in climate change research and the importance of the UN Paris climate change negotiations.

You can view Steve's lecture at:

http://www.victoria.ac.nz/antarctic/about/events/s-t-lee-lecture/s.t.-lee-lecture-2015

And his media interviews:

Radio NZ 'Nine to Noon' - http://www.radionz.co.nz/national/programmes/ninetonoon/audio/201770834/east-antarctica-ice-sheet-melting-faster

Radio NZ 'Our Changing World' - http://www.radionz.co.nz/national/programmes/ourchanging world/audio/201770705/east-antarctica-not-a-'sleeping-giant'

NZ Herald - http://www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=11315512

S.T. LEE YOUNG SCIENTIST EXCHANGE

The S.T. Lee Young Scientist Exchange Programme offered a researcher the opportunity to travel between the University of Alaska Fairbanks and Victoria University.

From the 8-23 October, the ARC welcomed Christian Kienholz as the recipient of the 2015 S.T. Lee Young Researcher Travel Award. Affiliated with the University of Alaska Fairbanks, Christian models the current and future evolution of selected Alaska glaciers, using a model suite originally developed by the ARC's Brian Anderson. "The visit was very useful, allowing me to discuss the model and my modifications directly with the developer of the code. Collaboration with Brian further allowed me to initiate some of the upcoming programing efforts and to discuss the future of the model in general," says Christian.

"My visit confirmed that although our field areas differ in many aspects, there is significant overlap between the glacier research at the ARC and my work. In addition to the glacier modelling, we discussed various other methods and results of our work."

Among the highlights was Brian's introduction to glaciology group's unmanned aerial vehicle setup for glacier surveying, his presentation of their efforts for deriving transient snow line elevations through airborne campaigns, and the discussion of a regional mass balance study led by Andrew Mackintosh, which sheds new light on the atypical recent advances of some New Zealand mountain glaciers.

"Overall, I benefited greatly from the immersion in the group and am very grateful for having received the S.T. Lee Travel Award. In addition to the scientific enrichment, I was delighted to escape the long Fairbanks winter for a few weeks."

Christian Kienholz at Cape Reinga, New Zealand - Photo: Christian Kienholz

THIN ICE ON AMERICAN TELEVISION

Cape Roberts, Antarctica - Photo: Richard Jones

Thin Ice: The Inside Story of Climate Science screened in the United States and New Zealand.

It's now over two years since the global launch of the film *Thin Ice– the Inside Story of Climate Science* (Earth Day April 2013). In 2015, its reach expanded in the United States and New Zealand through work with our distributor, Green Planet Films, together with KRCB North Bay, California, with the production of a shorter (56 minute) version by DOX Productions, London, for American Public Television (APT). This has led to around 460 telecasts covering 45% of the United States since July. APT-World-wide are now also marketing it.

Here in New Zealand the shorter version has made it easier to promote to secondary schools as a roadshow (screening + Q&A), with support from the Tindall Foundation and help from Auckland promoter Simon Kemp-Roberts. The roadshow launched with a New Zealand Premiere of the "Directors' Cut" in Auckland by Lucy Lawless (a.k.a. Xena, Warrior Princess), followed by presentations to seven local schools (see Outreach section pg 31) and 1300 students in September. In both the United States and New Zealand we have promoted the film as "climate science made clear" for young people and the wider public in the lead up to the Paris climate conference which took place in December.

Shortening the film involved removing a couple of sections less critical for the story line, and in a few places some text that dated the film. Interestingly, though the issue has become more pressing, the science in the film has not dated. The new version has been screened by invitation at several key film festivals, including the Jackson Hole Wildlife Film Festival, USA, and the Blue Ocean Festival in Monaco.

The film's New Zealand profile has been enhanced by the new version screening in art house cinemas in the four main centres in November through Lighthouse Cinemas, and its broadcast on TV One on 5 December with assistance from New Zealander of the Year, Stephen Tindall. TV One on Demand recorded 3000 viewings.

VISITORS TO THE ARC

The ARC hosted a variety of visitors during the year.

In January, a Jilin University delegation visited the ARC to talk with Tim Naish and Alex Pyne on their research interests on scientific polar drilling. The delegation included Professor Sun Youhong, Dean of the College of Construction Engineering, Professor Lin Xueyu, Dean of the Institute of Water Resources and Environment, Professor Su Xiaosi, Vice Dean of the Institute of Water Resources and Environment, and Professor Liu Baochang, Vice Dean of the College of Construction Engineering.

From February until June the ARC welcomed Fulbright Distinguished Teacher, Hakan Armagan, to do research on energy policies and the environmental sustainability of New Zealand. Originally from Turkey, Hakan has been teaching physics for the last eleven years, as well as an energy and nuclear science course since 2007 at Burke High School in Omaha, Nebraska. Working under the guidance of Tim Naish (ARC) and Mike Taylor (School of Education) Hakan looked at a broader picture of New Zealand's energy story; the science and the social aspects. He visited power stations and learned from the policy makers, MPs, academics, experts, activists, film makers, CEOs and teachers, as well as studied Māori perspectives on land and water use.

Hakan Armagan

He learned that sustainability is more than 80% renewable energy for electricity. For New Zealand large scale agricultural and manufacturing practices, and environmental policies matter.

"New Zealand has been a leader on the world stage for being the first country to give women the right to vote and declaring itself nuclear free. With regard to climate change issues, it will be interesting to see what Kiwis decide to do" says Hakan.

Then on 4 November five members of Victoria University Antarctic Expedition (VUWAE) 9 met here at the ARC to celebrate 50 years since their expedition. They were geologists Warwick Prebble (Leader) and Jim Cole, physicists Robin Bell and Ray Hoare, and biologist Alan Baker. Geologists Tony Ewart (Queensland) and Don Palmer (Ohio) sent their best wishes. The remaining members could not be located or were known to have passed away.

ARC Director Tim Naish welcomed the VUWAE members and spoke about current Antarctic research. VUWAE 9 members each gave a brief outline of their 1964-65 work – geologists on Black Island, Brown Peninsula, the Koettlitz ice free region and Taylor Valley; physicists and biologist on Brown Peninsula; lakes Vanda, Miers and Taylor; and the Wright and Miers valleys. Peter Barrett, Andrew Mackintosh, Nancy Bertler, and Rob McKay outlined more recent projects.

"It was terrific to be able to get together and share our past experiences," says Robin.

VUWAE 9: (left to right) Robin Bell, Warwick Prebble, Alan Baker, Jim Cole and Ray Hoare
Photo: Tim Naish

ARC ENDOWED DEVELOPMENT FUND

Field training, Antarctica - Photo: Sam Taylor-Offord

The ARC Endowed Development Fund has awarded 70 grants to postgraduate students since its inception in 2004.

This substantial fund enables the ARC to give small grants of up to $4000 to postgraduate students with research links to Antarctica and enables some amazing opportunities to be taken up, that would not have otherwise been possible. Examples include; participation in international summer schools in glaciology, modelling and paleoclimatology, the opportunity to work with collaborators in world-class analytical facilities, and the ability to travel to international conferences and workshops to present their scientific discoveries on a world-stage.

The 2015 recipients were:

Christine Bylenga (School of Biological Sciences) travelled to Auckland to undertake lipid analyses.

Georgia Grant (ARC) will travel to Standford University, USA in 2016 to undertake oxygen isotope analyses.

Cassandra Trinh-Le (ARC) received funding to enable her to have 10Be analyses conducted on her samples for her MSc.

Richard Jones (ARC/SGEES) attended both the Paleo Constraints on Past Sea Level Rise (PALSEA) Workshop in Tokyo and the XIX INQUA Congress in Nagoya, Japan in July.

Matt Ryan (SGEES/ARC) also attended the XIX INQUA Congress in Japan.

Juliet Sefton (ARC) received support to undertake supplementary laboratory work on her Master's work, travelling to Stanford University, California to the Stable Isotope Laboratory.

Finally Shaun Eaves (ARC) received one month salary support prior to his postdoctoral position starting here at the ARC.

Discussions are underway with the Victoria University Foundation on a new fundraising campaign to increase the size of the Endowed Development Fund.

The attendees of the PALSEA workshop in Tokyo - Photo: AORI, University of Tokyo

AWARDS AND APPOINTMENTS

In 2015 ARC staff and students were awarded the following:

Nancy Bertler and Rob McKay — Marsden grant on "Predicting a sea change: Antarctic ice-ocean interactions in a warming world".

Lionel Carter — Royal Society of New Zealand 2015 Hutton Medal.

Gavin Dunbar — Transferred from the Senior Research Fellow to the Senior Lecturer scale in the 2015 Academic Promotion Round.

Shaun Eaves — Appointed as a Postdoctoral Research Fellow.

Nick Golledge — Rutherford Discovery Fellowship on "Modelling the response of the Antarctic ice sheet to a warming world and its contribution to future sea-level rise".

Huw Horgan — University Research Fund for the project "Tasman Glacier decay and basal sliding".

Richard Jones — Appointed as a Postdoctoral Research Fellow.

Andrew Mackintosh — University Research Development Fund for work on "Climate during the Antarctic Cold Reversal".

Andrew Mackintosh — Elected to the Council of the International Glaciological Society.

Andrew Mackintosh — Elected to the International Union of Geodesy and Geophysics Visioning Committee.

Andrew Mackintosh — Re-elected as the Secretary General of the International Association of Cryospheric Sciences, a constituent of the International Union of Geodesy and Geophysics.

Andrew Mackintosh — Member of the International Scientific Programme Committee, 26th General Assembly of the International Union of Geodesy and Geophysics.

Andrew Mackintosh — Appointed as Review Editor and Editorial Board Member of the journal *Frontiers in Cryospheric Sciences*.

Rob McKay — Appointed chair of Australia and New Zealand IODP Consortium Science Committee.

Tim Naish — Appointed co-chair of the Scientific Committee on Antarctic Research, Past Antarctic Ice Sheets Project.

Tim Naish — Appointed to Chilean Research Funding Agency FONDAP Programme International Assessment Panel to select a Centre of Research Excellence in Antarctic Research.

Tim Naish — Earth Sciences, Editor-in-Chief of the journal *Antarctic Science*, Cambridge University Press.

Kristina Pascher — 'Best Student Talk' at the 14th Meeting of the International Association of Radiolarists, Antalya, Turkey, in March.

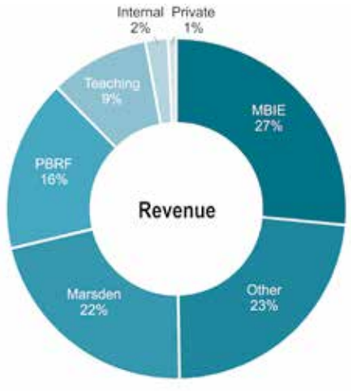
Matt Ryan — 'Best Student Poster' award at the XIX INQUA Congress in Nagoya, Japan in July.

FINANCIAL SUMMARY

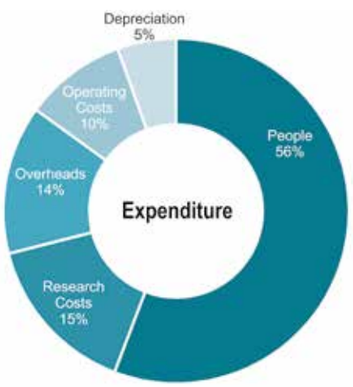
The ARC finances include both a Centre budget and grant funds held by the Research Trust of Victoria University of Wellington. The total ARC revenue and expenditure for 2015 are summarized in the charts below (all figures are exclusive of GST), these figures combine the Centre budget that operates over the Victoria University financial year (January-December) and Research Trust grant budgets which operate over the life of the projects. As such, the year-end balances for revenue versus expenditure in Research Trust grants are often out-of-phase.

In 2015, the ARC received a total of $2.68M in revenue and a corresponding expenditure of $2.48M. The individual cost centre budget had a $6K deficit, However, the ARC's research funding contribution to the University via overheads from Research Trust grants was $346K, thus overall the ARC contributed $340K of revenue to the University.

2015 Finances



Around 72% of our funding is from external sources. The highest proportion of which came from the Ministry of Business, Innovation and Employment (MBIE) funding via six sub-contracts from GNS Science and NIWA generating revenue of $710K. Just over $620K of 'Other' funding includes two Rutherford Fellowships, NZARI funding, and grants from other national and international organisations. Six Marsden grants contributed $578K. The remaining 28% of revenue is made up of PBRF, Teaching, Private and Internal grants. PBRF (Performance-Based Research Fund) is calculated by Victoria University based on external research funding that meets 'PBRF' criteria and the quality rating of staff. 'Teaching' is the contribution from SGEES, based on hours, for teaching and supervision by ARC staff, as well as a proportion of PBRF graduate completion income. 'Internal' University funded grants for staff and students contributed $57K. Finally, 'Private' revenue were donations held by the Victoria University Foundation that have been transferred to the Research Trust.



Over half of the expenditure ($1.38M), is related to staff costs associated with salaries, annual leave, and superannuation. 'Research Costs' expenditure of $377K are those directly associated with research projects such as fieldwork expenses, sub-contractors, conference attendance, analyses, and student scholarships. 'Overheads' of $346K were transferred directly from grants by the University to cover services provided by the Research Office and central University. General 'Operating' costs of the Centre was $237K and included costs associated with leasing computers, phones, space charges, printing, and stationary. 'Depreciation' of CAPEX equipment came to $136K.

New funding success

The ARC successfully secured the following new funding in 2015:

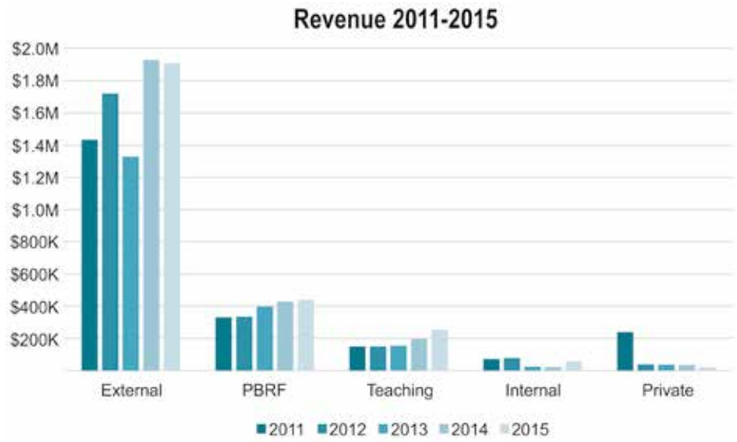
Rutherford Discovery Fellowship - "Modelling the response of the Antarctic ice-sheet to a warming world and its contribution to future sea-level rise" $800k over five years for Nick Golledge.

Marsden Fund - "Predicting a sea change: Antarctic ice-ocean interactions in a warming world" $810K over three years for Nancy Bertler and Rob McKay.

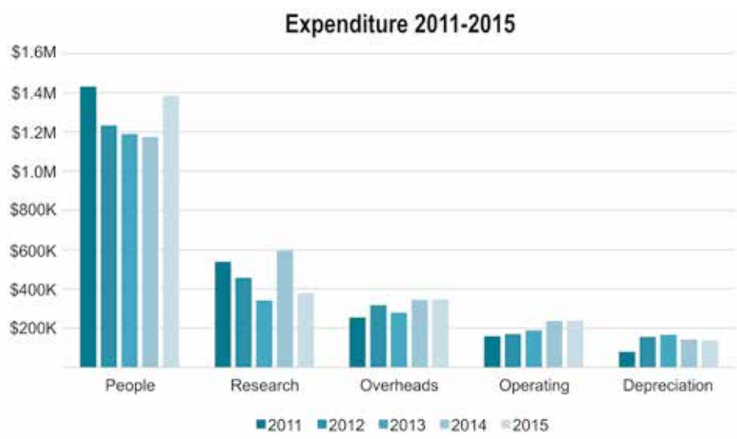
Research Development Fund - "Climate during the Antarctic Cold Reversal" $10K for Andrew Mackintosh.

University Reasearch Fund - "Tasman Glacier decay and basal sliding" $29K for Huw Horgan.

Five year summary



'External' combines the revenue from from MBIE, Marsden, and 'Other' sources. Despite a slight decrease of $20K in 2015 from the previous year, external revenue has maintained at a higher level since the significant drop in 2013 due to the loss of one of our major programmes. 'PBRF' has continued to increase each year. Revenue from 'Teaching' also increased by almost $58K in 2015 due to more graduate completion funding coming through. 'Internal' funding increased in 2015 due to two new University grants awarded. For 'Private' funding, the chart reflects how the donations are transferred from the Victoria University Foundation to the Research Trust as income to be spent, rather than reflecting new donations.



'People' related costs are by far our greatest expenditure. The $209K increase this year from 2014 relates to two new postdoctoral appointments, pay increases/promotions and increased superannuation membership. 'Research Direct Costs' reflect the cycle of research projects with higher costs in the fieldwork and analyses years as occurred in 2014. 'Overheads' paid to the University in 2015 were similar to 2014 as the overheads for the two new postdoctuates were waived to make the positions viable. The basic operational costs for the Centre remained stable over the 2014-2015 period. 'Depreciation' costs increased in 2012 due to the capitilisation of our $1M Ice Core Drill however in 2014 it decreased again when $290K of this drill was written-off.

OUTREACH

Scott Base, Antarctica - Photo: Becky Goodsell

The ARC is committed to presenting our research and knowledge to the wider community.

Media interviews

TV3 'Newsworthy': 15 October "Paris climate change conference", Tim Naish.

TV3 'Newsworthy': 15 October "Antarctic ice melt", Tim Naish.

ABC Radio (Australia): 15 October "Antarctic ice shelf collapse and unstoppable sea-level rise 'very likely' without tough climate action, say scientists", Nick Golledge. http://www.abc.net.au/news/2015-10-15/antarctic-ice-shelf-sea-level-rise-warning/6853780

Busan e-FM 'Morning Wave in Busan': 25 May "Stability of Antarctica in a warming world", Gavin Dunbar. www.befm.or.kr

Radio NZ 'Summer Report': 6 January "NZ glaciers retreating rapidly", Andrew Mackintosh and Brian Anderson. http://www.radionz.co.nz/national/programmes/summerreport/audio/20163038/it-could-take-centuries-to-reverse-damage-to-nz-glaciers

Radio NZ 'Saturday Morning': 28 March "The state of Antarctic ice shelves", Tim Naish. http://www.radionz.co.nz/national/programmes/saturday/20150328

Radio NZ 'Our Changing World': 15 October "Antarctica's contribution to sea-level rise", Nick Golledge. http://www.radionz.co.nz/national/programmes/ourchangingworld/audio/201774595/antarctica's-contribution-to-sea-level-rise

Radio NZ 'Morning Report': 15 October "Five years to cut emissions or see Antarctica's ice cap melt", Nick Golledge. http://www.radionz.co.nz/national/programmes/morningreport/audio/201774712/five-years-to-cut-emissions-or-see-antarctica's-ice-cap-melt

Radio NZ 'News': 25 October "NZ's glaciers have shrunk by a third", Andrew Mackintosh and Brian Anderson. http://www.radionz.co.nz/news/national/287912/nz's-glaciers-have-shrunk-by-a-third-report

Radio NZ 'Our Changing World': 26 November "Antarctic glacier's past rapid retreat", Richard Jones and Andrew Mackintosh. http://www.radionz.co.nz/national/programmes/ourchangingworld/audio/201780508/antarctic-glacier%27s-past-rapid-retreat

Dominion Post: 24 June "South Island's Everest-like chill nothing compared to -36°C in Lower Hutt", Nancy Bertler. http://www.stuff.co.nz/national/69644698/south-islands-everestlike-chill-nothing-compared-to-36c-in-lower-hutt

Dominion Post: 15 October "Wellington faces another half-metre of sea-level rise, warns scientist", Nick Golledge. http://www.stuff.co.nz/dominion-post/news/73004195/wellington-faces-another-halfmetre-of-sea-level-rise-warns-scientist

Guardian (UK): 14 October "Antarctic ice sheets face catastrophic collapse without deep emissions cuts", Nick Golledge. http://www.theguardian.com/environment/2015/oct/14/antarctic-ice-sheets-face-catastrophic-collapse-without-deep-emissions-cuts

Hutt News: 7 April, "Dr. Bertler's fascination with ice", Nancy Bertler. http://www.pressreader.com/new-zealand/the-hutt-news/textview

NZ Herald: 5 June "If emission talks focus only on short-term costs, we will pay dearly", Tim Naish. http://www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=11459987

NZ Herald: 11 June "What causes ancient oceans to rise?", Tim Naish and Nancy Bertler. http://www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=11463462

NZ Herald: 28 June "Antarctica - our big icy threat", Nancy Bertler. www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=11472481

NZ Herald: 13 September "The big read: Climate change and the fate of Antarctica" reports on the S.T. Lee Lecture by Steve Rintoul and talks with Tim Naish. http://www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=11512463

NZ Herald: 15 October "New climate study bad news for Antarctica", Nick Golledge with commentary from Tim Naish. http://www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=11529762

NZ Herald: 27 November "Cold warning from Antarctica's past", Richard Jones. http://www.nzherald.co.nz/world/news/article.cfm?c_id=2&objectid=11552246

NZ Herald: 30 November "Climate of Hope" series, Q&A with Tim Naish. http://www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=11553445

NZ Listener: 13 February "Thaw point" by Rebecca Priestley featuring Tim Naish.

Otago Daily Times: 4 July "On thin ice", Nancy Bertler.

Otago Daily Times: 19 October "Bleak picture painted for Antarctic ice sheet", Nick Golledge. http://www.odt.co.nz/lifestyle/magazine/359539/waiting-tide

Stuff: 16 September "NZ forests face threats in warming world", Matt Ryan. http://i.stuff.co.nz/environment/72107756/nz-forests-face-threats-in-warming-world

Talks to the public and policymakers

Greater Wellington Regional Council: 17 August "Antarctica's melting ice – consequences for Wellington", Nancy Bertler.

Korean Polar Research Institute: 3 August "Rapid thinning of an East Antarctic outlet glacier during Holocene climate stability", Richard Jones.

Marlborough District Council: 18 June "Climate change impacts", Tim Naish.

McGuinness Institute 'One Ocean Launch': 12 May "The role of global warming on Ocean Change", Tim Naish.

McGuinness Institute: 22 May "Antarctic climate change", Tim Naish.

NZARI Winter School: 15-17 May Training media/stakeholders on the role of Antarctica in climate change, Tim Naish and Nancy Bertler.

NZ Institute of International Affairs 'Antarctic Treaty Symposium': 27 February, Tim Naish.

NZ Institute of International Affairs: 4 December "New Zealand at COP21: Leader or laggard?", Tim Naish.

NZ Parliament 'Oceans Policy Group': 6 May "Climate change", Tim Naish.

Parliamentary Commission for the Environment: 14 September "Sea-level rise discussion". Tim Naish, Nick Golledge and Steve Rintoul (S.T. Lee lecturer).

RSNZ New Fellows Seminar: 21 October "Implications of Antarctic ice sheet sensitivity for sea-level rise", Tim Naish.

VUW Public Lecture Series: 19 August "Why are we arguing about climate change?", Tim Naish and Marc Wilson (School of Psychology).

VUW Public Lecture Series: 21 October "Potential collapse of the West Antarctic Ice Sheet", Nancy Bertler.

School & community groups

Annual NZ Rhododendron Society Conf.: 18 October "Rhododendrons in the Antarctic", Tim Naish.

Baradene College of the Sacred Heart: 23 September "*Thin Ice* screening and panel discussion", Peter Barrett.

Botany Downs Secondary College: 24 September "*Thin Ice* screening and panel discussion", Peter Barrett.

East Harbour Environmental Association: 2 June "Sea-level rise and Antarctic ice: There are big questions, but are there answers?", Nancy Bertler.

Francis Douglas Memorial College: 30 March "Climate change and Antarctica", Tim Naish.

GNS Science Hutt Valley School Science Day: 3 March, Tour of ARC/GNS ice core facility, Nancy Bertler.

'Hands on Geo': 4 September - visit of Wellington schools to SGEES, Shaun Eaves and Andrew Mackintosh.

Inglewood High School: 21 October "Future sea-level rise and its impact on New Zealand", Nancy Bertler.

Kaipara College: 22 September "*Thin Ice* screening and panel discussion", Peter Barrett.

Khandallah Presbyterian Church: 7 October "Climate Change", Tim Naish.

King's College & Michael Park School: 18 September "*Thin Ice* screening and panel discussion", Peter Barrett.

Long Bay College: 21 September "*Thin Ice* screening and panel discussion", Peter Barrett.

New Plymouth Boys High School: 15 June "How New Zealand's land and ocean 'tick'", Lionel Carter.

New Plymouth Boys High School: 21 October "Future sea-level rise and its impact on New Zealand", Nancy Bertler.

Otari School: 9 November 'Fieldwork in Antarctica', Bella Duncan.

Sci21: October - website presentation on climate change, Tim Naish http://sci21.co.nz/speakers/tim_naish/

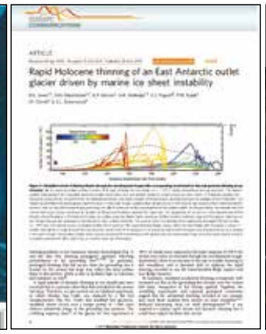
U3A Wellington City: 11 September 'Glaciers and ice sheets in a warming world', Andrew Mackintosh.

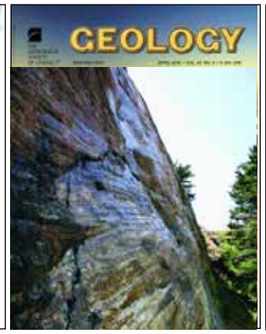
Waitakere College: 17 September "*Thin Ice* screening and panel discussion", Peter Barrett.

Wellington Club: 8 September "Climate Change", Tim Naish.

Wellington Rotary Club: 2 March "Climate change and New Zealand's future", Tim Naish.

PUBLICATIONS AND INVITED PRESENTATIONS





Peer-reviewed publications (34)

Alley, R.B., Anandakrishnan, S., Christianson, K., **Horgan**, H.J., Muto, A., Parizek, B.R., Pollard, D., Walker, R.T., (2015). Ocean forcing of ice-sheet retreat: West Antarctica and more. *Annual Review of Earth and Planetary Sciences* 201(43): 7.1-7.25.

Bostock, H.C., Tracey, D.M., Currie, K.I., **Dunbar**, G.B., Handler, M.R., Mikaloff Fletcher, S.E., Smith, A.M., Williams, M.J.M., (2015). The carbonate mineralogy and distribution of habitat-forming deep-sea corals in the southwest pacific region. *Deep Sea Research Part I: Oceanographic Research Papers* 100: 88-104. doi:10.1016/j.dsr.2015.02.008

Bracegirdle, T.J., **Bertler**, N., Carleton, A.M., Ding, Q., Fogwill, C.J., Fyfe, J.C., Hellmer, H., Karpechko, K. Kusahara, Larour, E., Mayewski, P.A., Meier, W.N., Polvani, L. M., Russell, J.L., Stevenson, S.L., Turner, J., van Wessem, J.M., Wainer, I., (2016). A multi-disciplinary perspective on climate model evaluation for Antarctica. *Bulletin of American Meteorological Society*. doi: 10.1175/BAMS-D-15-00108.1 (available online 2015)

Bravo, C., Rojas, M., **Anderson**, B.M., **Mackintosh**, A.N., Sagredo, E., Moreno, P.I., (2015). Modelled glacier equilibrium line altitudes during the mid-Holocene in the southern mid-latitudes. *Climate of the Past* 11: 1575-1586. doi:10.5194/cp-11-1575-2015

Cossu, R., Forrest, A.L., **Roop**, H.A., **Dunbar**, G.B., Vandergoes, M.J., Levy, R.H., Stumpner, P., Schladow, S.G., (2016). Seasonal variability in turbidity currents in Lake Ohau, New Zealand, and their influence on sedimentation. *Marine and Freshwater Research*. doi:10.1071/MF15043 (available online 2015)

Dadic, R., Schneebeli, M., **Bertler**, N.A.N., Schwikowski, M., Matzl, M., (2015). Extreme snow metamorphism in the Allan Hills, Antarctica, as an analogue for glacial conditions with implications for stable isotope composition. *Journal of Glaciology* 61(230): 1171-1182.

de Boer, B., Dolan, A.M., Bernales, J., Gasson, E., Goelzer, H., **Golledge**, N.R., Sutter, J., Huybrechts, P., Lohmann, G., Rogozhina, I., Abe-Ouchi, A., Saito, F., van deWal, R.S.W., (2015). Simulating the Antarctic ice sheet in the Late-Pliocene warm period: PLISMIP-ANT, an ice-sheet model intercomparison project. *The Cryosphere* 9: 881-903.

Dutton, A., Webster, J., **Zwartz**, D., Lambeck, L., Wohlfarth, B., (2015). Tropical tales of polar ice: Evidence of Last Interglacial polar ice sheet retreat recorded by fossil reefs of the granitic Seychelles islands. *Quaternary Science Reviews* 107: 182-196. doi: 10.1016/j.quascirev.2014.10.025

Eaves, S.R., Winckler, G., Schaefer, J.M., Vandergoes, M.J., **Mackintosh**, A., Townsend, D., Alloway, B., Ryan, M., Li, X., (2015). A test of the global cosmogenic 3He production rate in the South West Pacific region (39°S). *Journal of Quaternary Science* 30(1): 79-87. doi: 10.1002/jqs.2760

Emanuelsson, B.D., Baisden, W.T., **Bertler**, N.A.N., Keller, E.D., Gkinis, V., (2015). High-resolution continuous flow analysis setup for water isotopic measurement from ice cores using laser spectroscopy. *Atmospheric Measurement Techniques* 8: 2869-2883. doi:10.5194/amt-8-2869-2015

Fisher, A.T., Mankoff, K.D., Tulaczyk, S.M., Tyler, S.W., Foley, N. and the WISSARD Science Team (including **Horgan**, H.), (2015). High geothermal heat flux measured below the West Antarctic Ice Sheet. *Science Advances* 1(6): e1500093. doi: 10.1126/sciadv.1500093

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Golledge, N.R., Kowalewski, D.E, **Naish**, T.R., Levy, R.H., Fogwill, C.J., Gasson, E.G.W., (2015). The multi-millennial Antarctic commitment to future sea-level rise. *Nature* 526: 421-425. doi:10.1038/nature15706

Gutt, J., **Bertler**, N., Bracegirdle, T., Buschmann, A., Comiso, J., Hosie, G., Isla, E., Schloss, I., Smith, C., Tournadre, J., Xavier, J., (2015). The Southern Ocean ecosystem under multiple climate change stresses - an integrated circumpolar assessment. *Global Change Biology* GCB-14-1154. doi:10.1111/gcb.12794

Horgan, H.J., **Anderson**, B., Alley, R.B., Chamberlain, C.J., Dykes, R., Kehrl, L.M., Townend, J., (2015). Glacier velocity variability due to rain-induced sliding and cavity formation. *Earth and Planetary Science Letters* 432: 273–282. doi:10.1016/j.epsl.2015.10.016

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Iribarren Anacona, P., **Mackintosh**, A., and Norton, K., (2015). Reconstruction of a glacial lake outburst flood (GLOF) in the Engaño Valley, Chilean Patagonia: Lessons for GLOF risk management. *Science of the Total Environment* 527–528: 1-11. doi:10.1016/j.scitotenv.2015.04.096

Jones, R.S., Lowe, J., Palmer, A., **Eaves**, S., **Golledge**, N., (in press). Dynamics and palaeoclimatic inferences of a Loch Lomond Stadial glacier: Coire Ardair, Creag Meagaidh, Western Highlands, Scotland. *Proceedings of the Geologists' Association*. http://dx.doi.org/10.1016/j.pgeola.2015.11.004 (available online 2015)

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Kuehl, S.A., Alexander, C.R., Blair, N.E., Harris, C.K., Marsaglia, K.M., Ogston, A.S., Orpin, A.R., Roering, J.J., Bever, A., Bilderback, E.L., **Carter**, L., Cerovski-Darriau, C., Childress, L.B., Corbett, D.R., Hale, R., Leithold, E.L., Litchfield, N., Moriarty, J.M., Page, M.J., Pierce, L.E.R., Upton, P., Walsh, J.P., (2016). A source to sink perspective of the Waipaoa River margin. *Earth-Science Reviews* 153: 301-334. doi: 10.1016/j.earscirev.2015.10.001 (available online 2015)

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Mayewski, P.A., Bracegirdle, T., Goodwin, I., Schneider, D., **Bertler**, N.A.N., Birkel, S., Carleton, A., England, M.H., Kang, J.-H., Khan, A., Russell, J., Turner, J., Velicogna, I., (2015). Potential for Southern Hemisphere climate surprises. *Journal of Quaternary Science* 30: 391–395. doi: 10.1002/jqs.2794

McKay, R., **Golledge**, N.R., Maas, S., **Naish**, T., Levy, R., **Dunbar**, G., Kuhn, G., (2016). Antarctic marine ice-sheet retreat in the Ross Sea during the early Holocene. *Geology* 44(1): 7-10. doi:10.1130/G37315.1 (available online 2015)

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Pascher, K.M., Hollis, C.J., Bohaty, S.M., Cortese, G., **McKay**, R.M., Seebeck, H., Suzuki, N., Chiba, K., (2015). Expansion and diversification of high-latitude radiolarian assemblages in the late Eocene linked to a cooling event in the southwest Pacific. *Climate of the Past* 11: 1599-1620. doi:10.5194/cp-11-1599-2015

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Roop, H.A., Levy, R., **Dunbar**, G.B., Vandergoes, M.J., Howarth, J., Fitzsimons, S., Moon, H.S., Zammit, C., Ditchburn, R., Baisden, T., Yoon, H.I., (2016). A hydroclimate-proxy model based on sedimentary facies in an annually laminated sequence from Lake Ohau, South Island, New Zealand. *Journal of Paleolimnology* 55(1): 1-16. (available online 2015)

Skinner,L., McCave, I.N., **Carter**, L., Fallon, S., Scrivner, A.E., Primeau, F., (2015). Reduced ventilation and enhanced magnitude of the deep Pacific carbon pool during the last glacial period. *Earth and Planetary Science Letters* 411: 45-52.

Solomina, O.N., Bradley, R.S., Hodgson, D.A., Ivy-Ochs, S., Jomelli, V., **Mackintosh**, A.N., and others, (2015). Holocene glacier fluctuations. *Quaternary Science Reviews* 111: 9-34. doi:10.1016/jquascirev.2014.11.018

Tuohy, A., **Bertler**, N.A.N., **Neff**, P., Edwards, R., **Emanuelsson**, D., Beers, T., Mayewski, P., (2015). Transport and deposition of toxic heavy metals in the Ross Sea region, Antarctica. *Journal of Geophysical Research – Atmospheres* 120(20): 10,996–11,011. doi:10.1002/2015JD023293

Books/book chapters

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Carter, L. and Burnett, D.B., (2015). Subsea Telecommunications. In: Smith, H.D., Suárez de Vivero, J.L., Agardy, T.S., (eds), *Routledge Handbook of Ocean Resources and Management*. Routledge; London and New York, 640pp.

Carter, L., (2015). Chapter 9 Water World including Carter, L and Bostock H., Ocean Cross Roads; Orpin A., and Carter L., The Great Recycler; Carter L., and Bostock, H., An Ocean in Motion in Graham I., (ed). *Continent on the Move,* GSNZ Miscellaneous Publication, pp. 219-237

Invited keynote/plenary presentations

Carter, L., (2015). Climate vs Tectonics: mass-flows detected by repeated telecommunication cable breaks off Taiwan. *7th International Symposium on Submarine Mass Movements and their Consequences*, Wellington, New Zealand, 1-4 November 2015.

Carter, L., (2015). Cables and the Marine Environment. Coordinating Ministry for Maritime Affairs of the Republic of Indonesia and the International Cable Protection Committee (ICPC) Joint Workshop on Submarine Cables, Jog, Jakarta, 18-19 October 2015.

Eaves, S.R., (2015). Reconstructing past climate using mountain glaciers. *Southern Hemisphere Assessment of Past Climate Workshop*, University of New South Wales, Sydney, Australia, February 2015.

McKay, R., (2015). Antarctic Cenozoic climate history from sedimentary records: ANDRILL and beyond. *Royal Society (UK) Theo Murphey meeting "Subglacial Antarctic lake exploration: First results and future plans,* Chicheley, Buckinghamshire, UK, 30-31 March 2015.

Naish, T., (2015). Constraining the Antarctic contribution to interglacial sea-level rise. *AGU Fall 2015 Meeting*, San Francisco, USA, 14-18 December 2015.

Naish, T., (2015). Paleoclimate perspectives on Antarctic ice sheet sensitivity. *University of Southampton*, Southhampton, UK, July 2015.

Naish, T., (2015). Paleoclimate perspectives on Antarctic ice sheet sensitivity. *EGU General Assembly*, Vienna, Austria, 12-17 April 2015.

Naish, T., (2015). Umbrove Lecture, University of Utrecht, Utrecht, The Netherlands. April 2015.

Naish, T. and Escutia, C., (2015). Antarctic paleoclimate records and their insights into ice sheet variability and climate change. Netherlands Oceanographic Institute (NIOZ), Texel, Netherlands, April 2015.

CONFERENCES

Oral presentations

Anderson, B. and **Mackintosh**, A., (2015). The response of debris-covered, lake-calving glaciers to warming; Southern Alps, New Zealand. *International Symposium on Glaciology in High-Mountain Asia*, Kathmandu, Nepal, 2–6 March 2015.

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Eaves, S.R., **Mackintosh**, A., Norton, K.P., **Jones**, R.S., (2015). Glacial geomorphology of the Spenser Mountains, NZ: Tracking climate change through the last glacial termination. *Annual Conference of the Geoscience Society of New Zealand,* Wellington, New Zealand, 25-27 November 2015.

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Ryan, M.T., Newnham, R.M., Vandergoes, M.J., **Dunbar**, G.B., Smith, E.G.C., Neil, H., Bostock, H., Alloway, B.V., Rees, A.B.H., Sabaa, A., Hayward, B., Scott, Wilmshurst, J.M., Li, X., (2015). Ocean-atmospheric interactions from south-west New Zealand, over the last two glacial-interglacial cycles. *XIX INQUA Congress*, Nagoya, Japan, 26 July-2 August 2015.

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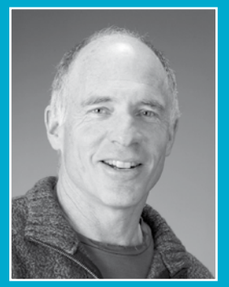

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